INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

J.184

(03/2001)

SERIES J: CABLE NETWORKS AND TRANSMISSION OF TELEVISION, SOUND PROGRAMME AND OTHER MULTIMEDIA SIGNALS

Miscellaneous

Digital broadband delivery system: Out-of-band transport

ITU-T Recommendation J.184

(Formerly CCITT Recommendation)

ITU-T J-SERIES RECOMMENDATIONS

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ITU-T Recommendation J.184

Digital broadband delivery system: Out-of-band transport

Summary

This Recommendation specifies the Physical Layer and the Data Link Layer (including the MAC Layer) of two out-of-band cable system transport protocols, denoted as Mode A and Mode B, which are currently in operation.

Source

ITU-T Recommendation J.184 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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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

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ITU-T Recommendation J.184

Digital broadband delivery system: Out-of-band transport

1 Scope

This Recommendation describes the Physical Layer and Data Link Layer (including the MAC Layer) used in cable networks which employ an Out-Of-Band channel architecture. There are two methods used for Out-of-band (OOB) transport in cable systems. These two methods are denoted as Mode A and Mode B, respectively. Their detailed specifications are described in this Recommendation.

2 Definitions

This Recommendation defines the following terms:

2.1 forward data channel: A data channel carried from the headend to the terminal device in a modulated channel at a rate of 1.544 to 3.088 Mbit/s. The FDC carries IP traffic only for:

- Conditional access for analogue signals.
- Entitlement management messages for digital signals.
- General messaging.
- Application download.
- PC data services.
- Variable bit rate (VBR) download.
- Broadcast data.
- Network management.

2.2 reverse data channel: A data channel transmitted from the terminal device to the headend in a modulated channel at a rate of 0.256 to 3.088 Mbit/s. The RDC carries IP traffic only for:

- Messaging.
- Personal computer data services.
- Network management.

2.3 upstream: Transmission from terminal device to Headend.

2.4 downstream: Transmission from Headend to terminal device.

2.5 (OOB) Out-of-band: Outside of the programming channels band. The OOB channels provide communication channels between the network and the terminal.

2.6 QPSK/differential coding: A special QPSK system that uses differential encoding scheme to resolve the 90° ambiguity in the detection of the QPSK signal at the demodulator.

3 Requirements

In the implementation of digital services over cable television networks, there is a need for messaging and signalling between the cable system headend and the subscriber terminal device in both the forward channel in the downstream direction and the reverse channel in the upstream direction. These functions are implemented through the use of appropriate transport protocols and of an auxiliary transport stream of adequate data capacity. This auxiliary data stream can be transported in the multiplex that carries the main transport stream for the main programme channel (in-band transmission). It can also be transported as a separate data channel that fits in the lower part of the frequency spectrum, below the one allocated to programme channels in cable television systems (out-of-band transmission).

This Recommendation describes out-of-band transport protocols for messaging and signalling between the cable system headend and subscriber terminal devices in the forward data channel in the downstream direction and the reverse data channel in the upstream direction.

Two alternatives are described for the out-of-band transport protocol: Mode A and Mode B. They are specified in Annexes A and B, respectively.

Each mode consists of specifications for the forward data channel in the downstream direction and the reverse data channel in the upstream direction.

3.1 Forward Data Channels (FDC)

Mode A Forward Data Channel supports a data rate of 2.048 Mbit/s and Mode B supports data rates of 1.544 and 3.088 Mbit/s. Table 1 shows the lower layer protocol stacks for these out-of-band FDCs. It should be noted that in Mode B, time critical aspects of the Media Access Control (MAC) protocol sublayer are implemented in the SL-ESF Frame Payload Structure. The remainder of the MAC sublayer is implemented via the MAC message in the Payload.

Table 1/J.184 – Out-of-band forward data channel lower layer protocols

<table>
<tr><td rowspan="5">OOB FDC
Lower Layer Protocols</td><td>Mode A</td><td>Mode B</td></tr>
<tr><td>Payload</td><td>Payload</td></tr>
<tr><td>Data Link Layer</td><td>ATM Cell Format</td></tr>
<tr><td>MAC Sublayer:
– MAC Packet
– MPEG-2 TS</td><td rowspan="2">Link/Physical Layer:
– Reed-Solomon
– Interleaving
– SL-ESF Frame Payload Structure
– SL-ESF Format
– Randomizer
– QPSK/differential coding</td></tr>
<tr><td>Physical Layer:
– Randomizer
– Reed-Solomon
– Interleaving
– QPSK/differential coding</td></tr>
</table>

3.2 Reverse Data Channels (RDC)

The RDCs may be present anywhere within the network-supported passband. There are two alternatives for the out-of-band RDCs as defined in Mode A and Mode B. Table 2 shows the lower layer protocol stacks for the out-of-band RDCs.

Table 2/J.184 – Out-of-band reverse data channel lower layer protocols

<table>
<tr><td rowspan="5">OOB RDC
Lower Layer Protocols</td><td>Mode A</td><td>Mode B</td></tr>
<tr><td>Payload</td><td>Payload</td></tr>
<tr><td>Data link Layer/AAL5</td><td>Data link Layer/AAL5</td></tr>
<tr><td>MAC Sublayer:
– MAC Packet Sublayer
– ATM Cell Format</td><td>MAC Sublayer:
– MAC Signalling Message
– ATM Cell Format</td></tr>
<tr><td>Physical Layer:
– Randomizer
– Reed-Solomon
– Burst QPSK/differential coding</td><td>Physical Layer:
– Reed-Solomon
– Randomizer
– Burst QPSK/differential coding</td></tr>
</table>

Detailed protocols for FDCs and RDCs for Mode A and B are specified in Annexes A and B, respectively.

ANNEX A

Digital broadband delivery system: Out-of-band transport – Mode A

A.1 Introduction

This annex describes a transport protocol used in the cable network which employs the Out-Of-Band channel architecture. The physical layer is specified for the transport mechanism for the Out-Of-Band (OOB) cable system currently in practice in North America. Specifications of the MAC Layer and the Link Layer are also provided as "Informative sections". These Informative sections may be updated in the future, recognizing the potential adaptation of DOCSIS MAC Layer Specification [3].

A.2 Acronyms

This annex uses the following acronyms:

AAL	ATM Adaptation Layer
ATM	Asynchronous Transfer Mode
AWGN	Additive White Gaussian Noise
BW	BandWidth
CBD	Connection Block Descriptor
CRC	Cyclic Redundancy Check
CW	ClockWise
DAVIC	Digital Audio Video Council
DCM	Default Configuration Message
DLL	Data Link Layer
DOCSIS	Data Over Cable System Interface Specification
FEC	Forward Error Correction
GF	Galois Field

IB	In-Band
IBTM	In-Band Timebase Message
ID	IDentification
IE	Information Element
IP	Internet Protocol
LFSR	Linear Feedback Shift Register
MAC	Media Access Control
MAP	Map of Bandwidth Allocation
MCNS	Multimedia Cable Network System
MPEG	Moving Picture Experts Group
Msymb/s	Mega symbols per second
NRC	Network Related Control
OBTM	Out-of-Band Timebase Message
OOB	Out-of-Band
PDU	Protocol Data Unit
PER	Packet Error Rate
PN	Pseudo-random Number
PT	Payload Type
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
R-S	Reed-Solomon Coding
SDU	Service Data Unit
SER	Symbol Error Rate
TDMA	Time Division Multiple Access
TS	Transport Stream
UPM	UPstream MAC

A.3 References

Normative references

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published.

Normative reference list

[1] IEEE 0802-1990, *Local and Metropolitan Area Networks: Overview and Architecture*, and ISO/IEC 10039:1991, *Information technology − Open Systems Interconnection − Local area networks − Medium Access Control (MAC) service definition.*

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

Bibliography

[3] CableLabs: Data-Over-Cable-Service Interface Specifications (DOCSIS): Radio Frequency Interface Specification, *SP-RFIv1.1.I01-990311* (1999). <http://www.opencable.com>.

[4] Digital Audio Visual Council 1.4 Specification Part 8, Lower Layer Protocols and Physical Interfaces. (http://www.davic.org/.)

[5] CLARK (G.C.), CAIN (J.B.): Error-Correction Coding for Digital Communications, *Plenum Press*, (1981).

A.4 Out-of-band system specifications

This annex specifies the Physical Layer and the Data Link Layer (including the MAC Layer) of the Out-of-Band cable system transport. Clause A.5 describes the Physical Layer protocol. Clause A. 6 describes the Data Link Layer protocol.

The MAC Layer specification refers to the DOCSIS [3]. However, not all DOCSIS specifications for the MAC Layer are required. The minimum set is specified. Future enhancements toward full DOCSIS compliance might be expected.

This annex assumes that the reader has some:

1) fundamental understanding of the conventional cable frequency plan; and
2) familiarity with the Ethernet specification and the Reed-Solomon Coding of Error Correction Schemes.

Also, use of the references denoted in A.3 is highly recommended for a full understanding of this annex.

A.5 Physical layer specification

This clause describes the physical layer of the Out-Of-Band downstream and upstream channels.

A.5.1 Physical layer For OOB transmission

The aggregate information rate of the Out-Of-Band (OOB) channel is 2.048 Mbit/s. Up to 1.544 Mbit/s may be utilized for access control and other control information as well as application data, application program downloads, program guides, etc. The OOB data channel provides continuous communication from a Headend to Digital Terminals. The Digital Terminal typically remains powered-up even when it is in the "off" state. The OOB channel remains active independent of the tuned video channel, whether the received TV channel is analogue or digital, and whether the Digital Terminal box is turned "on" or "off". Thus, whenever the Digital Terminal connected to the coaxial cable and AC power, the OOB channel is active for downstream communication.

A.5.1.1 OOB transmission format

Table A.1 summarizes the physical attributes of the OOB channel.

Table A.1/J.184 – Out-of-band transmission specifications

Parameter name	Specifications
Modulation:	QPSK, differential coding for 90° phase invariance
Symbol Rate:	1.024 Msymb/s
Symbol Size:	2 bits per symbol
Channel Spacing (BW):	1.8 MHz
Transmission Frequency Band:	70 to 130 MHz
Carrier Centre Frequency (default):	75.25 (Note) MHz ± 0.01%
Data Rate:	2.048 Mbit/s ± 0.01%
Forward Error Correction:	96, 94 Reed-Solomon block code, T = 1, 8 bit symbols
FEC Framing	Locked to MPEG-TS, two FEC blocks per MPEG packet
Interleaving	Convolutional (96, 8)
Nominal Information Rate:	2.005 Mbit/s (132.8 bit/s margin)
Frequency Response:	Raised Cosine filter, α = 0.5 (receiver only)
NOTE – Other possible OOB carrier centre frequencies are 72.75 MHz and 104.2 MHz.	

The OOB channel spacing is 1.8 MHz with frequency step size of 50 kHz. The centre frequency for the downstream cable frequency plan can be between 70 to 130 MHz, with 75.25 MHz as the default value.

A.5.1.2 OOB coding scheme

The forward-error-correction scheme for the OOB channel is composed of the randomization, Reed-Solomon (R-S) coding, and interleaving layers as shown in Figure A.1.

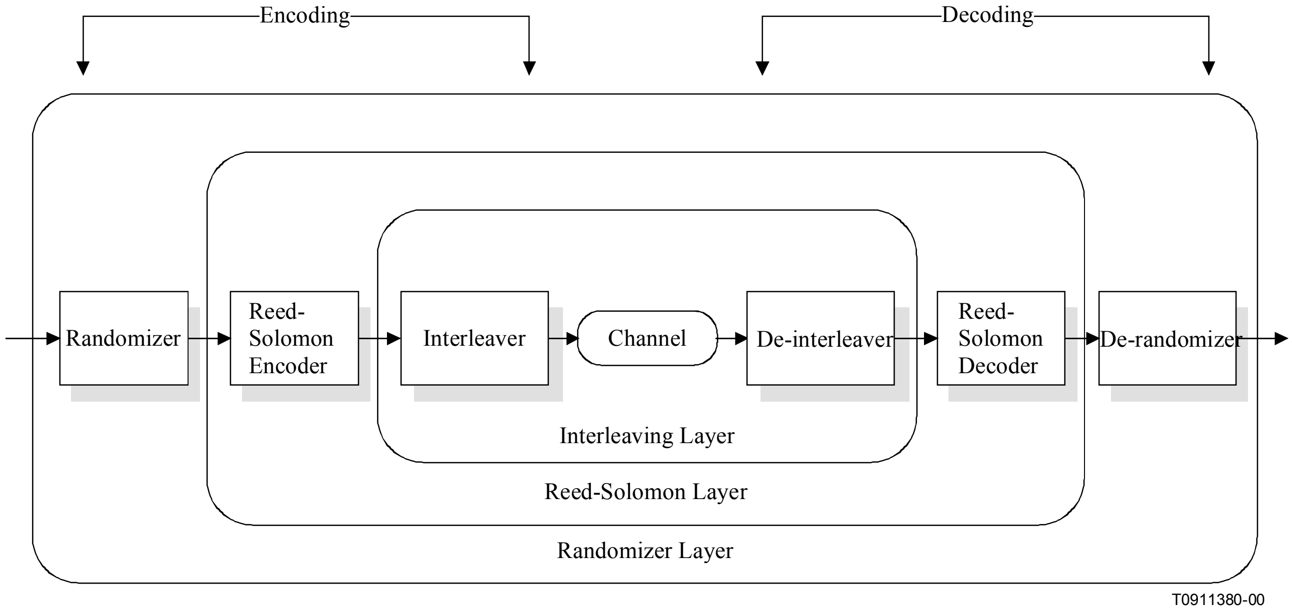


Figure A.1/J.184 – A block diagram for layers of coding in the OOB channel

A.5.1.2.1 OOB randomizer

The MPEG-TS is randomized to ensure balanced modulation by removing unequal excitation of the QPSK modulation states. The randomizer circuit performs the exclusive OR function on the input MPEG transport sequence with the randomizer's Pseudo-random Number (PN) generator output sequence. The randomization frame consists of two MPEG packets with the randomizer PN generator reset at the start of every second MPEG-TS packet. MPEG-TS Sync bytes are inverted on alternate packets to improve receiver synchronization performance.

The randomizer is a 13-bit counter implemented as a Linear Feedback Shift Register (LFSR) as shown in Figure A.2. Binary arithmetic and taps are placed at the output of stages 13, 11, 10, and 1. The stages 2 through 9 are loaded with a seed value of "0". The corresponding generating polynomial is defined as:

$$f(X) = X^{13} + X^{11} + X^{10} + X + 1$$

The same circuit is used for de-randomizing the received MPEG-TS packets. The sync symbol of the first MPEG-TS packet in a frame remains 0x47 after randomization because the first randomizer output byte after reset is "0x00". The second MPEG-2 Sync byte is changed by the randomizer but will be returned to the MPEG-TS standard value 0x47 by the de-randomizer at the receive site.

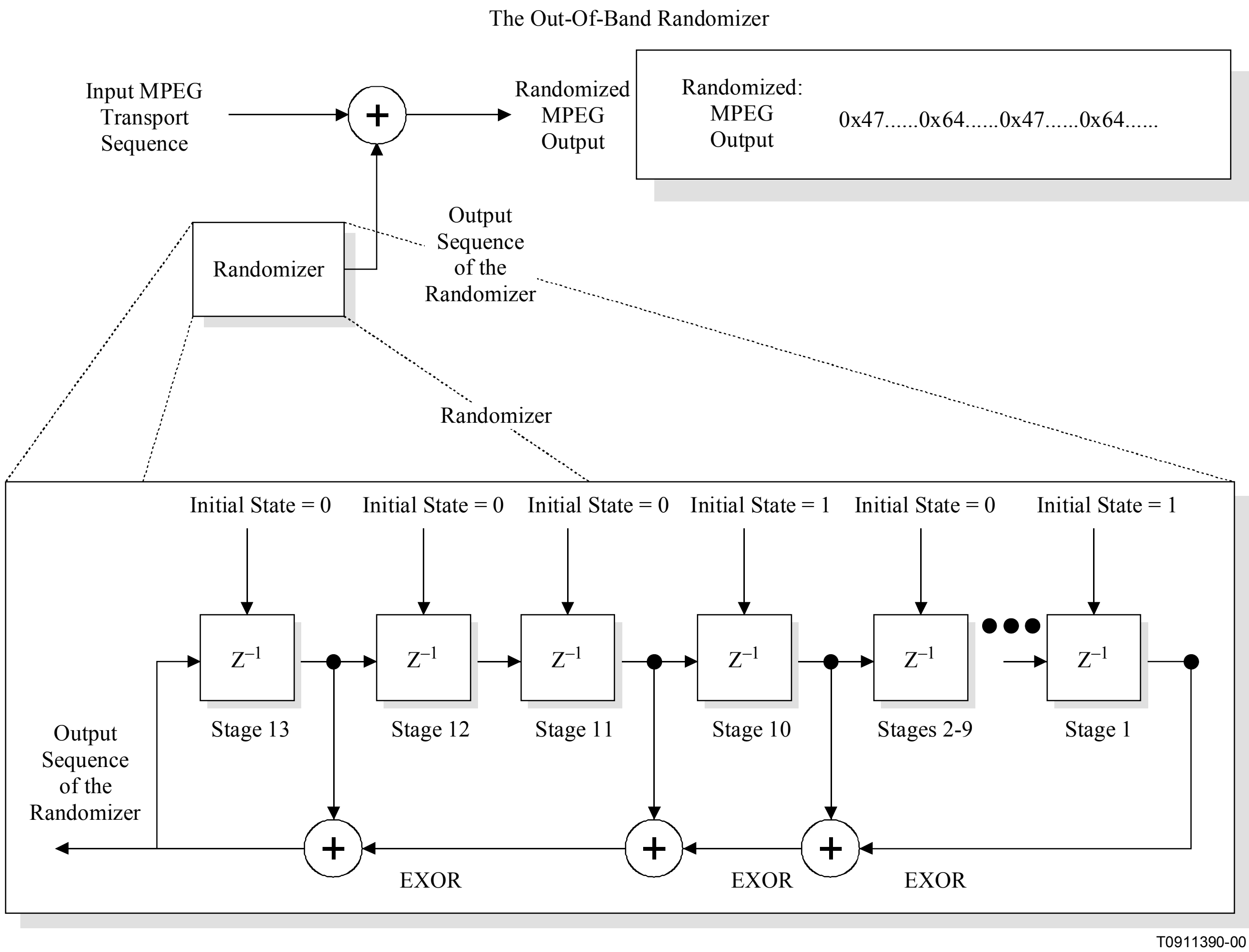


Figure A.2/J.184 – The out-of-band randomizer

A.5.1.2.2 Forward Error Correction Code

The forward-error-correction (FEC) code in the OOB transmission system is a Reed-Solomon (R-S) block code [5]. No codeword shortening and padding is used with the R-S coding. No convolutional coding is required for the relatively robust QPSK transmission on cable-TV transmission networks. The FEC scheme uses (94, 96) Reed-Solomon code defined over Galois Field GF(2^8). The R-S code is T = 1 (96, 94) over Galois Field GF(256), which is capable of performing 1 symbol error-correction every R-S block of 96 symbols. The (94, 96) code is equivalent to a (253, 255) R-S code with 159 leading zero symbols followed by 96 non-zero symbols.

The GF(256) is constructed based on the following primitive polynomial over GF(2), namely:

$$p(X) = X^8 + X^4 + X^3 + X^2 + 1$$

The generating polynomial for the R-S code is defined as:

$$g(X) = (X - \alpha)(X - \alpha^2)$$

where α is a primitive element in GF(256). The OOB FEC frame consists of two Reed-Solomon blocks. This OOB FEC frame equals one MPEG transport packet as illustrated in Figure A.3.

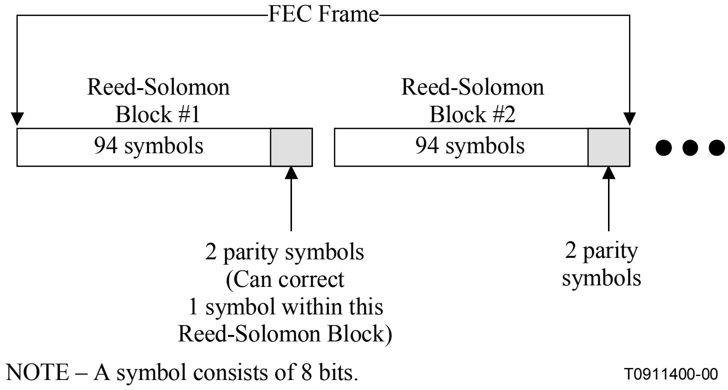
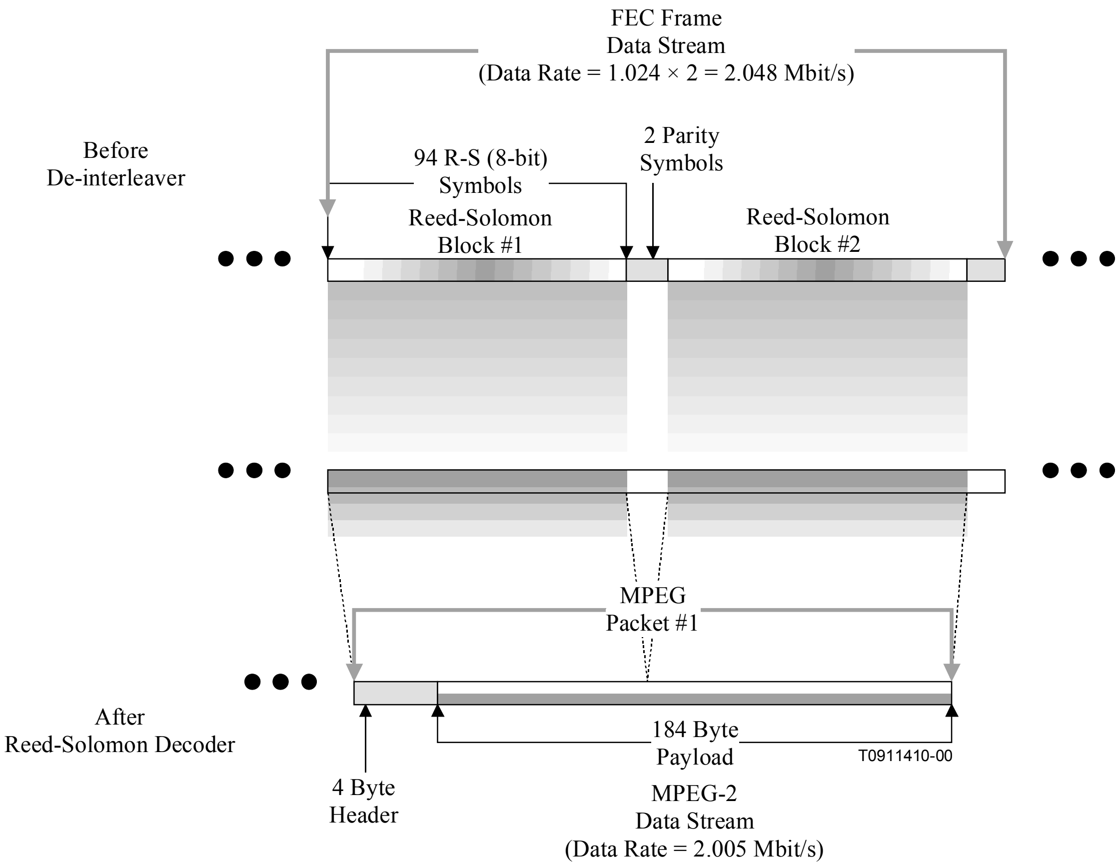


Figure A.3/J.184 – The OOB FEC frame packet format



NOTE – The MPEG Data Stream is synchronized with the FEC Frame Data Stream.

Figure A.4/J.184 – The out-of-band FEC frame to MPEG-TS framing

Mapping from an FEC Frame to an MPEG-TS packet is illustrated in Figure A.4. The first 94 bytes are un-altered and used directly as received. The next 2 bytes are the parity bytes obtained from the Reed-Solomon polynomial calculation. Two blocks of 96 bytes are sent for every 188 byte MPEG packet received. The FEC frame is reset at the start of each MPEG-TS packet.

A.5.1.2.3 OOB interleaver

Interleaving the coded R-S symbols before transmission and de-interleaving after the reception may cause multiple burst errors during transmission to be spread out in time. Thus, the receiver has to handle them as if they were random errors. Separating the R-S symbols in time enables the random-error-correcting R-S code to be useful in a bursty-noisy environment. Using a convolutional interleaver with a depth of I = 8 symbols, the R-S T = 1 (96, 94) decoder can correct an error burst of 8 symbols, which corresponds to a burst noise protection of 32 μs.

Interleaving is synchronized to the R-S blocks and hence to MPEG-TS packets. MPEG-TS Sync bytes always pass through commutator branch 1 of the interleaver and hence are not delayed through the interleaver. The convolutional interleave algorithm delays various blocks of bytes in a systematic way, as illustrated in Figure A.5.

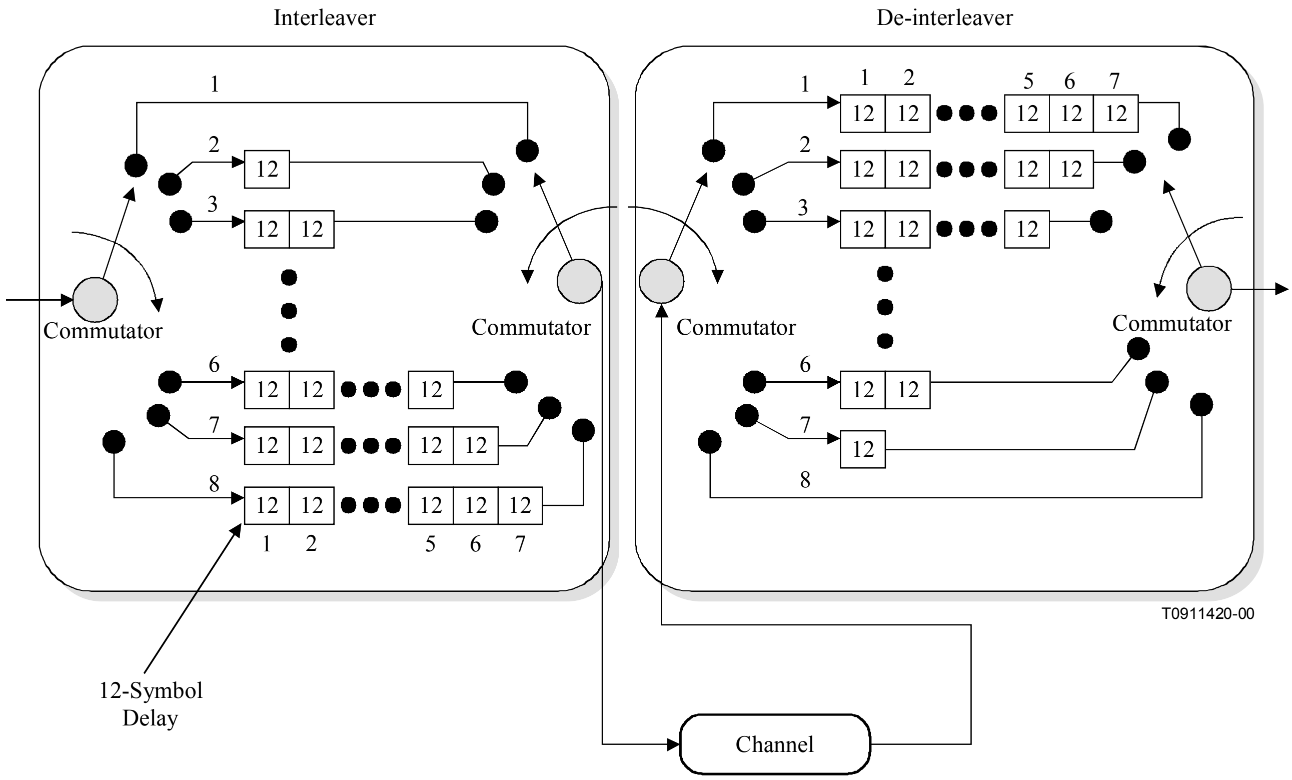


Figure A.5/J.184 – Out-of-band interleaving functional block diagram

A.5.1.3 OOB QPSK mapping

The OOB modulator uses differential encoding scheme to resolve the 90° ambiguity in the detection of the QPSK signal at the demodulator. The OOB QPSK demodulator should be capable of handling both forms of differential coding as listed in Table A.2. Also, a means of selecting the appropriate form of decoding for the user's system must be present in the QPSK demodulator.

Table A.2/J.184 – The differential coding scheme for OOB QPSK signal

I Data	Q Data	Default Carrier Phase Changes	Alternate Carrier Phase Changes
0	0	No Change	No Change
0	1	–90 degrees CW	+90 degrees CW
1	0	+90 degrees CW	–90 degrees CW
1	1	180 degrees	180 degrees

A.5.1.4 OOB modulator RF output

The OOB QPSK modulator RF output specifications are shown in Table A.3.

Table A.3/J.184 – The OOB modulator RF output

Parameter name	Specification
Centre Frequency RF Output	75.25 MHz carrier frequency, same as specified in Table A.1
Step Size for RF Output	50 kHz
RF Output Power range	+30 to +50 dBmV
Output level stability vs time & temperature	±2 dB
Output level stability vs frequency changes	±2 dB
RF Centre frequency accuracy	±0.01%
I/Q Amplitude Imbalance	0.5 dB typical
I/Q Phase Imbalance	1.0 degree typical

A.5.1.5 OOB carrier input power at receiver

The received power level of the OOB carrier at the subscriber's decoder is from +5 dBmV to −10 dBmV at 75 Ω cable impedance.

A.5.2 Physical layer for return-path transmission

A.5.2.1 Return-path modem description

For most applications, the return-path data sent from the subscriber site to the cable-TV headend is generated and must be transmitted in short bursts. The small ATM protocol cell structure is well suited to this need. A block code FEC is used to allow both correction of some transmission errors and detection of packets that cannot be corrected. For many applications upstream packets that cannot be corrected can be retransmitted. Block or convolutional interleaving is not appropriate since their function is to spread out error bursts over many FEC blocks. These upstream transmissions are often a single FEC block.

A.5.2.2 RF return path packet format

The upstream data sent from subscriber Digital Terminals to the Headend is in ATM packet format. Each ATM packet is concatenated with a 28-bit Unique Word, a one byte Packet Sequence counter, and 8 Reed-Solomon parity bytes as shown in Table A.4. The 28-bit Unique Word, which can be written as (I, Q), is used to identify the start of the data packet for robust Sync detection by the return-path receiver. The packet sequence byte consists of a message number (3 bits), and a sequence number (5 bits). The message number is used to associate upstream cells with a particular Protocol Data Unit (PDU). It is incremented every time the first cell of a new PDU is sent. The sequence number, which has a field length of 5 bits, is used to identify the order of the cells within a PDU. It starts at 0 for each new message number, and used by the headend return-path demodulator to detect missing cells for the RF modem report-backs.

Table A.4/J.184 – Upstream Packet Format

Parameter	Specification
Unique Word	28 bits (1100 1100 1100 1100 1100 1100 0000)
Packet Sequence	1 byte
ATM data	53 bytes
R-S parity	8 bytes

A.5.2.3 RF Return-Path Forward Error Correction

The FEC code in the return-path transmission link is a R-S T = 4 (62, 54) code over the GF(256) field. Each R-S symbol consists of 8 bits. This FEC code is capable of correcting four symbol errors for a R-S block of 62 symbols. The following primitive polynomial over GF(256) is used:

$$p(X) = X^8 + X^7 + X^2 + X + 1$$

The generator polynomial for this FEC code is:

$$g(x) = (X - \alpha^{120})(X - \alpha^{121})(X - \alpha^{122})(X - \alpha^{123})(X - \alpha^{124})(X - \alpha^{125})(X - \alpha^{126})(X - \alpha^{127})$$

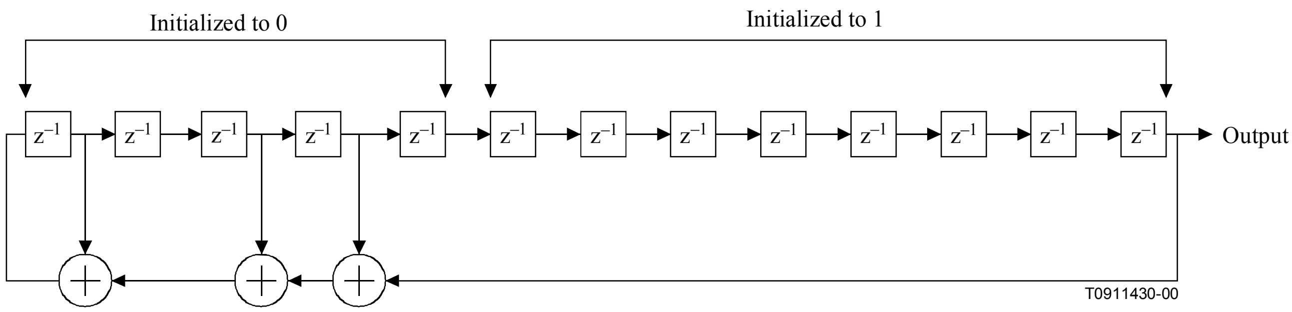
where α is a primitive element in GF(256).

The encoding circuit is efficiently implemented via shift registers using arithmetic over GF(256).

A.5.2.4 RF return-path randomizer

The randomizer circuit uses a PN generator, which employs a 13-bit shift register. The input bit stream is XOR'ed with this PN sequence. Taps are located at the output of stages 1, 3, 4 and 13 of the shift register. Stages 1 to 5 of the shift register are always initialized to zero for each packet. Stages 6-13 are initialized to a programmable value. The 8-bit default value for this initialization is all ones (0xFF). The randomizer is shown in Table A.5. The generating polynomial is identical to the one used in the OOB randomization circuit.

Table A.5/J.184 – RF return path randomizer



A.5.2.5 RF return path modulator

The return path modulator uses differential encoding to enable phase invariant reception at the headend. Two modes of differential decoding are defined to accommodate different system local oscillators. The default mode is used unless the alternate is explicitly selected. The two differential coding schemes are defined in Table A.6 as follows:

Table A.6/J.184 – Phase change of QPSK carrier

I Data	Q Data	Output	
		Default mode	Alternate mode
0	0	No Change	No Change
0	1	+90 degrees CW	–90 degrees CW
1	0	–90 degrees CW	+90 degrees CW
1	1	180 degrees	180 degrees

The output data from the differential encoder feeds the Nyquist pulse shaping filters which are implemented using Square Root Raised Cosine filters with a 50% roll-off ($\alpha = 0.5$). The output of the filters feeds the QPSK modulator which assigns two input bits per symbol. The data transmission rate of the signal is 256 kbit/s. The return-path modulator operates over the entire specified frequency range from 8 to 40 MHz.

The return path modulator output specifications are summarized in Table A.7.

Table A.7/J.184 – RF return-path modulator output specifications

Parameter name	Specification
Modulation Type	Differentially-Encoded QPSK
Access Scheme	Polling and ALOHA (programmable)
Data Transmission Rate	256 kbit/s ± 50 ppm
Symbol Rate	128 kbit/s ± 50 ppm
Channel Spacing	192 kHz
Transmit Filter Shape	Square-Root Raised Cosine, $\alpha = 0.5$
FEC Code	R-S T = 4 (62, 54) over GF(256)
RF Output Power Range	+24 dBmV to +60 dBmV
Spurious Output Level (idle state)	< –30 dBmV (in-band), < –65 dBmV (out-of-band)
Spurious Output Level (active state)	< –50 dBc (in-band), < –65 dBmV (out-of-band)
Frequency Range	8.096 MHz to 40.160 MHz in 192 kHz steps
System Clock Frequency	4.096 MHz

A.5.2.6 RF return-path demodulator specification (Informative)

The return-path differentially-encoded QPSK demodulator uses the same FEC code as the modulator. The required C/(N+I) of the input signal, which includes interference effect (I) due to ingress and impulse noise in the return-path channels, is equal or greater than 20 dB at packet error rate (PER) less than $1 \cdot 10^{-7}$. The required C/(N+I) assumes the simultaneous presence of multiple impairments in the upstream channel. PER is the ratio of the number of error packets to the total number of transmitted packets. The return-path demodulator specifications are summarized in Table A.8.

Table A.8/J.184 – RF return-path demodulator specifications

Parameter Name	Specification
RF Input Level	3 ± 10 dBmV
C/(N+I) of Input Signal	≥ 20 dB @ PER < $1 \cdot 10^{-7}$ (post FEC)
Block Synchronization	Unique Word
Channel Tuning Resolution	8 kHz
Signal Level Measurement Accuracy	±2 dB at the input
Spurious and Harmonics Level	< −40 dBc @ 128 kHz (In-band)
PER Packet Error Rate	

A.5.3 Extended practice for return-path transmission (Informative)

This clause provides the specifications of the extended practice for return-path transmission systems. The higher upstream transmission rates are optional for new Digital Terminals and cable modems applications.

The return-path modulator output specifications are summarized in Table A.9. It references to DOCSIS RFI specifications: *Radio Frequency Interface Specification* SP-RFIv1.1-I01-990311 [3]. As DOCSIS is still evolving with extended practices for more enhanced data features, the current implementation may be upgraded as future needs arise.

The maximum channel bandwidth (measured at −30 dB) is 25% larger than the symbol rate (in kHz), except for the lowest symbol rate case, which has a bandwidth of 192 kHz.

Table A.9/J.184 – RF Return-Path Modulator Output Specifications

Parameter name	Specification
Modulation Type	Differentially-Encoded QPSK and 16-QAM
Symbol Rate	128, 160, 320, 640, 1 280, 2 560 ksym/s ± 50 ppm
RF Output Power Range	8 to 58 dBmV (QPSK), 8 to 55 dBmV (16-QAM)
Transmit Output Power Accuracy	±2 dB
Output Power Step Size Accuracy	±0.4 dB
Transmit Filter Shape	Square-Root Raised Cosine, $\alpha = 0.25$
FEC Code	Programmable R-S T = 1 to T = 10 over GF(256)
Integrated Phase Noise (in-band)	≤ −43 dBc (including discrete spurious noise)
Spurious Output Level	−53 dBc (during bursts), −72 dBc or −59 dBmV (between bursts)
Frequency Range	5 to 42 MHz

The extended transmission specifications, which are based on DOCSIS/MCNS specifications [3] for the RF return-path demodulator, are summarized in Table A.10.

Table A.10/J.184 – Return-path demodulator specifications

Parameter name	Specification
Nominal Received Power Range (for each carrier)	−16 to +14 dBmV (160 ksym/s) −13 to +17 dBmV (320 ksym/s) −10 to +20 dBmV (640 ksym/s) −7 to +23 dBmV (1 280 ksym/s) −4 to +26 dBmV (2 560 ksym/s)
RF Input Signal Level Range	±6 dB of nominal received power
Maximum Received Power	< 35 dBmV
Block Synchronization	Variable-length preamble up to: 512 symbols (QPSK), 256 symbols (16-QAM)
Group-Delay Variation (in-band)	≤ 100 ns
SER Symbol Error Rate	

A.6 Data link layer

This clause describes the Data Link Layer of the Out-Of-Band downstream and upstream channels. It specifies the communication between Network Related Control (NRC), for example the Network Controller at the Headend, and the Digital Terminal. The Medium Access Control sublayer is comprised of control messages, described within this clause, and is independent of the physical layer; hence it may reside above any different rate of the physical layer, In-Band or Out-Of-Band, without any loss of functionality. Another MAC characteristic is that it can be tailored to accommodate different traffic characteristics dynamically or per configuration. At present, only contention-mode access (ALOHA, non-TDMA) is considered as a requirement. Therefore, any TDMA related consideration is strictly optional.

The Data Link Layer, along with its MAC (Media Access Control) sublayer, is responsible for transporting Network Layer PDUs between the Digital Terminal and the Headend. The layer also provides segmenting and reassembly of higher layer PDUs, e.g. network layer, as well as routing to the corresponding protocol stack. Additional information about general DLL and MAC functionality may be found in IEEE 0802-1990, *Local and Metropolitan Area Networks: Overview and Architecture* [1], and ISO/IEC 10039:1991, *Information Technology − Open Systems Interconnection − Local Area Networks − Medium Access Control (MAC) service definition* [1].

To maximize the synergy on the In-Band and Out-Of-Band, the link layer syntax is MPEG-2 TS based. This is described further in the clauses below. Additional detail may be found in ITU-T H.222.0 | ISO/IEC 13818-1, *Information technology – Generic coding of moving pictures and associated audio information: Systems* [2].

A.6.1 Application PDU Processing

Figures A.6 and A.7 show the packetization schemes for upstream and downstream, respectively.

For the upstream direction, the higher protocol layers hand off the SDU to the data link layer. The data link layer adds the Upstream Link Layer Header and Upstream Link Layer Trailer. Padding may also be necessary so that the entire Data Link Layer PDU (i.e. Upstream Link Layer Header + Higher Layer PDU + Padding + Upstream Link Layer Trailer) is a multiple of 48 bytes. The pad character is 0x00. The CRC in the Link Layer Trailer is computed over the entire Data Link PDU.

In the downstream direction, MPEG-2 transport packets are received and filtered based on PID values. Following this, Data Link Layer messages are reassembled, address filtered, and CRC checked. From an MPEG-2 point of view, Data Link Layer messages form an MPEG-2 private stream. The reassembly of those messages from the underlying MPEG-2 transport packets is as per the MPEG-2 specification, using the Payload Unit Start Indicator bit in the MPEG-2 transport packet header. Those messages addressed to the Digital Terminal are processed by the Digital Terminal. For packets containing higher layer application PDUs, the PDU is extracted, reassembled and routed based on the Protocol ID field.

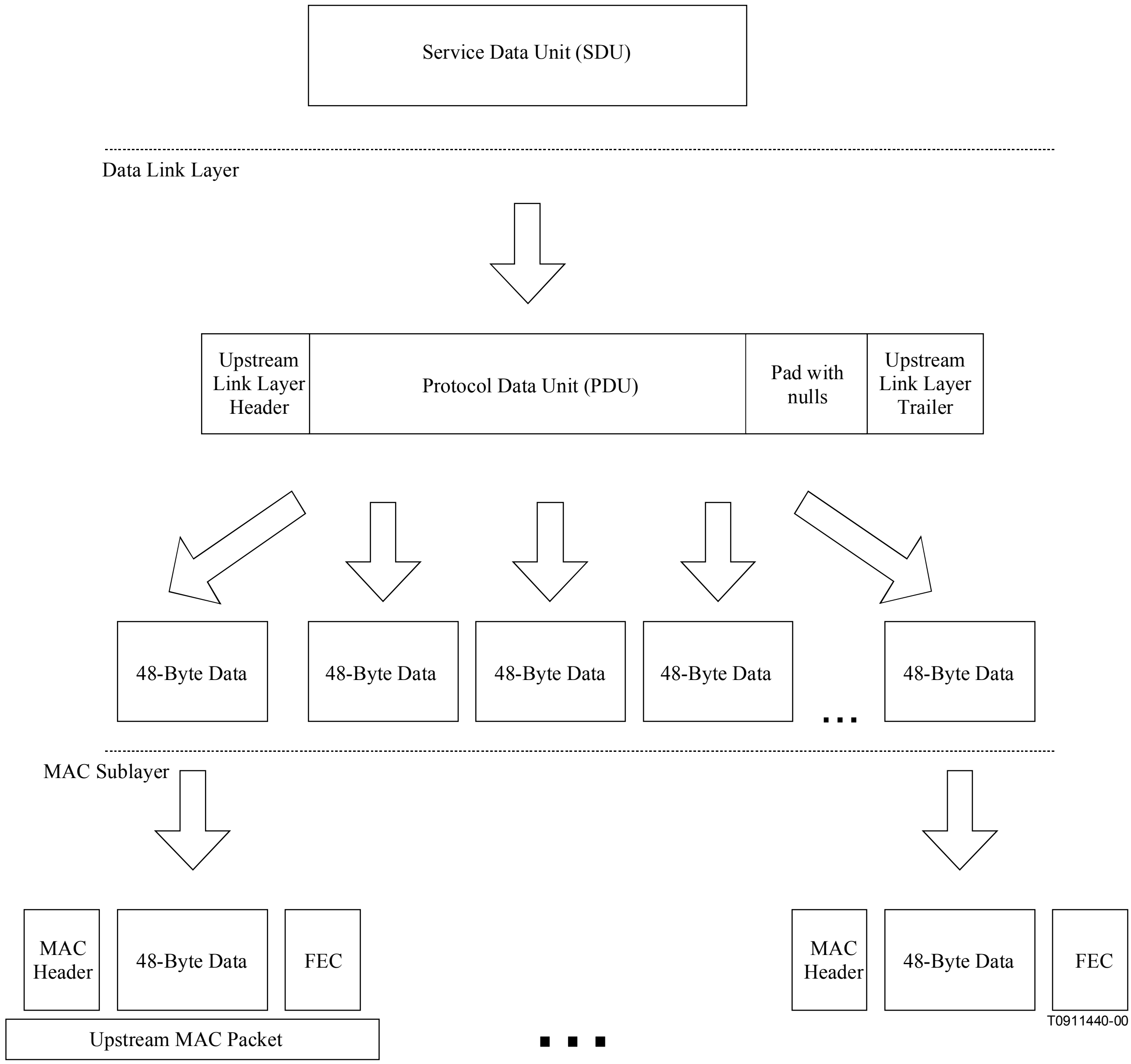


Figure A.6/J.184 – Upstream data link layer processing of application PDUs

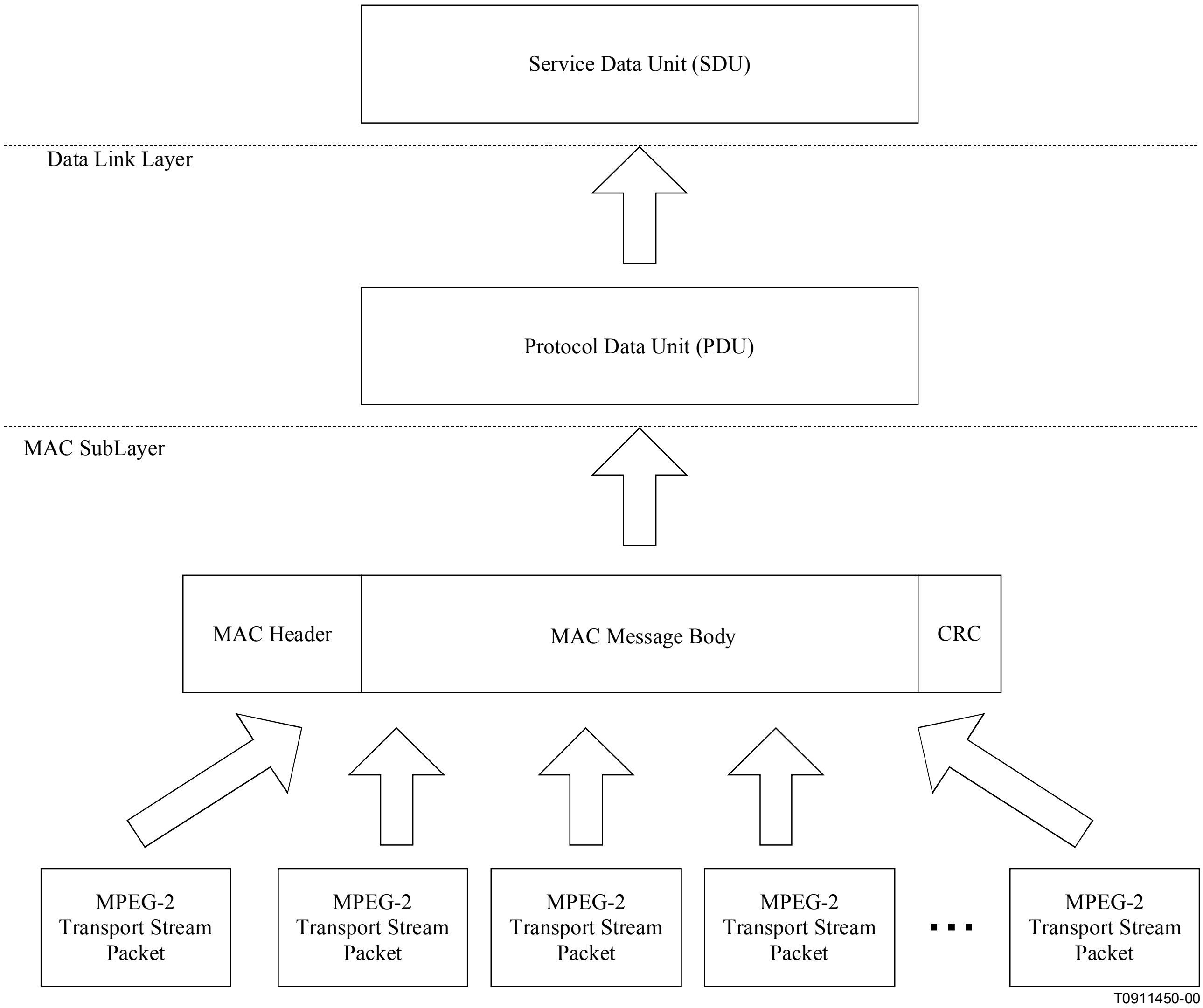


Figure A.7/J.184 – Downstream data link layer processing of application PDUs

A.6.2 Link layer headers/trailers

Link Layer Headers/Trailers encapsulate the downstream and upstream PDUs. In both directions, the Link Layer Headers include a protocol identifier which allows multiple protocol stacks to reside above the Data Link Layer. Also, the Link Layer Headers provide information such as the length of the higher layer PDU.

A.6.2.1 Upstream link layer header

The Upstream Link Layer Header includes a protocol ID which allows multiple protocol stacks to reside over the Data Link Layer. The upstream link layer trailer includes information which is needed to reassemble received MAC packets into Link Layer packets in the headend. The upstream link layer header and trailer are defined as follows:

Upstream_LL_Header(){	Bits	Bytes	Bit Number/ Description
Protocol_ID	**8**	**1**	
}			

Upstream_LL_Trailer(){	Bits	Bytes	Bit Number/ Description
Reserved	**16**	**2**	
Msg_Length	**16**	**2**	in bytes
CRC	**32**	**4**	
}			

Protocol_ID

Protocol_ID identifies the protocol stack above the Data Link Layer. The current protocols defined are (see Table A.11):

Table A.11/J.184 – Protocol IDs

Protocol ID	Protocol
0x00	IP
0x01	Simple Connectionless Protocol (SCP)
0x02	Administration Protocol

Protocol_ID "1" is for compressed form of UDP/IP. Protocol_ID "2" is for administrative functions above the MAC layer.

Msg_Length

This is the length of the original higher layer PDU in bytes, plus the Upstream Link Layer Header. It does not include padding or the Upstream Link Layer Trailer.

CRC

32-bit CRC function, computed over the entire Data Link Layer PDU, including the padding field.

A.6.2.2 Padding

The entire Data Link Layer PDU, including the Upstream Link Layer Header, the Higher Layer PDU, and the Upstream Link Layer Trailer, must be a multiple of 48 bytes. In order to achieve this, it may be necessary to add padding between the higher layer PDU and the Upstream Link Layer Trailer. The padding character is 0x00.

A.6.2.3 Downstream link layer header

The Downstream Link Layer Header consists of a Protocol Identifier. This Protocol ID allows multiple protocol stacks to reside over the Data Link Layer.

The following header is prefixed to higher layer PDUs in the downstream direction. Its purpose is to aid in the reassembly of PDUs.

Downstream_LL_Header(){	**Bits**	**Bytes**	**Bit Number/ Description**
Protocol_ID	**8**	**1**	
}			

Protocol_ID

Same as in the Upstream Link Layer Header in A.6.2.1.

A.6.2.4 Upstream CRC function

In the upstream direction, the CRC is part of the link layer. In the downstream direction, the CRC is part of the MAC sublayer.

The polynomial for the CRC used in the upstream direction is the CRC ITU-T polynomial as shown below:

$$x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^{8} + x^{7} + x^{5} + 1$$

A.6.2.5 Downstream CRC function

The downstream trailer consists of the CRC. The polynomial for the downstream CRC calculation is as follows:

$$x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^{8} + x^{7} + x^{5} + x^{4} + x^{2} + x + 1$$

The initial seed for the calculation is 0xffffffff.

A.6.2.6 Acknowledgment protocol

A simple acknowledgment protocol is used which allows for an acknowledgment message transmitted by the Headend in response to each upstream MAC cell received. After transmitting each MAC cell upstream, the terminal will await either an acknowledgment message or the expiration of a timer. If no acknowledgment is received and the timer expires, the Digital Terminal uses a randomized backoff algorithm to wait and retransmit the cell. The randomization is required to prevent two colliding stations from becoming synchronized and continuously colliding as they backoff and retry. This contention resolution scheme is an exponential random backoff algorithm similar to the one used by Ethernet.

The upstream MAC cell contains a retry counter. The retry counter is set to 0 for the initial transmission of an upstream cell. Every time the cell is retransmitted, the retry counter is increased. The retry counter is used by Headend equipment to determine what the collision level is on a particular upstream channel. A key parameter for the Acknowledgment Protocol is the MAX_ACKNOWLEDGMENT_TIME parameter.

The retry counter and the MAX_ACKNOWLEDGMENT_TIME are programmable.

A.6.3 Segmentation and reassembly

A.6.3.1 Upstream

The upstream segmentation and reassembly algorithm is based on ATM Adaptation Layer 5 (AAL5). The Upstream Link Layer Trailer corresponds to the AAL5 Trailer and contains the Msg_Length field which indicates the length of the original higher layer PDU. As with AAL5, the lower layer MAC packets contain a field (Payload Type) to indicate which MAC packet is the *last* MAC packet in a PDU. By knowing which MAC packet is the last MAC packet, and given that the entire Data Link Layer PDU was padded out to a 48-byte multiple, it is possible to extract the Msg_Length field from the last MAC packet. Using this field, it is then possible to compute the number of MAC packets which make up the PDU.

A.6.3.2 Downstream

In the downstream direction, packets are segmented into an MPEG-2 transport stream. Reassembly utilizes information in the transport packet header and is defined in the MPEG-2 specification.

A.6.3.3 Maximum PDU sizes

In the upstream direction, the Link Layer can accept PDUs up to a maximum of 1 024 bytes. Including the header and trailer overhead, this would translate into a maximum of 22 MAC packets.

In the downstream direction, the Link Layer can accept PDUs up to a maximum of 1 010 (= 1 024 – 14) bytes for singlecast PDUs, or 1 015 (= 1 024 – 9) bytes for broadcast PDUs. This is derived by subtracting the Link Layer Header and CRC from 1 024 byte, the limitation of MPEG-2 messages.

A.6.4 MAC information transport

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 Headend and the Digital Terminal for Media Access Control. These messages are divided into three categories: Initialization, Provisioning and Sign-On Management, Connection Management and Link Management.

A.6.4.1 Downstream MAC Message Format

NOTE – All messages are sent most significant bit first.

Downstream_MAC (){	**Bits**	**Bytes**	**Bit Number/ Description**
Message_Type	**8**	**1**	
Always_zero	**1**	**2**	15: set to 0
Address_Type	**3**		14..12
Message_Length	**12**		11..0
If (Address_Type==			
singlecast_unit){			
unit_creation_address	**40**	**5**	
}			
If (Address_Type==			
singlecast_network){			
network_address	**40**	**5**	
}			
If (Address_Type==			
multicast40_address){			
multicast40_address	**40**	**5**	
}			
If (Address_Type==			
multicast16_address){			
multicast16_address	**16**	**2**	
}			

If (Address_Type== multicast24_address){			
multicast24_address	**24**	**3**	
}			
Message_Type_Version_Field	**8**	**1**	
frames_extention_flag	1		7: set to 0
segmentation_overlay_included	1		6: set to 0
message_preamble	1		5: set to 0
message_type_version	5		4..0: set to 0
}			

Message_Type

This field indicates the type of message being transmitted. For the MAC Layer, two message types are defined – one for interactive application data (i.e. user data that have been adapted (segmented) into MAC packets), the other for MAC Signalling Messages. See Table A.12.

Table A.12/J.184 – MAC Message Type Values

Value	Message type
0x8E	Interactive Data
0x8F	MAC Signalling

Address_Type

Address_Type defines the type of address included in the message. Table A.13 outlines defined address types:

Table A.13/J.184 – Address Types

Value	Address type
0x00	broadcast
0x01	singlecast_unit
0x02	singlecast_network
0x03	multicast40
0x04	multicast16
0x05	multicast24

Message_Length

Message_Length, expressed in bytes, includes all fields following the Message_Length field itself (including the CRC).

Message_Type_Version_Field

This field contains three flags (all set to 0) and the Message_Type_Version_Field, which must be set to 0 as well.

The address types are for the downstream direction to the Set Top Box as the message name specifies. As the address fields are of different lengths, the downstream header size will vary with different address types.

A.6.4.2 Upstream packet format

The upstream packet format is as follows:

Reserved (1 bit)	Message Number (2 bits)	Seq. Num (5 bits)	MAC CTRL (4 bits)	UPM Address (24 bits)	PT (3 bits)	Ack Req. (1 bit)	Retry Counter (8 bits)	PAYLOAD (48 bytes)

Each upstream packet is prefixed by a unique word (28 bits) which allows the burst demodulator to identify the start of the packet. Upstream packets also include an 8-byte FEC field for error detection and correction.

Upstream_Packet(){	**Bits**	**Bytes**	**Bit Number/Description**
Reserved	**1**	**1**	7
Message_Number	**2**		{6..5}/Increments for each new PDU
Sequence_Number	**5**		{4..0}/Increments for each new MAC packet transmitted upstream. Starts at 0 for each new Segmented PDU Number.
MAC_Control_Field	**4**	**4**	{31..28}/Used to identify the nature of the MAC packet.
UPM_Address	**24**		{27..4}/Upstream MAC Address. Identifies decoder-transmitting packet.
Payload_Type	**3**		{3..1}/1 for last MAC packet in a PDU. 0: Otherwise.
ACK_Required	**1**		{0}/1 for MAC packets requiring Acknowledgment. 0: Otherwise.
Retry_Counter	**8**	**1**	Increments for each retransmission of a MAC packet.
Payload	**384**	**48**	Payload
}			

Message_Number

The Message_Number, or the Segmented PDU Number field is used to associate packets with a particular PDU. It increments every time the first packet of a new PDU is sent.

Sequence_Number

The Sequence_Number is used to identify the order of packets within a PDU. It starts at 0 for each new Message_Number (see above). The Sequence_Number does not increment when a packet is re-transmitted because an acknowledgment was not received.

MAC_Control_Field

The MAC_Control_Field identifies the nature of the MAC Packet. Table A.14 shows values for the MAC Control Field:

Table A.14/J.184 – MAC control field values

MAC control field	Description
0000	Application Data
0001	Application Data, no segmentation
1001	MAC Signalling Messages
1000	Reserved
1100	Reserved

UPM_Address

The Upstream MAC, UPM_Address is used in the NRC to associate a received packet with a particular decoder.

Payload_Type (PT)

This field is used by the reassembly engine. In AAL5, the information needed to reassemble a higher layer PDU from individual ATM packets (MAC packets in this system) is contained in the last packet. Therefore, the last packet must be indicated. This field is set to 0x01 if the packet is the last (or only) packet which makes up a PDU. The field is 0 otherwise.

Ack_Required

A value of 1 indicates that the packet requires an explicit acknowledgment from the NRC. A value of 0 indicates that no acknowledgment is required or expected.

Retry_Counter

This field indicates the number of times the decoder had to retry when sending a packet upstream before it was correctly received. The NRC equipment can examine this field for statistics and diagnostic information. The first time a packet is transmitted upstream, this field is set to 0. It increments every time the same packet is retransmitted because an acknowledgment was not received.

Payload

This is the data portion of the packet and contains 48 bytes of data. Since higher level PDUs are already padded up to 48 bytes, no additional padding is needed. For MAC Signalling Messages, which may be shorter than 48 bytes, the remainder of the payload is padded with the null (0x00) character.

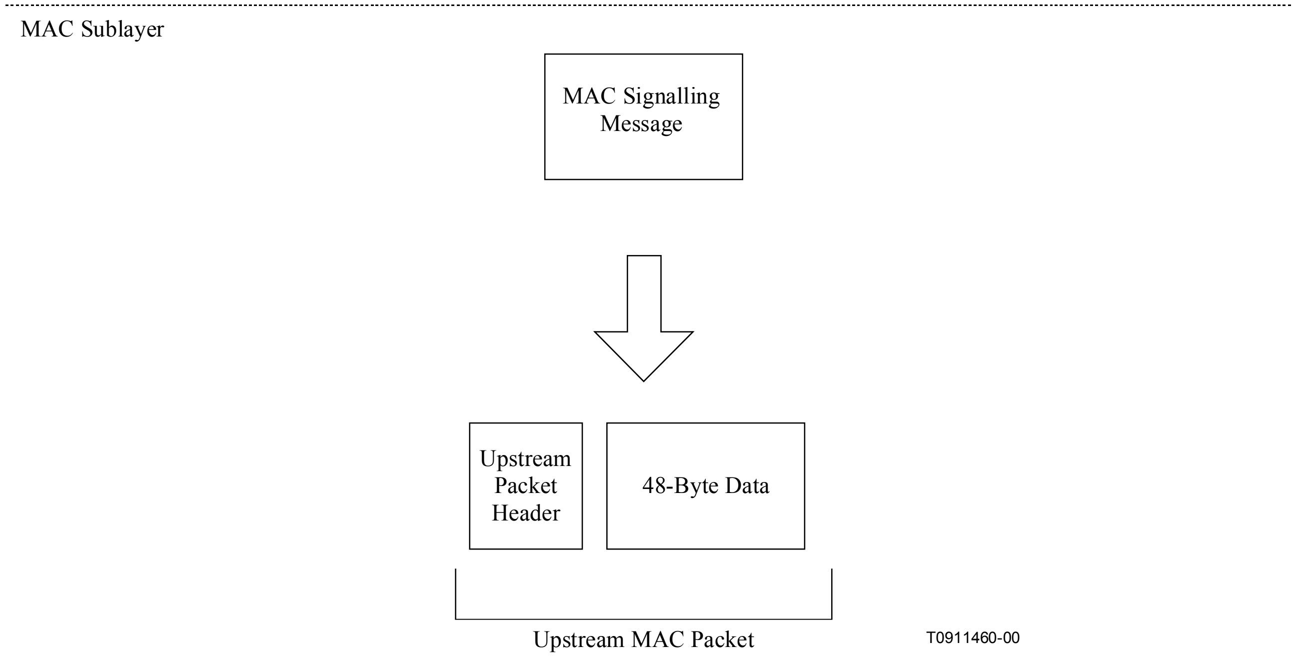
A.6.5 MAC signalling messages

A.6.5.1 MAC signalling message encapsulation

MAC signalling messages are part of the MAC sublayer. As such, they are transported in MAC packets. In the upstream direction, MAC signalling messages are placed directly into a MAC packet, and do not contain the Link Layer Header, nor do they contain the CRC field. The Payload Type field in the upstream MAC header is, by definition, 1, for all MAC signalling messages. Note that since MAC Signalling Messages may be less than 48 bytes, the remainder of the 48-byte payload in the MAC packet should be padded up with the null (0x00) character.

In the downstream direction, MAC signalling messages do not contain the downstream link layer header. They are prefaced by the MAC header and appended with the CRC. MAC Signalling messages are designated by the value of the Message Type field.

Figures A.8 and A.9 indicate the encapsulation for MAC Signalling Messages.



NOTE – MAC Control field in MAC Header indicates MAC signalling.

Figure A.8/J.184 – Encapsulation of MAC signalling messages upstream

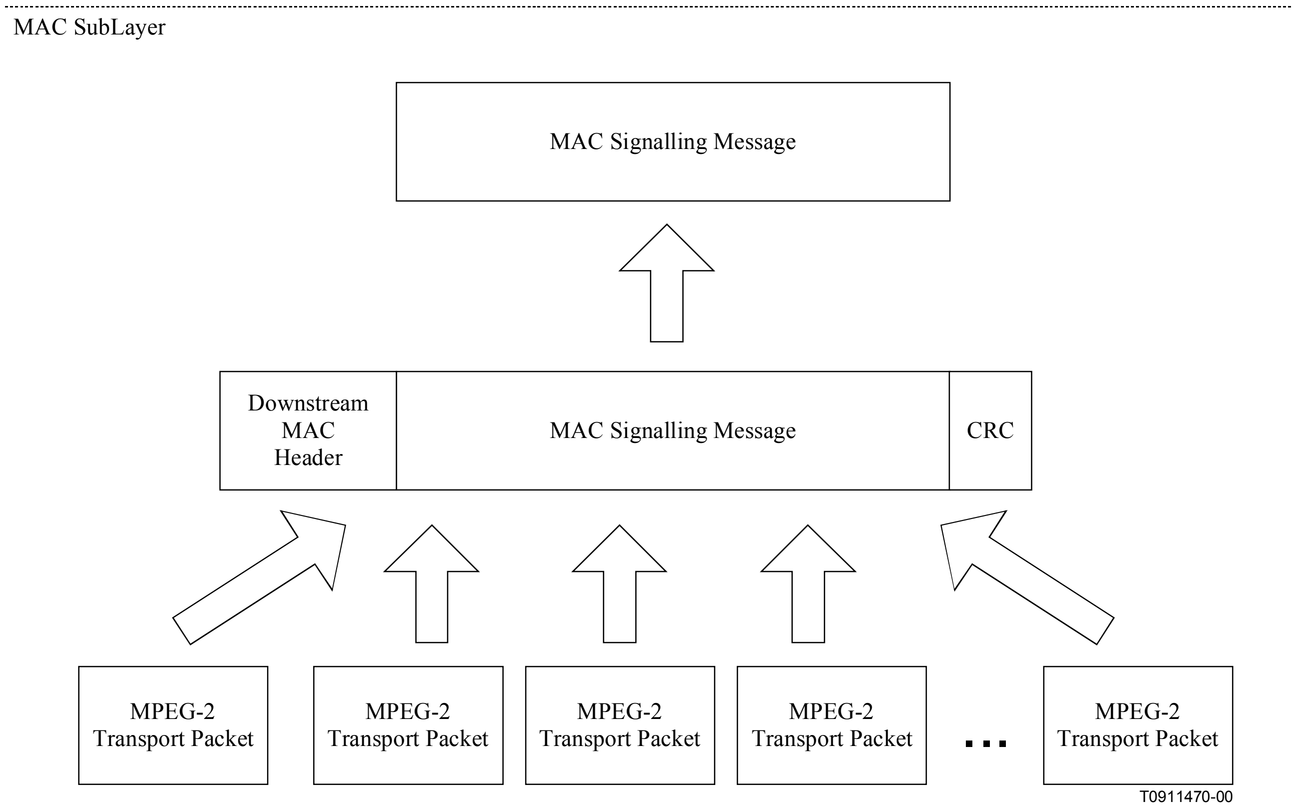


Figure A.9/J.184 – Encapsulation of MAC signalling messages downstream

A.6.5.2 MAC signalling message format

The MAC Signalling Message below is defined in the DAVIC specification [4]. All MAC signalling messages, whether upstream or downstream, conform to this message format.

NOTE – All messages are sent most significant bit first.

MAC_Signalling_Message(){	Bits	Bytes	Bit Number/ Description
Message_Configuration		**1**	
Protocol_Version	5		7..3:{enum}
Syntax_Indicator	3		2..0:{enum}
Message_Type	**8**	**1**	
if (Syntax_Indicator==001) {			
MAC_Address	**48**	**6**	
}			
MAC_Information_Elements ()		**N**	
}			

Protocol_Version

Protocol_Version is a 5-bit enumerated type used to identify the current MAC version.

For this version of the MAC, the Protocol Version will be 0x1f.

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,
                                      Reserved 2..7        };
```

MAC_Address

MAC_Address is a 48-bit value representing the unique MAC address of the Digital Terminal. Specifically, the MAC address is the 40-bit unit address of the terminal, with the most significant 8 bits set to 0.

A.6.5.3 ALOHA MAC Messages

The table below shows the MAC message types defined by DAVIC [4].

Messages shown in *italics* are transmitted from the Digital Terminal to the headend.

Messages which are used in the ALOHA MAC are underlined in the table below.

Message type value	Message name	Addressing type
0x01-0x1F	**MAC Initialization, Provisioning and Sign-On Message**	
0x01	Provisioning Channel Message	Broadcast
0x02	Default Configuration Message	Broadcast
0x03	Sign-On Request Message	Broadcast
0x04	*Sign-On Response Message*	Singlecast
0x05	Ranging and Power Calibration Message	Singlecast
0x06	*Ranging and Power Calibration Response Message*	Singlecast
0x07	Initialization Complete Message	Singlecast
0x08-0x1F	[Reserved]	Singlecast
0x20-0x3F	**MAC Connection Establishment and Termination Msgs**	
0x20	Connect Message	Singlecast
0x21	*Connect Response Message*	Singlecast
0x22	*Reservation Request Message*	Singlecast
0x23	Reservation Response Message	Broadcast
0x24	Connect Confirm Message	Singlecast
0x25	Release Message	Singlecast
0x26	*Release Response Message*	Singlecast
0x27	*Idle Message*	Singlecast
0x28	Reservation Grant Message	Singlecast
0x29	Reservation ID Assignment	Singlecast
0x2A	*Reservation Status Request*	Singlecast
0x2B	*Reservation ID Response Message*	Singlecast
0x2C-0x3F	[Reserved]	
0x40-0x5F	**MAC Link Management Msgs**	
0x40	Transmission Control Message	Singlecast/ Broadcast
0x41	Reprovision Message	Singlecast
0x42	*Link Management Response Message*	Singlecast
0x43	Status Request Message	Singlecast
0x44	*Status Response Message*	Singlecast
0x45-0x5F	[Reserved]	
0x60-0x6F	**Private MAC Extensions**	
0x60	Logical Address Message	Singlecast
0x61	Contention Channel List Message	Broadcast
0x62	Acknowledge/Power Adjust Message	Singlecast
0x63	Synchronization Timebase Message	Broadcast

A.6.5.3.1 <MAC> Default Configuration Message

The <MAC> DEFAULT CONFIGURATION MESSAGE is sent by the headend to the Digital Terminal. The message provides default parameter and configuration information to the Digital Terminal. The format of the message is shown below.

Default_Configuration_Message(){	**Bits**	**Bytes**	**Bit Number/ Description**
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	**13**	**2**	15..3
Upstream_Transmission_Rate	**3**		2..0
Max_Power_Level	**8**	**1**	
Min_Power_Level	**8**	**1**	
Power_Increment	**8**	**1**	
Timebase_Terminal_Count	**32**	**4**	
Ticks_Per_Timeslot	**16**	**2**	
OBTM_Correction_Factor	**32**	**4**	
IBTM_Correction_Factor	**32**	**4**	
Idle_Interval_Timer	**16**	**2**	in seconds
Default_Response_Collection_Time_Window	**16**	**2**	in seconds
Init_Abort_Timer	**16**	**2**	in seconds
}			

Sign-On_Increment_Power_Retry_Count

Sign-On_Incr_Pwr_Retry_Count is an 8-bit unsigned integer representing the number of attempts the Digital Terminal should try to enter the system at the same power level before incrementing its power level. The power level is incremented by 0.5 decibels each time.

Service_Channel_Frequency

This is the upstream frequency that the Digital Terminal should use to enter the network. All Sign-On messages should be sent on this frequency initially.

Backup_Service_Channel_Frequency

During network entry, if the terminal reaches maximum power on the service channel and still has not been able to enter the network, it will switch to the backup service channel and will try to enter the network. If this also fails, it will switch back to the service channel and try again, alternating between the two until it can enter the network. Not all systems will have a backup service channel. If none is available, this field should be set to 0.

Service_Channel_Control_Field, Backup_Service_Channel_Control_Field, Service_Channel_Frame_Length, Service_Channel_Last_Slot, Upstream_Transmission_Rate

These parameters are not applicable to the ALOHA MAC.

Maximum_Power_Level

MAX_Power_Level is an 8-bit unsigned integer representing the maximum power the Digital Terminal shall be allowed to use to transmit upstream. Maximum_Power_Level is defined in units of 0.5 dBuV. A maximum power level of 60 dBmV is required.

Minimum_Power_Level

MIN_Power_Level is an 8-bit unsigned integer representing the minimum power the Digital Terminal shall be allowed to use to transmit upstream. Minimum_Power_Level is defined in units of 0.5 dBuV. A minimum power level of 24 dBmV is required.

Power_Increment

This is the amount by which the terminal should increment its power level when attempting to enter the network. It is expressed in increments of 0.5 decibels.

Timebase_Terminal_Count, Ticks_Per_Timeslot, OBTM_Correction_Factor, IBTM_Correction_Factor

These parameters apply only to TDMA versions of the MAC and are therefore "don't-cares" for the ALOHA MAC.

Idle_Interval_Timer

Idle_Interval_Timer is a 16-bit unsigned integer representing the amount of time (in seconds) the Digital Terminal shall wait between transmission of <MAC> IDLE MESSAGES. A value of 0 indicates that the terminal should not generate idle messages.

Default_Response_Collection_Time_Window

Used in the ALOHA MAC. The terminal will wait a random amount of time between 0 and Default_Response_Collection_Time_Window seconds after powering up before attempting to enter the network. This parameter may be set to 0 to indicate that the terminal should attempt to enter the network immediately upon powering up. *This parameter was not included in the original DAVIC [4] message.*

Init_Abort_Timer

This timer is used with the ALOHA MAC. When the terminal is waiting for the MAC Sign On Request or Logical Address message to continue initialization, it will set this timer. Should the timer expire before one of these messages is received, the terminal will assume the initialization process has failed and will restart the initialization process. A value of 0 is used to indicate that the terminal should use its internally coded default value for this timer. The unit of the Init_Abort_Timer is expressed in "seconds".

A.6.5.3.2 <MAC> Sign-On Request Message

For the ALOHA version of the MAC, the <MAC> SIGN-ON REQUEST MESSAGE is sent to a specific Digital Terminal to request that the Digital Terminal attempt to enter the network.

Sign-On_Request_Message(){	**Bits**	**Bytes**	**Bit Number/ Description**
Sign-On_Control_Field		**1**	
Reserved	6		7..2
Upstream_Frequency_Included	1		1:{no, yes}
Address_Filter_Params_Included	1		0:{no, yes}
Response_Collection_Time_Window	**16**	**2**	in seconds
If (Address_Filter_Params_Included==yes) {			
Address_Position_Mask	**8**	**1**	
Address_Comparison_Value	**8**	**1**	
}			
if (Upstream_Frequency_Included==yes){			
Upstream_Frequency	**32**	**4**	**in Hz**
}			
}			

Sign-On_Control_Field

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

Upstream_Frequency_Included

This flag indicates whether the Digital Terminal should use an upstream frequency other than the Service Channel's frequency to enter the network.

NOTE – This feature was not provided for in the original DAVIC [4] specification.

Address_Filter_Parameters_Included

These parameters will not be used in the ALOHA MAC.

Response_Collection_Time_Window

After receiving a Sign-On Request message, the terminal will wait a random amount of time between 0 and Response_Collection_Time_Window seconds before responding with the MAC Sign-On Response Message.

Upstream_Frequency

If included, this is the frequency on which the Digital Terminal should attempt to enter the network.

A.6.5.3.3 <MAC> Sign-On Response Message

The <MAC> SIGN-ON RESPONSE MESSAGE is sent by the Digital Terminal in order to enter the network. This message is sent on the Service Channel to the network. When a terminal first enters the network using this message, it should set the Syntax Indicator in the MAC Signalling Message Header to 1 and include its 48-bit MAC address in the header.

Sign-On_Response_Message(){	Bits	Bytes	Bit Number/ Description
Return_Path_Id	**16**	**2**	
Downstream_Path_Id	**16**	**2**	
Digital_Terminal_Status	**32**	**4**	{enum}
Digital_Terminal_Capabilities		**2**	
Reserved	**15**		1..15
True IP Capable	**1**		0: {no, yes}
Digital_Terminal_Error_Code	**16**	**2**	{enum}
Digital_Terminal_Retry_Count	**8**	**1**	
}			

Return_Path_Id, Downstream_Path_Id

These 16-bit Ids have been assigned to the terminal prior to the ALOHA MAC initialization and are sent upstream in the <MAC> SIGN ON RESPONSE MESSAGE.

Digital_Terminal_Status

See definition in <MAC> STATUS RESPONSE MESSAGE.

Digital_Terminal_Capabilities

This bit field parameter is used to indicate to the headend what the terminal's capabilities are. Currently the only defined value indicates whether terminal supports true IP or not.

Digital_Terminal_Error_Code

Digital_Terminal_Error_Code is a 16-bit unsigned integer that indicates the error condition within the Digital Terminal.

```
enum Digital Terminal_Error_Code   {No_Error=0,
                                     Range_Response_Timeout_Error,
                                   Default_Connection_Timeout,
                                   Connect_Confirm_Timeout,
                                     Upstream_Sign_On_Failed,
                                   Reserved 5..2^16–1       };
```

Digital_Terminal_Retry_Count

Digital_Terminal_Retry_Count is an 8-bit unsigned integer that indicates the number of transmissions of the <MAC> SIGN-ON RESPONSE MESSAGE.

A.6.5.3.4 <MAC> Transmission Control Message

The <MAC> TRANSMISSION CONTROL MESSAGE is sent to the Digital Terminal from the headend to control upstream transmission on ALOHA channels.

Transmission_Control_Message(){	Bits	Bytes	Bit Number/ Description
Transmission_Control_Field		**1**	
Reserved	6		7..2
Return_Path_Included	1		1: {no, yes}
Stop_Upstream_Transmission	1		0: {no, yes}
if (Return_Path_Included == yes) {			
Return_Path_Id	16	**2**	
}			
}			

Transmission_Control_Field

Transmission_Control_Field specifies the control being asserted on the channel.

If Return_Path_Included is set to 1, a Return_Path_Id will be present in the message, and the terminal should only process this message if its Return_Path_Id matches the one in the message.

Stop_Upstream_Transmission: A 1 in this bit indicates that the terminal should halt all upstream ALOHA transmission, including <MAC> Idles, after sending the response to this message. The terminal may resume upstream transmission upon receiving a <MAC> Transmission Control Message with a Stop Upstream Transmission bit set to 0, OR upon receiving a MAC Sign On Request message.

A.6.5.3.5 <MAC> Link Management Response Message

The <MAC> LINK MANAGEMENT RESPONSE MESSAGE is sent by the Digital Terminal to the headend to indicate reception and processing of the previously sent Link Management Message. The format of the message is shown below.

Link_Management_Response_Message(){	Bits	Bytes	Bit Number/ Description
Link_Management_Message_Type	**8**	**1**	
}			

Link_Management_Message_Type

The Link_Management_Message_Type is the message type to which this message is in response. For example, if this message is in response to a <MAC>TRANSMISSION CONTROL MESSAGE, the Link_Management_Message_Type field will be 0x40, whereas if this message is being sent in response to a <MAC>Logical Address Message, its value will be 0x60.

A.6.5.3.6 <MAC> Idle Message

This message is sent upstream to the headend when the idle timer has expired and the terminal has not sent any cells upstream which required an Acknowledgment in the idle timer interval. The idle timer interval is configured in the <MAC> Default Configuration Message. This message is NOT sent upstream if the terminal has been told to stop upstream transmission with a <MAC> TRANSMISSION CONTROL MESSAGE.

Idle_Message(){	Bits	Bytes	Bit Number/ Description
Idle_Sequence_Count	**8**	**1**	
Number_Open_Sockets	**8**	**1**	
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**	
}			
}			

Idle_Sequence_Count

Idle_Sequence_Count is an 8-bit unsigned integer representing the count of <MAC> IDLE MESSAGES transmitted while the Digital Terminal is Idle.

Number_Open_Sockets

Number_Open_Sockets is an 8-bit unsigned integer representing the number of sockets open on the Digital Terminal.

Number_Error_Codes_Included

The terminal may report error codes in the idle message. The number of codes reported in the message is indicated by this field.

Error_Param_Code, Error_Param_Value

Error_Param_Code is an 8-bit enumerated type field which indicates the type of error that occurred. For some types of errors, there may be a count associated with them. This count may be indicated in the Error_Param_Value field.

A.6.5.3.7 <MAC> Status Request Message

The <MAC> STATUS REQUEST MESSAGE is sent by the headend to the Digital Terminal to retrieve information about the health, connection information and error states of the Digital Terminal. The headend can request either the address parameters, error information, connection parameters or physical layer parameters from the Digital Terminal. The headend can only request one parameter type at a time to a particular Digital Terminal.

NOTE 1 – Terminals which have had their upstream transmission suspended with a <MAC> Transmission Control message will still respond to <MAC> Status Request messages.

Status_Request_Message(){	Bits	Bytes	Bit Number/ Description
Status_Control_Field		**1**	
Reserved	4		7..4
Status_Type	3		3..1:{enum}
Frequency_Included	1		0: {no, yes}
if (Frequency_Included==yes)			
Response_Frequency	32	**4**	in Hz
}			

Status_Type

Status_Type is a 3-bit enumerated type that indicates the status information the Digital Terminal should return.

```
enum Status_Type        {   Status_Only=0,
                         Address_Params,
                         Error_Params,
                         Physical_Layer_Params,
                         Reserved 4..7    };
```

Frequency_Included

This bit indicates if the frequency on which the terminal should respond is included in the message. If the frequency is not included, the terminal will randomly pick from available upstream frequencies on what frequency to respond.

Response_Frequency

If this field is included, it is used to indicate on what frequency the terminal should respond.

NOTE 2 – This frequency must be in the Contention Channel List message which the terminal is using or the message will be discarded.

A.6.5.3.8 <MAC> Status Response Message

The <MAC> STATUS RESPONSE MESSAGE is sent by the Digital Terminal in response to the <MAC> STATUS REQUEST MESSAGE issued by the headend. The contents of the information provided in this message will vary depending on the request made by the headend and the state of the Digital Terminal.

Status_Response_Message(){	Bits	Bytes	Bit Number/ Description
Digital_Terminal_Status	**32**	**4**	{enum}
Response_Fields_Included		**1**	
Reserved	5		7..3
Address_Params_Included	1		2:{no, yes}
Error_Information_Included	1		1:{no, yes}
Physical_Layer_Params_Included	1		0:{no, yes}
if (Address_Params_Included==yes) {			
MAC_Address	**48**	**6**	
IP_Address	**32**	**4**	
Return_Path_Id	**16**	**2**	
Downstream_Path_Id	**16**	**2**	
}			
if (Error_Information_Included==yes) {			
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 (Physical_Layer_Params_Included==yes) {			
Power_Control_Setting	**8**	**1**	
MAC_Transmission_Mode	**8**	**1**	{enum}
Polling_Frequency	**32**	**4**	
}			
}			

Digital_Terminal_Status

Digital_Terminal_Status is a 32-bit enumerated type that indicates the current state of the Digital Terminal.

enum Digital_Terminal_Status { Signing_On_Service_Channel,
Signing_On_Backup_Channel,
Signing_On_Upstream_Verification,
Interactive_Running,
Tranmission_Stopped,
Reserved $5..2^{32}-1$ };

Response_Fields_Included

Response_Fields_Included is an 8-bit unsigned integer that indicates what parameters are contained in the upstream status response.

Address_Parameters:

MAC_Address

MAC_Address is a 6-byte address assigned to the Digital Terminal.

IP_Address

This is the 32-bit IP Address assigned to the terminal.

Return_Path_Id, Downstream_Path_Id

These are the path identifications of the terminal.

Error Parameters:

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_Param_Code

Error_Param_Code is an 8-bit enumerated type representing the type of error reported by the Digital Terminal.

```
enum Error_Param_Code {        TBD,
                               Reserved        1..255   };
```

Error_Param_Value

Error_Param_Value is a 16-bit unsigned integer representing error counts detected by the Digital Terminal.

Physical Parameters:

Power_Control_Setting

Power_Control_Setting is an 8-bit unsigned integer representing the absolute power attenuation that the Digital Terminal is using for upstream transmission.

MAC_Transmission_Mode

This parameter will indicate if the terminal has had its upstream transmission stopped by the headend via a <MAC> Transmission Control message or not.

```
Enum_MAC_Transmission_Mode { Transmission Stopped=0,
                             Transmission Allowed,
                             Reserved 2..2^32−1        };
```

Polling_Frequency

This is the polling frequency assigned to the terminal for the NRC poll responses. It will have been configured by the NRC.

A.6.5.3.9 <MAC> Logical Address Message

The <MAC> LOGICAL ADDRESS MESSAGE is sent to the Digital Terminal from the headend to configure address types supported by the Digital Terminal.

Logical_Address_Message(){	Bits	Bytes	Bit Number/ Description
Address_Fields_Included		**1**	
Network_Addr_Included	1		7 (no, yes)
Multicast40_Included	1		6:{no, yes}
Multicast24_Included	1		5:{no, yes}
Multicast16_Included	1		4:{no, yes}
Return_Path_Id_Included	1		3:{no, yes}
UPM_Address_Included	1		2:{no, yes}
IP Address Included	1		1:{no, yes}
reserved	1		
if (Network_Addr_Included == yes) {			
Network_Address	**40**	**5**	
}			
if (Multicast40_Included == yes) {			
Multicast40_Address	**40**	**5**	
}			
if (Multicast24_Included == yes) {			
Multicast24_Address	**24**	**3**	
}			
if (Multicast16_Included == yes) {			
Multicast16_Address	**16**	**2**	
}			
if (Return_Path_Id_Included == yes) {			
Return_Path_Id	**16**	**2**	
}			
if (UPM_Address_Included == yes) {			
UPM_Address	**24**	**3**	
}			
if (IP_Address_Included == yes) {			
IP_Address	**32**	**4**	
}			
}			

Address_Fields_Included

This field specifies which addresses will be set by this message. Each bit corresponds to a different address type. Address types include the 40-bit network address, the 40, 24 and 16-bit multicast addresses, and a 32-bit IP Address. The return path a terminal occupies may also be conveyed in this message. If the Upstream MAC Address is included in this message, the UPM_Address_Included flag will be set to 1.

Following this field are the actual address fields.

A.6.5.3.10 <MAC>Contention Channel List Message

The <MAC> CONTENTION CHANNEL LIST MESSAGE is broadcast periodically to the Digital Terminals. Digital Terminals operating with frequency hopping enabled on the upstream will use this list to determine which upstream channels are available for their use. All Digital Terminals using contention channels use this list to determine the appropriate backoff parameters for a particular channel.

Contention_Channel_List_Message(){	Bits	Bytes	Bit Number/ Description
Message_Format_Field		**1**	
Explicit_Frequencies_Included	1		7 {no, yes}
Return_Path_Id_Included	1		6 {no, yes}
Backoff_Parameters_Included	1		5 {no, yes}
Reserved	5		4..0
if (Return_Path_Id_Included==yes)			
Return_Path_Id;	**16**	**2**	
if (Backoff_Parameters_Included==yes){			
Time_Unit;	**16**	**2**	in µs
Xmax;	**8**	**1**	
Cell_Abort_Count;	**8**	**1**	
Max_Acknowledgment_Time;	**8**	**1**	in units of 10 ms
Backoff_Bias;	**8**	**1**	
MAC_Abort_Count;	**8**	**1**	
}			
Number_of_Channels_Listed;	**8**	**1**	
for (i=0;i<Number_of_Channels_Listed;++i){			
Channel_Format_Field[i]		**1**	
Frequency_Hopping_Allowed	1		7 {no, yes}
Reserved	7		6..0
if(Explicit_Frequencies_Included==yes)			in Hz
Upstream_Frequency[i];	**32**	**4**	
Else			
Upstream_Channel_Number[i];	**8**	**1**	
}			
}			

Message_Format_Field

The Message_Format_Field has bits to indicate whether or not this message contains the explicit frequency (in Hz) or upstream frequencies, or refers to those frequencies by a channel number. Also indicated in the Message_Format_Field is whether or not backoff algorithm parameters are included which apply to these upstream frequencies, and whether or not a Return_Path_Id is included in this message. The presence of a Return_Path_Id field would indicate that this message is for one particular return path.

Return_Path_Id

Specifies which return path this message applies to. Only included if the appropriate bit is set in the Message_Format_Field.

Time_Unit, Xmax, Cell_Abort_Count, Max_Acknowledgment_Time, Backoff_Bias, MAC_Abort_Count

These parameters are used by the binary exponential backoff algorithm in the Digital Terminal.

Number_of_Channels_Listed

This field indicates how many contention channels are described in this message.

Channel_Format_Field

Frequency_Hopping_Allowed

For each channel described in the message, the Frequency_Hopping_Allowed bit indicates if Frequency Hopping is allowed on the channel (i.e. if frequency hopping Digital Terminals may hop onto this frequency). Frequencies in the <MAC> CONTENTION CHANNEL LIST MESSAGE which do not have this bit set may have terminals on them that do not employ frequency hopping. (For the initial version of the ALOHA MAC, the only frequencies in this list will be those with frequency hopping enabled.)

Upstream_Frequency

This field indicates a valid upstream frequency in Hz to use.

Upstream_Channel_Number

This field indicates a valid upstream channel to use for frequency hopping.

A.6.5.3.11 <MAC>Acknowledge/Power Adjust Message

The <MAC> ACKNOWLEDGE/POWER ADJUST MESSAGE is sent to a Digital Terminal to acknowledge the receipt of one or more upstream MAC cells and to optionally have the Digital Terminal make a change to its transmitting power. This message is sent using singlecast addressing to a Digital Terminal.

Acknowledge/Power_Adjust_Message(){	**Bits**	**Bytes**	**Bit Number/ Description**
Acknowledge_Field		**1**	
Ack_or_Nak	1		7 (0=ack,1=nak)
Message_Number	2		(6, 5)
Sequence Number	5		(4..0)
Power_Control_Setting	**8**	**1**	
}			

Acknowledge_Field

The most significant bit of this byte indicates whether this is a positive acknowledgment or a negative acknowledgment. The following 7 bits correspond to the message number and sequence number being acknowledged or not-acknowledged.

Power_Control_Setting

Power_Control_Setting is an 8-bit signed integer to be used to set the new upstream power level of the Digital Terminal. A positive value represents an increase of the output power level.

$$\text{new output\_power\_level} = \text{current output\_power\_level} + \text{power\_control\_setting} \times 0.5 \text{ dB}$$

ANNEX B

Digital broadband delivery system: Out-of-band transport – Mode B

B.1 Introduction

B.1.1 Revision history

This annex describes the Physical Layer and Data Link Layer (including the MAC Layer) used in cable networks which employ an Out-Of-Band channel architecture. This is one of two methods used for Out-Of-Band (OOB) transport in cable systems currently in practice in North America. The method described in this annex is referred to as Mode B.

B.1.2 Acronyms

Table B.1-1 provides a definition of the acronyms used throughout this annex.

Table B.1-1/J.184 – Acronyms

AAL	ATM Adaptation Layer	CAT	Conditional Access Table
AAL1	ATM Adaptation Layer 1	CATV	Cable Television
AAL5	ATM Adaptation Layer 5	CCM	Continuous Code Management
ACK	Acknowledge	CDN	Cable Digital Network
ACS	Access Control and Security	CDT	Carrier Definition Table
AG	Administrative Gateway	CF	Continuous Feed
AHE	Analogue Headend	CFS	Continuous Feed Session
AMS	Alarms Management Subsystem	CM	Configuration Management
AM-VSB	Amplitude Modulation – Vestigial-Sideband	CMB	CRC Message Block
API	Applications Programmatic Interface	CMIP	Common Management Information Protocol
ARP	Address Resolution Protocol	CMIS	Common Management Information Service
ASN	Abstract Syntax Notation	CMS	Customer Management System
ATM	Asynchronous Transfer Mode	CORBA	Common Object Request Broker Architecture
ATSC	Advanced Television System Committee	CRC	Cyclical Redundancy Check
BASS	Business Applications Support System	CS	Convergence Sublayer
BCS	Broadcast Control Suite	CW	Control Word
BFS	Broadcast File Server	DAP	Directory Access Protocol
BM/G	Broadband Multiplexer/Gateway	DAVIC	Digital Audio Visual Council
BMM	Broadcast Manager Module	DBAPI	Database Application Programming Interface
BOOT TERM	Boot Terminal	DBDS	Digital Broadband Delivery System
BOSS	Business Operations Support System	DBS	Digital Broadcast Service
BPS	Bits per second	DCT	Display Channel Table
CA	Conditional Access	DES	Digital Encryption Standard
CAA	Conditional Access Authority (PowerKEY)	DHCT	Digital Home Communications Terminal
CAM	Conditional Access Manager	DHCTSE	Digital Home Communications Terminal Secure Element

Table B.1-1/J.184 – Acronyms

DHEI	Digital Headend Extended Interface	ID	Identifier
DIS	Digital Interactive Service	IDL	Interface Definition Language
DMS	Digital Multicast Service	IETF	Internet Engineering Task Force
DMSI	Digital Multicast Service Information	IGU	Integrated Gateway Unit
DNCS	Digital Network Control System	IP	Internet Protocol
DS-3	Digital Signal Level 3	IPA	Internet Protocol Address
DSM-CC/DSMCC	Digital Storage Media Command and Control	IPPV	Impulse Pay Per View
DVB	Digital Video Broadcasting (European)	IRC	Incrementally Related Carrier
DVB-ASI	Digital Video Broadcasting Asynchronous Serial Interface	ITU	International Telecommunication Union
DVSG	Digital Video Software Group	IVSN	Interactive Video Services Network
EA	Entitlement Agent (PowerKEY)	IXC	Inter-Exchange Carrier
EAI	External Alarm Interface	L1	Level 1
ECM	Entitlement Control Message	LAN	Local Area Network
EIA	Electronic Industries Association	LCR	Local Clock Reference
EID	Entitlement Identifier	LCT	Logical Channel Table
EM	Element Manager. Generically, any control software that manages hardware elements.	LDAP	Lightweight Directory Access Protocol
EMM	Entitlement Management Message	LOC	Line of Code
ENT	Entitlement Name Table	LUG	Line Up Group
EPG	Electronic Program Guide	MAC	Media Access Control
ESBI	External Status and Billing Interface	Mbps	Mega bits per second
ESF	Extended SuperFrame	MHz	Mega-Hertz
EUT	Entitlement Unit Table	MIB	Management Information Base
FAS	Frame Alignment Signal	MMDS	Multi-Megabyte Digital Service
FAT	Forward Applications Transport	MMT	Modulation Mode Table
FDDI	Fiber Data Distribution Interface	MPEG	Moving Picture Experts Group
FDM	Frequency Division Multiplexed	MSK	Multi-Session Key
FEC	Forward Error Correction	MUX	Multiplexer
FPM	Forward Purchase Messages	N/A	Not Applicable
FTP	File Transfer Protocol	NAK	Not Acknowledged
GBAM	Global Broadcast Authenticated Message	NE	Network Element
GOP	Group Of Pictures	NFS	Network File System
GPS	Global Positioning System	NI	Network Inventory
GUI	Graphical User Interface	NIC	Network Information Centre
HEC	Headend Code	NIT	Network Information Table
HEX	Hexadecimal	NMS	Network Management System
HFC	Hybrid Fibre Coax	NSAP	Network Service Access Point
HID	Hub ID	NTP	Network Time Protocol
HRC	Harmonically Related Carrier	NTSC	National Television System Committee
IANA	Internet Assigned Number Authority	NVOD	Near Video On Demand
IBDS	Interactive Broadband Delivery System	NVSC	Non-Volatile Storage Cell

Table B.1-1/J.184 – Acronyms

OC-3	Optical Carrier Level 3	SI	Service Information
OMG	Object Management Group	SID	Session Identifier
OMS	Object Management Server	SLIP	Serial Line Internet Protocol
ONC	Open Network Computing	SM	System Manager
OQPSK	Offset Quadrature Phase Shift Keying	SMI	Structure of Management Information
ORB	Object Request Broker	SMS	Subscriber Management System
OS	Operating System	SN	Sequence Number
OSF	Operations System Functions	SNMP	Simple Network Management Protocol
OSI	Open Systems Interconnection	SNP	Sequence Number Protection
OSS	Operations Support System	SNVM	Secure Non-Volatile Memory
OUI	Organization Unique Identifier	SONET	Synchronous Optical Network
PA	Physical Address	SP	Service Provider
PAT	Program Association Table	SPE	Synchronous Payload Envelope
PCR	Program Clock Reference	SRM	Session and Resource Manager
PDU	Payload Data Unit	SSL	Secure Sockets Layer
PEN	Private Enterprise Number	STS-3c	Synchronous Transport Signal level 3 concatenation (155.552 Mbit/s)
PES	Packetized Elementary Stream	SW	Software
PID	Process ID	SWIF	Single Wire Interface
PIN	Personal Identification Number	TCP	Transport Control Protocol
PKCS	Public Key Cryptography Standards	TCP/IP	Transport Control Protocol/Internet Protocol
PKYCS	Power Key Control Suite	TDMA	Time Division Multiple Access
PMT	Program Map Table	TED	Transition Encryption Decryption
POSIX	Portable Operating System Interface Unix	TLI	Transport Level Interface
POTS	Plain Old Telephone Service	TMN	Telecommunications Management Network
PPV	Pay Per View	TS	Transport Stream
PRBS	Pseudo-Random Bit Stream	UDP	User Datagram Protocol
PS	Program Stream	UI	User Interface
PSI	Program Specific Information	UNISON	Unidirectional SONET
PVC	Permanent Virtual Circuit	UPA	Ultra SPARC Port Architecture
QAM	Quadrature Amplitude Modulation	UPS	Universal Power Supply
QPSK	Quadrature Phase Shift Keying	USID	Universal Service Identifier
RDBMS	Relational Database Management System	VASP	Value-Added Service Provider
RF	Radio Frequency	VBI	Video Blanking Interval
RPC	Remote Procedure Call	VCI	Virtual Circuit Indicator
RS	Reed-Solomon (coding)	VCR	Video Cassette Recorder
SAR	Segmentation and Reassembly	VCT	Virtual Channel Table
SAR-PDU	Segmentation and Reassembly Protocol Data Unit	VOD	Video On Demand
SET	Secure Electronic Transaction	VPI	Virtual Path Indicator
Sev	Severity	VSP	Video Service Provider
SG	Service Gateway	XDR	External Data Representation

B.1.3 References

Informative

[1] Digital Audio Visual Council 1.2 Specification part 8: Lower Layer Protocols and Physical Interfaces, 1997 (http://www.davic.org).

Normative references

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published.

Normative reference list

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

[3] ITU-T I.363.5 (1996), *B-ISDN ATM adaptation layer specification*: *Type 5 AAL*.

B.2 DAVIC out-of-band and upstream signalling

The following has been extracted from the DAVIC 1.2 part 8 [Ref. 1] specification: Section 7.8, *Passband Bidirectional PHY on coax*. This does not include or track the issuance of corrigenda.

This Physical Layer Interface supports transmission over radio frequency coax (up to 1 GHz bandwidth). It is referred to as the bidirectional QPSK-link on HFC (Hybrid Fibre Coax).

This Physical Layer Interface describes the complete physical layer structure, i.e. framing structure, channel coding and modulation for each direction Downstream and Upstream. For the downstream QPSK modulation channel Grade A is mandatory and Grade B is optional. For the upstream QPSK channel Grade B is mandatory and Grades A and C are optional.

A summary of the spectrum allocation is depicted in Figure B.2-1.

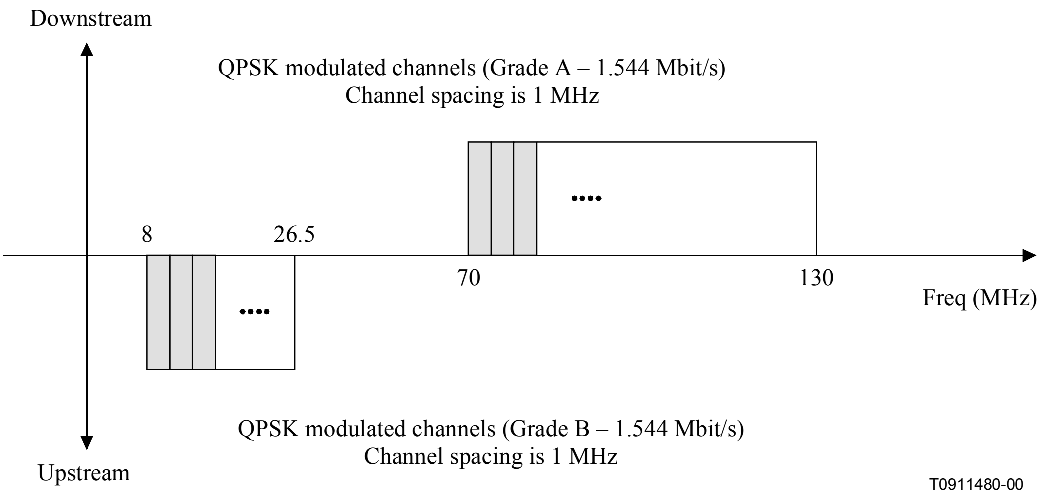


Figure B.2-1/J.184 – Spectrum allocation For the bidirectional PHY on coax

The Passband Bidirectional PHY on coax and the Passband Unidirectional PHY on coax may be used together on the same physical medium. Figure B.2-2 shows the spectrum allocation in this case.

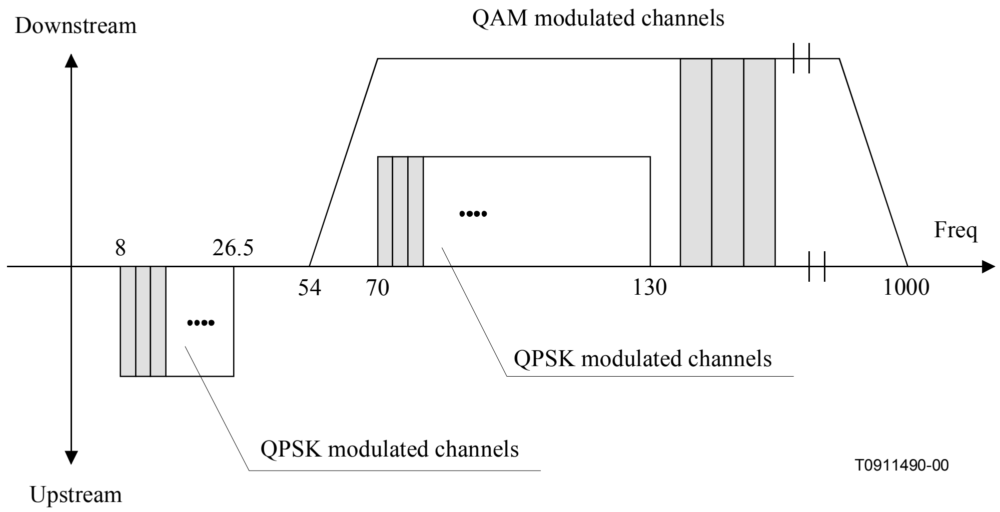


Figure B.2-2/J.184 – Spectrum allocation for the integrated unidirectional and bidirectional passband PHY on a single coax

Conceptual block diagrams of the DHCT transceivers are shown in Figure B.2-3.

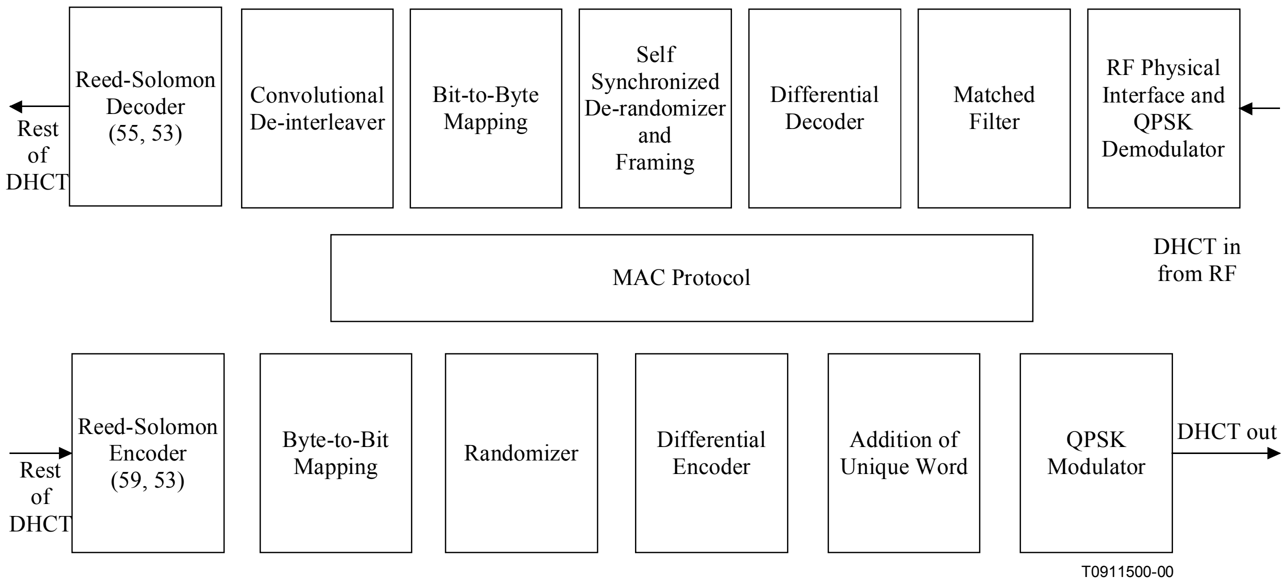


Figure B.2-3/J.184 – DHCT OOB transceiver conceptual block diagram

B.2.1 Downstream physical interface specification

To carry downstream information a combination of quadrature phase shift keying (QPSK) and a framing structure are specified. QPSK is specified due to its increased error performance, its spectral efficiency, and its low peak to average power allow transmission at a high average power. The DAVIC specified Grade A QPSK is mandatory with Grade B being optional.

B.2.1.1 Quadrature Phase Shift Keying (QPSK)

QPSK modulation is used as a means of encoding digital information over wireline or fibre 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.

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

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

where T is the symbol period.

The output signal shall be defined as:

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

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 QPSK signal parameters are:

RF bandwidth	$BW = (f_b/2) * (1 + \alpha)$
Occupied RF Spectrum	$[f_c – BW/2, f_c + BW/2]$
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 both bit rates: 1.544 Mbit/s (Grade A) and 3.088 Mbit/s (Grade B), the Power Spectrum at the QPSK transmitter shall comply to the Power Spectrum Mask given in Table B.2-1 and Figure B.2-4. The Power Spectrum Mask shall be applied symmetrically around the carrier frequency.

Table B.2-1/J.184 – QPSK downstream 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

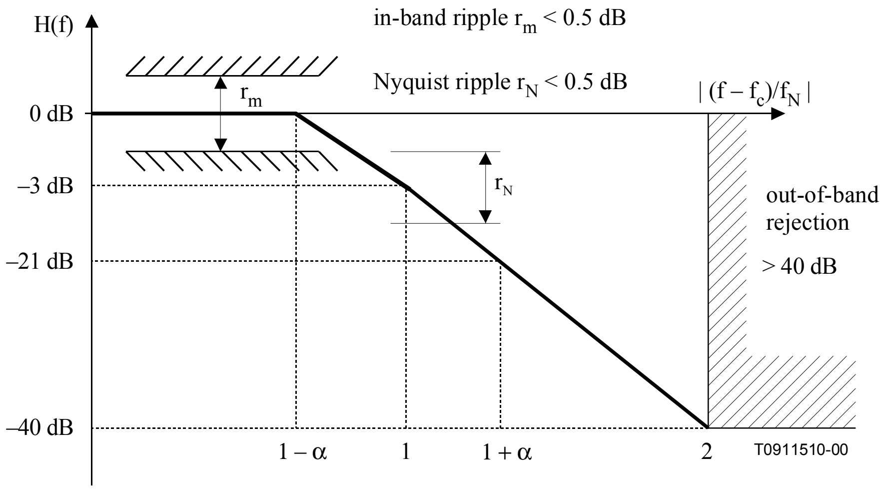


Figure B.2-4/J.184 – QPSK downstream transmitter power spectrum

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 implementation of the QPSK (de)modulator shall comply to the specifications given in Table B.2-2.

Table B.2-2/J.184 – Specifications for QPSK modulation (Downstream)

	Specifications for QPSK Modulation (Downstream)
Transmission Rate	1.544 Mbit/s for Grade A 3.088 Mbit/s for Grade B A QPSK demodulator shall support Grade A (B is optional)
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 (centre frequency granularity)

Table B.2-2/J.184 – Specifications for QPSK modulation (Downstream)

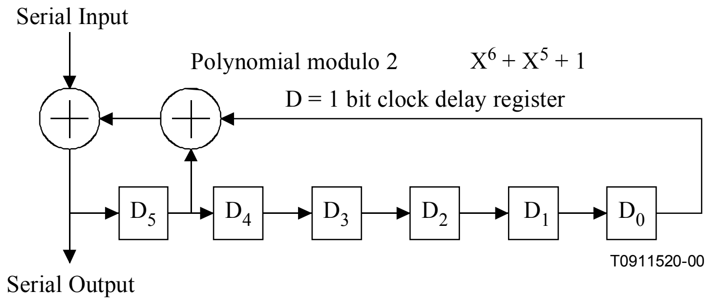
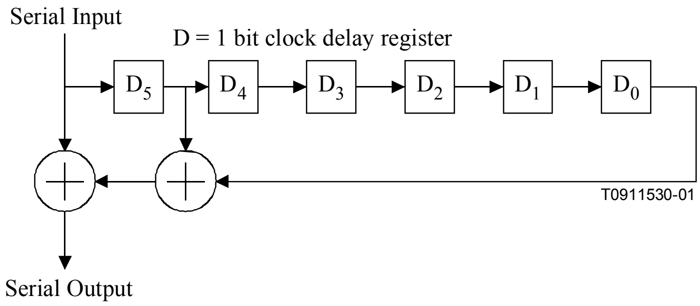
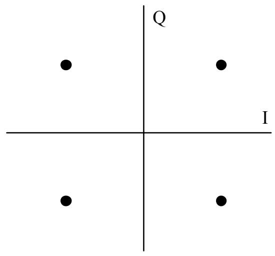
	Specifications for QPSK Modulation (Downstream)
Randomization	After addition of the FEC bytes, MSB first byte to serial conversion is performed and then, all of the 1.544 Mbit/s or 3.088 Mbit/s data is passed through a six register linear feedback shift register (LFSR) randomizer to ensure a random distribution of ones and zeroes. The generating polynomial is: $x^6 + x^5 + 1$. Randomizer:  A complementary self-synchronizing de-randomizer is used in the receiver to recover the data. De-randomizer: 
Differential Encoding	Bytes entering the byte-to-symbol encoder are divided into four bit pairs, each bit pair generating one QPSK symbol. Byte boundaries coincide with bit pair boundaries: that is, no bit pairs overlap two bytes. The bit pair corresponding to the MSBs of the byte is sent first. Within each bit pair, the more significant bit is referred to a "A" and the less significant as "B". 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 degrees 1 1 180 degrees 1 0 –90 degrees Initialization: The differential encoder state at the start of the payload (equivalent to at the end of the preamble) must be [I, Q] = [01].

Table B.2-2/J.184 – Specifications for QPSK modulation (Downstream)

	Specifications for QPSK Modulation (Downstream)
Signal Constellation	The outputs I, Q from the differential encoder map to the phase states as follows: 
Carrier Centre Frequency Range	70 to 130 MHz. The receiver shall operate over the entire specified frequency range.
Frequency Stability	±50 ppm measured at the upper limit of the frequency range
Symbol Rate Accuracy	±50 ppm
Transmitter Power Spectrum 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 B.2-1
Carrier Suppression	>30 dB
I/Q Amplitude Imbalance	<1.0 dB
I/Q Phase Imbalance	<2.0 degree
Receive Power Level at the demodulator input (downstream out-of-band)	42-75 dBmicroV (RMS) (75 Ohms)
C/N at the DHCT input (Nyquist bandwidth, white noise)	>20 dB for BER<1x10E015–10 (after R/S error correction) (i.e. 1 error in 2 hours at 1.5 Mbit/s) >18 dB for BER <1x10E–6 before R/S error correction

B.2.1.2 Coaxial cable impedance

The coaxial cable nominal impedance shall be 75 Ohms over the frequency range as specified in Table B.2-2.

B.2.1.3 Framing structure

The framing organization shall be based on Signalling Link Extended Superframe (SL-ESF) format, an SL-ESF payload structure, and an ATM cell structure.

B.2.1.4 Signalling Link Extended Superframe (SL-ESF) Framing Forms

The Signalling Link Extended Superframe (SL-ESF) frame structure is illustrated in Figure B.2-5. The bitstream is partitioned into 4 632 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.

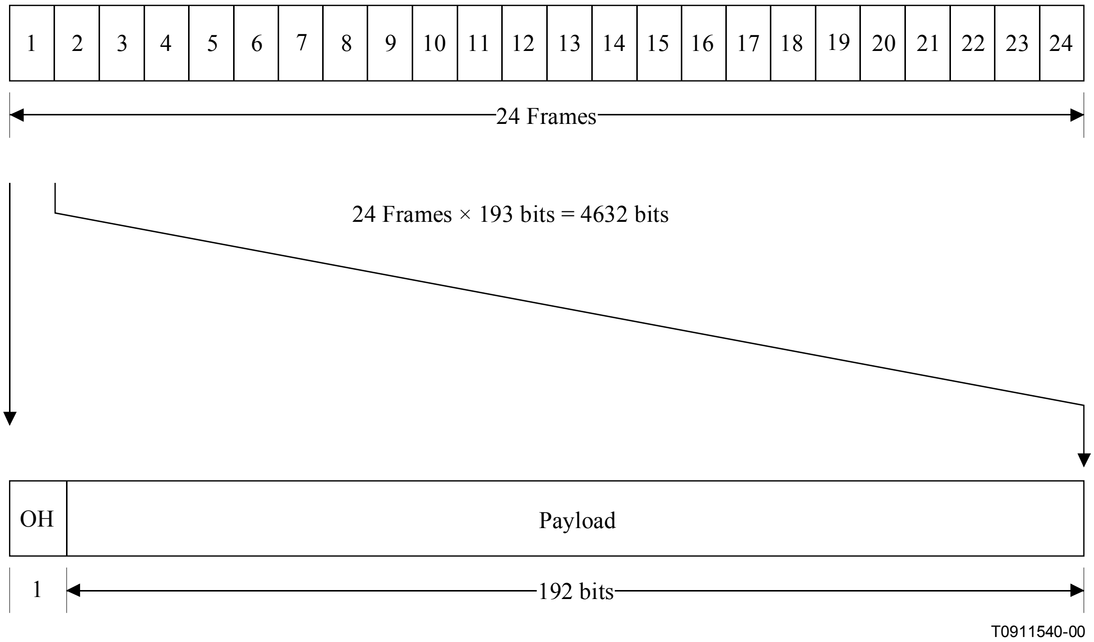


Figure B.2-5/J.184 – SL-ESF frame structure

B.2.1.5 SL-ESF 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 illustrated in Table B.2-3.

Table B.2-3/J.184 – Extended superframe overhead structure

Frame Number	Bit Number	Overhead Bit	Data (192 bits)	
1	0	**M1**		♦ Slot Position
2	193	C1		
3	386	M2		
4	579	F1 = 0		
5	772	M3		
6	965	C2		
7	1 158	M4		
8	1 351	F2 = 0		
9	1 544	**M5**		♦ Slot Position
10	1 737	C3		
11	1 930	M6		
12	2 123	F3 = 1		
13	2 316	M7		
14	2 509	C4		
15	2 702	M8		
16	2 895	F4 = 0		

Table B.2-3/J.184 – Extended superframe overhead structure

Frame Number	Bit Number	Overhead Bit	Data (192 bits)	
17	3 088	**M9**		♦ Slot Position
18	3 281	C5		
19	3 474	M10		
20	3 667	F5 = 1		
21	3 860	M11		
22	4 053	C6		
23	4 246	M12		
24	4 439	F6 = 1		
FAS Frame Alignment Signal (F1-F6) DL Mbit/s Data Link (M1-M12) CRC Cyclic Redundancy Check (C1-C6)				

B.2.1.6 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

B.2.1.7 ESF cyclic redundancy check

The Cyclic Redundancy Check field (Table B.2-3) contains the CRC-6 check bits calculated over the previous Extended Superframe (CRC Message block [CMB] size = 4 632 bits). Before calculation, all 24 frame overhead bits are equated to the value "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 $x^6 + x + 1$ of the CMB. C1 is the most significant bit of the remainder. The initial remainder value is preset to all zeroes.

B.2.1.8 ESF M-bit data link

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

- to mark the slot positions for the upstream Contention based and Contentionless based signalling links;
- to provide slot count information for upstream message bandwidth allocation management in the DHCT.

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

Think of M-bits M10-M1 as a register, which counts from 0 to N, where N is an integer which indicates slot position cycle size (the value of N is sent in the MAC Default Configuration Message as Service_Channel_Last_Slot). The upstream slot position register indicates the upstream slot positions that will correspond to the next SL-ESF frame. Upstream slot positions are counted from 0 to N. There are 3 upstream slots per upstream slot position when the upstream data rate is 1.544 Mbit/s, there are 6 upstream slots per upstream slot position when the upstream data rate is 3.088 Mbit/s, and there is 0.5 upstream slot per upstream slot position when the upstream data rate is 256 kbit/s. The corresponding upstream slot rates are: therefore: 3000 upstream slots/s when the upstream data rate is 1.544 Mbit/s, 6000 upstream slots/s when the upstream data rate is 3.088 Mbit/s, and 500 upstream slots/se when the upstream data rate is 256 kbit/s. 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 {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 (see Table B.2-3) 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_value (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".

B.2.1.9 SL-ESF frame 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 Figure B.2-6.

1	**← 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

Figure B.2-6/J.184 – SL-ESF payload structure format

The SL-ESF payload structure consists of 5 rows of 57 bytes each, 4 rows of 58 bytes each which includes 1 byte trailer, and 1 row of 59 bytes, which includes a 2-byte trailer. The first bit of the SL-ESF payload structure follows the M1 bit of the SL-ESF frame. The SL-ESF payload fields are defined as follows.

The two T fields shall be set to 0 to facilitate future enhancements.

Rxa-Rxc is a 24-bit field containing slot configuration information for the related upstream channel "x" and is defined as:

Rxa = (b0 ... b7)
Rxb = (b8 ... b15)
Rxc = (b16 ... b23)

qpsk_x_slot_configuration = (b0 ... b23)

= slot configuration information for the upstream channel "x"

where:

b0	= ranging control slot indicator for next 3 ms period
b1-b6	= slot boundary definition field for next 3 ms period
b7	= slot 1 reception indicator for second previous 3 ms period
b8	= slot 2 reception indicator for second previous 3 ms period
b9	= slot 3 reception indicator for second previous 3 ms period
b10	= slot 4 reception indicator for second previous 3 ms period
b11	= slot 5 reception indicator for second previous 3 ms period
b12	= slot 6 reception indicator for second previous 3 ms period
b13	= slot 7 reception indicator for second previous 3 ms period
b14	= slot 8 reception indicator for second previous 3 ms period
b15	= slot 9 reception indicator for second previous 3 ms period
b16-17	= reservation control for next superframe
b18-b23	= CRC-6 parity (see definition in SL-ESF section)

When the upstream data channel is a 256 kbit/s data channel, then only the first three slot reception indicators are valid. These slot indicators refer to the three available slots which span over two 3 ms period periods in the 256 kbit/s. When the upstream data channel is a 3.088 Mbit/s data channel, two consecutive qpsk_slot_configuration fields are used. The definition of the first slot configuration field is unchanged. The definition of the second slot configuration field extends the boundary definition to upstream slots 10 through 18, and the reception indicators cover upstream slots 10 through 18.

When the Downstream MAC channel is a 3.088 Mbit/s data channel, the Slot Configuration fields in superframe-B are used when one or more 3.088 Mbit/s upstream QPSK channels are being utilized. The index for the overhead bytes in superframe-B will be R9a, R9b … R16a, R16b, R16c.

Reed-Solomon encoding shall be performed on each ATM cell with T = 1. 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 **= 02hex**

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

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 B.2-7, 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) cells (where M = N/I, N = 55 = error protected frame length, I = interleaving depth). The input and output switches shall be synchronized.

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.

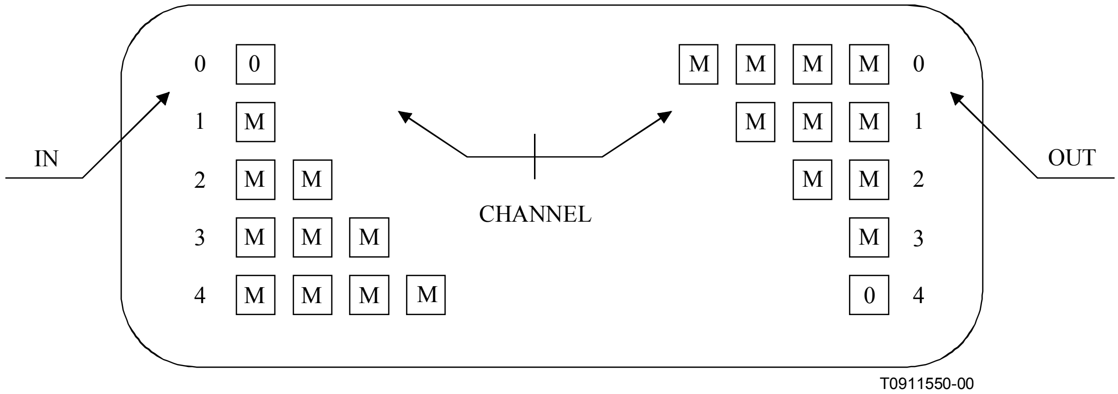


Figure B.2-7/J.184 – Conceptual diagram of the convolutional interleaver and De-interleaver

B.2.1.10 Definition of slot configuration fields

Ranging Control 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 3 ms period are designated as ranging control slots. A ranging control message may be transmitted in the second ranging control slot, and the first and third ranging control slots may not be used for transmission (guardband 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 regions within the 3 ms period such that slots of a similar type are contained within the same region. The order of the regions is Ranging slot, Contention based slots, Reserved slots and Contentionless based slots. If a ranging slot is available within a 3 ms period it will consist of the first three slot times in the 3 ms period. A ranging slot is indicated by b0 = 1. The boundaries between the remaining regions of the 3 ms are defined by b1-b6. The boundaries are defined in Figure B.2-8.

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

Figure B.2-8/J.184 – Boundary definitions

The boundary positions are defined by b1-b6 in Figure B.2-9.

row = Contention based/Reserved region boundary

column = Reserved packet/Contentionless based region boundary

(example: b0 = 0, b1-b6 = 22: Contention (1-2), Reserved (3-5), Contentionless (6-9))

	0	1	2	3	4	5	6	7	8	9
0[a)]	0	1	2	3	4	5	6	7	8	9
1 [a)]		10	11	12	13	14	15	16	17	18
2 [a)]			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

a) 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 mean that there are no ALOHA slots, because slots 1-3 are defined as ranging control slots.

Figure B.2-9/J.184 – Slot boundary definition field values

The remaining values of the Slot Boundary Definition Field are provided in Figure B.2-10.

b1-b6 value	Ranging Control slots	Contention slots	Reservation slots	Contentionless 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 – For b1-b6 = 55-63, b0 must be set to 1.

Figure B.2-10/J.184 – Additional slot boundary definition field values for extended range control slots

The values in Figures B.2-9 and B.2-10 are derived from b1-b6 in the following manner:

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

When the upstream data channel is a 256 kbit/s data channel, then only the first three slot boundary positions are valid. In this case, only the first three rows and columns in Figure B.2-9 are valid, and Figure B.2-10 is not valid. When the upstream data channel is a 3.088 Mbit/s data channel, each slot boundary definition field applies to 9 slots within the 3 ms period. In this case, there will be two slot boundary definition fields which define the 3 ms period.

Slot Reception Indicators (b7-b15) – When a slot reception indicator is active ("1"), this indicates that a cell was received without collision. The relationship between a given US slot and its indicator is shown in Figure B.2-11. When the indicator is inactive ("0"), this indicates that either a collision was detected or no cell was received in the corresponding upstream slot.

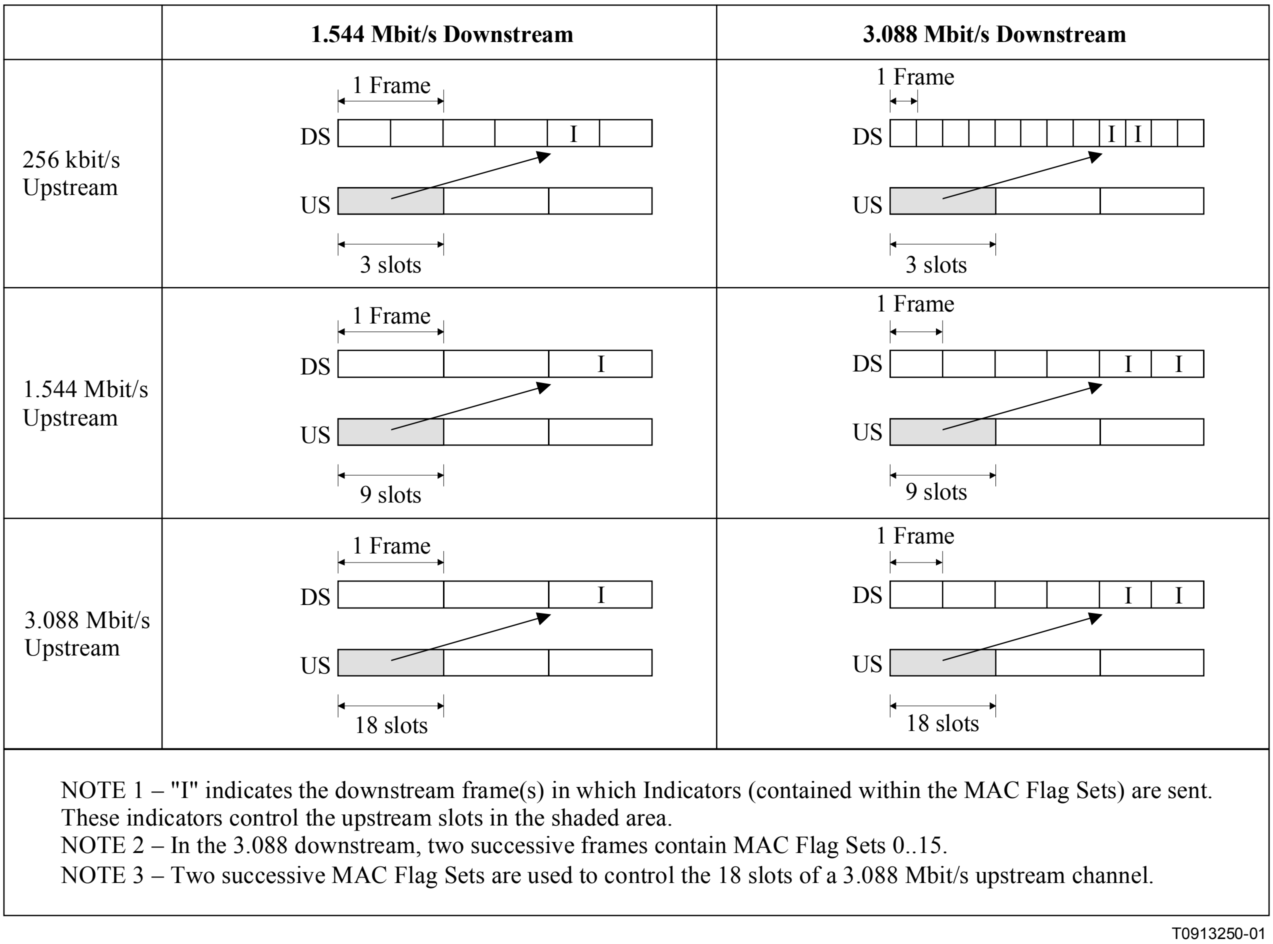


Figure B.2-11/J.184 – Relationship of US slot to DS indicator

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.

CRC-6 Parity (b18-b23) – This field contains a CRC-6 parity value calculated over the previous 18 bits. The CRC-6 parity value is described in the SL-ESF frame format Section.

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.

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.

B.2.1.11 ATM cell structure

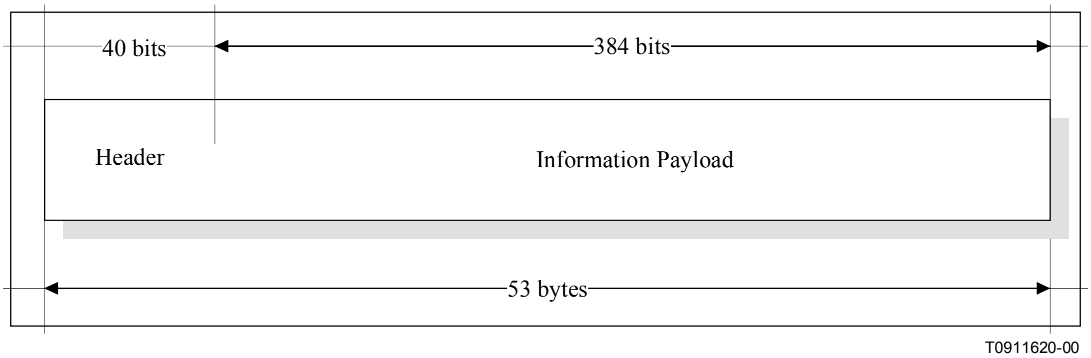


Figure B.2-12/J.184 – ATM cell structure

The format for each ATM cell structure is illustrated in Figure B.2-12. This structure and field coding shall be consistent with the structure and coding given in [ITU-T I.361] [Ref. 2] for ATM UNI, both for the ATM and non-ATM based passband bidirectional PHY on coax.

B.2.2 Upstream physical interface specification

To carry upstream information a combination of quadrature phase shift keying (QPSK) and a Time Division Multiplexing structure are specified. QPSK is specified due to its increased error performance, its spectral efficiency, and its ability to be transmitted at higher than average power levels. DAVIC specified Grade B is mandatory with Grades A and C being optional.

B.2.2.1 Quadrature Phase Shift Keying (QPSK)

An overview of QPSK modulation has been provided in the downstream QPSK modulation section.

The QPSK signal parameters are:

RF bandwidth	$BW= (f_b/2) \times (1 + \alpha)$
Occupied RF Spectrum	$[f_c – BW/2, f_c + BW/2]$
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 three bit rates: 256 kbit/s (Grade A), 1.544 Mbit/s (Grade B) and 3.088 Mbit/s (Grade C), the Power Spectrum at the QPSK transmitter shall comply to the Power Spectrum Mask given in Table B.2-4 and Figure B.2-13. The Power Spectrum Mask shall be applied symmetrically around the carrier frequency.

Table B.2-4/J.184 – QPSK upstream transmitter power spectrum

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

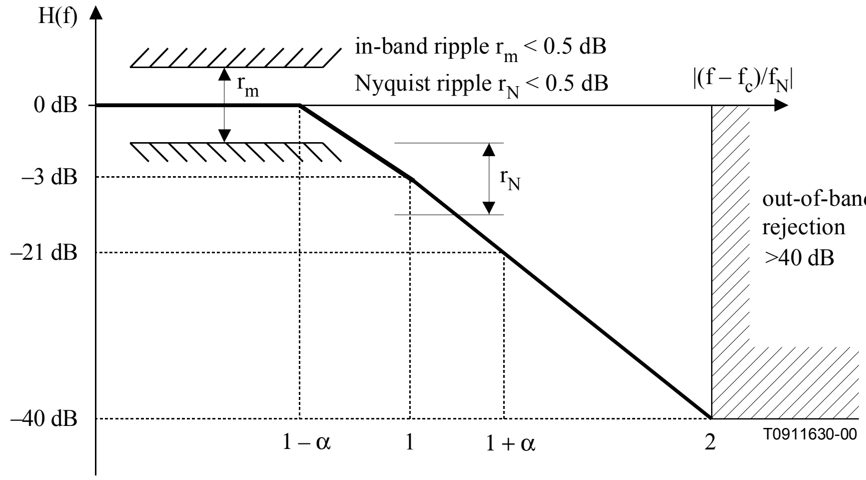


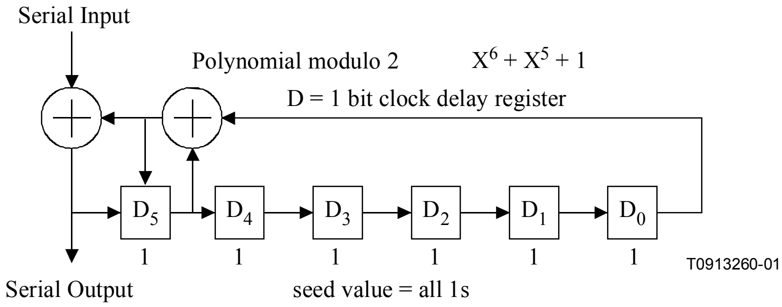
Figure B.2-13/J.184 – QPSK upstream transmitter power spectrum

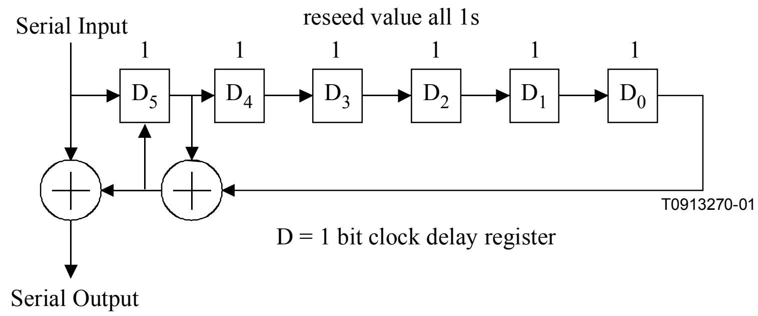
The specifications which shall apply to QPSK modulation for the upstream channel are given in Table B.2-5.

Table B.2-5/J.184 – Specifications for QPSK modulation (Upstream)

	Specifications for QPSK modulation (Upstream)
Transmission Rate	Three grades of modulation transmission rate are specified: Grade Rate A 256 kbit/s B 1.544 Mbit/s C 3.088 Mbit/s A QPSK modulator (transmitter) shall support B grade of transmission with A and C grades of transmission being optional. A QPSK demodulator (receiver) shall support B grade with A and C being optional.
Modulation	Differentially encoded QPSK
Transmit Filtering	$\alpha = 0.30$ square root raised cosine for Grade A (256 kbit/s), Grade B (1.544 Mbit/s), and Grade C (3.088 Mbit/s)
Channel Spacing	200 kHz for Grade A (256 kbit/s) 1 MHz for Grade B (1.544 Mbit/s) 2 MHz for Grade C (3.088 Mbit/s)
Frequency Step Size	50 kHz for Grade A, Grade B and Grade C
Unique Word	The unique word is four bytes: CC CC CC 0D hex, transmitted in this order.

Table B.2-5/J.184 – Specifications for QPSK modulation (Upstream)

<table>
<tr><th></th><th>Specifications for QPSK modulation (Upstream)</th></tr>
<tr><td>Randomization</td><td>
The unique word shall be sent in the clear. After addition of the FEC bytes, randomization shall apply only to the 53-byte payload area and 6 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. The 472-bit binary sequence generated by the shift register starts with 00000100… The first "0" is to be added to the first bit after the unique word.
Randomizer:


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.
De-randomizer:


</td></tr>
<tr><td>Differential Encoding</td><td>
Bytes entering the byte-to-symbol encoder are divided into four bit pairs, each bit pair generating one QPSK symbol. Byte boundaries coincide with bit pair boundaries: that is, no bit pairs overlap two bytes. The bit pair corresponding to the MSBs of the byte is sent first. Within each bit pair, the more significant bit is referred to as "A" and the less significant as "B". The differential encoder shall accept bits (A, B) in sequence, and generate phase changes as follows:
<table>
<tr><th>A</th><th>B</th><th>Phase Change</th></tr>
<tr><td>0</td><td>0</td><td>none</td></tr>
<tr><td>0</td><td>1</td><td>+90 degrees</td></tr>
<tr><td>1</td><td>1</td><td>180 degrees</td></tr>
<tr><td>1</td><td>0</td><td>–90 degrees</td></tr>
</table>
</td></tr>
</table>

Table B.2-5/J.184 – Specifications for QPSK modulation (Upstream)

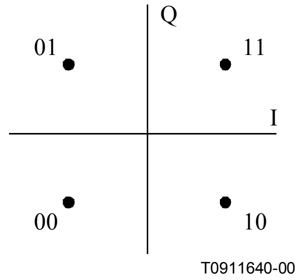
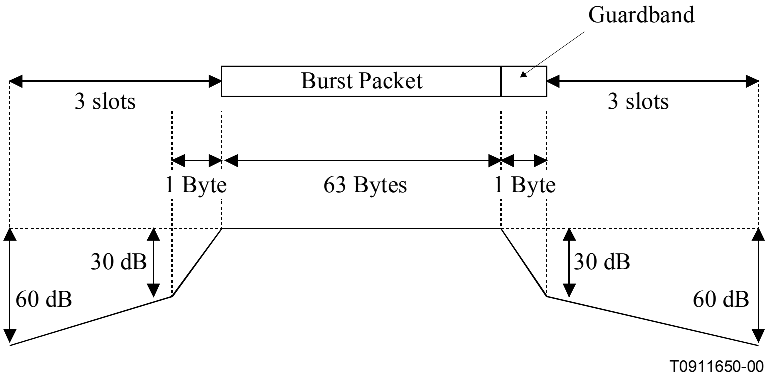
	Specifications for QPSK modulation (Upstream)
Signal Constellation	The outputs I, Q from the differential encoder map to the phase states as follows:  This constellation is used for the detection of the Unique Word, which is not differentially encoded.
Carrier Centre Frequency Range	8-26.5 MHz. The transmitter shall operate over the entire specified frequency range. The lowest carrier centre frequency is 8 MHz.
Frequency Stability	±50 ppm measured at the upper limit of the frequency range
Symbol Rate Accuracy	±50 ppm
Transmitter Power Spectrum Mask	A common mask for all three bit rates: 256 kbit/s (Grade A), 1.544 Mbit/s (Grade B) and 3.088 Mbit/s (Grade C) is given in Table B.2-4.
Carrier Suppression when Transmitter Active	>30 dB
Carrier Suppression when Transmitter Idle	The Carrier Suppression shall be more than 60 dB below nominal power output level, over the entire power output range and 30 dB right after or before transmission. Details are shown in the figure below. NOTE – 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 degree
Transmit Power Level at the modulator output (upstream)	85-113 dBmicroV (RMS) (75 Ohms)

Table B.2-5/J.184 – Specifications for QPSK modulation (Upstream)

	Specifications for QPSK modulation (Upstream)
C/N at the demodulator input at the A3 reference point (Nyquist bandwidth, white noise)	>20 dB @ 1x10E-6 packet loss (after error correction) NOTE – A packet loss occurs when one or more bits per packet (after error correction) are uncorrectable.

B.2.2.2 Coaxial cable impedance

The coaxial cable nominal impedance shall be 75 Ohms over the frequency range as specified, see Table B.2-5.

B.2.2.3 Time Division Multiple Access (TDMA)

TDMA allows a DAVIC DHCT access onto a signalling channel for upstream Application control information. The TDMA technique is used for communication between the DHCT and the Service Provider System. TDMA is based on dividing access by multiple set-top units onto a shared signalling channel. This technique provides a negotiated bandwidth allocation slot access method.

B.2.2.3.1 Slot definition

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 message packets do not overlap during transmission. The period between sequential start times are identified as slots. Each slot is a point in time when a message 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. Since all DHCTs reference the same time base, the slot times are aligned for all DHCTs. However, since there is propagation delay in any transmission network, a time base ranging method accommodates deviation of transmission due to propagation delay.

The upstream slot rates are 3000 upstream slots/s when the upstream data rate is 1.544 Mbit/s and 500 upstream slots/s when the upstream data rate is 256 kbit/s.

The format of the upstream slot is shown in Figure B.2-14. A Unique Word (UW) (4 bytes) provides a burst mode acquisition method. The payload area (53 bytes) contains a single message cell as described previously. The RS Parity field (6 bytes) provides t = 3 Reed-Solomon protection RS (59, 53) over the payload area. The Guardband (1 byte) provides spacing between adjacent packets.

Reed-Solomon encoding shall be performed on each ATM cell with T = 3. This means that 3 erroneous byte per ATM cell can be corrected. This process adds 6 parity bytes to the ATM cell to give a codeword of (59, 53). Reed-Solomon encoding is performed on the ATM cell before upstream data randomization.

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

Code Generator Polynomial: $g(x) = (x + \mu^0)(x + \mu^1)(x + \mu^2) \ldots (x + \mu^5)$, **where** μ **= 02hex**

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

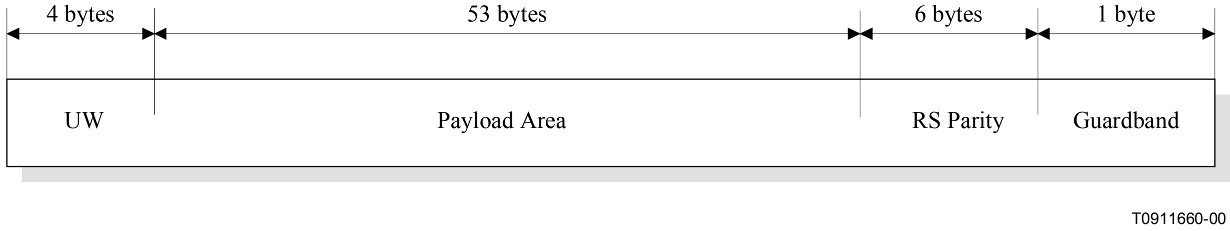


Figure B.2-14/J.184 – Upstream Slot Structure

This structure and field coding shall be consistent with the structure and coding given in [ITU-T I.361] [Ref. 2] for ATM UNI.

B.2.2.3.2 Slot definition assignment

Since the TDMA signalling link is used by DHCTs 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 DHCT may be assigned multiple message slots for increased messaging throughput. Additional slot assignments are provided to the DHCT from the downstream signalling information flow.

B.2.2.4 Contention based access

Upstream session related control information and network related control information are provided via a service channel using quadrature phase shift keying (QPSK) along with a contention-based protocol.

Contention based access is used for managing contention of transmission over a signalling link. For the DAVIC system, this protocol is utilized as a technique for signalling between an DHCT and the Delivery System's Service-Related Control function. Contention based access provides instant channel allocation for the DHCT.

The Contention based technique is used for multiple subscribers that will have equal access to the signalling channel. It is probable that simultaneous transmissions will occur. The Contention based technique provides resolution of signalling throughput when simultaneous transmissions occur.

B.2.2.4.1 Slot definition

The slot definition utilized for the contention based access is the same as that defined in the TDMA clause B.2.2.3.1.

B.2.2.4.2 Positive Acknowledgment

For each ATM cell transmitted by the DHCT, a positive acknowledgment is sent back by the NMS, utilizing the reception indicator field, for each successfully received ATM cell. In contention based access mode, a positive acknowledgment indicates that a collision did not occur. A collision occurs if two or more DHCTs attempt ATM cell transmission during the same slot. A collision will be assumed if a DHCT does not receive a positive acknowledgment. If a collision occurs, then the DHCT will initiate a retransmission procedure.

B.2.2.5 Relationship between downstream MAC control channels and upstream channels

Up to 8 QPSK Upstream channels can be related to each downstream channel which is designated as a MAC control channel. 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 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 perform MAC functions for each of these related upstream channels is transmitted via the downstream MAC control channel.

B.2.2.6 Slot location and alignment for the QPSK upstream channels

Transmission on each QPSK upstream channel is based on dividing access by multiple DHCTs 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 ATM cells do not overlap during transmission.

The slot position reference for upstream slot locations is received via the related downstream MAC control channel by each DHCT. Since each DHCT 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 3000 upstream slots/s when the upstream data rate is 1.544 Mbit/s and 500 upstream slots/s when the upstream data rate is 256 kbit/s.

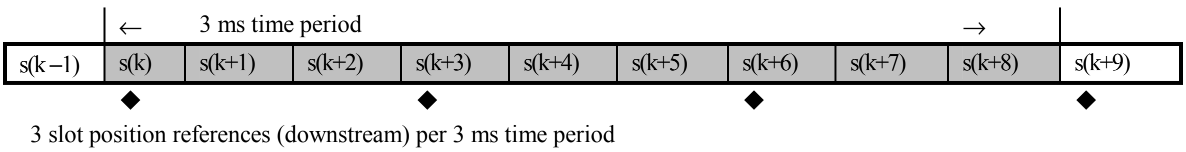
The number of slots available in any one second is given by:

number of slots/s = (upstream data rate/512) + extra guardband

where extra guardband may be designated between groups of slots for alignment purposes.

B.2.2.6.1 Upstream data rate – 1.544 Mbit/s

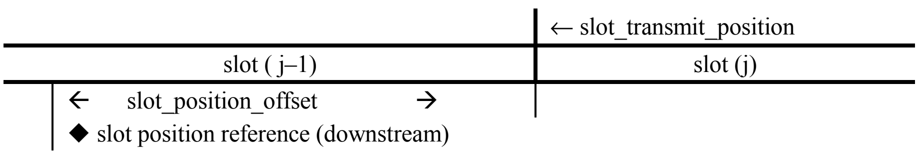
In the case where the upstream data rate is 1.544 Mbit/s, the upstream slots are numbered as shown below, where k is a multiple of 9.



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

slot_transmit_position = slot_position_reference + slot_position_offset

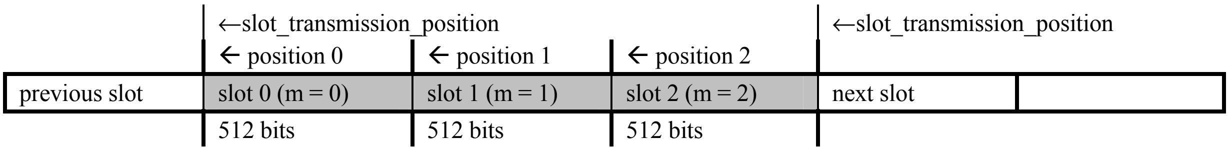
where slot_position_offset is derived from the Time_Offset_Value provided via the Range_and_Power_Calibration_Message.



In the case where the upstream data rate is 1.544 Mbit/s, the actual slot transmission locations are given by:

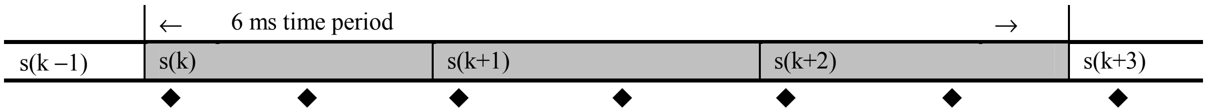
slot_transmission_location (m) = slot_transmission_position + (m x 512);

where m = 0, 1, 2; is the position of the slot with respect to the slot_transmission_position.



B.2.2.6.2 Upstream data rate – 256 kbit/s

In the case where the upstream data rate is 256 kbit/s, the upstream slots are numbered as shown below, where k is a multiple of 3:

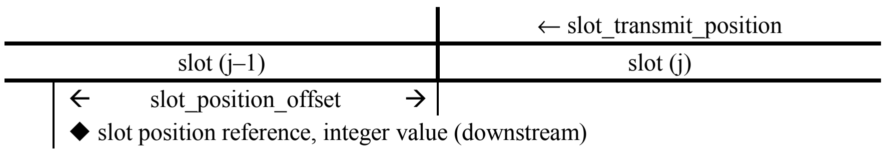


6 slot position references (downstream) per 6 ms time period

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

slot_transmit_position = slot_position_reference (integer) + slot_position_offset

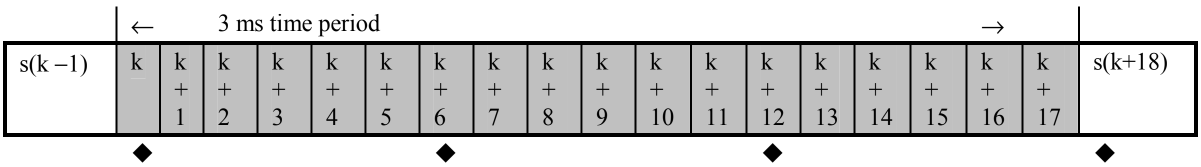
where only the slot_position_references corresponding to integer values are valid and the slot_position_offset is derived from the Time_Offset_Value provided via the Range_and_Power_Calibration_Message.



In the case where the upstream data rate is 256 kbit/s, the actual slot transmission locations correspond directly to the integer valued slot position references.

B.2.2.6.3 Upstream Data Rate – 3.088 Mbit/s

In the case where the upstream data rate is 3.088 Mbit/s, the upstream slots are numbered as shown below, where k is a multiple of 18.

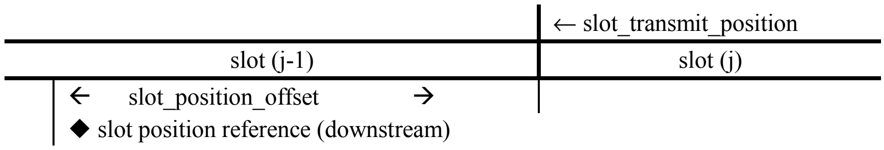


3 slot position references (downstream) per 3 ms time period

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

slot_transmit_position = slot_position_reference + slot_position_offset

where slot_position_offset is derived from the Time_Offset_Value provided via the Range_and_Power_Calibration_Message.



In the case where the upstream data rate is 3.088 Mbit/s, the actual slot transmission locations are given by:

$$\text{slot\_transmission\_location (m)} = \text{slot\_transmission\_position} + (m \times 512)$$

where m = 0, 1, 2, 3, 4, 5 is the position of the slot with respect to the slot_transmission_position.

	←slot_transmission_position						←slot_transmission_position
	← pos 0	← pos 1	← pos 2	← pos 3	← pos 4	← pos 5	
previous slot	slot 0 (m=0)	slot 1 (m=1)	slot 2 (m=2)	slot 3 (m=3)	slot 4 (m=4)	slot 5 (m=5)	next slot
	512 bits	512 bits	512 bits	512 bits	512 bits	528 bits	

B.2.3 Media access control functionality

This clause contains the specifications for Media Access Control (MAC) Protocol to be used for communication across a Hybrid Fibre Coax (HFC) network. It specifies the communication between Network Related Control (NMS) at the Access Subnetwork and the Digital Home Cable Terminal (DHCT).

B.2.3.1 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 (Figure B.2-15) are hidden from the above layers.

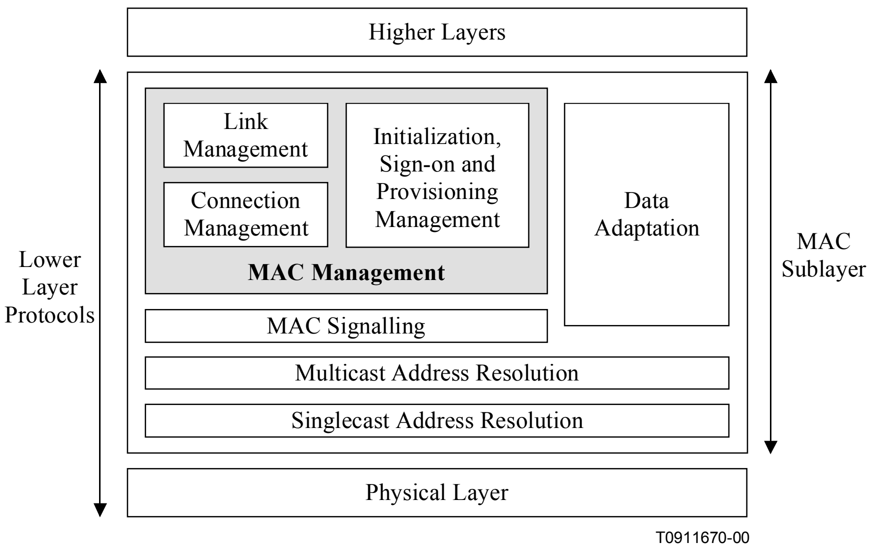


Figure B.2-15/J.184 – MAC reference model

This clause focuses on the required message flows between the NMS and the DHCT for Media Access Control. These areas are divided into three categories: Initialization, Provisioning and Sign On Management, Connection Management and Link Management.

B.2.3.2 Upstream and downstream channel types

This clause defines the upstream and downstream channel types supported by the Media Access Control Protocol.

B.2.3.2.1 Downstream out-of-band channel requirements

The Media Access Control Protocol supports multiple downstream Channels. In instances where multiple Channels are used, the NMS shall specify a single Out-Of-Band frequency where DHCTs perform Initialization, Provisioning and Sign-On Functions. In instances where only a single frequency is in use, the NMS shall utilize that frequency for Initialization, Provisioning and Sign-On functions.

B.2.3.2.2 Upstream channel requirements

The Media Access Control protocol supports multiple upstream channels. One of the upstream channels shall be designated the Service Channel. The Service Channel shall be used by DHCTs entering the network via the Initialization, Provisioning and Sign-On 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.

B.2.3.3 MAC information transport

To support the delivery of MAC related information to and from the DHCT, a dedicated Virtual Channel shall be utilized. The VPI, VCI for this channel shall be 0x000, 0x0021.

AAL5 (as specified in [ITU-T I.363.5] [Ref. 3]) adaptation shall be used to encapsulate each MAC SDU in ATM cells. All upstream MAC messages shall be restricted to a single cell. A single cell MAC SDU can accommodate up to 40 bytes.

Since MAC related information is terminated at the DHCT and NMS a privately defined message structure will be utilized. The format of the MAC message structure is illustrated below.

NOTE – All messages are sent most significant bit first.

MAC_message(){	**Bits**	**Bytes**	**Bit Number/ Description**
Message_Configuration		**1**	
Protocol_Version	5		7..3:{enum}
Syntax_Indicator	3		2..0:{enum}
Message_Type	**8**	**1**	
if (Syntax_Indicator==001) {			
MAC_Address	**48**	**6**	
}			
MAC_Information_Elements ()		**N**	
}			

Protocol Version

Protocol_Version is a 5-bit enumerated type used to identify the current MAC version.

enum Protocol_Version	{	DAVIC 1.0 Compliant Device, SCTE OOB Transport mode B, Reserved 2..31 };

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,
                              Reserved 2..7    };
```

MAC Address

MAC_Address is a 48-bit value representing the unique MAC address of the DHCT.

B.2.3.4 MAC message types

All MAC message types are listed in Table B.2-6. The MAC message types are divided into the logical MAC states of Initialization, Sign On, Connection Management and Link Management. Messages in *italics* represent upstream transmission from DHCT to NMS. MAC messages are sent using Broadcast or Singlecast Addressing. Singlecast address shall utilize the 48-bit MAC address.

Table B.2-6/J.184 – DAVIC MAC messages

Message type value	Message name	Addressing type
0x01-0x1F	**MAC Initialization, Provisioning and Sign-On Message**	
0x01	Provisioning Channel Message	Broadcast
0x02	Default Configuration Message	Broadcast
0x03	Sign-On Request Message	Broadcast
0x04	*Sign-On Response Message*	Singlecast
0x05	Ranging and Power Calibration Message	Singlecast
0x06	*Ranging and Power Calibration Response Message*	Singlecast
0x07	Initialization Complete Message	Singlecast
0x08-0x1F	[Reserved]	
0x20-0x3F	**MAC Connection Establishment and Termination Msgs**	
0x20	Connect Message	Singlecast
0x21	*Connect Response Message*	Singlecast
0x22	*Reservation Request Message*	Singlecast
0x23	Reservation Response Message	Broadcast
0x24	Connect Confirm Message	Singlecast
0x25	Release Message	Singlecast
0x26	*Release Response Message*	Singlecast
0x27	*Idle Message*	Singlecast
0x28	Reservation Grant Message	Broadcast
0x29	Reservation ID Assignment	Singlecast
0x2A	*Reservation Status Request*	Singlecast
0x2B	*Reservation ID Response Message*	Singlecast
0x2C-0x3F	[Reserved]	

Table B.2-6/J.184 – DAVIC MAC messages

Message type value	Message name	Addressing type
0x40-0x5F	**MAC Link Management Msgs**	
0x40	Transmission Control Message	Singlecast
0x41	Reprovision Message	Singlecast
0x42	*Link Management Response Message*	Singlecast
0x43	Status Request Message	Singlecast
0x44	*Status Response Message*	Singlecast
0x45-0x5F	[Reserved]	

B.2.3.4.1 MAC initialization, provisioning and sign on

This clause defines the procedure for Initialization, Provisioning and Sign On that the MAC shall perform during power on or Reset.

B.2.3.4.1.1 Initialization and provisioning

1) Upon a DHCT becoming active (i.e. powered up), it must first find the current provisioning frequency. The DHCT shall receive the **<MAC> Provisioning Channel Message**. This message shall be sent aperiodically on all downstream OOB channels when there are multiple channels. In the case of only a single channel, the message shall indicate the current channel to be utilized for Provisioning. Upon receiving this message, the DHCT shall tune to the Provisioning Channel.
2) After a valid lock indication on a Provisioning Channel, the DHCT shall await the **<MAC> DEFAULT CONFIGURATION MESSAGE**. When received, the DHCT 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 B.2-16 below shows the signalling sequence.

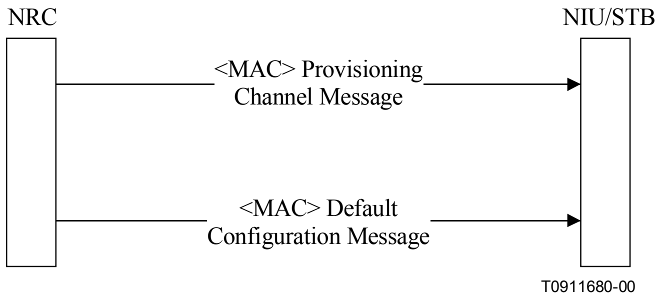


Figure B.2-16/J.184 – Initialization and provisioning sequence

B.2.3.4.1.2 Sign on and calibration

The DHCT shall Sign On via the Sign-On Procedure. A state diagram for Ranging and Calibration is given in Figure B.2-18. The signalling flow for Sign-On is shown in Figure B.2-17 and described below. Reception Indicators shall be ignored during the Sign-On and Calibration process.

1) The DHCT shall tune to the downstream Provisioning channel and the upstream service channel with the information provided in the Initialization and Provisioning sequence.

2) The DHCT shall await the **<MAC> Sign-On Request Message** from the Network Related Control Entity. The DHCT shall utilize Contention based entry on the service channel to access the network.

3) Upon receiving the **<MAC> Sign-On Request Message**, the DHCT shall respond with the **<MAC> Sign-On Response Message.** The Sign-On Response Message shall be transmitted on a Ranging Control Slot.

4) The NMS, upon receiving the Sign-On Response Message shall validate the DHCT and send the **<MAC> Ranging and Power Calibration Message.**

5) The DHCT 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 Control Slot.

6) The NMS shall send the **<MAC> Initialization Complete Message** when the DHCT is calibrated. The DHCT is assumed to be calibrated if the message arrives within a window of 1.5 symbols (upstream rate) and a power within a window of 1.5 dB from their optimal value.

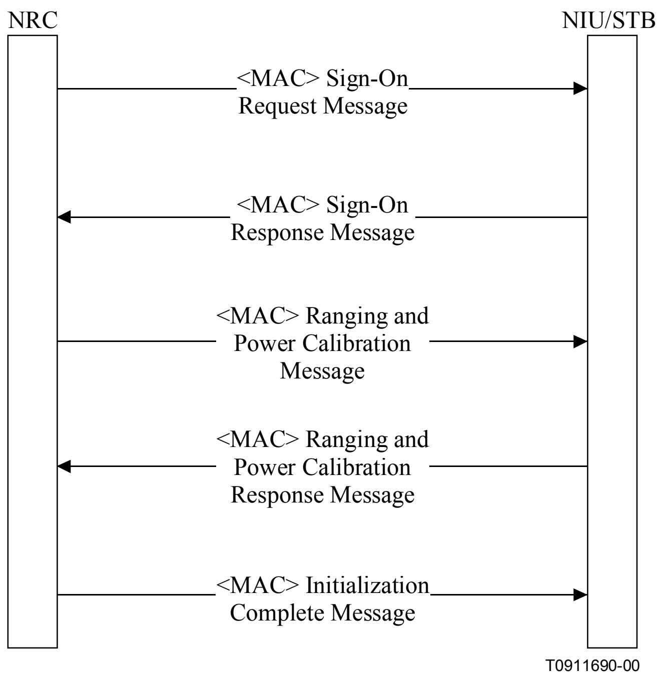


Figure B.2-17/J.184 – Sign-on messaging sequence

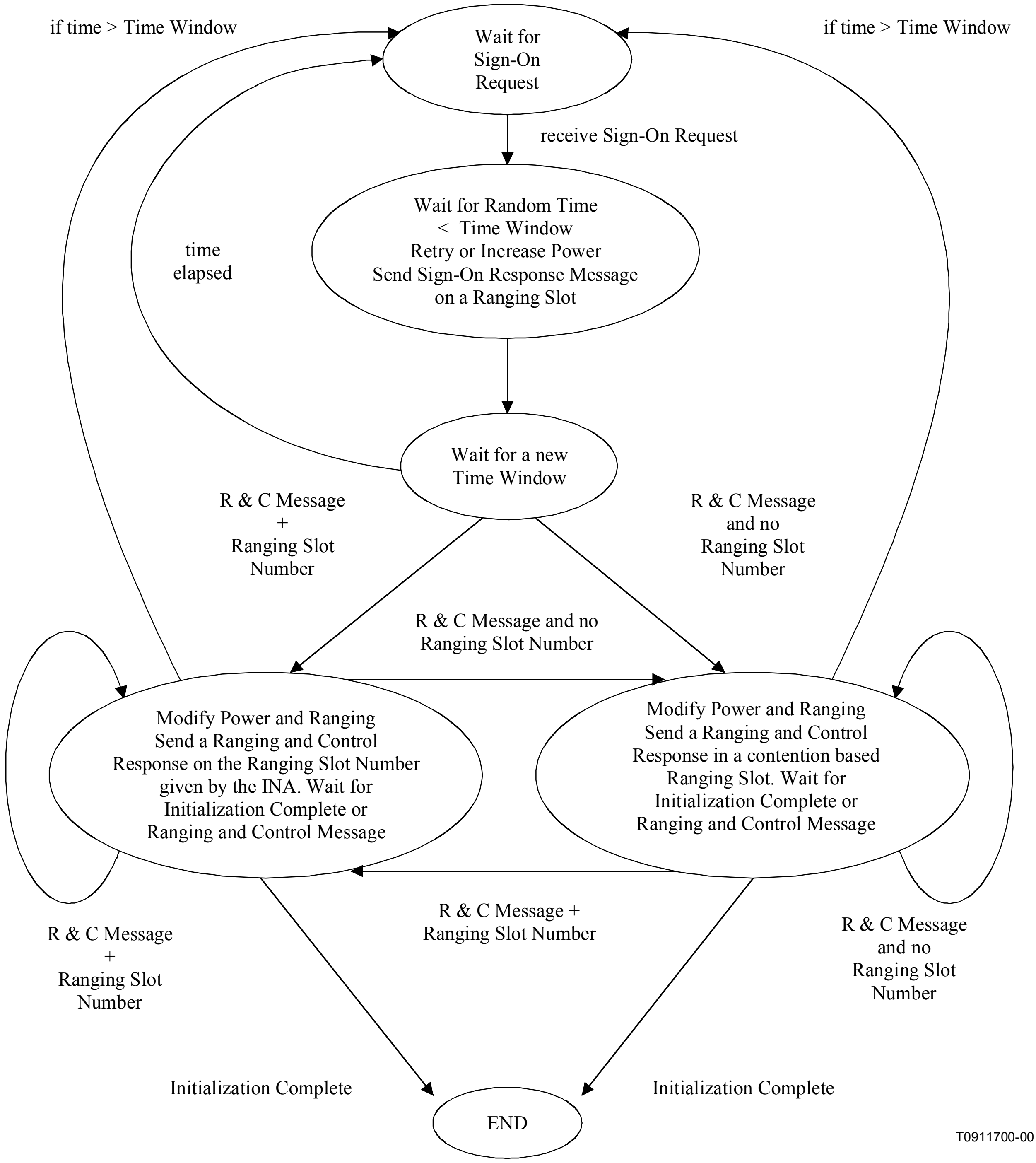


Figure B.2-18/J.184 – State diagram for ranging and calibration

B.2.3.4.2 Connection management

This clause defines the MAC support for Connection Establishment and Release.

B.2.3.4.2.1 Connection establishment

Once a DHCT has completed the Calibration State, it shall enter the Connection State. A low bit rate permanent connection can be assigned to a DHCT by the NMS. The NMS can assign an upstream channel for contention or contentionless based access to the network. In either case after the initial calibration procedure, the NMS provides a Default Connection to the DHCT that the DHCT shall utilize to communicate to the network. A given connection (identified by a Connection_ID) shall be assigned, at most, a single VPI/VCI. The message flow for such Connection Establishment is shown in Figure B.2-19.

For all the traffic sent contention access, a collision is assumed if the appropriate reception indicator of the slot used for transmission is not set. A counter at the DHCT records the number, denoted by backoff_exponent, of collisions encountered by a cell. 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 cell. In particular, the random number indicates the number of contention access slots the DHCT shall wait before it transmits. The first transmission is carried out in a random cell within the contention based 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.

In addition to the simple connect and release messages used to establish and remove connections, the MAC message set provides two additional messages to handle dynamic reallocation of bandwidth and channels. The Transmission Control Message and the Reprovision Message provide the ability to redefine the parameters of each connection individually or as group.

The existing messages allow reallocation of resources on the network for an individual DHCT. For example, the existing connections for a single DHCT may be removed, the channel changed, and new connections re-established to the existing sessions. The Reprovision Message allows for modification of the current connection parameters including channel assignment. Gross reallocation of bandwidth or channels is provided by moving all connections from one channel to another channel at once. The Transmission Control Message provides a method to rapidly change the channel frequencies and other associated parameters for a single DHCT or all DHCTs assigned to a given channel.

1) After Initialization, Provisioning and Sign-On Procedures are complete, the NMS shall assign a default upstream and downstream connection to the DHCT. This connection can be assigned on any of the upstream channels except the upstream service channel ranging area. The DHCT shall assign the default connection by sending the **<MAC> Connect Message** to the DHCT. This message shall contain the upstream connection parameters and downstream frequency on which the default connection is to reside.
2) The DHCT, 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.
3) Upon receipt of the **<MAC> Connect Message**, the NMS shall confirm the new connection to proceed by sending the **<MAC> Connect Confirm Message**.

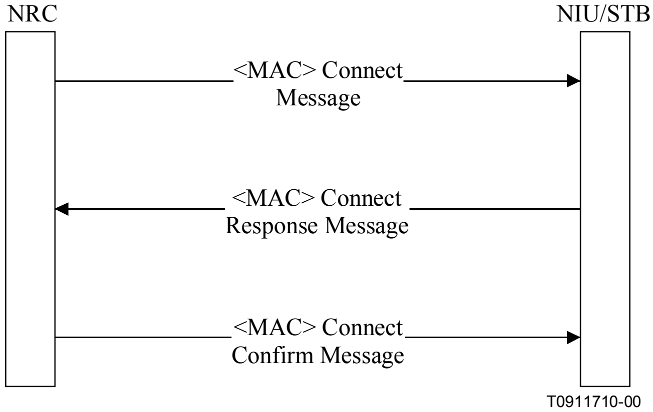


Figure B.2-19/J.184 – Connection establishment signalling sequence

Different access modes are provided to the DHCT 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 contentionless type data. The following rules define how to select access modes:

- *Data connections*

  When the NMS assigns a connection ID to the DHCT, it either specifies a slot list to be used (Contentionless access) or the DHCT shall use contention or reserved access by following this algorithm:

  When the DHCT must send more cells than what was assigned by the NMS, it can use contention access only if the number of cells to transmit is less than Maximum_contention_access_message_length (specified in the MAC Connect Message from the NMS). In that case, it must wait for the slot reception indicator before it is allowed to send other cells with the same VPI/VCI value. The DHCT can send one request for reservation access if the number of cells is less than Maximum_reservation_access_message_length (specified in the MAC Connect Message from the NMS). If more cells must be transmitted, the DHCT must send multiple requests for reservation access.

- *MAC messages*

  MAC messages can be sent on contention access or reservation access. MAC messages sent upstream must be less than 40 bytes long. If the MAC information exceeds 40 bytes, it must be segmented into multiple 40 bytes independent MAC messages. Ranging access can only be used for specific MAC messages.

The following Upstream Access Types are defined:

- *Contention Access*

  `Contention Access` indicates that data 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 used to determine the connection, type and direction of the data of higher layers. Contention based access provides instant channel allocation for the DHCT. The Contention based technique is used for multiple subscribers that will have equal access to the channel. Since simultaneous transmissions will occur, a positive acknowledgment of reception by the NMS is sent in the reception indicator field of the OOB downstream channel. A collision will be assumed if a DHCT does not receive a positive acknowledgment.

- *Contentionless Access*

  `Contentionless_Access` indicates that data is sent in slots assigned to the Contentionless based access region in the upstream channel. These slots are uniquely assigned to a connection by the NMS.

- *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 on a frame by frame basis to a connection by the NMS. This assignment is made at the request of the DHCT for a given connection.

- *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 NMS such that their slots fall within the correct allocated time. The Ranging Access area is either in the Contention Access region or in slots assigned to the reservation region in the upstream channel. The reservation slots are uniquely assigned on a frame by frame basis to the DHCT.

B.2.3.4.2.2 Connection release

This clause defines the MAC signalling requirements for connection release. Figure B.2-20 below displays the signalling flow for releasing a connection.

1) Upon receiving the **<MAC> Release Message** from the NMS, the DHCT shall tear down the indicated upstream connections.
2) Upon tear down of the upstream connection, the DHCT shall send the **<MAC> Release Response Message** on the upstream frequency currently being used by the DHCT for MAC Messages.

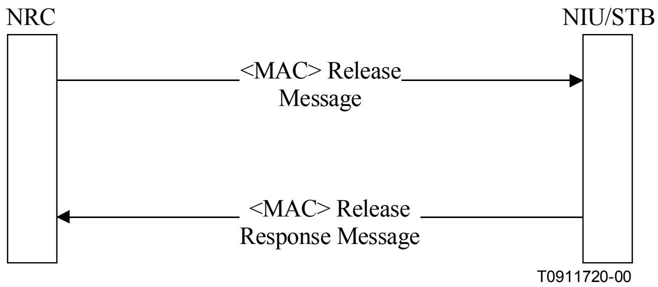


Figure B.2-20/J.184 – Connection release signalling

B.2.3.4.3 MAC link management

The MAC Link Management tasks provide continuous monitoring and optimization of upstream resources. These functions include:

- Power and Timing Management.
- TDMA Allocation Management.
- Reservation Allocation Management.
- Channel Error Management.

B.2.3.4.3.1 Power and timing management

Power and Timing Management shall provide continuous monitoring of upstream transmission from the DHCT. The **<MAC> Ranging and Power Calibration Message** is used to maintain a DHCT within predefined thresholds of power and time.

The Upstream Burst Demodulator shall continuously monitor the upstream burst transmissions from an DHCT. Upon detection of an DHCT outside the predefined range, the NMS shall send the **<MAC> Ranging and Power Calibration Message** to the DHCT.

B.2.3.4.3.2 TDMA allocation management

To ensure optimum assignment of TDMA resources, the NMS 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 NMS shall dynamically reconfigure the upstream TDMA assignments to a DHCT or group of DHCT. The **<MAC> Reprovision Message** is utilized to change previously established connection parameters.

B.2.3.4.3.3 Channel error management

During periods of connection inactivity, the DHCT shall enter an Idle Mode. Idle mode is characterized by periodic transmission by the DHCT of a **<MAC> Idle Message**. The Idle Mode transmission shall occur at a periodic rate sufficient for the NMS to establish Packet Error Rate statistics.

B.2.3.4.4 MAC message definitions

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.

B.2.3.4.4.1 Initialization, provisioning and sign-On messages

This clause provides a detailed definition of the MAC messages for Initialization, Provisioning and Sign-On procedures.

B.2.3.4.4.1.1 <MAC> Provisioning Channel Message

The <MAC> PROVISIONING CHANNEL MESSAGE is sent by the NMS to direct the DHCT to the proper Out-Of-Band frequency where provisioning is performed. The format of the message is shown below.

Provisioning_Channel_Message(){	**Bits**	**Bytes**	**Bit Number/ Description**
Provisioning_Channel_Control_Field		**1**	
Reserved	7		7..1
Provisioning_Frequency_Included	1		0:{no, yes}
if (Provisioning_Channel_Control_Field == Provisioning_Frequency_Included) {			
Provisioning_Frequency	**32**	**4**	
Downstream_Type	**8**	**1**	{enum}
}			
}			

Provisioning Channel Control Field

`Provisioning_Channel_Control_Field` is used to specify the downstream frequency where the DHCT will be provisioned.

Provisioning Frequency Included

`Provisioning_Frequency_Included` is a Boolean, when set indicates that a downstream OOB frequency is specified that the DHCT should tune to begin the provisioning process. When cleared, 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 DHCT provisioning occurs. The unit of measure is Hz.

Downstream Type

`Downstream_Type` is an 8-bit enumerated type indicating the modulation format for the downstream connection.

```
enum    Downstream_Type    {    Reserved,
                                QPSK_1.544,
                                QPSK_3.088,
                                Reserved 3..255  };
```

B.2.3.4.4.1.2 <MAC> Default Configuration Message

The <MAC> DEFAULT CONFIGURATION MESSAGE is sent by the NMS to the DHCT. The message provides default parameter and configuration information to the DHCT. The format of the message is shown below.

Default_Configuration_Message(){	**Bits**	**Bytes**	**Bit Number/ Description**
Regs_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	**13**	**2**	
Max_Power_Level	**8**	**1**	
Min_Power_Level	**8**	**1**	
Upstream_Transmission_Rate	**3**	**1**	{enum}
Max_Backoff_Exponent	**8**	**1**	
Min_Backoff_Exponent	**8**	**1**	
Idle_Interval	**16**	**2**	
}			

Sign-On Increment Power Retry Count

`Regs_Incr_Pwr_Retry_Count` is an 8-bit unsigned integer representing the number of attempts the DHCT should try to enter the system at the same power level before incrementing its power level.

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 Hz.

MAC_Flag_Set

`MAC_Flag_Set` is a 5-bit field indicating the MAC Flag set number assigned to the service channel (i.e. R1a, R1b and R1c represent MAC Flag set 1). It can take the values 1..16. Values 0 and 17..31 are invalid.

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

In the OOB downstream case, each SL-ESF frame structure contains eight sets of MAC 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 SL-ESF frame occurs during a 3 ms interval providing 8 sets of MAC Flags. In the case of a 3.088 Mbit/s downstream bit rate, two SL-ESF frames occur during a 3 ms interval, providing 16 sets of MAC Flags. The second set of MAC Flags (contained in the second SL-ESF) 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 MAC Flags are required. In this case, the MAC_Flag_Set parameter represents the first of two successively assigned MAC Flag sets.

Service Channel

`Service_Channel` is a 3-bit field which defines the channel assigned to the Service_Channel_Frequency. Although the function provided by this parameter is superseded in the DAVIC 1.2 specification by the MAC_Flag_Set, it is retained in order to identify the logical channel assigned to the DHCT.

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 Hz.

Backup_MAC_Flag_Set

`Backup_MAC_Flag_Set` is a 5-bit field representing the MAC 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.

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.

Service Channel Frame Length

`Service_Channel_Frame_Length` is a 16-bit unsigned integer representing the number of slots in the upstream Contentionless based Service Channel. The unit of measure is slots.

Service Channel Last Slot

`Service_Channel_Last_Slot` is a 13-bit unsigned integer representing the last slot in the Service Channel.

Maximum Power Level

`MAX_Power_Level` is a 8-bit unsigned integer representing the maximum power the DHCT shall be allowed to use to transmit upstream. The unit of measure is 0.5 dBµV.

Minimum Power Level

`MIN_Power_Level` is an 8-bit unsigned integer representing the minimum power the DHCT shall be allowed to use to transmit upstream. The unit of measure is 0.5 dBμV.

Upstream Transmission Rate

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

```
enum Upstream_Transmission_Rate    {    Upstream_256K,
                                        Upstream_1.544M,
                                        Upstream_3.088M
                                        Reserved 3..7    };
```

MIN_Backoff_Exponent

`MIN_Backoff_Exponent` is an 8-bit unsigned integer representing the minimum value of the backoff exponent counter.

MAX_Backoff_Exponent

`MAX_Backoff_Exponent` is an 8-bit unsigned integer representing the minimum value of the backoff exponent counter.

Idle_Interval

`Idle_Interval` is a 16-bit unsigned integer representing the predefined interval for the MAC Idle Messages. The unit of the measure is in milliseconds.

B.2.3.4.4.1.3 <MAC> Sign-On Request Message

The <MAC> SIGN-ON REQUEST message is issued periodically by the NMS to allow a DHCT to indicate its presence in the network. The format of this subcommand is shown below. The Sign_On_Request_Message is ignored by the DHCT unless it is in the sign-on mode.

Sign-On_Request_Message(){	**Bits**	**Bytes**	**Bit Number/ Description**
Sign-On_Control_Field	**8**	**1**	
Reserved	7		7-1
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.

Address Filter Parameters Included

`Address_Filter_Params_Included` is a Boolean, when set, indicates that the DHCT 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 duration of time the DHCT has to respond to the SIGN-ON REQUEST. The unit of measure is ms.

Address Position Mask

`Address_Position_Mask` is an 8-bit unsigned integer that indicates the bit positions in the DHCT MAC address that are used for address filtering comparison. This parameter represents the number of bits that the Address Comparison Value should be left shifted before the compare operation. It has a range from 0 to 40.

Address Comparison Value

`Address_Comparison_Value` is an 8-bit unsigned integer that specifies the value that the DHCT should use for MAC address comparison. These eight bits are compared against the 8 bits of the MAC address after shifting according to the Address Position Mask.

B.2.3.4.4.1.4 <MAC> Sign-On Response Message

The <MAC> Sign-On Response Message is sent by the DHCT in response to the <MAC> Sign-On Request Message issued by the NMS Entity.

Sign-On_Response_Message(){	**Bits**	**Bytes**	**Bit Number/ Description**
DHCT_Status		**4**	
Reserved	29		31..3
Network_Address_Registered	1		2:{no, yes}
Default_Connection_Established	1		1:{no, yes}
Calibration_Operation_Complete	1		0:{no, yes}
DHCT_Error_Code		**2**	
Reserved	13		15..3
Connect_Confirm_Timeout	1		2:{no, yes}
Default_Connection_Timeout	1		1:{no, yes}
Range_Response_Timeout	1		0:{no, yes}
DHCT_Retry_Count	**8**	**1**	
}			

DHCT Status

`DHCT_Status` is a 32-bit field that indicates the current state of the DHCT. It has the following subfields:

`Network_Address_Registered` indicates that the Network Interface Module has registered its Network Address with the Application Module.

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

`Calibration_Operation_Complete` indicates that the Network Interface Module has been successfully calibrated.

DHCT Error Code

`DHCT_Error_Code` is an 16-bit field that indicates the error condition within the DHCT. It has the following subfields:

`Connect_Confirm_Timeout`

`Default_Connection_Timeout`

`Range_Response_Timeout`

Retry Count

`Retry_Count` is a 8-bit unsigned integer that indicates the number of transmissions of the <MAC> Sign-On Response Message. This field is always included in the response to the <MAC> Sign-On Request Message.

B.2.3.4.4.1.5 <MAC> Ranging and Power Calibration Message

The <MAC> RANGING AND POWER CALIBRATION MESSAGE is sent by the NMS to the DHCT to adjust the power level or time offset the DHCT is using for upstream transmission. The format of this message is shown below.

Ranging_and_Power_Calibration_Message(){	**Bits**	**Bytes**	**Bit Number/ Description**
Range_Power_Control_Field		**1**	
Reserved	5		7..3
Ranging_Slot_Included	1		2:{no, yes}
Time_Adjustment_Included	1		1:{no, yes}
Power_Ajustment_Included	1		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	**13**	**2**	
}			
}			

Range and Power Control Field

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

Time Adjustment Included

`Time_Adjustment_Included` is a Boolean, when set indicates that a relative Time Offset Value is included that the DHCT should use to adjust its upstream Contentionless based transmission.

Power Adjust Included

`Power_Adjust_Included` is a Boolean, when set indicates that a relative Power Control Setting is included in the message.

Ranging Slot Included

`Ranging_Slot_Included` is a Boolean, when set indicates the calibration slot is included in the message.

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. A positive value indicates an adjustment back in time. The unit of measure is 100 ns.

Power Control Setting

`Power_Control_Setting` is an 8-bit signed integer to be used to set the new upstream power level of the DHCT. A positive value represents an increase of the output power level.

$$\text{new output\_power\_level} = \text{current output\_power\_level} + \text{power\_control\_setting} \times 0.5 \text{ dB}$$

Ranging Slot Number

`Ranging_Slot_Number` is a 13-bit unsigned integer that represents the slot number assigned for ranging the DHCT. It shall be assigned by the NMS in the reservation area. The NCR shall assure that an unassigned slot precedes and follows the ranging slot.

B.2.3.4.4.1.6 <MAC> Ranging and Power Calibration Response Message

The <MAC> RANGING AND POWER CALIBRATION RESPONSE Message is sent by the DHCT to the NMS in response to the <MAC> RANGING AND POWER CALIBRATION MESSAGE. The format of the message is shown below.

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

Power Control Setting

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

B.2.3.4.4.1.7 Initialization Complete Message

The <MAC> INITIALIZATION COMPLETE Message is sent by the NMS to the DHCT to indicate the end of the MAC Sign-On and Provisioning procedure. The DHCT shall be disabled after receiving a non-zero Completion_Status_Field value.

Initialization_Complete_Message(){	Bits	Bytes	Bit Number/ Description
Completion_Status_Field		**1**	
Reserved	4		7..4
Invalid_DHCT	1		3:{no, yes}
Timing_Ranging_Error	1		2:{no, yes}
Power_Ranging_Error	1		1:{no, yes}
Transmitter_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_DHCT` is a Boolean that (when set to 1) indicates that the DHCT 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.

– `Transmitter_Error` is a Boolean that (when set to 1) indicates a transmitter error.

B.2.3.4.4.2 Connection management messages

This clause defines the MAC messages for connection establishment and release.

B.2.3.4.4.2.1 <MAC> Connect Message

Connect_Message (){	Bits	Bytes	Bit Number/ Description
Connection_ID	**32**	**4**	
Session_Number	**32**	**4**	
Resource_Number	**16**	**2**	
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_Assigned; i++){			
Slot_Number	**13**	**2**	
}			
}			
if (Connection_Control_Field ==			
Cyclic_Assignment) {			
Contentionless_Start	**16**	**2**	
Contentionless_Dist	**16**	**2**	
Number_Cycle_Slots_Defined	**16**	**2**	
}			
}			

Connection ID

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

Session Number

`Session_Number` is a 32-bit unsigned integer representing the Session that the connection parameters are associated.

Resource Number

`Resource_Number` is a 16-bit unsigned integer providing a unique number to the resource defined in the message.

Connection Control Field

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

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

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

`Upstream_Channel_Number` is a 3-bit unsigned integer that provides an identifier for the upstream channel.

`Slot_List_Included` is a Boolean that indicates that the Slot List is included in the message.

`Cyclic_Assignment` is a Boolean that indicates Cyclic Assignment.

Frame Length

`Frame_Length` is a 16-bit unsigned number represents the number of successive slots in the contentionless access region that associated with each contentionless 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 allocating slots it represents the number of successive slots associated with the Contentionless_Start_Slot and those which are multiples of Contentionless_Distance from the Contentionless_Start_Slot.

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.

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 should be transmitted by making multiple reservation requests.

Downstream ATM Connection Block Descriptor

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

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

`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 an 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.

```
enum Downstream_Type        {      QAM,
                                   QPSK_1.544,
                                   QPSK_3.088,
                                   Reserved 3..255     };
```

Downstream MPEG Connection Block Descriptor

Downstream_CBD_MPEG(){	**Bits**	**Bytes**	**Bit Number/ Description**
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 Hz.

`Program_Number` is a 16-bit unsigned integer uniquely referencing the downstream virtual connection assignment.

Upstream ATM Connection Block Descriptor

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

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

`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 an 5 bit field representing the MAC Flag set assigned to the connection. In the OOB downstream SL-ESF frame payload structure, each set of three bytes, denoted by Rxa-Rxc, comprise a flag set. These eight flag sets are assigned the numbers 0..7. In the case of a 3.088 Mbit/s upstream channel, two successive flag sets are required to define a 3 ms period. In this case, this parameter represents the first of two successively assigned flag sets. In the case of a 3.088 Mbit/s OOB downstream, two successive SL-ESF frames define the 3 ms interval. The Rxa-Rxc bytes of the first frame represent flag sets 0..7 while the Rxa-Rxc bytes of the second frame represent flag sets 8..15.

```
enum Upstream_Rate      {   Upstream_256K,
                                Upstream_1.544M,
                                Upstream_3.088M,
                                Reserved 3..7   };
```

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 13-bit unsigned integer that represents the Contentionless based Slot Number assigned to the DHCT.

Contentionless Start

`Contentionless_Start` is a 16-bit unsigned integer that represents the starting upstream slot within the contentionless access region that is assigned to the DHCT. The DHCT may use the next Frame_Length slots of the contentionless access regions.

Contentionless Distance

`Contentionless_Distance` is 16-bit unsigned integer that represents the distance in upstream slots between additional slots assigned to the DHCT. The DHCT is assigned all slots that are a multiple of Contentionless_Distance from the Contentionless_Start_Slot within the contentionless access region.

The DHCT may use the next Frame_Length slots of the contentionless access regions from each of these additional slots.

Number Cyclic Slots Defined

`Number_Cyclic_Slots Defined` is a 16-bit unsigned integer that represents the number of slots assigned by the message. The unit of measure is in assigned slots.

B.2.3.4.4.2.2 <MAC> Connect Response Message

The <MAC> CONNECT RESPONSE MESSAGE is sent to the NMS from the DHCT in response to the <MAC> CONNECT MESSAGE. The message shall be transmitted on the upstream frequency specified in the <MAC> CONNECT MESSAGE.

Connect_Response_Message(){	**Bits**	**Bytes**	**Bit Number/ Description**
Connection_ID	**32**	**4**	
}			

Connection ID

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

B.2.3.4.4.2.3 <MAC> Connect Confirm Message

The <MAC> Connect Confirm message is sent from the NMS to the DHCT. Its usage is recommended when NMS validation of new connection is required.

Connect_Confirm_Message(){	**Bits**	**Bytes**	**Bit Number/ Description**
Connection_ID	**32**	**4**	
}			

Connection ID

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

B.2.3.4.4.2.4 <MAC> Reservation Request Message

Reservation_Request_Message (){	**Bits**	**Bytes**	**Bit Number/ Description**
Reservation_ID	**16**	**2**	
Reservation_Request_Slot_Count	**8**	**1**	
}			

Reservation_ID

`Reservation_ID` is a 16-bit unsigned number representing a locally assigned identifier for the connection. This is used as a short identifier by the DHCT 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 DHCT. This is the number of sequential slots that will be allocated in the reservation region of the upstream channel. The NMS will respond with the Reservation_Acknowledge_Message granting the request.

B.2.3.4.4.2.5 <MAC> Reservation Grant Message

The <MAC> RESERVATION GRANT MESSAGE is used to indicate to the DHCT which slots have been allocated in response to the Reservation_Request_Message. The DHCT 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 below.

Reservation_Grant_Message (){	**Bits**	**Mnemonic**
Reference_Slot	**16**	uimsbf
Number_Grants	**8**	uimsbf
for (i=1;i<=Number_Grants;i++) {		
Reservation_ID	**16**	uimsbf
Grant_Slot_Count	**4**	uimsbf
Remaining_Slot_Count	**5**	uimsbf
Grant_Control	**2**	uimsbf
Grant_Slot_Offset	**5**	uimsbf
}		
}		

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 NMS shall send this message in a downstream slot such that it is received by the DHCT before the Reference_Slot exists on the upstream channel.

Number_grants

`Number_Grants` is an 8-bit unsigned number representing the number of grants contained within this message.

Reservation_ID

`Reservation_ID` is a 16-bit unsigned number representing a locally assigned identifier for the connection. This is used as a short identifier by the DHCT 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. Upon receipt of this message the DHCT is assigned Grant_Slot_Count sequential slots in the reservation access region of the upstream channel starting at the position indicated by the Reference_Slot and Grant_Slot_Offset values. 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.

Remaining_Slot_Count

`Remaining_Slot_Count` is a 5-bit unsigned number representing the remaining slots to be granted by the NMS with subsequent grant messages. A value of 0x1F indicates that 31 or more slots will be made available in the future. A value of 0x0 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 DHCT 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.

Grant_Control

`Grant_Control` is a 2-bit unsigned number coded as 0 (reserved for future use).

Grant_Slot_Offset

`Grant_Slot_Offset` is a 5-bit unsigned integer 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. Upon receipt of this message the DHCT is assigned Grant_Slot_Count sequential slots in the reservation access region of the upstream channel.

B.2.3.4.4.2.6 <MAC> Reservation ID Assignment Message

The <MAC> Reservation ID Assignment Message is used to assign the DHCT a Reservation_ID. The DHCT 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 below.

Reservation_ID_Assignment_Message (){	**Bits**	**Bytes**	**Bit Number/ Description**
Connection_ID	**32**	**4**	
Reservation_ID	**16**	**2**	
Grant_Protocol_Timeout	**16**	**2**	
}			

Connection ID

`Connection_ID` is a 32-bit unsigned integer representing a global connection identifier for the DHCT Dynamic Connection.

Reservation_ID

`Reservation_ID` is a 16-bit unsigned number representing a locally assigned identifier for the connection. This is used as a short identifier by the DHCT to identify the appropriate Reservation_Grant_Messages.

Grant_Protocol_Timeout

`Grant_Protocol_Timeout` is a 16-bit unsigned number representing the time in milliseconds that the DHCT should wait before verifying the status of pending grants. This parameter specifies the time that the DHCT should wait after sending the Reservation_Request Message or after receiving the last Reservation_Grant_Message, with an entry addressed to the DHCT containing a non-zero Remaining_slot_count, before initiating a reservation status request. If the DHCT has pending grants and the timeout occurs, it should send the Reservation_Status_Request_Message to the NMS. The NMS will respond with the Reservation_Grant_Message (probably without granting any slots) to inform the DHCT of any remaining slots left to be granted. This allows the DHCT to correct any problems should they exist such as issuing an additional request for slots or waiting patiently for additional grants.

B.2.3.4.4.2.7 <MAC> Reservation ID Response Message

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 below.

Reservation_ID_Response_Message (){	**Bits**	**Bytes**	**Bit Number/ Description**
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 DHCT Dynamic Connection.

Reservation_ID

`Reservation_ID` is a 16-bit unsigned number representing a locally assigned identifier for the connection. This is used as a short identifier by the DHCT to identify the appropriate Reservation_Grant_Messages.

B.2.3.4.4.2.8 <MAC> Reservation Status Request

The <MAC> RESERVATION STATUS REQUEST Message is used to determine the status of the outstanding grants to be assigned by the NMS. This message is only sent after the Grant protocol timeout is exceeded. The NMS will respond with the Reservation_Grant_Message (possibly without granting any slots) to inform the DHCT of any remaining slots left to be granted. This allows the DHCT 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 below.

Reservation_Status_Request_Message (){	**Bits**	**Bytes**	**Bit Number/ Description**
Reservation_ID	**16**	**2**	
Remaining_Request_Slot_Count	**8**	**1**	
}			

Reservation_ID

`Reservation_ID` is a 16-bit unsigned number representing a locally assigned identifier for the connection. This is used as a short identifier by the DHCT 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 DHCT is expecting to be granted.

B.2.3.4.4.2.9 <MAC> Release Message

The **<MAC> Release Message** is sent from the NMS to the DHCT to terminate a previously established connection.

Release_Message(){	**Bits**	**Bytes**	**Bit Number/ Description**
Number_of_Connections	**8**	**1**	
for(i=0;i<Number_of_Connections; i++){			
Connection_ID	**32**	**4**	
}			
}			

Number_of_Connections

`Number_of_Connections` is an 8-bit unsigned integer representing the number of Connection Identifiers listed in the <MAC> Release Message.

Connection ID

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

B.2.3.4.4.2.10 <MAC> Release Response Message

The <MAC> RELEASE RESPONSE MESSAGE is sent by the DHCT to the NMS to acknowledge the release of a connection. The format of the message is given below.

Release_Response_Message (){	**Bits**	**Bytes**	**Bit Number/ Description**
Connection_ID	**32**	**4**	
}			

Connection ID

`Connection_ID` is a 32-bit unsigned integer representing the global connection Identifier used by the DHCT for this connection.

B.2.3.4.4.2.11 <MAC> Idle Message

The **<MAC> Idle Message** is sent by the DHCT within the DHCT to the NMS at predefined intervals when upstream connection buffers are empty.

Idle_Message(){	Bits	Bytes	Bit Number/ Description
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 of <MAC> IDLE MESSAGES transmitted while the DHCT is Idle.

Power Control Setting

`Power_Control_Setting` is an 8-bit unsigned integer representing the absolute power attenuation that the DHCT is using for upstream transmission.

B.2.3.4.4.3 Link management messages

B.2.3.4.4.3.1 <MAC> Transmission Control Message

The <MAC> TRANSMISSION CONTROL MESSAGE is sent to the DHCT from the NMS to control several aspects of the upstream transmission. This includes stopping upstream transmission, re-enabling transmission from a DHCT or group of DHCTs and rapidly changing the upstream frequency being used by a DHCT or group of DHCTs. To identify a group of DHCTs for switching frequencies, the <MAC> TRANSMISSION CONTROL MESSAGE is sent in broadcast mode with the `Old_Frequency` included in the message. When broadcast with the `Old_Frequency`, the DHCT shall compare its current frequency value to `Old_Frequency`. When equal, the DHCT shall switch to the new frequency specified in the message. When not equal, the DHCT shall ignore the new frequency and remain on its current channel.

Transmission_Control_Message(){	Bits	Bytes	Bit Number/ Description
Transmission_Control_Field		**1**	
Reserved	3		7..5
Stop_Upstream_Transmission	1		4:{no, yes}
Start_Upstream_Transmission	1		3:{no, yes}
Old_Frequency_Included	1		2:{no, yes}
Switch_Downstream_OOB_Frequency	1		1:{no, yes}
Switch_Upstream_Frequency	1		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_Parameters		**2**	
New_Upstream_Channel_Number	3		7..5
Reserved	2		4..3
Upstream_Rate	3		2..0:{enum}
MAC_Flag_Set	5		7..3
Reserved	3		2..0
}			
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	**32**	**4**	
Downstream_Type	**8**	**1**	{enum}
}			
}			

Transmission Control Field

`Transmission_Control_Field` specifies the control being asserted on the channel.

It consists of the following subfields:

`Stop_Upstream_Transmission` is a Boolean, when set indicates that the DHCT should halt its upstream transmission.

`Old_Frequency_Included` is a Boolean, 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.

`Start_Upstream_Transmission` is a Boolean, when set indicates that the Network Interface Module should resume transmission on it upstream channel. The DHCT shall respond to the ranging and power calibration message regardless of the setting of the `Start_Upstream_Transmission` bit.

`Switch_Upstream_Frequency` is a Boolean 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 DHCT to stop transmission and change channel. This would be followed by the <MAC> TRANSMISSION CONTROL MESSAGE with the `start_upstream_transmission` bit set.

`Switch_Downstream_OOB_Frequency` is a Boolean when set indicates that a new downstream OOB frequency is included in the message.

Old Upstream Frequency

`Old_Upstream_Frequency` is a 32-bit unsigned integer representing the frequency that should be used by the DHCT 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 centre frequency. The unit of measure is Hz.

New Upstream Channel Number

`New_Upstream_Channel_Number` is a 3-bit unsigned integer that provides an identifier for the upstream channel.

Upstream Rate

`Upstream_Rate` is an 3-bit enumerated type indicating the data rate for the upstream connection.

```
enum Upstream_Rate     {     Upstream_256K,
                                  Upstream_1.544M,
                                  Upstream_3.088M,
                                  Reserved 3..7       };
```

MAC_Flag_Set

`MAC_Flag_Set` is a 5-bit field representing the MAC Flag set assigned to the connection. In the OOB downstream SL-ESF frame payload structure, each set of three bytes, denoted by Rxa-Rxc, comprise a flag set. These eight flag sets are assigned the numbers 0..7. In the case of a 3.088 Mbit/s upstream channel, two successive flag sets are required to define a 3 ms period. In this case, this parameter represents the first of two successively assigned flag sets. In the case of a 3.088 Mbit/s OOB downstream, two successive SL-ESF frames define the 3 ms interval. The Rxa-Rxc bytes of the first frame represent flag sets 0..7 while the Rxa-Rxc bytes of the second frame represent flag sets 8..15.

Old Downstream OOB Frequency

`Old_Downstream_OOB_Frequency` is a 32-bit unsigned integer representing the frequency that should be used by the DHCT 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 Hz.

Downstream_Type

`Downstream_Type` is an 8-bit enumerated type indicating the modulation format for the downstream connection.

enum	Downstream_Type	{	Reserved, QPSK_1.544, QPSK_3.088, Reserved 3..255 };

B.2.3.4.4.3.2 <MAC> Reprovision Message

The <MAC> REPROVISION MESSAGE is sent by the NMS to the DHCT to reassign upstream resources (maintaining the originally requested QoS parameters at the establishment of the connection). This message is intended for channel maintenance by the NMS to redistribute or reassign resources allocated to a DHCT.

Reprovision_Message (){	**Bits**	**Bytes**	**Bit Number/ Description**
Reprovision_Control_Field		**1**	
Reserved	2		7..6
New_Downstream_IB_Frequency	1		5:{no, yes}
New_Downstream_OOB_Frequency	1		4:{no, yes}
New_Upstream_Frequency_Included	1		3:{no, yes}
New_Frame_Length_Included	1		2:{no, yes}
New_Cyclic_Assignment_Included	1		1:{no, yes}
New_Slot_List_Included	1		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**	{enum}

}			
if (Reprovision_Control_Field == New_Frequency_Included) {			
New_Upstream_Frequency	**32**	**4**	
New_Upstream_Parameters		**2**	
New_Upstream_Channel_Number	3		7..5
Reserved	2		4..3
Upstream_Rate	3		2..0:{enum}
MAC_Flag_Set	5		7..3
Reserved	3		2..0
}			
if (Reprovision_Control_Field == New_Frame_Length_Included) {			
New_Frame_Length	**16**	**2**	
}			
if (Reprovision_Control_Field == New_Slot_List_Included | | New_Cyclic_Assignment_Included) {			
Number_of_Connections	**8**	**1**	
}			
for(i=0;i<Number_of_Connections;i++) {			
Connection_ID	**32**	**4**	
if (Reprovision_Control_Field == New_Slot_List_Included) {			
Number_Slots_Defined	**8**	**1**	
for(i=0;i<Number_Slots_Assigned; i++){			
Slot_Number	**13**	**2**	
}			
}			
if (Reprovision_Control_Field == New_Cyclic_Assignment_Included) {			
Contentionless_Start	**16**	**2**	
Contentionless_Dist	**16**	**2**	
Number_Cyclic_Slots_Defined	**16**	**2**	
}			
}			
}			

Reprovision Control Field

`Reprovision_Control_Field` specifies what modifications to upstream resources are included.

It consists of the following subfields:

– `New_Upstream_OOB_Frequency` is a Boolean that indicates that a new downstream OOB frequency is specified in the message.

– `New_Upstream_IB_Frequency` is a Boolean that indicates that a new downstream IB frequency is specified in the message. This field is reserved in order to maintain compatibility with DAVIC.

– `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.

– `New_Slot_List_Included` is a Boolean that indicates that a new slot list is specified in the message.

– `New_Cyclical_Assignment_Included` is a Boolean that indicates that a new cyclical assignment is specified in the message.

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 Hz. This field is not expected to be used but is reserved for compatibility with DAVIC.

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 Hz.

Downstream_Type

`Downstream_Type` is an 8-bit enumerated type indicating the modulation format for the downstream connection.

```
enum Downstream_Type    {    Reserved,
                             QPSK_1.544,
                             QPSK_3.088,
                             Reserved 3..255  };
```

New Upstream Frequency

`New_Upstream_Frequency` is a 32-bit unsigned integer representing the reassigned upstream carrier centre frequency. The unit of measure is Hz.

New Upstream Channel Number

`New_Upstream_Channel_Number` is a 3-bit unsigned integer that provides an identifier for the upstream channel.

Upstream Rate

`Upstream_Rate` is a 3-bit enumerated type indicating the data rate for the upstream connection.

```
enum Upstream_Rate   {    Upstream_256K,
                              Upstream_1.544M,
                              Upstream_3.088M,
                              Reserved 3..7  };
```

MAC_Flag_Set

`MAC_Flag_Set` is a 5-bit field representing the MAC Flag set assigned to the connection.

New Frame Length

`New_Frame_Length` is a 16-bit unsigned integer representing the size of the reassigned upstream Contentionless based frame. The unit of measure is in slots.

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 13-bit unsigned integer that represents the Contentionless based Slot Number assigned to the Network Interface Module.

Contentionless Start

`Contentionless_Start` is a 16-bit unsigned integer that represents the starting upstream slot within the contentionless access region that is assigned to DHCT. The DHCT may use the next Frame_Length slots of the contentionless access regions.

Contentionless Distance

`Contentionless_Distance` is a 16-bit unsigned integer that represents the distance in upstream slots between additional slots assigned to the DHCT. The DHCT is assigned all slots that are a multiple of Contentionless_Distance from the Contentionless_Start_Slot within the contentionless access region. The DHCT may use the next Frame_Length slots of the contentionless access regions from each of these additional slots.

Number Cyclic Slots Defined

`Number_Cyclic_Slots_Defined` is a 16-bit unsigned integer that represents the number of slots assigned by the message. The unit of measure is in assigned slots.

B.2.3.4.4.3.3 <MAC> Link Management Response Message

The <MAC> LINK MANAGEMENT RESPONSE MESSAGE is sent by the DHCT to the NMS to indicate reception and processing of the previously sent Link Management Message. The format of the message is shown below.

Link_Management_Response_Message(){	**Bits**	**Bytes**	**Bit Number/ Description**
Link_Management_Msg_Number	**16**	**2**	
}			

Link Management Message Number

`Link_Management_Msg_Number` is a 16-bit unsigned integer representing the previously received link management message. The valid values for `Link_Management_Msg_Number` are:

Message Name	**Link_Management_Msg_Number**
Transmission Control Message	Transmission Control Message Type Value
Reprovision Message	Reprovision Message Type Value

B.2.3.4.4.3.4 <MAC> Status Request Message

The STATUS REQUEST message is sent by the NMS to the DHCT to retrieve information about the DHCTs health, connection information and error states. The NMS can request either the address parameters, error information, connection parameters or physical layer parameters from the DHCT. The NMS can only request one parameter type at a time to a particular DHCT.

Status_Request_Message(){	**Bits**	**Bytes**	**Bit Number/ Description**
Status_Control_Field		**1**	
Reserved	5		7..3
Status_Type	3		2..0:{enum}
}			

Status Control Field

`Status_Control_Field` is a 3-bit enumerated type that indicates the status information the DHCT should return.

```
enum Status_Control_Field      {        Address_Params,
                                            Error_Params,
                                            Connection_Params,
                                            Physical_Layer_Params,
                                            Reserved 4..7    };
```

B.2.3.4.4.3.5 <MAC> Status Response Message

The <MAC> STATUS RESPONSE MESSAGE is sent by the DHCT in response to the <MAC> STATUS REQUEST MESSAGE issued by the NMS. The contents of the information provided in this message will vary depending on the request made by the NMS and the state of the DHCT.

Status_Response_Message(){	Bits	Bytes	Bit Number/ Description
DHCT_Status		**4**	
Reserved	29		31..3
Network_Address_Registered	1		2:{no, yes}
Default_Connection_Established	1		1:{no, yes}
Calibration_Operation_Complete	1		0:{no, yes}
Response_Fields_Included		**1**	
Reserved	4		7..4
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) {			
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**	
Time_Offset_Value	**16**	**2**	

Upstream_Frequency **Downstream_Frequency** } }	**32** **32**	**4** **4**	

DHCT Status

`DHCT_Status` is a 32-bit field that indicates the current state of the DHCT. It contains the following subfields:

– `Network_Address_Registered` indicates that the Network Interface Module has registered its Network Address with the Application Module.

– `Default_Connection_Established` indicates that the Network Interface Module has been assigned Default Connection parameters.

– `Calibration_Operation_Complete` indicates that the Network Interface Module has been successfully calibrated.

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 DHCT.

MAC Address

`MAC_Address` is a 6-byte address assigned to the DHCT.

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 Param Code

`Error_Param_Code` is an 8-bit enumerated type representing the type of error reported by the DHCT.

```
enum Error_Param_Code     {     Framing_Bit_Error_Count,
                                Slot_Configuration_CRC_Error_Count,
                                Reed_Solomon_Error_Count,
                                ATM_Packet_Loss_Count
                                Reserved      4..255  };
```

Error Param Value

`Error_Param_Value` is a 16-bit unsigned integer representing error counts detected by the DHCT.

Number of Connections

`Number_of_Connections` is an 8-bit unsigned integer that indicates the number of connections that are specified in the response.

Connection ID

`Connection_ID` is a 32-bit unsigned integer representing the global connection Identifier used by the DHCT for this connection.

Power Control Setting

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

Time Offset Value

`Time_Offset_Value` is a 16-bit signed integer representing a relative offset of the upstream transmission timing. 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 connection. The unit of measure is in Hz.

Downstream Frequency

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

B.2.3.4.4.4 MAC message timeouts

The minimum time that the NMS will wait for a response from the DHCT varies with the message type as follows in Table B.2-7:

Table B.2-7/J.184 – MAC Message Timeouts

Message	Timeout
Ranging and Power Calibration Response Message	2 seconds
Connect Response Message	10 seconds
Reservation ID Response Message	None
Release Message	10 seconds (1 retry)
Transmission Control Message	10 seconds (no retries)
Status Response Message	2 × Idle period

The modulator expects to receive <MAC> Idle messages from each settop periodically, according to the Idle period provided in the NMS provisioning parameter screen. The QPSK modulator will wait 2 idle periods before sending a <MAC> Status Request message. The control field of the <MAC> Status Request Message will indicate a request for connection parameters. If the settop does not send a response after 3 <MAC> Status Request Messages, all of its connections are released at the modulator. Additionally, if the settop sends back connection parameters that contain connection IDs the modulator did not assign, a <MAC> Release message is sent to release the connection(s).

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Printed in Switzerland
Geneva, 2002