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J.112
Annex A
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SERIES J: CABLE NETWORKS AND TRANSMISSION OF TELEVISION, SOUND PROGRAMME AND OTHER MULTIMEDIA SIGNALS

Interactive systems for digital television distribution

Transmission systems for interactive cable television services

Annex A: Digital Video Broadcasting: DVB interaction channel for Cable TV (CATV) distribution systems

ITU-T Recommendation J.112 – Annex A

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ITU-T Recommendation J.112

Transmission systems for interactive cable television services

ANNEX A

Digital Video Broadcasting: DVB interaction channel for Cable TV (CATV) distribution systems

Summary

This annex is the baseline specification for the provision of the interaction channel for CATV networks.

It is not intended to specify a return channel solution associated to each broadcast system because the interoperability of different delivery media to transport the return channel is desirable.

The solutions provided in this annex are a part of a wider set of alternatives to implement interactive services for Digital Video Broadcasting (DVB) systems.

Source

Annex A to ITU-T Recommendation J.112 was prepared by ITU-T Study Group 9 (2001-2004) and approved under the WTSA Resolution 1 procedure on 9 March 2001.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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ANNEX A

Digital Video Broadcasting: DVB interaction channel for Cable TV (CATV) distribution systems

A.1 Scope

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It is not intended to specify a return channel solution associated to each broadcast system because the interoperability of different delivery media to transport the return channel is desirable.

The solutions provided in this annex for interaction channel for CATV networks are a part of a wider set of alternatives to implement interactive services for Digital Video Broadcasting (DVB) systems.

A.2 References

The following Recommendations and other references contain provisions, which through reference in this text, constitute provisions of this annex:

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.
- A non-specific reference to an ETS shall also be taken to refer to later versions published as an EN with the same number.

[1] ITU-T I.361 (1999), *B-ISDN ATM layer specification*.

[2] ITU-T I.363 (1993), *B-ISDN ATM Adaptation Layer (AAL) specification*.

[3] ANSI X3.92-1981, *Data Encryption Algorithm*.

[4] ANSI X3.106-1983, *Modes of Operation for the Data Encryption Algorithm*.

[5] IETF RFC 2104, *HMAC: Keyed-Hashing for Message Authentication*.

[6] ETSI EN 301 192, *Digital Video Broadcasting (DVB); DVB specification for data broadcasting*.

[7] ETSI EN 300 429, *Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for cable systems*.

[8] IETF RFC 1483, *Multiprotocol Encapsulation over ATM Adaptation Layer 5*.

[9] IETF RFC 2131, *Dynamic Host Configuration Protocol*.

[10] IETF RFC 951, *Bootstrap Protocol*.

[11] IETF RFC 791, *Internet Protocol*.

[12] ATM Forum AF-UNI-0010.002, *ATM User-Network Interface Specification V3.1*.

[13] IETF RFC 2236, *Internet Group Management Protocol, Version 2*.

[14] ETSI TR 100 815, *Digital Video Broadcasting (DVB); Guidelines for the handling of Asynchronous Transfer Mode (ATM) signals in DVB systems*.

[15] ISO/IEC 8802-3:1996, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications*.

[16] ITU-T I.432.X (1996), *B-ISDN user-network interface – Physical layer specification*.

[17] ETSI TR 101 196, *Digital Video Broadcasting (DVB); Interaction channel for Cable TV distribution systems (CATV); Guidelines for the use of ETS 300 800*.

[18] ETSI EN 301 199, *Digital Video Broadcasting (DVB); Interaction channel for Local Multi-point Distribution Systems (LMDS)*.

[19] EN 50083-2 (BS), *Cabled distribution systems for television and sound signals – Part 2: Electromagnetic compatibility for equipment*.

[20] ITU-T H.222.0 (2000) | ISO/IEC 13818-1:2000, *Information technology – Generic coding of moving pictures and associated audio information: Systems*.

[21] ETSI EN 300 468, *Digital Video Broadcasting (DVB); Specification for Service Information (SI) in DVB systems*.

[22] IETF RFC 2364, *PPP Over AAL5*.

[23] IETF RFC 1332, *The PPP Internet Protocol Control Protocol (IPCP)*.

[24] ETSI ETS 300 800, *Digital Video Broadcasting (DVB); Interaction channel for Cable TV distribution systems (CATV)*.

A.3 Abbreviations

This annex uses the following abbreviations:

ATM	Asynchronous Transfer Mode
BC	Broadcast Channel
BIM	Broadcast Interface Module
BRA	Basic Rate Access
CATV	Cable Television
CBC	Cipher Block Chaining
CM	Cable Modem
Connection Id	Connection Identifier
CRC	Cyclic Redundancy Check
DAVIC	Digital Audiovisual Council
DCE	Data Communication Equipment
DES	Data Encryption Standard
D-H	Diffie-Hellman
DL	Data Link
DTE	Data Termination Equipment
DTMF	Dual-Tone Multifrequency (dialling mode)

DVB	Digital Video Broadcasting
EKE	Explicit Key Exchange
FAS	Frame Alignment Signal
FIFO	First In, First Out
GSTN	General Switched Telephone Network
HEC	Header Error Control
HMAC	Hash-based Message Authentication Code
IB	In-Band
IC	Interaction Channel
IIM	Interactive Interface Module
INA	Interactive Network Adapter
IQ	In-phase and Quadrature Components
IRD	Integrated Receiver Decoder
ISDN	Integrated Services Digital Network
IV	Initialization Vector
LFSR	Linear Feedback Shift Register
LSB	Least Significant Bit
MAC	Media Access Control
MKE	Main Key Exchange
MMDS	Multi-channel Multi-point Distribution Systems
MPEG	Moving Picture Experts Group
MSB	Most Signicant Bit
MTU	Maximum Transmission Unit
NIU	Network Interface Unit
NSAP	Network Service Access Point
OH	OverHead
OOB	Out-of-Band
OSI	Open Systems Interconnection
PID	Packet Identifier, defined by ISO/IEC 13818 (MPEG-2)
PM	Pulse Modulation
PRNG	Pseudo-Random Number Generator
PSTN	Public Switched Telephone Network
QAM	Quadrature Amplitude Modulation
QKE	Quick Key Exchange
QoS	Quality of Service
QPSK	Quaternary Phase Shift Keying
Reservation Id	Reservation Identifier

SHA-1	Secure Hash Algorithm 1
SL-ESF	Signalling Link Extended SuperFrame
SMATV	Satellite Master Antenna Television
STB	Set-Top Box
STU	Set-Top Unit
TDMA	Time-Division Multiplex Access
TS	Transport Stream
VCI	ATM Virtual Channel Identification, defined by ITU-T I.363 [2]
VPI	ATM Virtual Path Identification, defined by ITU-T I.363 [2]

A.4 Reference model for system architecture of narrow-band interaction channels in a broadcasting scenario (asymmetric interactive services)

A.4.1 Protocol stack model

For asymmetric interactive services supporting broadcast to the home with narrow-band return channel, a simple communications model consists of the following layers:

– **physical layer**: where all the physical (electrical) transmission parameters are defined;

– **transport layer**: defines all the relevant data structures and communication protocols like data containers, etc;

– **application layer**: interactive application software and run-time environments (e.g. home shopping application, script interpreter, etc.).

A simplified model of the OSI layers was adopted to facilitate the production of specifications for these nodes. Figure A.1 points out the lower layers of the simplified model and identifies some of the key parameters for the lower two layers. Following the user requirements for interactive services, no attempt will be made to consider higher layers in the present annex.

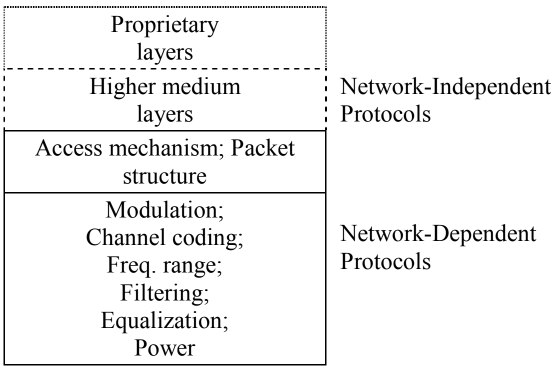


Figure A.1/J.112 – Layer structure for generic system reference model

This annex addresses the CATV network-specific aspects only.

A.4.2 System model

Figure A.2 shows the system model which is to be used within DVB for interactive services.

In the system model, two channels are established between the service provider and the user:

– **Broadcast Channel (BC)**: a unidirectional broadband broadcast channel including video, audio and data. BC is established from the service provider to the users. It may include the Forward Interaction path.

– **Interaction Channel (IC)**: a bidirectional interaction channel is established between the service provider and the user for interaction purposes. It is formed by:

  • **Return Interaction path** (return channel): from the user to the service provider. It is used to make requests to the service provider or to answer questions. It is a narrowband channel. Also commonly known as return channel.

  • **Forward Interaction path**: from the service provider to the user. It is used to provide some sort of information by the service provider to the user and any other required communication for the interactive service provision. It may be embedded into the broadcast channel. It is possible that this channel is not required in some simple implementations which make use of the broadcast channel for the carriage of data to the user.

The user terminal is formed by the Network Interface Unit (NIU) (consisting of the Broadcast Interface Module (BIM) and the Interactive Interface Module (IIM)) and the Set-Top Unit (STU). The user terminal provides interface for both broadcast and interaction channels. The interface between the user terminal and the interaction network is via the Interactive Interface Module.

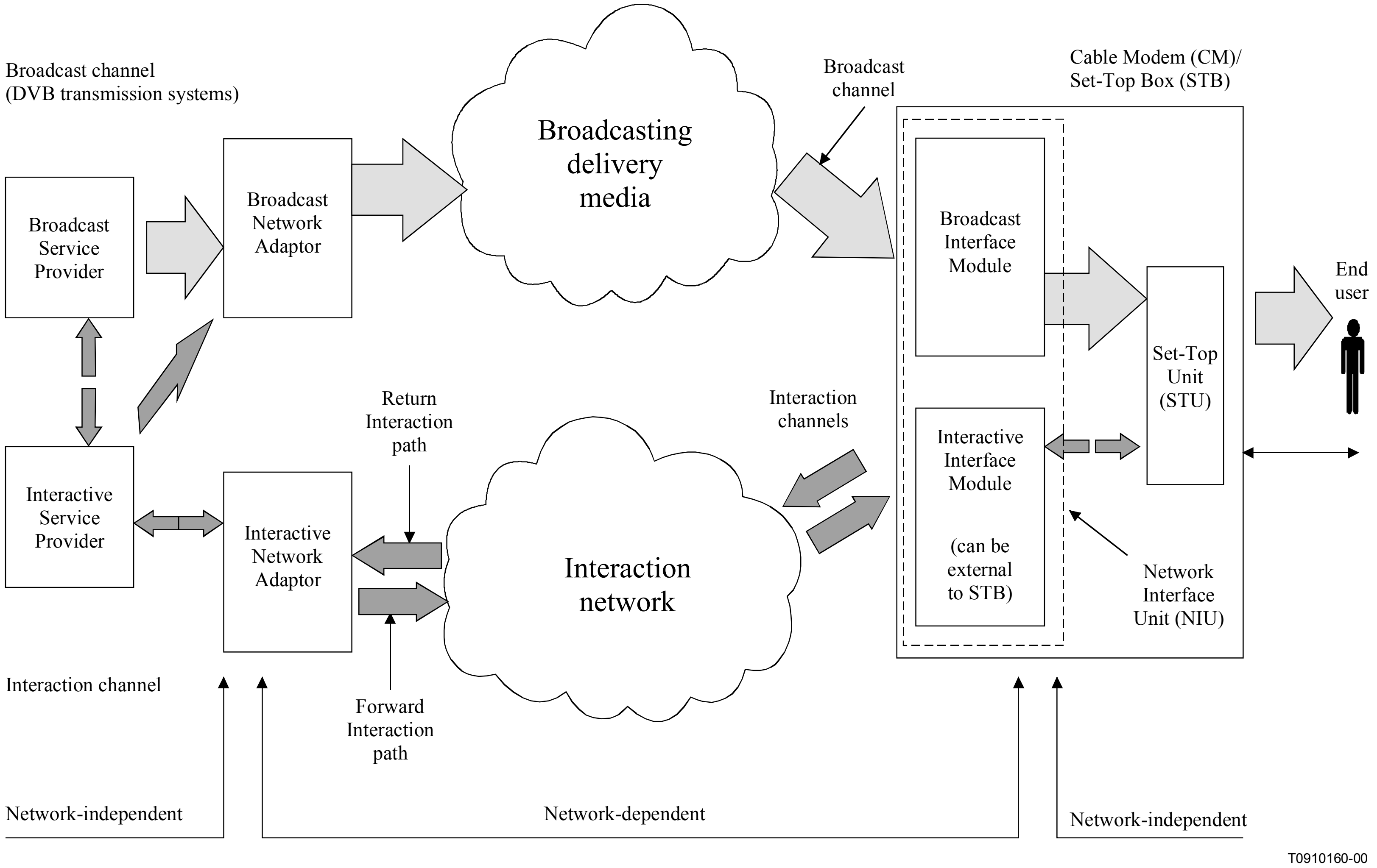


Figure A.2/J.112 – A generic system reference model for interactive systems

A.5 DVB interaction channel specification for CATV networks

The CATV infrastructures can support the implementation of the return channel for interactive services suitable for DVB broadcasting systems.

CATV can be used to implement interactive services in the DVB environment, providing a bidirectional communication path between the user terminal and the service provider.

A.5.1 System concept

The interactive system is composed of Forward Interaction path (downstream) and Return Interaction path (upstream). The general concept is to use downstream transmission from the INA to the NIUs to provide synchronization and information to all NIUs. This allows the NIUs to adapt to the network and send synchronized information upstream.

Upstream transmission is divided into time slots which can be used by different users, using the technique of Time-Division Multiple Access (TDMA). One downstream channel is used to synchronize up to 8 upstream channels, which are all divided into time slots. A counter at the INA is sent periodically to the NIUs, so that all NIUs work with the same clock. This gives the opportunity to the INA to assign time slots to different users.

Three major access modes are provided with this system. The first one is based on contention access, which lets users send information at any time with the risk of having a collision with other user's transmissions. The second and third modes are contention-less based, where the INA either provides a finite amount of slots to a specific NIU, or a given bit rate requested by a NIU until the INA stops the connection. These access modes are dynamically shared among time slots, which allows NIUs to know when contention based transmission is or is not allowed. This is to avoid a collision for the two contention-less based access modes.

Periodically, the INA will indicate to new users that they have the possibility to go through a sign-on procedure, in order to give them the opportunity to synchronize their clock to the network clock, without risking collisions with already active users. This is done by leaving a larger time interval for new users to send their information, taking into account the propagation time required from the INA to the NIUs and back.

A.5.1.1 Out-of-band/In-band principle

This interactive system is based either on out-of-band (OOB) or in-band (IB) downstream signalling. However, Set-Top Boxes/Cable Modems do not need to support both systems.

In the case of OOB signalling, a Forward Interaction path is mandatory. This path is reserved for interactivity data and control information only. However, it is also possible to send higher bit rate downstream information through a DVB-C channel whose frequency is indicated in the forward information path.

In the case of IB signalling, the Forward Information path is embedded into the MPEG-2 TS of a DVB-C channel. Note that it is not mandatory to include the Forward Information path in all DVB-C channels.

Both systems can provide the same quality of service. However, the overall system architecture will differ between networks using IB Set-Top Boxes/Cable Modems and OOB Set-Top Boxes/Cable Modems. Note also that both types of systems may exist on the same networks under the condition that different frequencies are used for each system.

A.5.1.2 Spectrum allocation

Figure A.3 indicates a possible spectrum allocation. Although not mandatory, a guideline is provided to use the following preferred frequency ranges: 70 MHz to 130 MHz and/or 300 MHz to 862 MHz for the Forward Interaction path (downstream OOB) and 5 MHz to 65 MHz for the Return Interaction path (upstream), or parts thereof. To avoid filtering problems in the bidirectional RF amplifiers and in the Set-Top Boxes/Cable Modems, the upper limit 65 MHz for the upstream flow shall not be used together with the lower limit 70 MHz for the downstream flow in the same system. Furthermore, to avoid intermediate frequency impairments of Set-Top Boxes/Cable Modems as well as analogue receivers in the same network, it could be necessary to leave out some parts of the range 5...65 MHz which includes the intermediate frequency ranges of these appliances.

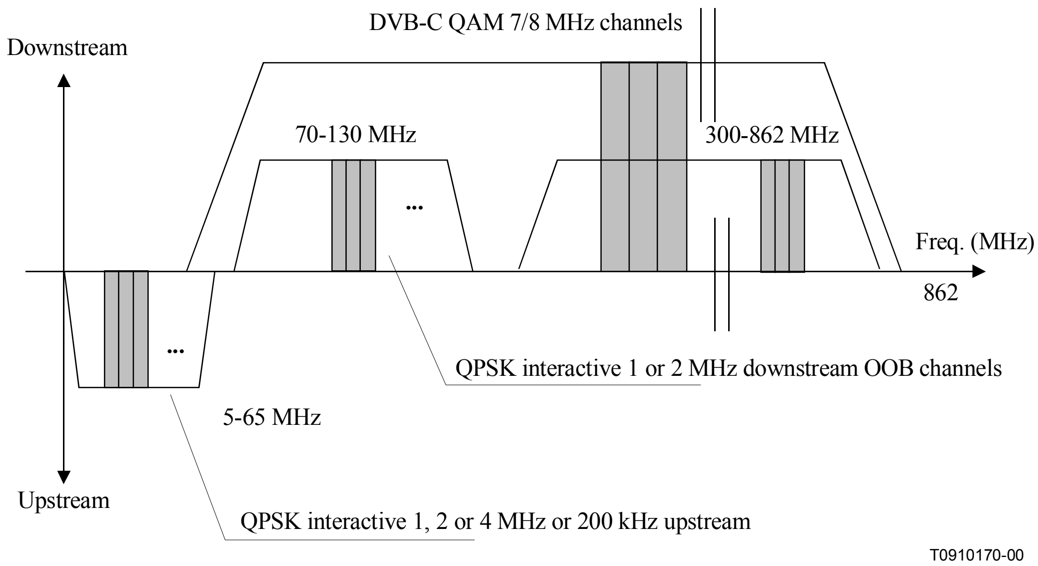


Figure A.3/J.112 – DVB preferred frequency ranges for CATV interactive systems

A.5.1.3 FDM/TDMA multiple access

A multiple access scheme is defined in order to have different users share the same transmission media. Downstream information is sent broadcast to all users of the networks. Thus, an address assignment exists for each user which allows the INA to send information singlecast to one particular user. Two addresses are stored in the Set-Top Boxes/Cable Modems in order to identify users on the network:

– MAC address: It is a 48-bit value representing the unique MAC address of the NIU. This MAC address may be hard coded in the NIU or may be provided by external source.

– NSAP address: It is a 160-bit value representing a network address. This address is provided by higher layers during communication.

Upstream information may come from any user in the network and shall therefore also be differentiated at the INA using the set of addresses defined above.

Upstream and OOB downstream channels are divided into separate channels of 1 or 2 MHz bandwidth for downstream and 1, 2 or 4 MHz or 200 kHz for upstream. Each downstream channel contains a synchronization frame used by up to 8 different upstream channels, whose frequencies are indicated by the Media Access Control (MAC) protocol.

Within upstream channels, users send upstream packets with TDMA type access. This means that each channel is shared by many different users, who can either send upstream packets with a possibility of collisions when this is allowed by the INA, or request transmission and use the slots assigned by the INA to each user specifically. Assuming each channel can therefore accommodate thousands of users at the same time, the upstream bandwidth can easily be used by all users present on the network at the same time.

The TDMA technique utilizes a slotting methodology which allows the transmit start times to be synchronized to a common clock source. Synchronizing the start times increases message throughput of this signalling channel since the upstream packets do not overlap during transmission. The period between sequential start times are identified as slots. Each slot is a point in time when an upstream packet can be transmitted over the signalling link.

The time reference for slot location is received via the downstream channels generated at the Delivery System and received simultaneously by all set-top units. Note that this time reference is not sent in the same way for OOB and IB signalling. Since all NIU's reference the same time base, the slot times are aligned for all NIU's. However, since there is propagation delay in any transmission network, a time base ranging method accommodates deviation of transmission due to propagation delay.

Since the TDMA signalling link is used by NIUs that are engaged in interactive sessions, the number of available message slots on this channel is dependent on the number of simultaneous users. When messaging slots are not in use, an NIU may be assigned multiple message slots for increased messaging throughput. Additional slot assignments are provided to the NIU from the downstream signalling information flow.

There are different access modes for the upstream slots:

– reserved slots with fixed rate reservation (Fixed rate Access: the user has a reservation of one or several time slots in each frame enabling, e.g. for voice, audio);
– reserved slots with dynamic reservation (Reservation Access: the user sends control information announcing his demand for transmission capacity. He gets grants for the use of slots);
– contention-based slots (these slots are accessible for every user. Collision is possible and solved by a contention resolution protocol);
– ranging slots (these slots are used upstream to measure and adjust the time delay and the power).

These slots may be mixed on a single carrier to enable different services on one carrier only. If one carrier is assigned to one specific service, only those slot types will be used which are needed for this service.

A.5.1.4 Bit rates and framing

For the interactive downstream OOB channel, a transmission bit rate of 1.544 Mbit/s or 3.088 Mbit/s may be used. The support of 3.088 Mbit/s is mandatory, of 1.544 Mbit/s is optional for both INA and NIU. For downstream IB channels, no other constraints than those specified in the DVB-C specifications exist, but a guideline is to use rates multiples of 8 kbit/s.

Downstream OOB channels continuously transmit a frame based on T1 type framing, in which some information is provided for synchronization of upstream slots. Downstream IB channels transmit some MPEG-2 TS packets with a specific PID for synchronization of upstream slots (at least one MPEG-2 TS packet containing synchronization information shall be sent in every period of 3 ms).

For upstream transmission, the INA can indicate 8 types of transmission channels to the users: 6.176 Mbit/s with QPSK modulation, 12.352 Mbit/s with 16QAM modulation, 3.088 Mbit/s with QPSK modulation, 6.176 Mbit/s with 16QAM modulation, 1.544 Mbit/s with QPSK modulation, 3.088 Mbit/s with 16QAM modulation, 256 kbit/s with QPSK modulation and 512 kbit/s with 16QAM modulation. The support of 3.088 Mbit/s with QPSK modulation is mandatory, of other combinations of rates and modulations is optional for both INA and NIU. The INA is responsible for indicating which rate and modulation may be used by NIUs. All NIUs and INAs shall support QPSK modulation.

There are two options for the upstream framing, depending on the modulation type. QPSK slot framing consists of upstream packets of 512 bits (256 symbols). 16QAM slot framing consists of upstream packets of 1024 bits (256 symbols). The bits are sent in a bursty mode from the different users present on the network. The upstream slot rates are 12 000 upstream slots/s when the upstream transmission bit rate is 6.176 Mbit/s (QPSK)/12.352 Mbit/s (16QAM), 6000 upstream slots/s when the upstream transmission bit rate is 3.088 Mbit/s (QPSK)/12.176 Mbit/s (16QAM), 3000 upstream slots/s when the upstream transmission bit rate is 1.544 Mbit/s (QPSK)/3.088 Mbit/s (16QAM) and 500 upstream slots/s when the upstream transmission bit rate is 256 kbit/s (QPSK)/512 kbit/s (16QAM).

Throughout this annex, the term **upstream packet** refers to the overall data that is transmitted in a single burst. One upstream packet may contain 1 or 2 ATM cells, depending on the modulation type.

A.5.2 Lower physical layer specification

In this clause, detailed information is given on the lower physical layer specification. Figures A.4 to A.7 show the conceptual block diagrams for implementation of this annex.

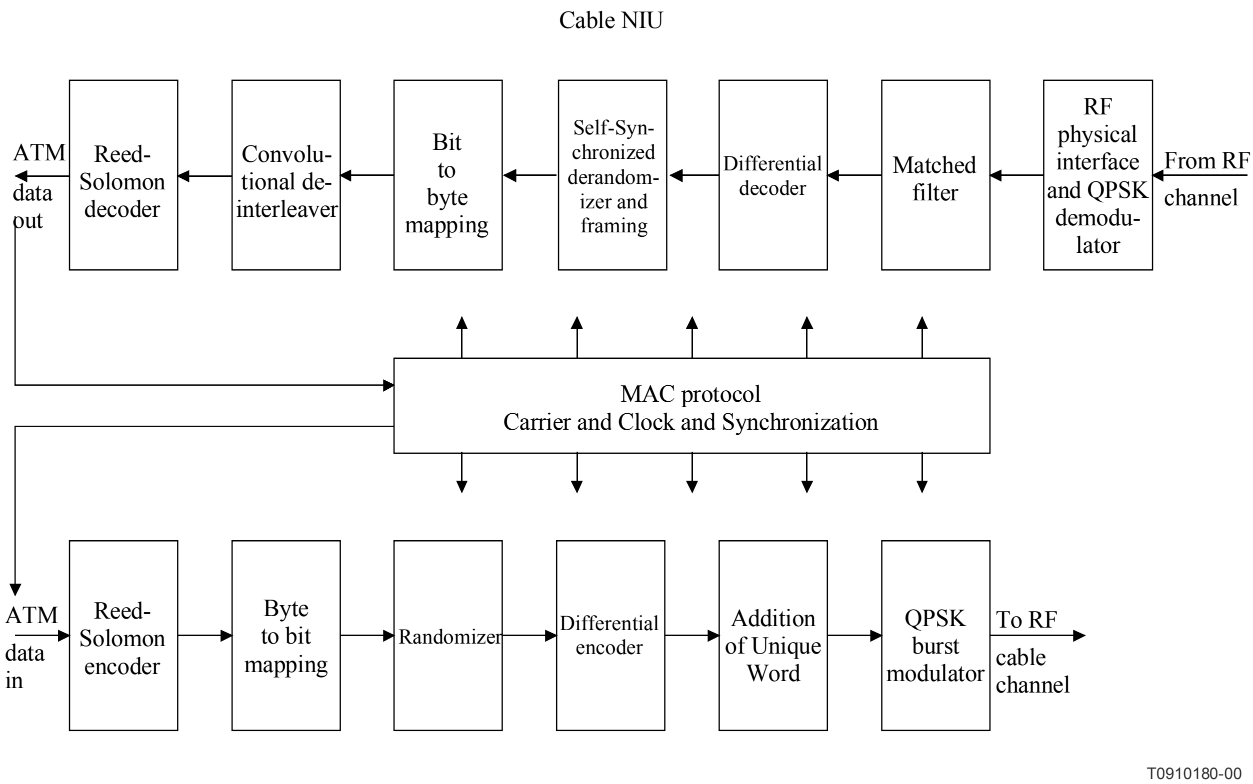


Figure A.4/J.112 – Conceptual block diagram for the NIU OOB transceiver

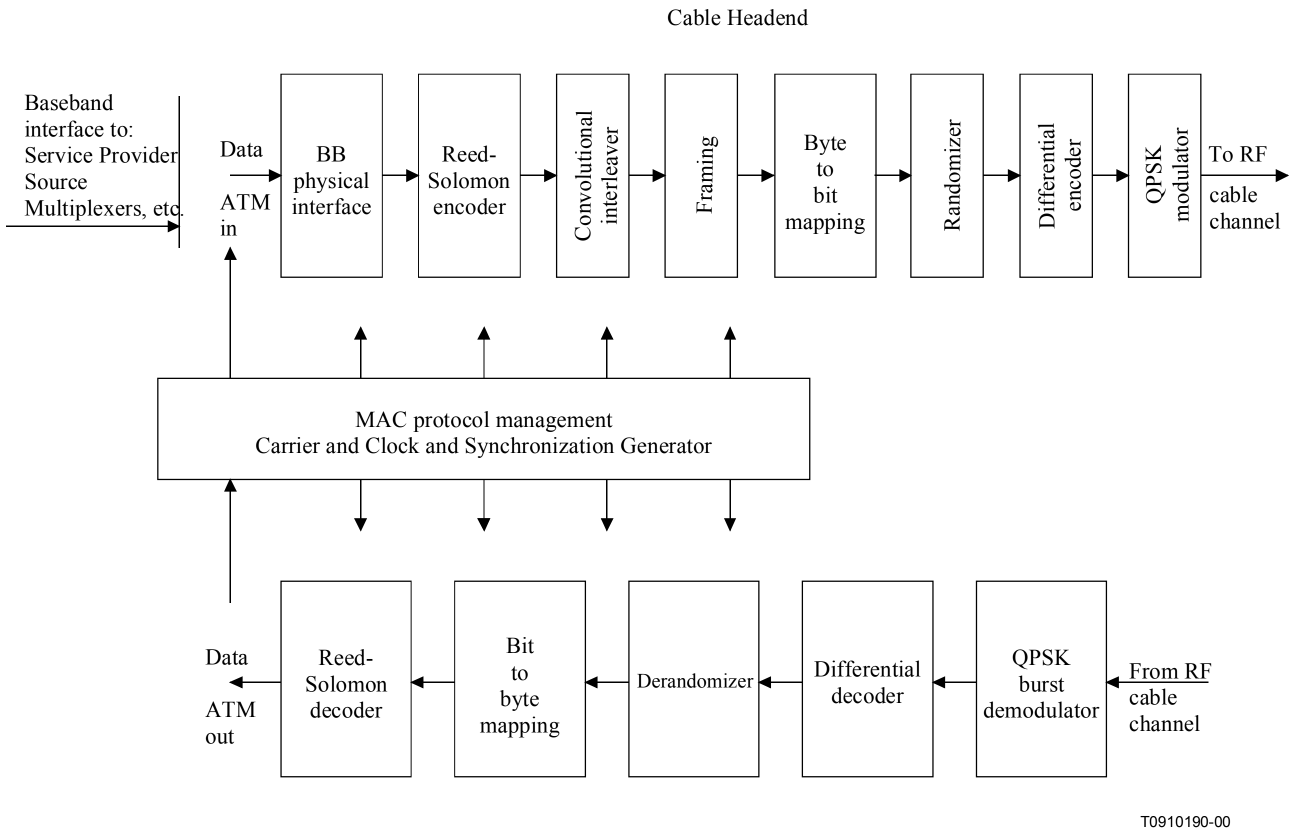


Figure A.5/J.112 – Conceptual block diagram for the OOB headend transceiver

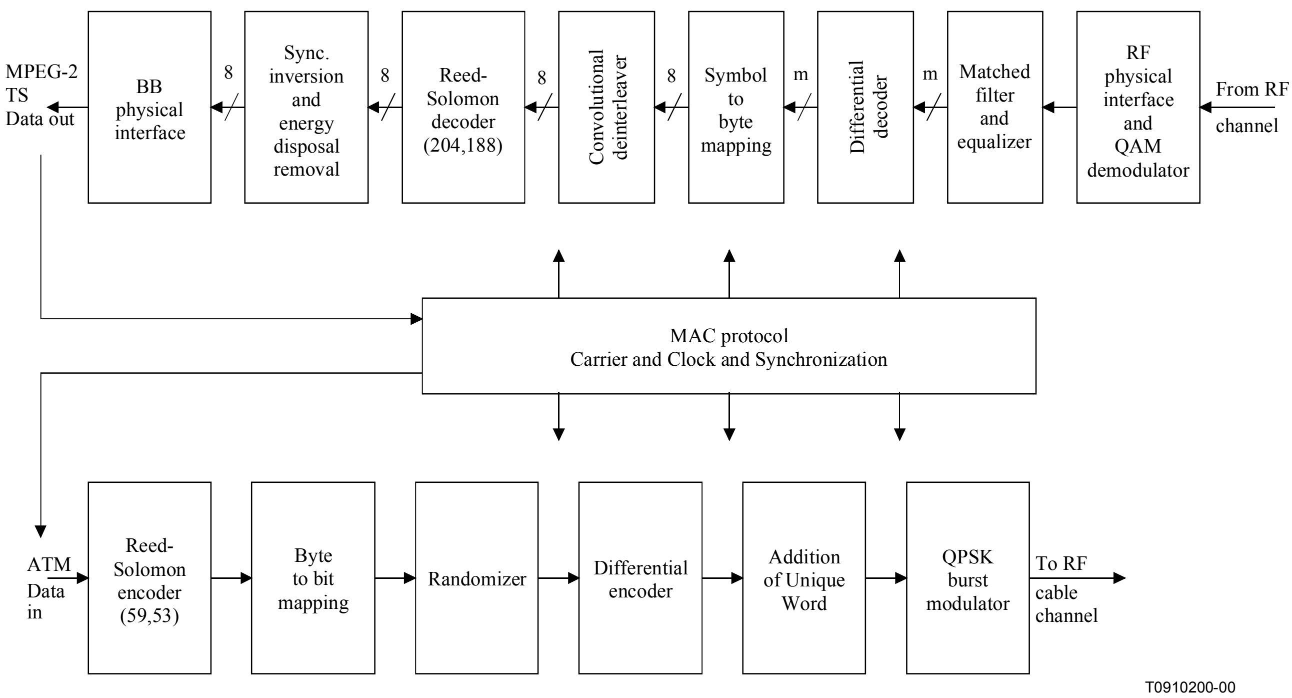


Figure A.6/J.112 – Conceptual block diagram for the IB NIU transceiver

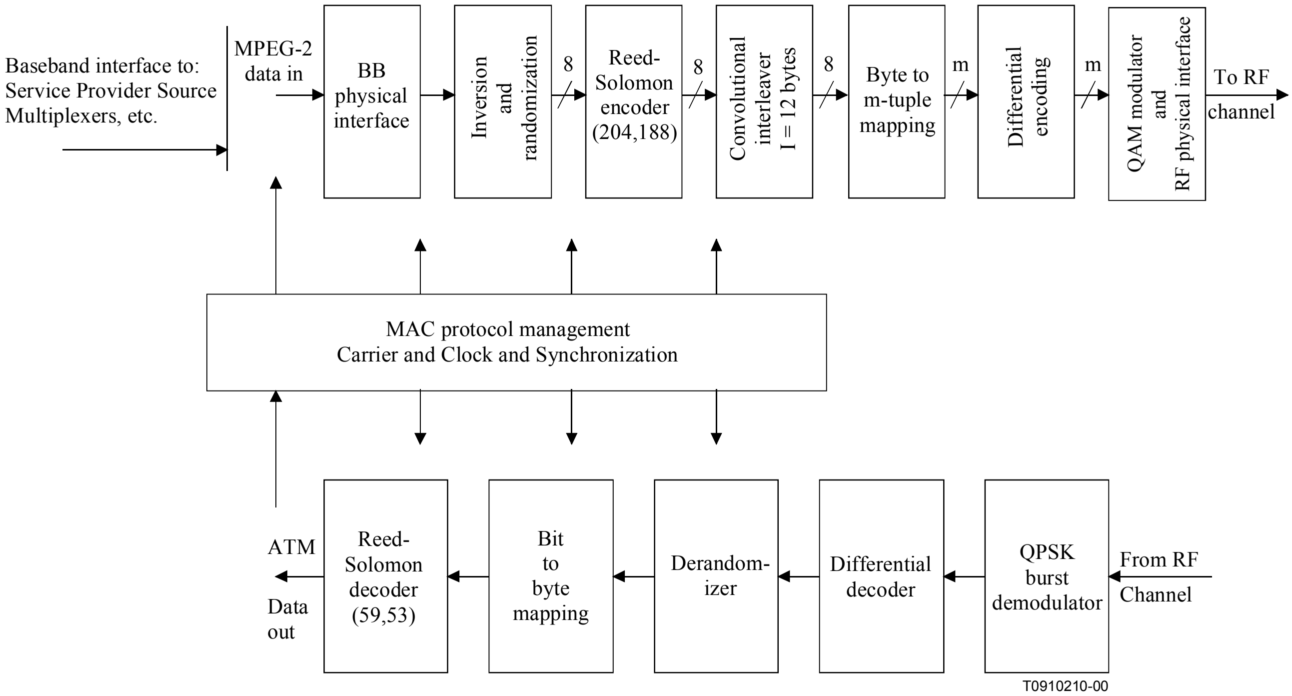


Figure A.7/J.112 – Conceptual block diagram for the IB headend transceiver

A.5.2.1 Forward interaction path (downstream OOB)

A.5.2.1.1 Frequency range (downstream OOB)

Refer to A.5.1.2.

A.5.2.1.2 Modulation and mapping (downstream OOB)

QPSK modulation is used as a means of encoding digital information over wireline or fiber transmission links. The method is a subset of Phase-Shift Keying (PSK) which is a subset of Phase Modulation (PM). Specifically QPSK is a four-level use of digital phase modulation (PM). Quadrature signal representations involve expressing an arbitrary phase sinusoidal waveform as a linear combination of a cosine wave and a sine wave with zero starting phases.

QPSK systems require the use of differential encoding and corresponding differential detection. This is a result of the receivers having no method of determining if a recovered reference is a sine reference or a cosine reference. In addition, the polarity of the recovered reference is uncertain.

Differential encoding transmits the information in encoded phase differences between the two successive signals. The modulator processes the digital binary symbols to achieve differential encoding and then transmits the absolute phases. The differential encoding is implemented at the digital level.

The differential encoder shall accept bits A, B in sequence, and generate phase changes in Table A.1:

Table A.1/J.112 – Phase changes associated with bits A, B

A	B	Phase change
0	0	none
0	1	+90°
1	1	180°
1	0	–90°

In serial mode, A arrives first. The outputs I, Q from the differential encoder map to the phase states as in Figure A.8.

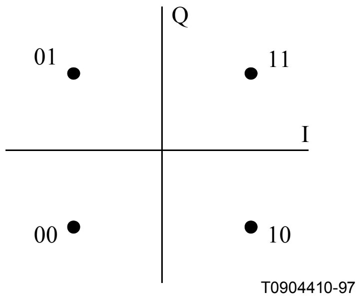


Figure A.8/J.112 – Mapping for the QPSK constellation (downstream OOB)

The phase changes can also be expressed by the following formulas (assuming the constellation is mapped from I and Q as shown above:

$$\begin{cases} A_k = \overline{(I_{k-1} \oplus Q_{k-1})} \times (Q_{k-1} \oplus Q_k) + \overline{(I_k \oplus Q_{k-1})} \times (I_k \oplus I_{k-1}) \\ B_k = \overline{(I_{k-1} \oplus Q_{k-1})} \times (I_{k-1} \oplus I_k) + \overline{(I_{k-1} \oplus Q_k)} \times (Q_k \oplus Q_{k-1}) \end{cases}$$

where k is the time index.

I/Q amplitude imbalance shall be less than 1.0 dB, and phase imbalance less than 2.0°.

A.5.2.1.3 Shaping filter (downstream OOB)

The time-domain response of a square-root raised-cosine pulse with excess bandwidth parameter α is given by:

$$g(t) = \frac{\sin\left[\frac{\pi t}{T}(1-\alpha)\right] + \frac{4\alpha t}{T}\cos\left[\frac{\pi t}{T}(1+\alpha)\right]}{\frac{\pi t}{T}\left[1-\left(\frac{4\alpha t}{T}\right)^2\right]}$$

where T is the symbol period.

The output signal shall be defined as:

$$S(t) = \sum_n \left[I_n \times g(t-nT) \times \cos(2\pi f_c t) - Q_n \times g(t-nT) \times \sin(2\pi f_c t)\right]$$

with I_n and Q_n equal to ±1, independently from each other, and f_c the QPSK modulator's carrier frequency.

The QPSK modulator divides the incoming bit stream so that bits are sent alternately to the in-phase modulator I and the out-of-phase modulator Q. These same bit streams appear at the output of the respective phase detectors in the demodulator where they are interleaved back into a serial bit stream.

The occupied bandwidth of a QPSK signal is given by the equation:

$$\text{Bandwidth} = \frac{f_b}{2}(1+\alpha)$$

where:

f_b	=	bit rate
Symbol Rate	=	$f_s = f_b/2$
Nyquist Frequency	=	$f_N = f_s/2$
α	=	excess bandwidth = 0.30

The power spectrum at the transmitter shall comply to the power spectrum mask given in Table A.2 and Figure A.9. The power spectrum mask shall be applied symmetrically around the carrier frequency.

Table A.2/J.112 – QPSK downstream transmitter power spectrum

$\| (f - f_c)/f_N \|$	**Power spectrum**
$\leq 1 - \alpha$	0 ± 0.25 dB
at 1	−3 ± 0.25 dB
at $1 + \alpha$	≤–21 dB
≥2	≤–40 dB

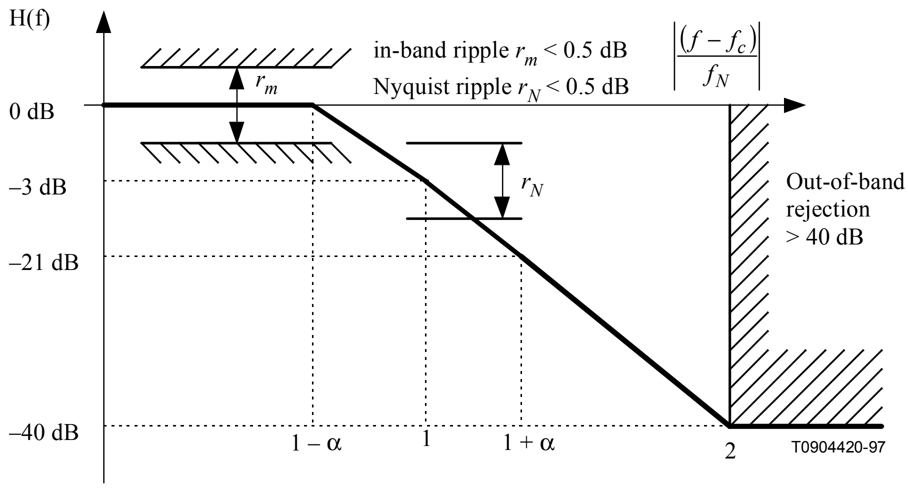


Figure A.9/J.112 – QPSK downstream transmitter power spectrum

Systems require the use of differential encoding and corresponding differential detection. This is a result of the receivers having no method of determining if a recovered reference is a sine reference or a cosine reference. In addition, the polarity of the recovered reference is uncertain.

Differential encoding transmits the information in encoded phase differences between the two successive signals. The modulator processes the digital binary symbols to achieve differential encoding and then transmits the absolute phases. The differential encoding is implemented at the digital level.

A.5.2.1.4 Randomizer (downstream OOB)

After addition of the FEC bytes (see A.5.3.1), all of the 1.544 Mbit/s (or 3.088 Mbit/s) data is passed through a six-register linear feedback shift register (LFSR) randomizer to ensure a random distribution of ones and zeros. The output of the randomizer shall be the quotient of the input data multiplied by x^6 and then divided by the generator polynomial $x^6 + x^5 + 1$. Byte/serial conversion shall be MSB first. A complementary self-synchronizing de-randomizer is used in the receiver to recover the data. (See Figures A.10 and A.11.)

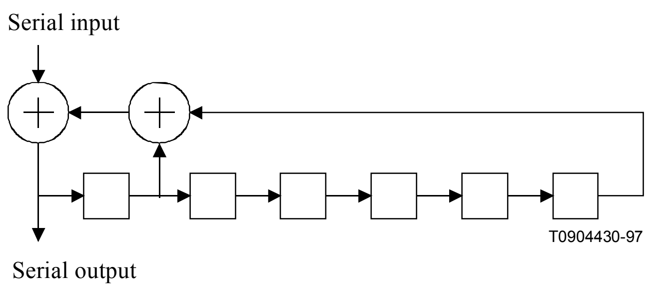


Figure A.10/J.112 – Example randomizer

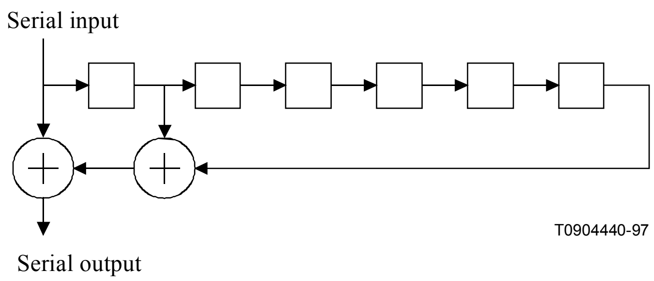


Figure A.11/J.112 – Example de-randomizer

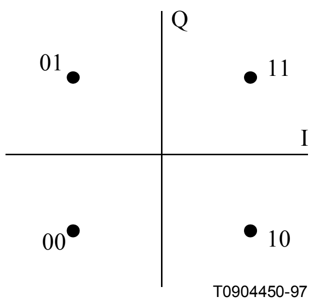
A.5.2.1.5 Bit rate (downstream OOB)

The bit rate (BR) shall be 1.544 Mbit/s or 3.088 Mbit/s. The support of 3.088 Mbit/s is mandatory, of 1.544 Mbit/s is optional for both INA and NIU. Symbol rate accuracy should be within ±50 ppm.

A.5.2.1.6 Receiver power level (downstream OOB)

The receiver power level shall be in the range 42 dBμV to 75 dBμV (RMS) (75 Ω) at its input.

A.5.2.1.7 Summary (downstream OOB)

Transmission rate	1.544 Mbit/s for Grade A (optional for INA and NIU) 3.088 Mbit/s for Grade B (mandatory for INA and NIU)
Modulation	Differentially encoded QPSK
Transmit filtering	Filtering is alpha = 0.30 square root raised cosine
Channel spacing	1 MHz for Grade A 2 MHz for Grade B
Frequency step size	250 kHz (center frequency granularity)
Randomization	After addition of the FEC bytes, all of the 1.544 Mbit/s (or 3.088 Mbit/s) data is passed through a six-register linear feedback shift register (LFSR) randomizer to ensure a random distribution of ones and zeros. The generating polynomial is: $x^6 + x^5 + 1$. Byte/serial conversion shall be MSB first. A complementary self-synchronizing de-randomizer is used in the receiver to recover the data.
Differential encoding	The differential encoder shall accept bits A, B in sequence, and generate phase changes as follows: A B Phase Change 0 0 none 0 1 +90° 1 1 180° 1 0 −90° In serial mode, A arrives first.
Signal constellation	The outputs I, Q from the differential encoder map to the phase states as in Figure A.12.  **Figure A.12/J.112 – QPSK constellation**
Frequency range	recommended but not mandatory 70 MHz to 130 MHz and/or 300 MHz to 862 MHz
Frequency stability	±50 ppm measured at the upper limit of the frequency range
Symbol rate accuracy	±50 ppm
Carrier suppression	>30 dB
I/Q amplitude imbalance	<1.0 dB

I/Q phase imbalance	<2.0°
Receive power level at the NIU input	42-75 dBμV (RMS) (75 Ω)
Transmit spectral mask	A common mask for both bit rates: 1.544 Mbit/s (Grade A) and 3.088 Mbit/s (Grade B) is given in Table A.2 and in Figure A.9.

A.5.2.1.8 Bit error rate downstream OOB (informative)

Bit error rate at the NIU should be less than 10^{-10} (after error correction, i.e. 1 error in 2 hours at 1.5 Mbit/s) at C/N > 20 dB for downstream transmission. C/N is the carrier-to-noise ratio relevant for the demodulation process (Nyquist bandwidth for white noise).

A.5.2.2 Forward interaction path (downstream IB)

The IB Forward Interaction Path shall use a MPEG-2 TS stream with a modulated QAM channel as defined by EN 300 429 [7]. Frequency range, channel spacing, and other lower physical layer parameters should follow that specification. The accuracy of the downstream frequency shall be ±50 ppm.

A.5.2.3 Return interaction path (upstream)

The upstream path allows two types of modulation: QPSK and 16QAM. Every upstream channel will use a single modulation type: QPSK, or 16QAM.

A.5.2.3.1 Frequency range (upstream)

The frequency range is not specified as mandatory although a guideline is provided to use the 5 MHz to 65 MHz. Frequency stability shall be in the range ±50 ppm measured at the upper limit of the frequency range.

A.5.2.3.2 Modulation and mapping (upstream)

The input bits will be mapped into I/Q constellations according to the following:

QPSK symbols – I_1 Q_1

16QAM symbols – I_1 Q_1 I_0 Q_0

where:

I_1 is the MSB for QPSK/16QAM

Q_1 is the LSB for QPSK

Q_0 is the LSB for 16QAM.

The MSB must be the first bit of the serial data into the modulator.

The unique word (CC CC CC 0D for QPSK and F3 F3 F3 F3 F3 F3 33 F7 for 16QAM; see A.5.3.3 for upstream framing) is not differentially encoded. For the remainder of the slot, the coding will be differential. The QPSK symbol map and 16QAM symbol map for the unique word are described in Figures A.13 and A.14.

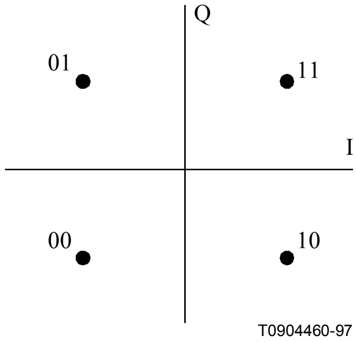


Figure A.13/J.112 – Mapping for the QPSK constellation (upstream)

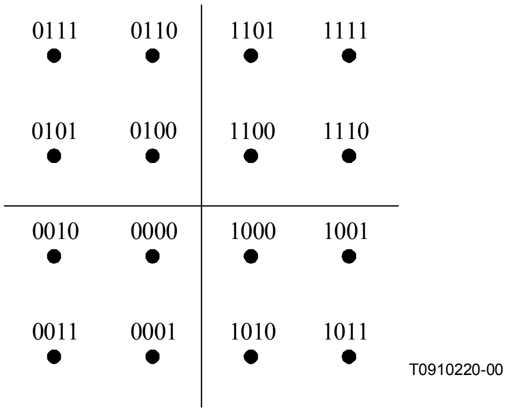


Figure A.14/J.112 – Mapping for the 16QAM constellation (upstream)

The differential encoding shall be done according to Table A.3. The current transmitted quadrant is derived from the previous transmitted quadrant and the current input bits.

Table A.3/J.112 – Differential encoding

Current input bits I_1 Q_1	Quadrant phase change	MSBs of the previous transmitted symbol	MSBs of the currently transmitted symbol
00	0°	11	11
00	0°	01	01
00	0°	00	00
00	0°	10	10
01	90°	11	01
01	90°	01	00
01	90°	00	10
01	90°	10	11
11	180°	11	00
11	180°	01	10
11	180°	00	11
11	180°	10	01

Table A.3/J.112 – Differential encoding

Current input bits I_1 Q_1	Quadrant phase change	MSBs of the previous transmitted symbol	MSBs of the currently transmitted symbol
10	270°	11	10
10	270°	01	11
10	270°	00	01
10	270°	10	00

I/Q amplitude imbalance shall be less than 1.0 dB, and phase imbalance less than 2.0°.

A.5.2.3.3 Shaping filter (upstream)

The time-domain response of a square-root raised-cosine pulse with excess bandwidth parameter α is given by:

$$g(t) = \frac{\sin\left[\frac{\pi t}{T}(1-\alpha)\right] + \frac{4\alpha t}{T}\cos\left[\frac{\pi t}{T}(1+\alpha)\right]}{\frac{\pi t}{T}\left[1-\left(\frac{4\alpha t}{t}\right)^2\right]}$$

where T is the symbol period.

The output signal shall be defined as:

$$S(t) = \sum_n \left[I_n \times g(t-nT) \times \cos(2\pi f_c t) - Q_n \times g(t-nT) \times \sin(2\pi f_c t)\right]$$

with I_n and Q_n equal to ±1 (QPSK)/±3 (16QAM), independently from each other, and f_c the QPSK/16QAM modulator's carrier frequency.

The QPSK/16QAM modulator divides the incoming bit stream so that bits are sent alternately to the in-phase modulator I and the out-of-phase modulator Q. These same bit streams appear at the output of the respective phase detectors in the demodulator where they are interleaved back into a serial bit stream.

The QPSK/16QAM signal parameters are:

$$\text{RF bandwidth } = \frac{f_b}{2}(1+\alpha)$$

Occupied RF Spectrum $[f_c - f_s/2, f_c + f_s/2]$

Symbol Rate $f_s = f_b/2$

Nyquist Frequency $f_N = f_s/2$

with f_b = bit rate, f_c = carrier frequency and α = excess bandwidth.

For all 8 channel types: 256 kbit/s QPSK (Grade A), 512 kbit/s 16QAM (Grade AQ), 1.544 Mbit/s QPSK (Grade B), 3.088 Mbit/s 16QAM (Grade BQ), 3.088 Mbit/s QPSK (Grade C), 6.176 Mbit/s 16QAM (Grade CQ), 6.176 Mbit/s QPSK (Grade D) and 12.352 Mbit/s 16QAM (Grade DQ), the Power Spectrum at the transmitter shall comply to the Power Spectrum Mask given in Table A.4 and Figure A.15. The Power Spectrum Mask shall be applied symmetrically around the carrier frequency.

Table A.4/J.112 – QPSK upstream transmitter power spectrum

$\lvert (f - f_c)/f_N \rvert$	**Power spectrum**
≤1 – α	0 ± 0.25 dB
at 1	–3 ± 0.25 dB
at 1 + α	≤–21 dB
≥2	≤–40 dB

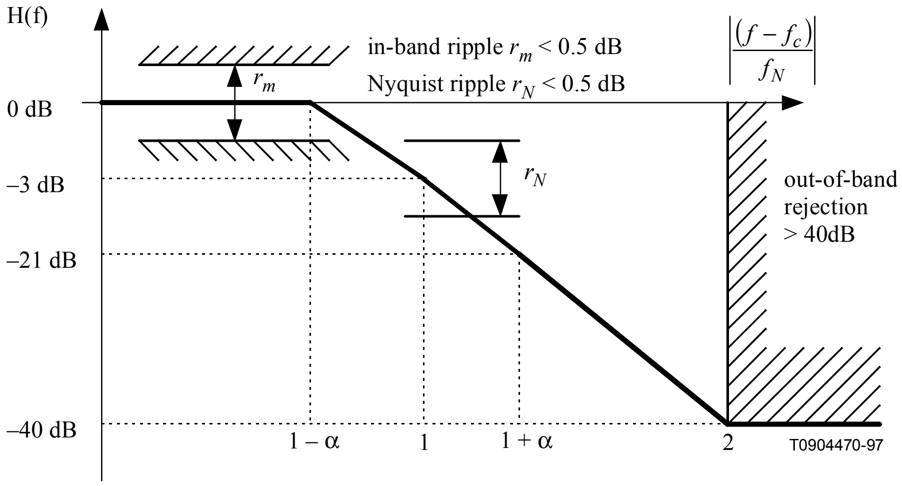


Figure A.15/J.112 – QPSK upstream transmitter power spectrum

The specifications which shall apply to modulation for the upstream channel are given in Table A.4.

A.5.2.3.4 Randomizer (upstream)

The unique word shall be sent in clear (see A.5.3.3). After addition of the FEC bytes, randomization shall apply only to the payload area and FEC bytes, with the randomizer performing modulo-2 addition of the data with a pseudo-random sequence. The generating polynomial is $x^6 + x^5 + 1$ with seed all ones. We assume the first value coming out of the pseudo-random generator taken into account is 0. Byte/serial conversion shall be MSB first. The binary sequence generated by the shift register starts with 00000100.... The first "0" is to be added in the first bit after the unique word.

A complementary non self-synchronizing de-randomizer is used in the receiver to recover the data. The de-randomizer shall be enabled after detection of the unique word.

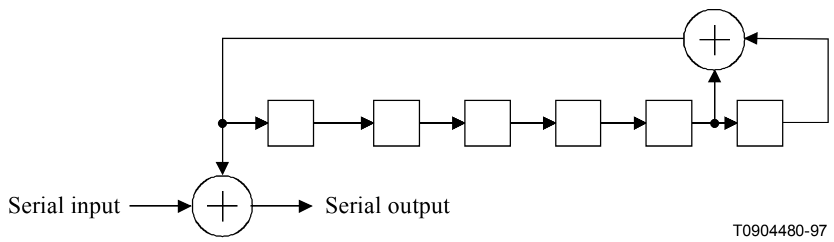


Figure A.16/J.112 – Randomizer

A.5.2.3.5 Pre-equalizer

In the case of 16QAM modulation, the NIU is responsible for configuring a transmit pre-equalizer according to messages received from the INA. The pre-equalizer will be a T-spaced equalizer with 8 taps. The taps coefficient real and imaginary parts will consist of 16 bits, coded in fractional two's complement notation.

The pre-equalizer will be configured during the ranging and power calibration phase. In the case of the first sign on the service channel, the calculation will be based on the QPSK symbols that are sent (by the NIU) in the <MAC> sign on response message (see A.5.5.4.2). To ensure proper calculation, the NIU should ensure that the slot containing the <MAC> sign on response message would be sent with at least 200 different QPSK symbols (regardless of the message length in bytes). In the case of reprovision to a 16QAM channel, the coefficients will be calculated according to 16QAM symbols.

Before initial ranging and calibration (at first sign on or in the case of a new upstream channel), the NIU MUST initiate the coefficients to 1 (center tap) and 0.

A.5.2.3.6 Bit rate (upstream)

Eight grades of modulation and transmission rate are specified (see Table A.5):

Table A.5/J.112 – Upstream bit-rates and modulations for modulation grades A, AQ, B, BQ, C, CQ, D and DQ

Grade	Rate
A	256 kbit/s QPSK (optional for INA and NIU)
B	1.544 Mbit/s QPSK (optional for INA and NIU)
C	3.088 Mbit/s QPSK (mandatory for INA and NIU)
D	6.176 Mbit/s QPSK (optional for INA and NIU)
AQ	512 kbit/s 16QAM (optional for INA and NIU)
BQ	3.088 Mbit/s 16QAM (optional for INA and NIU)
CQ	6.176 Mbit/s 16QAM (optional for INA and NIU)
DQ	12.352 Mbit/s 16QAM (optional for INA and NIU)

The support of 3.088 Mbit/s QPSK is mandatory, of other combinations of modulation and rate is optional for both INA and NIU.

Symbol rate accuracy should be within ±50 ppm.

For grades A and AQ, the rate is 500 slots/s. For grades B and BQ, the rate is 3000 slots/s. For grades C and CQ, the rate is 6000 slots/s. For grades D and DQ, the rate is 12 000 slots/s.

A.5.2.3.7 Transmit power level (upstream)

At the output, the transmit power level shall be in the range 85-113 dBμV (RMS) (75 Ω). In some geographic areas, it may be necessary to cover the range 85-122 dBμV (RMS) (75 Ω). However, note that high power may lead to electromagnetic compatibility problems. This power shall be adjustable by steps of 0.5 dB (nominally) by MAC messages coming from the INA.

Measured at the INA, the US power accuracy shall be better or equal to ±1.5 dB.

A.5.2.3.8 Upstream burst power and timing profiles

Because of the symbol shaping filter that spreads the symbol duration over Ts = 1/symbol_rate, a burst has a ramp up (before the first symbol) and a ramp down (after the last symbol) as shown in Figure A.17.

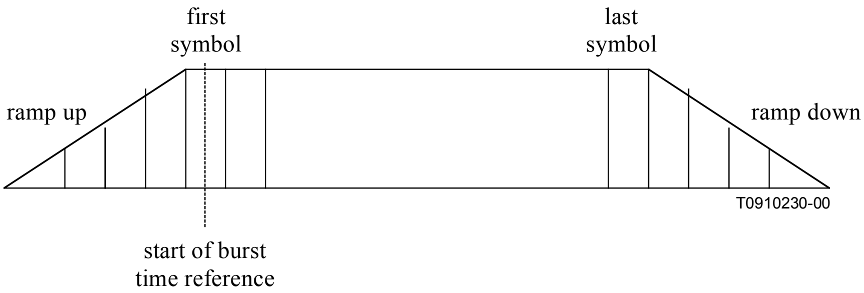


Figure A.17/J.112 – Burst ramp up and down

The ramps up and down of consecutive bursts can overlap.

The ramps shall be minimum 3 symbols long.

When the transmitter is idle the upstream power level attenuation shall be more than 60 dB (relative to the nominal burst power output level), over the entire power output range (the absolute maximum output power level should not exceed that specified in Table A.7). A terminal is considered to be idle if it is 3 slots before an imminent transmission or 3 slots after its most recent transmission.

4 symbols before the first symbol of a burst and 4 symbols after the last symbol, the upstream power level attenuation shall be more than 30 dB (relative to the nominal burst power output level), over the entire power output range.

After ranging and propagation delay compensation, the NIU/STB US timing accuracy shall be better than or equal to ±5/8th of a symbol (Upstream rate).

The time ranging accuracy provided by the MAC messages coming from the INA shall be better than or equal to ±1/8th of a symbol (upstream rate) or ±50 ns, whatever is the maximum (because the ranging unit is 100 ns).

The NIU messages shall then arrive at the INA in a window of ±0.75 symbols (upstream transmission bit rate) for bit rates of 256 kbit/s, 1.544 Mbit/s and 3.088 Mbit/s and in a window of ±0.78 symbols (upstream transmission bit rate) for the 6.176 Mbit/s case.

A.5.2.3.9 Interference (spurious) suppression

The noise and the spurious power at the output of the transmitting (upstream) device may not exceed the levels as shown in Table A.6. The measurement bandwidth is equal to the symbol rate (e.g. 1.544 kHz for 1.544 ksymb/s) below fd1 and equal to 7 MHz above fd1.

Table A.6/J.112 – Interference spurious suppression

	Transmitting burst	**Between bursts**
In-band	n.a.	−60 dBc (see Notes 1 and 2)
Adjacent band upstream	−40 dBc	−70 dBc (see Notes 1 and 2)
Other band within 5 ... fd1 MHz	−40 dBc	−70 dBc (see Note 1)
fd1 ... fd2 MHz (measured in 7 MHz)	45 dBμV	22 dBμV
> fd2 MHz (measured in 7 MHz)	30 dBμV	22 dBμV
fd1 Minimum downstream frequency in the network fd2 Minimum downstream frequency occupied by TV programs = min NOTE 1 – dBc is based on the carrier level during the burst. NOTE 2 – The additional suppression of 30 dB for inter burst is based on the connection max. 1000 NIU's per INA.		

A.5.2.3.10 Summary (upstream)

See Table A.7.

Table A.7/J.112 – Summary (upstream)

Upstream transmission Bit rate	Eight grades of modulation and transmission bit rate are specified: Grade Rate A 256 kbit/s QPSK (optional for INA and NIU) B 1.544 Mbit/s QPSK (optional for INA and NIU) C 3.088 Mbit/s QPSK (mandatory for INA and NIU) D 6.176 Mbit/s QPSK (optional for INA and NIU) AQ 512 kbit/s 16QAM (optional for INA and NIU) BQ 3.088 Mbit/s 16QAM (optional for INA and NIU) CQ 6.176 Mbit/s 16QAM (optional for INA and NIU) DQ 12.352 Mbit/s 16QAM (optional for INA and NIU) The support of 3.088 Mbit/s QPSK is mandatory, of other combinations of modulation and rate is optional for both INA and NIU.
Modulation	Differentially encoded QPSK/differentially encoded 16QAM
Transmit filtering	alpha = 0.30 square root raised cosine
Channel spacing	200 kHz for Grades A, AQ 1 MHz for Grades B, BQ 2 MHz for Grades C, CQ 4 MHz for Grades D, DQ
Frequency step size	50 kHz
Randomization	The unique word shall be sent in the clear. After addition of the FEC bytes, randomization shall apply only to the payload area and FEC bytes, with the randomizer performing modulo-2 addition of the data with a pseudo-random sequence. The generating polynomial is $x^6 + x^5 + 1$ with seed all ones. Byte/serial conversion shall be MSB first. A complementary non self-synchronizing de-randomizer is used in the receiver to recover the data. The de-randomizer shall be enabled after detection of the unique word.
Differential encoding	The differential encoder shall accept bits I_1 Q_1 I_0 Q_0 in sequence, and generate phase changes as follows. In serial mode, I_1 arrives first. See Table A.3 for details.

Table A.7/J.112 – Summary (upstream)

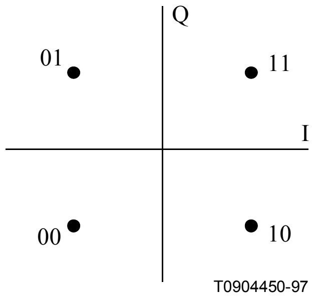
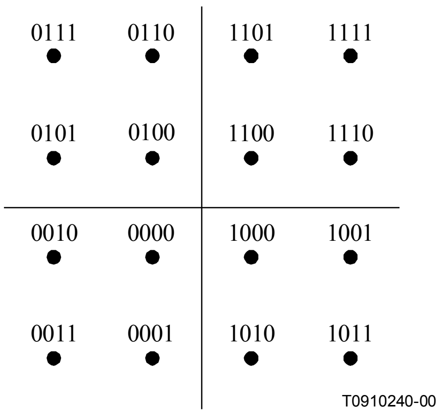
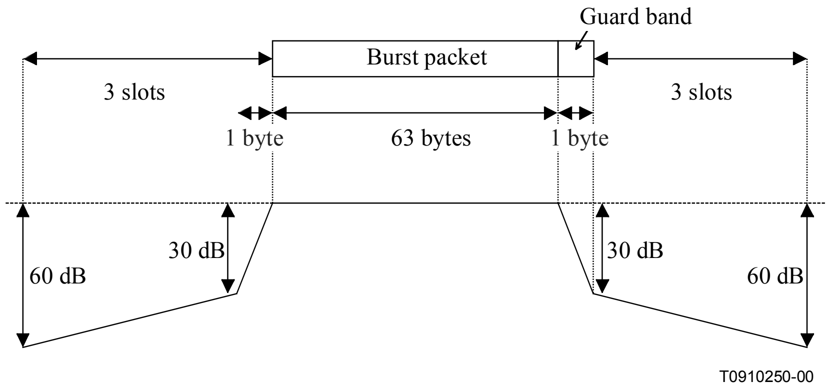
Signal constellation QPSK NOTE – The unique word (CC CC CC 0D hex) does not go through differential encoding.	The outputs I, Q from the differential encoder map to the phase states as in Figure A.18.  **Figure A.18/J.112 – Burst QPSK constellation**
Signal constellation 16QAM NOTE – The unique word (F3 F3 F3 F3 F3 F3 33 F7) does not go through differential encoding.	 **Figure A.19/J.112 – Burst 16QAM constellation**
Frequency range	5 MHz to 65 MHz recommended but not mandatory
Frequency stability	±50 ppm measured at the upper limit of the frequency range
Symbol rate accuracy	±50 ppm
Transmit spectral mask	A common mask for all eight upstream grades is given in Table A.4 and Figure A.15.
Carrier suppression when transmitter active	>30 dB

Table A.7/J.112 – Summary (upstream)

Burst power profile	Upstream power level attenuation shall be more than 60 dB relative to the nominal burst power output level over the entire power output range and 30 dB right after or before transmission. Idle Transmitter definition: A terminal is considered to be idle if it is 3 slots before an imminent transmission or 3 slots after its most recent transmission. 
I/Q amplitude imbalance	<1.0 dB
I/Q phase imbalance	<2.0°
Transmit power level at the modulator output (upstream)	85-113 dBμV (RMS) (75 Ω). In some geographic areas, it may be necessary to cover the range 85-122 dBμV (RMS) (75 Ω). In any case, cable networks shall comply with the EMC requirements of CENELEC EN 50083-2 [19] concerning radiated disturbance power by feed in of the transmit power.

A.5.2.3.11 Packet loss upstream (informative)

Upstream packet loss at the INA shall be less than 10^{-6} at C/N > 20 dB (after error correction) for upstream transmission.

NOTE – An upstream packet loss occurs when one or more bit per upstream packet (after error correction) are uncorrectable. The C/N is referred at the demodulator input (Nyquist bandwidth, white noise).

A.5.2.3.12 Maximum cable delay

This annex has been designed to support cable round-trip delays of up to 800 μs, which corresponds to a cable length of approximately 80 km. Larger delays than this may be accommodated, with judicious use of this annex.

A.5.3 Framing

A.5.3.1 Forward interaction path (downstream OOB)

A.5.3.1.1 Signalling link extended superframe framing format

The Signalling Link Extended Superframe (SL-ESF) frame structure is shown in Figure A.20. The bitstream is partitioned into 4632-bit Extended Superframes. Each Extended Superframe consists of 24 × 193-bit frames. Each frame consists of 1 overhead (OH) bit and 24 bytes (192 bits) of payload.

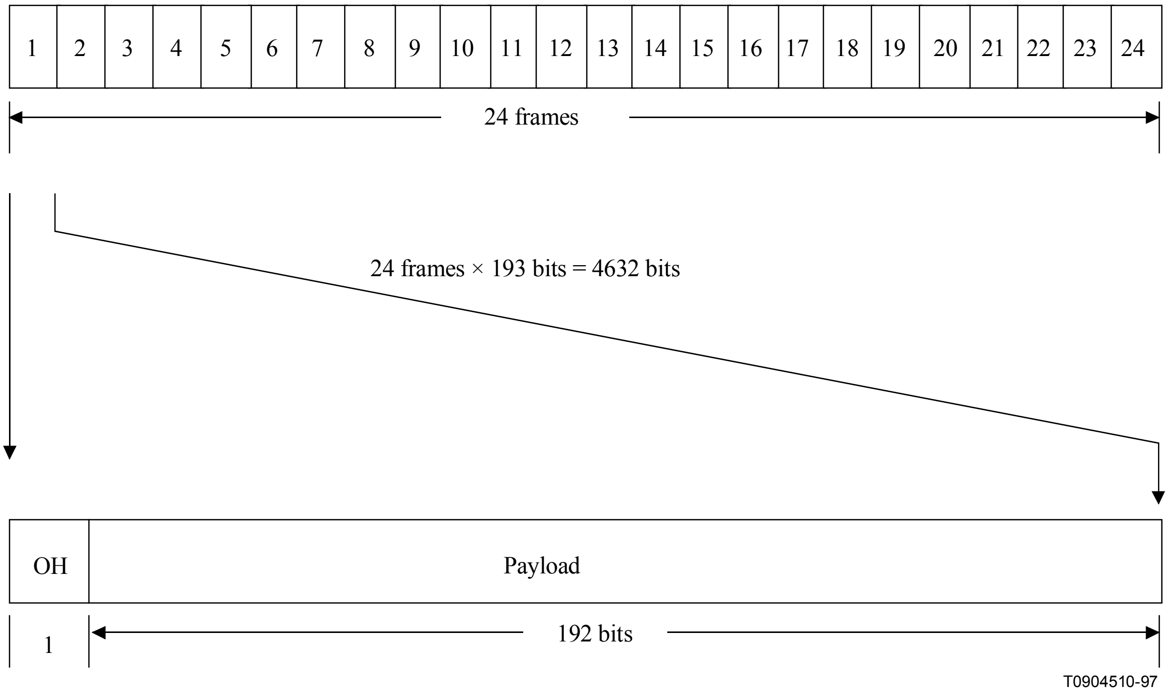


Figure A.20/J.112 – SL-ESF frame structure

A.5.3.1.2 Frame overhead

There are 24 frame overhead bits in the Extended Superframe which are divided into Extended Superframe Frame Alignment Signal (F1-F6), Cyclic Redundancy Check (C1-C6), and M-bit Data Link (M1-M12) as shown in Table A.8. Bit number 0 is received first.

Table A.8/J.112 – Frame overhead

Frame number	Bit number	Overhead bit	Data (192 bits)
1	0	**M1**	
2	193	C1	
3	386	M2	
4	579	F1 = 0	
5	772	M3	
6	965	C2	
7	1158	M4	
8	1351	F2 = 0	
9	1544	**M5**	
10	1737	C3	
11	1930	M6	
12	2123	F3 = 1	
13	2316	M7	
14	2509	C4	
15	2702	M8	

Table A.8/J.112 – Frame overhead

Frame number	Bit number	Overhead bit	Data (192 bits)
16	2895	F4 = 0	
17	3088	**M9**	
18	3281	C5	
19	3474	M10	
20	3667	F5 = 1	
21	3860	M11	
22	4053	C6	
23	4246	M12	
24	4439	F6 = 1	
FAS Frame Alignment Signal (F1-F6) DL Mbit Data Link (M1-M12) CRC Cyclic Redundancy Check (C1-C6)			

ESF Frame Alignment Signal

The ESF Frame Alignment Signal (FAS) is used to locate all 24 frames and overhead bit positions. The bit values of the FAS are defined as follows:

F1 = 0, F2 = 0, F3 = 1, F4 = 0, F5 = 1, F6 = 1.

ESF Cyclic Redundancy Check

The Cyclic Redundancy Check field contains the CRC-6 check bits calculated over the previous Extended Superframe (CMB – *CRC Message block*, size = 4632 bits). Before calculation, all 24 frame overhead bits are equal to "1". All information in the other bit positions is unchanged. The check bit sequence C1-C6 is the remainder after multiplication by x^6 and then division by the generator polynomial $x^6 + x^5 + 1$ of the CMB. C1 is the most significant bit of the remainder. The initial remainder value is preset to all zeros.

ESF Mbit data link

The M-bits in the SL-ESF serve for slot timing assignment (see A.5.4).

A.5.3.1.3 Payload structure

The SL-ESF frame payload structure provides a known container for defining the location of the ATM cells and the corresponding Reed-Solomon parity values. The SL-ESF payload structure is shown in Table A.9. When the INA has no data or MAC messages to send on the downstream OOB channel, it will send Idle ATM Cells as specified in [16], where the content of the Idle ATM Cell has been specified as:

0x00, 0x00, 0x00, 0x01, 0x52 (Idle ATM Cell header)

0x6A, 0x6A, ..., 0x6A (48 data bytes payload)

Table A.9/J.112 – ESF payload structure

	2		53	2		
1	R1a	R1b	ATM cell	RS parity		
2	R1c	R2a			R2b	
3	R2c	R3a				
4	R3b	R3c			R4a	
5	R4b	R4c				
6	R5a	R5b			R5c	
7	R6a	R6b				
8	R6c	R7a			R7b	
9	R7c	R8a				
10	R8b	R8c			T	T

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The SL-ESF payload structure consists of 5 rows of 57 bytes each, 4 rows of 58 bytes each, which includes a 1-byte trailer, and 1 row of 59 bytes, which includes a 2-byte trailer. The relative ordering of data between Table A.9 and Table A.8, is such that reading Table A.9 from left to right, and then top to bottom, corresponds to reading Table A.8 from top to bottom. The most significant bit of byte R1a in Table A.9 corresponds to Bit number 1 in Table A.8. The various SL-ESF payload fields are described below.

Define the downstream time-ticks T_{dn} and the upstream time-ticks T_{un} as follows:

The downstream channel is divided into 3 ms periods separated by downstream time-ticks T_{dn} and the upstream channel is divided into 3 ms periods separated by upstream time ticks T_{un} in case of upstream transmission bit rates of 1.544 Mbit/s, 3.088 Mbit/s and 6.176 Mbit/s. In case of an upstream transmission bit rate of 256 kbit/s, both downstream and upstream periods are 6 ms.

Then the time difference, $T_{un} – T_{dn}$, is called the Absolute_Time_Offset, and is defined:

$$\text{Absolute\_Time\_Offset} = T_{un} - T_{dn}$$

and:

$$\text{New Absolute\_Time\_Offset} = \text{current Absolute\_Time\_Offset} - \text{Time\_Offset\_Value}$$

(Time_Offset_Value is a field contained in the <MAC> Ranging And Power Calibration Message and is defined in A.5.5.4.3).

Before the NIU goes through the sign-on procedure for the first time, the current Absolute_Time_Offset is set according to the value passed in the Default Configuration message (taking into account the timing accuracies).

The NIU shall use the following definitions for using the R-bytes:

– the boundary information contained in the downstream period that starts by downstream time-tick T_{dn} relates to the slots in the upstream period that starts at upstream time-tick T_{un+1}. This upstream period is also called the "next" one;

– the reception information contained in the downstream period that starts by downstream time-tick T_{dn} relates to the slots in the upstream period that starts at upstream time-tick T_{un-2}. This upstream period is also called the "second previous" one.

ATM cell structure

The format for each ATM cell structure is shown in Figure A.21. This structure and field coding shall be consistent with the structure and coding given in ITU-T I.361 [1] for ATM UNI.

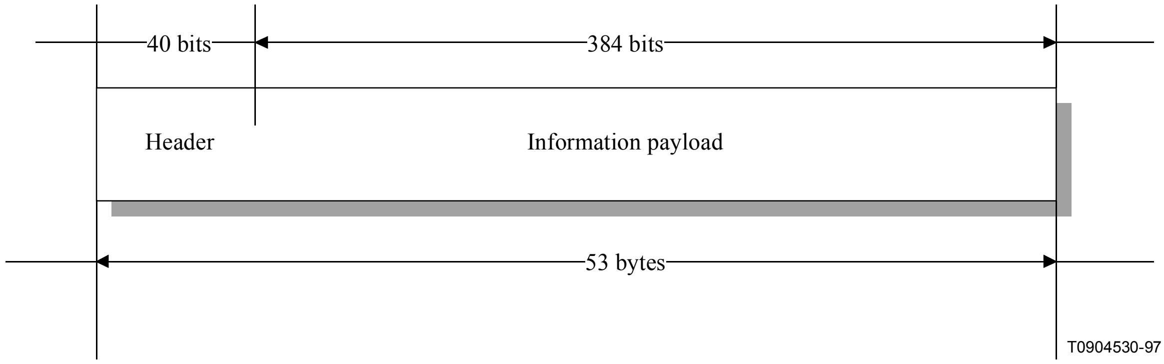


Figure A.21/J.112 – ATM cell format

The entire header (including the HEC byte) shall be protected by the Header Error Control (HEC) sequence. The HEC code shall be contained in the last byte of the ATM header. The HEC sequence shall be capable of:

– single-bit error correction;

– multiple-bit error detection.

Error detection in the ATM header shall be implemented as defined in [16]. The HEC byte shall be generated as described in [16], including the recommended modulo-2 addition (XOR) of the pattern 01010101b to the HEC bits. The generator polynomial coefficient set used and the HEC sequence generation procedure shall be in accordance with [16].

Channel coding and interleaving

Reed-Solomon encoding with t = 1 shall be performed on each ATM cell. This means that 1 erroneous byte per ATM cell can be corrected. This process adds 2 parity bytes to the ATM cell to give a codeword of (55,53).

The Reed-Solomon code shall have the following generator polynomials:

Code Generator Polynomial: $g(x) = (x + \mu^0)(x + \mu^1)$, where μ = 02 hex

Field Generator Polynomial: $p(x) = x^8 + x^4 + x^3 + x^2 + 1$

The shortened Reed-Solomon code shall be implemented by appending 200 bytes, all set to zero, before the information bytes at the input of a (255,253) encoder; after the coding procedure these bytes are discarded.

Convolutional interleaving shall be applied to the ATM cells contained in the SL-ESF. The Rxa-Rxc bytes and the two T bytes shall not be included in the interleaving process. Convolutional interleaving is applied by interleaving 5 lines of 55 bytes.

Following the scheme of Figure A.22, convolutional interleaving shall be applied to the error-protected packets. The convolutional interleaving process shall be based on the Forney approach, which is compatible with the Ramsey type III approach, with I = 5. The Interleaved frame shall be composed of overlapping error-protected packets and a group of 10 packets shall be delimited by the start of the SL-ESF.

The interleaver is composed of I branches, cyclically connected to the input byte-stream by the input switch. Each branch shall be a First-In, First-Out (FIFO) shift register, with depth ($M \times j$) cells (where M = N/I, N = 55 = error protected frame length, I = interleaving depth, j = branch index). The input and output switches shall be synchronized. Each cell of the FIFO shall contain one byte.

For synchronization purposes, the first byte of each error-protected packet shall be always routed into the branch "0" of the interleaver (corresponding to a null delay). The third byte of the SL-ESF payload (the byte immediately following R1b) shall be aligned to the first byte of an error-protected packet.

The de-interleaver is similar, in principle, to the interleaver, but the branch indexes are reversed (i.e. branch 0 corresponds to the largest delay). The de-interleaver synchronization is achieved by routing the third data byte of the SL-ESF into the "0" branch. (See Figure A.22.)

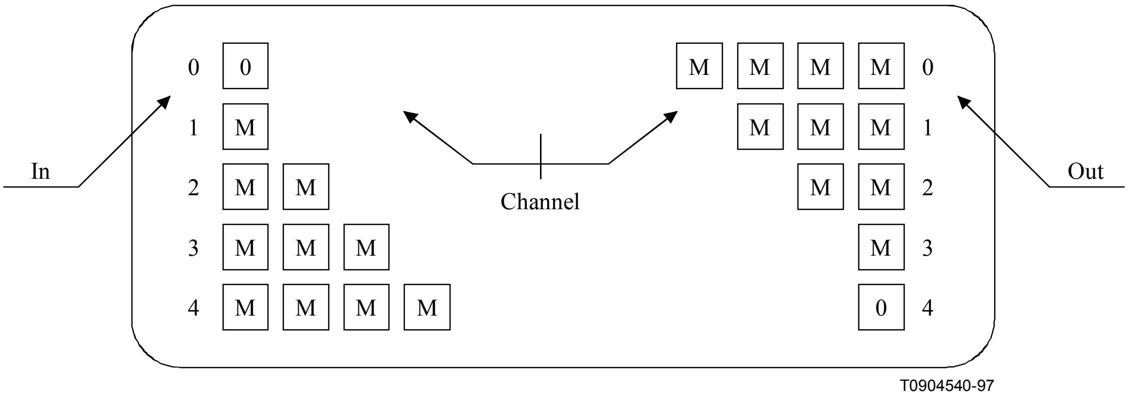


Figure A.22/J.112 – Interleaver and de-interleaver structures

Reception indicator fields and slot boundary fields

A downstream channel can control up to 8 upstream channels and contains control information for each of its associated upstream channels. This information is contained within structures known as Flags. A set of Flags is represented by either 24 bits (denoted b0...b23) or by 3 bytes (denoted Rxa, Rxb and Rxc):

Rxa = (b0...b7) = (msb...lsb)

Rxb = (b8...b15) = (msb...lsb)

Rxc = (b16...b23) = (msb...lsb)

One or more consecutive MAC flags are associated to one upstream channel. This link is done in the MAC messages Default Configuration Message, Connect Message, Reprovision Message and Transmission Control Message. To the upstream channel "c" (parameter Service_Channel or Upstream_Channel_Number or New_Upstream_Channel_Number of the MAC messages mentioned above) are associated the MAC flags "x" and the following as described below. "x" corresponds to the parameter MAC_Flag_Set of the previous MAC messages. It is a 5-bit field and can take the values 1...16. Values 0 and 17...31 are invalid.

In the OOB downstream case, each frame structure contains eight sets of Flags represented by Rxa, Rxb and Rxc, where x is replaced by the numbers 1...8. In the case of a 1.544 Mbit/s downstream bit rate, only one frame occurs during a 3 ms interval providing 8 sets of Flags. In the case of a 3.088 Mbit/s downstream bit rate, two frames A and B occur during a 3 ms interval, providing 16 sets of Flags. The second set of Flags (contained in B) are denoted by Rxa, Rxb and Rxc, where x is replaced by the numbers 9 through 16.

In case of a 3.088 Mbit/s upstream channel, two sets of Flags are required. In this case, the MAC_Flag_Set parameter represents the first of two successively assigned Flag sets (Rxa-Rxc, Rya-Ryc with y = (x + 1) with x belonging to [1, 7] for 1.544 Mbit/s DS and belonging to [1, 15] for 3.088 Mbit/s DS. In particular, if one downstream OOB 1.544 Mbit/s channel controls 3.088 Mbit/s upstream channels, at most 4 upstream channels can be controlled, due to the number of available Flags.

In case of a 6.176 Mbit/s upstream channel, four sets of Flags are required. In this case, the MAC_Flag_Set parameter represents the first of four successively assigned Flag sets (Rxa-Rxc, Rua-Ruc, Rva-Rvc, Rwa-Rwc with u = (x + 1), v = (x + 2), w = (x + 3), with x belonging to [1, 5] for 1.544 Mbit/s DS and belonging to [1, 13] for 3.088 Mbit/s DS. In particular, if one downstream OOB 3.088 Mbit/s channel controls 6.176 Mbit/s upstream channels, at most 4 upstream channels can be controlled, due to the number of available Flags. And if one downstream OOB 1.544 Mbit/s channel controls 6.176 Mbit/s upstream channels, at most 2 upstream channels can be controlled.

The bits b0 to b23 are defined as follows:

b0	=	ranging slot indicator for next 3 ms period (msb) (6 ms for 256 kbit/s)
b1-b6	=	slot boundary definition field for next 3 ms period (6 ms for 256 kbit/s)
b7	=	slot 1 reception indicator (as shown in Table A.13)
b8	=	slot 2 reception indicator (as shown in Table A.13)
b9	=	slot 3 reception indicator (as shown in Table A.13)
b10	=	slot 4 reception indicator (as shown in Table A.13)
b11	=	slot 5 reception indicator (as shown in Table A.13)
b12	=	slot 6 reception indicator (as shown in Table A.13)
b13	=	slot 7 reception indicator (as shown in Table A.13)
b14	=	slot 8 reception indicator (as shown in Table A.13)
b15	=	slot 9 reception indicator (as shown in Table A.13)
b16-17	=	reservation control for next 3 ms period (6 ms for 256 kbit/s)
b18-b23	=	CRC 6 parity (see definition in SL-ESF section)

When the upstream transmission grade is A/AQ, then only the first three slot reception indicators are valid. When the upstream transmission grade is B/BQ, then the 9 slots are valid. When the upstream transmission grade is C/CQ, the 9 slots of this field and the 9 slots of the following field are valid: two consecutive Slot Configuration fields are then used. The definition of the first Slot Configuration field is unchanged. The definition of the second Slot Configuration field extends the boundary definition to cover upstream slots 10 through 18, and the reception indicators to cover upstream slots 10 through 18. When the upstream transmission grade is D/DQ, four consecutive Slot Configuration fields are then used. The definition of the first Slot Configuration field is unchanged. The definition of the second Slot Configuration field extends the boundary definition to cover upstream slots 10 through 18, and the reception indicators to cover upstream slots 10 through 18. The definition of the third Slot Configuration field extends the boundary definition to cover upstream slots 19 through 27, and the reception indicators to cover upstream slots 19 through 27. The definition of the fourth Slot Configuration field extends the boundary definition to cover upstream slots 28 through 36, and the reception indicators to cover upstream slots 28 through 36.

In general, when the upstream rate is lower than the downstream rate, there are several OOB downstream superframes during groups of k upstream slots (where k = 3 for grade A/AQ upstream, k = 9 for grade B/BQ upstream). In that case, slot configuration information remain equal over all superframes corresponding to one group of k upstream slots.

Ranging Slot Indicator (b0): When this bit is active (b0 = 1), the first three slots of upstream channel "x" which correspond to the occurrence of the next superframe of the related downstream channel are designated as ranging slots. A ranging message may be transmitted in the second ranging slot according to the algorithm defined for ranging, and the first and third ranging slots may not be used for transmission (guard band for ranging operations).

Slot Boundary Definition field (b1-b6): Slot types are assigned to upstream slots using bits b0-b6. The slots are grouped into "spans". In the case of upstream grades A and AQ, a span is the 3 slots between two 6 (ms) time markers. Otherwise a span is 9 slots. In the case of upstream grades B and BQ there is 1 span between two 3 (ms) time markers. In the case of upstream grades C and CQ there are 2 spans between two 3 (ms) time markers. In the case of the upstream grades D and DQ there are 4 spans between two 3 (ms) time markers. Within each span, the bits b0-b6 define regions, such that slots of the same type are contained within the same region. The order of the regions is Ranging slots, Contention-based slots, Reserved slots and Fixed-rate-based slots. If a ranging slot is available within a "span", it will consist of the first three slot times in the "span", assuming b1-b6 are not in the range 55-63 (see Table A.12). A ranging slot is indicated by b0 = 1. The boundaries between the remaining regions of the "spans" are defined by b1-b6. The boundaries are defined as shown in Table A.10.

Table A.10/J.112 – Slot boundary definition field (b1-b6)

Boundary 0	
	slot 1
Boundary 1	
	slot 2
Boundary 2	
	slot 3
Boundary 3	
	slot 4
Boundary 4	
	slot 5
Boundary 5	
	slot 6
Boundary 6	
	slot 7
Boundary 7	
	slot 8
Boundary 8	
	slot 9
Boundary 9	

The boundary positions are defined by b1-b6 as shown in Table A.11.

Table A.11/J.112 – Boundary positions (b1-b6)

		Contention based/Reserved region boundary									
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Reserved slot/Fixed rate based region boundary	**0 (Note)**	0	1	2	3	4	5	6	7	8	9
	1 (Note)		10	11	12	13	14	15	16	17	18
	2 (Note)			19	20	21	22	23	24	25	26
	3				27	28	29	30	31	32	33
	4					34	35	36	37	38	39
	5						40	41	42	43	44
	6							45	46	47	48
	7								49	50	51
	8									52	53
	9										54

NOTE – When the ranging control slot indicator (b0) is set to "1", the values in rows 0-2 are illegal values, and values in row 3 means that there are no contention slots, because slots 1-3 are defined as ranging control slots.

Example

b0 = 0, b1-b6 = 22

⇒ Contention (1-2), reserved (3-5), Fixed rate (6-9)

The remaining values of the Slot Boundary Definition Field are provided in Table A.12.

Table A.12/J.112 – Slot boundary definition field

b1-b6 value	Ranging control slots	Contention slots	Reservation slots	Fixed rate slots
55	1-6	7-9	–	–
56	1-6	7-8	–	9
57	1-6	7	8-9	–
58	1-6	7	8	9
59	1-6	7	–	8-9
60	1-6	–	7-8	9
61	1-6	–	7	8-9
62	1-6	–	–	7-9
63	1-9	–	–	–

NOTE 1 – For b1-b6 = 55 to 63, b0 shall be set to 1. Note that for b1-b6 between 55 and 62, two ranging slots are provided (2 and 5). For b1-b6 = 63, three ranging slots are provided (2, 5 and 8).

The values in the above tables are derived from b1-b6 in the following manner:

$$b1 + (b2 \times 2) + (b3 \times 4) + (b4 \times 8) + (b5 \times 16) + (b6 \times 32)$$

Warning: This formula indicates that b6 is considered as the MSB of b1-b6 word, whereas b0 is the MSB of the entire word b0-b23. Although this "looks" inconsistent, it has not been changed for the purpose of compatibility with the DAVIC standard.

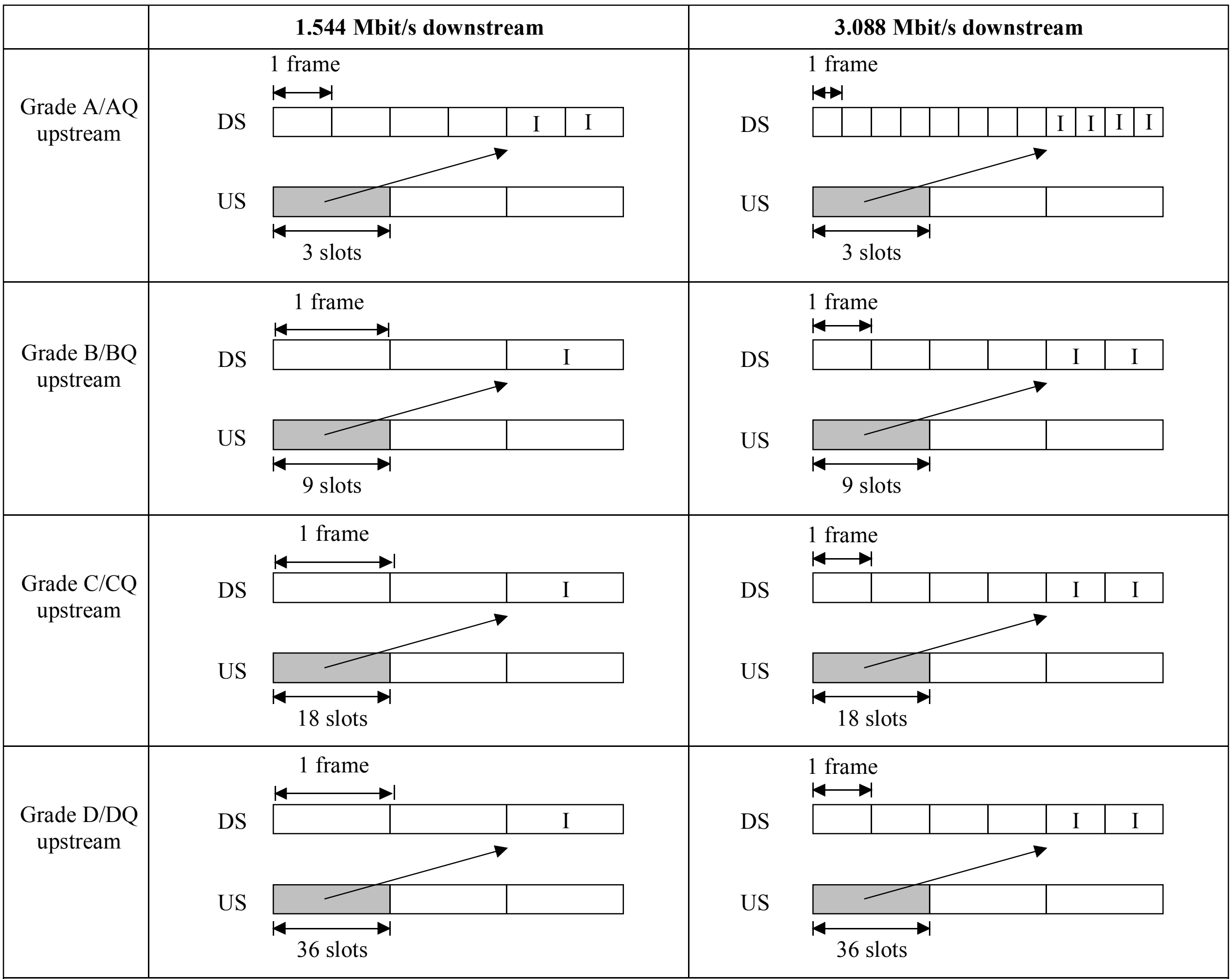
When the upstream data channel is a 256 kbit/s data channel, then only the first four rows and colums of Table A.11 are valid, and Table A.12 is not valid.

NOTE 2 – If slot boundary fields change while some NIUs have already been allocated slots in the reservation slots area, these NIUs are responsible for updating the list of physical slots. Specifically, slots are assigned by MAC Reservation Grant messages, which contain a Reference slot that does not depend on the slot boundary fields and a Grant_slot_count which corresponds to the number of slots assigned within the reservation slots boundary field. If the field changes, the list of physical slots on which the NIU can transmit automatically changes accordingly.

Slot Reception Indicators (b7-b15): When a slot reception indicator is active ("1"), this indicates that an upstream packet was received without collision. The relationship between a given US slot and its indicator is shown in Table A.13. When the indicator is inactive ("0"), this indicates that either a collision was detected or no upstream packet was received in the corresponding upstream slot.

Slot reception indicators lead to the retransmission procedure only when contention access is used as described in A.5.5.2.4.

Table A.13/J.112 – Relationship of US slot to DS indicator at the INA



NOTE 1 – "I" indicates the downstream frame(s) in which Indicators (contained within the Flag Sets) are sent. These indicators control the upstream slots in the shaded area.

NOTE 2 – In the 3.088 Mbit/s downstream, two successive frames contain Flag Sets 1...16.

NOTE 3 – Two successive Flag Sets are used to control the 18 slots of a grade C/CQ upstream channel. In this case you can control max. 4 upstreams using the 1.544 Mbit/s downstream.

NOTE 4 – Four successive Flag Sets are used to control the 36 slots of a grade D/DQ upstream channel. In this case you can control max. 2 upstreams using the 1.544 Mbit/s downstream and max. 4 upstreams using the 3.088 Mbit/s downstream.

NOTE 5 – Note that this table refers to the position of US slots with respect to the positions of DS superframes at the INA receiver. NIUs should have their Time_Offset_Value of transmission set such that this table applies.

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Reservation Control (b16-b17): When the reservation control field has the value of 0, no reservation attempts are allowed to be transmitted on the corresponding QPSK upstream channel during the slot positions associated with the next 3 ms period. When the reservation control field has the value of 1, reservation attempts can be made. The values 2 and 3 are reserved. A reservation attempt corresponds to sending a MAC Reservation Request message or a piggyback request (see MAC section), b16 is MSB.

CRC 6 Parity (b18-b23): This field contain a CRC 6 parity value calculated over the previous 18 bits. The CRC 6 parity value is described in the SL-ESF frame format clause A.5.3.1.2; b18 is MSB.

In the case where there is more than one OOB DS QPSK channel related to an upstream QPSK channel, the SL-ESF overhead bits and the payload R-bytes shall be identical in those OOB DS channels, with the exception of the overhead CRC (C1-C6) bits, which are specific to each of those OOB DS channels. Such related DS channels shall be synchronized (transmitted synchronously). This scenario applies for example when a lot more bandwidth is needed for DS information than US information. An NIU is not required to have more than one QPSK tuner.

The MAC messages that are required to perform the MAC functions for the upstream channel shall be transmitted on each of its related OOB DS channels.

Trailer bytes

These bytes are not used. They are equal to 0.

A.5.3.2 Forward interaction path (downstream IB)

A.5.3.2.1 IB signalling MPEG-2 TS format (MAC control message)

The structure that is utilized when the downstream QAM channel is carrying MPEG-2 TS packets is shown in Figure A.23. MSBs of each field are transmitted first.

4	3	2	3	26	26	40	40	40	4
MPEG Header	Upstream Marker	Slot Number	MAC Flg Control	MAC Flags	Ext. Flags	MAC msg.	MAC msg.	MAC msg.	rsrvc

Figure A.23/J.112 – Frame structure (MPEG-2 TS format)

where:

MPEG Header is the 4-byte MPEG-2 Transport Stream Header as defined in ITU-T H.222.0 | ISO/IEC 13818-1 [20] with a specific PID designated for MAC messages. This PID is 0x1C. The transport_scrambling_control field of the MPEG header shall be set to "00". (Informative notes: The transport_priority bit is ignored by the NIU. The payload_unit_start_indicator bit is ignored by the NIU for MPEG TS packets containing MAC messages. The adaptation_field_control bits must be be set to "01" for MPEG TS packets contatining MAC messages.)

Upstream Marker is a 24-bit field which provides upstream QPSK synchronization information. (As mentioned in A.5.1.4, at least one MPEG TS packet with synchronization information shall be sent in every period of 3 ms). The definition of the field is as follows:

– **bit 0: upstream marker enable (MSB)**

When this field has the value "1", the slot marker pointer is valid. When this field has the value "0", the slot marker pointer is not valid.

– **bits 1-3: MAC message framing**

Bit 1 relates to the first MAC message slot within the MPEG frame, bit 2 to the second, and bit 3 to the last slot. The meaning of each bit is:

– 0: A MAC message terminates in this slot.

– 1: A MAC message continues from this slot into the next, or the slot is unused, in which case the first two bytes of the slot are 0x0000.

After an unused slot, no more MAC messages can appear in that MPEG TS packet. One MAC message cannot be split to different MPEG TS packets. So the only valid interpretation of bits 1-3 is:

Bits 1-3	Slot 1	Slot 2	Slot 3
000	M040	M040	M040
001	M040	M040	Unused
010	M040	M080	
011	M040	Unused	Unused
100	M080		M040
101	M080		Unused
110	M120		
111	Unused	Unused	Unused

Where Mxxx means that a MAC message with not more than xxx bytes length is carried in that slot(s).

– **bits 4-7: reserved**

– **bits 8-23: upstream slot marker pointer**

The slot marker pointer is a 16-bit unsigned integer which indicates the number of downstream "symbol" clocks between the next Sync byte and the next 3 ms time marker. Bit 23 is to be considered as the most significant bit of this field.

Slot Number is a 16-bit field which is defined as follows: (as mentioned in A.5.1.4, at least one MPEG TS packet with synchronization information shall be sent in every period of 3 ms).

– **bit 0: slot position register enable (MSB)**

When this field has the value "1", the slot position register is valid. When this field has the value "0", the slot position register is not valid.

– **bits 1-3: reserved;**

– **bit 4 is set to the value "1". This bit is equivalent to M12 in the case of OOB downstream;**

– **bit 5: odd parity.**

This bit provides odd parity for upstream slot position register. This bit is equivalent to M11 in the case of OOB downstream.

– **bits 6-15: upstream slot position register**

The upstream slot position register is a 10-bit counter which counts from 0 to n with bit 6 the MSB. These bits are equivalent to M10-M1 in the case of OOB downstream.

(See A.5.4 for more information on the functionality of the upstream slot position register.)

MAC Flag Control is a 24-bit field (b0 (MSB), b1, b2...b23) which provides control information which is used in conjunction with the "MAC Flags" and "Extension Flags" fields. The definition of the MAC Flag Control field is as follows:

– b0-b2 Channel 0 control field

– b3-b5 Channel 1 control field

– b6-b8 Channel 2 control field

– b9-b11 Channel 3 control field

– b12-b14 Channel 4 control field

– b15-b17 Channel 5 control field

– b18-b20 Channel 6 control field

– b21-b23 Channel 7 control field

Each of the above Channel "c" Control Fields is defined as follows:

– Channel "c" control field (a, b, c) = (bn, bn+1, bn+2) where n = 3 × c

– bit a: 0 = MAC Flag Set of channel "c" disabled.

1 = MAC Flag Set of channel "c" enabled:

"MAC Flag Set of Channel "c" enabled" means that the Mac Flags assigned to the upstream channel "c" are valid in this MPEG TS packet. The relation between the channel number "c" and the assigned Mac Flag sets is provided in the "Default Configuration", "Connect", "Reprovision" and "Transmission control" messages.

In case of a 3.088 Mbit/s upstream channel, two sets of Flags are required. In this case, the MAC_Flag_Set parameter represents the first of two successively assigned Flag sets. The definition of the second slot configuration field extends the boundary definition to slots 10 through 18, and the reception indicators cover slots 10 through 18.

In case of a 6.176 Mbit/s upstream channel, four sets of Flags are required. In this case, the MAC_Flag_Set parameter represents the first of four successively assigned Flag sets. The definition of the second slot configuration field extends the boundary definition to slots 10 through 18, and the reception indicators cover slots 10 through 18. The definition of the third Slot Configuration field extends the boundary definition to cover upstream slots 19 through 27, and the reception indicators to cover upstream slots 19 through 27. The definition of the fourth Slot Configuration field extends the boundary definition to cover upstream slots 28 through 36, and the reception indicators to cover upstream slots 28 through 36.

bits b,c: 00 – all Flags valid for second previous 3 ms (6 ms for 256 kbit/s Upstream) period (out-of-band signalling equivalent):

– 01 – Flags valid for 1st ms (2 ms for 256 kbit/s Upstream) of previous 3 ms (6 ms for 256 kbit/s Upstream) period;

– 10 – Flags valid for 2nd ms (2 ms for 256 kbit/s Upstream) of previous 3 ms (6 ms for 256 kbit/s Upstream) period;

– 11 – Flags valid for 3rd ms (2 ms for 256 kbit/s Upstream) of previous 3 ms (6 ms for 256 kbit/s Upstream) period.

MAC Flags is a 26-byte field containing 8 slot configuration fields (24 bits each) which contain slot configuration information for the related upstream channels followed by two reserved bytes (The first 3 bytes correspond to MAC Flag Set 1, the second 3 bytes to MAC Flag Set 2, etc.). The definition of each slot configuration field is defined as follows:

b0 ranging control slot indicator for next 3 ms (6 ms for 256 kbit/s upstream) period (MSB)

b1-b6 slot boundary definition field for next 3 ms (6 ms for 256 kbit/s upstream) period

b7 slot 1 reception indicator for [second] previous 3 ms (6 ms for 256 kbit/s upstream) period

b8 slot 2 reception indicator for [second] previous 3 ms (6 ms for 256 kbit/s upstream) period

b9 slot 3 reception indicator for [second] previous 3 ms (6 ms for 256 kbit/s upstream) period b10 slot 4 reception indicator for [second] previous 3 ms (6 ms for 256 kbit/s upstream) period

b11 slot 5 reception indicator for [second] previous 3 ms (6 ms for 256 kbit/s upstream) period

b12 slot 6 reception indicator for [second] previous 3 ms (6 ms for 256 kbit/s upstream) period

b13 slot 7 reception indicator for [second] previous 3 ms (6 ms for 256 kbit/s upstream) period

b14 slot 8 reception indicator for [second] previous 3 ms (6 ms for 256 kbit/s upstream) period

b15 slot 9 reception indicator for [second] previous 3 ms (6 ms for 256 kbit/s upstream) period

b16-17 reservation control for next 3 ms (6 ms for 256 kbit/s upstream) period

b18-b23 CRC 6 parity

For a detailed description of the fields "ranging control slot indicator", "slot boundary definition", "reservation control" and "CRC 6 parity", please refer to A.5.3.1.3.

The slot configuration fields are used in conjunction with the MAC Flag Control field defined above. Note that when the MAC Flag Control field designates that a 1 ms (2 ms for 256 kbit/s upstream) flag update is enabled:

1) the reception indicators refer to the previous 3 ms (6 ms for 256 kbit/s upstream) period (the bracketed term [second] is omitted from the definition);
2) only the reception indicators which relate to slots which occur during the designated 1 ms (2 ms for 256 kbit/s upstream) period are valid; and
3) the ranging control slot indicator, slot boundary definition field, and reservation control field are valid and consistent during each 3 ms (6 ms for 256 kbit/s upstream) period.

Extension Flags is a 26-byte field which is used when the MAC_Flag_Set parameter associated to one of the upstream channels (this link is done in the MAC Default Configuration Message, Connect Message, Reprovision Message and Transmission Control Message) is greater than 8 for a 256 kbit/s or 1.544 Mbit/s upstream channel, greater than 7 for a 3.088 Mbit/s upstream channel or greater than 5 for a 6.176 Mbit/s upstream channel. The definition of the Extension Flags field is identical to the definition of the MAC Flags field above. The "Extension Flags" field contains the MAC Flags from 9 to 16.

The **MAC Message** field contains a 40-byte message; the general format is defined in A.5.5.2.7.

reserved field c is a 4-byte field reserved for future use.

A.5.3.2.2 Frequency of IB signalling information

IB downstream and upstream time-tick definition

In the case of IB, downstream time-tick T_{dn} is the 3 ms time marker Downstream (defined in A.5.4.2) (to derive the 6 ms period in the case of an upstream transmission bit rate of 256 kbit/s, see A.5.4.4).

IB Upstream Time-Tick, Absolute_Time_Offset and New_Absolute_Time_Offset definitions are the same as for OOB (see A.5.3.1.3).

Upstream marker and slot position register number

The MAC Control Message structures shall be transmitted one time every 3 ms with an enabled slot position register (slot_position_register_enable = 1) and a valid upstream marker (upstream_Marker_enable = 1) (i.e. both are valid in the same MPEG TS packet).

MAC Flag control, MAC Flags and Extension Flags

The MAC Control Message structures containing MAC Flag Control, MAC Flags and Extension Flags shall be transmitted so as to the NIU has at least 1 millisecond to process the MAC Flag Information.This information shall be received by the NIU between two downstream time-ticks (see A.5.3.1.3).

MAC messages

Additional MAC Control Message structures containing only MAC messages, i.e. with a disabled slot position register (slot_position_register_enable = 0), a disabled upstream marker (upstream_marker_enable = 0) may be transmitted at any time.

A.5.3.3 Return interaction path (upstream)

A.5.3.3.1 Slot format

The format of the upstream slot depends on the modulation used.

The format for QPSK modulation is shown in Figure A.24 below. A Unique Word (UW) (4 bytes) provides a burst mode acquisition method. The payload area (53 bytes) contains a single ATM cell. The RS Parity field (6 bytes) provides t = 3 Reed-Solomon protection RS (59,53) over the payload area. The guard band (1 byte) provides spacing between adjacent upstream packets.

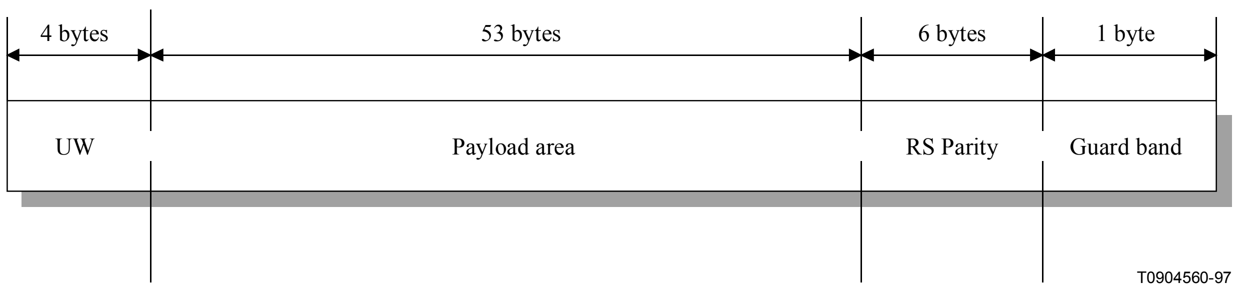


Figure A.24/J.112 – Slot format for QPSK

The format of an upstream packet for 16QAM modulation is shown in Figure A.25. A Unique Word (UW) (8 bytes) provides a burst mode acquisition method. The payload area (106 bytes) contains two ATM cells. The RS Parity field (12 bytes) provides t = 6 Reed-Solomon protection. In case the NIU sends 1 ATM cell in the slot, the data is sent in the first ATM cell, and the second ATM cell is sent as null ATM cell.

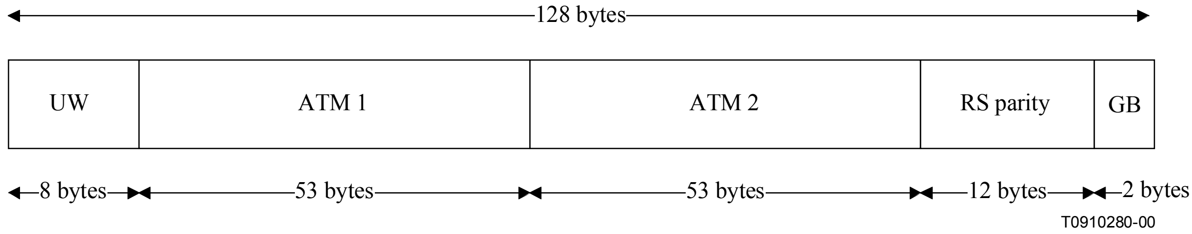


Figure A.25/J.112 – Slot format for 16QAM

The structure and field coding of the ATM cells shall be consistent with the structure and coding given in ITU-T I.361 [1] for ATM UNI.

Unique word

For QPSK modulation, the unique word is four bytes long: CC CC CC 0D hex. The unique word for mini-slots is four bytes: CC CC CC 0E hex, transmitted in this order.

For 16QAM modulation, the unique word is eight bytes long: F3 F3 F3 F3 F3 F3 33 F7 hex. The unique word for mini-slots is also 8 bytes long: F3 F3 F3 F3 F3 F3 33 FB.

ATM cell structure

The format for each ATM cell structure is illustrated in Figure A.26. This structure and field coding shall be consistent with the structure and coding given in ITU-T I.361 [1] for ATM UNI.

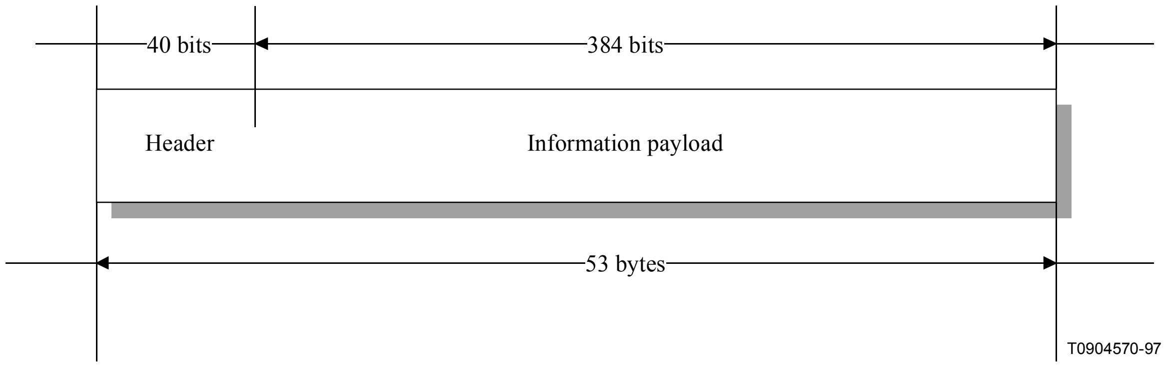


Figure A.26/J.112 – ATM cell format

The entire header (including the HEC byte) shall be protected by the Header Error Control (HEC) sequence. The HEC code shall be contained in the last byte of the ATM header. The HEC sequence shall be capable of:

– single-bit error correction;

– multiple-bit error detection.

Error detection in the ATM header shall be implemented as defined in [16]. The HEC byte shall be generated as described in [16], including the recommended modulo-2 addition (XOR) of the pattern 01010101b to the HEC bits. The generator polynomial coefficient set used and the HEC sequence generation procedure shall be in accordance with [16].

Channel coding

Reed-Solomon encoding shall be performed on the data contained in a single upstream packet (1 ATM cell for QPSK and the combined 2 ATM cells for 16QAM).

For QPSK T = 3, this means that 3 erroneous bytes per ATM cell can be corrected. This process adds 6 parity bytes to the ATM cell to give a codeword of (59,53). The shortened Reed-Solomon code shall be implemented by appending 196 bytes, all set to zero, before the information bytes at the input of a (255,249) encoder; after the coding procedure these bytes are discarded.

In the case of 16QAM modulation, the RS field should be calculated on the combined data stream of 2 ATM cells with T = 6. This will means that 6 erroneous byte for 2 ATM cells can be corrected. 12 parity bytes will be added, to give a codeword of (118,106).

The Reed-Solomon code shall have the following generator polynomials:

Code Generator Polynomial: $g(x) = (x + \mu^0)(x + \mu^1)\ (x + \mu^2)\ ...\ (x + \mu^5)$,

where μ = 02 hex

Field Generator Polynomial: $p(x) = x^8 + x^4 + x^3 + x^2 + 1$

Guard band

For QPSK, the guard band is 1 byte long (four QPSK symbols). It provides some extra protection against synchronization errors.

For 16QAM, the guard band is 2 bytes long (four 16QAM symbols). It provides some extra protection against synchronization errors.

For the mini-slot slot format, see A.5.7.2.

A.5.3.4 Minimum processing time

The NIU has to be able to process the boundary information in the MAC Flag sets within 1 ms.

A.5.4 Slot timing assignment

A.5.4.1 Downstream slot position reference (downstream OOB)

Upstream synchronization is derived from the downstream extended superframe (OOB) by noting the slot positions as shown in Table A.14.

Table A.14/J.112 – Downstream slot position reference

Frame number	Bit number	Overhead bit	Slot position reference
1	0	**M1**	♦ Slot position (see Note)
2	193	C1	
3	386	M2	
4	579	F1 = 0	
5	772	M3	
6	965	C2	
7	1158	M4	
8	1351	F2 = 0	
9	1544	**M5**	♦ Slot position

Table A.14/J.112 – Downstream slot position reference

Frame number	Bit number	Overhead bit	Slot position reference
10	1737	C3	
11	1930	M6	
12	2123	F3 = 1	
13	2316	M7	
14	2509	C4	
15	2702	M8	
16	2895	F4 = 0	
17	3088	**M9**	♦ Slot position
18	3281	C5	
19	3474	M10	
20	3667	F5 = 1	
21	3860	M11	
22	4053	C6	
23	4246	M12	
24	4439	F6 = 1	
NOTE – The first slot position is also called the 3 ms time marker in the case of 1.544 Mbit/s rate downstream. For the 3.088 Mbit/s rate downstream, the 3 ms time marker only appears once every two superframes. The M12 bit (see A.5.4) is used to differentiate between the two superframes.			

A.5.4.2 Downstream slot position reference (downstream IB)

Upstream synchronization is derived from the Transport Stream by noting the 3 ms time marker Downstream as shown in Figure A.27. From the bits of the upstream marker field contained in the MPEG-2 TS packet, the 3 ms time marker is obtained by counting a number of symbol clocks equal to (b23-b8). This marker is equivalent to the first slot position of the superframe for the OOB case.

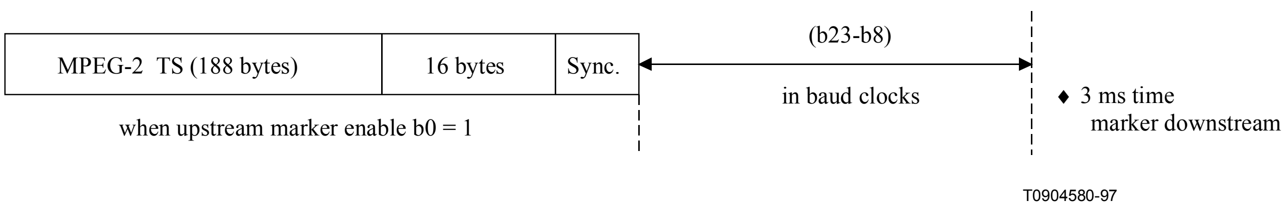


Figure A.27/J.112 – Position of the 3 ms time marker for IB signalling

In order to describe how the US slot position is derived from the location of the DS 3 ms time marker at the NIU, consider the following system diagram in Figure A.28:

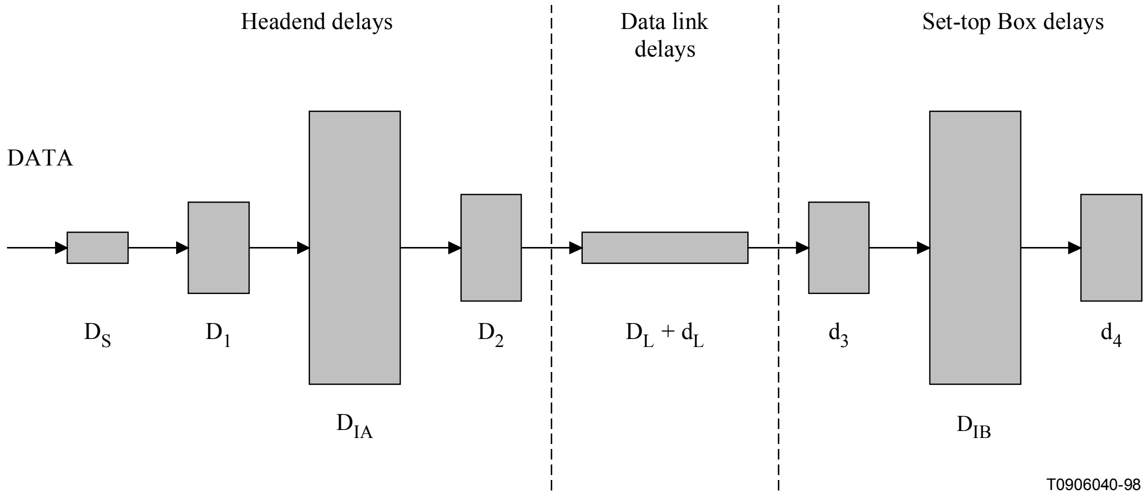


Figure A.28/J.112 – System model for timing analysis

The delay between the location of the end of the Upstream Marker and the beginning of the next Sync byte, designated as D_S, is a constant value for each bit rate equal to the equivalent time of 197 bytes, or

$$(197 \times 8/x) \text{ symbol clocks}$$

where:

x = 4, for 16QAM
5, for 32QAM
6, for 64QAM
7, for 128QAM
8, for 256QAM

There will be some processing delay in the Headend hardware between the location where the Upstream Marker is inserted in the MAC packet and the arrival of the data into the interleaver. This should be a constant delay, D_1, which is the same for every incoming byte, including the sync byte following the Upstream Marker.

The delay due to the interleaving process in the Headend is D_{IA} and will be zero for each sync byte.

There will be some processing delay in the Headend hardware between the output of the interleaver and the output of the QAM modulator. This should be a constant delay, D_2, for every byte in the outgoing stream.

The data link is composed of two delay values, D_L, the constant link delay that every STU experiences, and d_L, the variable link delay for each STU which is due to the fact that each STU is located at a different distance from the Headend. This variable link delay is compensated for by the ranging operation.

There will be some processing delay in the STU hardware between the input of the QAM demodulator and the input of the de-interleaver. This delay is design dependent, d_3, and may be a constant delay or a variable delay for each byte in the data stream.

The delay due to the de-interleaving process in the STU is D_{IB}, and will be equal to the entire interleave delay for each sync byte.

The total interleave delay,

$$D_I = D_{IA} + D_{IB}$$

will be constant for each byte. The value will be given by

$$D_I = \frac{204 \times 8 \times (\text{interleave\_depth} - 1)}{\text{bit rate}}$$

for example, if the modulation is QAM 64 with a baud rate of 5.0 Mbit/s,

$$D_I = 204 \times 8 \times 11/30\text{M} = 598.4\ \mu\text{s or } 2.992 \text{ symbol clocks}$$

There will be some processing delay in the STU hardware between the output of the de-interleaver and the circuitry that utilizes the Upstream marker and following sync byte for generating the local 3 ms time marker. This delay, which includes Reed-Solomon FEC, is design dependent, d_4, and may be a constant delay or a variable delay for each byte in the data stream.

The accumulated delay in the data link is composed of a number of constant terms and three variable terms. The constant terms will be identical for every STU that is utilizing a particular QAM channel for in-band timing and thus becomes a fixed offset between when the counter which is loading the Upstream Marker value and the actual location of the 3 ms time marker at each STU. Each STU is responsible for compensating for the design-dependent delays, d_3 and d_4, before utilizing the Upstream Marker value for generating the 3 ms time marker. The variable link delay, d_L, will be compensated for via the ranging algorithm, in the same way as performed when out-of-band signalling is employed.

A.5.4.3 Upstream slot positions

Transmission on each QPSK/16QAM upstream channel is based on dividing access by multiple NIU units by utilizing a negotiated bandwidth allocation slot access method. A slotting methodology allows the transmit slot locations to be synchronized to a common slot position reference, which is provided via the related downstream MAC control channel. Synchronizing the slot locations increases message throughput of the upstream channels since the upstream packets do not overlap during transmission.

The slot position reference for upstream slot locations is received via the related downstream MAC control channel by each NIU. Since each NIU receives the downstream slot position reference at a slightly different time, due to propagation delay in the transmission network, slot position ranging is required to align the actual slot locations for each related upstream channel. The upstream slot rates are 12 000 upstream slots/s when the upstream transmission grade is D/DQ, 6000 upstream slots/s when the upstream transmission grade is C/CQ, 3000 upstream slots/s when the upstream transmission grade is B/BQ and 500 upstream slots/s when the upstream transmision grade is A/AQ.

The number of slots available in any one second is given by:

$$\text{number of slots/s} = \frac{\text{upstream transmission bit rate}}{\text{number of bits per upstream packet}} - \text{extra guard band}$$

where extra guard band may be designated between groups of slots for alignment purposes. The number of bits per upstream packet is 512 for QPSK and 1024 for 16QAM.

The M-bits in the SL-ESF serve two purposes:

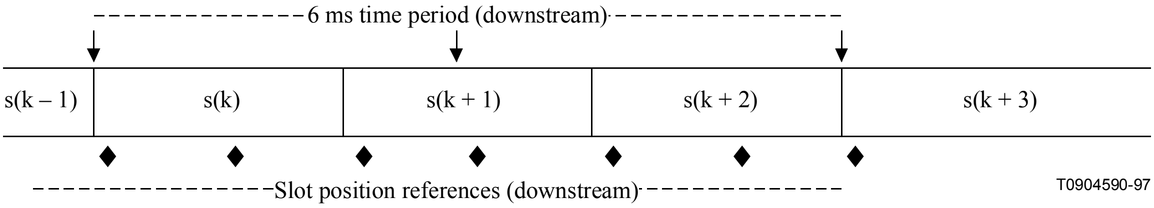
– to mark the slot positions for the upstream Contention and Reservation and Fixed Rate based signalling links (see A.5.4);

– to provide slot count information for upstream message bandwidth allocation management in the NIU.

M-bits M1, M5, and M9 mark the start of an upstream slot position for upstream message transmission.

A.5.4.3.1 Rate 256 kbit/s QPSK, 512 kbit/s 16QAM

In the case where the upstream transmission grade is A/AQ and the downstream OOB rate is 1.544 Mbit/s, the upstream slots are numbered as follows:

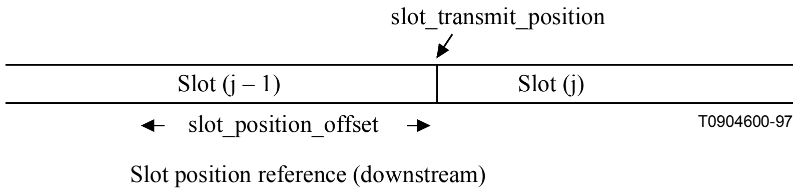


where k is a multiple of 3. In the case where the downstream OOB rate is 3.088 Mbit/s, there are 12 slot position references downstream during the transmission of 3 upstream packets. In the case of IB downstream, packet "k" is sent when the 3 ms time marker is received.

The relationship between the received slot position reference and the actual slot transmit position is given by:

slot_transmit_position = slot_position_reference (valid) + slot_position_offset

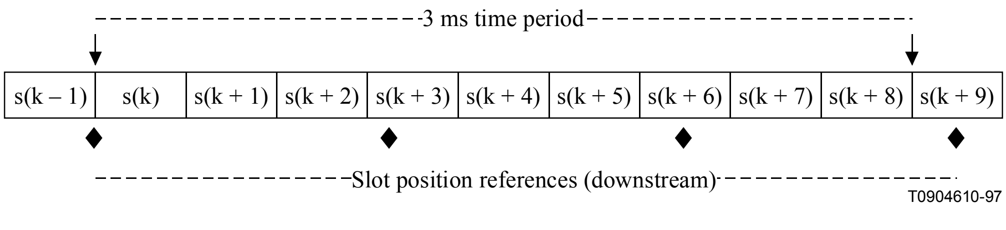
where only the slot_position_references which cause the upstream_slot_position_counter to be loaded with an integer value are valid (see A.5.4.4), and the slot_position_offset is derived from the Time_Offset_Value provided via the Range_and_Power_Calibration_Message in the MAC protocol.



In the case where the upstream transmission grade is A/AQ, the actual slot transmission locations correspond directly to the slot transmit positions.

A.5.4.3.2 Rate 1.544 Mbit/s QPSK, 3.088 Mbit/s 16QAM

In the case where the upstream transmission grade is B/BQ and the downstream OOB rate is 1.544 Mbit/s, the upstream slots are numbered as follows:

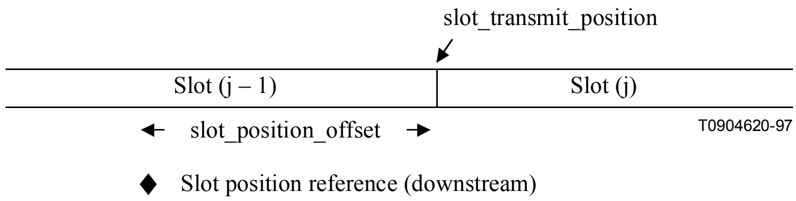


where k is a multiple of 9. In the case where the downstream OOB rate is 3.088 Mbit/s, there are 6 slot position references downstream during the transmission of 9 upstream packets. In the case of IB downstream, packet "k" is sent when the 3 ms time marker is received.

The relationship between the received slot position reference and the actual slot transmit position is given by:

slot_transmit_position = slot_position_reference(valid) + slot_position_offset

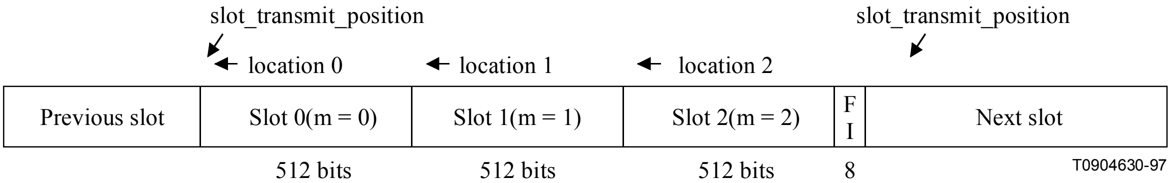
where only the slot_position_references which cause the upstream_slot_position_counter to be loaded are valid (see A.5.4.4), and the slot_position_offset is derived from the Time_Offset_Value provided via the Range_and_Power_Calibration_Message in the MAC protocol.



In the case where the upstream transmission grade is B/BQ, the actual slot transmission locations are given by

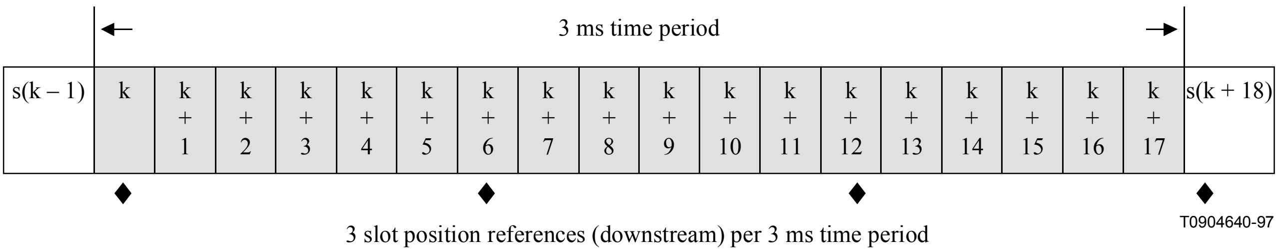
slot_transmission_location (m) = slot_transmit_position + (m × number of bits per upstream packet);

where m = 0, 1, 2: the position of the slot with respect to the slot_transmit_position. This leaves a free time interval (FI = 8 bits) before the next slot_transmit_position occurs, during which no NIU transmits anything. The number of bits per upstream packet is 512 for QPSK and 1024 for 16QAM.



A.5.4.3.3 Rate 3.088 Mbit/s QPSK, 6.176 Mbit/s 16QAM

In the case where the upstream transmission grade is C/CQ and the downstream OOB rate is 1.544 Mbit/s, the upstream slots are numbered as shown below, where k is a multiple of 18.

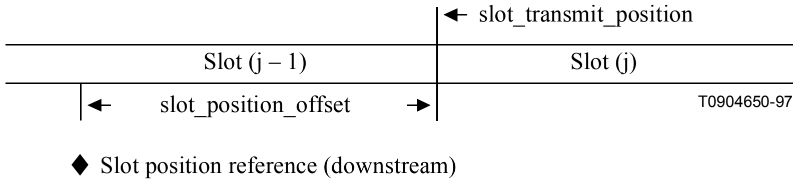


In the case where the downstream OOB rate is 3.088 Mbit/s, there are 6 slot position references downstream during the transmission of 18 upstream packets. In the case of IB downstream, packet "k" is sent when the 3 ms time marker is received.

The relationship between the received slot position reference and the actual slot transmit position is given by:

slot_transmit_position = slot_position_reference(valid) + slot_position_offset

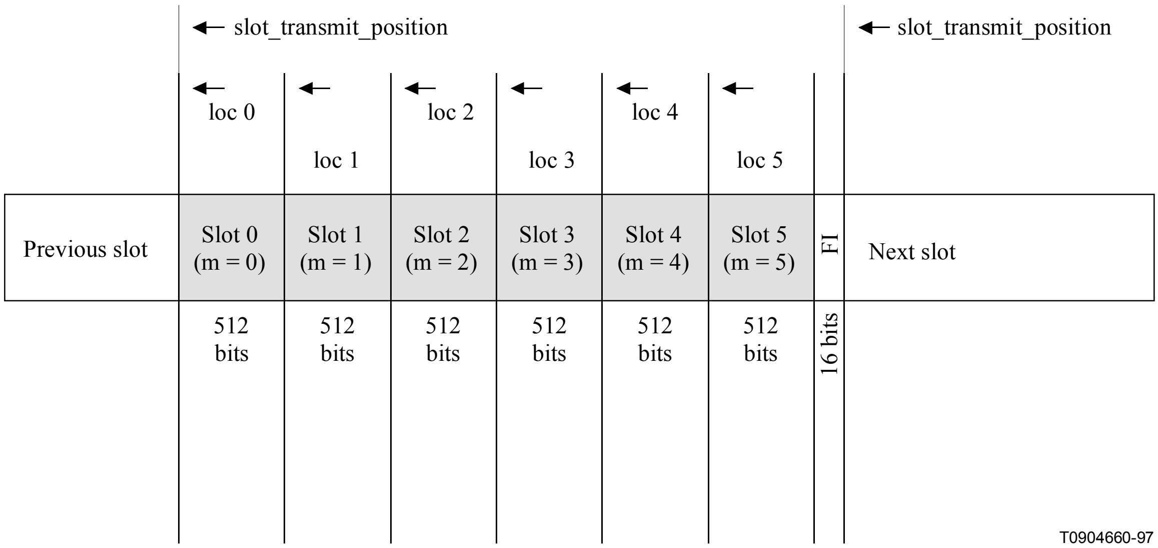
where only the slot_position_references which cause the upstream_slot_position_counter to be loaded are valid (see A.5.4.4), and the slot_position_offset is derived from the Time_Offset_Value provided via the Range_and_Power_Calibration_Message.



In the case where the upstream transmission grade is C/CQ, the actual slot transmission locations are given by:

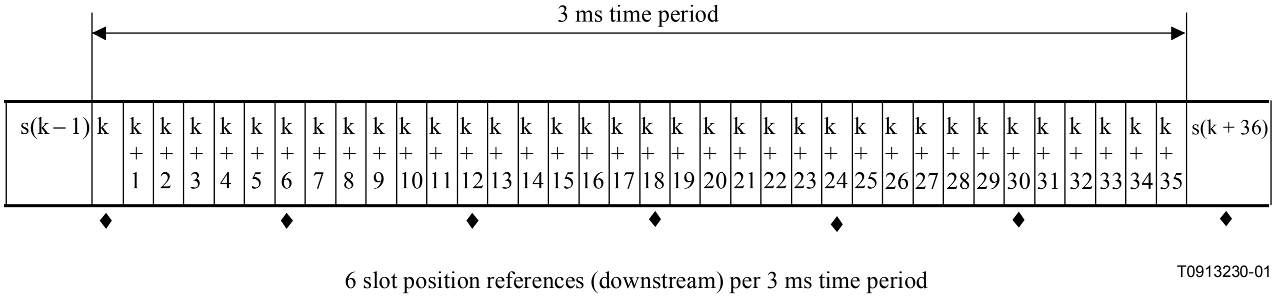
slot_transmission_location (m) = slot_transmit_position + (m × number of bits per upstream packet)

where m = 0, 1, 2, 3, 4, 5: the position of the slot with respect to the slot_transmit_position. This leaves a free time interval (FI = 16 bits) before the next slot_transmit_position occurs, during which no NIU transmits anything. The number of bits per upstream packet is 512 for QPSK and 1024 for 16QAM.



A.5.4.3.4 Rate 6.176 Mbit/s QPSK, 12.352 Mbit/s 16QAM

In the case where the upstream transmission grade is D/DQ and the downstream OOB rate is 1.544 Mbit/s, the upstream slots are numbered as shown below, where k is a multiple of 36.

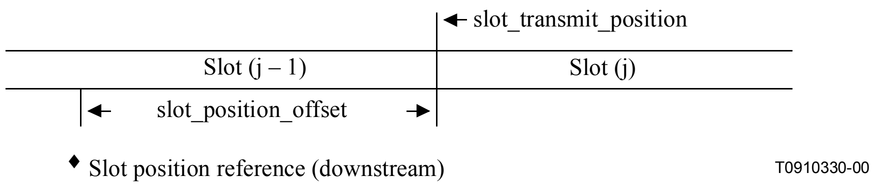


In the case where the downstream OOB rate is 3.088 Mbit/s, there are 6 slot position references downstream during the transmission of 36 upstream packets. In the case of IB downstream, packet "k" is sent when the 3 ms time marker is received.

The relationship between the received slot position reference and the actual slot transmit position is given by:

slot_transmit_position = slot_position_reference(valid) + slot_position_offset

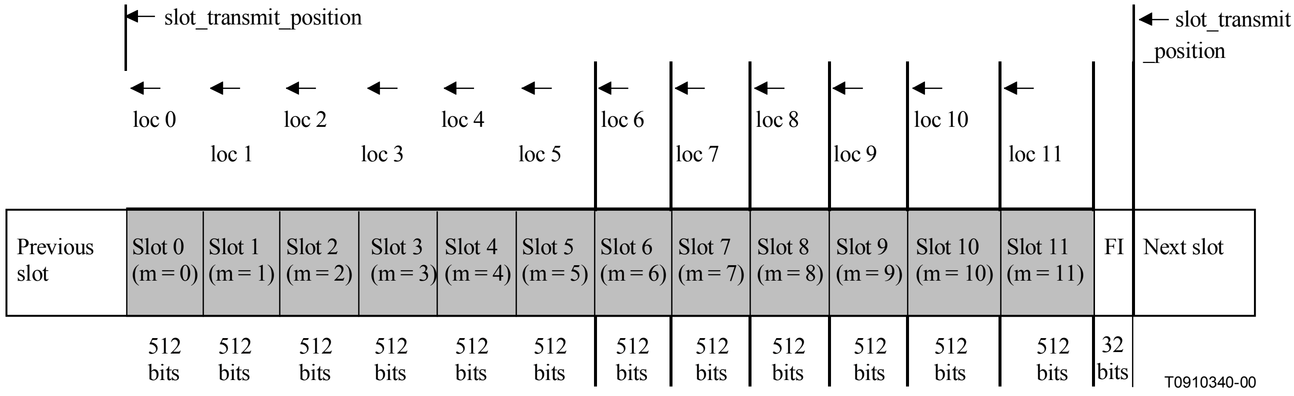
where only the slot_position_references which cause the upstream_slot_position_counter to be loaded are valid (see A.5.4.4), and the slot_position_offset is derived from the Time_Offset_Value provided via the Range_and_Power_Calibration_Message.



In the case where the upstream transmission grade is D/DQ, the actual slot transmission locations are given by:

slot_transmission_location (m) = slot_transmit_position + (m × number of bits per upstream packet)

where m = 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11: the position of the slot with respect to the slot_transmit_position. This leaves a free time interval (FI = 32 bits)) before the next slot_transmit_position occurs, during which no NIU transmits anything. The number of bits per upstream packet is 512 for QPSK and 1024 for 16QAM.



A.5.4.4 Slot position counter

The M-bits M10-M1 are a register, called the upstream slot position register, which counts from 0 to N, incrementing by one every 3 ms, where N is an unsigned integer which indicates slot position cycle size; the value of N is calculated from Service_Channel_Last_Slot sent in the Default Configuration Message and the upstream transmission bit rate of the service channel. For the case of a grade A/AQ service channel, the maximum value of Service_Channel_Last_Slot is 1535, for the cases of grade B/BQ and grade C/CQ the maximum value is imposed to be 8189, and for the case of grade D/DQ the maximum value is imposed to be 8171. The value of N shall be the same for all DS carriers, and N is related to the number of US slots by:

$$\text{Number\_of\_US\_Slots} = 3 \times m \times (N + 1)$$

where m is related to US rate as described below.

The upstream slot position register indicates the upstream slot positions that will correspond to the next SL-ESF frame.

For QPSK modulation, there are 12 upstream slots per ms when the upstream transmission bit rate is 6.176 Mbit/s, 6 upstream slots per ms when the upstream transmission bit rate is 3.088 Mbit/s, 3 upstream slots per ms when the upstream transmission bit rate is 1.544 Mbit/s, and there is 0.5 upstream slot per ms when the upstream transmission bit rate is 256 kbit/s. The correspondingD upstream slot rates are, therefore, 12 000 upstream slots/s when the upstream transmission bit rate is 6.176 Mbit/s, 6000 upstream slots/s when the upstream transmission bit rate is 3.088 Mbit/s, 3000 upstream slots/s when the upstream transmission bit rate is 1.544 Mbit/s, and 500 upstream slots/s when the upstream transmission bit rate is 256 kbit/s.

For 16QAM modulation, there are 12 upstream slots per ms when the upstream transmission bit rate is 12.352 Mbit/s, 6 upstream slots per ms when the upstream transmission bit rate is 6.176 Mbit/s, 3 upstream slots per ms when the upstream transmission bit rate is 3.088 Mbit/s, and there is 0.5 upstream slot per ms when the upstream transmission bit rate is 512 kbit/s. The corresponding upstream slot rates are, therefore, 12 000 upstream slots/s when the upstream transmission bit rate is 12.352 Mbit/s, 6000 upstream slots/s when the upstream transmission bit rate is 6.176 Mbit/s, 3000 upstream slots/s when the upstream transmission bit rate is 3.088 Mbit/s, and 500 upstream slots/s when the upstream transmission bit rate is 512 kbit/s.

For QPSK modulation, there are 36 upstream mini-slots per ms when the upstream data rate is 6.176 Mbit/s, there are 18 upstream mini-slots per ms when the upstream data rate is 3.088 Mbit/s, there are 9 upstream mini-slots per ms when the upstream data rate is 1.544 Mbit/s, and there are 1.5 upstream mini-slots per ms when the upstream data rate is 256 kbit/s. The corresponding upstream mini-slot rates are, therefore, 36 000 upstream mini-slots/s when the upstream data rate is

6.176 Mbit/s, 18 000 upstream mini-slots/s when the upstream data rate is 3.088 Mbit/s, 9000 upstream mini-slots/s when the upstream data rate is 1.544 Mbit/s, and 1500 upstream mini-slots/s when the upstream data rate is 256 kbit/s. The algorithm to determine the upstream slot position counter value is given below.

For 16QAM modulation, there are 36 upstream mini-slots per ms when the upstream data rate is 12.352 Mbit/s, there are 18 upstream mini-slots per ms when the upstream data rate is 6.176 Mbit/s, there are 9 upstream mini-slots per ms when the upstream data rate is 3.088 Mbit/s, and there are 1.5 upstream mini-slots per ms when the upstream data rate is 512 kbit/s. The corresponding upstream mini-slot rates are, therefore, 36 000 upstream mini-slots/s when the upstream data rate is 12.352 Mbit/s, 18 000 upstream mini-slots/s when the upstream data rate is 6.176 Mbit/s, 9000 upstream mini-slots/s when the upstream data rate is 3.088 Mbit/s, and 1500 upstream mini-slots/s when the upstream data rate is 512 kbit/s.

In the case of OOB downstream, the algorithm to determine the upstream slot position counter value is given below:

```
if (downstream_rate == 3.088 Mbit/s) {n = 1;}
else {n = 0;}
upstream_slot_position_register = value of M-bits latched at bit_position M11 (M10-M1)
if (upstream_rate == 1.544 Mbit/s) {m = 3;}
else if (upstream_rate == 3.088 Mbit/s) {m = 6;}
        else if (upstream_rate == 6.176 Mbit/s) {m = 12;}
            else {m = 0.5}
if (bit_position == M1 and previous M12 == 1)
        {upstream_slot_position_counter = upstream_slot_position_register × 3 × m;}
if (bit_position == M5)
        if ( (n == 0) or (n == 1 and previous M12 == 0) )
            {upstream_slot_position_counter = upstream_slot_position_counter + m;}
if (bit_position == M9)
        if ( (n == 0) or (n == 1 and previous M12 == 1) )
            {upstream_slot_position_counter = upstream_slot_position_counter + m;}
if (bit_position == M11)
        {temp_upstream_slot_position_register = (M10, M9, M8, ..., M1);}
if ( (bit_position == M12 and M12 == 1) )
        {upstream_slot_position_register = temp_upstream_slot_position_register;}
```

where the M-bits will be defined as follows:

M1-M10	=	10 bit ESF counter which counts from 0 to N with M10 the most significant bit (MSB);
M11	=	odd parity for the ESF counter, i.e. M11 = 1 if the ESF Counter (M1-M10) has an even number of bits set to 1;
M12	=	1: ESF counter valid; 0: ESF counter not valid.

The values assigned to M12 are as follows:

1) When the QPSK downstream channel bit rate is 1.544 Mbit/s, the M12 bit is always set to the value "1".

2) When the QPSK downstream channel bit rate is 3.088 Mbit/s, the information is always transmitted in pairs of superframe, where superframe-A is the first superframe in the pair, and superframe-B is the second superframe in the pair. In this case, the M12 bit of superframe-A is set to the value "0" and the M12 bit of superframe-B is set to the value "1".

3) When the downstream channel is IB, M12 = 1.

In the case of IB downstream, the upstream slot timing should mimic that of the OOB downstream.

A.5.5 MAC functionality

A.5.5.1 MAC reference model

The scope of this clause is limited to the definition and specification of the MAC Layer protocol. The detailed operations within the MAC layer are hidden from the above layers.

This clause focuses on the required message flows between the INA and the NIU for Media Access Control. These areas are divided into three categories: Initialization, Provisioning and Sign-On Management, Connection Management, and Link Management. (See Figure A.29.)

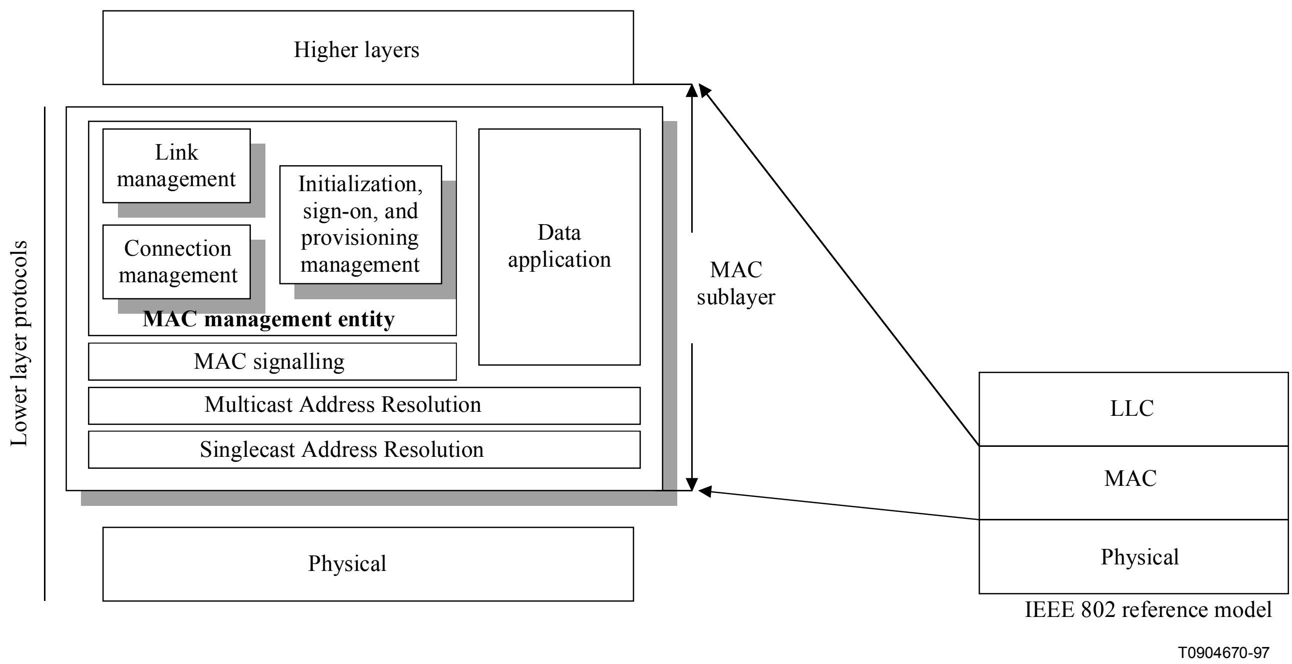


Figure A.29/J.112 – MAC reference model

A.5.5.2 MAC concept

A.5.5.2.1 Relationship between higher layers and MAC protocol

The goal of the MAC protocol is to provide tools for higher layer protocols in order to transmit and receive data transparently and independently of the physical layer. Higher layer services are provided by the INA to the STU. The INA is thus responsible for indicating the transmission mode and rate to the MAC layer for each type of service.

Specifically, for each connection provided by higher layers on the INA side (VPI/VCI), a connection Id is associated at the MAC layer. The maximum number of simultaneous connections that a NIU should support is defined as follows:

– Level A: Only one connection at a time can be handled by a NIU;
– Level B: As many connections as needed, defined dynamically by the INA, following higher layers requests.

NOTE 1 – Note that in this case all connections should be assigned to the same frequency upstream and downstream for implementation reasons.

NOTE 2 – However, bandwidth (time slots) does not need to be assigned immediately by the INA for a given connection. This means that a connection Id may exist at the NIU side without associated slot numbers.

The INA is responsible of providing transmission bandwidth to the NIUs when needed by higher layers. However, since the NIU shall transmit all data from the STU, the NIU is also responsible for requesting for more bandwidth if not already provided by the INA.

An initial connection is allocated to the STB by the INA, following the succesful completion of sign-on at power up. This connection can be used to send data from higher layers leading to further interactive connections. Note that this connection can be associated to a zero transmission rate (no initial bandwidth allocation).

A.5.5.2.2 Relationship between physical layer and MAC protocol

Up to 8 upstream channels can be related to each downstream channel which is designated as a MAC control channel. These upstream channels can be used in different, physically separated coaxial cells where space division multiplexing (SDM) is applied or within a single cell where frequency division multiplexing (FDM) is applied. Mixed scenarios where space and frequency division multiplexing is applied in either upstream or downstream direction are also possible. Network scenarios showing when to apply SDM or FDM can be found in [17]. An example of a frequency allocation for the FDM scenario is shown in Figure A.30. This relationship consists of the following items:

1) Each of these related upstream channels share a common slot position. This reference is based on 1-millisecond time markers in case of OOB and 3-millisecond time markers in case of IB that are derived via information transmitted via the downstream MAC control channel.
2) Each of these related upstream channels derive slot numbers from information provided in the downstream MAC control channel.
3) The Messaging needed to perform MAC functions for each of these related upstream channels is transmitted via the downstream MAC control channel.

The Media Access Control protocol supports multiple downstream channels. In instances where multiple channels are used, the INA shall specify a single OOB frequency called the Provisioning Channel, where NIU's perform Initialization and Provisioning functions. If both 1.544 Mbit/s and 3.088 Mbit/s downstream OOB channels coexist on the network, there should be one Provisioning Channel with each rate. Also, in networks where IB NIUs exist, provisioning should be included in at least one IB channel. An aperiodic message is sent on each downstream control channel which points to the downstream Provisioning Channel. In instances where only a single frequency is in use, the INA shall utilize that frequency for Initialization and Provisioning functions.

The Media Access Control protocol supports multiple upstream channels.

There are 2 types of upstream channels:

• Upstream channels that support only QPSK modulation.
• Upstream channels that support only 16QAM modulation.

The INA is responsible for classifying the different channels according to the INA and NIU capabilities.

INAs that support only QPSK modulation will allocate only QPSK channels. All NIUs regardless of their capabilities will use the QPSK channels with QPSK modulation.

INAs that support 16QAM modulation will allocate QPSK channels and 16QAM channels. NIUs that support 16QAM modulation should use the 16QAM upstream channels (but the INA is permitted to assign them to QPSK channels). NIUs that support only QPSK modulation will use only QPSK upstream channels.

One of the available upstream channels shall be designated the Service Channel. The Service Channel (and Back-up Service Channel) will use QPSK modulation. It may be necessary to provide a Back-up Service Channel to make the system more reliable, e.g. in a noisy environment. The Service Channel and the Back-up Service Channel, respectively, shall be used by NIUs entering the network via the Initialization and Provisioning procedure. The remaining upstream channels shall be used for upstream data transmission. In cases where only one upstream channel is utilized, the functions of the Service Channel shall reside in conjunction with regular upstream data transmission.

The Provisioning Channel is the frequency channel on which the Default configuration message is transmitted. There can be several Provisioning channels in the system.

The Service Channel is the frequency channel to which the Default configuration message field Service channel frequency points. The ranging following the Default configuration message is carried out on that Service channel. There can be several Service channels in the system. (See Figure A.30.)

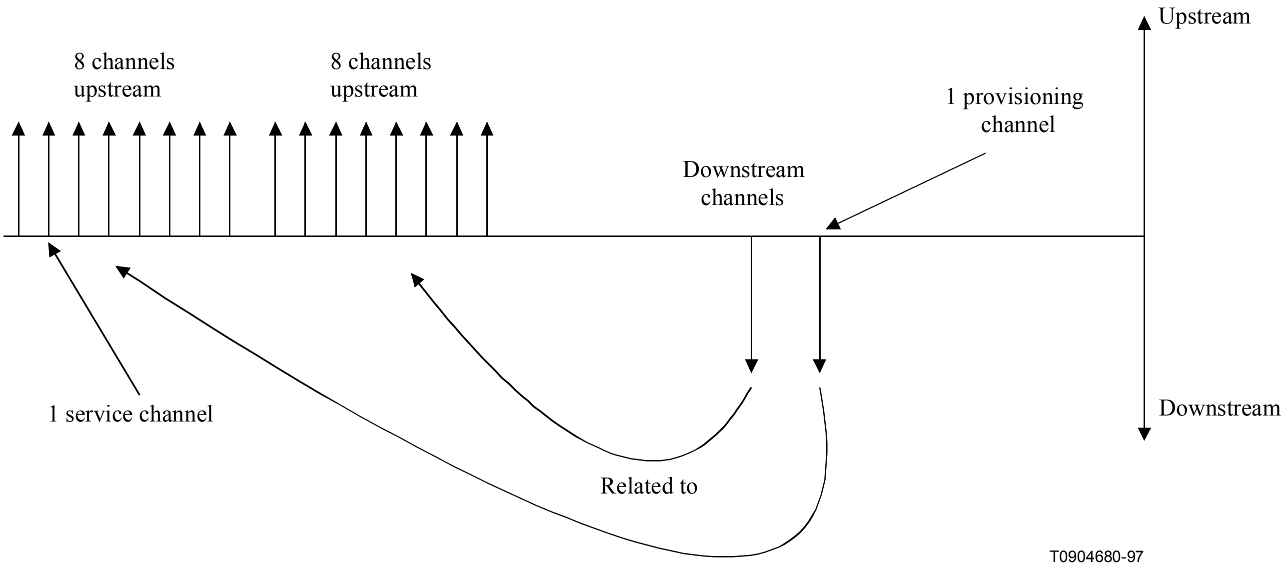


Figure A.30/J.112 – Example of a frequency allocation for the FDM scenario

Upstream frequency change

All connections of a NIU are on the same frequency channel. The upstream frequency can be changed by Reprovision or Transmission control message (see A.5.5.10.2 and A.5.5.10.4). If any of these messages change the frequency, the frequency is changed immediately; all connections remain established in any case.

When no stop_upstream_transmission command was given before or in the Reprovision or Transmission control message, sign-on is entered immediately after the upstream frequency change, reservation grants are lost and fixed rate slots are kept. (If the frequency change was made by the <MAC> Transmission Control Message, the fixed-rate slot assignments remain the same. If the frequency change was made by the <MAC> Reprovision Message, the fixed-rate slot assignments remain the same except if new slot assignments are provided in this message.)

When a stop_upstream_transmission command was given, sign-on is performed after a start_upstream_transmission command is received, reservation grants are lost and fixed-rate slots are kept.

If any of the parameters: Upstream_Channel_Number, Upstream_Rate or MAC_Flag_Set has been changed, reservation grants as well as fixed-rate slots are lost and the connection is still kept.

Downstream frequency channel types

There are three types of content in the downstream direction MAC messages and MAC flags, data and video. There can be two types of physical channels: QPSK and QAM downstream channels. The QAM downstream channel may carry either MPEG or MAC messages directly on the physical layer frame structure. The possible combinations of the content and physical channels are shown in Table A.15.

Table A.15/J.112 – Possible combinations of downstream content types and physical channels (NIU Capabilities)

	MAC		Data	
Case	**OOB**	**IB**	**QPSK**	**QAM**
1	X		X	
2	X			X
3	X		X	X
4		X		X

Combination establishment

The NIU tunes to either a QPSK or QAM channel on which it locates the provisioning channel. The NIU tunes to it and gets its MAC information on that channel. If the Connect message gives a new downstream frequency, the MAC information is found on that frequency, if it is the same type of frequency channel.

Change of downstream frequency

The downstream frequency can be changed by using either Reprovision or Transmission control message (see A.5.5.10.2 and A.5.5.10.4). All NIU connections which use the same physical frequency channel (DS QPSK or DS QAM) are located on the same frequency. When the downstream frequency changes, the connections on the earlier downstream frequency remain established in any case.

When no stop_upstream_transmission command was given before or in the Reprovision or Transmission control message, no sign-on is performed, reservation grants are lost, and fixed-rate slots are kept.

When a stop_upstream_transmission command was given, sign-on is performed after a start_upstream_transmission command, reservation grants are lost, and fixed-rate slots are kept.

Change of combination

The combination can be changed with Connect message only immediately after the sign-on procedure or with Reprovision message at any time. The signalling channel cannot be changed to a different type of downstream channel.

A.5.5.2.3 Relationship between physical layer slot position counter and MAC slot assignment

M10-M1 is a 10-bit superframe counter at the INA side, whereas the upstream slot position counter is an upstream slot counter at the NIU side. The NIU slot position counter (M10-M1 $\times$ 3 $\times$ m, where m = 0.5 for 256 kbit/s, m = 3 for 1.544 Mbit/s, m = 6 for 3.088 Mbit/s and m = 12 for 6.176 Mbit/s) may be implemented as a 16-bit counter which is compared to the 13-bit slot numbers assigned by the INA in MAC messages (list assignment). When the counter value equals any assigned value, the NIU is allowed to send a packet upstream.

A.5.5.2.4 Access modes (Contention/Ranging/Fixed rate/Reservation)

Different access modes are provided to the NIUs within access regions specified by information contained in the slot boundary fields of the downstream superframes. The limits between access regions allow users to know when to send data on contention without risks of collision with data of Reservation or Fixed Rate regions. Also, the separation between reservation and fixed rate regions provides two ways of assigning slots to NIUs. The following rules define how to select access modes:

- *Data connections*

  When the INA assigns a connection Id to the NIU, it either specifies a slot list to be used (Fixed rate access) or the NIU shall use contention or reserved access by following this algorithm:

  – When the NIU shall send more upstream packets for a specific VPI/VCI than what was assigned by the INA, it can use contention access only if the number of upstream packets to transmit is less than Maximum_contention_access_message_length (specified in the MAC Connect Message from the INA). The details of the contention access mechanism is explained below under a). The NIU can send one request for reservation access if the number of upstream packets is less than Maximum_reservation_access_message_length (specified in the MAC Connect Message from the INA). If more upstream packets shall be transmitted, the NIU shall send multiple requests for reservation access. If the NIU/STB is forced to use reservation access, and it has not yet been assigned a Reservation_Id, then it shall wait for an assignment before transmitting.

- *MAC messages*

  MAC messages can be sent on contention access, reservation access, fixed-rate access or ranging access (ranging access is only allowed for calibration purposes).

Note that the VPI/VCI=0x00/0x0021 connection used for MAC messages is always set up, so the INA does not assign a particular connection Id which is normally used for reservation requests. Thus, in order to use reservation access, slots assigned for other connections may be used for MAC messages.

a) *Contention Access*

`Contention_Access` indicates that data (MAC or bursty data traffic) is sent in the slots assigned to the contention access region in the upstream channel. It can be used either to send MAC messages or data. The VPI/VCI of the ATM cells are then used to determine the type and direction of the data in higher layers. Contention-based access provides instant channel allocation for the NIU.

The Contention-based technique is used for multiple subscribers that will have equal access to the signalling channel. It is possible that simultanuous transmissions occur in a single slot, which is called a "collision". The INA utilizes the reception indicators to inform the NIUs whether successful reception of upstream packets has been obtained.

The NIU executes a separate contention process for each VPI/VCI connection that requires contention access. The contention process is initiated by transmitting the first upstream packet in a contention slot. This contention slot is randomly chosen from the available contention slots in the first frame that contains at least one contention slot. The contention process has to wait until the reception indicator of the slot is received. If the indicator contains a positive acknowledgement, the upstream packet has been successfully received, and the next upstream packet, if present, can be transmitted by continuing the contention process. If the indicator contains a negative acknowledgement, a collision has been detected and the upstream packet can be retransmitted according to the procedure defined below. If the reception indicator is not received (e.g. due to CRC error), the NIU proceeds as if a positive acknowledgement would have been received.

If a collision has occurred, the NIU is not obliged to retransmit the upstream packet that was originally transmitted. Instead, it may choose to update the contents of the upstream packet, transmit another upstream packet belonging to the same VPI/VCI connection, or choose not to retransmit at all. In the latter case, the NIU is not allowed to restart a contention process for the same VPI/VCI connection at an earlier slot than the latest possible contention slot in which it could have retransmitted the upstream packet in the first contention process. Note that the allowed choices make it possible for the NIU to update the queue status when the upstream packet to be retransmitted contains a grant request.

A counter at the /STB records the number, denoted by backoff_exponent, of collisions encountered by an upstream packet. The backoff_exponent counter starts from a value determined by the Min_Backoff_Exponent variable. The backoff_exponent is used to generate a uniform random number between 1 and 2^backoff_exponent. This random number is used to schedule retransmission of the collided upstream packet. In particular, the random number indicates the number of contention access slots the /STB shall wait before it transmits. The first transmission is carried out in a random slot within the contentionbased access region. If the counter reaches the maximum number, determined by the Max_Backoff_Exponent variable, the value of the counter remains at this value regardless of the number of subsequent collisions. After a successful transmission, the backoff_exponent counter is reset to a value determined by the Min_Backoff_Exponent variable. Informational Statement: The random access algorithm is unstable; the INA is expected to have intelligence to detect an unstable state of the random access algorithm and to solve it.

For mini-slot contention resolution, refer to A.5.7.3.

b) *Ranging Access*

`Ranging_access` indicates that the data is sent in a slot preceded and followed by slots not used by other users. These slots allow users to adjust their clock depending on their distance to the INA such that their slots fall within the correct allocated time. They are either in the ranging slots region when the ranging control slot indicator **b0** received during the previous superframe was 1 (or when b1-b6 = 55 to 63), or reserved if the INA indicates to the NIU that a specific slot is reserved for ranging (via the Ranging and Power Calibration Message). In the latter case, the NIU is forbidden from ranging in the ranging slots region before the assigned slot appears.

Simultaneous transmissions in ranging slots are resolved through the procedure defined in A.7.1.

c) *Fixed-rate Access*

NOTE – Fixed rate is called contentionless in DAVIC.

`Fixedrate_Access` indicates that data is sent in slots assigned to the fixed-rate-based access region in the upstream channel. These slots are uniquely assigned to a connection by the INA. It is not allowed that the INA changes the boundary fields such that an assigned fixed-rate slot does not fit anymore in the fixed-slot region.

d) *Reservation Access*

`Reservation_Access` implies that data is sent in the slots assigned to the reservation region in the upstream channel. These slots are uniquely assigned once to a connection by the INA. This assignment is made at the request of the NIU for a given connection. It is also allowed to use such an assignment in the fixed-rate region. One reservation grant only grants consecutive slots in the same type of region. Requests are indicated via a request message in a contention slot, in a contention mini-slot, in a reserved slot, in a fixed-rate slot or via the Piggybacking mechanism.

A.5.5.2.5 MAC error-handling procedures

Error-handling procedures are under definition (Time-out windows, power outage, etc.). An informative note on some error-handling procedures can be found in A.7.

A.5.5.2.6 MAC messages in the mini-slots

MAC reservation request messages may also be transported in the mini-slot structure. For 16QAM modulation, the framing of the mini-slot Reservation Requests is described in A.5.6.2. For QPSK modulation, it is described in A.5.6.2 and in the following.

Error correction and/or detection is performed using a 2-byte Reed-Solomon code. For QPSK modulation, Reed-Solomon encoding shall be performed on the 14 bytes following the Unique Word with T = 1 (see Figure A.31). For 16QAM modulation, Reed-Solomon encoding shall be performed on the 9 bytes following the Unique Word with T = 1 (see Figure A.32).This process adds 2 parity bytes to the MAC message in the mini-slot to give a code word of (16,14). Reed-Solomon encoding is performed on the MAC message in the mini-slot before upstream data randomization. The shortened Reed-Solomon code shall be implemented by appending 239 bytes, all set to zero, before the information bytes at the input of a (255,253) encoder; after the coding procedure these bytes are discarded.

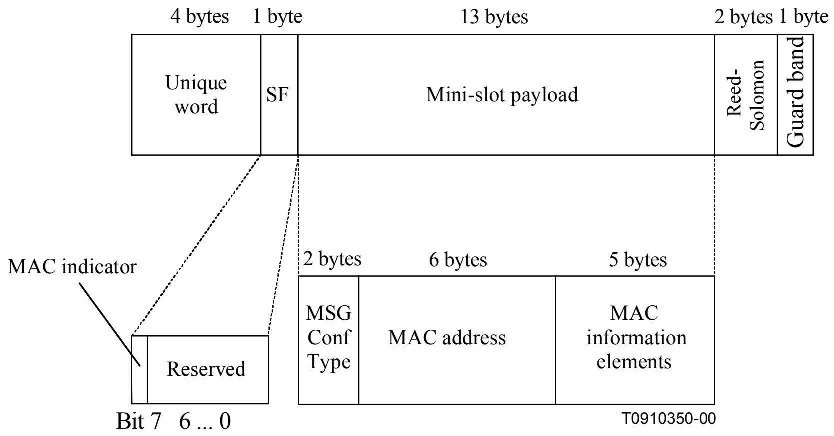
The Reed-Solomon code shall have the following generator polynomials:

– Code Generator Polynomial: $g(x) = (x + \mu^0)(x + \mu^1)$

  where $\mu = 02_{hex}$

– Field Generator Polynomial: $p(x) = x^8 + x^4 + x^3 + x^2 + 1$

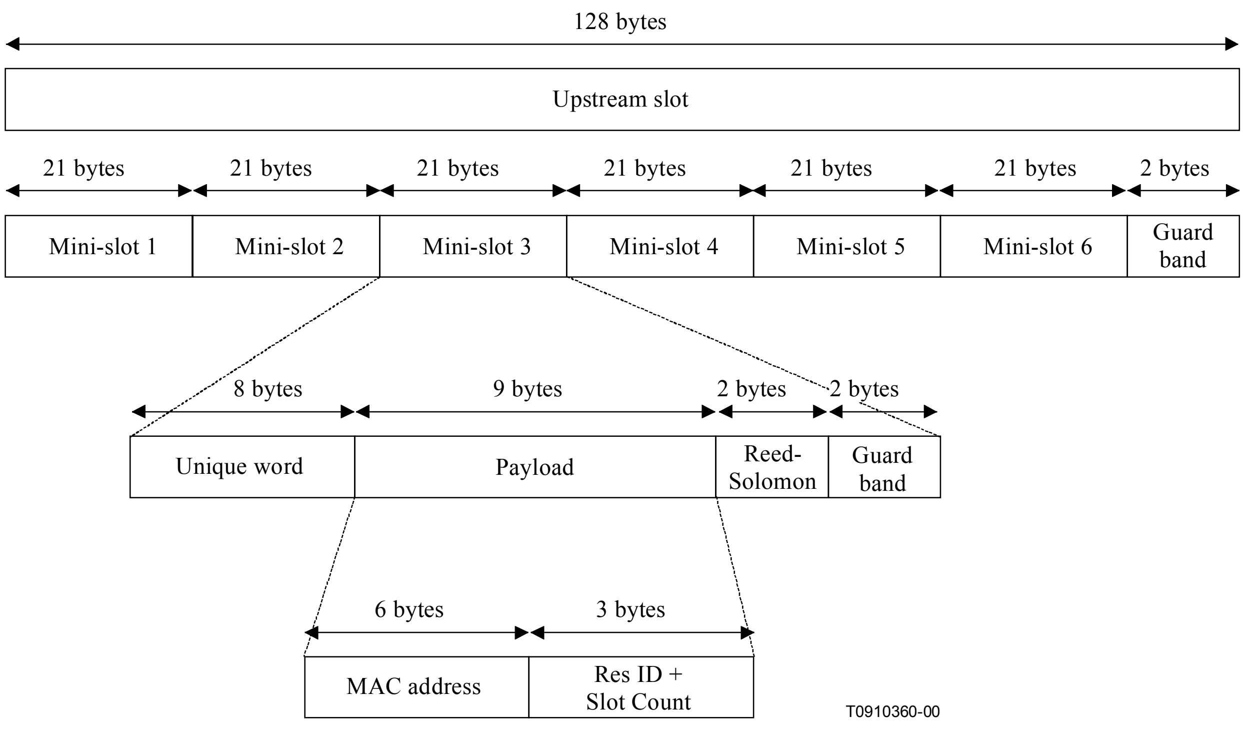
For QPSK modulation, the Start Field (SF) for the QPSK mini-slot MAC messages is defined in Figure A.31. The SF byte, the 13 payload bytes and the 2 RS bytes of the mini-slots are randomized and differentially encoded as defined for upstream ATM cells, whereas the unique word is sent in clear and not differentially encoded.



Unique word = 0xCCCCCC0E
SF = Start Field (Bit 7: MAC indicator, always set to 1; Bits 6 ... 0: reserved, shall be set to zero)

Figure A.31/J.112 – MAC messages in the QPSK mini-slots

For 16QAM modulation, the mini-slot format is described in Figure A.32.



Unique word = 0xF3F3F3F3F3F333FB

Figure A.32/J.112 – MAC messages in the 16QAM mini-slots

Reservation Request Message

For QPSK modulation, the Reservation Request Message has the same structure as in the case it is transported in an upstream ATM cell. The MAC message structure for carrying the Reservation Request Message is shown in Figure A.33.

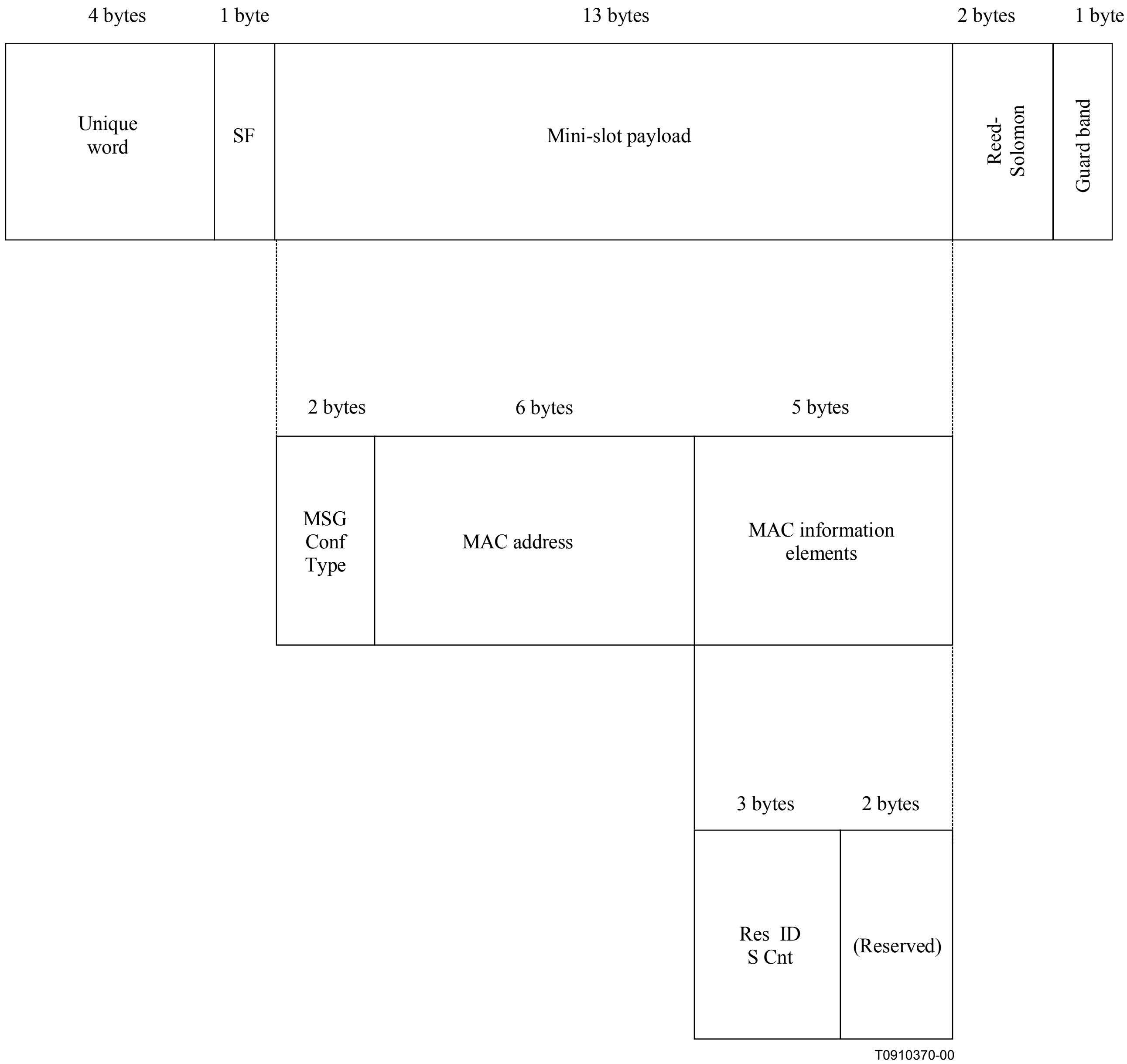


Figure A.33/J.112 – Reservation Request Message in the QPSK Mini-slot MAC message structure

For 16QAM, the reservation request format is described in Figure A.32.

A.5.5.2.7 MAC message format

The MAC message types are divided into the logical MAC states of Initialization, Sign-On, Connection Management and Link Management. MAC messages are sent using Broadcast or Singlecast Addressing. Singlecast addressing shall utilize the 48-bit MAC address.

Regardless of the INA/NIU support for 16QAM modulation, the initialization, provisioning, sign-on and callibration messages (initial calibration) will be sent using QPSK modulation. In case the INA/NIU support 16QAM modulation, and the NIU uses an upstream channel with 16QAM modulation, all the following messages will be sent using 16QAM modulation (see Table A.16):

Table A.16/J.112 – MAC messages

Message type value		Transmit direction	Addressing type
0x00-0x1F	**MAC Initialization, Provisioning, and Sign-On Messages**		
0x00	Used for fragmented messages (continued message)	up/downstr.	Scast or Bcast
0x01	Provisioning Channel Message	downstream	Broadcast
0x02	Default Configuration Message	downstream	Broadcast
0x03	Sign-On Request Message	downstream	Broadcast
0x04	Sign-On Response Message	upstream	Singlecast
0x05	Ranging and Power Calibration Message	downstream	Singlecast
0x06	Ranging and Power Calibration Response Message	upstream	Singlecast
0x07	Initialization Complete Message	downstream	Singlecast
0x08-0x0B	[Reserved]		
0x0C	Security Sign-on (see Note)	downstream	Singlecast
0x0D	Security Sign-on Response (see Note)	upstream	Singlecast
0x0E-0x1E	[Reserved]		
0x1F	Wait (see Note)	upstream	Singlecast
0x20-0x3F	**MAC Connection Establishment and Termination Messages**		
0x20	Connect Message	downstream	Singlecast
0x21	Connect Response Message	upstream	Singlecast
0x22	Reservation Request Message	upstream	Singlecast
0x23	Unused		Broadcast
0x24	Connect Confirm Message	downstream	Singlecast
0x25	Release Message	downstream	Singlecast
0x26	Release Response Message	upstream	Singlecast
0x28	Reservation Grant Message	downstream	Broadcast
0x29	Reservation Id Assignment	downstream	Singlecast
0x2A	Reservation Status Request	upstream	Singlecast
0x2B	Reservation Id Response Message	downstream	Singlecast
0x2C	Resource Request Message	upstream	Singlecast
0x2D	Resource Request Denied Message	downstream	Singlecast
0x2E	Suppression Data Message	up-/downstr.	Singlecast
0x2F	Suppression Acknowledgment Message	up-/downstr.	Singlecast
0x30	Main Key Exchange (see Note)	downstream	Singlecast
0x31	Main Key Exchange Response (see Note)	upstream	Singlecast

Table A.16/J.112 – MAC messages

Message type value		Transmit direction	Addressing type
0x32	Quick Key Exchange (see Note)	downstream	Singlecast
0x33	Quick Key Exchange Response (see Note)	upstream	Singlecast
0x34	Explicit Key Exchange (see Note)	downstream	Singlecast
0x35	Explicit Key Exchange Response (see Note)	upstream	Singlecast
0x36-0x3F	[Reserved]		
	MAC Link Management Messages		
0x27	Idle Message	upstream	Singlecast
0x40	Transmission Control Message	downstream	Scast or Bcast
0x41	Reprovision Message	downstream	Singlecast
0x42	Link Management Response Message	upstream	Singlecast
0x43	Status Request Message	downstream	Singlecast
0x44	Status Response Message	upstream	Singlecast
0x45-0x5F	[Reserved]		
NOTE – Optional MAC messages for the security option.			

To support the delivery of MAC-related information to and from the NIU, a dedicated Virtual Channel shall be utilized. The VPI/VCI for this channel shall be 0x00/0x0021. MAC messages shall not be encrypted. Therefore, any ATM cell carrying a MAC message shall have the least significant two bits of its GFC field set to 00. The most significant two bits of the GFC field are reserved for future use, and shall be set to 00.

The timer accuracy of the MAC messages shall be ±3 ms in the NIU, and the INA shall take this into account.

- *Upstream MAC messages*

  AAL5 (as specified in ITU-T I.363) adaptation shall be used to encapsulate each MAC PDU in an ATM cell. Upstream MAC information should be single-cell 40-byte messages.

- *Downstream OOB MAC messages*

  AAL5 (as specified in ITU-T I.363) adaptation shall be used to encapsulate each MAC PDU in an ATM cell. Downstream OOB MAC information may be longer than 40 bytes. All downstream MAC messages shall be restricted to less than or equal to 120 bytes.

- *Downstream IB MAC messages*

  Downstream IB MAC messages are limited to a size of 120 bytes and shall be carried in a single MPEG TS packet. Longer messages shall be split into separate messages. No AAL5 layer is defined for MPEG-2 TS packets. MAC messages shall therefore be sent as explained in A.5.3.2 using the three MAC Message Framing bits.

- *MAC Fragmentation Protocol (optional)*

  Larger MAC messages up to 512 bytes may optionally be supported using the MAC fragmentation protocol. This cabability is indicated by the NIU in the MAC_Sign_On_Response.

A multi-fragment MAC message is composed of consecutive individual MAC messages with Syntax_Indicator equal to Fragment_No_MAC_Address or Fragment_MAC_Address_Included.

The `Fragment_Count` field of each individual MAC message indicates the number of fragments remaining of the full message, decreasing by one for each consecutive fragment. Thus, the first fragment has `Fragment_Count` equal to the total number of fragments in the message, and the last fragment has `Fragment_Count == 1`.

Furthermore, the type of MAC message is indicated by the `Message_Type` field of the first fragment, whereas all subsequent fragments have `Message_Type == 0`.

The sender of a fragmented MAC message shall not interleave any other fragmented MAC messages for the same receiver into the string of fragments. This includes any fragmented broadcast MAC messages, which shall therefore not be sent while there are any incomplete fragmented messages outstanding.

MAC messages of unfragmented syntax type can be interleaved with fragments destined for the same NIU. They are deemed to have arrived before the fragmented message, and should be processed immediately.

The receiver of a fragmented MAC message shall discard any message with missing fragments, as implied by the uniformly decreasing `Fragment_Count` field in consecutive fragments. Likewise, it shall discard any stray fragments with `Message_Type == 0`, for instance in the case where the first fragment was lost during transport.

The length of each fragment is implied by its transport context: ATM/AAL5 for upstream and OOB downstream, MPEG encapsulation for IB downstream, etc.

The MAC_Information_Elements fields of each fragment are concatenated to form the MAC_Information_Elements field of the full MAC message. The message type is conveyed in the first fragment.

In the upstream direction, all fragments shall be of syntax type Fragment_MAC_Address_Included, in order to allow the INA to use the MAC address to distinguish inter-mixed MAC messages and fragments coming from separate NIUs.

For a broadcast in the downstream direction, each fragment is of syntax type Fragment_No_MAC_Address. For a singlecast downstream message, the first fragment shall be of syntax type Fragment_MAC_Address_Included, and include the MAC address of the target NIU. Subsequent fragments can also include the same MAC address value, or can be Fragment_No_MAC_Address, omitting the MAC address, when the INA ensures that the fragment is associated with the immediately preceding fragment in the transport stream, that is, not separated by messages or fragments for other NIUs.

Since MAC-related information is terminated at the NIU and INA, a privately defined message structure will be utilized. The format of this message structure is illustrated in Table A.17.

NOTE 1 – All messages are sent most significant bit first.

NOTE 2 – For all MAC messages where the parameter length is smaller than the field, the parameter shall be right justified with leading bits set to 0. All reserved fields in the MAC messages shall be set to 0.

NOTE 3 – Message 0x23 is not used in the present release of the MAC protocol. It refers to DAVIC 1.0 protocol which is not supported by the present annex.

NOTE 4 – When no MAC_Address is specified in the message, it means that the message is sent broadcast. (Syntax_indicator = 000).

NOTE 5 – Negative integers are sent in 2's complement.

Table A.17/J.112 – MAC message structure

	Bits	Bytes	Bit number/Description
`MAC_message(){`			

`Message_Configuration`
`Protocol_Version`
`Syntax_Indicator`
	8
	5
	3
		1	

`Message_Type`	**8**	**1**	
`If (Syntax_Indicator == 001 || Syntax_Indicator == 011) {`			
`MAC_Address`	**(48)**	**(6)**	
`}`			
`If (Syntax_Indicator == 010 || Syntax_Indicator == 011)) {`			
`Reserved`	**(8)**	**(1)**	
`Fragment_Count`	**(8)**	**(1)**	
`}`			
`MAC_Information_Elements ()`		**N**	
`}`			

MAC Information Elements

`MAC_Information_Elements` is a multiple-byte field that contains the body of one and only one MAC message.

Protocol Version

`Protocol_Version` is a 5-bit field used to identify the current MAC version. The value for this parameter is given in Table A.18.

Table A.18/J.112 – Protocol_Version coding

Value	Definition
0	DAVIC 1.0 compliant device (not consistent with this annex)
1	DAVIC 1.1 compliant device
2	DAVIC 1.2 compliant device
3-19	Reserved
20	EN 301 199 compliant device [18]
21-28	Reserved
29	ETS 300 800 V2 and DAVIC 1.5 compliant device
30	ETS 300 800 V1 compliant device
31	Reserved

Syntax Indicator

`Syntax_Indicator` is a 3-bit enumerated type that indicates the addressing type contained in the MAC message.

```
Enum Syntax_Indicator {No_MAC_Address, MAC_Address_Included,
Fragment_No_MAC_Address, Fragment_MAC_Address, reserved 4...7};
```

MAC Address

`MAC_Address` is a 48-bit value representing the unique MAC address of the NIU. This MAC address may be hard-coded in the NIU or be provided by external source.

Fragment Count

Identification of fragment in a MAC message transmitted in multiple fragments. A MAC message divided into N fragments, will be transmitted with `Fragment_Count` = N, N – 1, ... 1.

A.5.5.3 MAC Initialization and Provisioning

This clause defines the procedure for Initialization and Provisioning that the MAC shall perform during power-on or Reset. All INA/NIU will send and receive the messages during initialization and provisioning using QPSK modulation.

1) Upon a NIU becoming active (i.e. powered up), it shall first find the current provisioning frequency. The NIU shall receive the <MAC> Provisioning Channel Message. This message shall be sent aperiodically (at least one in 900 ms) on all downstream channels carrying MAC information when there are multiple channels. In the case of only a single channel, the message shall indicate the current channel is to be utilized for Provisioning. Upon receiving this message, the NIU shall tune to the Provisioning Channel. In the case of IB downstream, the IB channel to be used during provisioning can additionally be given by using EN 300 468 [21].

2) After a valid lock indication on a Provisioning Channel, the NIU shall await the <MAC> Default Configuration Message. When received, the NIU shall configure its parameters as defined in the default configuration message. The Default Configuration Parameters shall include default timer values, default power levels, default retry counts as well as other information related to the operation of the MAC protocol.

Figure A.34 shows the signalling sequence.

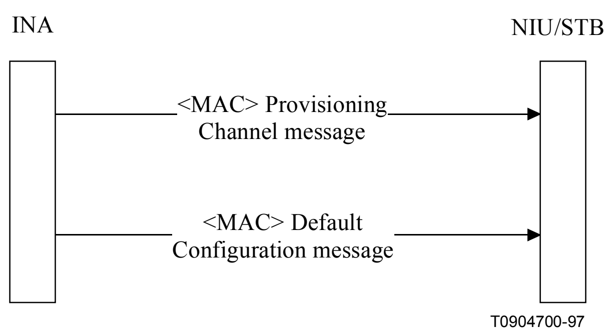


Figure A.34/J.112 – Initialization and Provisioning Signalling

A.5.5.3.1 <MAC> Provisioning Channel Message (broadcast downstream)

The <MAC> Provisioning Channel Message is sent by the INA to direct the NIU to the proper frequency where provisioning is performed. The format of the message is shown in Table A.19.

Table A.19/J.112 – Provisioning Channel message structure

	Bits	Bytes	Bit number/Description
`Provisioning_Channel_Message(){`			

`Provisioning_Channel_Control_Field`
`Reserved`
`Provisioning_Frequency_Included`
	8
	7
	1
		1	
			7-1
			0: {no = 0, yes = 1}

`if (Provisioning_Frequency_Included) {`			
`Provisioning_Frequency`	**(32)**	**(4)**	
`DownStream_Type`	**(8)**	**(1)**	
`}`			
`}`			

Provisioning Channel Control Field

`Provisioning_Channel_Control_Field` is used to specify which parameters are included in the message:

`Provisioning_Frequency_Included` is a boolean which, when set, indicates that a downstream frequency is specified that the NIU should tune to begin the provisioning process. When cleared, it indicates that the current downstream frequency is the provisioning frequency.

Provisioning Frequency

`Provisioning_Frequency` is a 32-bit unsigned integer representing the Out-of-band Frequency in which NIU provisioning occurs. The unit of measure is in Hz.

Downstream Type

`DownStream_Type` is an 8-bit enumerated type indicating the modulation format for the downstream connection. {QAM_MPEG, QPSK_1.544, QPSK_3.088, 3...255 reserved}}

A.5.5.3.2 <MAC> Default Configuration Message (broadcast downstream)

The <MAC> Default Configuration Message is sent by the INA to the NIU. The message provides default parameter and configuration information to the NIU. The format of the message is shown in Table A.20.

Table A.20/J.112 – Default Configuration message structure

	Bits	Bytes	Bit number/Description
`Default_Configuration_Message(){`			
`Sign_On_Incr_Pwr_Retry_Count`	**8**	**1**	
`Service_Channel_Frequency`	**32**	**4**	
`Service_Channel_Control_Field`		**1**	
`MAC_Flag_Set`	5		7..3
`Service_Channel`	3		2..0
`Backup_Service_Channel_Frequency`	**32**	**4**	
`Backup_Service_Channel_Control_Field`		**1**	
`Backup_MAC_Flag_Set`	5		7..3
`Backup_Service_Channel`	3		2..0
`Service_Channel_Frame_Length`	**16**	**2**	
`Service_Channel_Last_Slot`	**16**	**2**	
`Max_Power_Level`	**8**	**1**	
`Min_Power_Level`	**8**	**1**	
`Upstream_Control_Field`		**1**	
`Reserved`	5		7..3
`Upstream_Transmission_Rate`	3		2..0
`Max_Backoff_Exponent`	**8**	**1**	
`Min_Backoff_Exponent`	**8**	**1**	
`Idle_Interval`	**16**	**2**	
`Absolute_Time_Offset`	**16**	**2**	
`frequency_ranging_step`	**8**	**1**	
`Number_of_Timeouts`	**8**	**1**	
`for (I=0; I<Number_of_Timeouts;I++) {`			
`Field`		**(1)**	
`Code`	(4)		
`Value`	(4)		
`}`			
INA_Capabilities		**4**	
Encapsulation	8		31..24
US_Bitrate	8		23..16
DS_OOB_Bitrate	4		15..12
Capabilities_extended_included	1		11: {no, yes}
Reserved	1		10: shall be 0
DS_Header_Suppression	1		9: {no, yes}
US_Header_Suppression	1		8: {no, yes}
Piggy_Back_Capable	1		7: {no, yes}
Resource_Request_Capable	1		6: {no, yes}
Fragmented_MAC_Messages	1		5: {no, yes}
Security_Supported	1		4: {no, yes}

Table A.20/J.112 – Default Configuration message structure

	Bits	Bytes	Bit number/Description
Minislots_for_Reservation	1		3: {no, yes}
Reserved_for_DAVIC	1		2: shall be 0
IB_Signalling	1		1: {no, yes}
OOB_Signalling	1		0: {no, yes}
If (INA_capabilities &= Capabilities_extended_included) {			
INA_capabilities_extended		**4**	
Reserved	30		31..3: shall be 0
Session_binding	1		2:{no, yes}
16QAM_minislots	1		1: {no, yes}
16QAM	1		0: {no, yes}
}			
}			

Sign-On Increment Power Retry Count

`Sign_On_Incr_Pwr_Retry_Count` is an 8-bit unsigned integer representing the number of attempts the NIU should try to enter the system at the same power level before incrementing its power level by steps of max. 2 dB.

Service Channel Frequency

`Service_Channel_Frequency` is a 32-bit unsigned integer representing the upstream frequency assigned to the service channel. The unit of measure is in hertz.

MAC Flag Set

`MAC_Flag_Set` is a 5-bit field representing the first Flag set assigned to the service channel. A downstream channel contains information for each of its associated upstream channels. This information is contained within structures known as MAC Flag Sets represented by either 24 bits (denoted b0...b23) or by 3 bytes (denoted Rxa, Rxb, Rxc). This information is uniquely assigned to a given upstream channel. Refer to A.5.3.1.3 and A.5.3.2.1 for the use of this parameter.

Service Channel

`Service_Channel` is a 3-bit field which defines the channel assigned to the Service_Channel_Frequency. It identifies the logical channel (denoted by "c") assigned to the NIU/STB. Refer to A.5.3.2.1 and A.5.3.3 for the use of this parameter.

Backup Service Channel Frequency

`Backup_Service_Channel_Frequency` is a 32-bit unsigned integer representing the upstream frequency assigned to the backup service channel. The backup service channel is used when entry on the primary service channel fails. The unit of measure is in hertz. If there is no Backup Service Channel, this parameter shall be equal to the Service Channel Frequency.

Backup MAC Flag Set

`Backup_MAC_Flag_Set` is a 5-bit field representing the first Flag set assigned to the backup service channel. The function of this field is the same as the MAC_Flag_Set above but with respect to the backup service channel. If there is no Backup Service Channel, this parameter shall be equal to the MAC Flag Set.

Backup Service Channel

`Backup_Service_Channel` is a 3-bit field which defines the channel assigned to the Backup Service_Channel_Frequency. The function of this field is the same as the Service_Channel above but with respect to the backup channel. If there is no Backup Service Channel, this parameter shall be equal to the Service Channel.

Service Channel Frame Length [reserved]

Unused in this version.

Service Channel Last Slot

`Service_Channel_Last_Slot` is a 16-bit unsigned integer representing the largest slot value of the NIU's upstream slot position counter (as defined in A.5.4.4).

Only 13 lowest significant bits shall be considered. 3 MSBs are reserved for future use.

Informative note: Since the value of `Service_Channel_Last_Slot` equals $((N + 1) \times 3 \times m) - 1$, where "N" is the maximum value of the upstream slot position register (M10-M1), and "m" is a constant dependent upon the upstream bit rate, (see A.5.4.4), one may use it to calculate the fixed number N. The NIU is capable of deriving the Last_Slot_number for each channel from N and the upstream bitrate of the respective channel.

Maximum Power Level

`MAX_Power_Level` is a 8-bit unsigned integer representing the maximum power the NIU shall be allowed to use to transmit upstream. The unit of measure is in dBμV (RMS) on 75 Ω.

Minimum Power Level

`MIN_Power_Level` is an 8-bit unsigned integer representing the minimum power the NIU shall be allowed to use to transmit upstream. The unit of measure is in dBμV (RMS) on 75 Ω.

Upstream Transmission Rate

`Upstream_Transmission_Rate` is a 3-bit enumerated type that indicates the upstream transmission bit rate.

```
enum Upstream_Transmission_Rate {Upstream_256K, Upstream_1.544M,
Upstream_3.088M, Upstream_6.176M, reserved 4...7};
```

Minimum Backoff Exponent

`MIN_Backoff_Exponent` is an 8-bit unsigned integer representing the minimum value of the backoff exponent counter. Only the 5 least significant bits are valid; the 3 most significant bits are reserved for future use.

Maximum Backoff Exponent

`MAX_Backoff_Exponent` is an 8-bit unsigned integer representing the maximum value of the backoff exponent counter. Only the 5 least significant bits are valid; the 3 most significant bits are reserved for future use.

Idle Interval

`Idle_Interval` is a 16-bit unsigned integer representing the predefined interval for the Idle Messages. Valid intervals shall be between 60 and 600, where the unit of the measure is in seconds. In addition, the value of zero indicates that no Idle messages shall be sent.

Absolute Time Offset

`Absolute_Time_Offset` is a 16-bit signed integer used to set the default Absolute_Time_Offset (defined in A.5.3.1.3) when first signing on. The unit of measure is 100 ns.

Frequency Ranging Step

Used only for LMDS (EN 301 199 [18]).

Number of Timeouts

`Number_of_Timeouts` is an 8-bit unsigned integer which identifies the number of time-out codes and values included in the message.

Code

`Code` is a 4-bit unsigned integer which identifies the time-out or group of time-outs (according to Tables A.21a, A.21b, A.22 and A.51) for which the following value is given.

Value

`Value` is a 4-bit unsigned integer which gives the value for the time-out or group of time-outs identified by the preceeding code. The time-out can be derived from Table A.21a:

Table A.21a/J.112 – Time-out coding

Value	Time-out (ms)
0	Infinite (disabled)
1	9
2	30
3	60
4	90
5	300
6	600
7	900
8	3000
9	6000
10	9000
11	30000
12	60000
13	Reserved
14	Reserved
15	Reserved

If no values are given in the <MAC> Default Configuration Message, the default values apply (see Table A.21b).

Table A.21b/J.112 – Headend time-out values

Code	Transaction(s)	Default value
0x0	Ranging and power calibration → Ranging and power calibration response Connect → Connect response (no frequency change) Release → Release response Transmission control → Link management response (no frequency change) Reservation Id assignment → Reservation Id response Reprovision → Link management response (no frequency change) Status request → Status response message Init. complete → Connect response Init. complete → Link management response	300
0x1	Connect → Sign-on response (only for frequency change) Reprovision → Sign-on response (only for frequency change) Transmission control → Sign-on response (only for frequency change)	3000

The unit for the time-outs is in miliseconds.

These time-outs apply when the mentioned two messages are consecutive (see Table A.22).

Table A.22/J.112 – Terminal Time-out values

Code	Transaction(s)	Default value
0x2	Default configuration interval (time between two Def. Conf. msg) Sign-on request interval	900
0x3	Sign-on response → Ranging and power calibration Sign-on response → Initialization complete Ranging and power calibration response → Ranging and power calibration Ranging and power calibration response → Initialization complete Connect response → Connect confirm Resource Request → Release Resource Request → Reservation_Id assignement	90
0x4	Initialization complete → Connect Resource Request → Resource Request Denied Resource Request → Connect Resource Request → Reprovision Time-out in ERROR state (time to wait before going to "Wait for Provisioning Message" state; see A.7.1)	300

The unit for the time-outs is in milliseconds.

These time-outs apply when the mentioned two messages are consecutive.

INA Capabilities

`INA_Capabilities` is a 32-bit field that indicates the capabilities of the INA. It has the following subfields:

`Encapsulation` is an 8-bit field that indicates the type(s) of encapsulation supported by the INA: {DIRECT_IP, Ethernet_MAC_Bridging, PPP, reserved 3...7}. Bit 0 is the LSB and corresponds to bit 24 of the INA_Capabilities field.

`US_Bitrate` is an 8-bit field that indicates the upstream bitrate(s) supported by the INA: {256 kbit/s, 1.544 Mbit/s, 3.088 Mbit/s, 6.176 Mbit/s, reserved 4...7}. Bit 0 is the LSB and corresponds to bit 16 of the INA_Capabilities field.

`DS_OOB_Bitrate` is a 4-bit field that indicates the downstream OOB bitrate(s) supported by the INA: {1.544 Mbit/s, 3.088 Mbit/s, reserved 2...3}. Bit 0 is the LSB and corresponds to bit 12 of the INA_Capabilities field.

`Capabilities_extended_included`: 1-bit field. If true, the message includes the INA_capabilities_extended field.

`Reserved`: Reserved for future use.

`DS_Header_Suppression` is a 1-bit field that indicates if the INA supports header suppression in downstream direction.

`US_Header_Suppression` is a 1-bit field that indicates if the INA supports header suppression in upstream direction.

`Piggy_Back_Capable` is a 1-bit field that indicates if the INA is able to process Piggyback requests and assignments.

`Resource_Request_Capable` is a 1-bit field that indicates if the INA is able to process <MAC> Resource Request Messages.

`Fragmented_MAC_Messages` is a 1-bit field that indicates that the INA is able to support MAC messages having the compound MAC_Information_Elements field of a single up to 512 bytes in size. This flag is also for backwards compatibility with INAs not supporting MAC message fragmentation and re-assembly. By not setting this bit, the INA indicates that it does not support fragmented MAC messages at all, and will not understand or utilize the Fragment_No_MAC_Address and Fragment_MAC_Address_Included MAC message syntax types.

`Security_Supported` is a 1-bit field that indicates that the INA is able to support the security extensions specified in this protocol.

`Minislots_for_Reservation` is a 1-bit field that indicates that the INA is capable of utilizing mini-slots.

`Reserved_for_DAVIC`: Reserved for compatibility with DAVIC.

`IB_Signalling` is a 1-bit field that indicates that the INA is capable of utilizing IB signalling.

`OOB_Signalling` is a 1-bit field that indicates that the INA is capable of utilizing OOB signalling.

INA Capabilities Extended

`INA_Capabilities_Extended` is a 32-bit field that indicates further capabilities of the INA. It has the following subfields:

`Reserved`: Reserved for future use.

`Session_binding` is a 1-bit boolean field, indicating if the INA supports session binding.

`16QAM_Minislots` is a 1-bit field that indicates if the INA supports 16QAM mini-slots.

`16QAM` is a 1-bit field that indicates if the INA supports 16QAM modulation.

A.5.5.4 Sign-On and Calibration

The NIU shall sign on via the Sign-On Procedure. The signalling flow for Sign-On is described below.

- The NIU shall tune to the downstream Provisioning channel and the upstream service channel with the information provided in the Initialization and Provisioning sequence.
- The NIU shall await the <MAC> Sign-On Request Message from the INA Entity.
- Upon receiving the <MAC> Sign-On Request Message, the NIU shall respond with the <MAC> Sign-On Response Message. The Sign-On Response Message shall be transmitted on a Ranging Slot. The NIU/STB shall either use settings of the last successful Sign-on procedure if it is enabled by the INA or the Min_Power_Level contained in the <MAC> Default Configuration Message.
- The INA, upon receiving the Sign-On Response Message, shall validate the NIU, either sending <MAC> Initialization Complete Message or the <MAC> Ranging and Power Calibration Message.
- The NIU shall respond to the <MAC> Ranging and Power Calibration Message with the <MAC> Ranging and Power Calibration Response Message. The <MAC> Ranging and Power Calibration Response Message shall be transmitted on a Ranging Slot (which can either be in the ranging region (b0 = 1) or reserved region (if a ranging slot number is given in the message). The calibration sequence is not always necessary.
- The INA shall send the <MAC> Initialization Complete Message when the NIU is calibrated. The NIU is assumed to be calibrated if the message arrives within a window of ±0.75 symbols (upstream rate) and a power within a window of ±1.5 dB from their optimal value.

See Figure A.35.

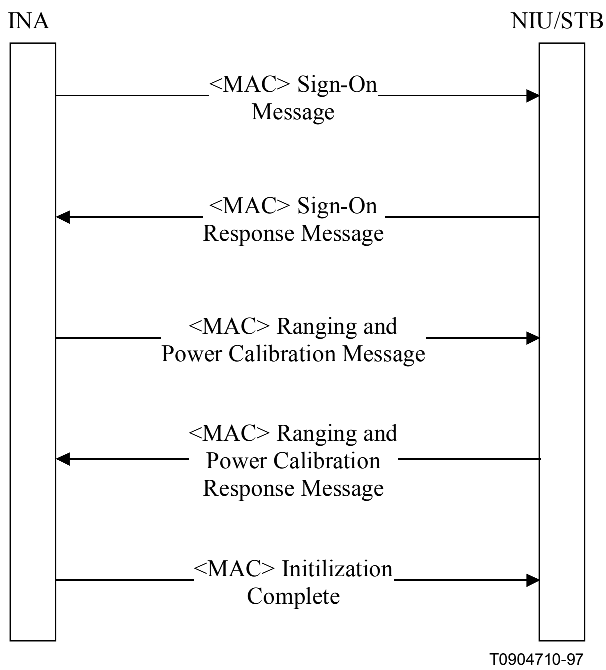


Figure A.35/J.112 – Ranging and Calibration Signalling

A more detailed description of the ranging and calibration process, including state diagrams and time-outs, is given in A.7.1 (Informative Note A).

A.5.5.4.1 <MAC> Sign-On Request Message (broadcast downstream)

The <MAC> Sign-On Request message is issued periodically by the INA to allow a NIU to indicate its presence in the network. The format of this subcommand is shown in Table A.23.

Table A.23/J.112 – Sign-On Request message structure

	Bits	Bytes	Bit number/Description
`Sign-On_Request_Message(){`			
`Sign-On_Control_Field`		**1**	
`Reserved`	6		7..2
`Need_Calibration`	1		1: {0 = enable rapid sign-on, 1 = disable rapid sign-on}
`Address_Filter_Params_Included`	1		0: {no, yes}
`Response_Collection_Time_Window`	**16**	**2**	
`if (Sign-On_Control_Field &= Address_Filter_Params_Included {`			
`Address_Position_Mask`	**(8)**	**(1)**	
`Address_Comparison_Value`	**(8)**	**(1)**	
}			
}			

Sign-On Control Field

`Sign-On_Control_Field` specifies what parameters are included in the SIGN-ON REQUEST:

`Need_Calibration` indicates to the NIU that it has to enter the sign-on process starting with the Min_Power_Level and Absolute_Time_Offset (and Frequency_Offset for LMDS) defined in the <MAC> Default_Configuration_message. If the bit is not set, the NIU is allowed to start the sign-on with the values for Power_Level and Time_Offset (and Frequency_Offset for LMDS) that it has used for its last upstream transmission after succesful sign-on. This bit is only to be taken into account for sign-on processes that follow the reception of a Transmission Control Message, Reprovision_Message or Connect_Message. In all other cases the parameters defined in the <MAC> Default_Configuration_Message have to be used independent of the setting of the Need_Calibration bit.

`Address_Filter_Params_Included` is a boolean, which, when set, indicates that the NIU should respond to the SIGN-ON REQUEST only if its address matches the filter requirements specified in the message.

Response Collection Time Window

`Response_Collection_Time_Window` is a 16-bit unsigned integer that specifies the maximum time for the SIGN-ON RESPONSE message transmission randomization. The unit of measure is the millisecond (ms).

Address Position Mask

`Address_Position_Mask` is an 8-bit unsigned integer that indicates the bit positions in the NIU MAC address that are used for address filtering comparison. The bit positions are comprised between bit number `Mask` and `Mask`+7. `Mask` = 0 corresponds to the 8 LSBs of the address, i.e. it represents the number of bits shifted to the left. The maximum value is 40.

Address Comparison Value

`Address_Comparison_Value` is an 8-bit unsigned integer that specifies the value that the NIU should use for MAC address comparison. (See Figure A.36.)

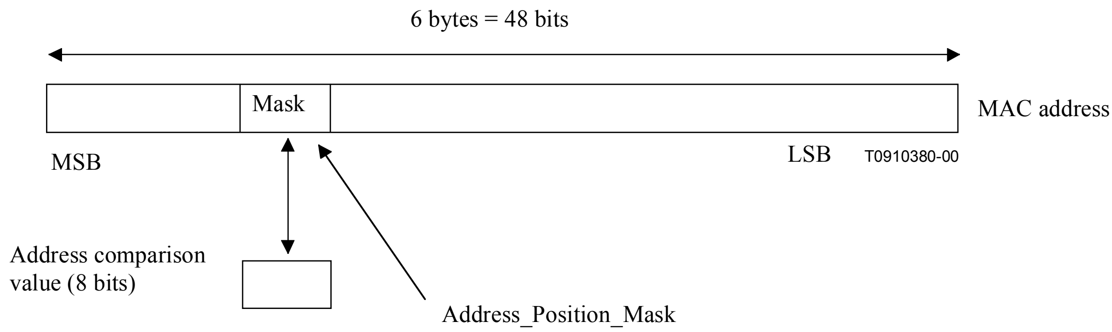


Figure A.36/J.112 – Position of Mask in MAC address

A.5.5.4.2 <MAC> Sign-On Response Message (upstream Ranging)

The <MAC> Sign-On Response Message is sent by the NIU in response to the <MAC> Sign-On Request Message issued by the INA Entity. The NIU shall wait for a random time less than `Response_Collection_Time_Window` to send this message.

If the sign-on procedure did not start at the Min_Power_Level (see A.5.6.3), when the NIU has not received any response from the INA after `Sign_On_Incr_Pwr_Retry_Count` attempts, it shall retry with the Min_Power_Level.

See Table A.24.

Table A.24/J.112 – Sign-On Response message structure

	Bits	Bytes	Bit number/Description
`Sign-On_Response_Message(){`			
`NIU/STB_Status`		**4**	
`Reserved`	29		31..3
`Network_Address_Registered`	1		2:{no, yes}
`Connection_Established`	1		1:{no, yes}
`Reserved for compatibility`	1		0
`NIU/STB_Error_Code`		**2**	
`Reserved`	13		15..3
`Connect_Confirm_Timeout`	1		2:{no, yes}
`First_Connection_Timeout`	1		1:{no, yes}
`Range_Response_Timeout`	1		0:{no, yes}
`NIU/STB_Retry_Count`	**8**	**1**	

Table A.24/J.112 – Sign-On Response message structure

	Bits	Bytes	Bit number/Description
NIU/STB_Capabilities		**4**	
Encapsulation	8		31..24
US_Bitrate	8		23..16
DS_OOB_Bitrate	4		15..12
Capabilities_extended_included	1		11: {no, yes}
Reserved	1		10: shall be zero
DS_Header_Suppression	1		9: {no, yes}
US_Header_Suppression	1		8: {no, yes}
Piggy_Back_Capable	1		7: {no, yes}
Resource_Request_Capable	1		6: {no, yes}
Fragmented_MAC_Messages	1		5:{no, yes}
Security_Supported	1		4:{no, yes}
Minislots_for_Reservation	1		3: {no, yes}
Reserved_for_DAVIC	1		2: shall be zero
IB_Signalling	1		1: {no, yes}
OOB_Signalling	1		0: {no, yes}
if (NIU_capabilities &= capabilities_extended_included) {			
NIU_capabilities_extended		**4**	
Reserved	30		31..4: must be 0
Session_binding	1		3:{no,yes}
Extended_Reprovision	1		2: {no, yes}
16QAM_minislots	1		1: {no, yes}
16QAM	1		0: {no, yes}
}			
}			

NIU/STB Status

`NIU/STB_Status` is a 32-bit field that indicates the current state of the NIU/STB. It has the following subfields:

`Network_Address_Registered` indicates that the Network Interface Module has registered its NSAP Address with the Application Module. The NSAP Address is not currently used but remains reserved for this purpose.

`Connection_Established` indicates that the Network Interface Module has been assigned Connection parameters.

NIU/STB Error Code

`NIU/STB_Error_Code` is a 16-bit field that indicates the error condition within the NIU/STB. It has the following subfields:

– `Connect_Confirm_Timeout` (set to 1 for transition SCE:E4 or DCE:E8; see A.7.2);

– `First_Connection_Timeout` (set to 1 for transition DCE:E2; see A.7.2);

– `Range_Response_Timeout` (set to 1 for transition RC:E13; see A.7.1).

In case of a time-out in the current signalling, the corresponding subfield is set to one; see A.7.1 (Informative Note A).

NIU/STB Retry Count

NIU/STB_Retry_Count is an 8-bit unsigned integer that indicates the number of transmissions of the <MAC> Sign-On Response. This field is always included in the response to the <MAC> Sign-On Request. This field shall be initialized to zero whenever a Sign-On procedure is started, and this field shall be incremented by one each time the message is transmitted until the Sign-On procedure completes or the value reaches its maximum value (255). In the case that this field reaches its maximum value, it shall remain at the maximum value for the remainder of the current Sign-On procedure.

NIU/STB Capabilities

NIU/STB_Capabilities is a 32-bit field that indicates the capabilities of the NIU/STB. It has the following subfields:

Encapsulation is an 8-bit field that indicates the type(s) of encapsulation supported by the NIU/STB: {DIRECT_IP, Ethernet_MAC_Bridging, PPP, reserved 3...7}. Bit 0 is the LSB and corresponds to bit 24 of the NIU/STB_Capabilities field.

US_Bitrate is an 8-bit field that indicates the upstream bitrate(s) supported by the NIU/STB: {256 kbit/s, 1.544 Mbit/s, 3.088 Mbit/s, 6.176 Mbit/s, reserved 4...7}. Bit 0 is the LSB and corresponds to bit 16 of the NIU/STB_Capabilities field.

DS_OOB_Bitrate is a 4-bit field that indicates the downstream OOB bitrate(s) supported by the NIU/STB: {1.544 Mbit/s, 3.088 Mbit/s, reserved 2...3}. Bit 0 is the LSB and corresponds to bit 12 of the NIU/STB_Capabilities field.

Capabilities_extended_included: 1-bit field. If set to true, the message includes the NIU_capabilities_extended_field.

Reserved: Reserved for future use.

DS_Header_Suppression is a 1-bit field that indicates if the NIU supports header suppression in downstream direction.

US_Header_Suppression is a 1-bit field that indicates if the NIU supports header suppression in upstream direction.

Piggy_Back_Capable is a 1-bit field that indicates if the NIU is able to append Piggyback requests onto a PDU ATM cell.

Resource_Request_Capable is a 1-bit field that indicates if the NIU is able to send <MAC> Resource Request Messages.

Fragmented_MAC_Messages is a 1-bit field that indicates that the NIU/STB is able to support MAC messages having the compound MAC_Information_Elements field of a single message up to 512 bytes in size. This flag is also for backwards compatibility with NIU/STBs not supporting MAC message fragmentation and re-assembly. By not setting this bit, the NIU/STB indicates that it does not support fragmented MAC messages at all, and will not understand or utilize the Fragment_No_MAC_Address and Fragment_MAC_Address_Included MAC message syntax types.

Security_Supported is a 1-bit field that indicates that the NIU/STB is able to support the security extensions specified in this protocol.

Minislots_for_Reservation is a 1-bit field that indicates that the NIU/STB is capable of utilizing mini-slots.

Reserved_for_DAVIC: Reserved for compatibility with DAVIC.

IB_Signalling is a 1-bit field that indicates that the NIU/STB is capable of utilizing IB signalling.

`OOB_Signalling` is a 1-bit field that indicates that the NIU/STB is capable of utilizing OOB signalling.

NIU/STB Capabilities Extended

`NIU/STB_Capabilities_Extended` is a 32-bit field that indicates the capabilities of the NIU/STB. It has the following subfields:

`Reserved`: Reserved for future use.

`Session_binding` is a 1-bit field that indicates if the NIU supports session binding.

`Extended_Reprovision` is a 1-bit field that indicates if the NIU supports extended reprovision.

`16QAM_Minislots` is a 1-bit field that indicates if the NIU supports 16QAM minislots.

`16QAM` is a 1-bit field that indicates if the NIU supports 16QAM modulation.

A.5.5.4.3 <MAC> Ranging and Power Calibration Message (singlecast downstream)

The <MAC> Ranging and Power Calibration Message is sent by the INA to the NIU to adjust the power level or time offset the NIU is using for upstream transmission. The format of this message is shown in Table A.25. Mini-slots are not used for ranging.

Table A.25/J.112 – Ranging and Power Calibration message structure

	Bits	Bytes	Bit number/Description
`Ranging_and_Power_Calibration_Message(){`			

`Range_Power_Control_Field`
`Reserved`
`Equalizer_coefficients_included`
`Ranging_Slot_Included`
`Time_Adjustment_Included`
`Power_Adjustment_Included`
	
	4
	1
	1
	1
	1
		1	
			7-4: shall be 0.
			3: {no, yes}
			2: {no, yes}
			1: {no, yes}
			0: {no, yes}

`if (Range_Power_Control_Field &= Time_Adjustment_Included ) {`			
`Time_Offset_Value`	**(16)**	**(2)**	
}			
`if (Range_Power_Control_Field &= Power_Adjustment_Included ) {`			
`Power_Control_Setting`	**(8)**	**(1)**	
}			
`if (Range_Power_Control_Field &= Ranging_Slot_Included) {`			
`Ranging_Slot_Number`	**(16)**	**(2)**	
}			
`if (Range_Power_Control_Field &= Equalizer_coefficients_included) {`			
`Equalizer_coefficients`	**(256)**	**(32)**	
}			
}			

Range and Power Control Field

`Range_Power_Control_Field` specifies which Range and Power Control Parameters are included in the message.

Equalizer coefficients included

`Equalizer_coefficients_included` indicates if the message include a new set of coefficients for the NIU pre-equalizer.

Time Adjustment Included

`time_adjustment_included` is a boolean which, when set, indicates that a relative Time Offset Value is included that the NIU should use to adjust its upstream slot transmit position.

Power Adjust Included

`power_adjust_included` is a boolean which, when set, indicates that a relative Power Control Setting is included in the message

Ranging Slot Included

`Ranging_Slot_Included` is a boolean which, when set, indicates the calibration slot available. When this bit equals 1, the NIU shall send its response on the slot number given by **Ranging Slot Number.** When this bit equals 0, the NIU shall respond on a ranging slot as mentioned in A.7.1.

Time Offset Value

`Time_Offset_Value` is a 16-bit short integer representing a relative offset of the upstream transmission timing. A negative value indicates an adjustment forward in time (later). A positive value indicates an adjustment back in time (earlier). The unit of measure is 100 ns (The NIU will adjust approximately its time offset to the closest value indicated by the Time_Offset_Value parameter, which implies that no extra clock is needed to adjust to the correct offset).

Power Control Setting

`Power_Control_Setting` is an 8-bit signed integer to be used to set the new power level of the NIU. (A positive value represents an increase of the ouput power level.)

New output_power_level = current output_power_level + power_control_setting × 0.5 dB

Ranging Slot Number

`Ranging_Slot_Number` is a 16-bit unsigned integer that represents the reserved access Slot Number assigned for Ranging the NIU. It shall be assigned by the INA in the reservation area. The INA shall assure that an unassigned slot precedes and follows the ranging slot.

Only 13 lowest significant bits shall be considered. 3 MSBs are reserved for future use.

Equalizer coefficients

`Equalizer_coefficients` field is a 32-byte field that lists the new coefficients for the NIU pre-equalizer. The taps coefficient real and imaginary parts will consist of 16 bits, coded in fractional two's complement notation. The NIU will convolve these coefficients with the current coefficients. The coding order will be: tap0 [real, imag], tap1[real, imag], and so on.

A.5.5.4.4 <MAC> Ranging and Power Calibration Response Message (upstream ranging or reserved)

The <MAC> Ranging and Power Calibration Response Message is sent by the NIU to the INA in response to the <MAC> Ranging and Power Calibration Message. The format of the message is shown in Table A.26.

Table A.26/J.112 – Ranging and Power Calibration Response message structure

	Bits	Bytes	Bit number/Description
`Ranging_Power_Response_Message(){`			
`Power_Control_Setting`	**8**	**1**	
`}`			

Power Control Setting

`Power_Control_Setting` is an 8-bit unsigned integer representing the actual power used by the NIU for upstream transmission. The unit of measure is 0.5 dBμV.

A.5.5.4.5 <MAC> Initialization Complete Message (singlecast downstream)

The <MAC> Initialization Complete Message is sent by the INA to the /STB to indicate the end of the Sign-On and Provisioning procedure. The STB/ shall reenter the initialization process after receiving a non-zero Completion_Status_Field value. The <MAC> Transmission Control Message can be used to stop the NIU from sending upstream messages.

	Bits	Bytes	Bit number/Description
`Initialization_Complete_Message(){`			
`Completion_Status_Field`		1	
`Reserved`	4		7..4
`Invalid_STB/`	1		3: {no, yes}
`Timing_Ranging_Error`	1		2: {no, yes}
`Power_Ranging_Error`	1		1: {no, yes}
`Other_Error`	1		0: {no, yes}
`}`			

Completion Status Field

`Completion_Status_Field` is an 8-bit field that indicates errors in the initialization phase. It has the following subfields:

`Invalid_STB/` is a boolean that (when set to 1) indicates that the STB/ is invalid.

`Timing_Ranging_Error` is a boolean that (when set to 1) indicates that the ranging has not succeeded.

`Power_Ranging_Error` is a boolean that (when set to 1) indicates that the power ranging has not succeeded.

`Other_Error` is a boolean that (when set to 1) indicates an error with unspecified type.

A.5.5.5 Connection establishment

Two cases shall be considered:

1) Establishment of the first (initial) connection;
2) Establishment of additional connections.

A.5.5.5.1 Establishment of the first (Initial) connection

After Initialization, Provisioning and Sign-On Procedures are complete, the INA shall assign an upstream and downstream connection to the NIU. This connection can be assigned on any of the upstream channels, according to the NIU/INA capabilities:

NIUs that support 16QAM modulation can be assigned upstream channels that use either QPSK or 16QAM modulation. NIUs that support only QPSK modulation will be assigned any of the QPSK upstream channels.

The INA shall assign the connection by sending the <MAC> Connect Message to the NIU. This message shall contain the upstream connection parameters, the downstream frequency on which the connection is to reside, and the channel modulation. From this point, the NIU will use the modulation that is indicated by the channel (16QAM/QPSK).

The NIU, upon receiving the <MAC> Connect Message shall tune to the required upstream and downstream frequencies and send the <MAC> Connect Response Message confirming receipt of the message. However, if the US and/or the DS frequency contained in the <MAC> Connect Message is different than the current US and/or DS frequency, the NIU/STB shall tune to the new frequency(ies) and enter the Sign-On procedure as defined in A.5.6.3, the Connection_Established flag being set and the NIU/STB retry count reset. The NIU/STB shall send the <MAC> Connect Response Message after the <MAC> Initialization Complete Message.

Upon receipt of the <MAC> Connect Response Message, the INA shall confirm the new connection by sending the <MAC> Connect Confirm Message.

See Figure A.37.

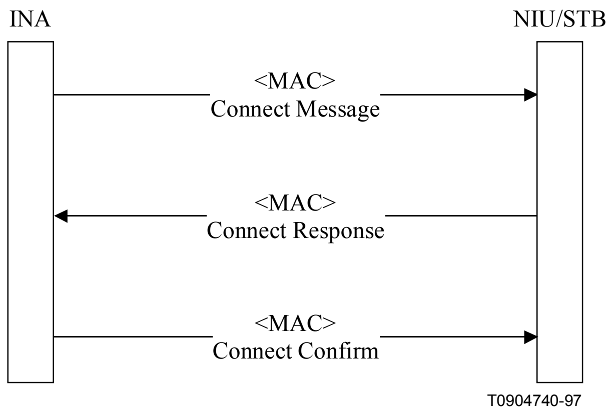


Figure A.37/J.112 – Connection signalling for the initial connection

A more detailed description of the connection establishment process, including state diagrams and time-outs, is given in A.7.2 (Informative Note A).

<MAC> Connect Message (singlecast downstream)

See Table A.27.

Table A.27/J.112 – Connect message structure

	Bits	Bytes	Bit number/Description
Connect_Message (){			
Connection_Id	**32**	**4**	
Session_Number	**32**	**4**	
Connection_Control_Field_Aux		**1**	
Connection_control_field2_included	1		7: {no, yes}
IPv6_add	1		6: {no, yes}
Priority_Included	1		5: {no, yes}
Flowspec_DS_Included	1		4: {no, yes}
Session_Binding_US_Included	1		3: {no, yes}
Session_Binding_DS_Included	1		2: {no, yes}
Encapsulation_Included	1		1: {no, yes}
DS_Multiprotocol_CBD_Included	1		0: {no, yes}
Resource_Number	**8**	**1**	
Connection_Control_Field		**1**	
DS_ATM_CBD_Included	1		7: {no, yes}
DS_MPEG_CBD_Included	1		6: {no, yes}
US_ATM_CBD_Included	1		5: {no, yes}
Upstream_Channel_Number	3		4..2
Slot_List_Included	1		1: {no, yes}
Cyclic_Assignment	1		0: {no, yes}
Frame_Length	**16**	**2**	
Maximum_Contention_Access_Message_Length	**8**	**1**	
Maximum_Reservation_Access_Message_Length	**8**	**1**	
if (Connection_Control_Field &= DS_ATM_CBD_Included) {			
Downstream_ATM_CBD()	**(64)**	**(8)**	
}			
if (Connection_Control_Field &= DS_MPEG_CBD_Included) {			
Downstream_MPEG_CBD()	**(48)**	**(6)**	
}			
if (Connection_Control_Field &= US_ATM_CBD_Included) {			
Upstream_ATM_CBD()	**(64)**	**(8)**	
}			
if (Connection_Control_Field &= Slot_List_Included) {			
Number_Slots_Defined	**(8)**	**(1)**	
for (i = 0; i < Number_Slots_Defined; I++{			
Slot_Number	**(16)**	**(2)**	
}			
}			

Table A.27/J.112 – Connect message structure

	Bits	Bytes	Bit number/Description
if (MAC_Control_Params == Cyclic_Assignment){			Fixed RateAccess
Fixedrate_Start	**(16)**	**(2)**	
Fixedrate_Dist	**(16)**	**(2)**	
Fixedrate_End	**(16)**	**(2)**	
}			
if (Connection_Control_Field_Aux &= DS_Multiprotocol_CBD_Included) {			
Downstream_Multiprotocol_CDB()	**(48)**	**(6)**	
}			
if (Connection_Control_Field_Aux &= Encapsulation_Included) {			
Encapsulation	**(8)**	**(1)**	
}			
If (Connection_Control_Field_Aux &= priority_Included) {			
Priority	**(8)**	**(1)**	
If (Connection_Control_Field_Aux &= flowspec_DS_Included) {			
Max_packet_size	**(16)**	**(2)**	in bytes
Average_bitrate	**(16)**	**(2)**	in bytes/s
Jitter	**(8)**	**(1)**	in ms
}			
If (Connection_Control_Field_Aux &= upstream_session_binding_Included) && (Connection_Control_Field_Aux != IPv6 add) {			
US_session_binding_control	**(32)**	**(4)**	
NIU_client_source_IP_add	**(32)**	**(4)**	
NIU_client_destination_IP_add	**(32)**	**(4)**	
NIU_client_source_port	**(16)**	**(2)**	
NIU_client_destination_port	**(16)**	**(2)**	
Upstream_transport_protocol	**(8)**	**(1)**	
NIU_client_source_MAC_add	**(48)**	(6)	
NIU_client_destination_MAC_add	**(48)**	**(6)**	
Upstream_interent_protocol	**(16)**	**(2)**	
Upstream_session_Id	**(32)**	**(4)**	
}			
if (Connection_control_aux_ Field &= downstream_session_binding_Included) && (Connection_Control_Field_Aux != IPv6 add) {			
DS_session_binding_control	**(32)**	**(4)**	
INA_client_source_IP_add	**(32)**	**(4)**	
INA_client_destination_IP_add	**(32)**	**(4)**	
INA_client_source_port	**(16)**	**(2)**	
INA_client_destination_port	**(16)**	**(2)**	

Table A.27/J.112 – Connect message structure

	Bits	Bytes	Bit number/Description
Downstream_transport_protocol	**(8)**	**(1)**	
INA_client_source_MAC_add	**(48)**	**(6)**	
INA_client_destination_MAC_add	**(48)**	**(6)**	
Dowstream_interent_protocol	**(16)**	**(2)**	
Dowstream_session_Id	**(32)**	**(4)**	
}			
if (Connection_Control_Field_Aux &=aux_control_field2_included) {			
Connection_control_field2 Reserved Upstream_modulation_included	 (7) (1)	**(1)**	 7..1: shall be 0 0: {no, yes}
if (Connection_Control_Field2 &= Upstream_modulation_included) {			
Upstream_Modulation	**(8)**	**(1)**	
}			
}			

Connection Id

`Connection_Id` is a 32-bit unsigned integer representing a connection Identifier for the NIU Dynamic Connection.

Session Number

`Session_Number` is a 32-bit unsigned integer representing the Session that the connection parameters are associated. This parameter is not used by the present annex.

Connection Control Field Aux

`Connection_control_field2_included`: a 1-bit field. If true, the message includes a Connection_control_field2 field.

`IPv6_add`: if set to 1, IP addresses at the session binding blocks are IPv6 compatible.

`Priority_included`: if set to 1, the message includes a priority field.

`Flowspec_DS_included`: if set to 1, the message includes a downstream flow spec.

`Session_binding_US_Included`: if set to 1, the message includes a session binding description for the upstream.

`Session_binding_DS_included`: if set to 1, the message includes a session binding description for the downstream.

`Encapsulation_Included` is a boolean that indicates that the type of encapsulation is included in the message.

`DS_Multiprotocol_CBD_Included` is a boolean that indicates that the Downstream Multiprotocol Descriptor is included in the message.

Resource Number

`Resource_Number` is an 8-bit unsigned integer providing a unique number to the resource defined in the message. If the Connect Message is the result of a Resource Request by the NIU, it shall be equal to the Resource_Request_Id of the Resource Request; otherwise, it shall be 0.

Connection Control Field

`DS_ATM_CBD_Included` is a boolean that indicates that the Downstream Descriptor is included in the message.

`DS_MPEG_CBD_Included` is a boolean that indicates that the Downstream Descriptor is included in the message.

`US_ATM_CBD_Included` is a boolean that indicates that the Upstream Descriptor is included in the message.

`Upstream_Channel_Number` is a 3-bit unsigned integer which identifies the logical channel (denoted by 'c') assigned to the NIU/STB. Refer to A.5.3.2.1 for the use of this parameter.

`Slot_List_Included` is a boolean that indicates that the Slot List is included in the message. Having Cyclic Assignments and Slot List Assignments for the same Connect_Id at the same time is not allowed.

`Cyclic_Assignment` is a boolean that indicates Cyclic Assignment. Having Cyclic Assignments and Slot List Assignments for the same Connect_Id at the same time is not allowed.

The connection type can be deduced from the presence or the absence of the Connection Control Fields relative to the CBDs. The following table summarizes the valid combinations:

DS_ATM_CBD	DS_MPEG_CBD	Connection type
YES	NO	OOB
NO	YES	DVB Multiprotocol Encapsulation over MPEG [6]
YES	YES	Reserved for ATM over DVB Data piping over MPEG [14]

All other combinations will not be used by the INA. If so, the message shall be ignored by the NIU/STB (no <MAC>Connect Response Message shall be sent).

Frame Length

`Frame_length`: This 16-bit unsigned number represents the number of successive slots in the fixed rate access region associated with each fixed rate slot assignment. In the slot_list method of allocating slots it represents the number of successive slots associated with each element in the list. In the cyclic method of alocating slots it represents the number of successive slots associated with the Fixedrate_Start_slot and those which are multiples of Fixedrate_Distance from the Fixedrate_Start_slot within the Fixed rate access region.

Maximum Contention Access Message Length

`Maximum_contention_access_message_length` is an 8-bit number representing the maximum length of a message in upstream packets that may be transmitted using contention access. Any message greater than this should use reservation access.

Maximum Reservation Access Message Length

`Maximum_reservation_access_message_length` is an 8-bit number representing the maximum length of a message in upstream packets that may be transmitted using a single reservation access. Any message greater than this shall be transmitted by making multiple reservation requests.

Downstream ATM Connection Block Descriptor

See Table A.28.

Table A.28/J.112 – Downstream_ATM_CBD substructure

	Bits	Bytes	Bit number/Description
`Downstream_ATM_CBD(){`			
`Downstream_Frequency`	32	4	
`Downstream_VPI`	8	1	
`Downstream_VCI`	16	2	
`Downstream_Type`	8	1	
}			

`Downstream_Frequency` is a 32-bit unsigned integer representing the Frequency where the connection resides. The unit of measure is in hertz.

`Downstream_VPI` is an 8-bit unsigned integer representing the ATM Virtual Path Identifier that is used for downstream transmission over the Dynamic Connection.

`Downstream_VCI` is a 16-bit unsigned integer representing the ATM Virtual Channel Identifier that is used for downstream transmission over the Dynamic Connection.

`DownStream_Type` is an 8-bit enumerated type indicating the modulation format for the downstream connection. {QAM_MPEG, QPSK_1,544, QPSK_3,088, 3...255 reserved}.

Downstream MPEG Connection Block Descriptor

See Table A.29.

Table A.29/J.112 – Downstream_MPEG_CBD substructure

	Bits	Bytes	Bit number/Description
`Downstream_MPEG_CBD(){`			
`Downstream_Frequency`	32	4	
`Program_Number`	16	2	
}			

`Downstream_Frequency` is a 32-bit unsigned integer representing the Frequency where the connection resides. The unit of measure is in hertz.

`Program_Number` is a 16-bit unsigned integer uniquely referencing the downstream virtual connection assignment (PID of the MPEG-2 header, **not** equal to the program number defined by MPEG-2!). Only the 13 least significant bits are valid; the three most significant bits are reserved for future use.

Upstream ATM Connection Block Descriptor

See Table A.30.

Table A.30/J.112 – Upstream_ATM_CBD substructure

	Bits	Bytes	Bit number/Description
Upstream_ATM_CBD(){			
Upstream_Frequency	**32**	**4**	
Upstream_VPI	**8**	**1**	
Upstream_VCI	**16**	**2**	
		1	
MAC_Flag_Set	5		7..3
Upstream_Rate	3		2..0
}			

`Upstream_Frequency` is a 32-bit unsigned integer representing the channel on assigned to the connection. The unit of measure is in hertz.

`Upstream_VPI` is an 8-bit unsigned integer representing the ATM Virtual Path Identifier that is used for upstream transmission over the Dynamic Connection.

`Upstream_VCI` is a 16-bit unsigned integer representing the ATM Virtual Channel Identifier that is used for upstream transmission over the Dynamic Connection.

`MAC_Flag_Set` is a 5-bit field representing the first Flag set assigned to the logical channel. A downstream channel contains information for each of its associated upstream channel. This information is contained within structures known as MAC Flag Sets represented by either 24 bits (denoted b0...b23) or by 3 bytes (denoted Rxa, Rxb, Rxc). This information is uniquely assigned to a given upstream channel. Refer to A.5.3.1.3 and A.5.3.2.1 for the use of this parameter.

`Upstream_Rate` is a 3-bit enumerated type indicating the upstream transmission grade for the upstream connection. {Upstream_A_AQ, Upstream_B_BQ, Upstream_C_CQ, Upsteam_D_DQ, 4...7 reserved}

Number of Slots Defined

`Number_Slots_Defined` is an 8-bit unsigned integer that represents the number of slot assignments contained in the message. The unit of measure is slots.

Slot Number

`Slot_Number` is a 16-bit unsigned integer that represents the Fixed rate based Slot Number assigned to the NIU. Only 13 lowest significant bits shall be considered. 3 MSBs are reserved for future used.

Fixed Rate Start

`Fixedrate_Start` – This 16-bit unsigned number represents the starting slot within the fixed rate access region that is assigned to the NIU. The NIU may use the next Frame_length slots of the fixed rate access regions. Only 13 lowest significant bits shall be considered. 3 MSBs are reserved for future used.

Fixed Rate Distance

`Fixedrate_Distance` – This 16-bit unsigned number represents the distance in slots (taking into account all slots of all regions) between additional slots assigned to the NIU. The NIU is assigned all slots that are a multiple of Fixedrate_Distance from the Fixedrate_Start_slot which do not exceed Fixedrate_End_slot. The NIU may use the next Frame_length slots of the fixed rate access regions from each of these additional slots.

Fixed Rate End

`Fixedrate_End` – This 16-bit unsigned number indicates the last slot that may be used for fixed rate access. The slots assigned to the NIU, as determined by using the Fixedrate_Start_slot, the Fixedrate_Distance and the Frame_length, cannot exceed this number. Only 13 lowest significant bits shall be considered. 3 MSBs are reserved for future use.

Downstream Multiprotocol Connection Block Descriptor

See Table A.31.

Table A.31/J.112 – Downstream_Multiprotocol_CBD substructure

	Bits	Bytes	Bit number/Description
Downstream_Multiprotocol_CBD(){			
MAC_Address	**48**	**6**	
}			

`MAC_Address` is a 48-bit MAC address, identifiying the only MAC address (for the connection established by this <MAC> Connect_Message) (used, for example, for multicast) to filter on in the DVB Multiprotocol Encapsulation header, according to EN 301 192 [6]. By default (for connections where no Downstream_Multiprotocol_CBD is given in the <MAC> Connect_Message) the NIU filters on its own MAC address and the Broadcast MAC address FF:FF:FF:FF:FF:FF.

`Encapsulation` is an 8-bit field that indicates the type of encapsulation provided: {Direct_IP, Ethernet_MAC_Bridging, PPP, reserved 3...7}

`Priority`: 1-byte field. The value of the field defines the priority of the connection. Connections with low priority field value can be reprovisioned in order to accommodate the requirements of connections with high priority field. Priority values will be given according to the following table:

Application	Priority values
Standard data flow applications	0-79
Applications with QoS requirements	80-200
High priority applications	201-255

Downstream flow spec

The downstream flow spec has 3 parameters:

`Max_Packet_size`: the size of the maximum packet (bytes) that will be sent through the connection in the downstream. The packet size includes propriety protocols header, transport protocol (UDP/TCP) header, and the IP header. The packet size does not include the Ethernet header.

`Average_bitrate`: the average bit rate, in bytes/s.

`Jitter`: the total jitter that downstream packets can expirience. (See Figure A.38.)

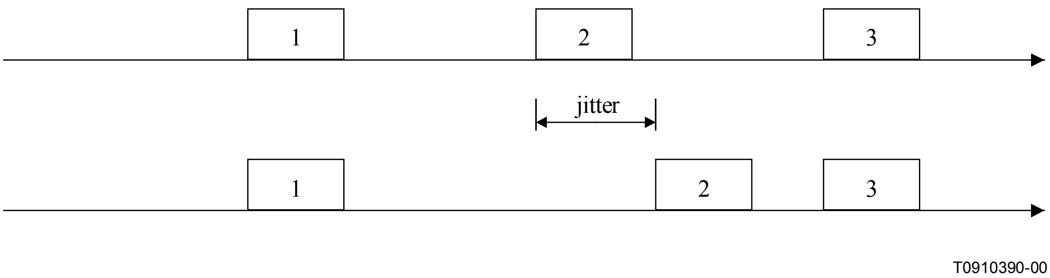


Figure A.38/J.112 – Downstream jitter definition

Session binding information

See Figure A.39.

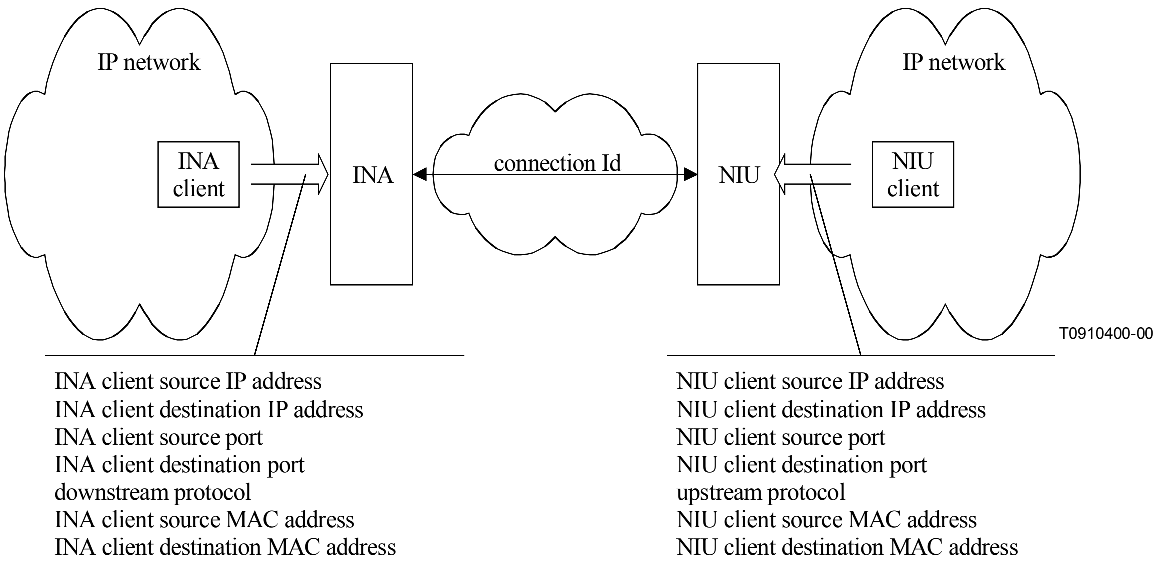


Figure A.39/J.112 – Session binding information

The upstream and downstream session binding blocks identify clients that are using the connection. The clients are identified by their source and destination, the source and destination ports (if relevant), and the protocol.

In most cases, the downstream and upstream session binding will be identical.

(NIU client source IP address = INA client destination IP address, NIU client source port = INA client destination port, and neccesarily upstream protocol = downstream protocol).

In this case, only the upstream session binding is sent.

The message will contain a DS session binding only if there is a difference in the INA and NIU source destination ports and addresses.

(NIU client source IP address ≠ INA client destination IP address, NIU client source port ≠ INA client destination port).

US_session_binding_control: the interpretation of the US session binding block depends on the value of US_session_binding_control field. The field acts as a bitmap, indicating the existence of the different session binding parameters. If the bit attached to the session binding parameter is set to 1, then the parameter exists in the message. If not, the session binding parameter does not exist. When a bit corresponding to a field which is not defined at the moment is set to 1, the NIU MUST treat that field as a 32-bit long field, and MAY ignore it.

The mapping between the current session binding parameters and the US_session_binding_control field is described in the following table:

US_session_binding_control bit number	US session binding parameter
0	NIU_client_source_IP_add
1	NIU_client_destination_IP_add
2	NIU_client_source_port
3	NIU_client_destination_port
4	Upstream_transport_protocol
5	NIU_client_source_MAC_add
6	NIU_client_destination_MAC_add
7	Upstream_internet_protocol
8	Upstream_session_Id
10-31	Reserved (must be set to 0)

NIU_client_source_IP_add: the IP source address of the NIU client.

NIU_client_destination_IP_add: the IP destination address of the INA client.

NIU_client_source_port: the source port of the INA client.

NIU_client_destination_port: the destination port of the INA client.

Upstream_transport_protocol: the transport protocol used by the NIU client (UDP/TCP).

NIU_client_source_MAC_add: a 48-bit unsigned integer that identifies the Ethernet MAC address of the NIU client.

NIU_client_destination_MAC_add: a 48-bit unsigned integer that identifies the destination Ethernet MAC address of the NIU client.

Upstream_internet_protocol: a 16-bit field, defining the Internet protocol, as described in the Ethernet header.

Upstream_session_Id: a 32-bit field, describing the session_Id, as defined for PPPoE protocol.

DS_session_binding_control: the interpretation of the DS session binding block depends on the value of DS_session_binding_control field. The field acts as a bitmap, indicating the existence of the different session binding parameters. If the bit attached to the session binding parameter is set to 1, then the parameter exists. If not, the session binding parameter does not exist. When a bit corresponding to a field which is not defined at the moment is set to 1, the NIU MUST treat that field as a 32-bit long field, and MAY ignore it.

The mapping between the current session binding parameters and the DS_session_binding_control field is described in the following table:

DS_session_binding_control bit number	DS session binding parameter
0	INA_client_source_IP_add
1	INA_client_destination_IP_add
2	INA_client_source_port
3	INA_client_destination_port
4	Downstream_transport_protocol
5	INA_client_source_MAC_add
6	INA_client_destination_MAC_add
7	Downstream_internet_protocol
8	Downstream_session_Id
10-31	Reserved (must be set to 0)

`INA_client_source_IP_add`: the IP source address of the INA client.

`INA_client_destination_IP_add`: the IP destination address of the INA client.

`INA_client_source_port`: the source port of the INA client.

`INA_client_destination_port`: the destination port of the INA client.

`Downstream_transport_protocol`: the transport protocol used by the INA client (UDP/TCP).

`INA_client_source_MAC_add`: a 48-bit unsigned integer that identifies the Ethernet MAC address of the INA client.

`INA_client_destination_MAC_add`: a 48-bit unsigned integer that identifies the destination Ethernet MAC address of the INA client.

`Downstream_internet_protocol`: a 16-bit field, defining the Internet protocol, as described in the Ethernet header.

`Downstream_session_Id`: a 32-bit field, describing the session_Id, as defined for PPPoE protocol.

Connection control field2

`Reserved`: 7-bit field, for future use. Shall be set to 0.

`Upstream_modulation_included`: if set to true, the message includes the upstream channel modulation type. If the INA supports 16QAM, the field must be true.

Upstream modulation

`Upstream_modulation`: 8-bit field enumerated type indicating the upstream channel modulation {QPSK, 16QAM, 3...7 reserved}

<MAC> Connect Response (upstream contention or reserved)

The <MAC> Connect Response Message is sent to the INA from the NIU in response to the <MAC> Connect Message. The message shall be transmitted on the upstream frequency specified in the <MAC> Connect Message. If the Upstream frequency is different than the current upstream frequency, then the procedure described in A.5.6.3 shall be used before the <MAC> Connect Response Message is sent. If the Connect Confirm message does not arrive within the specified time interval, the NIU shall resend the Connect Response message. (See Table A.32.)

Table A.32/J.112 – Connect Response message structure

	Bits	Bytes	Bit number/Description
`Connect_Response(){`			
`Connection_Id`	32	4	
`}`			

Connection Id

`Connection_Id` is a 32-bit unsigned integer representing a global connection Identifier for the NIU Dynamic Connection.

<MAC> Connect Confirm (singlecast downstream)

The <MAC> Connect Confirm message is sent from the INA to the NIU. (See Table A.33.)

Table A.33/J.112 – Connect Confirm message structure

	Bits	Bytes	Bit number/Description
`Connect_Confirm(){`			
`Connection_Id`	32	4	
`}`			

Connection Id

`Connection_Id` is a 32-bit unsigned integer representing a global connection Identifier for the NIU Dynamic Connection.

A.5.5.5.2 Establishment of additional connections

The INA can assign additional connections by using the <MAC> Connect Message described previously. The NIU can request such connections using the <MAC> Resource Request Message. Besides, the message sequence is the same as for the initial connection, with the following restrictions:

– For one NIU, the US frequency shall be the same for all connections, and the OOB and IB frequencies shall be the same for all OOB and IB connections respectively.

– If a <MAC> Connect Message is received with new values of US and/or DS frequency, the NIU/STB will ignore the message.

– If needed, the INA will use one of the resource management procedure to modify the US or DS frequency (see A.5.5.10.2 and Link Management) before sending the additional <MAC> Connect Message.

See Figure A.40.

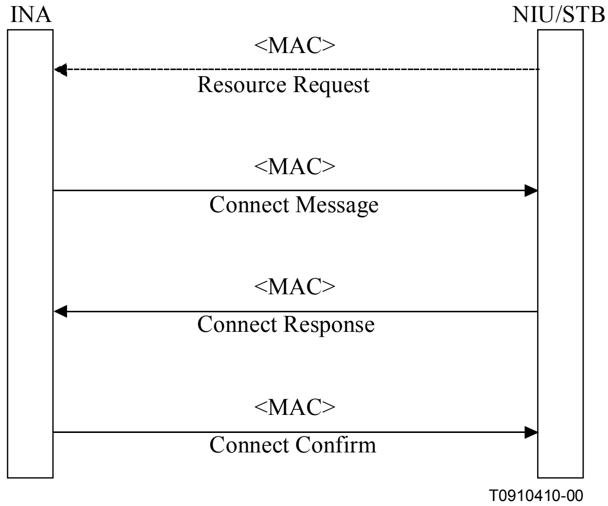


Figure A.40/J.112 – Connection signalling for additional connections

A more detailed description of the connection establishment process, including state diagrams and time outs, is given in A.7.2 and A.7.5 (Informative Note A).

<MAC> Resource Request Message (Upstream)

The NIU may request a new connection, may request to change the parameters of an existing connection and may request to release an existing connection by sending a <MAC> Resource Request Message to the INA. The INA can answer to that request by sending a <MAC> Connect Message, a <MAC> Reservation_Id Assignment Message/<MAC> Reprovision Message or a <MAC> Release Message, respectively, to the NIU or by sending a <MAC> Resource Request Denied Message to the NIU. (See Table A.34.)

Table A.34/J.112 – Resource Request message structure

	Bits	Bytes	Bit number/Description
Resource_Request_Message() {			
Resource_Request_Id	**8**	**1**	
Connection_Id	**32**	**4**	
Field		**1**	
Aux_control_field_included	1		7: {no, yes}
Admit_flag	1		6: {no, yes}
Priority_included	1		5: {no, yes}
Max_packet_size_included	1		4: {no, yes}
Session_binding_US_Included	1		3: {no, yes}
Release_Requested	1		2: {no, yes}
Reservation_Id_Requested	1		1: {no, yes}
Cyclic_Assignment_Needed	1		0: {no, yes}
Requested_Bandwidth	**24**	**3**	**unit in slot/1200 ms**
Maximum_Distance_Between_Slots	**16**	**2**	**unit in slot**
Encapsulation	**8**	**1**	
If (Field &= aux_control_field_Included) {			

Table A.34/J.112 – Resource Request message structure

	Bits	Bytes	Bit number/Description
Aux_control_field		**(1)**	
Reserved	(5)		7..2 must be 0
IPv6_add	(1)		2: {no,yes}
Flowspec_DS_included	(1)		1:{no, yes}
Session_binding_DS_included	(1)		0: {no, yes}
}			
If (Field &= priority_Included) {			
Priority	**(8)**	**(1)**	
}			
If (Field &= max_packet_size_Included) {			
Frame_length	**(16)**	**(2)**	in slots
}			
If (aux_control_Field &= Flowspec_DS_included) {			
Max_packet_size	**(16)**	**(2)**	in bytes
Average_bitrate	**(16)**	**(2)**	in bytes/s
Jitter	**(8)**	**(1)**	in ms
}			
If (Field &= session_binding_US_Included) && (Aux_control_field != IPv6_add) { {			
NIU_client_source_IP_add	**(32)**	**(4)**	
US_session_binding_control	**(32)**	**(4)**	
NIU_client_destination_IP_add	**(32)**	**(4)**	
NIU_client_source_port	**(16)**	**(2)**	
NIU_client_destination_port	**(16)**	**(2)**	
Upstream_transport_protocol	**(8)**	**(1)**	
NIU_client_source_MAC_add	**(48)**	**(6)**	
NIU_client_destination_MAC_add	**(48)**	**(6)**	
Upstream_internet_protocol	**(16)**	**(2)**	
Upstream_session_Id	**(32)**	**(4)**	
}			
If (aux_control_Field &= session_binding_DS_Included) && (Aux_control_field != Ipv6_add) { {			
DS_session_binding_control	**(32)**	**(4)**	
INA_client_source_IP_add	**(32)**	**(4)**	
INA_client_destination_IP_add	**(32)**	**(4)**	
INA_client_source_port	**(16)**	**(2)**	
INA_client_destination_port	**(16)**	**(2)**	
Downstream_transport_protocol	**(8)**	**(1)**	
INA_client_source_MAC_add	**(48)**	**(6)**	
INA_client_destination_MAC_add	**(48)**	**(6)**	
Downstream_internet_protocol	**(16)**	**(2)**	

Table A.34/J.112 – Resource Request message structure

	Bits	Bytes	Bit number/Description
Downstream_session_Id	(32)	(4)	
}			
}			

Resource_Request_Id: an 8-bit unsigned integer which identifies the resource request. The value of the Resource_Request_Id is incremented by 1 for every new resource request of the NIU. The value may not be 0.

Connection_Id: a 32-bit field which identifies the connection for which changes are requested. If the value of Connection_Id is zero, a new connection is requested.

Aux_control_field_included: if set to 1, the message control auxiliary control field.

Admit_flag: if set to 1, the resources requested by the message should not be granted for the moment. The INA has to guarantee that, at the moment the resources were committed (admit_flag = 0), the resources will be granted for the connection.

Priority_included: if set to 1, the message includes a priority field.

Frame_length_included: if set to 1, the message includes a frame_length field.

Session_binding_US_Included: if set to 1, the message includes a session binding description for the upstream.

Release_Requested: if set to 1, the release of the connection is requested. In this case, all following parameters of the message shall be ignored by the INA.

Reservation_Id_Requested: if set to 1, a Reservation_Id is requested for the connection.

Cyclic_Assignment_Needed: if set to 1, cyclic assignment is requested for fixed rate access for the connection. If Requested_Bandwidth is zero, this field is ignored by the INA.

Requested_Bandwidth: gives the requested bandwidth for fixed rate access for the connection in slot/1200 ms.

Maximum_Distance_Between_Slots: gives the requested maximum distance between assigned fixed rate slots. If Requested_Bandwidth is zero, this field is ignored by the INA.

Encapsulation: an 8-bit field that indicates the type of encapsulation requested: {Direct_IP, Ethernet_MAC_Bridging, PPP, reserved 3...7}.

Aux control field

Reserved: 5-bit field; must be set to 0.

IPv6_add: if set to true, the IP addresses at the session binding blocks are IPv6 compatible.

Flowspec_DS_included: if set to 1, indicates that the message includes a flowspec field for the downstream.

Session_binding_DS_included: if set to 1, the message includes a session binding description for the upstream.

Connection_Id: a 32-bit field which identifies the connection for which changes are requested. If the value of Connection_Id is zero, a new connection is requested. If the connection Id is not zero, but the INA can not attach a connection to the connection Id, the connection was requested for a packet cable session, and the connection_Id is the gate number associated with the connection.

`Priority`: 1-byte field. The value of the field defines the priority of the connection. Connections with low priority field value can be reprovisioned in order to accommodate the requirements of connections with high priority field. Priority values will be given according to the following table:

Application	Priority values
Standard data flow applications	0-79
Applications with QoS requirements	80-200
High priority applications	201-255

Upstream flow spec

The description of the upstream flow spec is done with 3 parameters:

`Frame_length`: the number of consecutive slots that are required for the maximum packet size that will be sent through the connection in the upstream.

`Requested_Bandwidth`: gives the requested bandwidth for fixed rate access for the connection in slot/1200 ms.

`Maximum_Distance_Between_Slots`: gives the requested maximum distance between assigned fixed rate slots. If Requested_Bandwidth is zero, this field is ignored by the INA.

The INA MUST calculate the requested data rate and the allowed jitter in the following way:

The INA calculates the data rate by calculating the average_distance_between_slots, requested by the NIU. If the INA allocates for the NIU the number of slots defined by NIU_frame_length, every average_distance_between_slots, the NIU will not expirience any jitter.

$$\text{Average\_distance\_between\_slots} = \frac{\text{number of slots@1200 ms} \times \text{max. packet size}}{\text{requested\_bandwidth}}$$

The jitter every packet delivered by the NIU can tolerate is:

$$\text{Jitter} = \text{maximum\_distance\_between\_slots} - \text{average\_distance\_between\_slots}$$

When the INA allocates the slots for the NIU, it MUST take into consideration the bandwidth requested by the NIU and the maximum delay.

See Figure A.41.

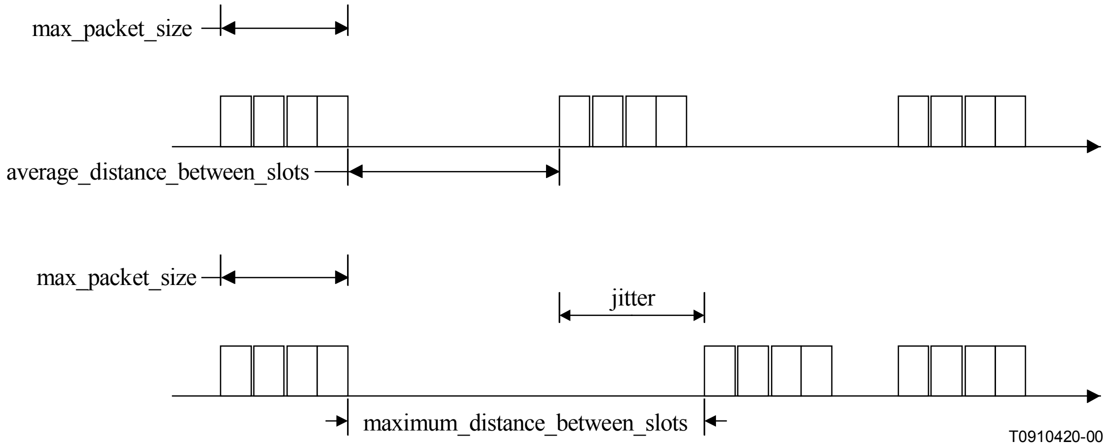


Figure A.41/J.112 – Upstream jitter definition

Downstream flow spec (see A.5.5.5.1)

The downstream flow spec has 3 parameters:

`Max_Packet_size`: the size of the maximum packet (bytes) that will be sent through the connection in the downstream. The packet size includes propriety protocols header, transport protocol (UDP/TCP) header, and the IP header. The packet size does not include the Ethernet header.

`Average_bitrate`: the average bit rate, in bytes/s.

`Jitter`: the total jitter that downstream packets can experience.

Session binding information (see A.5.5.5.1)

The upstream and downstream session binding blocks identify clients that are using the connection. The clients are identified by their source and destination, the source and destination ports (if relevant), and the protocol.

In most cases, the downstream and upstream session binding will be identical.

(NIU client source IP address = INA client destination IP address, NIU client source port = INA client destination port , and neccesarily upstream protocol = downstream protocol).

In this case, only the downstream session binding is sent.

The message will contain a US session binding only if there is a difference in the INA and NIU source destination ports and addresses

(NIU client source IP address ≠ INA client destination IP address, NIU client source port ≠ INA client destination port).

`US_session_binding_control`: the interpretation of the US session binding block depends on the value of US_session_binding_control field. The field acts as a bitmap, indicating the existence of the different session binding parameters. If the bit attached to the session binding parameter, is set to 1, then the parameter exists in the message. If not, the session binding parameter does not exist. When a bit corresponding to a field which is not defined at the moment is set to 1, the NIU MUST treat that field as a 32-bit long field, and MAY ignore it.

The mapping between the current session binding parameters and the US_session_binding_control field is described in the following table:

US_session_binding_control bit number	US session binding parameter
0	NIU_client_source_IP_add
1	NIU_client_destination_IP_add
2	NIU_client_source_port
3	NIU_client_destination_port
4	Upstream_transport_protocol
5	NIU_client_source_MAC_add
6	NIU_client_destination_MAC_add
7	Upstream_internet_protocol
8	Upstream_session_Id
10-31	Reserved

`NIU_client_source_IP_add`: the IP source address of the NIU client.

`NIU_client_destination_IP_add`: the IP destination address of the INA client.

`NIU_client_source_port`: the source port of the INA client.

`NIU_client_destination_port`: the destination port of the INA client.

`Upstream_transport_protocol`: the transport protocol used by the NIU client.

`NIU_client_source_MAC_add:` a 48-bit unsigned integer that identifies the Ethernet MAC address of the NIU client.

`NIU_client_destination_MAC_add`: a 48-bit unsigned integer that identifies the destination Ethernet MAC address of the NIU client.

`Upstream_internet_protocol`: a 16-bit field, defining the Internet protocol, as described in the Ethernet header.

`Upstream_session_Id`: a 32-bit field, describing the session_Id, as defined for PPPoE protocol.

`DS_session_binding_control`: the interpretation of the DS session binding block depends on the value of DS_session_binding_control field. The field acts as a bitmap, indicating the existence of the different session binding parameters. If the bit attached to the session binding parameter is set to 1, then the parameter exists. If not, the session binding parameter does not exist. When a bit corresponding to a field which is not defined at the moment is set to 1, the NIU MUST treat that field as a 32-bit long field, and MAY ignore it.

The mapping between the current session binding parameters and the DS_session_binding_control field is described in the following table:

DS_session_binding_control bit number	DS session binding parameter
0	INA_client_source_IP_add
1	INA_client_destination_IP_add
2	INA_client_source_port
3	INA_client_destination_port
4	Downstream_transport_protocol
5	INA_client_source_MAC_add
6	INA_client_destination_MAC_add
7	Downstream_internet_protocol
8	Downstream_session_Id
10-31	Reserved

`INA_client_source_IP_add`: the IP source address of the INA client.

`INA_client_destination_IP_add`: the IP destination address of the INA client.

`INA_client_source_port`: the source port of the INA client.

`INA_client_destination_port`: the destination port of the INA client.

`Downstream_transport_protocol`: the transport protocol used by the INA client.

`INA_client_source_MAC_add`: a 48-bit unsigned integer that identifies the Ethernet MAC address of the INA client.

`INA_client_destination_MAC_add`: a 48-bit unsigned integer that identifies the destination Ethernet MAC address of the INA client.

`Downstream_internet_protocol`: a 16-bit field, defining the internet protocol, as described in the Ethernet header.

`Downstream_session_Id`: a 32-bit field, describing the session_Id, as defined for PPPoE protocol.

<MAC> Resource Request Denied Message (singlecast downstream)

The INA may respond to a resource request of the NIU with a <MAC> Resource Request Denied Message (see Table A.35):

Table A.35/J.112 – Resource Request Denied message structure

	Bits	Bytes	Bit number/Description
`Resource_Request_Denied_Message() {`			
`Resource_Request_Id`	8	1	
`}`			

`Resource_Request_Id` is an 8-bit unsigned integer which identifies the resource request which is denied.

A.5.5.6 Connection Release

This clause defines the MAC signalling requirements for connection release. Figure A.42 displays the signalling flow for releasing a connection. The NIU can request the release of a connection using the <MAC> Resource Request Message.

1) The NIU may request the release of a connection using the <MAC> Resource Request Message, or the INA itself can initiate the release process.
2) Upon receiving the <MAC> Release Message from the INA, the NIU shall tear down the upstream connection established for the specified Connection_Id.
3) Upon teardown of the upstream connection, the NIU shall send the <MAC> Release Response Message on the upstream channel previously assigned for that connection. If the Connection_Id is unknown by the NIU, it shall send zero in the response message. If the Number_of_Connections in the Connection Release Message is zero, then the NIU shall release all open connections.

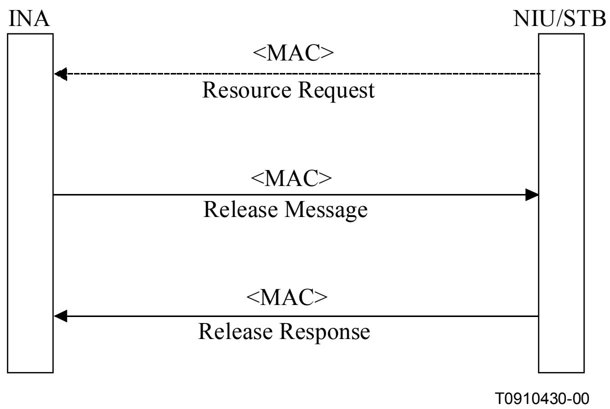


Figure A.42/J.112 – Connection release signalling

A more detailed description of the connection release process, including state diagrams and time-outs, is given in A.7.3 and A.7.5 (Informative Note A).

<MAC> Release Message (singlecast downstream)

The <MAC> Release Message is sent from the INA to the NIU to terminate a previously established connection. (See Table A.36.)

Table A.36/J.112 – Release message structure

	Bits	Bytes	Bit number/Description
`Release_Message(){`			
`Number_of_Connections`	8	1	
for (i = 0; i < Number_of_Connections; i++){			
`Connection_Id`	(32)	(4)	
}			
}			

Connection Id

`Connection_Id` is a 32-bit unsigned integer representing a global connection Identifier for the NIU Dynamic Connection.

<MAC> Release Response (upstream contention or reserved)

The <MAC> Release Response Message is sent by the NIU to the INA to acknowledge the release of a connection. The format of the message is shown in Table A.37.

Table A.37/J.112 – Release Response message structure

	Bits	Bytes	Bit number/Description
`Release_Response_Message (){`			
`Connection_Id`	32	4	
}			

Connection Id

`Connection_Id` is a 32-bit unsigned integer representing the global connection Identifier used by the NIU for this connection.

A.5.5.7 Fixed rate access

Fixed rate access is provided by the INA using the <MAC> Connect Message. The INA is also allowed to assign slots in fixed rate access to a connection in response to a <MAC> Reservation Request Message.

A.5.5.8 Contention based access

The NIU shall use contention based slots specified by the slot boundary definition fields (Rx) to transmit contention based messages or payload (see A.5.3.1.3). The format of contention based MAC messages is described by the MAC message format (see A.5.5.2.7). The format for payload transmission is described in A.5.5.2.4.

A.5.5.9 Reservation access

This clause defines the MAC signalling requirements for reservation access. Figure A.43 displays the signalling flow for reserving an access.

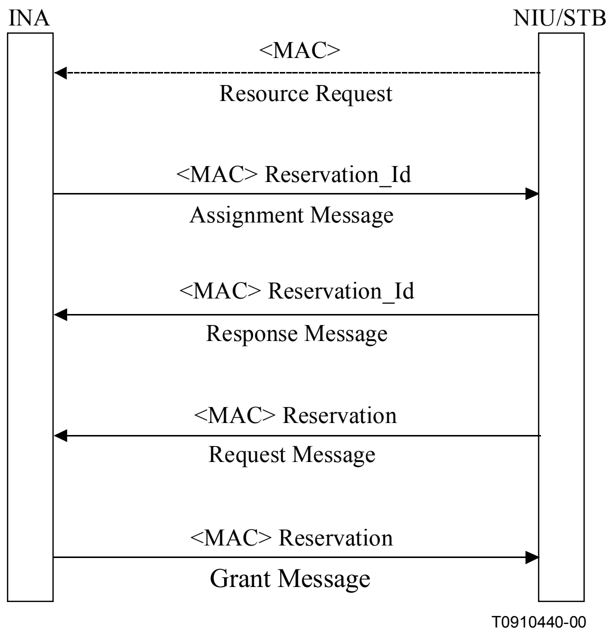


Figure A.43/J.112 – Reservation access signalling

1) The NIU can request a Reservation_Id using the <MAC> Resource Request Message.

2) The NIU shall wait for a <MAC> Reservation Id Assignment Message from the INA before it can request reservation access and before it can send Piggyback Reservation Requests.

3) At any time when needed after receiving the reservation Id, the NIU can request a certain number of slots to the INA using the <MAC> Reservation Request Message.

3a) The INA shall respond to that message using the <MAC> Reservation Grant Message.

3b) If the NIU has not received the <MAC> Reservation Grant Message before the `Grant_Protocol_Timeout`, it shall send a <MAC> Reservation Status Request to the INA. This leads back to 3) or 4).

4) At any time when needed after receiving the reservation Id, the NIU can request one of three prespecified number of slots (specified by the Piggy_Back_Request_Values, which are set in the Reservation_Id_Assignment_Message) by setting the two MSBs of the GFC contained in any Upstream ATM cell owned by given connection – to the correct corresponding value (01, 10 or 11; 00 indicates no requested Piggyback reservation).

4a) The INA shall respond to the Piggyback request using the <MAC> Reservation Grant Message.

4b) If the NIU has not received the <MAC> Reservation Grant Message before the Grant_Protocol_Timeout, it shall send a <MAC> Reservation Status Request to the INA. This leads back to 4) or 3).

4c) It is allowed to use "Continuous Piggybacking": Using this mechanism, the NIU requests the minimum number of slots possible (set of GFC_xx_Slots values) via a Piggybacking request in the last slot of a payload data upstream transmission even if no further data is in the upstream queue of the NIU. In the granted slot, an AAL5 frame with zero length can be sent upstream if no payload data is available. In this slot again a piggybacking request for the minimum possible number of slots can be issued. Instead of using the piggybacking indication with a zero payload AAL5 frame, it is also allowed to send a reservation request message in the upstream slot with Reservation_Request_Slot_Count = 1. Short idle periods up to the length indicated in the Reservation Id Assignment Message can therefore be bridged without the need for contention access at the time where the next payload data is to be transferred. This improves the access delay, since the probability of collisions is avoided. On the other hand, some bandwidth might be wasted. It is up to the INA to set the maximum time for the bridging period (Continous_Piggy_Timeout in the Reservation_Id_Assignment_Message or the Configuration_Message) by taking into account the tradeoff between throughput and access delay.

A more detailed description of the reservation process, including state diagrams and time-outs, is given in A.7.4 and A.7.5 (Informative Note A).

<MAC> Reservation Id Assignment Message (singlecast downstream)

The <MAC> Reservation Id Assignment Message is used to assign the NIU a Reservation_Id. In addition, the Reservation_Id_assignment_message contains the three different reservation grant sizes used in the Piggyback procedure and the time-out for continuous piggybacking. The NIU identifies its entry in the Reservation_grant_message by comparing the Reservation_Id assigned to it by the Reservation_Id_assignment_message and the entries in the Reservation_Grant_message.

The format of the message is given in Table A.38.

Table A.38/J.112 – Reservation Id Assignment message structure

	Bits	Bytes	Bit number/Description
Reservation_Id_Assignment_Message (){			
Connection_Id	**32**	**4**	
Reservation_Id	**16**	**2**	
Grant_protocol_timeout	**16**	**2**	
Piggy_Back_Request_Values		**4**	
Continuous_Piggy_Back_Timeout	8		Unit is 9 ms
FC_11_Slots	8		
FC_10_Slots	8		
FC_01_Slots	8		
}			

Connection Id

`Connection_Id` is a 32-bit unsigned integer representing a global connection identifier for the NIU Dynamic Connection.

Reservation Id

`Reservation_Id` is a 16-bit unsigned number representing an identifier for the connection. This is used as a short identifier by the NIU to identify the appropriate Reservation_Grant_Messages.

Grant protocol time-out

`Grant_protocol_timeout` is a 16-bit unsigned number representing the time in milliseconds that the NIU should wait before verifying the status of pending grants. This parameter specifies the time that the NIU should wait after receiving the last <MAC> Reservation_grant_message, with an entry addressed to the NIU, before initiating a reservation status request. If the NIU has pending grants and the time-out occurs, it should send the Reservation_status_request message to the INA. The INA will respond with the Reservation_grant_message (probably without granting any slots) to inform the NIU of any remaining slots left to be granted. This allows the NIU to correct any problems should they exist, such as issuing an additional request for slots or waiting patiently for additional grants.

Piggyback Request Values

`Continuous_Piggy_Back_Timeout` is an 8-bit unsigned integer value representing the time period that can be bridged using the Continuous Piggybacking mechanism. The unit of the value is 9 ms. The time-out value indicates how long a NIU is allowed to request upstream slots with an empty payload data upstream queue after the first continuous piggybacking request was sent on the upstream channel. In order to offer an improved transmission performance (if the traffic characteristics are taken into account) a time period of up to 2.286 s can be bridged without using contention slots. If the value is set to zero, Continuous Piggybacking is disabled. If the value is set to 255, the time-out period is infinite.

`GFC_11_Slots` is an 8-bit unsigned value representing the number of slots being requested if the NIU sets the two MSBs of the GFC to a value of 11.

`GFC_10_Slots` is an 8-bit unsigned value representing the number of slots being requested if the NIU sets the two MSBs of the GFC to a value of 10.

`GFC_01_Slots` is an 8-bit unsigned value representing the number of slots being requested if the NIU sets the two MSBs of the GFC to a value of 01.

<MAC> Reservation Id Response Message (upstream contention or reserved)

The <MAC> Reservation Id Response Message is used to acknowledge the receipt of the <MAC> Reservation_Id_Assignment message.

The format of the message is given in the following table.

	Bits	Bytes	Bit number/Description
`Reservation_Id_Response_Message (){`			
`Connection_Id`	**32**	**4**	
`Reservation_Id`	**16**	**2**	
}			

Connection Id

`Connection_Id` is a 32-bit unsigned integer representing a global connection identifier for the NIU/STB Dynamic Connection.

Reservation Id

`Reservation_Id` is a 16-bit unsigned number representing an identifier for the connection. This is used as a short identifier by the NIU/STB to identify the appropriate Reservation_Grant_Messages.

<MAC> Reservation Request Message (upstream contention or reserved)

See Table A.39.

Table A.39/J.112 – Reservation Request message structure

	Bits	Bytes	Bit number/Description
`Reservation_Request_Message (){`			
`Reservation_Id`	16	2	
`Reservation_request_slot_count`	8	1	
`}`			

This message is sent from the NIU to the INA.

Reservation Id

`Reservation_Id` is a 16-bit unsigned number representing an identifier for the connection. This is used as a short identifier by the NIU to identify the appropriate Reservation_Grant_Messages.

Reservation Request Slot Count

`Reservation_request_slot_count` is an 8-bit unsigned number representing the number of slots requested by the NIU. This is the number of sequential slots that will be allocated in the reservation region of the upstream channel. The INA will respond with the Reservation_Grant message granting the request.

<MAC> Reservation Grant Message (broadcast downstream)

The <MAC> Reservation Grant Message is used to indicate to the NIU which slots have been allocated in response to the Reservation Request message. The NIU identifies its entry in the Reservation_grant_message by comparing the Reservation_Id assigned to it by the Reservation_Id_assignment_message and the entries in the Reservation_Grant_message.

The format of the message is given in Table A.40.

Table A.40/J.112 – Reservation Grant message structure

	Bits	Bytes	Bit number/Description
`Reservation_Grant_Message (){`			
`Reference_slot`	16	2	
`Number_grants`	8	1	
`for (I = 0; I < Number_grants; I++){`			
`Reservation_Id`	(16)	(2)	

`Grant_Slot_count`
`Remaining_slot_count`
`Grant_slot_offset`
	
	(4)
	(5)
	(7)
		(2)	
			15..12
			11..7
			6..0

`}`			
`Number_of_US_Channels`	8	1	
`for (I = 0; I < Number_of_US_Channels; I++) {`			

`Minislot_Control_Field`
`Upstream_Channel_Number`
`MS_Feedback_Included`
`MS_Allocation_Included`
`MS_16QAM_Enhancement_Included`
`Reserved`
	
	(3)
	(1)
	(1)
	(1)
	(3)
		(1)	
			7..5
			4: {no, yes}
			3: {no, yes}
			2: {no, yes}
			1..0: shall be 0

Table A.40/J.112 – Reservation Grant message structure

	Bits	Bytes	Bit number/Description
If (MS_Feedback_Included || MS_Allocation_Included) {			
MS_Reference_Field	**(16)**	**(2)**	
}			
If (MS_Feedback_Included) {			
Number_of_Feedbacks	**(8)**	**(1)**	
for (I = 0; I < Number_of_Feedbacks; I++) {			
Feedback_Offset	**(8)**	**(1)**	
Feedback_Collision_Number_1	**(8)**	**(1)**	
Feedback_Collision_Number_2	**(8)**	**(1)**	
Feedback_Collision_Number_3	**(8)**	**(1)**	
}			
}			
If (MS_Allocation_Included) {			
Entry_Field Stack_Entry Reserved Entry_Spreading	 (1) (3) (12)	**(2)**	 15 14..12 11..0
Number_of_Allocations	**(8)**	**(1)**	
for (I = 0; I < Number_of_Allocations; I++) {			
Allocation_Offset	**(8)**	**(1)**	
Allocation_Collision_Number	**(8)**	**(1)**	
}			
}			
If (MS_Feedback_Included)||(MS_allocation _included)) && (MS_16QAM_Enhancement_Included {			
Number_of_Feedbacks	**(8)**	**(1)**	
for (I = 0; I < Number_of_Feedbacks; I++) {			
Feedback_Offset	**(8)**	**(1)**	
Feedback_Collision_Number_4	**(8)**	**(1)**	
Feedback_Collision_Number_5	**(8)**	**(1)**	
Feedback_Collision_Number_6	**(8)**	**(1)**	
}			
}			
If (MS_allocation_Included) && (MS_16QAM_Enhancement_Included {			
Number_of_Allocations			
for (I = 0; I < Number_of_Allocations; I++) {			

Table A.40/J.112 – Reservation Grant message structure

	Bits	Bytes	Bit number/Description
`Allocation_Offset`	(8)	(1)	
`Allocation_Collision_Number_Set2`	(8)	(1)	
}			
}			
}			
}			

Reference slot

`Reference_slot` is a 16-bit unsigned number indicating the reference point for the remaining parameters of this message. This represents a physical slot of the upstream channel. Since the upstream and downstream slots are not aligned, the INA shall send this message in a downstream slot such that it is received by the NIU before the Reference_slot exists on the upstream channel. Only 13 lowest significant bits shall be considered. 3 MSBs are reserved for future use.

Number grants

`Number_grants` is an 8-bit unsigned number representing the number of grants contained within this message. This can either correspond to grants for different NIUs, or to different connection_Ids for the same NIU.

Reservation Id

`Reservation_Id` is a 16-bit unsigned number representing an identifier for the connection. This is used as a short identifier by the NIU to identify the appropriate Reservation_Grant_Messages.

Grant slot count

`Grant_slot_count` is a 4-bit unsigned number representing the number of sequential slots currently granted for the upstream burst. A value of zero indicates that no slots are being granted. This would typically be the case in a response to a Reservation_status_request message.

Upon receipt of this message the NIU is assigned Grant_slot_count sequential slots in the region of the upstream channel starting at the position indicated by the Reference_slot and Grant_slot_offset values (jumps are needed in the case where the number of slots granted exceeds the length of this region).

Remaining slot count

`Remaining_slot_count` is a 5-bit unsigned number representing the remaining slots to be granted by the INA with subsequent grant messages. A value of 0x1f indicates that 31 or more slots will be made available in the future. A value of 0x00 indicates that no additional slots will be granted in the future and that the slots granted in this message represent the only remaining slots available for the connection. The NIU should monitor this count to determine if sufficient slots remain to satisfy current needs. Should additional slots be required because of lost grant messages or additional demand, additional slots should be requested using the Reservation_request_message. Additional Reservation_request_messages shall be sent only when the Remaining_slot_count is less than 15. To minimize contention on the upstream channel, the Reservation_request_message may be sent in one of the slots granted by the Reservation_grant_message. The remaining slot count is calculated for each grant in a Reservation Grant message.

Grant slot offset

`Grant_slot_offset` is a 7-bit unsigned number representing the starting slot to be used for the upstream burst. This number is added to the Reference slot to determine the actual physical slot.

Number of US Channels

`Number_of_US_Channels` is an 8-bit unsigned integer representing the number of upstream channels in this message.

Mini-slot Control Field

`Upstream_Channel_Number` is a 3-bit unsigned integer representing the upstream channel concerned by this iteration.

`MS_Feedback_Included` is a boolean that indicates that Minislot Feedback Section is included in the message.

`MS_Allocation_Included` is a boolean that indicates that Minislot Allocation Section is included in the message.

`MS_16QAM_Enhancement_Included` is a boolean that indicates that for 16QAM upstream modulation the mini-slot feature is used with two sets of 3 mini-slots each that are embedded in one 128-byte upstream packet.

Mini-slot Reference Field

`Minislot_Reference_Field` is a 16-bit field of which the 13 LSBs represent the reference ATM slot number.

Number of Feedbacks

`Number_of_Feedbacks` is an 8-bit unsigned integer representing the number of three mini-slot feedback groups included.

Feedback Offset

`Feedback_Offset` is an 8-bit unsigned integer representing the offset of the group of three mini-slots in full slots. This number is added to the Minislot_Reference_Field to determine the actual physical slot.

Feedback Collision Number 1

`Feedback_Collision_Number_1` is an 8-bit unsigned integer representing the first mini-slot collision identification in the group of three mini-slots. The values 0xFF and 0xFE indicate idle and successful transmission, respectively. Other values are called Collision_Number and are used to resolve contentions (see Allocation_Collision_Number field).

Feedback Collision Number 2

`Feedback_Collision_Number_2` is an 8-bit unsigned integer representing the second mini-slot collision identification in the group of three mini-slots. The values 0xFF and 0xFE indicate idle and successful transmission, respectively. Other values are called Collision_Number and are used to resolve contentions (see Allocation_Collision_Number field).

Feedback Collision Number 3

`Feedback_Collision_Number_3` is an 8-bit unsigned integer representing the third mini-slot collision identification in the group of three mini-slots. The values 0xFF and 0xFE indicate idle and successful transmission, respectively. Other values are called Collision_Number and are used to resolve contentions (see Allocation_Collision_Number field).

Entry Field

`Stack_Entry` is a boolean parameter. When it is set to 0, collision resolution is according to the tree algorithm (see A.5.6.3) and NIUs with new requests have to wait for mini-slots with the Allocation_Collision_Number equal to 0 to enter the request contention process. When Stack_Entry is set to one, NIUs with new requests can enter the request contention process in any mini-slot (independent of the value of Allocation_Collision_Number). After entering in this way to the contention process, the collision resolution is identical to the tree mode. So, the difference between Stack_Entry set to 0 or to 1 is that in the latter case NIUs do not have to wait for mini-slots with Allocation_Collision_Number equal to 0 before they can start sending a new request in contention mode.

`Entry_Spreading` is a 14-bit unsigned integer that is used to control the number of NIUs that enter the request contention process in mini-slots. The NIU generates a random number between 0 and Entry_Spreading (the random number generator in the NIU shall have a uniform distribution). If this number falls within the window from 0 to 2, then the NIU contends for access in the corresponding mini-slot; otherwise, it will not transmit a request but wait for the next appropriate set of mini-slots and follow the same procedure again.

Number of Allocations

`Number_of_Allocations` is an 8-bit unsigned integer representing the number of contention resolution allocations included.

Allocation Offset

`Allocation_Offset` is an 8-bit unsigned integer representing the offset of the group of three mini-slots in full slots to be added to the Minislot_Reference_Field to determine the physical slot number of the group of three mini-slots.

Allocation Collision Number

`Allocation_Collision_Number` is an 8-bit unsigned integer associated with the group of three mini-slots. Only NIUs having their Collision_Number equal to Allocation_Collision_Number are allowed to transmit in these mini-slots.

Number of Feedbacks

`Number_of_Feedbacks` is an 8-bit unsigned integer representing the number of three mini-slot feedback groups included.

Feedback Offset

`Feedback_Offset` is an 8-bit unsigned integer representing the offset of the second group of three mini-slots in full slots. This number is added to the Minislot_Reference_Field to determine the actual physical slot.

Feedback Collision Number 4

`Feedback_Collision_Number_4` is an 8-bit unsigned integer representing the fourth mini-slot collision identification in the group of three mini-slots. The values 0xFF and 0xFE indicate idle and successful transmission, respectively. Other values are called Collision_Number and are used to resolve contentions (see Allocation_Collision_Number field).

Feedback Collision Number 5

`Feedback Collision Number 5` is an 8-bit unsigned integer representing the fifth mini-slot collision identification in the group of three mini-slots. The values 0xFF and 0xFE indicate idle and successful transmission, respectively. Other values are called Collision_Number and are used to resolve contentions (see Allocation_Collision_Number field).

Feedback Collision Number 6

`Feedback_Collision_Number_6` is an 8-bit unsigned integer representing the sixth mini-slot collision identification in the group of three mini-slots. The values 0xFF and 0xFE indicate idle and successful transmission, respectively. Other values are called Collision_Number and are used to resolve contentions (see Allocation_Collision_Number field).

Number of Allocations

`Number_of_Allocations` is an 8-bit unsigned integer representing the number of contention resolution allocations included.

Allocation Offset

`Allocation_Offset` is an 8-bit unsigned integer representing the offset of the second group of three mini-slots in full slots to be added to the Minislot_Reference_Field to determine the physical slot number of the group of three mini-slots.

Allocation_Collision_Number_Set2

`Allocation_Collision_Number_Set2` is an 8-bit unsigned integer associated with the second group of three mini-slots. Only NIUs having their Collision_Number equal to Allocation_Collision_Number_Set2 are allowed to transmit in these mini-slots.

<MAC> Reservation Status Request (upstream contention or reserved)

The <MAC> Reservation Status Request Message is used to determine the status of the outstanding grants to be assigned by the INA. This message is only sent after the Grant protocol time-out is exceeded. The INA will respond with the Reservation_grant_message (possibly without granting any slots) to inform the NIU of any remaining slots left to be granted. This allows the NIU to correct any problems should they exist such as issuing an additional request for slots or waiting patiently for additional grants.

The format of the message is given in Table A.41.

Table A.41/J.112 – Reservation Status Request message structure

	Bits	Bytes	Bit number/Description
Reservation_Status_Request_Message (){			
Reservation_Id	**16**	**2**	
Remaining_request_slot_count	**8**	**1**	
}			

Reservation Id

`Reservation_Id` is a 16-bit unsigned number representing an identifier for the connection. This is used as a short identifier by the NIU to identify the appropriate Reservation_Grant_Messages.

Remaining request slot count

`Remaining_request_slot_count` is an 8-bit unsigned number representing the number of slots that the NIU is expecting to be granted.

A.5.5.10 MAC Link Management

The MAC Link Management tasks provide continuous monitoring and optimization of upstream resources. These functions include:

– Power and Timing Management;

– Fixed rate Allocation Management;

– Channel Error Management.

A.5.5.10.1 Power, Timing and Equalizer Management

The procedure shall provide continuous monitoring of upstream transmission from the NIU. The <MAC> Ranging and Power Calibration Message is used to maintain a NIU within predefined thresholds of power and time, and to adjust the pre-equalizer coefficients.

The Upstream Burst Demodulator shall continuously monitor the upstream burst transmissions from an NIU. Upon detection of an NIU outside the predefined range, the INA shall send the <MAC> Ranging and Power Calibration Message to the NIU.

The pre-equalizer coefficients should be typically updated only when the INA recognizes that the channel response was changed.

The NIU/STB upstream power accuracy shall be better than or equal to ±1.5 dB. The NIU/STB power resolution shall be 0.5 dB nominally.

A detailed description of the recalibration process, including state diagrams and time outs, is given in A.7.6 (Informative Note A).

A.5.5.10.2 TDMA Allocation Management

To ensure optimum assignment of TDMA resources, the INA shall ensure the upstream allocation of TDMA resources for various connections remain intact when allocating resources to a new connection. However, in the event that reconfiguration is required to minimize fragmentation of resources, then the INA shall dynamically reconfigure the upstream TDMA assignments to a NIU or group of NIUs. The <MAC> Reprovision Message is utilized to change previously established connection parameters.

The NIU can request the change of some parameters of existing connections by use of the <MAC> Resource Request Message, in which case the <MAC> Reprovision Message can be used by the INA to confirm the requested changes.

A detailed description of the reprovisioning process, including state diagrams and time-outs, is given in A.7.5 and A.7.7 (Informative Note A).

For a description of upstream and downstream frequency changes, see A.5.5.2.2.

<MAC> Reprovision Message (singlecast downstream)

The <MAC> REPROVISION MESSAGE is sent by the INA to the NIU to:

- reassign upstream resources (maintaining the originally requested QoS parameters at the establishment of the connection);
- reprovision the NIU from one INA to another INA;
- reprovisioning the NIU within one INA;
- change connection parameters.

When this message is sent in order to change the QoS parameters of a connection, it should refer only to 1 connection (since the new_frame_length parameter refers to all the connections in the message).

Two levels of reprovision can be supported by the NIU: basic and extended reprovision. Extended reprovision is provided for reprovisionning the NIU from one INA to another and/or changing the connection parameters. The following parameter groups are supported only by a NIU that supports extended reprovision (according to its NIU_Capabilities):

- Minimum Reservation Length;
- Maximum Contention Length;
- New Connection parameters;
- New DS parameters.

See Figure A.44 and Table A.42.

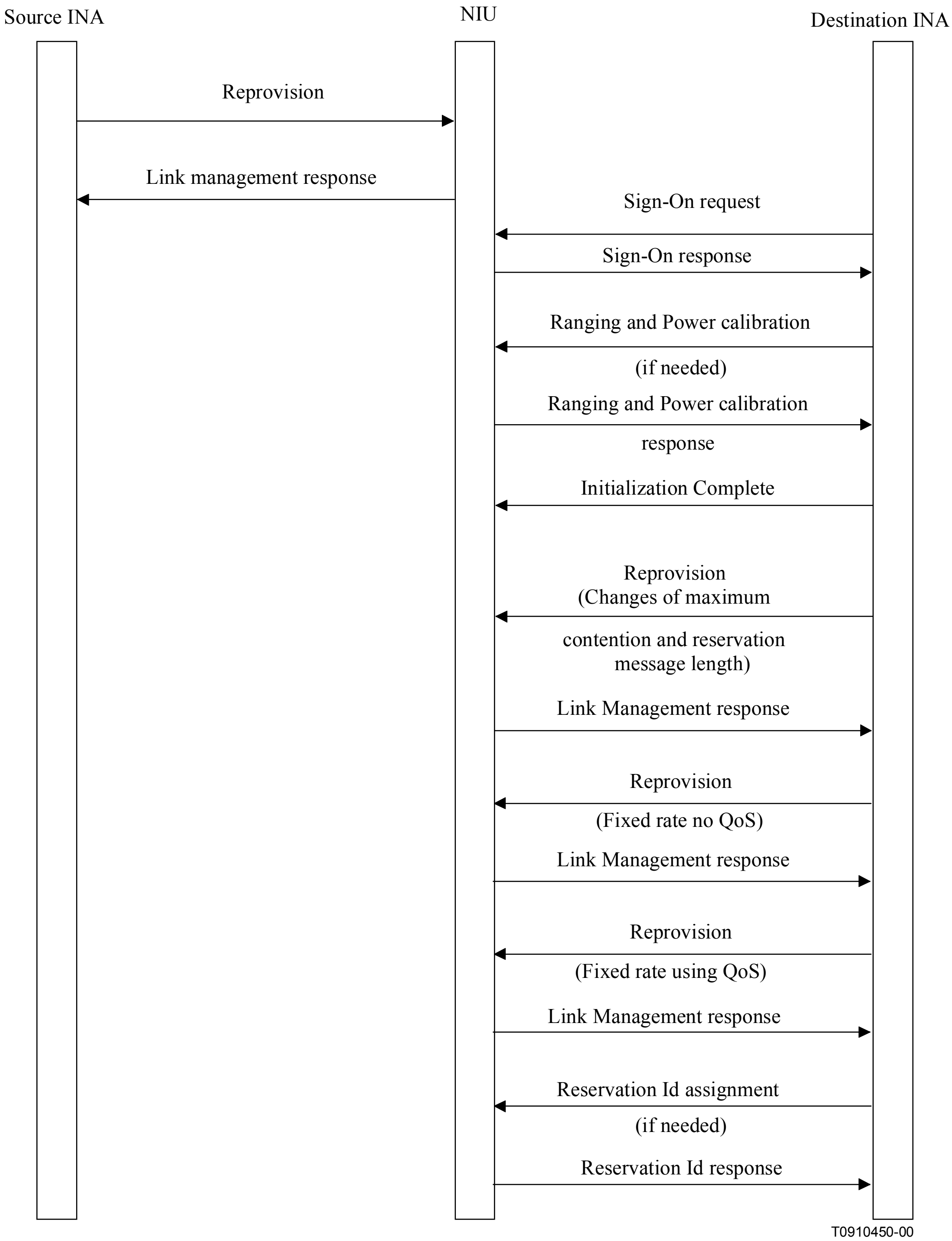


Figure A.44/J.112 – Example MAC message flow to reprovision a NIU from one INA to another INA

Table A.42/J.112 – Reprovision message structure

	Bits	Bytes	Bit number/Description
Reprovision_Message (){			
Reprovision_Control_Field Reprovision_Control_aux_field_included Delete_Reservation_Ids New_Downstream_IB_Frequency New_Downstream_OOB_Frequency New_Upstream_Frequency_Included New_Frame_Length_Included New_Cyclical_Assignment_Included New_Slot_List_Included	 1 1 1 1 1 1 1 1	**1**	 7: {no, yes} 6: {no, yes} 5: {no, yes} 4: {no, yes} 3: {no, yes} 2: {no, yes} 1: {no, yes} 0: {no, yes}
if (Reprovision_Control_Field &= New_Downstream_IB_Frequency) {			
New_Downstream_IB_Frequency	**(32)**	**(4)**	
}			
if (Reprovision_Control_Field &= New_Downstream_OOB_Frequency) {			
New_Downstream_OOB_Frequency	**(32)**	**(4)**	
DownStream_Type	**(8)**	**(1)**	
}			
if (Reprovision_Control_Field &= New_Upstream_Frequency_Included) {			
New_Upstream_Frequency	**(32)**	**(4)**	
New Upstream Parameters New_Upstream_Channel Number Reserved Upstream_Rate MAC_Flag_Set Upstream_Modulation	 (3) (2) (3) (5) (3)	**(2)**	 15..13 12..11 10..8: enum 7..3 2..0: enum
}			
if (Reprovision_Control_Field &= New_Frame_Length_Included){			
New_Frame_Length	**(16)**	**(2)**	**9-0: Unsigned**
}			
if (Reprovision_Control_Field &= New_Slot_List_Included || New_Cyclical_Assignment_Included || Delete_Reservation_Ids){			
Number_of_Connections	**(8)**	**(1)**	
for (i = 0; i < Number_of_Connections; i++){			
Connection_Id	**(32)**	**(1)**	
if (Reprovision_Control_Field &= new_slot_list_included){			Fixed rate access
Number_Slots_Defined	**(8)**	**(1)**	
for (i = 0; i < Number_Slots_Assigned; i++){			

Table A.42/J.112 – Reprovision message structure

	Bits	Bytes	Bit number/Description
Slot_Number	**(16)**	**(2)**	
}			
}			
if (Reprovision_Control_Field &= new_cyclic_Assignment_included){			Fixed rate access
Fixedrate_Start	**(16)**	**(2)**	
Fixedrate_Dist	**(16)**	**(2)**	
Fixedrate_End	**(16)**	**(2)**	
}			
}			
}			
if (Reprovision_Control_Field &= Control_aux_field_included){			
Reprovision_Control_aux_field		**(2)**	
Reserved	7		15..9: shall be 0
New_Maximum_Reservation_Length	(1)		8: {no, yes}
New_Maximum_Contention_Length	(1)		7: {no, yes}
New_Connections_Specified	(1)		6: {no, yes}
New_DS_Specified	(1)		5: {no, yes}
IPv6_add	1		4: {no, yes}
New_priority_included	1		3: {no, yes}
New_DS_flowspec_included	1		2: {no, yes}
New_US_session_binding_included	1		1: {no, yes}
New_DS_session_binding_included	1		0: {no, yes}
}			
if (Reprovision_Control_aux_Field &= new_priority_included){			
Priority	**(8)**	**(1)**	
}			
if (Reprovision_Control_aux_Field &= new_DS_flowspec_included){			
Max_packet_size	**(16)**	**(2)**	in bytes
Average_bitrate	**(16)**	**(2)**	in bytes/s
Jitter	**(8)**	**(1)**	in ms
}			
if (Reprovision_Control_aux_Field &= new_US_session_binding_included))&& (Reprovision_Control_aux_field!= IPv6_add) {			
US_session_binding_control	**(32)**	**(4)**	
NIU_client_source_IP_add	**(32)**	**(4)**	
NIU_client_destination_IP_add	**(32)**	**(4)**	
NIU_client_source_port	**(16)**	**(2)**	
NIU_client_destination_port	**(16)**	**(2)**	
Upstream_transport_protocol	**(8)**	**(1)**	
NIU_client_source_MAC_add	**(48)**	**(6)**	
NIU_client_destination_MAC_add	**(48)**	**(6)**	
Upstream_internet_protocol	**(16)**	**(2)**	

Table A.42/J.112 – Reprovision message structure

	Bits	Bytes	Bit number/Description
Upstream_session_Id	(32)	(4)	
}			
if (Reprovision_Control_aux_Field &= new_DS_session_binding_included){			
DS_session_binding_control	(32)	(4)	
INA_client_source_IP_add	(32)	(4)	
INA_client_destination_IP_add	(32)	(4)	
INA_client_source_port	(16)	(2)	
INA_client_destination_port	(16)	(2)	
Downstream_transport_protocol	(8)	(1)	
INA_client_source_MAC_add	(48)	(6)	
INA_client_destination_MAC_add	(48)	(6)	
Downstream_internet_protocol	(16)	(2)	
Downstream_session_Id	(32)	(4)	
}			
if (Reprovision_Control_Aux_Field &= New_DS_Specified){			
Reserved	(4)		7..4
New_DS_Modulation	(4)		3..0
New_DS_Symbol_Rate	(32)	(4)	
}			
if (Reprovision_Control_Aux_Field &= New_Connections_Specified){			
Connections	(8)	(1)	
for (i = 0; i < Connections; i++){			
Old_Connection_Id	(32)	(4)	
New_Connection_Id	(32)	(4)	
New_PID	(16)	(2)	
New_DSM-CC_MAC	(48)	(6)	
New_DS_VC	(24)	(3)	
New_US_VC	(24)	(3)	
}			
}			
if (Reprovision_Control_Aux_Field &= New_Maximum_Contention_Length){			
Maximum_Contention_Access_Message_Length	(8)	(1)	
}			
if (Reprovision_Control_Aux_Field &= New_Maximum_Reservation_Length){			
Maximum_Reservation_Access_Message_Length	(8)	(1)	
}			
}			

Reprovision Control Field

`Reprovision_Control_Field` specifies what modifications to upstream resources are included. It consists of the following subfields:

`Reprovision_Control_aux_field_included`: if set to 1, indicates that the message includes an auxiliary control field.

`Delete_Reservation_Ids` is a boolean that indicates that the NIU/STB shall delete all Reservation_Ids that have been assigned to the Connection_Ids contained in this message.

`New_Downstream_IB_Frequency` is a boolean that indicates that a new downstream IB frequency is specified in the message.

`New_Downstream_OOB_Frequency` is a boolean that indicates that a new downstream OOB frequency is specified in the message.

`New_Upstream_Frequency_Included` is a boolean that indicates that a new upstream frequency is specified in the message.

`New_Frame_Length_Included` is a boolean that indicates that a new upstream frame is specified in the message. In the Reprovision Message the Frame_Length is a global value which applies to all connection_Id referred to in this message.

`New_Cyclical_Assignment_Included` is a boolean that indicates that a new cyclical assignment is specified in the message. If the connection has already cyclic fixed rate slots or a slot list assigned, these slots are lost. Having Cyclic Assignements and Slot List Assignments for the same Connect_Id at the same time is not allowed.

`New_Slot_List_Included` is a boolean that indicates that a new slot list is specified in the message. If the connection has already cyclic fixed rate slots or a slot list assigned, these slots are lost. Having Cyclic Assignments and Slot List Assignments for the same Connect_Id at the same time is not allowed.

New Downstream IB Frequency

`New_Downstream_IB_Frequency` is a 32-bit unsigned integer representing the reassigned downstream IB carrier center frequency. The unit of measure is in hertz.

New Downstream OOB Frequency

`New_Downstream_OOB_Frequency` is a 32-bit unsigned integer representing the reassigned downstream OOB carrier center frequency. The unit of measure is in hertz.

DownStream Type

`DownStream_Type` is an 8-bit enumerated type indicating the modulation format for the downstream connection. {reserved, QPSK_1.544, QPSK_3.088, 3..255 reserved}

New Upstream Frequency

`New_Upstream_Frequency` is a 32-bit unsigned integer representing the reassigned upstream carrier center frequency. The unit of measure is in hertz.

New Upstream Parameters

`New_Upstream_Channel_Number` is a 3-bit unsigned integer which identifies the new logical channel (denoted by 'c') assigned to the NIU/STB. Refer to A.5.3.2.1 for the use of this parameter.

`Upstream_Rate` is a 3-bit enumerated type indicating the upstream transmission grade for the upstream connection. {Upstream_A_AQ, Upstream_B_BQ, Upstream_C_CQ, Upstream_D_DQ, 4..7 reserved}

MAC_Flag_Set is a 5-bit field representing the first MAC Flag set assigned to the new logical channel. A downstream channel contains information for each of its associated upstream channel. This information is contained within structures known as MAC Flag Sets represented by either 24 bits (denoted b0...b23) or by 3 bytes (denoted Rxa, Rxb, Rxc). This information is uniquely assigned to a given upstream channel. Refer to A.5.3.1.3 and A.5.3.2.1 for the use of this parameter.

Upstream_Modulation: 3-bit field enumerated type indicating the upstream channel modulation {QPSK, 16QAM, 2..7 reserved}

New Frame Length

New_Frame_Length is a 16-bit unsigned integer representing the size of the reassigned upstream Fixed rate based frame. The unit of measure is in slots. New_Frame_Length is valid only for connect_Ids that are contained in this message.

Number of Slots Defined

Number_Slots_Defined is an 8-bit unsigned integer that represents the number of slot assignments contained in the message. The unit of measure is in slots.

Slot Number

Slot_Number is a 16-bit unsigned integer that represents the Fixed rate based Slot Number assigned to the Network Interface Unit. Only 13 lowest significant bits shall be considered. 3 MSB are reserved for future used.

Fixed rate Start

Fixedrate_Start: This 16-bit unsigned number represents the starting slot within the fixed rate access region that is assigned to the NIU. The NIU may use the next Frame_length slots of the fixed rate access regions. Only 13 lowest significant bits shall be considered. 3 MSBs are reserved for future use.

Fixed rate Distance

Fixedrate_Distance: This 16-bit unsigned number represents the distance in slots between additional slots assigned to the NIU. The NIU is assigned all slots that are a multiple of Fixedrate_Distance from the Fixedrate_Start_slot which do not exceed Fixedrate_End_slot. The NIU may use the next Frame_length slots of the fixed rate access regions from each of these additional slots.

Fixed rate End

Fixedrate_End: This 16-bit unsigned number indicates the last slot that may be used for fixed rate access. The slots assigned to the NIU, as determined by using the Fixedrate_Start_slot, the Fixedrate_Distance and the Frame_length, cannot exceed this number. Only 13 lowest significant bits shall be considered. 3 MSBs are reserved for future use.

Reprovision_Control_aux_field

Reserved: 7-bit field; must be set to 0.

New_Maximum_Reservation_Length is a boolean that indicates a new maximum reservation access message length specification is present in the message (part of extended reprovision capability).

New_Maximum_Contention_Length is a boolean that indicates a new maximum contention access message length specification is present in the message (part of extended reprovision capability).

New_Connections_Specified is a boolean that indicates a connection mapping table is present in the message (part of extended reprovision capability).

New_DS_Specified is a boolean that indicates a new downstream specification is present in the message (part of extended reprovision capability).

`IPv6_add`: if set to 1, the IP addresses at the session binding blocks are IPv6 compatible.

`New_priority_included`: if set to 1, a new priority is sent for the connection.

`New_DS_flowspec_included`: if set to 1, indicates that the message includes a new flow spec field for the downstream.

`New_US_session_binding_included`: if set to 1, the message includes a session binding description for the upstream.

`New_DS_session_binding_included`: if set to 1, the message includes a session binding description for the downstream.

`Priority`: 1-byte field. The value of the field defines the priority of the connection. Connections with low priority field value can be reprovisioned in order to accommodate the requirements of connection with high priority field. Priority values will be given according to the following table:

Application	Priority values
Standard data flow applications	0-79
Applications with QoS requirements	80-200
High priority applications	201-255

Downstream flow spec (see A.5.5.5.1)

The downstream flow spec has 3 parameters:

`Max_Packet_size`: the size of the maximum packet (bytes) that will be sent through the connection in the downstream. The packet size will be calculated with the overhead created by layer 3 header and above. Meaning that the packet size includes propriety protocols header, transport protocol (UDP/TCP) header, and the IP header. The packet size does not include the Ethernet header.

`Average_bitrate`: the avearge bit rate, in bytes/s.

`Jitter`: the total jitter a downstream packet may expirience.

Session binding information (see A.5.5.5.1)

The upstream and downstream session binding blocks identify clients that are using the connection. The clients are identified by their source and destination, the source and destination ports (if relevant), and the protocol.

In most cases, the downstream and upstream session binding will be identical.

(NIU client source IP address = INA client destination IP address, NIU client source port = INA client destination port , and neccesarely upstream protocol = downstream protocol).

In this case, only the downstream session binding is sent.

The message will contain a US session binding only if there is a difference in the INA and NIU source destination ports and addresses.

(NIU client source IP address ≠ INA client destination IP address, NIU client source port ≠ INA client destination port).

`US_session_binding_control`: the interpretation of the US session binding block depends on the value of US_session_binding_control field. The field acts as a bitmap, indicating the existence of the different session binding parameters. If the bit attached to the session binding parameter is set to 1, then the parameter exists in the message. If not, the session binding parameter does not exist. When a bit corresponding to a field which is not defined at the moment is set to 1, the NIU MUST treat that field as a 32-bit long field, and MAY ignore it.

The mapping between the current session binding parameters and the US_session_binding_control field is described in the following table:

US_session_binding_control bit number	US session binding parameter
0	NIU_client_source_IP_add
1	NIU_client_destination_IP_add
2	NIU_client_source_port
3	NIU_client_destination_port
4	Upstream_transport_protocol
5	NIU_client_source_MAC_add
6	NIU_client_destination_MAC_add
7	Upstream_internet_protocol
8	Upstream_session_Id
10-31	Reserved

`NIU_client_source_IP_add`: the IP source address of the NIU client.

`NIU_client_destination_IP_add`: the IP destination address of the INA client.

`NIU_client_source_port`: the source port of the INA client.

`NIU_client_destination_port`: the destination port of the INA client.

`Upstream_transport_protocol`: the transport protocol used by the NIU client (UDP/TCP).

`NIU_client_source_MAC_add`: a 48-bit unsigned integer that identifies the Ethernet MAC address of the NIU client**.**

`NIU_client_destination_MAC_add`: a 48-bit unsigned integer that identifies the destination Ethernet MAC address of the NIU client.

`Upstream_internet_protocol`: a 16-bit field, defining the Internet protocol, as described in the Ethernet header.

`Upstream_session_Id`: a 32-bit field, describing the session_Id, as defined for PPPoE protocol.

`DS_session_binding_control`: the interpretation of the DS session binding block depends on the value of DS_session_binding_control field. The field acts as a bitmap, indicating the existence of the different session binding parameters. If the bit attached to the session binding parameter is set to 1, then the parameter exists. If not, the session binding parameter does not exist. When a bit corresponding to a field which is not defined at the moment is set to 1, the NIU MUST treat that field as a 32-bit long field, and MAY ignore it.

The mapping between the current session binding parameters and the DS_session_binding_control field is described in the following table:

DS_session_binding_control bit number	DS session binding parameter
0	INA_client_source_IP_add
1	INA_client_destination_IP_add
2	INA_client_source_port
3	INA_client_destination_port
4	Downstream_transport_protocol
5	INA_client_source_MAC_add
6	INA_client_destination_MAC_add
7	Downstream_internet_protocol
8	Downstream_session_Id
10-31	Reserved

`INA_client_source_IP_add`: the IP source address of the INA client.

`INA_client_destination_IP_add`: the IP destination address of the INA client.

`INA_client_source_port`: the source port of the INA client.

`INA_client_destination_port`: the destination port of the INA client.

`Downstream_transport_protocol`: the transport protocol used by the INA client (UDP/TCP).

`INA_client_source_MAC_add`: a 48-bit unsigned integer that identifies the Ethernet MAC address of the INA client.

`INA_client_destination_MAC_add`: a 48-bit unsigned integer that identifies the destination Ethernet MAC address of the INA client.

`Downstream_internet_protocol`: a 16-bit field, defining the Internet protocol, as described in the Ethernet header.

`Downstream_session_Id`: a 32-bit field, describing the session_Id, as defined for the PPPoE protocol.

New DS Modulation

`New_DS_Modulation` is a 4-bit enumerated type indicating the modulation format for the downstream connection. {Reserved, QPSK, QAM8, QAM16, QAM32, QAM64, QAM128, QAM256, 8..15 reserved}.

New DS Symbol Rate

`New_DS_Symbol_Rate` is a 32-bit unsigned integer representing the reassigned downstream symbol rate. The unit of measure is in symbols per second.

Connections

`Connections` is an 8-bit unsigned integer defining the number of connection mappings defined in the message.

Old Connection Id

`Old_Connection_Id` is a 32-bit unsigned integer defining the connection Id being redefined.

New Connection Id

`New_Connection_Id` is a 32-bit unsigned integer defining the connection Id to be used on the destination INA.

New PID

`New_PID` is a 16-bit unsigned integer defining MPEG program Id. Only the 13 least significant bits are valid; the three most significant bits are reserved for future use and must be zero.

New_DSM-CC_MAC

`New_DSM-CC_MAC` is a 6-byte field defining the MAC address that the NIU shall filter in the DSM-CC header for the connection. It shall be ignored if set to 00:00:00:00:00:00.

New DS VC

`New_DS_VC` is a 24-bit unsigned integer defining the downstream VC. The upper 8 bits define the ATM VPI and the lower 16 bits define the ATM VCI.

New US VC

`New_US_VC` is a 24-bit unsigned integer defining the upstream VC. The upper 8 bits define the ATM VPI and the lower 16 bits define the ATM VCI.

Maximum Contention Access Message Length

`Maximum_Contention_Access_Message_Length` is an 8-bit number representing the maximum length of a message in ATM-sized cells that may be transmitted using contention access. Any message greater than this should use reservation access. The new maximum contention access message length applies to the specified connections.

Maximum Reservation Access Message Length

`Maximum_Reservation_Access_Message_Length` is an 8-bit number representing the maximum length of a message in ATM-sized cells that may be transmitted using a single reservation access. Any message greater than this shall be transmitted by making multiple reservation requests. The new maximum reservation access message length applies to the specified connections.

A.5.5.10.3 Channel Error Management

During periods of connection inactivity (no upstream <MAC> transmission by an NIU), the NIU shall enter an Idle Mode. Idle mode is characterized by periodic transmission by the NIU of a <MAC> Idle Message. The Idle Mode transmission shall occur at a periodic rate sufficient for the INA to establish Upstream Packet Error Rate statistics. The Idle Message shall be sent only when the NIU/STB has at least one connection, after the <MAC> Connect Confirm Message is received.

A detailed description of idle message transmission, including state diagrams and time-outs, is given in A.7.10 (Informative Note A).

<MAC> Idle Message (upstream contention or reserved)

The <MAC> Idle Message is sent by the NIU within the STB to the INA at predefined intervals (between 1 and 10 minutes) when the NIU is in idle mode. However, the INA may disable sending Idle Messages by sending a value of zero in the Idle_Interval field contained in the <MAC> Default Configuration Message. (See Table A.43.)

Table A.43/J.112 – Idle message structure

	Bits	Bytes	Bit number/Description
`Idle_Message(){`			
`Idle_Sequence_Count`	**8**	**1**	
`Power_Control_Setting`	**8**	**1**	
`}`			

Idle Sequence Count

`Idle_Sequence_Count` is an 8-bit unsigned integer representing the count (modulo 256) of <MAC> Idle Messages transmitted while the NIU is Idle. It counts the number of transmitted Idle Messages since the last sign-on; thus, it starts counting at 0.

Power Control Setting

`Power_Control_Setting` is an 8-bit unsigned integer representing the actual power used by the NIU/STB for upstream transmission. The unit of measure is 0.5 dBμV.

A.5.5.10.4 Link Management Messages

<MAC> Transmission Control Message (singlecast or broadcast downstream)

The <MAC> Transmission Control Message is sent to the NIU from the INA to control several aspects of the upstream transmission. This includes stopping upstream transmission, re-enabling transmission from a NIU or group of NIUs and rapidly changing the upstream frequency being used by a NIU or group of NIUs (see A.5.5.2.2). To identify a group of NIUs for switching frequencies, the <MAC> Transmission Control Message is sent in broadcast mode with the `Old_Downstream_IB_Frequency` or `Old_Downstream_OOB_Frequency` included in the message. When broadcast with the `Old_Downstream_IB_Frequency / Old_Downstream_OOB_Frequency`, the NIU shall compare its current frequency value to `Old_Downstream_IB_Frequency / Old_Downstream_OOB_Frequency`. When equal, the NIU shall switch to the new frequency specified in the message. When unequal, the NIU shall ignore the new frequency and remain on its current channel.

It is possible to give both a new downstream and a new upstream frequency in one message. In this case, every NIU takes into account only the new frequencies, for which the old frequency field matches.

A detailed description of the transmission control process, including state diagrams and time-outs, is given in A.7.8 (Informative Note A).

See Table A.44.

Table A.44/J.112 – Transmission Control message structure

	Bits	Bytes	Bit number/ Description
Transmission_Control_Message(){			
Transmission_Control_Field Reserved Change_Timeouts Switch_Downstream_IB_Frequency Stop_Upstream_Transmission Start_Upstream_Transmission Old_Frequency_Included Switch_Downstream_OOB_Frequency Switch_Upstream_Frequency	 1 1 1 1 1 1 1 1	1	 7 6: {no, yes} 5: {no, yes} 4: {no, yes} 3: {no, yes} 2: {no, yes} 1: {no, yes} 0: {no, yes}
if (Transmission_Control_Field &= Switch_Upstream_Frequency && Old_Frequency_Included){			
Old_Upstream_Frequency	**(32)**	**(4)**	
}			
if (Transmission_Control_Field &= Switch_Upstream_Frequency){			
New_Upstream_Frequency	**(32)**	**(4)**	
 New_Upstream_Channel_Number Reserved Upstream_Rate	 (3) (2) (3)	**(1)**	 7..5 4..3 2..0: enum
 MAC_Flag_Set Upstream_Modulation	 (5) (3)	**(1)**	 7..3 2..0: enum
}			
if (Transmission_Control_Field &= Switch_Downstream_OOB_Frequency && Old_Frequency_Included){			
Old_Downstream__OOB_Frequency	**(32)**	**(4)**	
}			
if (Transmission_Control_Field &= Switch_Downstream_OOB_Frequency){			
New_Downstream_OOB_Frequency **Downstream_Type**	**(32)** **(8)**	**(4)** **(1)**	
}			
if (Transmission_Control_Field &= Switch_Downstream_IB_Frequency && Old_Frequency_Included){			
Old_Downstream__IB_Frequency	**(32)**	**(4)**	
}			
if (Transmission_Control_Field &= Switch_Downstream_IB_Frequency){			
New_Downstream_IB_Frequency	**(32)**	**(4)**	

Table A.44/J.112 – Transmission Control message structure

	Bits	Bytes	Bit number/ Description
}			
if (Transmission_Control_Field &= Change_Timeouts){			
Number_of_Timeouts	**(8)**	**(1)**	
for (I = 0; I < Number_of_Timeouts; I++) {			
Field		(1)	
Code	(4)		
Value	(4)		
}			
}			
}			

Transmission Control Field

`Transmission_Control_Field` specifies the control being asserted on the upstream channel:

`Change_Timeouts` is a boolean which, when set, indicates that time-out codes and values are included in the message. These time-outs are to be taken into account by the NIU in any case, even if the parameters Old_Upstream_Frequency, Old_Downstream_IB_Frequency or Old_Downstream_OOB_Frequency do not match.

`Switch_Downstream_IB_Frequency` is a boolean which, when set, indicates that a new downstream IB frequency is included in the message.

`Stop_Upstream_Transmission` is a boolean which, when set, indicates that the NIU should enter the "stopped" state without sending a Link_Management_Response_Message. Whilst in the "stopped" state, the NIU ignores all downstream <MAC> messages except Transmission_Control_Messages and Ranging_and_Power_Calibration_Messages. Transmission_Control_Messages are processed, but no Link_Management_Response_Messages are sent. Ranging_and_Power_Calibration_Messages are processed and Ranging_and_Power_Calibration_Response_Messages are still sent.

`Start_Upstream_Transmission` is a boolean which, when set, indicates that the Network Interface Unit, if it is in "stopped" state currently, should re-enter, or attempt to re-enter (in the case of having received an Initialization_Complete_Message containing a non-zero Completion_Status_Field) the "running" state by signing on and resuming transmission on its upstream channel.

`Old_Frequency_Included` is a boolean which, when set, indicates that the Old Frequency value is included in the message and should be used to determine if a switch in frequency is necessary.

`Switch_Downstream_OOB_Frequency` is a boolean which, when set, indicates that a new downstream OOB frequency is included in the message.

`Switch_Upstream_Frequency` is a boolean which, when set, indicates that a new upstream frequency is included in the message. Typically, the `switch_upstream_frequency` and the `stop_upstream_transmission` are set simultaneously to allow the NIU to stop transmission and change channel. This would be followed by the <MAC> Transmission Control Message with the `start_upstream_transmission` bit set.

Old Upstream Frequency

`Old_Upstream_Frequency` is a 32-bit unsigned integer representing the frequency that should be used by the NIU to compare with its current frequency to determine if a change in channel is required.

New Upstream Frequency

`New_Upstream_Frequency` is a 32-bit unsigned integer representing the reassigned upstream carrier center frequency. The unit of measure is in hertz.

`New_Upstream_Channel_Number` is a 3-bit unsigned integer which identifies the new logical channel (denoted by 'c') assigned to the NIU/STB. Refer to A.5.3.2.1 for the use of this parameter.

`Upstream_Rate` is a 3-bit enumerated type indicating the upstream transmission grade for the upstream connection. {Upstream_A_AQ, Upstream_B_BQ, Upstream_C_CQ, Upstream_D_DQ, 4..7 reserved}.

`MAC_Flag_Set` is a 5-bit field representing the first MAC Flag set assigned to the logical channel. A downstream channel contains information for each of its associated upstream channel. This information is contained within structures known as MAC Flag Sets represented by either 24 bits (denoted b0...b23) or by 3 bytes (denoted Rxa, Rxb, Rxc). This information is uniquely assigned to a given upstream channel. Refer to A.5.3.1.3 and A.5.3.2.1 for the use of this parameter.

`Upstream_Modulation`: 3-bit field enumerated type indicating the upstream channel modulation. {QPSK, 16QAM, 2..7 reserved}.

Old Downstream OOB Frequency

`Old_Downstream_OOB_Frequency` is a 32-bit unsigned integer representing the frequency that should be used by the NIU to compare with its current frequency to determine if a change in channel is required.

New Downstream OOB Frequency

`New_Downstream_OOB_Frequency` is a 32-bit unsigned integer representing the reassigned downstream OOB carrier centre frequency. The unit of measure is in hertz.

`DownStream_Type` is an 8-bit enumerated type indicating the modulation format for the downstream connection. {reserved, QPSK_1.544, QPSK_3.088, 3..255 reserved}.

Old Downstream IB Frequency

`Old_Downstream_IB_Frequency` is a 32-bit unsigned integer representing the frequency that should be used by the NIU to compare with its current frequency to determine if a change in channel is required.

New Downstream IB Frequency

`New_Downstream_IB_Frequency` is a 32-bit unsigned integer representing the reassigned downstream IB carrier centre frequency. The unit of measure is in hertz.

Number of Time-outs

`Number_of_Timeouts` is an 8-bit unsigned integer which identifies the number of time-out codes and values included in the message.

Code

`Code` is a 4-bit unsigned integer which identifies the time-out or group of time-outs (according to Tables A.21, A.22 and A.51) for which the following value is given.

Value

`Value` is a 4-bit unsigned integer which gives the value for the time-out or group of time-outs identified by the preceeding code according to Tables A.21, A.22 and A.51 (if specified).

<MAC> Link Management Response Message (upstream contention or reserved)

The <MAC> Link Management Response Message is sent by the NIU to the INA to indicate the reception and the completion of processing of the previously sent Reprovision or singlecast Transmission Control Message. The <MAC> Link Management Response Message is not sent in the following two cases:

– in response to a broadcast Transmission Control Message;

– after reception of a Transmission Control Message with Start bit set whilst in the ERROR_STOPPED state (see A.7.1).

The format of the message is shown in Table A.45.

Table A.45/J.112 – Link Management Response message structure

	Bits	Bytes	Bit number/Description
`Link_Management_Response_Message(){`			
`Link_Management_Msg_Number`	16	2	
`}`			

Link Management Message Number

`Link_Management_Msg_Number` is a 16-bit unsigned integer representing the previously received Reprovision or Transmission Control Message. The valid values for `Link_Management_Msg_Number` are shown in Table A.46.

Table A.46/J.112 – Link Management message number

Message Name	Link_Management_Msg_Number
Transmission Control Message	Transmission Control Message Type Value
Reprovision Message	Reprovision Message Type Value

<MAC> Status Request Message (downstream singlecast)

The Status Request message is sent by the INA to the NIU to retrieve information about the NIU's health, connection information and error states. The INA can request either the address parameters, error information, connection parameters or physical layer parameters from the NIU. The INA can only request one parameter type at a time from a particular NIU.

A detailed description of the status request process, including state diagrams and time-outs, is given in A.7.9 (Informative Note A).

See Table A.47.

Table A.47/J.112 – Status Request message structure

	Bits	Bytes	Bit number/Description
Status_Request_Message ( ){			
Status_Control_Field		**1**	
Status_Type	8		0..7:{enum type}
}			

Status Control Field

Status_Type is an 8-bit enumerated type that indicates the status information the NIU should return.

enum Status_Type {Address_Params, Error_Params, Connection_Params, Physical_Layer_Params, reserved 4..255};

<MAC> Status Response Message (upstream contention or reserved)

The <MAC> STATUS RESPONSE MESSAGE is sent by the NIU in response to the <MAC> STATUS REQUEST MESSAGE issued by the INA. The contents of the information provided in this message will vary depending on the request made by the INA and the state of the NIU. The message shall be dissociated into separate messages if the resulting length of the message exceeds 40 bytes, even if fragmentation of <MAC> messages is supported. (See Table A.48.)

Table A.48/J.112 – Status Response message structure

	Bits	Bytes	Bit number/Description
Status_Response(){			
NIU_Status		**4**	
Reserved	29		31..3
Network_Address_Registered	1		2
Connection_Established	1		1
Calibration_Operation_Complete	1		0
Response_Fields_Included		**1**	
Reserved	4		4..7
Address_Params_Included	1		3:{no, yes}
Error_Information_Included	1		2:{no, yes}
Connection_Params_Included	1		1:{no, yes}
Physical_Layer_Params_Included	1		0:{no, yes}
if (Response_Fields_Included &= Address_Params_Included){			
NSAP_Address	**(160)**	**(20)**	
MAC_Address	**(48)**	**(6)**	
}			
if (Response_Fields_Included &= Error_Information_Included){			

Table A.48/J.112 – Status Response message structure

	Bits	Bytes	Bit number/Description
`Number_Error_Codes_Included`	(8)	(1)	
for (i = 0; i < Number_Error_Codes_Included; i++){			
`Error_Param_code`	(8)	(1)	
`Error_Param_Value`	(16)	(2)	
}			
}			
if (Response_Fields_Included &= Connection_Params_Included) {			
`Number_of_Connections`	(8)	(1)	
for i = 0; i < Number_of_Connections; i++){			
`Connection_Id`	(32)	(4)	
}			
}			
if (Response_Fields_Included &= Physical_Layer_Params_Included) {			
`Power_Control_Setting`	(8)	(1)	
`Reserved`	(16)	(2)	
`Time_Offset_Value`	(16)	(2)	
`Upstream_Frequency`	(32)	(4)	
`OOB_Downstream_Frequency`	(32)	(4)	
`IB_Downstream_Frequency`	(32)	(4)	
`SNR_Estimated`	(8)	(1)	
`Power_Level_Estimated`	(8)	(1)	
}			
}			

NIU Status

`NIU_Status` is a 32-bit unsigned integer that indicates the current state of the NIU.

NIU_Status	NIU Status Code
Calibration_Operation_Complete	0x01
Connection_Established	0x02
Network_Address_Registered (reserved)	0x04

The state Calibration_Operation_Complete is reached after an Initialization Complete Message with status zero. The Connection_Established state indicates that the NIU has received a Connect Message indicating a connection which has not been released yet.

Response Fields Included

`Response_Fields_Included` is an 8-bit unsigned integer that indicates what parameters are contained in the upstream status response.

NSAP Address

`NSAP_Address` is a 20-byte address assigned to the NIU.

MAC Address

`MAC_Address` is a 6-byte address assigned to the NIU.

Number of Error Codes Included

`Number_Error_Codes_Included` is an 8-bit unsigned integer that indicates the number of error codes contained in the response.

Error Parameter Code

`Error_Parameter_Code` is an 8-bit unsigned integer representing the type of error reported by the NIU. Error_Parameter_Codes not supported by the NIU are not sent. (See Table A.49.)

Table A.49/J.112 – Error parameter code

Error parameter code name	Error parameter code
Reserved for compatibility	0x00
Slot_Configuration_CRC_Error_Count	0x01
Reed_Solomon_Error_Count	0x02
ATM_Packet_Loss_Count	0x03
Slot_Configuration_Count	0x04
SL-ESF_CRC_Error_Count	0x05
Reed_Solomon_Errors_Correctable	0x06
Reed_Solomon_Errors_Non_Correctable	0x07
SL-ESF_Frame_Count	0x08

`Reserved_For_Compatibility` is reserved for compatibility with ETS 300 800 Edition 1.

`Slot_Configuration_CRC_Error_Count` refers to the number of errors in Slot_Configuration_Count R bytes, as found by the CRC decoder.

`Reed_Solomon_Error_Count` refers to the number of errors as corrected by the Reed_Solomon decoder.

`ATM_Packet_Loss_Count` refers to the number of received ATM cells that were lost, either due to unrecoverable Reed-Solomon errors or because of an erroneous HEC of the ATM cells header.

`Slot_Configuration_Count` refers to the number of R-byte sets (Rxa-Rxc) used to calculate Slot_Configuration_CRC_Error_Count. This parameter is included so that NIUs can either measure only the errors in the R-byte set it is allocated to, or measure the errors in all R-byte sets.

`SL-ESF_CRC_Error_Count` refers to the number of CRC errors found in consecutive C1-C6.

`Reed_Solomon_Errors_Correctable` refers to MPEG frames received with correctable Reed-Solomon Errors (IB only).

`Reed_Solomon_Errors_Non_Correctable` refers to MPEG frames received with non-correctable Reed-Solomon Errors (IB only).

`SL-ESF_Frame_Count` refers to the number of frames the statistics in this message apply on.

Error Parameter Value

`Error_Parameter_Value` is a 16-bit unsigned integer representing error counts detected by the NIU. These values are set to 0 after they are transmitted to the INA. If the counter reaches its maximum value, it stops counting. The counter resumes counting after it is set to 0.

Number of Connections

`Number_of_Connections` is an 8-bit unsigned integer that indicates the number of connections that are specified in the response. Specifically, if the number of connections is too large to have a MAC message with less than 40 bytes, it is possible to send separate messages with only the number of connections indicated in each message.

Connection Id

`Connection_Id` is a 32-bit unsigned integer representing the global connection Identifier used by the NIU for this connection.

Power Control Setting

`Power_Control_Setting` is an 8-bit unsigned integer representing the actual power used by the NIU/STB for upstream transmission. The unit of measure is 0.5 dBμV.

Time Offset Value

`Time_Offset_Value` is a 16-bit short integer representing a relative offset of the upstream transmission timing (relative compared to the Absolute_Time_Offset given in the Default Configuration Message). A negative value indicates an adjustment forward in time. A positive value indicates an adjustment back in time. The unit of measure is 100 ns.

Upstream Frequency

`Upstream_Frequency` is a 32-bit unsigned integer representing the channel assigned to the connections. The unit of measure is in hertz.

Downstream Frequencies

`OOB_Downstream_Frequency` is a 32-bit unsigned integer representing the Frequency where the connections on Out-Of-Band channel resides. The unit of measure is in hertz. When not applicable, this field is set to 0.

`IB_Downstream_Frequency` is a 32-bit unsigned integer representing the Frequency where the connections on In-Band channel resides. The unit of measure is in hertz. When not applicable, this field is set to 0.

`SNR_Estimated` is an 8-bit unsigned integer specifying the NIU estimated signal-to-noise ratio of the downstream carrying MAC messages. The unit is dB × 2. If the NIU is not able to estimate the value, the value zero (0) is used.

`Power_Level_Estimated` is an 8-bit unsigned integer specifying the NIU estimated power level of the downstream carrying MAC messages. The unit is dBμV × 2. If the NIU is not able to estimate the value, the value zero (0) is used.

A.5.6 Mini-slots

A.5.6.1 Carrying mini-slots

Mini-slots may only be used to send <MAC> Reservation_Request messages. Only contention access is allowed for mini-slots.

Mini-slots can be utilized in both in-band signalled and out-of-band signalled systems. The in-band signalling uses the same control fields as the out-of-band signalling inside the MAC flags, and the MAC messages are the same for both in-band and out-of-band signalling cases. The phrase "mini-slot" refers to a physical frame structure of the upstream channel. The 64-byte (QPSK modulation) respectively 128-byte (16QAM modulation) upstream bursts are called upstream packets.

A.5.6.2 Mini-slot framing structure

In case mini-slots are used, the upstream slot structure is subdivided into three (QPSK) respectively six (16QAM) 21-byte-long mini-slots. Each of these mini-slots can be sent by different user terminals. The upstream channel can support a mixture of full slots and mini-slots. The format of the mini-slot is shown in the following figures.

For QPSK it contains a 4-byte Unique Word (the mini-slot UW and the full slot UW will differ to enable simple decoding of the full slots and the mini-slots by the PHY), a single-byte Start field, a 16-byte payload, and a single-byte guard band. (See Figure A.45.)

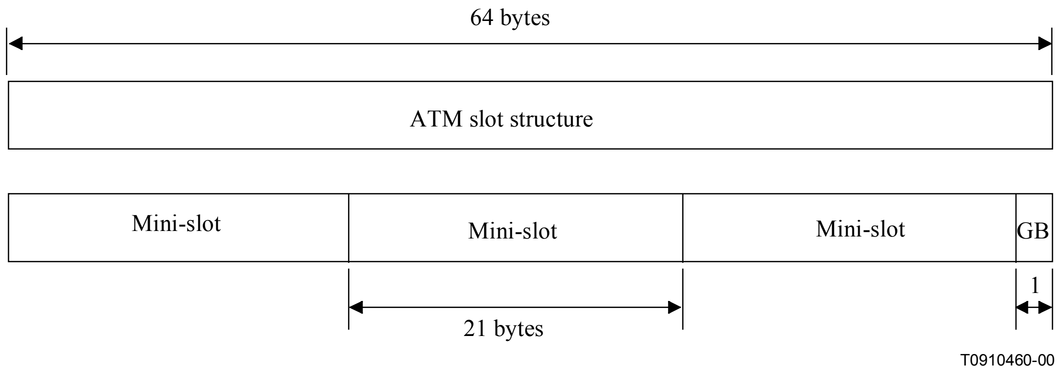


Figure A.45/J.112 – Mini-slot framing structure for QPSK

For the structure of the mini-slot itself, see A.5.5.2.6.

For 16QAM it contains an 8 byte Unique Word (the mini-slot UW and the full slot UW will differ to enable simple decoding of the full slots and the mini-slots by the PHY), a 9-byte payload + a 2-byte RS field, and a 2-byte guard band. (See Figure A.46.)

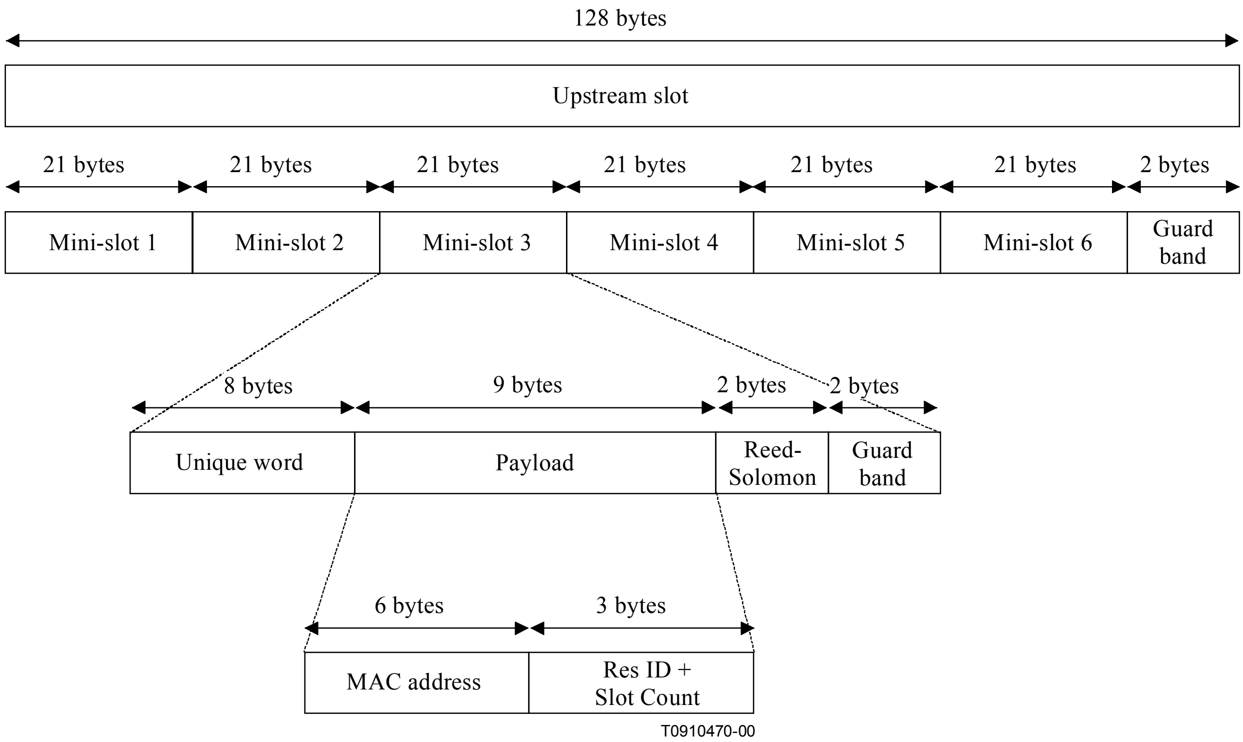


Figure A.46/J.112 – Mini-slot framing structure for 16QAM

A.5.6.3 Contention resolution for mini-slots

Mini-slots may carry the Reservation Request MAC message. The message is sent in a contention based mini-slot. In the case of collision, the resolution is carried out according to an INA-controlled ternary splitting algorithm (see Figure A.47). All necessary information is transmitted in the mini-slot feedback and mini-slot allocation sections of the Reservation_Grant_Message.

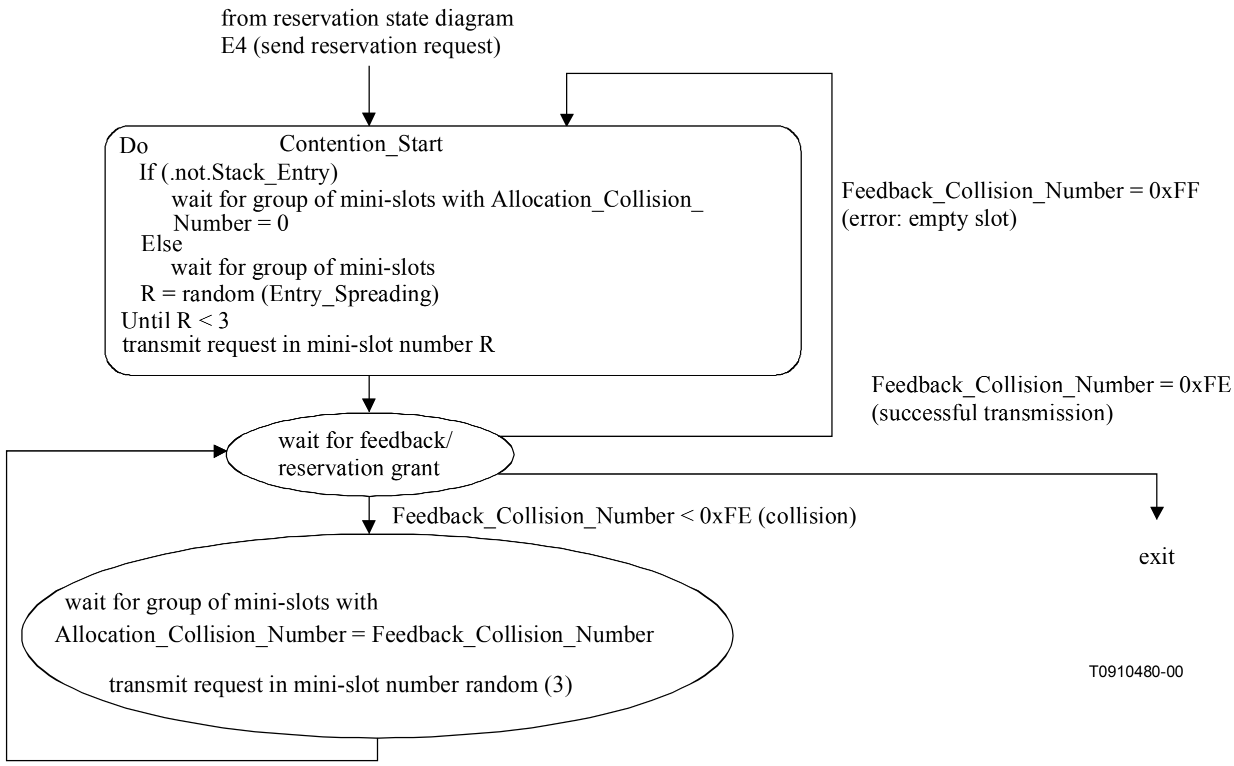


Figure A.47/J.112 – Ternary splitting algorithm

If Stack_Entry is not set, a NIU may enter the contention process only when the Allocation_Collision_Number is equal to zero. If Stack_Entry is set, the NIU may enter the contention resolution in any of the contention based mini-slots, independent of the value of Allocation_Collision_Number. In both cases the random number for the mini-slot selection in the range between 0 and Entry_Spreading shall be in the window from 0 to 2 before sending the request.

The Feedback_Collision_Number equals 0xFF and 0xFE for idle and successful transmission, respectively. All other values of the Collision_Number are numbered as collisions and are used to select the retransmission mini-slots: the NIU shall retransmit in a mini-slot having an Allocation_Collision_Number equal to Collision_Number.

The retransmission of the collided request takes place in a mini-slot that is randomly selected among the group of three mini-slots with the corresponding Allocation_Collision_Number.

A.5.7 Header suppression

The header suppression algorithm is based on the fact that for an IP session, most of the header fields are fixed. So, if we can determine in advance which fields will have a fixed value, we can save this fixed information on both sides of the link as reference. We will relate an IP packet to a session, and will only need to send the header changing fields. On the other side of the link, we will assign the packet to a session, and reconstruct the packet using the reference information.

A.5.7.1 The suppression scheme

Figure A.48 presents the suppression scheme in the upstream direction.

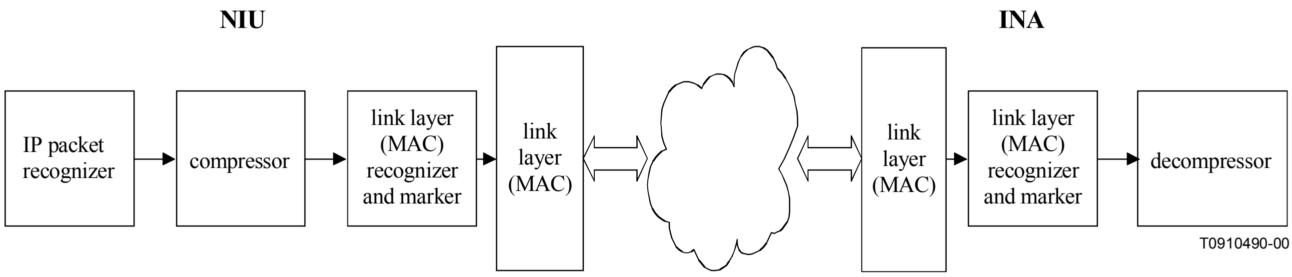


Figure A.48/J.112 – Suppression scheme

The scheme in the downstream is identical to that in the upstream (compressor is located at the INA, decompressor at the NIU).

The suppression scheme includes two types of blocks:

- Blocks that are responsible for the suppression implementation: these are the compressor and the decompressor blocks, and their implementation is described in A.5.7.2.
- Blocks that are intended to supply supporting services to the compressor and decompressor:
  1) IP recognizer: responsible for classifying the IP packets either as packets that should be suppressed or as other IP packets.
  2) Link layer recognizer and marker: this block will be responsible for classifying the decompressor input packets. It should identify the suppressed packets according to the suppression header.
  3) MAC.

The MAC should guarantee the following functions:

- Negotiate the suppression direction (upstream/downstream/upstream and downstream) and mask (see A.5.7.3).
- Deliver the value of the suppressed fields. Packets (suppressed or not) will be sent through the appropriate connection.

A.5.7.2 Suppression algorithm

The scheme abides by the following guidelines:

- A session is defined according to the IP source/destination addresses, and the source/destination port. Every session is identified by a context Id.
- A suppression mask is used for defining the fixed fields. Since the fixed fields change according to the protocols used with the IP layer, the mask will change according to the application.

The mask is interpreted according to the following rules:

- The mask is always 103 bits long.
- A bit in the mask acts as a flag for a header byte: if the mask bit is 0, the header matching byte is fixed, and should be suppressed.
- The bit/byte matching is according to the sending order.
- For DVB encapsulations, the matching will be as follows:
  – Direct IP encapsulation: the mask MSB matches the first IP header byte.
  – Ethernet MAC bridging: the mask MSB matches the first LLC/SNAP header byte.
- Every set of fixed fields' value has a generation number. If the value of fixed fields changes, the generation number also changes.

The suppression is performed in the following manner:

- Before sending suppressed packets, the suppressing entity (INA/NIU) MUST send a <MAC> Suppression Data message. The message defines if suppression is performed in this direction, and what the suppression mask is. The message also contains the value of the fixed fields that are being suppressed, the session context Id, and the generation number associated with the fixed fields' value.
- After sending the message, the suppressing entity can start sending suppressed packets. When a suppressed packet is received at the decompressor, it is identified and associated to a session according to the suppression header (using the context Id number). The decompressor checks that the packet generation number equals the saved fixed fields' generation number (as sent by the <MAC> message).

  If the generation numbers are not equal, the fixed fields' value known to the decompressor is not updated, and the packet cannot be reconstructed. If the numbers are equal, the fixed fields are added to the packet, and the packet is reconstructed.
- The decompressing entity MUST send a <MAC> suppression acknowledgment message within T_{ack} = 100 ms. The message acknowledges the receiving entity ability to reconstruct the suppressed packets.
- If a <MAC> suppression acknowledgment message was not received within T_{ack}, the suppressing entity MUST send another <MAC> suppression data message.
- If a <MAC> suppression acknowledgment message was not sent after T_{fail} = 1 s period, the suppressing entity MUST stop sending suppressed packets. The data SHOULD be sent through a different connection.

A.5.7.3 Negotiation of the suppression scheme

There are 3 options for the suppression scheme: upstream suppression, downstream suppression, and full duplex (upstream and downstream) suppression. For every direction (upstream/downstream), the decision whether to suppress or not and according to what mask is negotiated independently. The INA and the NIU negotiate through the <MAC> suppression data and <MAC> suppression acknowledgment messages. (See Figure A.49.)

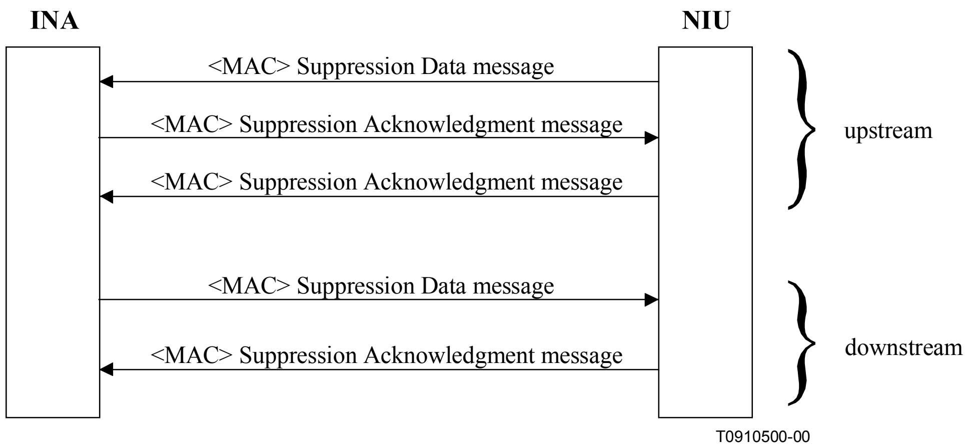


Figure A.49/J.112 – Suppression negotiation

- Upstream:

  The NIU sends a proposed mask and sets the suppression flag to "true" through the <MAC> suppression data message. The INA either accepts (sends the same mask and flag) or sends a subset suggestion (either with a new mask and the suppression flag set to "true", or the same mask and the suppression flag set to "false") through the <MAC> suppression acknowledgment message.

  If the INA changes the mask, the NIU can reply with another <MAC> suppression acknowledgment message, with the suppression flag set to "false".

- Downstream:

  The INA sends a proposed mask and sets the suppression flag to "true". The NIU either accepts (sends the same mask and flag) or refuses the suppression by sending a <MAC> suppression acknowledgment message with the suppression flag set to "false".

- Full duplex:

  In full duplex suppression, **both** downstream and upstream scenarios MUST be performed: the negotiation and initialization of suppression in the upstream is independent of the negotiation and initialization of the suppression in the downstream. The INA will send a <MAC> suppression data message for the downstream direction, and will receive a <MAC> suppression data message for the upstream direction. The NIU will send a <MAC> suppression data message for the upstream direction, and will receive a <MAC> suppression data message for the downstream direction.

A.5.7.4 Suppression header

The suppression header will be added to all suppressed packets. Figure A.50 describes the structure of an ATM cell that carries a suppressed packet. The suppression header is located right after the ATM header.

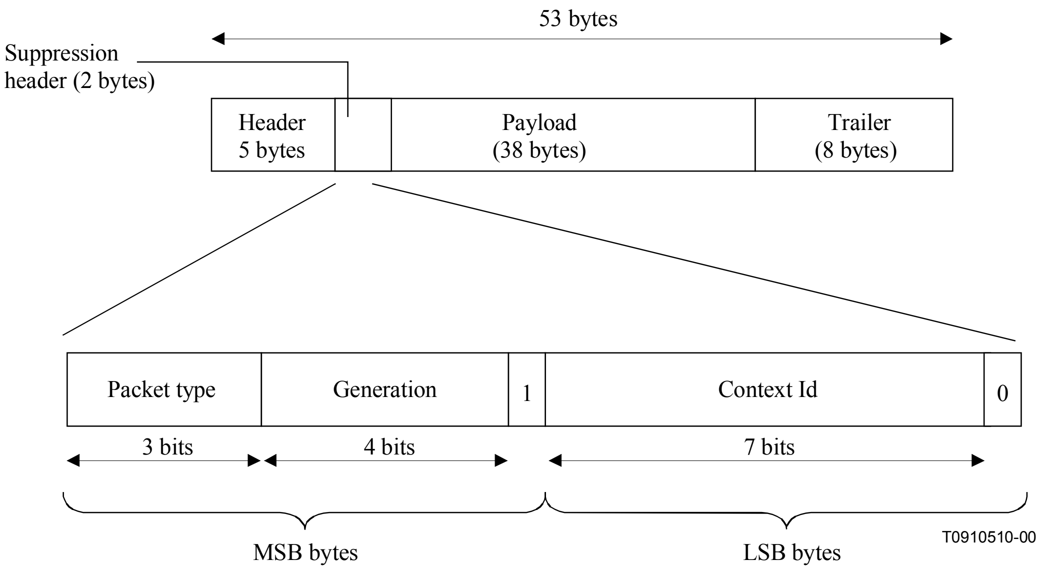


Figure A.50/J.112 – Suppression header

For Ethernet MAC bridging: the suppression for US, and OOB DS is done during AAL5 encapsulation – after adding the LLC/SNAP header and before the trailer is added. The suppression for IB DS is done during DSM-CC encapsulation: after adding the LLC/SNAP header and before CRC is added.

The header consists of 3 fields:

– **Packet type**: 3-bit. Defines the packet as created by the compressor.

Packet type	Value
Suppressed packet	0
Reserved	1
Not to be used	2-7

– **Generation**: 4-bit. The session current generation number (see A.5.7.1).

– **Context Id**: 7-bit. An identifier for the session (see A.5.7.1).

A.5.7.5 Header suppression <MAC> messages

A.5.7.5.1 <MAC> Suppression Data Message

The message is sent by the suppression initiator. It is used for negotiating the suppression mask and scheme, and for passing the fixed fields value. In case of upstream suppression, the NIU sends the message to the INA. In case of downstream suppression, the INA sends a singlecast message to the relevant NIU.

If needed, the message should be fragmented.

	Bits	Bytes	Bit number/Description
`Suppression_Data_Message(){`			
`Connection_Id`	**32**	**4**	
`Context_Id`	**8**	**1**	LSB bit is ignored
`Suppression control field`	**8**	**1**	
`Reserved`	5		Must be set to 0
`Direction`	1		2: {US, DS}
`Suppression_scheme_included`	1		1: {no, yes}
`Header_fields_included`	1		0: {no, yes}
`if (suppression_control_field&=suppression_sche_included){`			
`Suppression scheme`	**1**	**13**	
`Suppression mask`	103		
`Suppression flag`	1		103: {no, yes}
`}`			
`if (suppression_control_field &=header_field _included){`			
`Generation number`	**8**	**1**	4 MSBs are ignored
`Header length`	**8**	**1**	
`Header fields`			Up to 103 bytes
`}`			

`Connection_Id`: 4-byte field; the connection Id that suppressed packets are sent through.

`Context_Id`: 7-bit field. Context Id is an identifier for the session (see A.5.7.2). The suppression scheme header fields and generation number relates to suppressed packets that are sent through the connection Id and has that context Id in the suppression header.

`Suppression_control_field`: 8-bit control field.

`Direction`: if set to US, the message establishes suppression in the US. If set to DS, the message establishes suppression in the DS.

`Suppression_scheme_included`: a boolean, indicating whether the message includes a suppression mask and flag.

`Header_fields_included`: a boolean, indicating whether the message includes a value for the fixed fields.

`Suppression scheme`: 13-byte field.

`Suppression mask`: 103 bits, indicating what bytes of the header fields are suppressed. If the mask bit is 0, the matching header byte is suppressed (see A.5.7.2).

`Suppression flag`: a boolean. If set to "true", a suppression is performed.

`Generation number`: the generation number that is attached to the header fields value.

`Header length`: the number of bytes in the full header (the number of bytes that are sent in the `header fields` field).

`Header fields`: the full header of the packets (fixed and changing fields together). The field length changes according to the packet suppressed, but is limited to 103 bytes.

A.5.7.5.2 <MAC> Suppression Acknowledgment Message

This message acknowledges the receiving of a <MAC> suppression data message and for negotiating the suppression mask and scheme. If the message is sent by the INA, it is a singlecast message.

	Bits	Bytes	Bit number/Description
`Suppression_Acknowledgment_Message(){`			
`Connection_Id`	**32**	**4**	
`Context_Id`	**8**	**1**	LSB bit is ignored
`Suppression control field`	**8**	**1**	
`Reserved`	6		
`Direction`	1		2: {US,DS}
`Suppression_scheme_included`	1		1: {no, yes}
`Header_ack_included`	1		0: {no, yes}
`if (suppression_control_field&=suppression_sche_included){`			
`Suppression scheme`	1	13	
`Suppression mask`	103		
`Suppression flag`	1		103: {no, yes}
`}`			
`if (suppression_control_field &=header_field _included){`			
`Generation number`	8	1	4 MSBs are ignored
`}`			

`Connection_Id`: 4-byte field; the connection Id that suppressed packets are sent through.

`Context_Id`: 7-bit field. Context Id is an identifier for the session (see A.5.7.2). The suppression scheme header fields and generation number relates to suppressed packets that are sent through the connection Id and has that context Id in the suppression header.

`Suppression control field`: 8-bit control field.

`Direction`: if set to DS, the message acknowledges suppression in the DS. If set to US, the message acknowledge suppression in the US.

`Suppression_mask_included`: a boolean, indicating whether the message includes a suppression mask and flag.

`Suppression scheme`: 13-byte field.

`Suppression mask`: 103 bits, indicating what bytes of the header fields are suppressed. If the mask bit is 0, the matching header byte is suppressed (see A.5.7.2).

`Suppression flag`: a boolean. If set to "true", a suppression is performed.

`Generation number`: the generation number that is attached to the header fields' value.

A.5.7.6 Suppression of RTP sessions

Data packets that are carried by RTP protocols, contains the combination of RTP/UDP/IP headers.

Figure A.51 describes the fixed fields for the packets.

Figure A.52 describes the suppression mask for RTP sessions.

Figure A.53 describes the format of a suppressed packet (without a suppression header).

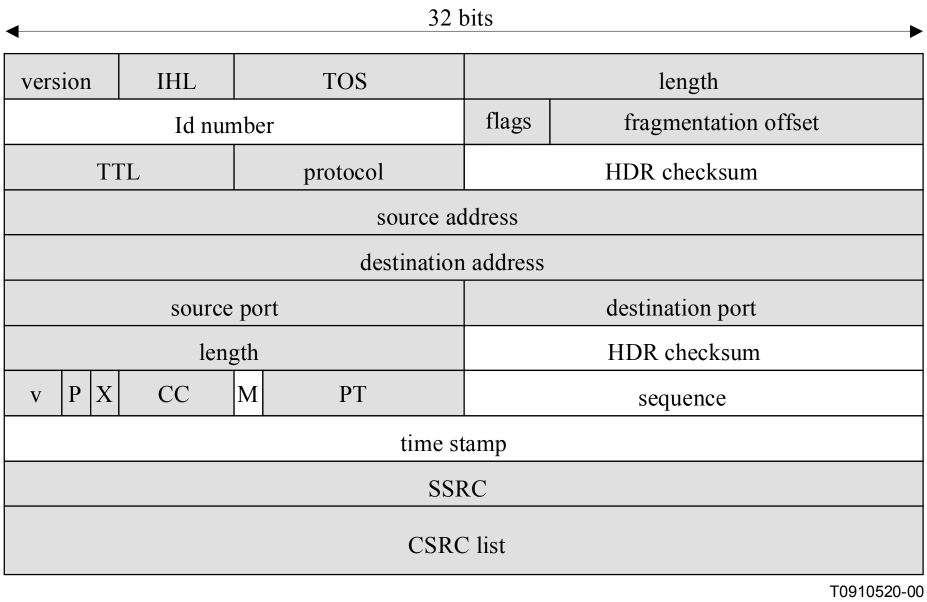


Figure A.51/J.112 – Fixed fields for RTP/UDP/IP

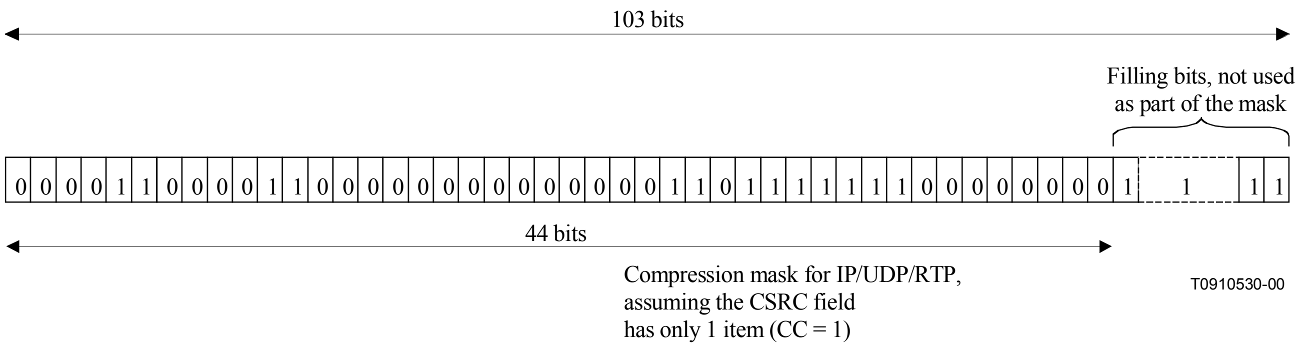


Figure A.52/J.112 – Suppression mask for RTP/UDP/IP

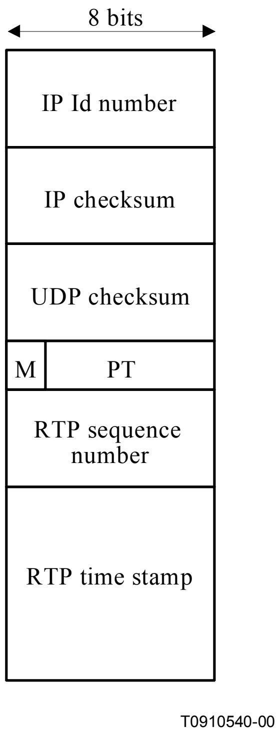


Figure A.53/J.112 – RTP/UDP/IP header with suppressed fields

A.5.8 Security (optional)

The security solution consists of two separate sub-systems:

– A new set of MAC messages used for authentication and key agreement between INA and NIU. These messages are used for key negotiation during connection set-up as well as for on-the-fly update of keys (see A.5.8.7);

– On-the-fly encryption and decryption of payload data streams passed between INA and NIU.

When a connection is being set up, before payload data is transferred, one of three new request/response MAC message-pairs is used to generate a session key specific to the payload stream associated with the connection.

The session key is a shared secret between the INA and the NIU: even if every MAC message is intercepted, the cryptographic properties of the protocol ensure that an eavesdropper cannot determine the session key value.

This is achieved by using a public-key protocol, which requires no up-front shared secret, or a simpler protocol based on a long-term shared secret between INA and NIU called a "cookie". The cookie is 160 bits long. It is also used for authenticating the NIU to the INA during connection set-up.

Each NIU will store its own cookie in non-volatile storage, whereas the INA will maintain a database of the cookie values of the NIUs on its network. Cookie values will be updated occasionally as dictated by security policy, but they are less vulnerable than session keys: a successful brute-force attack on a session key reveals nothing about the cookie value, nor any other session key.

The new MAC messages also implement a defence against clones: an NIU that is a physical copy of an existing NIU and attempts to operate on the network under the cloned identity (when the cloned NIU itself is not registered on the network). The anti-cloning measure is a simple non-volatile 8-bit counter that is incremented synchronously at the INA and NIU over time: if a clone NIU engages in traffic with the INA, this will be detected the next time the cloned NIU connects because the counter value will be out of synchronization.

If the clone attempts to operate concurrently with the cloned unit, there will be an immediate breakdown of functionality for both units, due to confusion within the MAC protocol. This amounts to a denial-of-service attack, and the INA should be prepared for this kind of protocol failure.

The following mathematical operators and symbols are used in this clause:

×	multiplication
^	power
~	concatenation
mod	modulo division
(unsigned char)x	ANSI C cast operator: converts value x to unsigned char
""	empty string (zero length)
nonce1	random string (INA)
nonce2	random string (NIU)

A.5.8.1 Cryptographic primitives

The key exchange protocols and data stream encryption is based on a set of well-established primitive cryptographic functions. The functions and their associated key sizes can be changed in the future, in case crypt-analytic or brute-force attacks become a realistic threat.

The specific set of functions and key sizes are negotiated between INA and NIU at sign-on time. The functions supported at the present time are Diffie-Hellman, HMAC-SHA1, and DES. Check current cryptographic literature for any updates regarding their security and use.

The following subclauses give a brief overview of the cryptographic primitives and details on how they are used in the protocol. Later subclauses describe the exact field layout of the new MAC messages.

The protocol parameters are described in terms of byte strings, where concatenation is denoted by the ~ operator. Integer quantities are represented as base-256 byte strings. Big-endian byte-ordering is used; that is, the most significant byte comes first. If necessary to reach a fixed length, the string is padded with zeros at the most significant end.

A.5.8.1.1 Public key exchange

A public key exchange primitive is used to allow the INA and NIU to agree on a secret, although communicating in public. The Diffie-Hellman scheme is based on unsigned integer arithmetic and works as follows (**^** denotes exponentiation):

The INA chooses two public values, a large prime number **m**, and a (small) number **g** which is a generator modulo **m** (that is, **g^a mod m** will generate all number from 0 to m-1 for varying **a**). The INA also chooses a secret number **x < m,** and sends the following three values to the NIU: **m**, **g**, **X = g^x mod m**.

The NIU chooses a secret value **y < m**, and responds to the INA with the value **Y = g^y mod m**.

The NIU now calculates **s = X^y mod m = (g^x)^y mod m = g^(x × y) mod m**, whereas the INA calculates **Y^x mod m = (g^y)^x mod m = g^(y × x) = s**, so the INA and NIU now agree on the value **s**.

The value of **s** is a secret shared between INA and NIU. To determine its value from the publicly communicated values **m**, **g**, **X**, and **Y**, an eavesdropper shall determine **x** or **y** by solving an equation of the form **Z = g^z mod m** for unknown **z**. This is known as the discreet logarithm problem and is computationally infeasible with current algorithms for sufficiently large values of **m**.

The parameter size supported are 512 bits for the prime number **m**, and hence also for the remaining values since all arithmetic is modulo **m**.

In the applicable MAC messages, the unsigned integer quantities **m**, **g**, **X**, and **Y** are encoded into fixed-size fields (64, 96 or 128 bytes) using big-endian byte-ordering.

A.5.8.1.2 Hashing

The protocol makes use of a keyed hash function that computes secure checksums which can only be verified with the possession of a secret key. The function has the one-way property, meaning that it is computationally infeasible to find an input value that maps to a given output value.

The hash function is also used to generate derived secret material based on a master secret. Because of the one-way property, the master secret is protected even if the derived secret is discovered.

In generic terms, the keyed hash function takes two byte strings as input, the **key** and a **data** string, and produces another string of bytes, the **digest**:

digest = H (key, data)

The **H** function shall accept key and data parameters of any size, whereas the protocol is designed to accept digests of any size.

The specification currently supports the HMAC-SHA1 function defined in IETF RFC 2104 [5]. It produces a 20-byte digest.

A.5.8.1.3 Encryption

Payload data is encrypted and decrypted using a symmetric-key block cipher, which is used in Cipher Block Chaining (CBC) mode with special handling of any final odd-size block.

In generic terms, the encryption and decryption functions take two byte strings as input, the key and a data block, and produce as output another data block of the same length:

ciphertext = E (key, plaintext)

D (key, ciphertext) = plaintext

The key length and block length is given by the chosen cipher, and the payload stream processing logic will apply it as appropriate to data units of various sizes.

The specification currently supports the DES algorithm, which has a block size of 8 bytes, and various options for key length based on an 8-byte raw key block (see A.5.8.5).

A.5.8.1.4 Pseudo-random numbers

The protocols used for generating secret values depend on the availability of a pseudo-random, that is, practically unpredictable, endless string of bytes. This will typically be produced with a Pseudo-Random Number Generator (PRNG) algorithm.

The random bytes are used to generate the secret Diffie-Hellman values, **x** and **y**, and for nonce values used during key exchange. The unpredictable nature of the random input ensures that different secret values are produced each time, and also prevents replay of old intercepted messages.

This annex does not require any particular algorithm, only that the INA and NIU each choose one that is well-established and cryptographically analysed.

The hardest aspect of using a PRNG is to initialize it with an unpredictable seed value. The seed should contain multiple high-granularity device-dependent time-samples, samplings of cable line noise, as well as any other available pseudo-random material, like file allocation tables, etc. These random source values are then hashed together to squeeze out the entropy for the seed value.

A.5.8.2 Main Key Exchange (MKE)

Main Key Exchange uses Diffie-Hellman to develop a shared secret between the INA and NIU, which is independent of the cookie value. Furthermore, it uses the cookie value to authenticate the NIU to the INA. It optionally uses the newly developed shared secret to update the cookie value. Finally, it derives a shared secret key used for the security context that is used to process payload stream data.

The exchange is initiated by the INA sending a message containing the Diffie-Hellman values, **m**, **g**, **X**, and a random nonce string, **nonce1**. The NIU responds with a message containing its Diffie-Hellman value, **Y**, a random nonce string, **nonce2**, and an authentication string, **auth**.

The INA and NIU each use the same formula to calculate the authentication string (**~** means concatenation):

auth = H (cookie, nonce1 ~ nonce2)

which is communicated by the NIU and checked by the INA. This proves the identity of the NIU, since it requires knowledge of the cookie to calculate the correct value of **auth**.

The NIU and INA each use the Diffie-Hellman values (see A.5.8.1.1) to arrive at the same secret value, **s**:

$$s = g\hat{}(x \times y) \bmod m.$$

This unsigned integer value is encoded as a byte string, of a length specified by the Diffie-Hellman parameter size, using big-endian byte ordering. It is then used to calculate a temporary shared secret string, **temp**:

temp = H (encode (s), nonce2 ~ nonce1).

If the cookie is to be updated, the new value is computed in sections for **n = 1, 2, …**:

newcookie(n) = H (temp ~ (unsigned char)1 ~ (unsigned char)n, "")

where (unsigned char) is the cast operator of the C programming language, and **""** is the empty string (zero length). These string values are computed and concatenated until the total length matches or exceeds the length of the cookie. The cookie is then obtained by taking the first 20 bytes out of the concatenated sections, starting from the beginning.

The session key used for payload stream encryption is likewise computed in sections:

key(n) = H (temp ~ (unsigned char) 2 ~ (unsigned char) n, "")

where, again, a sufficient number of sections are calculated to produce enough bytes to cover the length of the key. The session key is obtained "in the same manner as the cookie" by taking the required number of bytes out of the concatenated sections, starting from the beginning.

A.5.8.3 Quick Key Exchange (QKE)

Quick Key Exchange uses the existing cookie value to authenticate the NIU to the INA, and then derive a shared secret key used for the security context that is used to process payload stream data.

The exchange is initiated by the INA sending a message containing a random nonce string, **nonce1**. The NIU responds with a message containing a random nonce string, **nonce2**, and an authentication value, **auth**.

The value of **auth** is calculated in the same way as for Main Key Exchange, and is likewise used to verify the identity of the NIU (see A.5.8.2).

The NIU and INA then each calculate a temporary shared secret string, **temp**:

temp = H (cookie ~ (unsigned char)3, nonce2 ~ nonce1).

This value is used to produce the payload encryption key in the same way as for Main Key Exchange (see A.5.8.2).

A.5.8.4 Explicit Key Exchange (EKE)

Explicit Key Exchange is used by the INA to deliver a predetermined session key to the NIU. The session key is encrypted under a temporary key derived from the cookie value, and is used for the security context that is used to process payload stream data.

The delivery is performed by the INA sending a message containing a random nonce string, **nonce1**, and a byte string value, **encryptedkey**, which has the same length as a key used for payload encryption. The NIU responds with a message containing a random nonce string, **nonce2**, and an authentication value, **auth**.

The value of **auth** is calculated in the same way as for Main Key Exchange, and is likewise used to verify the identity of the NIU (see A.5.8.2).

Both the INA and NIU calculate a temporary shared secret string, **temp**:

temp = H (cookie ~ (unsigned char)4, nonce1)

which is used to produce sections of a temporary key, in the same way as for Main Key Exchange (see A.5.8.2). The INA uses these temporary **key** string sections to XOR with the session key to obtain the **encryptedkey** value, and the NIU performs a second XOR operation to decrypt the session key value.

For normal DES, 8 bytes of raw key data are delivered, which are used to derive the actual key with the appropriate number of effective bits, as described below (see A.5.8.5).

A.5.8.5 Key derivation

The actual key value used for processing payload data is derived from the **key** sections developed during key exchange. For DES, 8 bytes of raw key data is required, so a single 20-byte section, **key(1)**, computed by HMAC-SHA1 is sufficient.

In each byte, the least significant bit is not used (it can be used as an odd-parity bit of the remaining 7 bits), bringing the effective key size down to 56 bits.

Furthermore, when used in 40-bit mode, the two most significant bits of each byte in the key are zeroed.

A.5.8.6 Data stream processing

Security can be applied to various payload data streams selectively. The elementary unit is called a security context, which contains two session keys used for encrypting and decrypting a stream of payload data. Only one of the keys is used to process any particular payload unit. Each key can be used for processing both upstream and downstream payload data.

Having two keys allows negotiation of a new key to take place while payload data is processed using the old one, and then do an immediate switch-over once the new key is agreed upon, without interrupting payload traffic. The INA initiates the key exchanges, and can start using a session key for downstream traffic encryption once the key exchange is complete. For upstream traffic encryption, the NIU should use whichever key was used by the INA in the most recent encrypted payload unit.

A.5.8.6.1 Payload streams

A payload stream is identified by either of:

– a 24-bit (UNI) ATM virtual circuit VPI/VCI: this is used for ATM-based IB downstream, OOB downstream, and upstream payload data. The ATM circuit can be one-to-one, or one end-point of a multicast circuit;
– a 48-bit MAC-address: this is used for DVB Multiprotocol Encapsulation downstream payload data. The MAC-address can be the physical address of the STB or a pseudo-address used for MAC-address based multicasting.

When a payload stream is secured, the NIU and the INA will have matching security contexts, which are used to encrypt/decrypt both upstream and downstream traffic. For unsecured payload streams there is no security context, and payload data is not encrypted.

To support encrypted multicast traffic, the same security context will be created for each member using EKE (see subclause A.5.8.4), so that each NIU can decrypt the common payload data stream.

A.5.8.6.2 Data encryption

Within a payload data stream, data is carried in individual units at the various protocol layers. Encryption is applied at the lowest layer possible, consistent with the payload stream:

– ATM-based payload streams: the unit of encryption is a single ATM cell. The 48-byte cell payload is encrypted using the security context implied by the associated connection.
– Encryption is transparent to higher-level protocol layers, which see only unencrypted cell payloads.
– DVB Multiprotocol Encapsulation payload streams: the unit of encryption is a single DVB Multiprotocol Encapsulation section. The datagram_data_bytes (between the MAC address and the CRC/checksum) are encrypted using the security context implied by the associated connection. The DVB Multiprotocol Encapsulation payload to be encrypted will be adjusted to have a length of $n \times 8$ bytes (n is an integer) by adding an appropriate amount (0...7 bytes) of stuffing bytes before the CRC/checksum according to [6]. The CRC/checksum is calculated on the encrypted datagram bytes, while higher-level protocol layers see only unencrypted datagrams.

A.5.8.6.3 Encryption flags

There are flags in the header of each encryption unit specifying which of the two sessions keys of the security context is used.

The receiver will use the security context of the payload stream to see if decryption shall be done.

– ATM cells: the least significant two bits of the Generic Flow Control (GFC) field of the cell header are used:
  • 00: not encrypted
  • 01: reserved
  • 10: encrypted using session key 0
  • 11: encrypted using session key 1

The most significant two bits of the GFC field are reserved for future use, and shall be set to 00.

– DVB Multiprotocol Encapsulation sections, according to EN 301 192 [6]: the 2-bit payload_scrambling_control field in the section header is used:
  • 00: not encrypted
  • 01: reserved
  • 10: encrypted using session key 0
  • 11: encrypted using session key 1

The 2-bit address_scrambling_control field in the section header is 00 all the time (the address is not scrambled).

A.5.8.6.4 Chaining and initialization vector

Within encryption units, the block encryption algorithm is used in Cipher Block Chaining (CBC) mode: the first plain-text block is XOR'ed with an initialization vector (IV), and subsequent blocks are XOR'ed with the previous cipher-text block, before the block is encrypted. Decryption is opposite: each cipher-text block is first decrypted and then XOR'ed with the previous chaining value.

The value of the IV for a given encryption unit is zero.

A.5.8.7 Security establishment

Security issues are handled in the following situations:

– When a NIU registers on the network it will do an initial handshake with the INA to establish the level of security support, in particular the cryptographic algorithms and key sizes to be used subsequently.

  The handshake consists of **<MAC> Security Sign-on** and **<MAC> Security Sign-on Response** messages (see A.5.8.9.1 and A.5.8.9.2) which are exchanged immediately prior to the **<MAC> Initialization Complete** message.

  A failure during this stage of the protocol causes the INA to revert to non-secure interaction with the NIU.

– The security context of a secured payload stream is established when the underlying MAC connection is created, before any stream data is transmitted. One session key is agreed, and the cookie and/or clone counter values may be updated as part of the exchange.

  The key exchange consists of **<MAC> Main/Quick/Explicit Key Exchange** and **<MAC> Main/Quick/Explicit Key Exchange Response** messages (see A.5.8.9.3 to A.5.8.9.8) which are exchanged immediately prior to the <**MAC> Connect Confirm** message.

  A failure during this stage of the protocol causes the connection-set-up operation to fail.

– After a connection is in use, each session key of the security context of the payload stream can be updated on-the-fly, that is, without re-establishing the underlying connection, and without interrupting payload data traffic. The cookie and/or clone counter values cannot be updated as part of the exchange.

  A new session key is negotiated using the same MAC messages used during connection-set-up. There is no **<MAC> Connect Confirm** message.

  A failure during this stage of the protocol causes the connection to be dropped.

  While a session key of the security context is being updated for a particular connection, payload stream data traffic should be encrypted using the other session key or not at all. Once the key exchange is complete, the INA can start using it for subsequent downstream traffic, thereby directing the NIU to use it for upstream traffic.

All three variants of key exchange messages authenticate the NIU based on the existing cookie value. They also perform the clone detection counter check, and optionally increment the clone counter. Only the MKE can update the cookie.

The security MAC message flow is naturally serialized within the context of the particular connection that is being set up. But, in as far as multiple connections are being established concurrently, there can also be multiple concurrent key exchanges whose messages are interleaved. The NIU is free to complete outstanding key exchanges on separate connections in any order it chooses.

A.5.8.8 Persistent state variables

To facilitate authentication, key exchange, and clone detection, the NIU has a set of state variables whose values are retained across registrations and power cycles (see Table A.50):

Table A.50/J.112 – Persistent NIU variables

Name	Function	Size
`Cookie`	authentication cookie	160 bits
`Cookie_SN`	cookie sequence number	1 bit
`Clone_Counter`	clone detection counter	8 bits
`Clone_Counter_SN`	clone counter sequence number	1 bit

The sequence numbers are used to ensure that the INA and NIU can stay synchronized even in case the NIU drops off the net in the middle of a protocol exchange.

A.5.8.8.1 Guaranteed delivery

Within the set-up protocol for a MAC connection, the INA will ensure that a protocol exchange is complete before proceeding. If it doesn't receive a response MAC message within a given time interval, it will retransmit the original message unchanged. The NIU will do likewise in situations where it requires a response. If the number of retransmissions exceeds three, the protocol fails.

Due to race conditions, superfluous retransmissions may be generated by both the INA and the NIU. They shall discard such messages after the first message has in fact been received.

If the NIU is not ready to respond within the specified time-out, it can send **<MAC> Wait** messages (see A.5.8.9.9) to extend the time it has available to generate a proper response. Upon receiving the wait message, the INA will restart its timer and reset the retry count.

The protocol time-out values can be set by the <MAC> Default Configuration Message; otherwise, the following default values apply (see Table A.51):

Table A.51/J.112 – Protocol time-out values

Code	Protocol stage	Default value
0xD	Security Sign-On	90
0xE	Main Key Exchange	600
0xF	Quick Key Exchange Explicit Key Exchange	300
NOTE – The unit for the time-outs is the millisecond.		

A.5.8.9 Security MAC messages

A.5.8.9.1 <MAC> Security Sign-on (single-cast downstream)

As part of the registration process when a NIU attaches to the network, the INA and NIU will negotiate the specific set of cryptographic algorithms and parameters used in the key exchange protocols and for payload encryption.

The selections are global, and apply to all subsequent security exchanges for as long as the NIU is registered on the network.

The selections affect the layout of the subsequent key exchange messages, since they have fields that vary in size according to the choice of algorithms and parameters.

The INA indicates which algorithms and parameters it supports by setting the appropriate bits in the **<MAC> Security Sign-on** message. There are four classes of algorithms, and the INA will set one or more bits in each of the four fields to indicate which specific choices it supports (see Table A.52):

Table A.52/J.112 – Security Sign-On message structure

	Bits	Bytes	Bit number/Description	Parameter bytes
`Security_Sign-On (){`				
`Public_Key_Alg`		**1**	**Public key algorithm choices:**	P_{pka}:
`PKA_Reserved`	7		7...1: Reserved, shall be 0	
`PKA_DH_512`	1		0: (yes/no) Diffie-Hellman, 512 bits	64
`Hash_Alg`		**1**	**Hash algorithm choices:**	P_{ha}:
`HA_Reserved`	7		7...1: Reserved, shall be 0	
`HA_HMACSHA1`	1		0: (yes/no) HMAC-SHA1	20
`Encryption_Alg`		**1**	**Encryption algorithm choices:**	P_{ea}:
`EA_Reserved`	6		7...2: Reserved, shall be 0	
`EA_DES_56`	1		1: (yes/no) DES, 56 bit key	8
`EA_DES_40`	1		0: (yes/no) DES, 40 bit key	8
`Nonce_Size`		**1**	**Nonce size choices:**	P_{ns}:
`NS_Reserved NS_64`	7		7...1: Reserved, shall be 0	
	1		0: (yes/no) 8 random bytes	8
`Reserved`	**32**	**4**	**Reserved for future use, shall be 0**	
}				

If the security option is supported, the minimum subset to support is `PKA_DH_512`, `HA_HMACSHA1`, `EA_DES_40`, and `NS_64`.

EA_DES_56 is optional.

A.5.8.9.2 <MAC> Security Sign-on Response (upstream)

In its security sign-on response, the NIU indicates which specific algorithms and parameters to use. It does so by choosing one of the suggestions offered by the INA within each of the four classes.

The fields of the response message have the same definition as the message from the INA, except that exactly one bit will be set in each field.

If the NIU is unable to support any of the suggested algorithms for any class, it shall return an all-zero field value, and the INA will revert to non-secure communication or re-issue the **<MAC> Security Sign-on** message with different choices (see Table A.53).

Table A.53/J.112 – Security Sign-on Response message structure

	Bits	Bytes	Bit number/Description	Parameter bytes
`Security_Sign-On_Response () {`				
`Public_Key_Alg`		1	**Public key algorithm choices:**	P_{pka}:
`PKA_Reserved`	7		7...1: Reserved, shall be 0	
`PKA_DH_512`	1		0: (yes/no) Diffie-Hellman, 512 bits	64
`Hash_Alg`		1	**Hash algorithm choices:**	P_{ha}:
`HA_Reserved`	7		7...1: Reserved, shall be 0	
`HA_HMACSHA1`	1		0: (yes/no) HMAC-SHA1	20
`Encryption_Alg`		1	**Encryption algorithm choices:**	P_{ea}:
`EA_Reserved`	6		7...2: Reserved, shall be 0	
`EA_DES_56`	1		1: (yes/no) DES, 56-bit key	8
`EA_DES_40`	1		0: (yes/no) DES, 40-bit key	8
`Nonce_Size`		1	**Nonce size choices:**	P_{ns}:
`NS_Reserved`	7		7...1: Reserved, shall be 0	
`NS_64`	1		0: (yes/no) 8 random bytes	8
`Reserved`	**32**	**4**	**Reserved for future use, shall be 0**	
`}`				

A.5.8.9.3 <MAC> Main Key Exchange (singlecast downstream)

The Main Key Exchange message is used to start a cookie-independent key exchange with the NIU, and also instructs the NIU whether to update its cookie value and clone counter value (see Table A.54).

Table A.54/J.112 – Main Key Exchange message structure

	Bits	Bytes	Bit number/Description
`Main_Key_Exchange () {`			
`Connection_Id`	**32**	**4**	**MAC connection identifier**
`Flags`		**1**	
`Reserved`	4		7...4: shall be 0
`FL_Initializing`	1		3: (yes/no) first ever key exchange
`FL_Update_Cookie`	1		2: (yes/no) make new cookie value
`FL_Update_Counter`	1		1: (yes/no) increment clone counter
`FL_Session_Key`	1		0: select session key 0 or 1
`Reserved`	**8**	**1**	**Reserved for future use, shall be 0**
`Nonce`		P_{ns}	**Random string nonce1**
`DH_Modulus`		P_{pka}	**Diffie-Hellman modulus m**
`DH_Generator`		P_{pka}	**Diffie-Hellman generator g**
`DH_Public_X`		P_{pka}	**Diffie-Hellman public value X**
`}`			

The `FL_Session_Key` bit specifies which session key of the security context to update.

If the `FL_Update_Counter` bit is set, it instructs the NIU to increment its clone detection counter.

If the `FL_Update_Cookie` bit is set, it instructs the NIU to generate a new cookie value to be used for future authentications and key exchanges, and to reset the clone detection counter to zero.

Any updates to the cookie, clone counter, or their associated sequence number bits do not take effect until the following **<MAC> Connect Confirm** message is received by the NIU.

If the `FL_Initializing` bit is set, it tells the NIU that the `Authenticator` field in the response will be ignored.

The sizes of the multi-byte fields are determined by the parameters of the algorithms selected during security sign-on (see A.5.8.9.1).

The INA will use its own private Diffie-Hellman value, **x**, together with the fields of the response message from the NIU to derive the new session key value, as well as any new value for the cookie (see A.5.8.2).

A.5.8.9.4 <MAC> Main Key Exchange Response (upstream)

The Main Key Exchange Response message authenticates the NIU and completes the cookie-independent key exchange with the INA. It also contains the current value of the clone detection counter (see Table A.55).

Table A.55/J.112 – Main Key Exchange Response message structure

	Bits	Bytes	Bit number/Description
`Main_Key_Exchange_Response () {`			
`Connection_Id`	**32**	**4**	**MAC connection identifier**

`Flags`
`Reserved FL_Cookie_SN`
`FL_Counter_SN`
	
	6
	1
	1
		1	
			7...2: shall be 0
			1: cookie sequence number
			0: clone counter sequence number

`Clone_Counter`	**8**	**1**	**Current clone counter value**
`Nonce`		P_{ns}	**Random string nonce2**
`Authenticator`		P_{ha}	**Authentication value auth**
`DH_Public_Y`		P_{pka}	**Diffie-Hellman public value Y**
`}`			

The `FL_Counter_SN` bit is the current sequence number of the clone detection counter. The **`Clone_Counter`** field is the current value of the counter. A clone collision has been detected if the INA finds a mis-match from the expected value.

The `FL_Cookie_SN` bit is the sequence number of the cookie used for authentication.

If the `FL_Update_Cookie` bit was set by the INA, the NIU will generate a new cookie value and complement the cookie sequence number bit. It will also reset the clone counter value to zero and clear the clone counter sequence number bit.

If the `FL_Update_Counter` bit was set by the INA, the NIU will increment the value of the clone counter (modulo 256) and complement the clone counter sequence number bit.

Any updates to the cookie, clone counter, or their associated sequence number bits do not take effect, and shall not be committed to non-volatile storage, until the following **<MAC> Connect Confirm** message is received by the NIU.

The NIU uses its private Diffie-Hellman value, **y**, together with the message fields to derive the new session key value, as well as any new value for the cookie (see A.5.8.2).

A.5.8.9.5 <MAC> Quick Key Exchange (singlecast downstream)

The Quick Key Exchange message is used to start a cookie-dependent key exchange with the NIU, and also instructs the NIU whether to update its clone counter value (see Table A.56).

Table A.56/J.112 – Quick Key Exchange message structure

	Bits	Bytes	Bit number/Description
`Quick_Key_Exchange () {`			
`Connection_Id`	**32**	**4**	**MAC connection identifier**

`Flags`
`Reserved FL_Update_Counter`
`FL_Session_Key`
	8
	6
	1
	1
		1	
			7...2: shall be 0
			1: (yes/no) increment clone counter
			0: select session key 0 or 1

`Reserved`	**8**	**1**	**Reserved for future use, shall be 0**
`Nonce`		P_{ns}	**Random string nonce1**
}			

The `FL_Session_Key` bit specifies which session key of the security context to update.

If the `FL_Update_Counter` bit is set, it instructs the NIU to increment its clone detection counter.

The INA will use its knowledge of the cookie value together with the fields of the response message from the NIU to derive the session key value (see A.5.8.3).

A.5.8.9.6 <MAC> Quick Key Exchange Response (upstream)

The Quick Key Exchange Response message authenticates the NIU and completes the cookie-dependent key exchange with the INA. It also contains the current value of the clone detection counter (see Table A.57).

Table A.57/J.112 – Quick Key Exchange Response message structure

	Bits	Bytes	Bit number/Description
`Quick_Key_Exchange_Response () {`			
`Connection_Id`	**32**	**4**	**MAC connection identifier**

`Flags`
`Reserved`
`FL_Cookie_SN FL_Counter_SN`
	
	6
	1
	1
		1	
			7...2: shall be 0
			1: cookie sequence number
			0: clone counter sequence number

`Clone_Counter`	**8**	**1**	**Current clone counter value**
`Nonce`		P_{ns}	**Random string nonce2**
`Authenticator`		P_{ha}	**Authentication value auth**
}			

The FL_Cookie_SN bit is the sequence number of the cookie used for authentication.

The FL_Counter_SN bit is the current sequence number of the clone detection counter. The **Clone_Counter** field is the current value of the counter. A clone collision has been detected if the INA finds a mismatch from the expected value.

If the FL_Update_Counter bit was set by the INA, the NIU will increment the value of the clone counter (modulo 256) and complement the clone counter sequence number bit. The updated values do not take effect, and shall not be committed to non-volatile storage, until the following **<MAC> Connect Confirm** message is received by the NIU.

The NIU uses the cookie value together with the message fields to derive the session key value (see A.5.8.3).

A.5.8.9.7 <MAC> Explicit Key Exchange (singlecast downstream)

The Explicit Key Exchange message is used to securely deliver an existing session key value to the NIU, and also instructs the NIU whether to update its clone counter value (see Table A.58).

Table A.58/J.112 – Explicit Key Exchange message structure

	Bits	Bytes	Bit number/Description
Explicit_Key_Exchange (){			
Connection_Id	**32**	**4**	**MAC connection identifier**
Flags Reserved FL_Update_Counter FL_Session_Key	 6 1 1	**1**	 7...2: shall be 0 1: (yes/no) increment clone counter 0: select session key 0 or 1
Reserved	**8**	**1**	**Reserved for future use, shall be 0**
Nonce		**P_{ns}**	**Random string nonce1**
Encryptedkey		**P_{ea}**	**Encrypted session key**
}			

The FL_Session_Key bit specifies which session key of the security context to update.

If the FL_Update_Counter bit is set, it instructs the NIU to increment its clone detection counter.

The INA has used its knowledge of the cookie value to encrypt the session key value (see A.5.8.4).

A.5.8.9.8 <MAC> Explicit Key Exchange Response (upstream)

The Explicit Key Exchange Response message authenticates the NIU and acknowledges receipt of the delivered key. It also contains the current value of the clone detection counter (see Table A.59).

Table A.59/J.112 – Explicit Key Exchange Response message structure

	Bits	Bytes	Bit number/Description
`Explicit_Key_Exchange_Response () {`			
`Connection_Id`	**32**	**4**	**MAC connection identifier**

`Flags`
`Reserved`
`FL_Cookie_SN FL_Counter_SN`
	
	6
	1
	1
		1	
			7...2: shall be 0
			1: cookie sequence number
			0: clone counter sequence number

`Clone_Counter`	**8**	**1**	**Current clone counter value**
`Nonce`		P_{ns}	**Random string nonce2**
`Authenticator`		P_{ha}	**Authentication value auth**
}			

The `FL_Cookie_SN` bit is the sequence number of the cookie used for authentication and session key decryption. If the INA determines that it has used the wrong cookie for session key encryption, it will re-issue the **<MAC> Explicit Key Exchange** using the old cookie value.

The `FL_Counter_SN` bit is the current sequence number of the clone detection counter. The `Clone_Counter` field is the current value of the counter. A clone collision has been detected if the INA finds a mismatch from the expected value.

If the `FL_Update_Counter` bit was set by the INA, the NIU will increment the value of the clone counter (modulo 256) and complement the clone counter sequence number bit. The updated values do not take effect, and shall not be committed to non-volatile storage, until the following **<MAC> Connect Confirm** message is received by the NIU.

The NIU uses the cookie value together with the message fields to decrypt the session key value (see A.5.8.4).

A.5.8.9.9 <MAC> Wait (upstream)

The Wait message is used by the NIU to extend the time the INA waits for a reply to a given message. Upon receiving it, the INA will reset its time-out value and retry count (see A.5.8.8.1 and Table A.60).

Table A.60/J.112 – Wait message structure

	Bits	Bytes	Bit number/Description
`Wait () {`			
`Connection_Id`	**32**	**4**	**MAC connection identifier**
`Message_Type`	**8**	**1**	**Type of message from INA**
`Reserved`	**8**	**1**	**Reserved for future use, shall be 0**
}			

The `Message_Type` field is the message type value of the message received from the INA being processed. If the message is specific to a connection, the `Connection_Id` field identifies which; otherwise, this field is zero. The NIU indicates that it is currently unable to send a reply to the message.

A.6 Interactive Cable STB/Cable Data Modem Mid-Layer Protocol

This clause describes the mid layers to be used when this annex is used to implement Interactive Cable STB respectively Cable Data Modem applications. Three solutions are given for this application: Direct IP, Ethernet MAC bridging, and PPP. Direct IP is mandatory for both INA and NIU; the other two solutions are optional. Interoperability testing will be performed on Ethernet MAC bridging until the end of 1999.

A.6.1 Direct IP

The goal of this clause is to allow compatible and interoperable implementations for transmitting IP datagrams [11] over ATM AAL5 [8] and DVB Multiprotocol Encapsulation [6], as used by this annex for upstream and downstream transmission.

A.6.1.1 Framing

INA and NIU/STB shall support an MTU size of 1500 bytes.

A.6.1.1.1 Upstream and OOB downstream

The IP datagram shall be carried as such in the paylaod of the AAL5 CPCS-PDU. This method is described in RFC 1483 [8] as VC-based multiplexing for routed protocols and is generally also known as null encapsulation.

A.6.1.1.2 IB downstream

The IP datagram shall be carried as such in the DVB Multiprotocol Encapsulation sections of EN 301 192 [6]; LLC_SNAP_flag is set to zero. Each IP datagram shall be carried in a single section.

A.6.1.2 Addressing

In upstream framing structure and in downstream out-of-band framing structure, the addressing of a specific NIU/STB is done with a VPI/VCI pair. At least one VPI/VCI pair is assigned per NIU/STB. The following VPI/VCI pairs are reserved (see Table A.61):

Table A.61/J.112 – Reserved VPI/VCI values

VPI/VCI	Remark
any/0x0000...0x001F	Reserved for ATM use
0x00/0x0020	Reserved for DAVIC use
0x00/0x0021	Reserved for DVB MAC messages
0x00/0x0022	Reserved for DirectIP broadcast
0x00/0x0023	Reserved for Ethernet MAC Bridging broadcast

All other VPI/VCI pairs can be assigned by the INA for carrying IP traffic. The VPI/VCI is provided through the DVB MAC protocol.

A.6.1.2.1 IP broadcast and multicast from STB/NIU to INA

All upstream IP broadcast and multicast packets shall be transmitted with an upstream VPI/VCI given in a MAC connect message.

A.6.1.2.2 IP broadcast and multicast from INA to STB/NIU

IB downstream

For IB downstream, IP broadcast and multicast shall be carried out according to EN 301 192 [6] as described below:

IB downstream IP broadcast shall be transmitted with the broadcast MAC address FF:FF:FF:FF:FF:FF. An IP multicast group is joined according to the IGMP protocol [13]. Additionally, the INA may assign a new DVB MAC connection to the NIU/STB for that purpose, including a multicast MAC address. IB downstream multicast shall then be transmitted with that multicast MAC address.

OOB downstream

OOB downstream IP broadcast shall be transmitted with a VPI/VCI value of 0x00/0x0022. An IP multicast group is joined according to the IGMP protocol [13]. Additionally, the INA may assign a new MAC connection to the NIU/STB for that purpose. QPSK downstream multicast shall then be transmitted with the VPI/VCI given in the corresponding MAC Connect message.

A.6.1.3 IP address assignment

The NIU/STB shall use either the BOOTP or the DHCP protocol according to RFC 951 [10] and RFC 2131 [9] respectively to get an IP address from the network, unless a fixed IP address was assigned to the NIU/STB by the operator and made known to the INA. All additional IP addresses of customer premises equipment connected to the NIU/STB shall be assigned through BOOTP or DHCP, unless fixed IP addresses have been assigned by the operator. Singlecast downstream traffic with a destination IP address not assigned through BOOTP, DHCP, or the operator shall be discarded by the INA. Upstream traffic with a source host IP address not assigned through BOOTP, DHCP, or the operator shall be discarded by the NIU/STB and by the INA.

A.6.1.4 INA interfaces (Informative)

To be determined.

A.6.1.5 NIU/STB interfaces (Informative)

To be determined.

A.6.2 Ethernet MAC bridging

The goal of this clause is to allow compatible and interoperable implementations for transmitting ISO 8802-3 [15] Ethernet MAC frames [15] over ATM AAL5 [8] and DVB Multiprotocol Encapsulation [6], as used by this annex for upstream and downstream transmission.

A.6.2.1 Framing

A.6.2.1.1 Upstream and OOB downstream

The Ethernet MAC frame shall be carried in the paylaod of the AAL5 CPCS-PDU as described in RFC 1483 [8] as LLC encapsulation for bridged Ethernet/802.3 PDUs, using PID 0x00-07 (LAN FCS is not transmitted). No padding bytes are inserted between the LLC/SNAP header and the Ethernet MAC frame.

A.6.2.1.2 IB downstream

The Ethernet MAC frame shall be carried in the payload of the DVB Multiprotocol Encapsulation sections as described in EN 301 192 [6]; LLC_SNAP_flag is set to one. The value of the LLC/SNAP header is 0xAA-AA-03-00-80-C2-00-07. Each Ethernet MAC frame shall be carried in a single section.

A.6.2.2 Addressing

In upstream framing structure and in downstream out-of-band framing structure, the addressing of a specific NIU/STB is done with a VPI/VCI pair. At least one VPI/VCI pair is assigned per NIU/STB. The VPI/VCI pairs according to Table A.61 are reserved.

All other VPI/VCI pairs can be assigned by the INA for carrying Ethernet traffic. The VPI/VCI is provided through the DVB MAC protocol.

A.6.3 PPP

The goal of this clause is to allow compatible and interoperable implementations for transmitting PPP packets over ATM AAL5 and DVB Multiprotocol Encapsulation [6], as used by this annex for upstream and downstream transmission.

A.6.3.1 Framing

The implementation shall be done according to the RFC 2364 [22], paragraph 5.

A.6.3.1.1 Upstream and OOB downstream

The PPP frame shall be carried as such in the payload of the AAL5 CPCS-PDU. This method is described in RFC 2364 [22], Figure 1. The flag sequences that delimit the beginning and the end of each frame, do not exist any more. The Asynchronous Control Character Map (ACCM) is not negotiated. In this way, the stuffing procedure is no longer necessary.

A.6.3.1.2 IB downstream

The PPP datagrams shall be carried in the payload of the DSM-CC sections as described in EN 301 192 [6] (DVB multiprotocol encapsulation) with the LLC_SNAP_flag set to one. The encapsulation of PPP into LLC/SNAP is defined in RFC 2364 [22] "PPP over AAL5" (with the NLPID value for PPP set to 0xCF). Each PPP frame shall be carried in a single section.

A.6.3.2 Addressing

In upstream framing structure and in downstream out-of-band framing structure, the addressing of a specific NIU/STB is done with a VPI/VCI pair. At least one VPI/VCI pair is assigned per NIU/STB. The VPI/VCI pairs according to Table A.61 are reserved.

All other VPI/VCI pairs can be assigned by the INA for carrying PPP traffic. Each PPP connection will be associated to one VPI/VCI provided through the MAC DVB RC protocol.

A.6.3.3 IP address assignment

After receiving the MAC Connect confirm message, the NIU/STB uses the IPCP protocol included in the PPP protocol, according to RFC 1332 [23] to get an IP address from the network. The PPP protocol supports the case of a fixed IP address assigned to the STB/NIU.

In the case a fixed IP address has been assigned to the NIU/STB by the operator, the IPCP protocol shall be used to make this IP address known to the INA. The PPP IPCP *Configure-Request* of the NIU/STB states which IP address is used.

The INA can provide an(other) IP address by NAKing this option, and returning a valid IP-address. The NIU/STB shall use this IP address even in the case, the NIU/STB has a fixed one.

A.6.3.4 Additional IP addresses

In the case the NIU/STB is also connected to customer premises equipment by a LAN, one of the following IP address assignment schemes shall be implemented:

1) The LAN has its own IP subnet address and subnet mask: In this case the NIU/STB acts like a router, i.e. the IP subnet address and subnet mask of the LAN is completely independent of the INA.
2) BOOTP/DHCP messages from the LAN are sent transparently through the PPP link to a server at the INA side.

Singlecast downstream traffic with a destination IP address not assigned through PPP or BOOTP/DHCP shall be discarded by the INA. Upstream traffic with a source host IP address not assigned PPP or BOOTP/DHCP shall be discarded by the NIU/STB and by the INA.

A.6.3.5 Security

The PAP or CHAP protocols will supply authentication and authorization mechanisms both included in PPP.

A.6.3.6 INA interfaces (Informative)

To be determined.

A.6.3.7 NIU/STB interfaces (Informative)

To be determined.

A.7 (Informative Note A) MAC State transitions and time-outs

The boxes (in Figure A.54) represent states, state transitions are represented by arrows. State transitions are triggered by events, denoted by: "Ex: <event>". Triggers are either the reception of MAC messages or time-outs. An event can lead to a state transition depending on a condition, this is denoted by "Ex: <event> && <condition>".

A time-out timer runs in all the states. The values of these time-out counters are denoted by Tx.

On the following pages the events are acompagnied by actions that are performed by the state machine during the state transition. Some actions are performed only under a certain condition. To make this clear, "if then else" constructions are used.

A.7.1 Initialization, Provisioning, Sign-on and Calibration

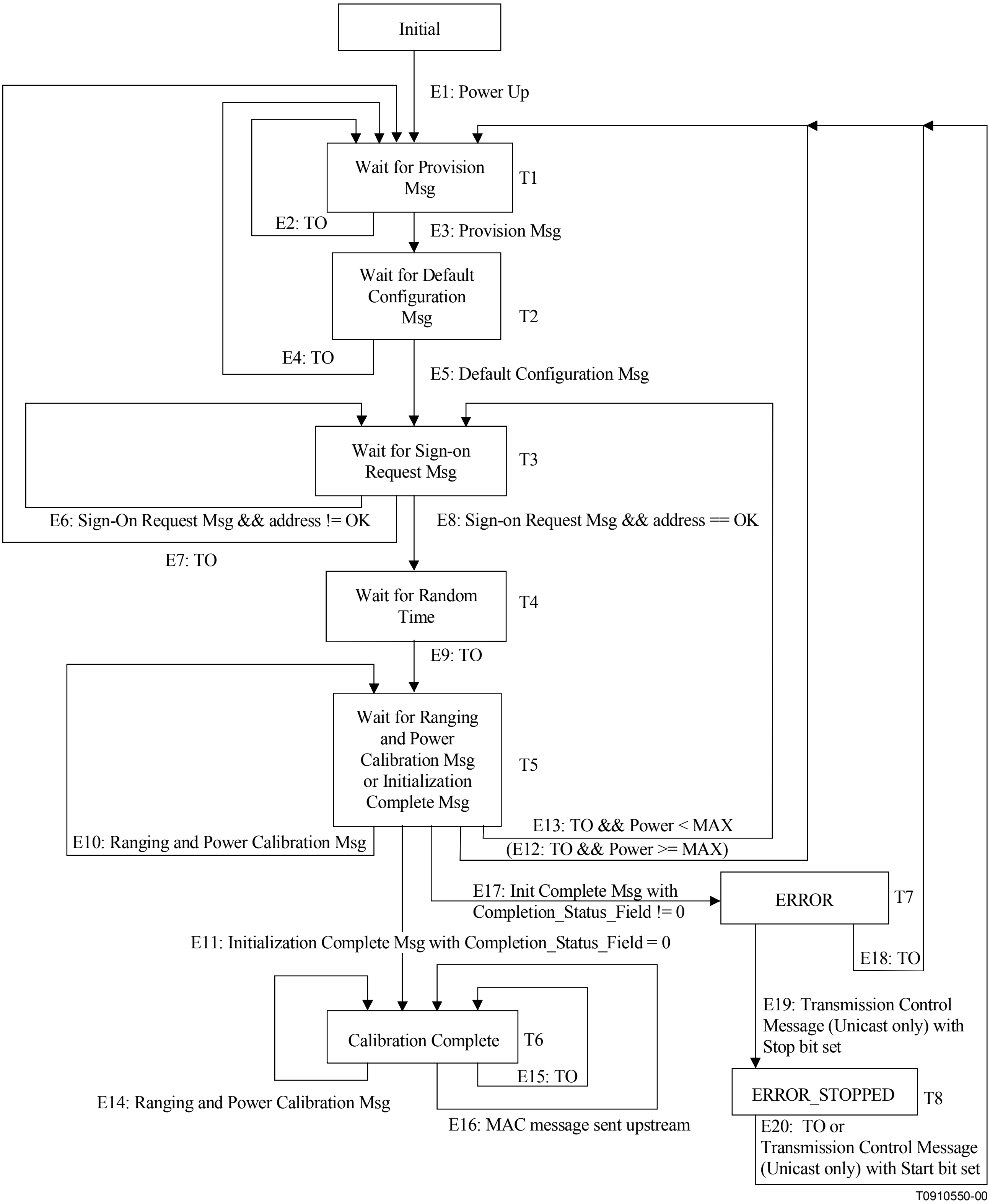


Figure A.54/J.112 – State diagram for ranging and calibration

E1 Power up:
Tune to any downstream channel
(re)set time-out to T1

E2 Time-out received:
Tune to next downstream channel
(re)set time-out to T1

E3 Provision Msg received:
IF current DS freq. != provision Freq.
Tune provision channel
(re)set time-out to T2

E4 Time-out received:
Do nothing
(re)set time-out to T1

E5 Default Configuration Msg received:
Tune to service channel
TimeOffset = Absolute_Time_Offset
Output_Power_Level = MIN_Power_Level
Power_Retry_Count = 0
Sign-On_Retry_Count = 0
(re)set time-out to T3

E6: Sign-on Msg && address != OK:
Do nothing
(re)set time-out to T3

E7: Time-out received:
Do nothing
(re)set time-out to T1

E8: Sign-on Msg && address == OK:
Sign-On_Retry_Count = min (Sign-On_Retry_Count+1, 255)
(re)set time-out to T4

E9: Time-out received:
Send Sign-on Response Msg in ranging area
(using last succesful power and timing settings, if allowed)
(re)set time-out to T5

E10: Ranging and Power Calibration Msg:
Time_Offset = Time_Offset + Time_Offset_Value
Output_Power_Level = min (Output_Power_Level + Power_Control_Setting × 0.5 dB,
MAX_Power_Level)
IF Ranging_Slot_Included
send Ranging and Power Calibration Response Msg on Ranging_Slot_Number
ELSE
send Ranging and Power Calibration Response Msg in ranging area
(re)set time-out to T5

E11 Initialization Complete Msg with Completion_Status_Field = 0:
(re)set time-out to T6

E12 Time-out received && Power >= MAX:
Do nothing
(re)set time-out to T1

```
E13   Time-out received && Power < MAX:
      Power_Retry_Count++
      IF Power_Retry_Count < Sign_On_Incr_Pwr_Retry_Count
          Do Nothing
      ELIF Tuned to Backup Service Channel
          Tune to Service Channel
          Output_Power_Level = min (Output_Power_Level + x dB, MAX_Power_Level)
          Power_Retry_Count = 0
      ELIF Service Channel != Backup Service Channel          (x ∈ [0.5...2])
          Tune to Backup Service Channel
          Power_Retry_Count = 0
      ELSE
          Output_Power_Level = min (Output_Power_Level + x dB, MAX_Power_Level)
          Power_Retry_Count = 0
      (re)set time-out to T3                                  (x ∈ [0.5...2])

E14   Ranging and Power Calibration Msg:
      Absolute_Time_Offset = Absolute_Time_Offset + Time_Offset_Value
      Output_Power_Level = min (Output_Power_Level + Power_Control_Setting × 0.5 dB,
                    MAX_Power_Level)
      IF Ranging_Slot_Included
          send Ranging and Power Calibration Response Msg on Ranging_Slot_Number
      ELSE
          send Ranging and Power Calibration Response Msg in ranging area
      (re)set time-out to T6

E15   Time-out received
      Send Idle Mgs
      (re)set time-out to T6

E16   MAC message sent upstream
      (re)set time-out to T6

E17   Initialization Complete Message received with Initialization Field != 0
      Set time-out to T7
      Go to ERROR state

E18   Time-out received
      Set time-out to T1
      Go to Wait_for_Provisioning state

E19   Transmission Control Message received (in Unicast address only) with Stop bit set
      Reset time-out to T8
      Go to ERROR_STOPPED state

E20   Transmission Control Message received (in Unicast address only) with Start bit set OR
      Time-out received
      Set time-out to T1
      Go to Wait_for_Provisioning state
```

Table A.62 links the time-out of the State Transition Diagram to the time-outs in the ETS 300 800 [24].

Table A.62/J.112 – Time-outs NIU SignOn STD

Time-out	Description	Code (see Def. Conf. Msg.)
T1	Provision Interval	Fixed 900 ms
T2	Default Configuration Interval	0x2
T3	Sign-on Message Interval	0x2
T4	Random (ResponseCollectionTimeWindow)	See Sign-on Requ. Msg.
T5	Sign-on Response → Rang. and Power Calibr. Sign-on Resp. → Initial. Complete Rang. and Power Calibr. Resp. → Rang. and Power Cal. Rang. and Power Calibr. Resp. → Initial. Complete	0x3
T6	Idle Interval	See Def. Conf. Msg.
T7	ERROR state to Wait_for_Provisioning interval	0x04
T8	ERROR_STOPPED state to Wait_for_Provisioning interval	Fixed 10 minutes

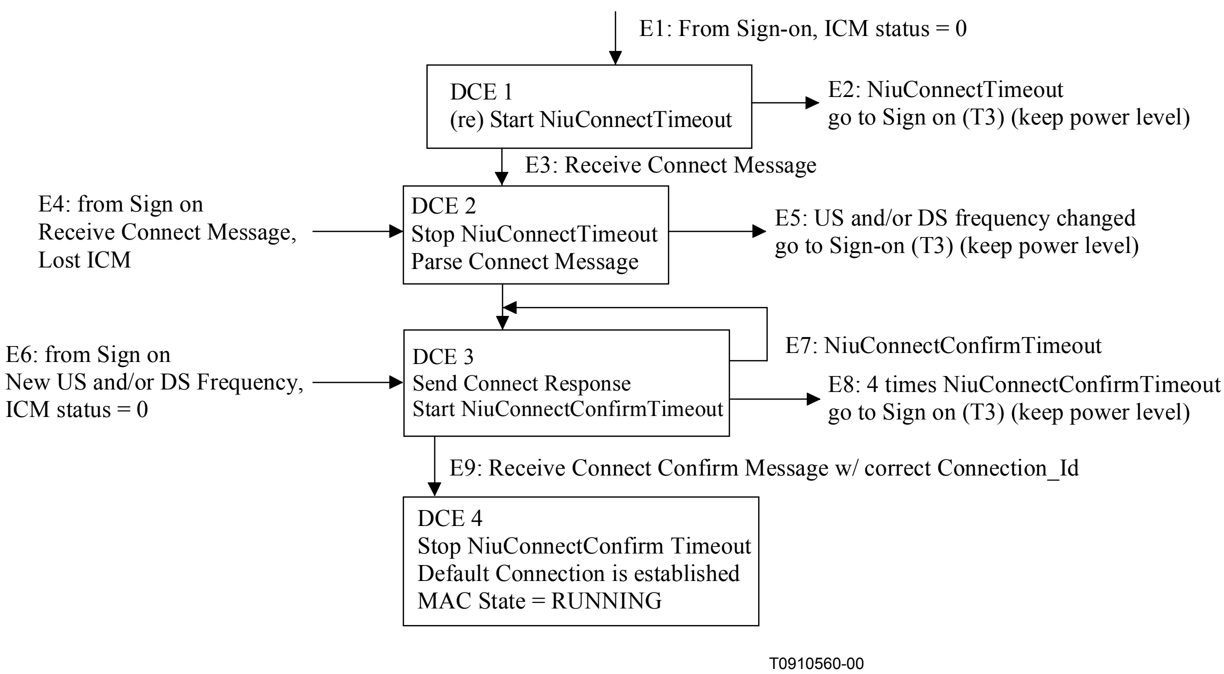
A.7.2 Connection establishment

Two cases of connection establishment exist: connection establishment of the first or default connection, and connection establishment of additional connections after the default connection has been successfully established.

If the STB detects the continuous loss of carrier or framing for longer than LofTimeout, then the STB will consider all connections released and will go to the Wait for Log-in state (T0?).

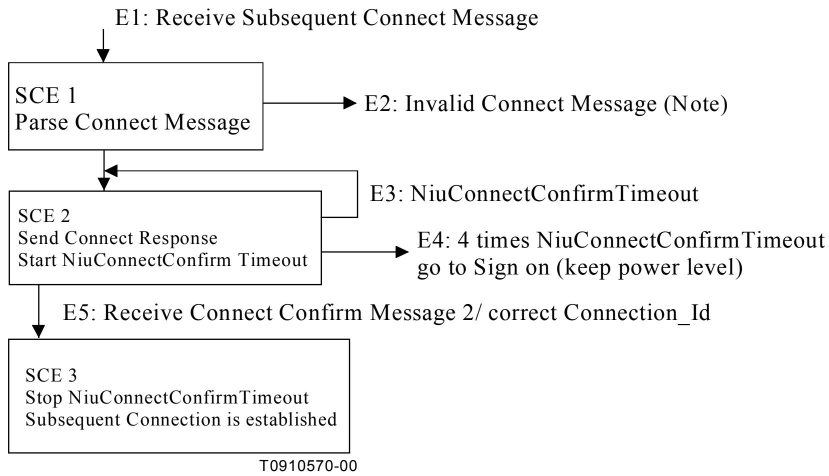
Default Connection Establishment

This procedure is started after a successful Sign-on and Calibration procedure. A special case exists when the STB loses the Initialization Complete Message but receives a Connect Message. In this special case, the STB shall proceed as if the Initialization Complete Message had been received.



Subsequent Connection Establishment

This procedure can be entered only when the STB has at least one operating (i.e. not STOPPED via a TCM) connection.

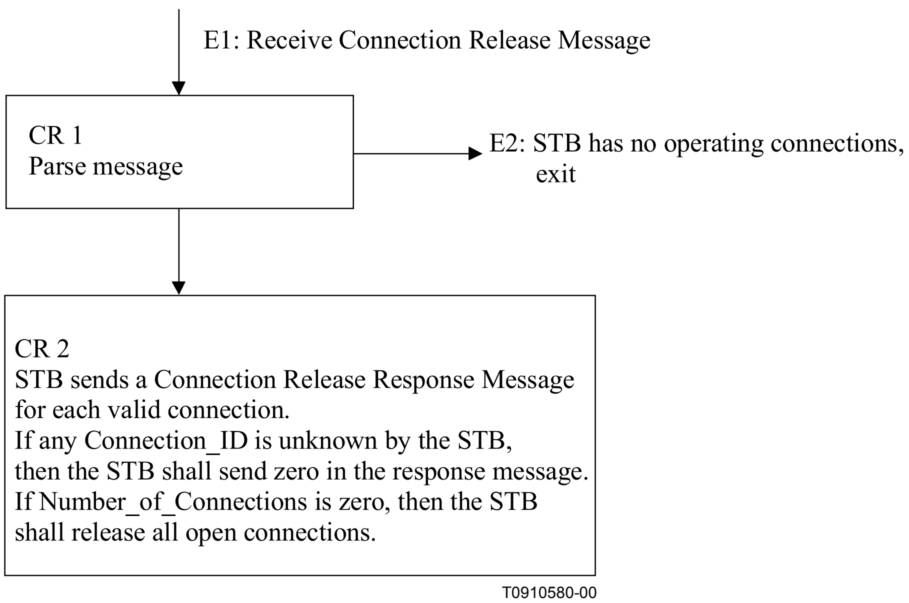


NOTE – Subsequent Connect Message Validity

```
if (US frequency is different than the current US frequency) {
    message invalid
}  else if (Connect Message contains both an IB and OOB DS frequency) {
    message invalid
}  else if (Connect Message contains an IB freq and the STB currently has an open connection on a different IB freq) {
    message invalid
}  else if (Connect Message contains an OOB freq and the STB currently has an open connection on a different OOB freq) {
    message invalid
}
```

A.7.3 Connection release

The STB may release connections only when it has at least one operating (i.e. not STOPPED by TCM) connection. If the STB has its number of connections reduced to one connection, then the remaining connection is considered the default connection.

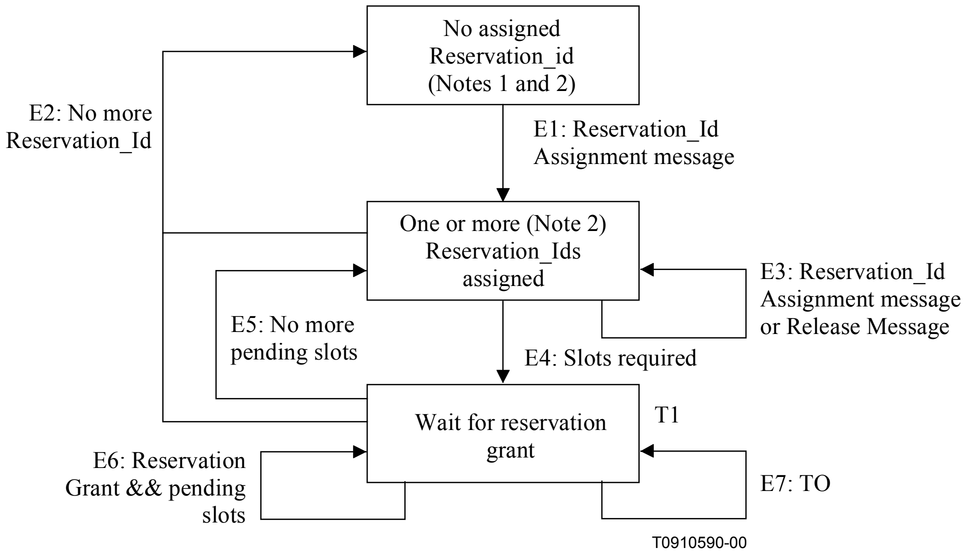


A.7.4 Reservation process

The figure below gives a state diagram of the reservation process. The boxes represent states, state transitions are represented by arrows. State transitions are triggered by events, denoted by: "Ex:<event>". Triggers are either the reception of MAC messages or time-outs. An event can lead to a state transition depending on a condition; this is denoted by "Ex:<event>&&<condition>".

A pending slot is defined as a slot for which no reservation request has been sent yet.

A requested slot is defined as a slot for which a reservation request has already been sent, but which is not yet granted.



NOTE 1 – 'No assigned Reservation_Id' State is to be linked to the state diagram of connection establishment process.
NOTE 2 – No Time-out is associated to this state since when transition shall occur is not in the scope of the specification.

E1 Reservation_Id Assignment message:

If a 'Reservation_Id assignment' message is received with a valid Connection_Id,

Send a 'Reservation_Id response' message

Consider new parameters

Go to 'One or more Reservation_Ids assigned'

E2 No more Reservation_Id:

If a 'Release' message closes the last connection with an assigned Reservation_Id,

Delete all slots allocated in reservation region for this connection

Go to 'No assigned Reservation_Id' state

If a 'Reprovisioning' message is received with 'Delete_Reservation_Ids' bit set,

Delete all slots allocated in reservation region

Go to 'No assigned Reservation_Id' state

E3 'Reservation_Id Assignment' message or 'Release' message:

If a 'Release' message closes the connection with an assigned Reservation_Id (but not the last),

Delete all slots allocated in reservation region for this connection

Stay in same state

If a 'Reservation_Id Assignment' message is received with a valid Connection_Id,

Consider new parameters

Send a 'Reservation_Id_Response' message

Stay in same state

E4 Reservation slots are required by the NIU:
If Piggyback allowed and is being implemented,
Send Piggyback request by setting the appropriate GFC field bit on any upstream ATM cell of this connection
OR
Send a 'Reservation Request' message with Reservation_Id corresponding to the connection
Maintain count of pending slots and requested slots for this connection
Set a timer to T1 (equal to 'grant_protocol_timeout' associated to the Reservation_Id)
Go to 'Wait for reservation grant' state
OR
If (Continuous_Piggy_Back_Timeout != 0) and (continuous piggyback timer not elapsed),
Send a 'Request indication' via Piggybacking in the last granted slot indicating the request of the minimum number of slots possible
If this is the first continuous Piggyback request, set timer for continuous piggybacking to "Continuous_Piggy_Back_Timeout"
Set timer of the connection to T1 (function of 'grant_protocol_timeout' associated to the Reservation_Id)
Go to 'Wait for reservation grant' state

E5 Reservation Grant message granting all requested slots:
If a 'reservation grant' message grants all the previous requests (i.e. with 'remaining_slot_count' field set to 0) and no pending slots,
Disable active timers
Go to 'One or more Reservation_Ids assigned' state

E6 Reservation Grant message but requested slots still to be granted:
If a 'reservation grant' message grants previous requests (but not all or some with 'remaining_slot_count' field different from 0)
For connection with request not completely granted
Set timer of the connection to T1 (equal to 'grant_protocol_timeout' associated to the reservation_Id)
Update number of requested slots with 'granted slot count' field
If 'remaining_slot_count' < 15 and (pending_slot_count != 0 or requested_slot_count != remaining_slot_count)
If Piggyback allowed and is being implemented
Send Piggyback request by setting the appropriate GFC field bit on the next upstream ATM cell – either a contention based ATM cell, a reservation based PDU or a fixed access based ATM cell
OR
Send a 'Reservation Request' message with reservation_Id corresponding to the connection
Maintain count of pending slots and requested slots for this connection
For completely granted connection
Disable timer of the connection
Set number of requested slots to 0 for this connection
If pending slots exist
If Piggyback allowed and is being implemented
Send Piggyback request by setting the appropriate GFC field bit on the next upstream message – either a contention based ATM cell, a reservation based PDU or a fixed access based ATM cell
OR

Send a 'Reservation Request' message with reservation_Id corresponding to the connection

Maintain count of pending slots and requested slots for this connection

Set timer of the connection to T1 (function of 'grant_protocol_timeout' associated to the reservation_Id)

If new slots are required for a connection, update number of pending slots.

Stay in same status

E7 Time-out received:

If an active timer ellapsed,

Send a reservation status request message for the associated connection

Set timer of the connection to T1 (function of 'grant_protocol_timeout' associated to the Reservation_Id)

If new slots are required for a connection, update number of pending slots.

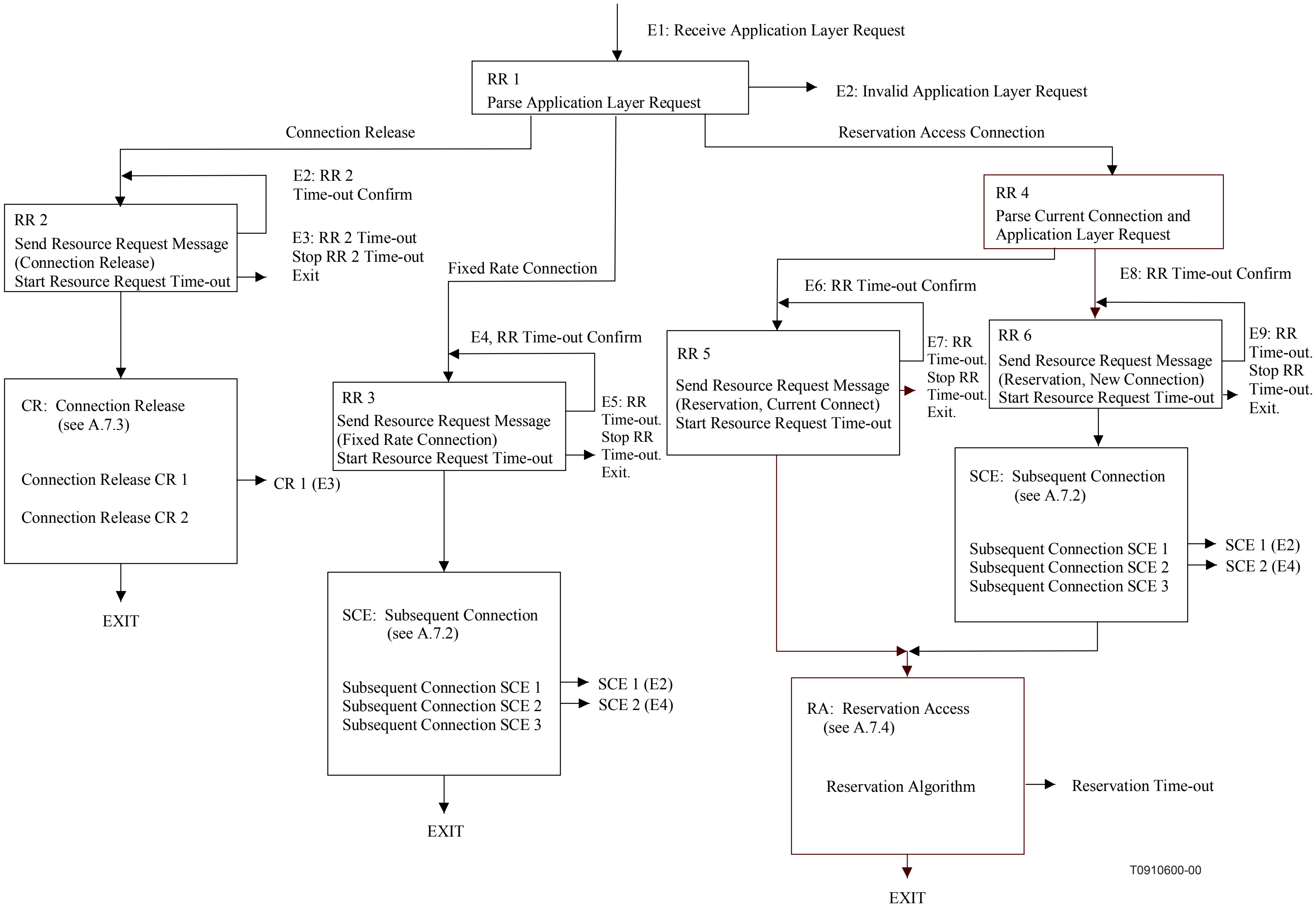
Stay in same status

Time-out T1 is dynamically set by the INA in the 'Reservation_Id_Assignment' message (grant_protocol_timeout parameter).

A.7.5 Resource request

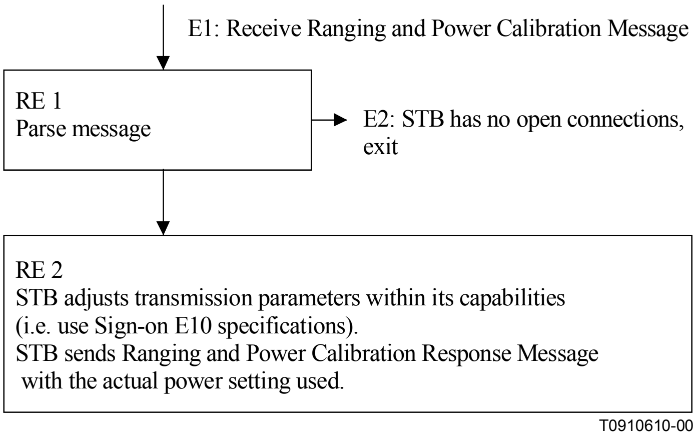
The NIU uses the <MAC> Resource Request Message to request a new connection or to change the parameters associated with an existing connection. In the above cases the resource allocation process is initiated by the NIU. After this initiation, the connections are allocated or changed by the INA using the MAC processes previously defined.

The following gives a state diagram of the Resource Request Processes, in terms of the processes already described and using the terminology as in the previous clauses.


E1: Receive Application Layer Request
RR 1
Parse Application Layer Request
E2: Invalid Application Layer Request
Connection Release
Reservation Access Connection
E2: RR 2
Time-out Confirm
RR 2
Send Resource Request Message
(Connection Release)
Start Resource Request Time-out
E3: RR 2 Time-out
Stop RR 2 Time-out
Exit
Fixed Rate Connection
RR 4
Parse Current Connection and
Application Layer Request
E8: RR Time-out Confirm
E6: RR Time-out Confirm
E4, RR Time-out Confirm
RR 5
Send Resource Request Message
(Reservation, Current Connect)
Start Resource Request Time-out
E7: RR
Time-out.
Stop RR
Time-out.
Exit.
RR 6
Send Resource Request Message
(Reservation, New Connection)
Start Resource Request Time-out
E9: RR
Time-out.
Stop RR
Time-out.
Exit.
CR: Connection Release
(see A.7.3)
Connection Release CR 1
Connection Release CR 2
CR 1 (E3)
RR 3
Send Resource Request Message
(Fixed Rate Connection)
Start Resource Request Time-out
E5: RR
Time-out.
Stop RR
Time-out.
Exit.
SCE: Subsequent Connection
(see A.7.2)
Subsequent Connection SCE 1
Subsequent Connection SCE 2
Subsequent Connection SCE 3
SCE 1 (E2)
SCE 2 (E4)
EXIT
SCE: Subsequent Connection
(see A.7.2)
Subsequent Connection SCE 1
Subsequent Connection SCE 2
Subsequent Connection SCE 3
SCE 1 (E2)
SCE 2 (E4)
EXIT
RA: Reservation Access
(see A.7.4)
Reservation Algorithm
Reservation Time-out
T0910600-00
EXIT

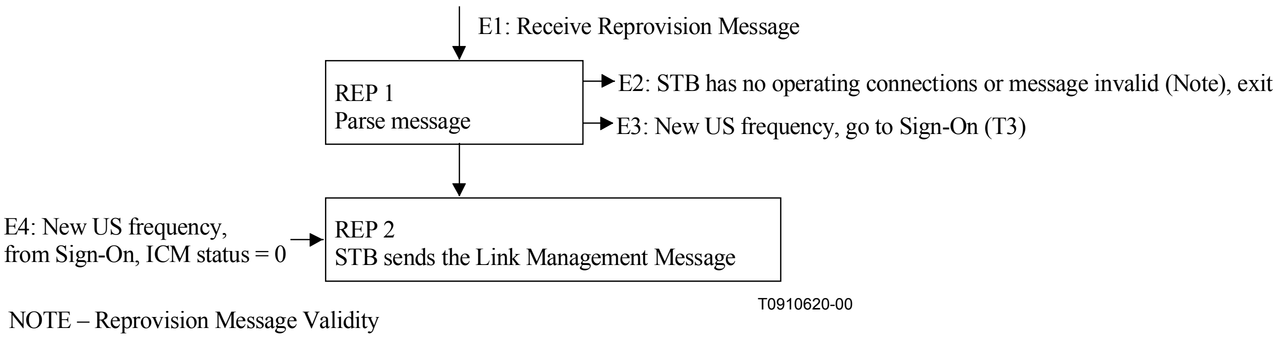
A.7.6 Recalibration

The STB may be recalibrated whenever it has at least one open (i.e. STOPPED or RUNNING) connection.



A.7.7 Reprovision message

The STB can be reprovisioned whenever it has at least one operating connection.

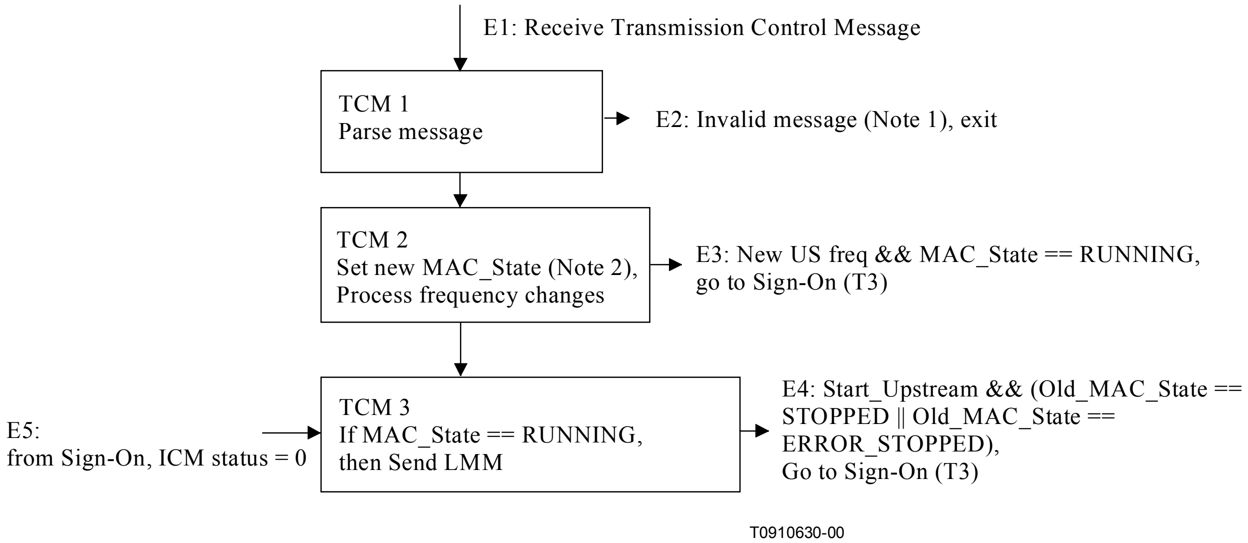


NOTE – Reprovision Message Validity
Besides invalid parameter values, the received Reprovision Message will be considered invalid of the message contains both new Cyclic and Slot List assignments

A.7.8 Transmission Control Message

The Transmission Control Message (TCM) controls aspects of upstream and downstream transmission. The commands are sent to the STB in either broadcast or singlecast mode. The STB is in one of the following MAC states:

– RUNNING: the STB has at least one operating connection.
– STOPPED: the STB has received a TCM stop_upstream_transmission command.
– ERROR: the STB has received a ICM with non-zero Completion_Status_Field.
– ERROR_STOPPED: the STB was in the ERROR state and received a TCM stop_upstream_transmission command.
– NONE: the STB has no open connections.



NOTE 1 – Invalid TCM

Besides invalid parameter values, the received TCM will be considered invalid if (Start_Upstream_Transmission && Stop_Upstream_Transmission) or (Old_Frequency != CurrentFrequency) in which case the STB will ignore the message.

NOTE 2 – New MAC

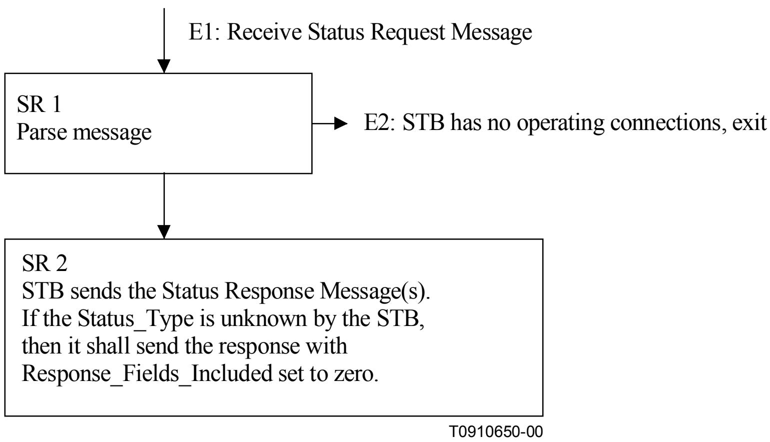
```
if (Start_Upstream_Transmission == 0 && Stop_Upstream_Transmission == 0) {
New_MAC_State = Old_MAC_State

} else if (Start_Upstream_Transmission == 0 && Stop_Upstream_Transmission == 1) {
        if (Old_MAC_State == ERROR) New_MAC_State = ERROR_STOPPED
        else if (Old_MAC_State == ERROR_STOPPED) New_MAC_State = ERROR_STOPPED
        else New_MAC_State = STOPPED

} else if (Start_Upstream_Transmission == 1 && Stop_Upstream_Transmission == 0) {
        if (Old_MAC_State == ERROR) New_MAC_State = ERROR
        else if (Old_MAC_State == ERROR_STOPPED && Broadcast) New_MAC_State = ERROR_STOPPED
        else New_MAC_State = RUNNING
}
```

A.7.9 Status Request Message

The STB can be queried for status whenever it has at least one operating connection.



A.7.10 Idle Message

The Idle Message is sent during periods of Upstream MAC message inactivity that exceeds a non-zero Idle_Interval by the STB whenever it has at least one operating connection.

A.8 MAC primitives (Informative)

In order to provide a common way to interface to the MAC functions, primitives are defined above the MAC Layer. These primitives are intended to cover both the Cable Modem (CM) and Set-Top Box (STB) applications, and the INA function of the Headends.

The MAC responsibility is mainly:

- the synchronization of the STB/CM to the network (initial physical link set-up) and establishment of the initial Connection;
- the management of the subsequent Connections between the INA and the STB/CM. (It gets the Connections allocated by the INA and insures also the functions relative to the various modes of communication, for example the acknowledgement of contention based transmissions or the reservation requests of bandwidth when needed);
- the periodical Link Management functions that insure a correct physical link (for example the power level and time offset modifications, or the re-assignations of resources requested by the INA).

The interface between MAC and the upper layer has been implemented using primitives. They have been defined as usually in the OSI layer model architecture.

Prefix: Identifier of the layer that provides the service.

Core: Name of the primitive, it is relative to the action performed.

Suffix: Indication of the data direction.

The advantage of primitives is that they provide a clear and deterministic mean of exchange between layers. In addition, this method permits an easier adaptation work as the final products can be implemented with various physical links between the NIU and the upper entity.

The MAC primitives can be split into two sets:

- The MAC Control and Resource primitives cover the signalling and link management information exchange between the MAC layer and the management entity of the STB/CM or the INA (see A.8.1).
- The MAC Data primitives cover the transport of data application payload between the MAC layer and upper layer entities (see A.8.2).

The primitives correspond to an event. They carry parameters. In order to facilitate their identification and by consequence their processing they are identified by a unique id.

The Id (Primitive_Id) is coded in 16 bits. The rules of numbering are:

- b15-b12 – Layer : 0 = MAC; 1 = DL (other values (2 to 0xF) are reserved)
- b11 – Control/Data: 1 = control primitive, 0 = data primitive
- b10-b0 – Primitive Nb: root value of the Primitive_Id

The root value of the Primitive_Id will be assigned starting from the value 1.

The primitives correspond to the definition of services that are deduced from the features of the MAC layer. But the various implementations of this annex will probably need more information exchanges based on new messages for manufacturers' specificity. In order to allow the definition and usage of proprietary primitives, the values starting at 0x7FF and assigned on a decreasing scheme down to 0x400 can be used.

All parameters of the primitives are coded in the order they are listed, with the MSB first for each parameter. Unless otherwise noted, the type of the parameters is unsigned integer.

A.8.1 Control and Resource primitives

A.8.1.1 On STB/CM side

A.8.1.1.1 <Prim> MAC_ACTIVATION_REQ

Parameter	Format	Comment
Primitive_Id	16	0x0801
DS_Type	8	Downstream type
DS_IB_Symb_Rate_Nb	8	Number of In-Band Symbol rates to try
DS_IB_Symb_Rate_List	16 [Nb]	List of Symbol rate values (in ksymb/s)
DS_Freq_Nb	8	Number of Frequencies to try
DS_Freq_List	32 [Freq_Nb]	List of Frequencies to try (in Hz)

The management entity asks the MAC layer to start the processing of network synchronization. It can provide the type of downstream channel. The list of frequencies is passed to accelerate the scanning. If no frequency is mentioned (Freq_Nb = 0), the MAC layer will make a scan on the full set of DVB-RC frequencies.

In In Band mode, the requestor can specify the Symbol rate. If it is not specified (i.e. DS_IB_Symb_Rate_Nb = 0), the MAC layer will try all the possible values.

After receiving this primitive, the MAC layer sets up the first frequency and starts the initial synchronization processing (Provisioning, Default Configuration, Sign-On exchange, Ranging and Power Calibration, Init Complete).

If it is not successful, the process is restarted for each new frequency in the list.

If all given frequencies in the list fail, a full scan is done.

When the Initialization Complete message is correctly decoded, or when the full set of frequencies and the full set of implemented downstream types has been tried without success, the primitive MAC_ACTIVATION_CNF is sent, specifying the success or the reason of the failure.

DS_Type: **0**: OOB 1.544 Mbit/s **1**: OOB 3.088 Mbit/s **2**: IB MPEG **255**: All possible

DS_IB_Symb_Rate_Nb: Number of In-Band Symbol Rate values to be used

DS_IB_Symb_Rate_List: Table of IB Symbol Rate values, unit is Ksymb/s

DS_Freq_Nb: Number of frequencies to try (next parameter)

DS_Freq_List: Table of frequency values, coded in hertz.

A.8.1.1.2 <Prim> MAC_ACTIVATION_CNF

Parameter	Format	Comment
Primitive_Id	16	0x0802
Error_Code	32	Success or reason of the failure
DS_Frequency	32	Downstream frequency effectively used
DS_Type	8	Downstream type effectively used
DS_Symb_Rate	16	Downstream In-Band symbol rate effectively used (Ksymb/s)
US_Frequency	32	Upstream frequency used
US_Type	8	Upstream type used
INA_Capabilities	32	Capabilities of the INA

This primitive indicates the result of the MAC_ACTIVATION_REQ or the change of any of the listed parameters (for example due to reprovisioning).

Error_code: A value of 0 means the success of the previous Activation Request; any other value will be used to indicate the reason of the failure. The least significant 8 bits are a copy of the Completion_Status_Field of the <MAC> Initialization Complete Message. If no <MAC> Initialization Complete Message was received, these bits are zero.

DS_Frequency: Value of the downstream frequency where the MAC locked; in hertz. Meaningless if Error_Code ≠ 0.

DS_Type: Downstream Type where the MAC locked (coding see above). Meaningless if Error_Code ≠ 0.

DS_Symb_Rate: Downstream symbol rate in Ksymb/s. Meaningless for Out-Of-Band and if Error_code ≠ 0.

US_Frequency: Upstream frequency used, in hertz. Meaningless if Error_code ≠ 0.

US_Type: 0: QPSK 256 kbit/s; 1: QPSK 1.544 Mbit/s; 2: QPSK 3.088 Mbit/s; 3: QPSK 6.176 Mbit/s; 4: 16-QAM 512 kbit/s; 5: 16-QAM 3.088 Mbit/s; 6: 16-QAM 6.176 Mbit/s; 7: 16-QAM 12.352 Mbit/s. Meaningless if Error_code ≠ 0.

INA_Capabilities: A copy of the INA_Capabilities field of the <MAC> Default Configuration Message in order to inform the higher layers of the NIU whether the INA is capable of Resource Requests, different encapsulation types, security, IB/OOB, ... Meaningless if Error_code ≠ 0.

A.8.1.1.3 <Prim> MAC_CONNECT_IND

Parameter	Format	Comment
Primitive_Id	16	0x0803
Connect_Id	32	Connection identifier
Res_Req_Id	8	If not null, correspond to the identifier of a previous Resource Request
US_Fixed_Bandwidth	32	Upstream capacity of the connection in Fixed rate mode
US_Frame_length	16	The frame length for fixed rate connections
US_Fixed_rate_distance	32	The distance between frames, for fixed rate connections
DS_VP_VC_valid	8	Validity flag of the 2 next fields
DS_VPI	8	VPI value to be filtered in downstream for this connection
DS_VCI	16	VCI value to be filtered in downstream for this connection
US_ frequency	32	The upstream frequency for this connection
US_VP_VC_valid	8	Validity flag of the 2 next fields
US_VPI	8	VPI value to be used in upstream for this connection
US_VCI	16	VCI value to be used in upstream for this connection
PID_valid	8	Validity flag of the next field
PID	32	MPEG PID value of the connection
MAC_add_valid	8	Validity flag of the next field
MAC_add	48	DSM-CC header MAC address of the connection
Encapsulation	8	Type of encapsulation for this connection

Parameter	Format	Comment
US_modulation_valid	8	Validity flag of the next field
US_modulation	8	The US modulation of the new connection
Priority_valid	8	Validity flag of the next field
Priority	8	Copy of the <MAC> Connect Message parameter
DS_Flowspec_valid		Validity flag of the next 3 fields
Max_packet_size	16	Copy of the <MAC> Connect Message parameter
Average_bitrate	16	Copy of the <MAC> Connect Message parameter
Jitter	8	Copy of the <MAC> Connect Message parameter
US_binding_valid	8	Validity flag of the next 10 fields
US_session_control_field	32	Control field for US session binding
NIU_client_source_IP_add	32	Copy of the <MAC> Connect Message parameter
NIU_client_destination_IP_add	32	Copy of the <MAC> Connect Message parameter
NIU_client_source_port	16	Copy of the <MAC> Connect Message parameter
NIU_client_destination_port	16	Copy of the <MAC> Connect Message parameter
Upstream_transport_protocol	8	Copy of the <MAC> Connect Message parameter
NIU_client_source_MAC_add	48	Copy of the <MAC> Connect Message parameter
NIU_client_destination_MAC_add	48	Copy of the <MAC> Connect Message parameter
US_internet_protocol	16	Copy of the <MAC> Connect Message parameter
US_session_Id	32	Copy of the <MAC> Connect Message parameter
DS_binding_valid	8	Validity flag of the next 10 fields
DS_session_control_field	32	Control field for US session binding
INA_client_source_IP_add	32	Copy of the <MAC> Connect Message parameter
INA_client_destination_IP_add	32	Copy of the <MAC> Connect Message parameter
INA_client_source_port	16	Copy of the <MAC> Connect Message parameter
INA_client_destination_port	16	Copy of the <MAC> Connect Message parameter
Downstream_transport_protocol	8	Copy of the <MAC> Connect Message parameter
INA_client_source_MAC_add	48	Copy of the <MAC> Connect Message parameter
INA_client_destination_MAC_add	48	Copy of the <MAC> Connect Message parameter
DS_internet_protocol	16	Copy of the <MAC> Connect Message parameter
DS_session_Id	32	Copy of the <MAC> Connect Message parameter

This primitive indicates that the MAC layer has received a Connect Message from the INA. The connection is either:

- the Default Connection (Connect Message) sent by the INA just after the Initialization Complete message (first connection);
- a subsequent Connect message;
- an answer to a Resource Request previously sent by the CM/STB (see Resource Request primitive);
- an indication of a change in the connection characteristics after reception of a Reprovisioning message.

Connect_Id: the identifier of the connection.

Res_Req_Id: If equal to 0, the connection corresponds to a spontaneous Connect Message coming from the INA; if not null, is the Id of the corresponding Resource Request.

US_Bandwidth: Gives the upstream transfer capacity in Fixed Rate mode (in slots/1200 ms). Zero if no fixed rate slots have been given by the INA.

US_Frame_length: The upstream frame length (slots), as given in the connect message, for fixed rate connections.

US_Fixed_rate_distance: The distance between frames, for fixed rate connections as given in the connect message.

DS_VPI/DS_VCI: VPI/VCI pair if the downstream CBD is mentioned in the Connect Message.

US_frequency: The connection upstream frequency, as mentioned in the Connect message.

US_VPI/US_VCI: VPI/VCI pair of the Upstream CBD, when this parameter is mentioned in the Connect Message. (This parameter is provided for implementations that compose the AAL5 CPCS-PDU outside the MAC layer.)

PID_valid: The PID in the next field is valid (0 means invalid parameter).

PID: In IB, the connection uses this PID. (This parameter is provided for implementations that insure data filtering outside the MAC layer.)

MAC_add: In IB/MPE, a Mac address can be provided for multicast. (This parameter is provided for implementations that insure section filtering outside the MAC layer.)

Encapsulation: Type of encapsulation provided. Correspond to the same field in the Connect message (i.e. Direct_IP, Ethernet_Mac_Bridging, PPP).

US_modulation_valid: The modulation in the next field is valid.

US_modulation: The upstream modulation of the new connection (as given in the connect message).

A.8.1.1.4 <Prim> MAC_RSV_ID_IND

Parameter	Format	Comment
Primitive_Id	16	0x0804
Connect_Id	32	Connection identifier
Res_Req_Id	8	If not null, corresponds to the identifier of a previous Resource Request

This primitive indicates to the upper layer that the connection can use Reservation mode from this time. It can be an answer to a previous Resource Request.

Connect_Id: the identifier of the connection.

Res_Req_Id: If equal to 0, the Reservation_Id corresponds to a spontaneous Reservation_Id_Assignment message coming from the INA. If not null, it gives the Identifier of a previous Resource Request.

A.8.1.1.5 <Prim> MAC_RELEASE_IND

Parameter	Format	Comment
Primitive_Id	16	0x0805
Connect_Id	32	Connection identifier
Res_Req_Id	8	If not null, corresponds to the identifier of a previous Resource Request

The MAC layer indicates that it has received a Release message for this connection from the INA.

Connect_Id: The identifier of the connection.

Res_Req_Id: If equal to 0, the primitive corresponds to a spontaneous Release message coming from the INA. If not null, it gives the Identifier of a previous Resource Request from the upper layer requesting the release.

A.8.1.1.6 <Prim> MAC_RESOURCE_REQ

Parameter	Format	Comment
Primitive_Id	16	0x0806
Connect_Id	32	Connection identifier
Resource_Type	8	Type of Resource requested
US_Bandwidth	32	Upstream transfer capability
Slot_distance	16	Distance between slots requested
Encapsulation	8	Type of encapsulation
Admit_flag	8	LSB to be copied to the corresponding flag in the <MAC> Res Req Message
Priority_valid	8	Validity flag of the next field
Priority	8	To be copied to the <MAC> Res Req Message
Frame_Length_valid	8	Validity flag of the next field
Frame_Length	16	To be copied to the <MAC> Res Req Message
DS_Flowspec_valid	8	Validity flag of the next 3 fields
Max_packet_size	16	To be copied to the <MAC> Res Req Message
Average_bitrate	16	To be copied to the <MAC> Res Req Message
Jitter	8	To be copied to the <MAC> Res Req Message
US_binding_valid	8	Validity flag of the next 10 fields
US_session_control_field	32	Control field for the US session binding
NIU_client_source_IP_add	32	To be copied to the <MAC> Res Req Message
NIU_client_destination_IP_add	32	To be copied to the <MAC> Res Req Message
NIU_client_source_port	16	To be copied to the <MAC> Res Req Message
NIU_client_destination_port	16	To be copied to the <MAC> Res Req Message
Upstream_transport_protocol	8	To be copied to the <MAC> Res Req Message
NIU_client_source_MAC_add	48	To be copied to the <MAC> Res Req Message
NIU_client_destination_MAC_add	48	To be copied to the <MAC> Res Req Message
US_internet_protocol	16	To be copied to the <MAC> Res Req Message
US_session_Id	32	To be copied to the <MAC> Res Req Message
DS_binding_valid	8	Validity flag of the next 10 fields
DS_session_control_field		
INA_client_source_IP_add	32	To be copied to the <MAC> Res Req Message
INA_client_destination_IP_add	32	To be copied to the <MAC> Res Req Message
INA_client_source_port	16	To be copied to the <MAC> Res Req Message
INA_client_destination_port	16	To be copied to the <MAC> Res Req Message
Downstream_transport_protocol	8	To be copied to the <MAC> Res Req Message
INA_client_source_MAC_add	48	To be copied to the <MAC> Res Req Message
INA_client_destination_MAC_add	48	To be copied to the <MAC> Res Req Message
DS_internet_protocol	16	To be copied to the <MAC> Res Req Message
DS_session_Id	32	To be copied to the <MAC> Res Req Message

This primitive is used by the upper layer to ask for new resource. The MAC layer will send a Resource Request message to the INA.

As specified in the Resource Request message definition, upper layer can ask for a new connection, or a new upstream capacity (fixed rate bandwidth or a Reservation id), or a connection release.

The final answer to this request shall be either a MAC_CONNECT_IND, or a MAC_RSV_ID_IND, or a MAC_RELEASE_IND or a MAC_RESOURCE_DENIED_IND.

Connect_Id: Is the identifier of the connection, if it exists. If the connection is for packet cable application, the number is the gate number associated with the connection (even if the connection does not exist).

Resource_Type: Type of Resource requested:

Bit field

- **bit 0** (0x01): a reservation id
- **bit 1** (0x02): a new connection in fixed rate mode
- **bit 2** (0x04): a new connection in cyclic fixed rate mode
- **bit 3** (0x08): upgrade bandwidth of an existing connection
- **bit 4** (0x10): release of an existing connection
- **bits 5 to 8**: reserved (must be set to 0)

US_Bandwidth: Requested bandwidth for Fixed rate mode; unit is in slots/1200 ms.

Slot_distance: When cyclic assignment is required, maximum distance between the slots; unit is in slots.

Encapsulation: Type of encapsulation requested. Corresponds to the same field in the Connect Message (i.e. Direct_IP, Ethernet_Mac_Bridging, PPP).

A.8.1.1.7 <Prim> MAC_RESOURCE_CNF

Parameter	Format	Comment
Primitive_Id	16	0x0807
Res_Req_Id	8	Identifier of the Resource Request

After reception of a MAC_RESOURCE_REQ, the MAC layer sends the Resource Request message to the INA, it creates an identifier and indicates it to the upper layer in order to identify the subsequent answer.

Res_Req_Id: The identifier of the last MAC_RESOURCE_REQ received by the MAC.

A.8.1.1.8 <Prim> MAC_RESOURCE_DENIED_IND

Parameter	Format	Comment
Primitive_Id	16	0x0808
Res_Req_Id	8	Identifier of the Resource Request

This primitive indicates the reception of a Resource Denied Message; it is received after a Resource Request that has been refused by the INA.

Res_Req_Id: The identifier of a previous Resource Request that has been denied by the INA.

A.8.1.2 On INA side

A.8.1.2.1 <Prim> MAC_INA_RESOURCE_REQ

Parameter	Format	Comment
Primitive_Id	16	0x0811
Primitive_Request_Id	16	Identifies the Primitive Request
MAC_address	48	MAC address of the NIU to which a new connection is requested
Connect_Id	32	Connection identifier; 0 or packet cable gate Id for a new connection
Resource_Type	8	Type of Resource requested
US_Bandwidth	32	Upstream bandwidth requested
Slot_distance	16	Maximum distance between slots in upstream requested
Frame_length	16	The frame length for fixed rate connections
Encapsulation	8	Type of encapsulation requested. Corresponds to the same field in the Connect Message (i.e. Direct_IP, Ethernet_Mac_Bridging, PPP)
Priority_valid	8	Validity flag of the next field
Priority	8	To be copied to the corresponding <MAC> Message
DS_Flowspec_valid		Validity flag of the next 3 fields
Max_packet_size	16	To be copied to the corresponding <MAC> Message
Average_bitrate	16	To be copied to the corresponding <MAC> Message
Jitter_	8	To be copied to the corresponding <MAC> Message
US_binding_valid	8	Validity flag of the next 10 fields
US_session_control_field	32	Control field for the US session binding
NIU_client_source_IP_add	32	To be copied to the corresponding <MAC> Message
NIU_client_destination_IP_add	32	To be copied to the corresponding <MAC> Message
NIU_client_source_port	16	To be copied to the corresponding <MAC> Message
NIU_client_destination_port	16	To be copied to the corresponding <MAC> Message
Upstream_transport_protocol	8	To be copied to the corresponding <MAC> Message
NIU_client_source_MAC_add	48	To be copied to the corresponding <MAC> Message
NIU_client_destination_MAC_add	48	To be copied to the corresponding <MAC> Message
US_internet_protocol	16	To be copied to the <MAC> Res Req Message
US_session_Id	32	To be copied to the <MAC> Res Req Message
DS_binding_valid	8	Validity flag of the next 10 fields
DS_session_control_field	32	Control field for the DS session binding
INA_client_source_IP_add	32	To be copied to the corresponding <MAC> Message
INA_client_destination_IP_add	32	To be copied to the corresponding <MAC> Message
INA_client_source_port	16	To be copied to the corresponding <MAC> Message
INA_client_destination_port	16	To be copied to the corresponding <MAC> Message
Downstream_transport_protocol	8	To be copied to the corresponding <MAC> Message
INA_client_source_MAC_add	48	To be copied to the corresponding <MAC> Message
INA_client_destination_MAC_add	48	To be copied to the corresponding <MAC> Message
DS_internet_protocol	16	To be copied to the <MAC> Res Req Message
DS_session_Id	32	To be copied to the <MAC> Res Req Message

This primitive is used by the upper layer to ask for a new resource. The upper layer can ask for a new connection, for the modification of an existing connection (e.g. fixed rate bandwidth or a reservation id), or for a connection release. The answer to this request shall be a <Prim> MAC_INA_RESOURCE_IND.

Primitive_Request_Id: Type of primitive requested.

MAC_address: MAC address of the NIU concerned by this request.

Connect_Id: Is the identifier of the connection, if it exists.

Resource_Type: Type of Resource requested:

Bit field

bit 0 (0x01): a reservation id

bit 1 (0x02): a new connection in fixed rate mode

bit 2 (0x04): a new connection in cyclic fixed rate mode

bit 3 (0x08): upgrade bandwidth of an existing connection

bit 4 (0x10): release an existing connection

bits 5 to 8: reserved (must be set to 0)

US_Bandwidth: Requested bandwidth for Fixed rate mode; unit is in slots/1200 ms.

Slot_distance: When cyclic assignment is required, maximum distance between the slots; unit is in slots.

US_Frame_length: The upstream frame length (slots), as given in the connect message, for fixed rate connections.

Encapsulation: Type of encapsulation requested. Corresponds to the same field in the Connect Message (i.e. Direct_IP, Ethernet_Mac_Bridging, PPP).

A.8.1.2.2 <Prim> MAC_INA_RESOURCE_IND

Parameter	Format	Comment
Primitive_Id	16	0x0812
Primitive_Request_Id	16	Identifies the Primitive Request; 0 if not requested by the STU/Headend Network Adapter
Connect_Id	32	Connection identifier
Resource_Type	8	Type of Resource allocated
Error_Code	32	Specifies the type of error, if happened; zero for no error
US_Bandwidth	32	Upstream Bandwidth allocated
Slot_distance	16	Maximum Distance between slots in upstream assigned
Frame_length	16	The frame length in slots, for fixed rate connections
Encapsulation	8	Type of encapsulation assigned. Corresponds to the same field in the Connect message (i.e. Direct_IP, Ethernet_Mac_Bridging, PPP)
Priority_valid	8	Validity flag of the next field
Priority	8	Copy of the corresponding <MAC> Message
DS_Flowspec_valid		Validity flag of the next 3 fields
Max_packet_size	16	Copy of the corresponding <MAC> Message

Parameter	Format	Comment
Average_bitrate	16	Copy of the corresponding <MAC> Message
Jitter	8	Copy of the corresponding <MAC> Message
US_binding_valid	8	Validity flag of the next 10 fields
US_session_control_field	32	Control field for US session binding
NIU_client_source_IP_add	32	Copy of the corresponding <MAC> Message
NIU_client_destination_IP_add	32	Copy of the corresponding <MAC> Message
NIU_client_source_port	16	Copy of the corresponding <MAC> Message
NIU_client_destination_port	16	Copy of the corresponding <MAC> Message
Upstream_transport_protocol	8	Copy of the corresponding <MAC> Message
NIU_client_source_MAC_add	48	Copy of the corresponding <MAC> Message
NIU_client_destination_MAC_add	48	Copy of the corresponding <MAC> Message
US_internet_protocol	16	To be copied to the <MAC> Res Req Message
US_session_Id	32	To be copied to the <MAC> Res Req Message
DS_binding_valid	8	Validity flag of the next 10 fields
DS_session_control_field	32	Control field for DS session binding
INA_client_source_IP_add	32	Copy of the corresponding <MAC> Message
INA_client_destination_IP_add	32	Copy of the corresponding <MAC> Message
INA_client_source_port	16	Copy of the corresponding <MAC> Message
INA_client_destination_port	16	Copy of the corresponding <MAC> Message
Downstream_protocol	8	Copy of the corresponding <MAC> Message
INA_client_source_MAC_add	48	Copy of the corresponding <MAC> Message
INA_client_destination_MAC_add	48	Copy of the corresponding <MAC> Message
DS_internet_protocol	16	To be copied to the <MAC> Res Req Message
DS_session_Id	32	To be copied to the <MAC> Res Req Message

This primitive indicates that the MAC layer has changed or released an existing connection or established a new connection. The connection is either:

- the Default Connection (Connect message sent by the INA just after the Initialization Complete message);
- a subsequent Connect message;
- an answer to a Resource Request previously sent by the CM/STB (see Resource Request primitive);
- an indication of a change in the connection characteristics after reception of a Reprovisioning message.

Primitive_Request_Id: Type of primitive requested.

Connect_Id: Is the identifier of the connection, if it exists.

Resource_Type: Type of Resource requested:

Bit field

bit 0 (0x01): a reservation id

bit 1 (0x02): a new connection in fixed rate mode

bit 2 (0x04): a new connection in cyclic fixed rate mode

bit 3 (0x08): upgrade bandwidth of an existing connection

bit 4 (0x10): release an existing connection

bits 5 to 8: reserved (must be set to 0)

Error_Code: If not null, the primitive is an answer to a previous MAC_Resource_REQ, and the request failed. The Error_Code value correspond to the problem (TBD). If the value is 0, the Resource has been successfully set.

DS_Bandwidth: Downstream Bandwidth requested. Unit to be determined.

DS_Jitter: Max. jitter in downstream requested. Unit to be determined.

US_Bandwidth: Requested bandwidth for Fixed rate mode; unit is in slots/1200 ms.

Slot_distance: When cyclic assignment is required, maximum distance between the slots; unit is in slots.

Encapsulation: Type of encapsulation requested. Corresponds to the same field in the Connect Message (i.e. Direct_IP, Ethernet_Mac_Bridging, PPP).

User_Port_valid: Validity flag of the next parameter (0 means invalid parameter).

User_Port_Id: Low latency Telephone port id.

Add_Port_Type: Bit field that specifies TCP/UDP Port number and IP address validity:

bit 0: next IP address fields are valid

bit 1: next Port nb fields are valid and are TCP port

bit 2: next Port nb fields are valid and are UDP port

bits 3 to 7: reserved (must be set to 0)

A.8.2 Data primitives

In this clause, two sets of primitives are presented: the first one at the Data Link level, the second at the MAC level. **One, and only one of them has to be used**; the choice will **depend on the CM/STB or INA respective implementations**.

The **DL_** primitives series is related to implementations where the MAC DVB-RC entity insures also the LLC function (in that case, it is in fact a Data Link layer).

- In OOB, it consists in AAL5 reassembly and datagram recomposition following the encapsulation mode of the connection (i.e. Direct_IP, Ethernet_MAC_bridging, PPP). The unit data are the datagrams.
- In IB, it consists in the MPE protocol filtering before datagram recomposition as in OOB.

The **MAC_** primitives series is intended to be used in systems where the MAC entity uses its native SDU as interface with the upper layer.

- In OOB, the ATM cells are the unit data exchanged.
- In IB, the downstream data unit is the payloads of the MPEG2_TS frame; the upstream data unit is the ATM cells.

A.8.2.1 <Prim> DL_DATA_IND

Parameter	Format	Comment
Primitive_Id	16	0x1001
Connect_Id	32	Connection identifier
Length	16	Length of the data buffer contained in the primitive
Data buffer	8 [Length]	Received Datagram

This primitive is used to transfer the application data filtered by the MAC layer. The Connection identifier can be used to mutiplex more efficiently the buffer when several connections exist.

A.8.2.2 <Prim> DL_DATA_REQ

Parameter	Format	Comment
Primitive_Id	16	0x1002
Connect_Id	32	Connection identifier
Length	16	Length of the data buffer contained in the primitive
Data buffer	8 [Length]	Datagram to be transmitted

The MAC layer is asked to transmit a network layer datagram. It will insure the segmentation function (and will use, in the NIU case, the upstream transmission mode of the connection).

A.8.2.3 <Prim> MAC_DATA_IND

Parameter	Format	Comment
Primitive_Id	16	0x0001
Connect_Id	32	Connection identifier
Data_Type	8	Type of data (ATM cells or MPEG packets)
Data_Unit_Nb	8	Number of ATM cells/MPEG packets contained in the primitive
Data_Unit_list	8 [Unit_Nb]	List of ATM Cells/MPEG packets

In OOB, when ATM cells whose VP/VC correspond to the value sent in a previous Connect Message, the MAC layer will then extract them from the physical frames and transfer to the application using this primitive. The broadcast VP/VC will also be taken into account.

In IB, the MAC layer filters the PID of the application, then extract the payload and passes it to the upper layer.

A.8.2.4 <Prim> MAC_DATA_REQ

Parameter	Format	Comment
Primitive_Id	16	0x0002
Connect_Id	32	Connection identifier
Content_retry_count	8	Number of retries in Contention mode
US_mode (NIU only)	8	Mode of Upstream transmission
ATM_Cells_Nb	8	Number of ATM cells/MPEG packets contained in the primitive
ATM_Cells_List	8 [ATM_Nb]	List of ATM Cells/MPEG packets

The upper layer asks the MAC layer to transmit messages. The data is formated as a variable list of ATM cells/MPEG packets.

In case of the NIU, the MAC layer is able to execute the transmission in the 3 modes defined by ETS 300 800. It is mentionned by the upper layer in the parameter US_mode that can take the following values:

Contention mode: As the ATM cells are transmitted in Contention region slots, each upstream packet must be acknowledged by the INA before the MAC layer sends the next one. If one acknowlegement is negative, the MAC layer will send it back "Contention_retry_count" times before stopping the transmission and indicating the error with the MAC_DATA_CONF primitive.

Reservation mode: Before sending the upper layer message, the MAC layer must ask for reserved slots by sending a Reservation Request message to the INA. When the reserved slots are allocated (Grant message), the MAC layer uses these slots to transmit the application message. Another case of reservation mode occurs when the upper layer asks for transmission in Contention mode, and the number of ATM cells exceeds the number of ATM cells permitted in Contention mode.

Fixed Rate mode: In this mode, the upper layer asks the MAC layer to use the Fixed Rate slots allocated to the connection.

A.8.2.5 <Prim> MAC_DATA_CONF

Parameter	Format	Comment
Primitive_Id	16	0x0003
Connect_Id	32	Connection identifier
Result	32	Success or reason of the failure. A value of 0 means the success of the previous Data Request; any other value will be used to indicate the reason of the failure (as mentioned below).
Data_Unit_Nb	8	Number of ATM cells/MPEG packets effectively transmitted
US_mode (NIU only)	8	The transmission mode effectively used

This primitive is sent as an answer to a previous MAC_DATA_REQ.

The Result parameter specifies the result of its execution. It can take the following values:

– "OK": The transmission succeeded.

– "Contention_Error": (NIU only) Contention_retry_count slots have not been acknowledged (in Contention mode); the transmission has stopped.

– "Reservation_Failure": (NIU only) The reservation request did not succeed (no answer from the INA to the request).

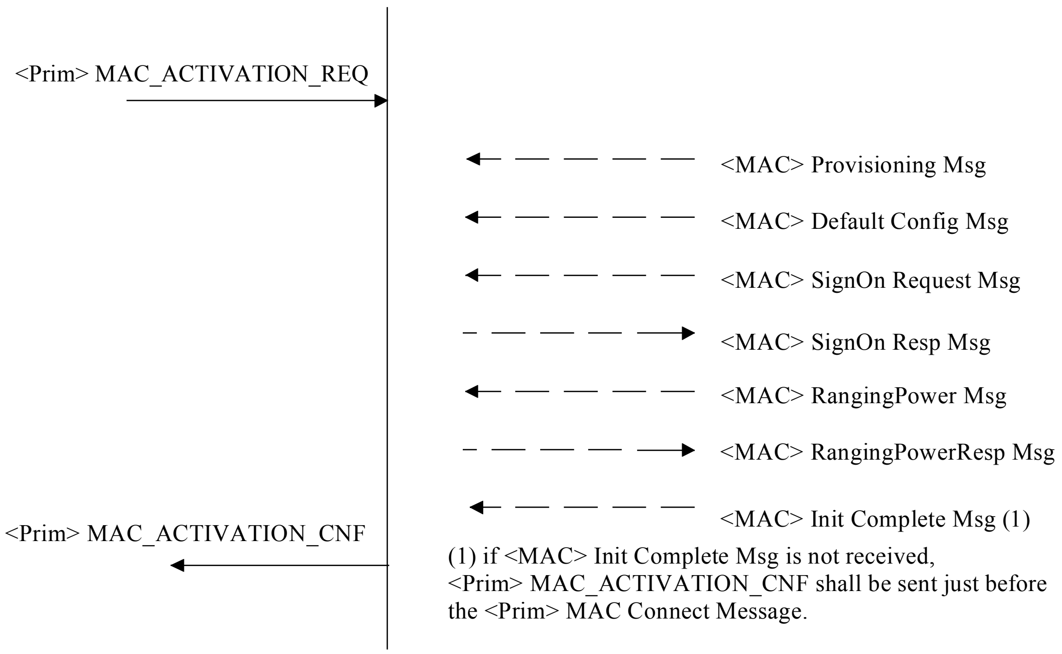
– "Reservation_Abort": (NIU only) Reservation request can be answered by several consecutive Grant messages; the sum of slots allocated in the successive Grant messages must then be equal to the requested number. This error occurs when Grant messages do not complete the number of slots in a predefined time-out.

– "Mode_Not_Permitted": (NIU only) If the application wants to use a transmission mode not allowed to this connection.

– "Unknown_Error": Error not identified.

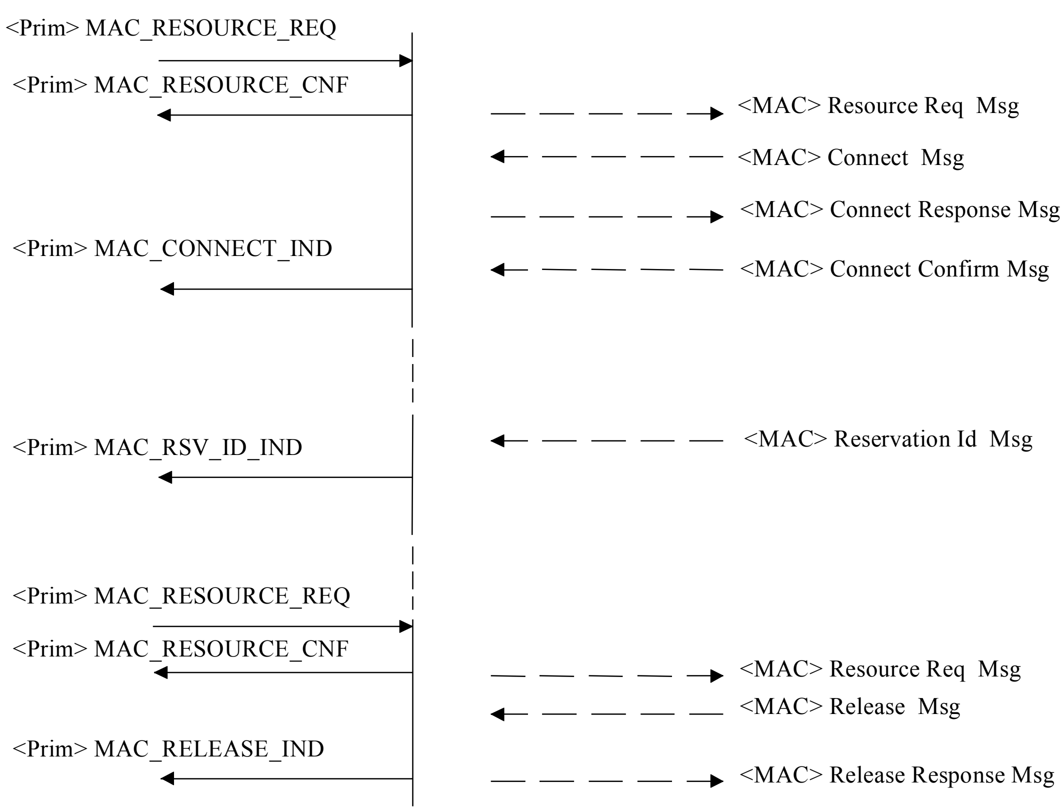
A.8.3 Example MAC Control scenarios

A.8.3.1 Example MAC Control scenario on STB/CM side



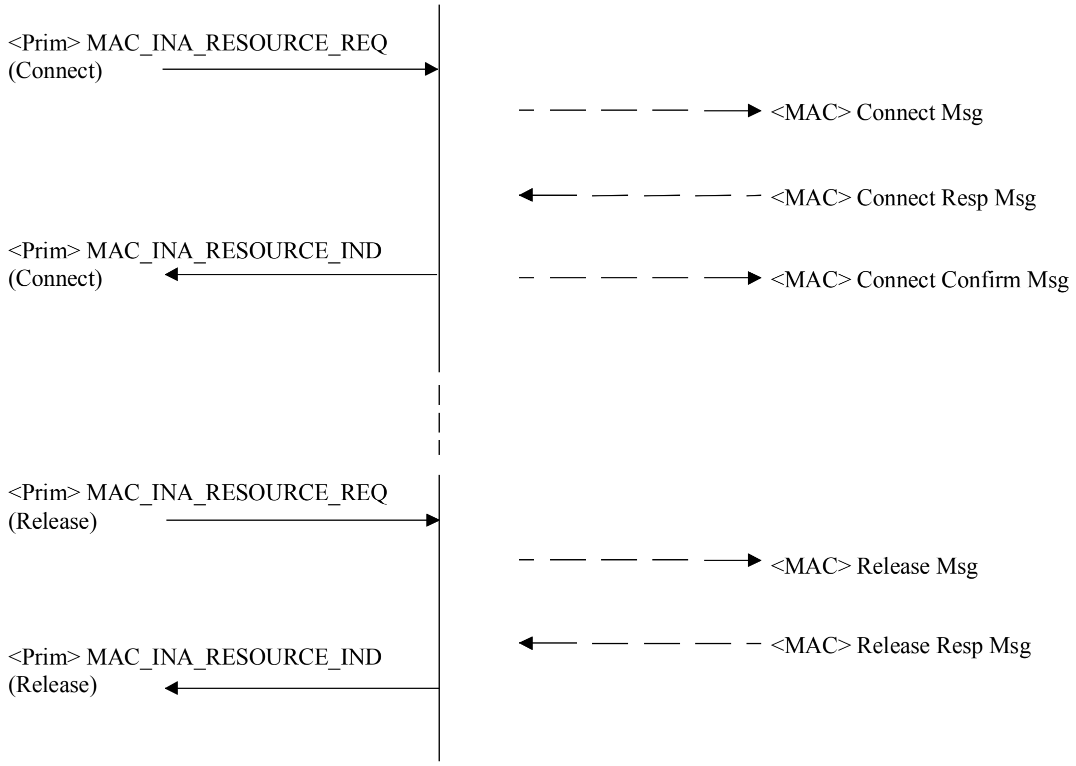
T0910660-00

A.8.3.2 Example Resource Management scenario on STB/CM side



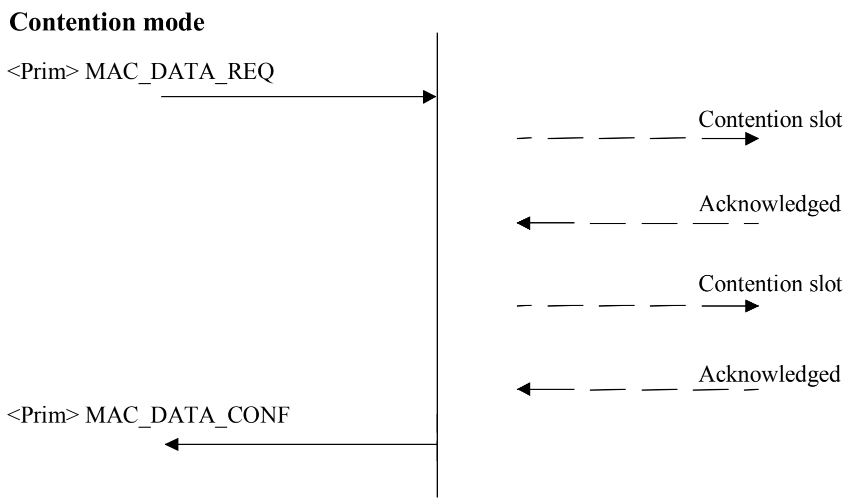
T0910670-00

A.8.3.3 Example Resource Management scenario on INA side

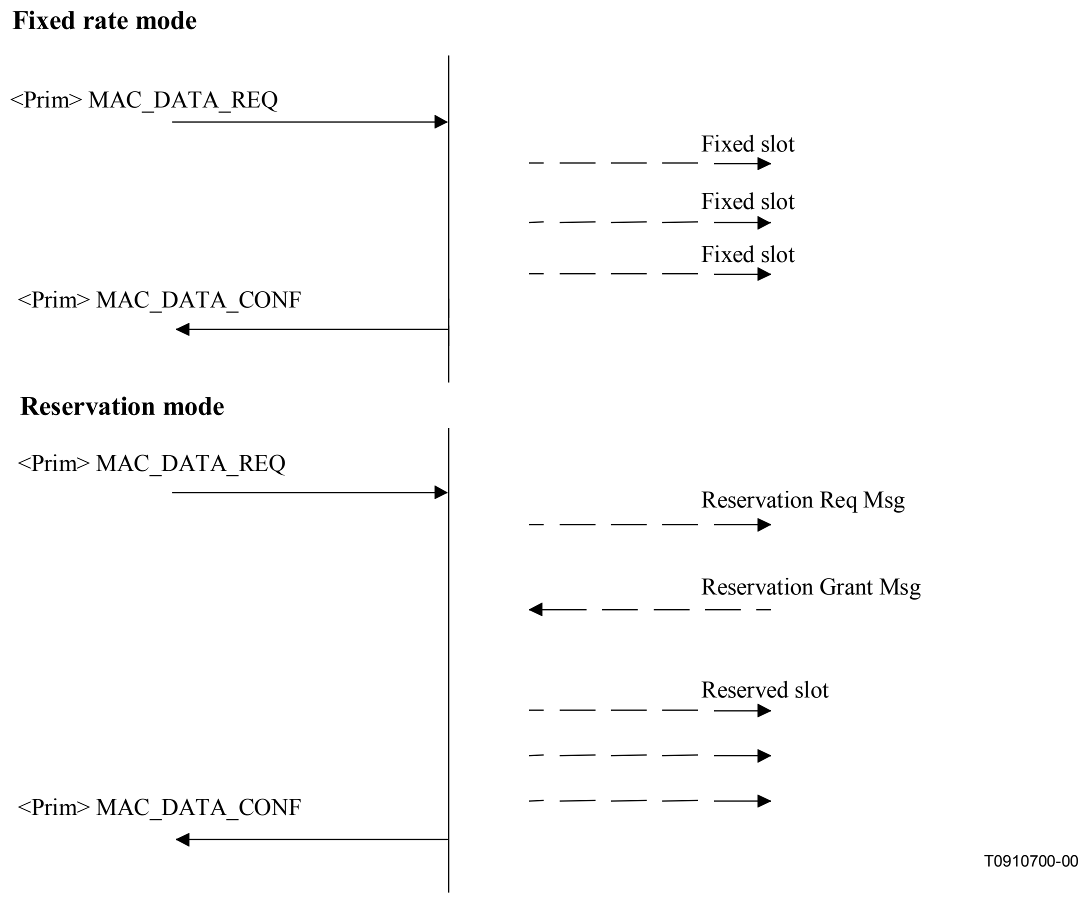


T0910680-00

A.8.3.4 Example Upstream Data Transfer scenarios



T0910690-00



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