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

Switched digital video over cable networks

Architecture and specification for radio over IP transmission systems

Recommendation ITU-T J.1107

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Architecture and specification for radio over IP transmission systems

Summary

As cable television (TV) networks migrate to deep fibre or fibre to the home (FTTH) architectures, it is now possible and easy to provide bidirectional high-quality media services that require very high-speed digital transmission of high-quality content. Cable TV networks provide services by transmitting radio frequency (RF) signals between the headend and a cable modem (CM). The configuration and devices of these networks are optimized for RF signal transmission. When migrating to all-fibre cable TV networks, changing the existing network devices to new network devices for service operators (SOs), who provide broadcasting and various data services through hybrid fibre coaxial (HFC)-based cable TV networks, is recommended. Therefore, a cost-effective solution for deployable and acceptable migration toward optic-based cable TV networks is required.

Recommendation ITU-T J.1107 provides a cost-effective adaptable solution for HFC-based cable TV network devices in optic-based cable TV networks. The purpose of the radio over Internet protocol (RoIP) system is to transmit data over cable service interface specifications (DOCSIS)-based upstream (US) RF signals of CM to cable modem termination system (CMTS) through IP transmission in optic-based cable TV networks.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T J.1107	2018-03-16	9	11.1002/1000/13564

Keywords

RoIP.

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1 Scope

This Recommendation describes the architecture and specification for radio over IP transmission (RoIP) systems in hybrid fibre coaxial (HFC)-based networks. The architecture described in this Recommendation is defined according to [ITU-T J.1106]. The architecture and specifications described in this Recommendation are defined as follows:

– radio over IP terminal system;

– radio over IP headend system.

2 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. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T J.210] Recommendation ITU-T J.210 (2006), *Downstream RF interface for cable modem termination systems*.

[ITU-T J.222.1] Recommendation ITU-T J.222.1 (2007), *Third-generation transmission systems for interactive cable television services - IP cable modems: Physical layer specification*.

[ITU-T J.222.2] Recommendation ITU-T J.222.2 (2007), *Third-generation transmission systems for interactive cable television services – IP cable modems: MAC and upper layer protocols*.

[ITU-T J.1106] Recommendation ITU-T J.1106 (2017), *Requirement for radio over IP transmission system*.

3 Definitions

3.1 Terms defined elsewhere

None.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CM Cable Modem

CMTS Cable Modem Termination System

DOCSIS Data Over Cable Service Interface Specifications

DS	Downstream
E/O	Electric to Optic
FTTH	Fibre To The Home
HFC	Hybrid Fibre Coaxial
OLT	Optical Line Terminal
OMUX	Optical Multiplexer
PON	Passive Optical Network
RF	Radio Frequency
RoIP	Radio over IP
SO	Service Operator
STB	Set-Top Box
US	Upstream

5 Conventions

In this Recommendation:

The keywords "**is required to**" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this document is to be claimed.

The keywords "**is recommended**" indicate a requirement which is recommended but which is not absolutely required. Thus this requirement need not be present to claim conformance.

The keywords "**is prohibited from**" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this document is to be claimed.

The keywords "**can optionally**" indicate an optional requirement which is permissible, without implying any sense of being recommended. This term is not intended to imply that the vendor's implementation must provide the option and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with the specification.

In the body of this document and its annexes, the words *shall*, *shall not*, *should*, and *may* sometimes appear, in which case they are to be interpreted, respectively, as *is required to*, *is prohibited from*, *is recommended*, and *can optionally*. The appearance of such phrases or keywords in an appendix or in material explicitly marked as *informative* are to be interpreted as having no normative intent.

6 Overview

As shown in Figure 1, the RoIP system [ITU-T J.1106] consists of an RoIP terminal and an RoIP headend. The RoIP terminal is located at the endpoint of an optic-based cable TV network and the RoIP headend is located between the cable modem termination system (CMTS) and optical network endpoint such as an optical line terminal (OLT). It is required to synchronize and transmit upstream (US) using a data over cable service interface specifications (DOCSIS)-based protocol [b-ANSI/SCTE 135-1 2008], [b-ANSI/SCTE 135-2 2008], [b-ANSI/SCTE 135-4 2008], [b-ANSI/SCTE 135-5 2008] for IP transmission.

For fibre to the home (FTTH), a broadcast signal and a signal to be output [ITU-T J.210] from the CMTS are radio frequency (RF) signals which have different center frequencies. These signals may be combined as a signal output by a combiner, and an RF signal to be output from the combiner may be output after being input to a downstream optical transmitter. Through the input and the output, an RF electrical signal may be converted to an optical signal.

An optical signal is different from a passive optical network (PON)-type signal used in general optical communications. The optical signal used in a PON turns on or off an optical source based on a bit value in a bit unit, whereas the optical signal obtained by the conversion in a downstream optical transmitter is an optical amplitude modulation signal to change the intensity of an optical source with respect to an amplitude of an RF signal.

The signal converted to an optical signal may be transmitted to a splitter through an optical cable after being amplified in an erbium-doped fibre amplifier (EDFA), and the signal, split at a rate of 1:N in the splitter, may be input to an optical network terminal (ONT) located on a customer's premise.

In the case of an ONT on a customer's premise, in addition to a function of the ONT used for PON-based optical communications, functions of restoring an optically modulated downstream RF signal and transmitting the signal through a coaxial cable and of detecting an upstream RF signal to be output from the cable modem or the set-top box (STB), digitizing the detected signal, and transmitting the digitized signal via an IP packet [ITU-T J.222.1, ITU-T J.222.2] may be added. It is the RoIP terminal.

Unlike the downstream RF signal, the upstream RF signal is converted into a digital signal by the RoIP terminal and transmits it formed of IP packets over the IP networks (i.e., xPON networks).

In the RoIP headend, the digital signal included in the received IP packet is recovered and the original analogue RF signal is transmitted it to the CMTS.

For the purpose of transmitting the upstream signal by the CM during the time interval allocated from the CMTS, it should be synchronized among CMTS, RoIP headend, RoIP terminal and CM.

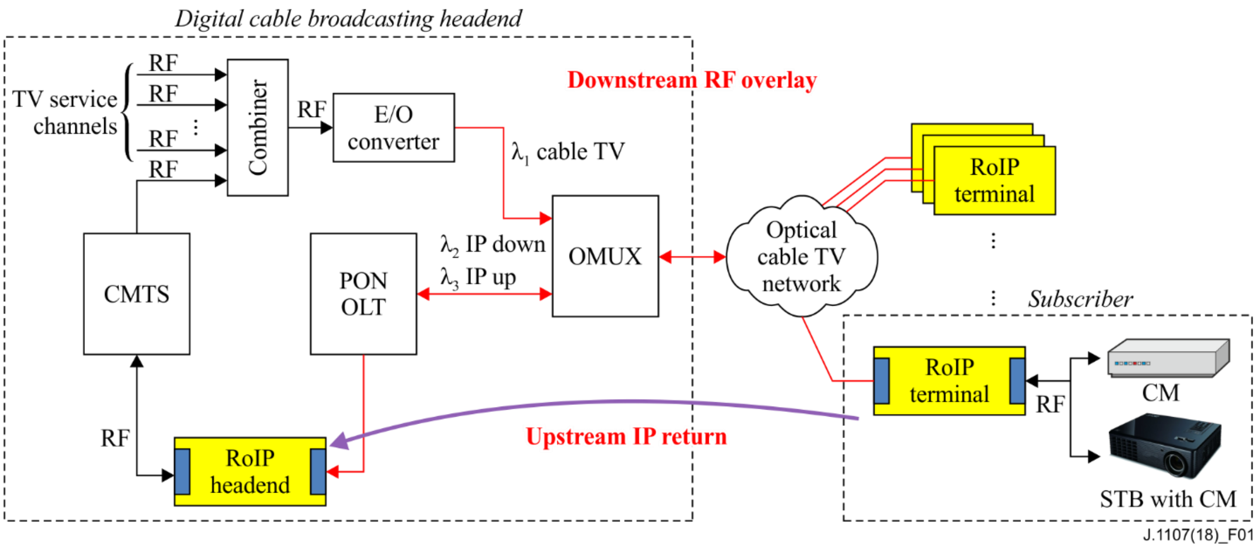

Figure 1 – System architecture for radio over Internet protocol

The RoIP system, including the RoIP headend and RoIP terminal, greatly reduces implementation costs for optical modulation as transmitting upstream RF signals in the optical-based cable TV networks, and it is also possible to reuse existing RF-based broadcasting equipment (e.g., STB, CMTS) operating in the cable-based cable TV networks.

7 Functional architecture

7.1 RoIP terminal

As the upstream RF signal is output from the CM or STB, the RoIP terminal detects the RF signal. The RoIP terminal performs an analog to digital conversion (ADC) on the detected RF signal to digitize the analog RF signal.

The RoIP terminal converts the detected digitized RF signal to the IP packet and transmits it to the headend.

Since upstream traffic transmission is performed through time division multiple access (TDMA), accurate timing synchronization in the network may be necessary. Thus, the timing synchronization between the RoIP terminal, located on the subscriber side, and the RoIP headend may be performed using a network synchronization protocol.

Timing information corresponding to the time when the upstream RF burst signal, output from the STB and CM, is input to the RoIP terminal after timing synchronization is obtained, is digitized and transmitted as an IP packet when the RF signal is transmitted.

After receiving the corresponding IP packet from the RoIP headend and checking timing information, all packets have a predetermined delay time and will generate and output an RF signal again. The CMTS then receives the upstream RF signal at the time assigned to each STB or CM.

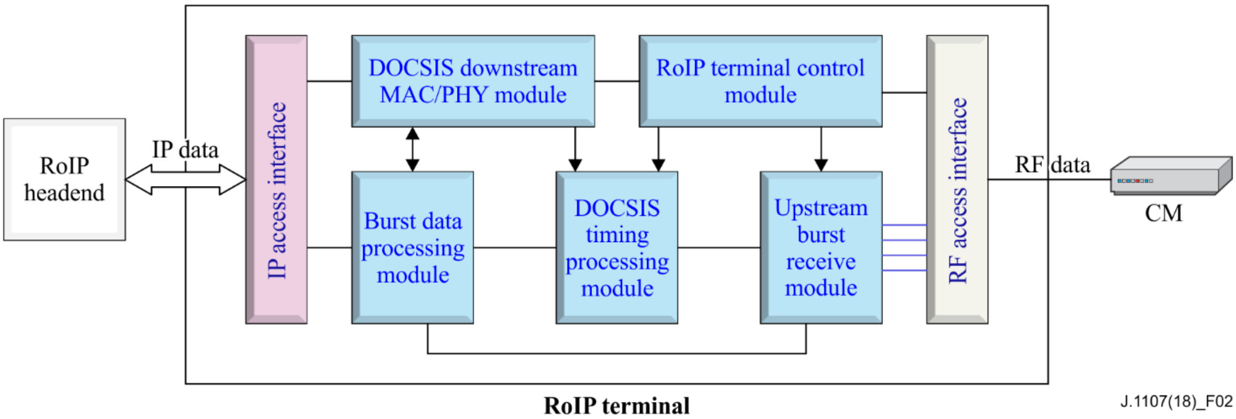

Figure 2 – Architecture for radio over Internet protocol terminal

As shown in Figure 2, the RoIP terminal consists of the following five modules:

1) DOCSIS downstream MAC/PHY module: demodulates the downstream signals transmitted from headend devices (e.g., CMTS) to cable terminal devices (e.g., CM, STB) and processes several multicast management messages (e.g., SYNC, UCD, MAP) procedures.

2) Upstream burst receive module: detects the upstream analog RF signal output from cable terminal devices (e.g., CM, STB), obtains the time that the RF signal is detected, converts it into a baseband digital signal, and transmits the converted signal with the obtained time to the DOCSIS timing processing module.

3) DOCSIS timing processing module: synchronizes the RoIP terminal with the RoIP headend using the RF upstream signal detection time of the cable terminal devices (e.g., CM, STB) and the bandwidth allocation information of the downstream multicast management messages.

4) Burst data processing module: compresses the baseband digital signal output from the upstream burst receive module and generates IP frames with information of the detected time and transmits it to IP networks.

5) RoIP terminal control module: analyzes information from the upstream channel and burst of the DOCSIS downstream MAC/PHY module, transmits it to upstream burst receive module. Gathers the status information of modules in the RoIP terminal and manages configuration of the modules.

7.2 RoIP headend

The digitized RF signal transmitted to the headend is input to the RoIP headend after passing through the OLT, an apparatus inside the RoIP headend connected to the IP networks (e.g., router, switch).

The RoIP headend reconstructs the original analog RF signal, sent from the cable network terminals, by receiving the digitized RF signal and performing a digital to analog conversion (DAC). The RoIP headend restores the reconstructed original RF signal and outputs it to the CMTS.

The CMTS treats receiving the reconstructed RF signal from the RoIP headend as receiving a signal from the CM or STB at the allocated time by itself.

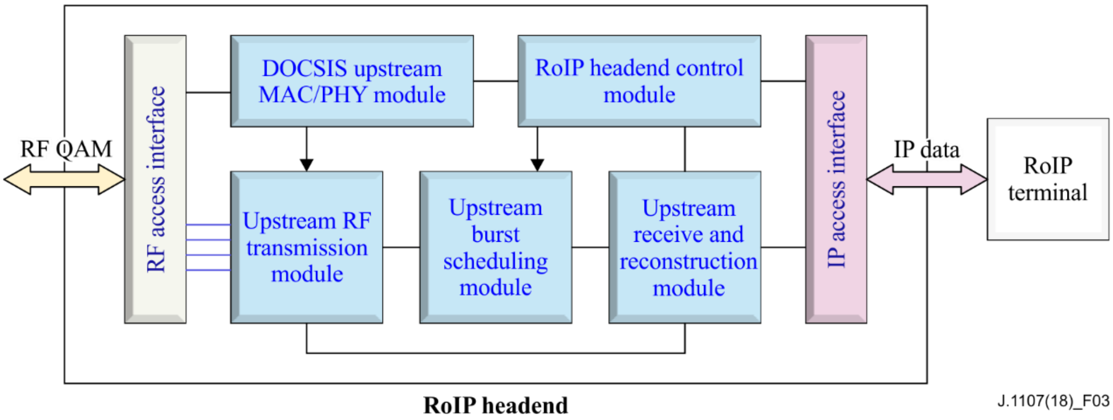

Figure 3 – Architecture for radio over Internet protocol headend

As shown in Figure 3, the RoIP headend consists of the following five modules:

1) DOCSIS upstream MAC/PHY module: synchronizes with the time of CMTS so that the upstream burst data received from the RoIP terminal can be transmitted according to the time set in the CMTS.

2) Upstream receive and reconstruction module: extracts digitized upstream RF signals sent by the RoIP terminal in the received IP packets and decompresses if the digital data has been compressed by the RoIP terminal.

3) Upstream burst scheduling module: performs the function to transmit the recovered upstream RF burst data sent by the RoIP terminal to the CMTS at the bandwidth designated by the CMTS.

4) Upstream RF transmission module: performs the function of converting the digitized upstream RF signal sent by the RoIP terminal into an analog RF signal at the frequency and speed specified by the CMTS and then transmitting it.

5) RoIP headend control module: handles DOCSIS message processing procedures required for network synchronization, manages the control and status information for modules configuring the RoIP headend, and provides user interface functions for operators.

8 Service flow

Figure 4 shows the service flow of RoIP service including RoIP headend and RoIP terminal.

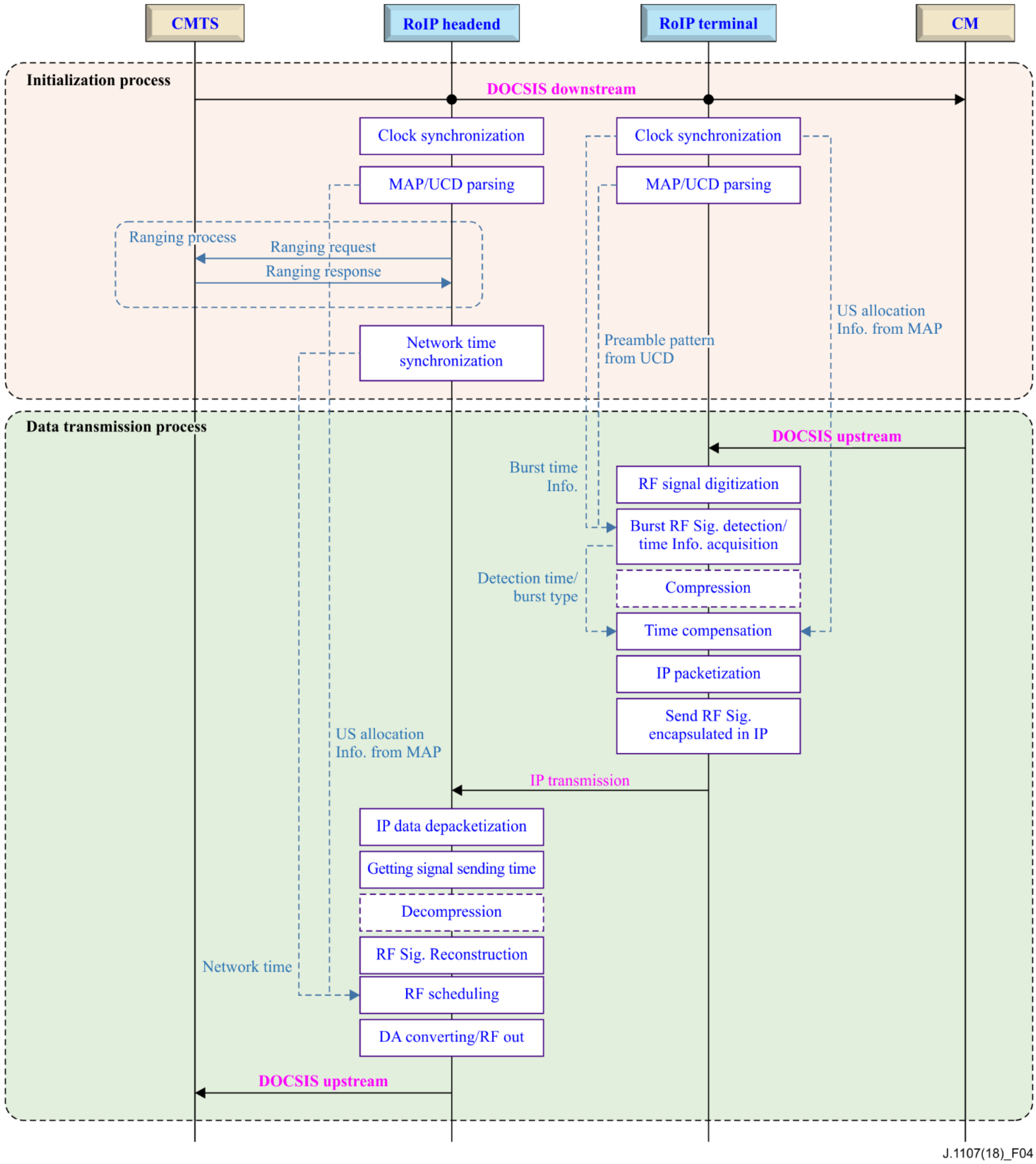

Figure 4 – Service flow of radio over Internet protocol service

8.1 Initialization process

8.1.1 RoIP headend

8.1.1.1 INIT-RoIP headend-01: clock synchronization

The RoIP headend synchronizes the local clock using the timestamp value included in the SYNC message of the DOCSIS downstream transmitted from the CMTS.

8.1.1.2 INIT-RoIP headend-02: MAP/UCD parsing

The RoIP headend interprets the header information in the MAC management message frame of the DOCSIS downstream and gets the channel information, preamble information of each burst type and upstream bandwidth allocation information in order to reschedule the upstream RF burst signal from the MAP/UCD.

8.1.1.3 INIT-RoIP headend-03: ranging process

The RoIP headend performs the DOCSIS ranging procedure on the upstream channels allowed to be used between the RoIP headend and the CMTS.

8.1.1.4 INIT-RoIP headend-04: network time synchronization

The RoIP headend performs network time synchronization after performing the ranging procedure.

8.1.2 RoIP terminal

8.1.2.1 INIT-RoIP terminal-01: clock synchronization

The RoIP terminal synchronizes the local clock using the timestamp value in the SYNC message of the DOCSIS downstream transmitted from the CMTS.

8.1.2.2 INIT-RoIP terminal-02: MAP/UCD parsing

The RoIP terminal interprets the header information in the MAC management message frame of the DOCSIS downstream and gets the channel information, preamble information of each burst type and upstream bandwidth allocation information from the MAP/UCD in order to receive the upstream RF burst signal from the CM.

8.2 Data transmission process

8.2.1 RoIP terminal

8.2.1.1 DT-RoIP terminal-01: RF signal digitization

The RoIP terminal converts the upstream RF burst signal to a digital signal.

8.2.1.2 DT-RoIP terminal-02: burst RF signal detection/time info. acquisition

The RoIP terminal detects the upstream RF burst signal transmitted from the CM using the preamble pattern obtained from the UCD, and acquires the clock time and determines burst type at detection time.

8.2.1.3 DT-RoIP terminal-03: compression

The RoIP terminal may compress the upstream burst signal converted into a digital signal.

8.2.1.4 DT-RoIP terminal-04: time compensation

The RoIP terminal estimates and compensates a transmission time of the upstream RF burst signal using the obtained clock time of the upstream RF burst signal, the determined burst type information, and the upstream band allocation information.

8.2.1.5 DT-RoIP terminal-05: IP packetization

The RoIP terminal packetizes the digitized upstream RF burst signal and the compensated transmission time information to IP packets.

8.2.1.6 DT-RoIP terminal-06: send RF signal encapsulated in IP

The RoIP terminal transmits the upstream RF burst signal encapsulated in the IP packet.

8.2.2 RoIP headend

8.2.2.1 DT-RoIP headend-01: IP data depacketization

The RoIP headend extracts the upstream RF burst signal in the received IP packets from the RoIP terminal.

8.2.2.2 DT-RoIP headend-02: getting signal sending time

The RoIP headend gets the transmitted time information of the upstream RF burst signal by the CM from the received IP packet.

8.2.2.3 DT-RoIP headend-03: decompression

The RoIP headend is required to perform decompression procedures as the RoIP terminal performs compression.

8.2.2.4 DT-RoIP headend-04: RF signal reconstruction

The RoIP headend reconstructs the original digitized upstream RF burst signal from the received IP packets.

8.2.2.5 DT-RoIP headend-05: RF scheduling

The RoIP headend schedules the sending time of the reconstructed upstream RF signal using the upstream allocation information and the transmission time of the extracted upstream RF burst signal.

8.2.2.6 DT-RoIP headend-06: DA converting/RF out

The RoIP headend converts the digital upstream RF burst signal to an analogue RF burst signal and sends it to the CMTS in the cable network.

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