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

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Contents

Foreword

This draft European Telecommunication Standard (ETS) has been produced by the Joint Technical Committee (JTC) of the European Broadcasting Union (EBU), Comité Européen de Normalisation ELECtrotechnique (CENELEC) and the European Telecommunications Standards Institute (ETSI), and is now submitted for the Public Enquiry phase of the ETSI standards approval procedure.

NOTE: The EBU/ETSI JTC was established in 1990 to co-ordinate the drafting of ETSs in the specific field of broadcasting and related fields. Since 1995 the JTC became a tripartite body by including in the Memorandum of Understanding also CENELEC, which is responsible for the standardization of radio and television receivers. The EBU is a professional association of broadcasting organizations whose work includes the co-ordination of its Members" activities in the technical, legal, programme-making and programme-exchange domains. The EBU has Active Members in about 60 countries in the European Broadcasting Area; its headquarters is in Geneva *.

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Digital Video Broadcasting (DVB) Project

Founded in September 1993, the DVB Project is a market-led consortium of public and private sector organizations in the television industry. Its aim is to establish the framework for the introduction of MPEG-2 based digital television services. Now comprising over 200 organizations from more than 25 countries around the world, DVB fosters market-led systems, which meet the real needs, and economic circumstances, of the consumer electronics and the broadcast industry.

Proposed transposition dates	
Date of latest announcement of this ETS (doa):	3 months after ETSI publication
Date of latest publication of new National Standard or endorsement of this ETS (dop/e):	6 months after doa
Date of withdrawal of any conflicting National Standard (dow):	6 months after doa

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1 Scope

This European Telecommunication Standard (ETS) is the baseline specification for the provision of interaction channel for CATV networks.

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

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

2 Normative references

This ETS incorporates by dated and undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this ETS only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

[1] ITU-T Recommendations: "V.21, V.22, V.22bis, V.23, V.25, V.32, V.32bis, V.34 and V.42".

[2] Official Journal of the European Communities, No. L 128, 23 May 1991: "Council Directive on the approximation of the laws of the Member States concerning telecommunications terminal equipment, including the mutual recognition of their conformity (91/263/EEC)". Referred in this ETS as the TTE Directive.

[3] DVB-PI-123/TM1326 Rev 2 (18th April 1995): "Interfaces for DVB-IRD".

[4] Draft prETS 300 802: "Digital Video Broadcasting (DVB); DVB network-independent protocols for interactive services".

[5] EN 50083: "Cabled Distribution Systems".

[6] ETS 300 429: "Digital Video Broadcasting (DVB); DVB framing structure, channel coding and modulation for cable systems".

[7] ETS 300 421: "Digital Video Broadcasting (DVB); DVB framing structure, channel coding and modulation for 11/12 GHz satellite services".

[8] ITU Recommendation I.361 (11/95): "B-ISDN ATM layer specification".

[9] ITU-T Recommendation I.363: "B-ISDN ATM Adaptation Layer specification".

[10] ISO 13818-1

3 Abbreviations

For the purposes of this ETS, the following abbreviations apply:

BC	Broadcast Channel
BRA	Basic Rate Access
CATV	CAble TV distribution system
DAVIC	Digital AudioVIsual Council
DCE	Data Communication Equipment
DTE	Data Termination Equipment
DTMF	Dual Tone Multi-Frequency (dialling mode)
DVB	Digital Video Broadcasting
GSTN	General Switched Telephone Network
IB	In-Band
IC	Interaction Channel
INA	Interactive Network Adapter

IQ	In-phase and Quadrature components
IRD	Integrated Receiver Decoder
ISDN	Integrated Services Digital Network
LSB	Least Significant Bit
MAC	Media Access Control
MMDS	Microwave Multi-point Distribution System
MPEG	Motion Picture Expert Group
MSB	Most Significant Bit
NIU	Network Interface Unit
NSAP	Network Service Access Point
OOB	Out Of Band
OSI	Open Systems Interconnection
PM	Pulse Modulation
PSK	Phase Shift Keying
PSTN	Public Switched Telephone Network
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
QPSK	Quaternary PSK
SMATV	Satellite Master Antenna Tele-Vision
STB	Set Top Box
STU	Set Top Unit
TDMA	Time Division Multiple Access
TS	Transport Stream

4 Reference Model for system architecture of narrowband interaction channels in a broadcasting scenario (asymmetric interactive services)

4.1 Protocol Stack Model

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

physical layer: Where all the physical (electrical) transmission parameters are defined.

transport layer: Defines all the relevant data structures and communication protocols like data containers, etc.

application layer: Is the interactive application software and runtime environments (e.g. home shopping application, script interpreter, etc.).

This ETS addresses the lower two layers (the physical and transport) leaving the application layer open to competitive market forces.

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

Layer Structure for Generic System Reference Model

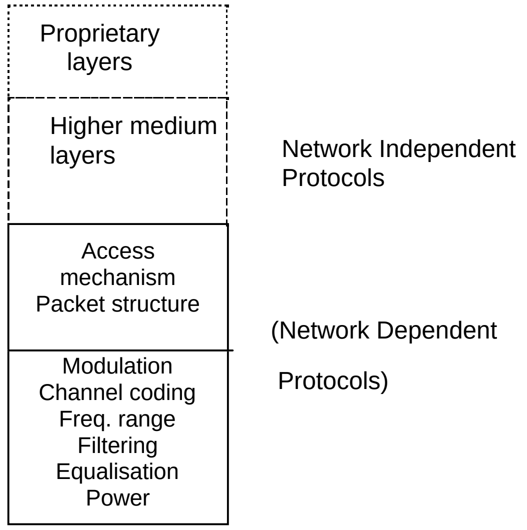


Figure 1: Layer structure for generic system reference model

This ETS addresses the PSTN/ISDN network specific aspects only. The network independent protocols will be specified separately (ITU-T Recommendation I.361 [8]).

4.2 System Model

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

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

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

- **Interaction Channel (IC)**: A Bi-directional Interaction Channel is established between the service provider and the user for interaction purposes. It is formed by:

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

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

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

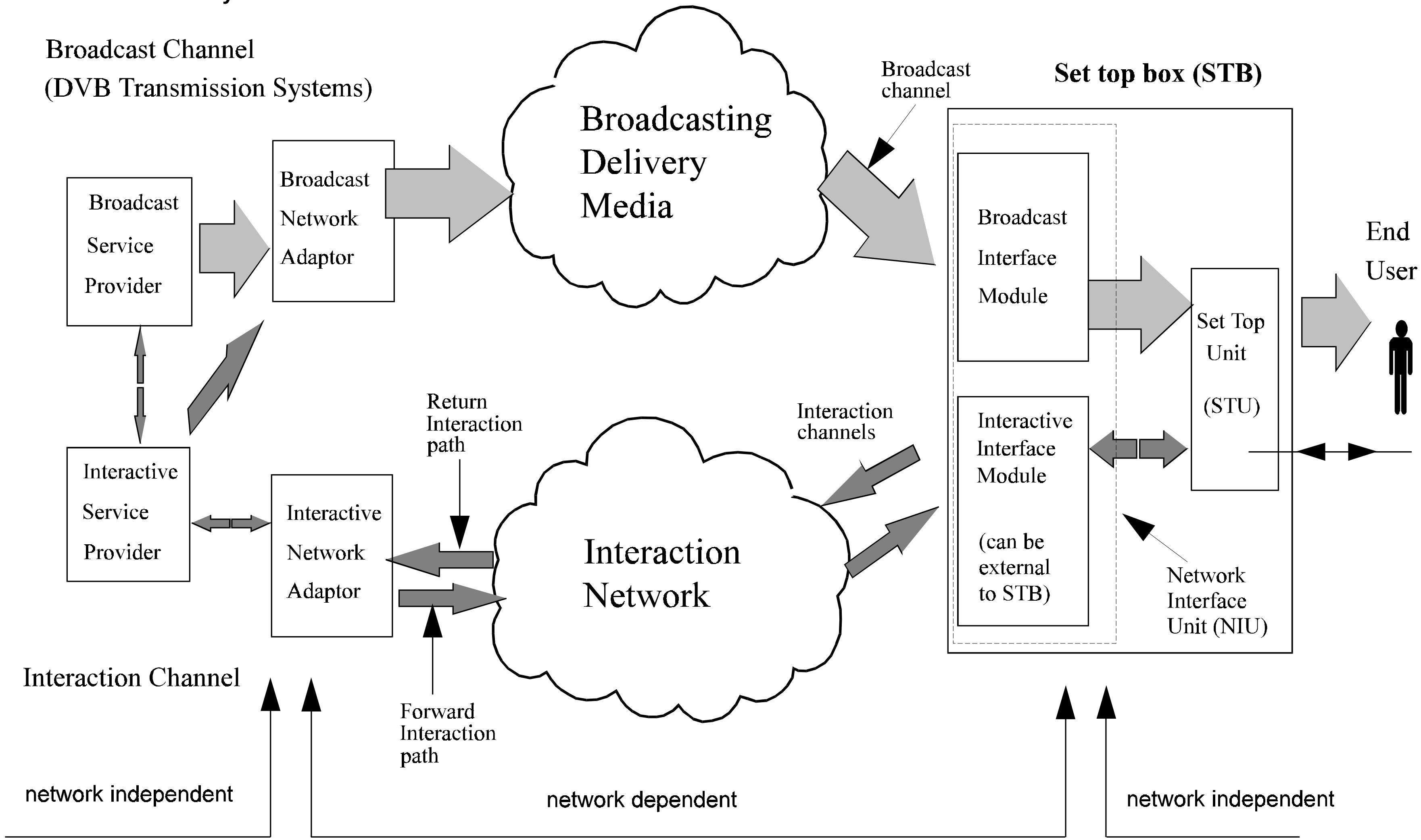


Figure 2: A generic system Reference Model for Interactive Systems

5 DVB interaction channel specification for CATV networks

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

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

5.1 System concept

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

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

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

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

5.1.1 Out-Of-Band (OOB) / In-Band (IB) principle

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

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

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

Both systems can provide the same quality of service. However, the overall system architecture will differ between networks using IB set top boxes and OOB set top boxes. Note also that both types of systems may exist on the same networks under the condition that different frequencies are used for each system.

5.1.2 Spectrum allocation

The figure 3 indicates a possible spectrum allocation. Although not mandatory, a guideline is provided to use the following preferred frequency ranges, 70 to 130 MHz and/or 300 to 862 MHz for the Forward Interaction path (downstream OOB) and 5 to 65 MHz for the Return Interaction path (upstream), or parts thereof. To avoid filtering problems in the bi-directional video amplifiers and in the Set Top Boxes, the upper limit 65 MHz for the upstream flow shall not be used together with the lower limit 70 MHz for the downstream flow in the same system.

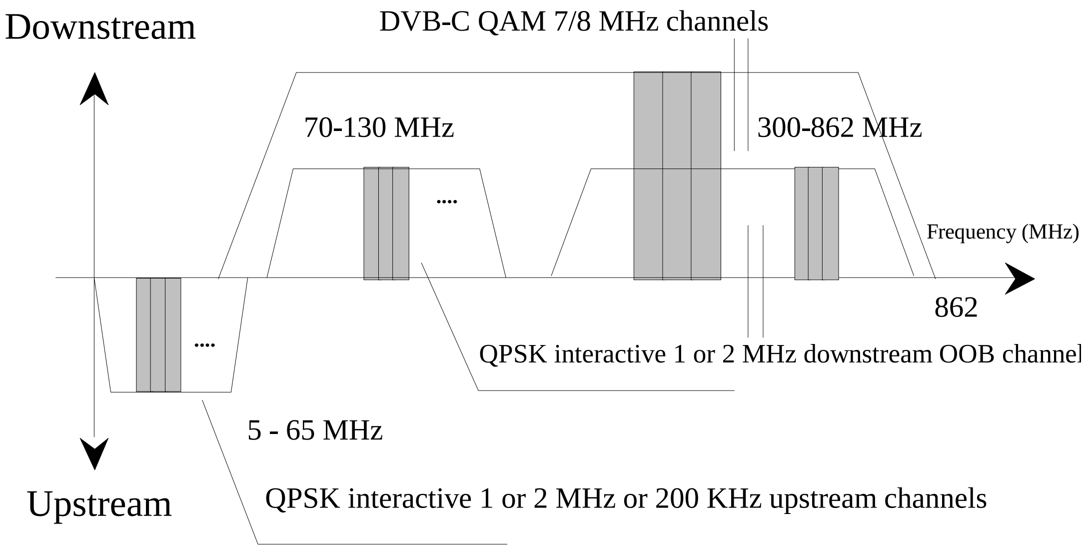


Figure 3: DVB preferred frequency ranges for CATV interactive systems

5.1.3 FDM/TDMA multiple access

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

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

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

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

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

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

The TDMA technique utilizes a slotting methodology which allows the transmit start times to be synchronized to a common clock source. Synchronizing the start times increases message throughput of this signalling channel since the 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. Note that this time reference is not sent in the same way for OOB and IB signalling. Since all NIUs reference the same time base, the slot times are aligned for all NIUs. However, since there is propagation delay in any transmission network, a time base ranging method accommodates deviation of transmission due to propagation delay.

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

There are different access modes for the upstream slots:

- reserved slots with fixed rate reservation (Fixed rate Access: the user has a reservation of one or several timeslots in each frame enabling, e.g. for voice, audio);

- reserved slots with dynamic reservation (Reservation Access: the user sends control information announcing his demand for transmission capacity. He gets grants for the use of slots);

- contention based slots (these slots are accessible for every user. Collision is possible and solved by a contention resolution protocol);

- ranging slots (these slots are used upstream to measure and adjust the time delay and the power).

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

5.1.4 Bit rates and Framing

For the interactive downstream OOB channel, a rate of 1,544 Mbit/s or 3,088 Mbit/s may be used. For downstream IB channels, no other constraints than those specified in the DVB cable specifications (ETS 300 429 [6]) exist, but a guideline would be to use rates multiples of 8 kbit/s.

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

For upstream transmission, the INA can indicate three types of transmission rates to users, specifically 3,088 Mbit/s, 1,544 Mbit/s or 256 kbit/s. The INA is responsible of indicating which rate may be used by NIUs. It would imply all NIUs to be able to either transmit with 256 kbit/s, 1,544 Mbit/s or 3,088 Mbit/s. Only the implementation of one of these bit rates would be mandatory.

Upstream framing consists of packets of 512 bits (256 symbols) which are sent in a bursty mode from the different users present on the network. The upstream slot rates are 6 000 upstream slots/s when the upstream data rate is 3,088 Mbit/s, 3 000 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.

5.2 Lower physical layer specification

In this subclause, detailed information is given on the lower physical layer specification. Figures 4 and 5 show the conceptual block diagrams for implementation of this ETS.

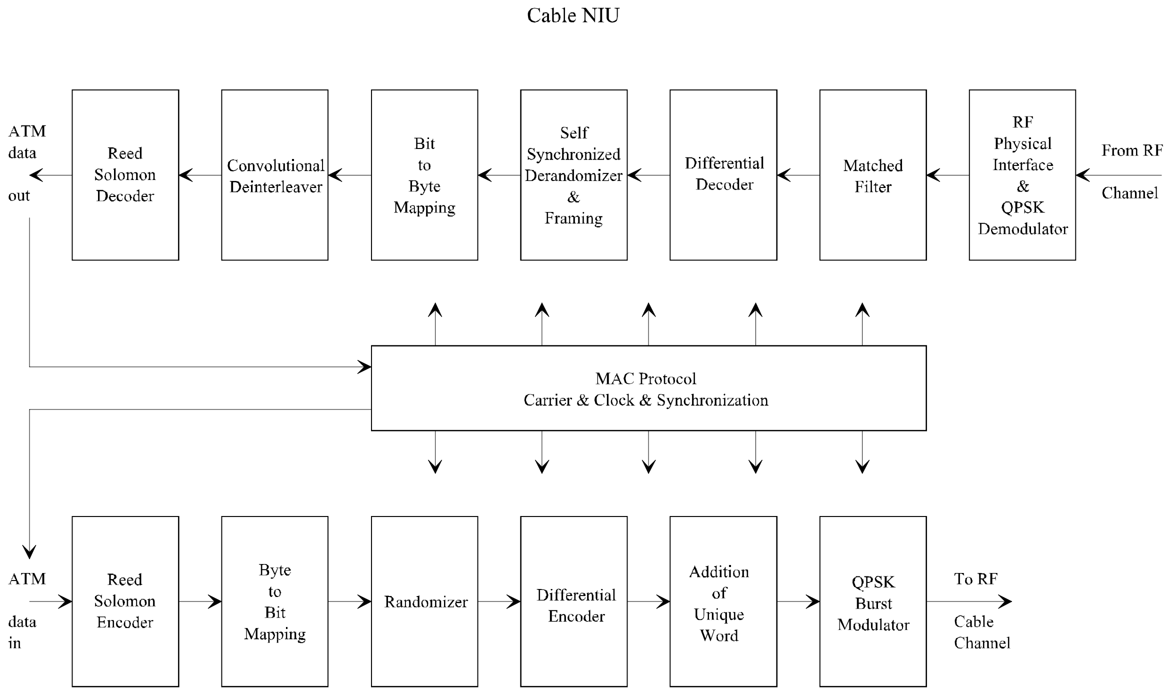


Figure 4: Conceptual block diagram for the NIU OOB Transceiver

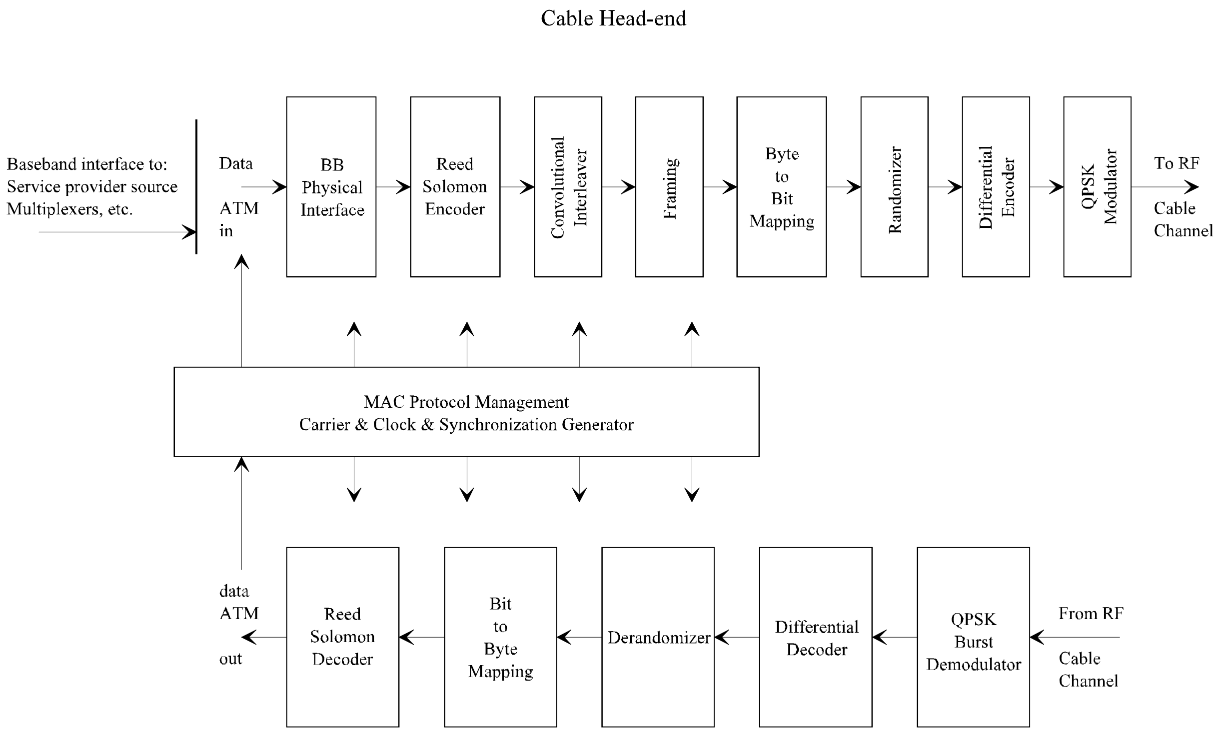


Figure 5: Conceptual block diagram for the OOB Head-end Transceiver

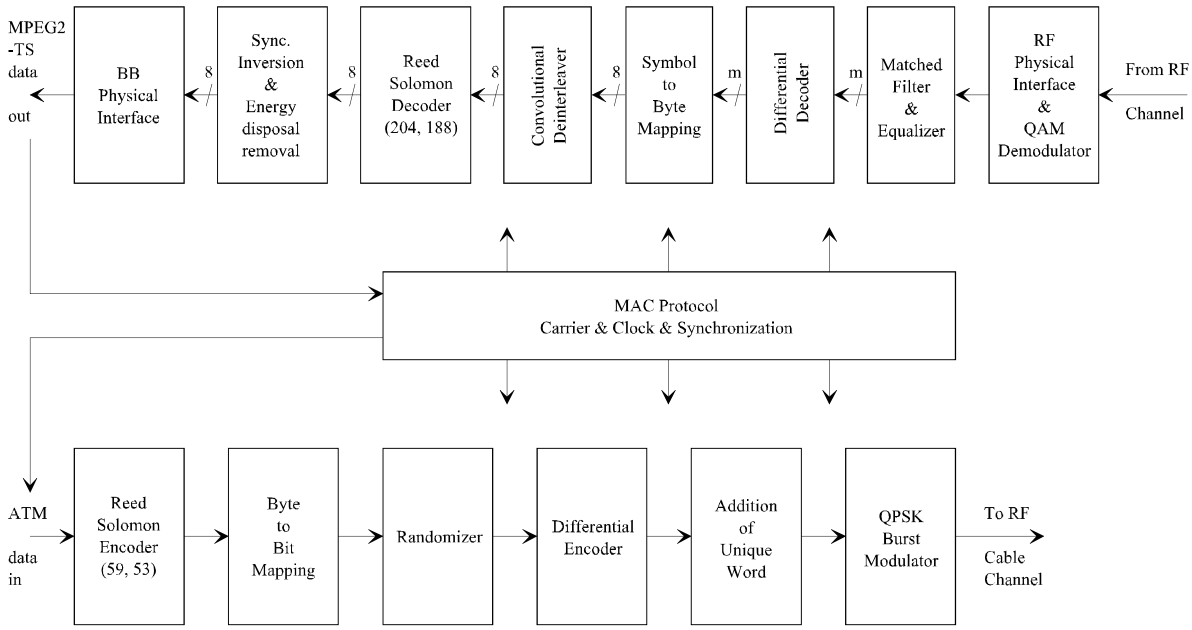


Figure 6: Conceptual block diagram for the IB NIU Transceiver

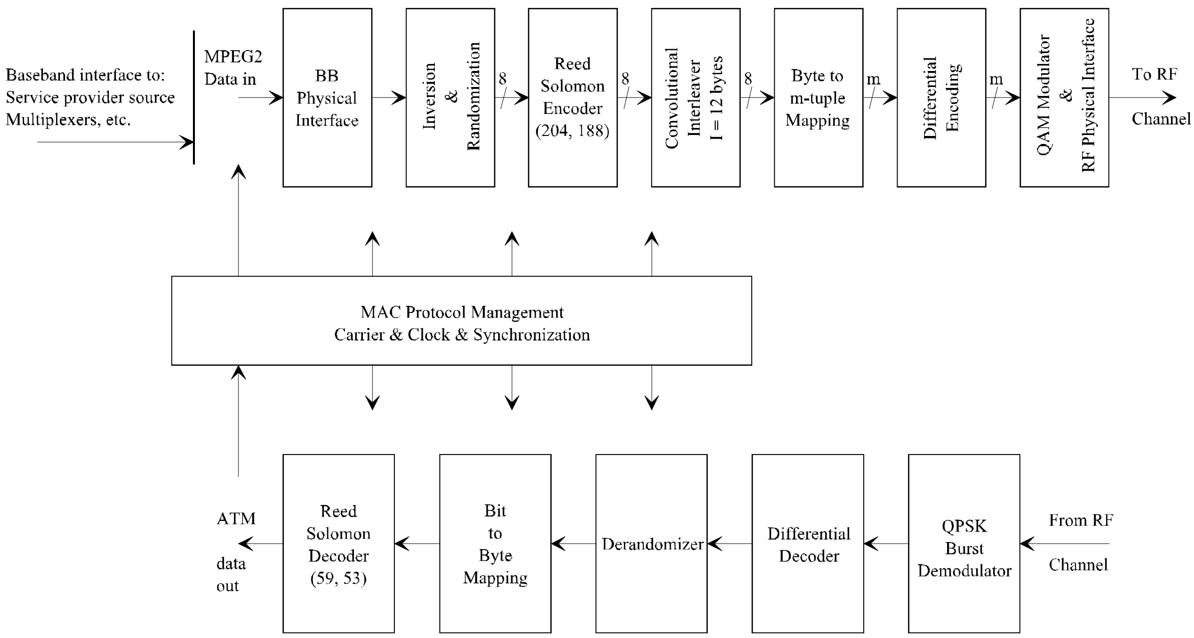


Figure 7: Conceptual block diagram for the IB Head-end Transceiver

5.2.1 Forward Interaction Path (Downstream OOB)

5.2.1.1 Frequency range (Downstream OOB)

The frequency range is not specified as mandatory although a guideline is provided to use the following preferred frequency ranges, 70 to 130 MHz and/or 300 to 862 MHz or parts thereof, in order to simplify the tuner of the NIU. Frequency stability shall be in the range ± 50 ppm measured at the upper limit of the frequency range.

5.2.1.2 Modulation and mapping (Downstream OOB)

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.

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

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

The differential encoder shall accept bits A, B in sequence, and generate phase changes as follows:

Table 1: Phase changes associated with bit A, B

A	B	Phase Change
0	0	none
0	1	+90°
1	1	180°
1	0	-90°

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

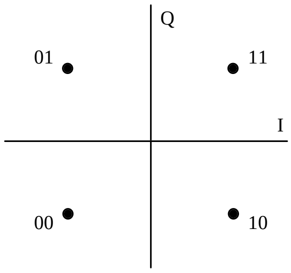


Figure 8: Mapping for the QPSK constellation (downstream OOB)

The phase changes can also be expressed by the following formulas (assuming the constellation is mapped from I and Q as shown in subclause 5.2.2.2):

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

where k is the time index.

I/Q amplitude imbalance shall be less than 1,0 dB, and phase imbalance less than 2,0°.

5.2.1.3 Shaping filter (Downstream OOB)

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

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

where T is the symbol period.

The output signal shall be defined as:

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

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

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

f_b = bit rate

α = excess bandwidth = 0,30

The spectral mask is as follows:

Table 2: Spectral mask for QPSK modulated signal

Bandwidth (MHz)	Response (dB)
0,5	0 ± 0,25
0,772	-3 ± 0,25
1,0	-24 ± 3
1,08	< -36
1,54	< -40
1,8	< -50

Carrier suppression shall be greater than 30 dB.

5.2.1.4 Randomizer (Downstream OOB)

After addition of the FEC bytes (see subclause 5.3), 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: $x^6 + x^5 + 1$. Byte/serial conversion shall be MSB first. A complementary self-synchronizing de-randomizer is used in the receiver to recover the data.

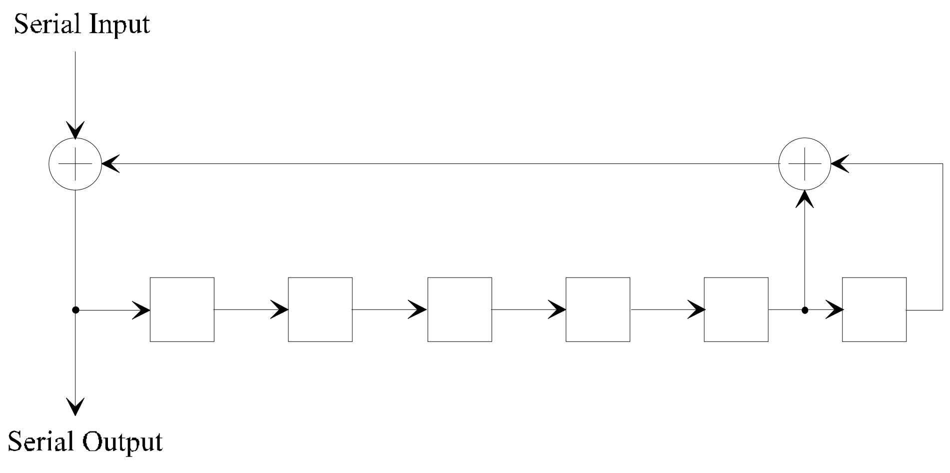


Figure 9: Randomizer

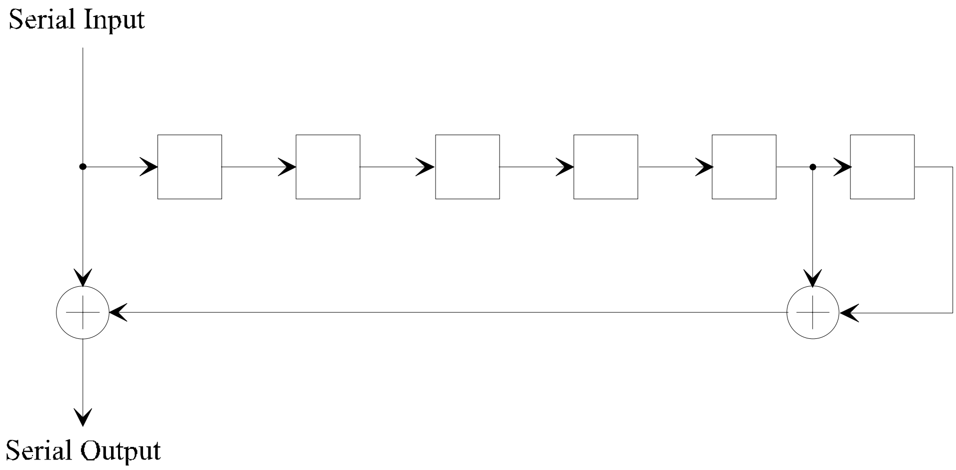


Figure 10: De-randomizer

5.2.1.5 Bit rate (Downstream OOB)

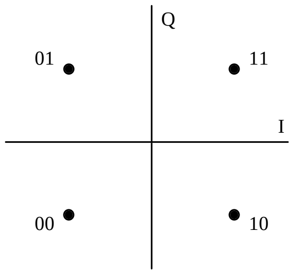
The bit rate shall be 1,544 Mbit/s or 3,088 Mbit/s. Only one of the bit rates is mandatory in the NIU. Symbol rate accuracy should be within ± 50 ppm.

5.2.1.6 Receiver power level (Downstream OOB)

The receiver power level shall be in the range 42 to 75 dBµV rms (75 Ω) at the input (A_b) reference point.

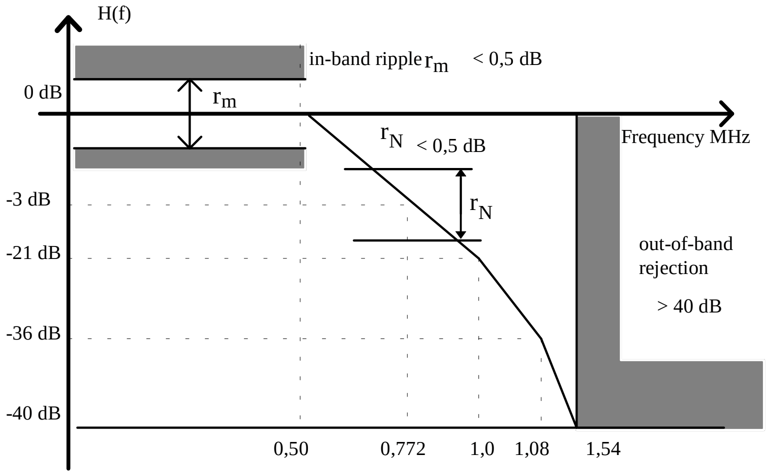
5.2.1.7 Summary (Downstream OOB)

Table 3: Summary (Downstream OOB)

Transmission Rate	1,544 Mbit/s for Grade A 3,088 Mbit/s for Grade B
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)
Randomization	After addition of the FEC bytes, all of the 1,544 Mbit/s (or 3,088 Mbit/s) data is passed through a six register Linear Feedback Shift Register (LFSR) randomizer to ensure a random distribution of ones and zeroes. The generating polynomial is: $x^6 + x^5 + 1$. Byte/serial conversion shall be MSB first. A complementary self-synchronizing de-randomizer is used in the receiver to recover the data.
Differential Encoding	The differential encoder shall accept bits A, B in sequence, and generate phase changes as follows: A B Phase change 0 0 none 0 1 +90° 1 1 180° 1 0 -90° In serial mode, A arrives first.
Signal Constellation	The outputs I, Q from the differential encoder map to the phase states as in figure 11.  **Figure 11**
Frequency Range	recommended but not mandatory 70 to 130 MHz and/or 300 to 862 MHz
Frequency Stability	± 50 ppm measured at the upper limit of the frequency range
Symbol Rate Accuracy	± 50 ppm
Transmit Spectral Mask	Bit rate = 1,544 Mbit/s (Grade A) Bandwidth (MHz) Response (dB) 0,50 ± 0,25 0,772 -3 ± 0,25 1,0 -24 ± 3 1,08 < -36 1,54 < -40 1,8 < -50 Bit rate = 3,088 Mbit/s (Grade B) Bandwidth (MHz) Response (dB) 1,5 0 ± 0,25 1,772 -3 ± 0,25 2,0 -24 ± 3 2,08 < -36 2,54 < -40

(continued)

Table 3 (concluded): Summary (Downstream OOB)

<table>
<tr><td>Carrier Suppression</td><td>> 30 dB</td></tr>
<tr><td>I/Q Amplitude Imbalance</td><td>< 1,0 dB</td></tr>
<tr><td>I/Q Phase Imbalance</td><td>< 2,0°</td></tr>
<tr><td>Receive Power Level at reference point A_b (downstream out-of-band)</td><td>42 - 75 dBμV rms (75 Ω)</td></tr>
<tr><td>Transmit Spectral Mask</td><td>Bit rate = 1,544 Mbit/s (Grade A)
<table>
<tr><th>Bandwidth (MHz)</th><th>Response (dB)</th></tr>
<tr><td>± 0,25</td><td></td></tr>
<tr><td>0,772</td><td>-3 ± 0,25</td></tr>
<tr><td>1,0</td><td>< -21</td></tr>
<tr><td>1,08</td><td>< -36</td></tr>
<tr><td>1,544</td><td>< -40</td></tr>
</table>


Bit rate = 3,088 Mbit/s (Grade B)
<table>
<tr><th>Bandwidth (MHz)</th><th>Response (dB)</th></tr>
<tr><td>1,0</td><td>0 ± 0,25</td></tr>
<tr><td>1,544</td><td>-3 ± 0,25</td></tr>
<tr><td>2,0</td><td>< -21</td></tr>
<tr><td>2,16</td><td>< -36</td></tr>
<tr><td>3,088</td><td>< -40</td></tr>
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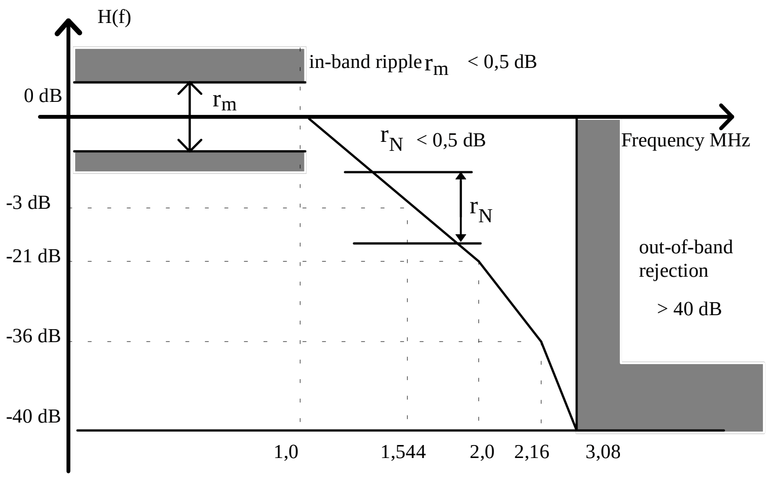


</td></tr>
</table>

5.2.1.8 Bit error rate downstream OOB (informative)

Bit error rate at the NIU should be less than 10^{-10} (after error correction, i.e. 1 error in 2 hours at 1,5 Mbit/s) at C/N > 20 dB for downstream transmission. C/N is the carrier-to-noise ratio relevant for the demodulation process (Nyquist bandwidth for white noise).

5.2.2 Forward Interaction Path (Downstream IB)

The IB Forward Interaction Path shall use a MPEG-2 TS stream with a modulated QAM channel as defined by ETS 300 429 [9]. Frequency range, channel spacing, and other lower physical layer parameters should follow that specification.

5.2.3 Return Interaction Path (Upstream)

5.2.3.1 Frequency range (Upstream)

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

5.2.3.2 Modulation and Mapping (Upstream)

The unique word (CC CC CC 0D, see subclause 5.3 for upstream framing) is not differentially encoded, the outputs I, Q map to the phase states as in figure 12.

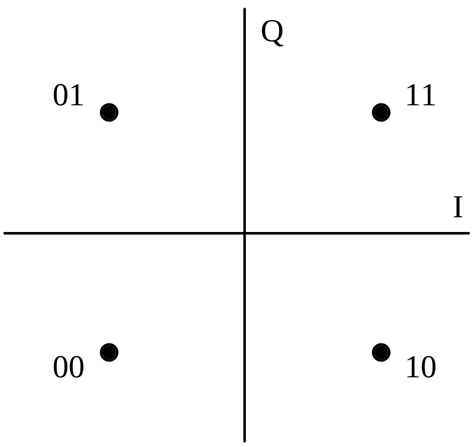


Figure 12: Mapping for the QPSK constellation (upstream)

For the remainder of the packet, the differential encoder shall accept bits A, B in sequence, and generate phase changes as follows. It starts with the first information di-bit and is initialized with the last di-bit of the unique word, i.e. (A,B = 0,1) since conversion is made MSB first.

Table 4: Phase changes corresponding to bits A, B

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

Phase changes correspond to the following formulas (assuming I and Q are mapped to the constellation as for the unique word):

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

where k is the time index.

I/Q amplitude imbalance shall be less than 1,0 dB, and phase imbalance less than 2,0°.

5.2.3.3 Shaping filter (Upstream)

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

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

where T is the symbol period.

The output signal shall be defined as:

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

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

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

f_b = bit rate

α = excess bandwidth = 0,30

The spectral mask is as follows:

Table 5: Spectral mask for bit rate = 256 kbit/s (Grade A)

Bandwidth (MHz)	Response (dB)
89,6	0 ± 0,5
128	-3 ± 0,5
192	-24 ± 3
1,08	< -30
1,544	< -40

Table 6: Spectral mask for bit rate = 1,544 Mbit/s (Grade B)

Bandwidth (MHz)	Response (dB)
0,5	0 ± 0,25
0,772	-3 ± 0,25
192	-24 ± 3
1,08	< -36
1,54	< -40

Table 7: Spectral mask for bit rate = 3,088 Mbit/s (Grade C)

Bandwidth (MHz)	Response (dB)
1,5	0 ± 0,25
1,772	-3 ± 0,25
2,0	-24 ± 3
2,08	< -36
2,54	< -40

Carrier suppression shall be greater than 30 dB.

5.2.3.4 Randomizer (Upstream)

The unique word shall be sent in clear (see subclause 5.3). After addition of the FEC bytes, randomization shall apply only to the payload area and FEC bytes, with the randomizer performing modulo-2 addition of the data with a pseudo-random sequence. The generating polynomial is $x^6 + x^5 + 1$ with seed all ones. We assume the first value coming out of the pseudo-random generator taken into account is 0. Byte/serial conversion shall be MSB first. The binary sequence generated by the shift register starts with 00000100… The first "0" is to be added in the first bit after the unique word.

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

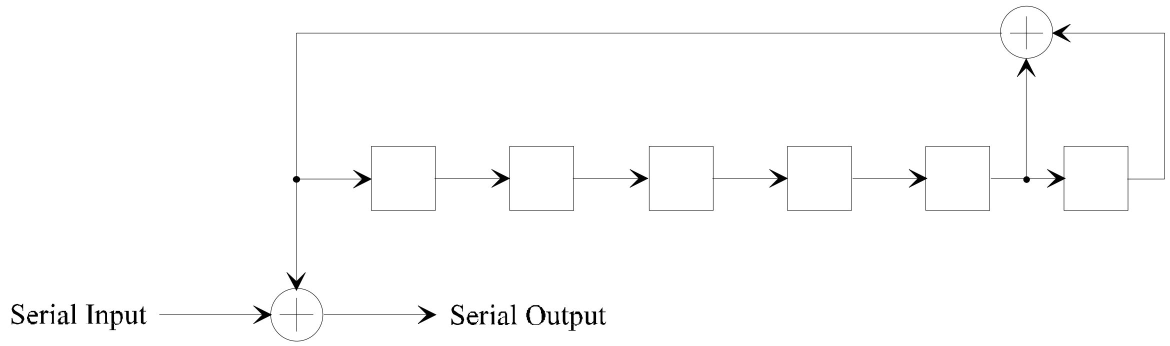


Figure 13: Randomizer

5.2.3.5 Bit rate (Upstream)

Three grades of modulation transmission rate are specified:

Table 8: Upstream bit-rates for modulation grades A, B and C

Grade	Rate
A	256 kbit/s
B	1,544 Mbit/s
C	3,088 Mbit/s

A QPSK modulator (NIU transmitter) may support A, B and C grades of transmission rate. Only the implementation of one of these grades should be mandatory. A QPSK demodulator (INA receiver) shall support at least one grade A, B or C, but may support all grades.

Symbol rate accuracy should be within ± 50 ppm.

For grade A, the rate is 500 slots/s. For grade B, the rate is 3 000 slots/s. For grade C, the rate is 6 000 slots/s.

5.2.3.6 Transmit power level (Upstream)

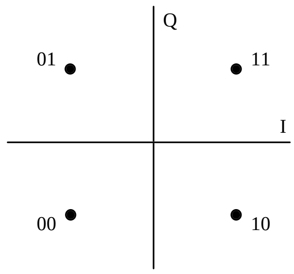
At the output (reference point A_b), the transmit power level shall be in the range 85 to 113 dBμV rms (75 Ω). In some geographic areas, it may be necessary to cover the range 85 to 122 dBμV rms (75 Ω). However, high power may lead to Electro-magnetic Compatibility (EMC) problems. This power shall be adjusted by steps of 0,5 dB by MAC messages coming from the INA.

5.2.3.7 Carrier suppression when idle (Upstream)

The carrier suppression shall be more than 60 dB below nominal power output level, over the entire power output range (The absolute maximum output power level should not exceed that specified in ETS 300 421 [7]). A terminal is considered to be idle if it is 3 slots before an imminent transmission or 3 slots after its most recent transmission.

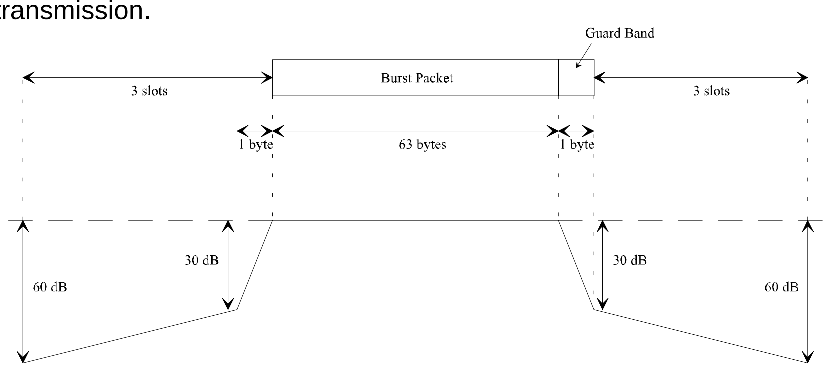
5.2.3.8 Summary (Upstream)

Table 9: Summary (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) may support A, B and C grades of transmission rate. Only the implementation of one of these grades should be mandatory. A QPSK demodulator (receiver) shall support at least one grade A, B, or C, but may support both grades.
Modulation	Differentially encoded QPSK
Transmit Filtering	alpha = 0,30 square root raised cosine
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
Randomization	The unique word shall be sent in the clear. After addition of the FEC bytes, randomization shall apply only to the payload area and FEC bytes, with the randomizer performing modulo-2 addition of the data with a pseudo-random sequence. The generating polynomial is $x^6 + x^5 + 1$ with seed all ones. Byte/serial conversion shall be MSB first. A complementary non self-synchronizing de-randomizer is used in the receiver to recover the data. The de-randomizer shall be enabled after detection of the unique word.
Differential Encoding	The differential encoder shall accept bits A, B in sequence, and generate phase changes as follows. In serial mode, A arrives first. A B Phase Change 0 0 none 0 1 +90° 1 1 180° 1 0 -90°
Signal Constellation NOTE: The unique word (0x CC CC CC 0D) does not go through differential encoding.	The outputs I, Q from the differential encoder map to the phase states as in figure 14.  **Figure 14**
Frequency Range	5-65 MHz recommended but not mandatory.
Frequency Stability	± 50 ppm measured at the upper limit of the frequency range

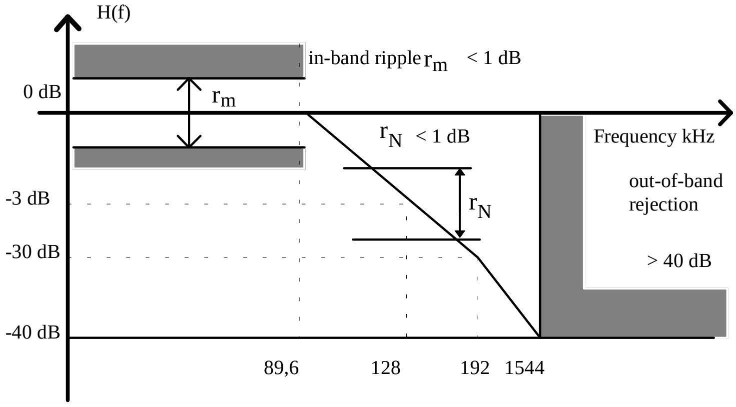
(continued)

Table 9 (continued): Summary (Upstream)

Transmission Rate	Three grades of modulation transmission rate are specified: <u>Grade Rate</u> A 256 kbit/s B 1,544 Mbit/s C 3,088 Mbit/s A QPSK modulator (transmitter) may support A, B and C grades of transmission rate. Only the implementation of one of these grades should be mandatory. A QPSK demodulator (receiver) shall support at least one grade A, B, or C, but may support both grades.
Symbol Rate Accuracy	± 50 ppm
Transmit Spectral Mask	Bit rate = 256 kbit/s (Grade A) <u>Bandwidth (kHz) Response (dB)</u> 89,6 0 ± 0,5 128 -3 ± 0,5 192 < -30 1 544 < -40 Bit rate = 1,544 Mbit/s (Grade B) <u>Bandwidth (MHz) Response (dB)</u> 0,5 0 ± 0,25 0,772 -3 ± 0,25 1,0 -24 ± 3 1,08 < -36 1,54 < -40 Bit rate = 3,088 Mbit/s (Grade C) <u>Bandwidth (MHz) Response (dB)</u> 1,5 0 ± 0,25 1,772 -3 ± 0,25 2,0 -24 ± 3 2,08 < -36 2,54 < -40
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 (see ETS 300 421 [7] for details) and 30 dB right after or before transmission. Idle Transmitter Definition: A terminal is considered to be idle if it is 3 slots before an imminent transmission or 3 slots after its most recent transmission. 

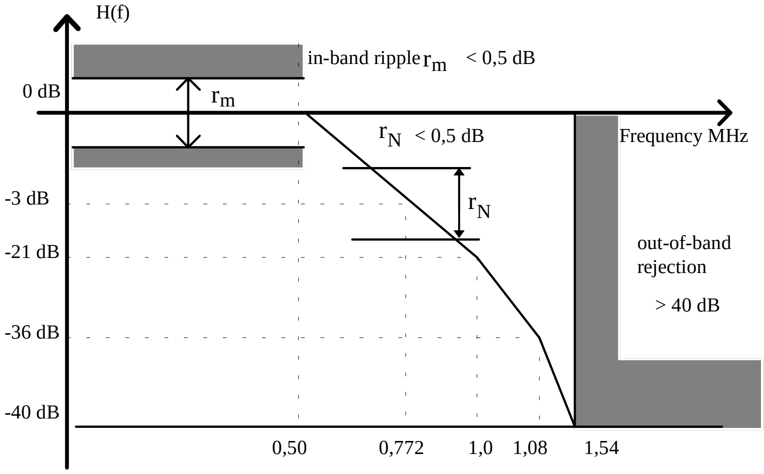
(continued)

Table 9 (continued): Summary (Upstream)

Transmission Rate	Three grades of modulation transmission rate are specified: <u>Grade</u> <u>Rate</u> A 256 kbit/s B 1,544 Mbit/s C 3,088 Mbit/s A QPSK modulator (transmitter) may support A, B and C grades of transmission rate. Only the implementation of one of these grades should be mandatory. A QPSK demodulator (receiver) shall support at least one grade A, B, or C, but may support both grades.
I/Q Amplitude Imbalance	< 1,0 dB
I/Q Phase Imbalance	< 2,0°
Transmit Power Level at the modulator output A_b (upstream)	85 to 113 dBµV rms (75 Ω). In some geographic areas, it may be necessary to cover the range 85 to 122 dBµV rms (75 Ω).
Transmit Spectral Mask	Bit rate = 256 kbit/s (Grade A) <u>Bandwidth (kHz)</u> <u>Response (dB)</u> 89,6 0 ± 0,5 128 -3 ± 0,5 192 < -30 1 544 < -40  Bit rate = 1,544 Mbit/s (Grade B) <u>Bandwidth (MHz)</u> <u>Response (dB)</u> 0,5 0 ± 0,25 0,772 -3 ± 0,25 1,0 < -21 1,08 < -36 1,544 < -40

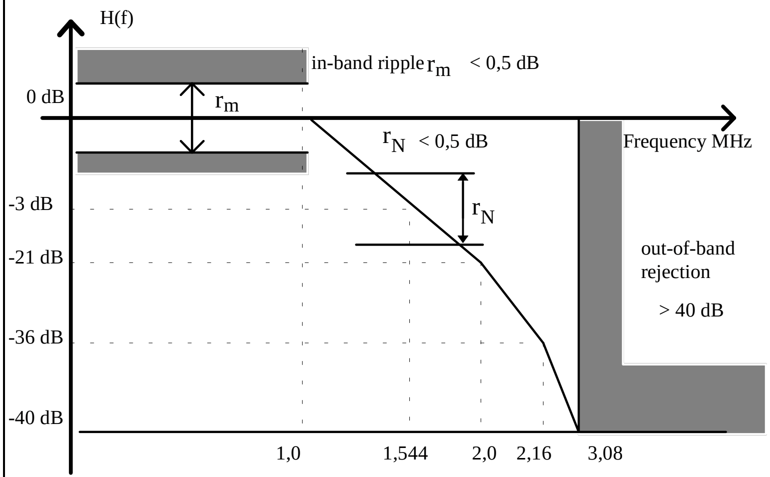
(continued)

Table 9 (concluded): Summary (Upstream)



Bit rate = 3,088 Mbit/s (Grade C)

Bandwidth (MHz)	Response (dB)
1,0	0 ± 0,25
1,544	-3 ± 0,25
2,0	< -21
2,16	< -36
3,088	< -40



5.2.3.9 Packet loss upstream (informative)

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

NOTE: A packet loss occurs when one or more bit per packet (after error correction) are un–correctable. The C/N is referred at the demodulator input at the Ax reference point (Nyquist bandwidth, white noise).

The maximum distance between INA and NIU shall be 50 km. The exact distance is to be checked as well as the rationale for its definition.

5.3 Framing

5.3.1 Forward Interaction Path (Downstream OOB)

5.3.1.1 Signalling Link Extended SuperFrame (SL-ESF) framing format

The SL-ESF frame structure is shown in figure 15. 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 (0H) bit and 24 bytes (192 bits) of payload.

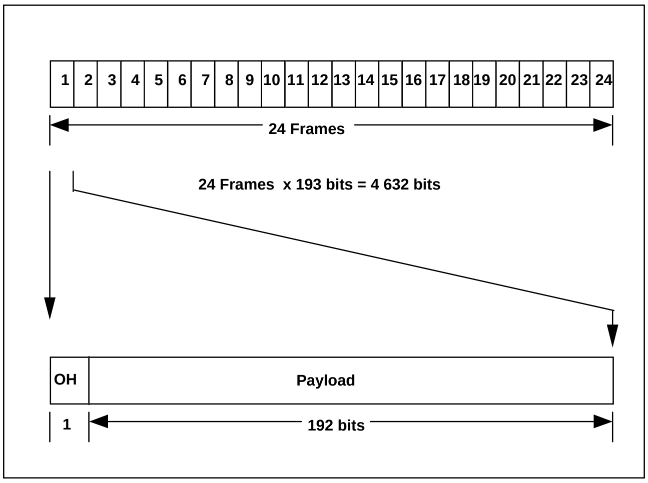


Figure 15: SL-ESF frame structure

5.3.1.2 Frame overhead

There are 24 frame overhead bits in the Extended SuperFrame (ESF) which are divided into Extended SuperFrame Frame Alignment Signal (F1-F6), Cyclic Redundancy Check (C1-C6), and M-bit Data Link (M1-M12) as shown in table 10.

Table 10: Frame overhead

Frame number	Bit number	Overhead bit	Data (192 bits)
1	0	**M1**	
2	193	C1	
3	386	M2	
4	579	F1 = 0	
5	772	M3	
6	965	C2	
7	1 158	M4	
8	1 351	F2 = 0	
9	1 544	**M5**	
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	
17	3 088	**M9**	
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: M-bit Data Link (M1 - M12) CRC: Cyclic Redundancy Check (C1 - C6)			

ESF Frame Alignment Signal

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

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

ESF Cyclic Redundancy Check

The Cyclic Redundancy Check field contains the CRC-6 check bits calculated over the previous Extended SuperFrame (CRC Message block [CMB] size = 4 632 bits). Before calculation, all 24 frame overhead bits are equal to "1". All information in the other bit positions is unchanged. The check bit sequence C1-C6 is the remainder after multiplication by x^6 and then division by the generator polynomial $x^6 + x + 1$ of the CMB. C1 is the Most Significant Bit (MSB) of the remainder. The initial remainder value is preset to all zeros.

ESF M-bit Data Link

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

5.3.1.3 Payload structure

The SL-ESF frame payload structure provides a known container for defining the location of the ATM cells and the corresponding Reed-Solomon parity values. The SL-ESF payload structure is shown in table 11.

Table 11: ESF Payload structure

	2		53	2		
1	R1a	R1b	ATM Cell	RS parity		
2	R1c	R2a			R2 b	
3	R2c	R3a				
4	R3b	R3c			R4 a	
5	R4b	R4c				
6	R5a	R5b			R5 c	
7	R6a	R6b				
8	R6c	R7a			R7 b	
9	R7c	R8a				
10	R8b	R8c			T	T

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.

ATM cell structure

The format for each ATM cell structure is shown in figure 16. This structure and field coding shall be consistent with the structure and coding given in ITU-T Recommendation I.361 [8] for ATM UNI.

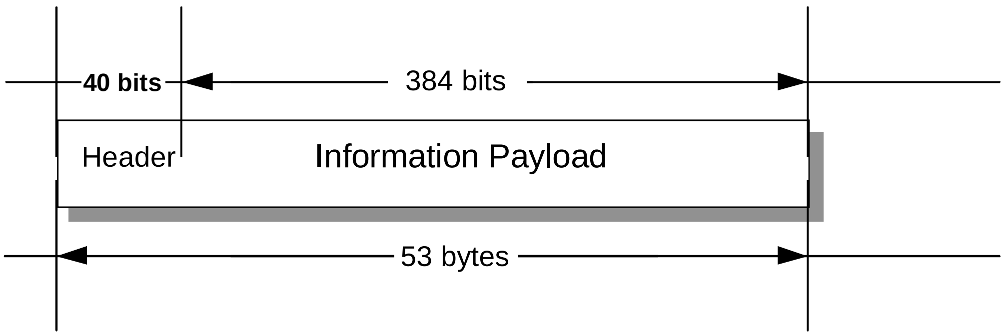


Figure 16: ATM cell format

Channel coding and interleaving

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

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

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

Field generator polynomial: $p(x) = x^8 + x^4 + x^3 + x^2 + 1$

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 the figure below, 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.

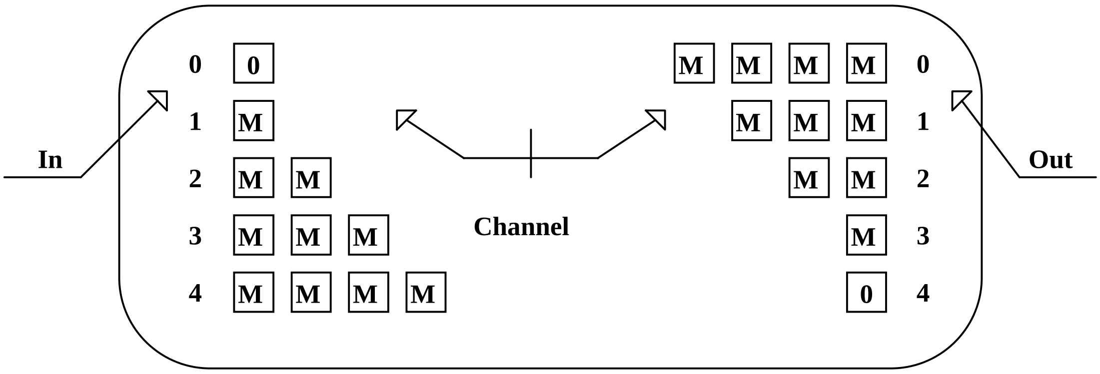


Figure 17: Interleaver and De-interleaver structures

Reception indicator fields and slot boundary fields

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

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

= slot configuration information for the upstream channel "x", where "x" is indicated to the NIU in the "Flag set" given in MAC messages (Default Configuration Message, Connect Message, Transmission Control Message) corresponding to a particular upstream frequency. Due to the different possible rates upstream (256 kb/s, 1,544 Mb/s, or 3,088 Mb/s), one channel may require up to two consecutive fields. Thus "x" denotes first field used for a particular upstream frequency.

b0	= ranging control slot indicator for next SuperFrame
b1-b6	= slot boundary definition field for next SuperFrame
b7	= slot 1 reception indicator for second previous SuperFrame
b8	= slot 2 reception indicator for second previous SuperFrame
b9	= slot 3 reception indicator for second previous SuperFrame
b10	= slot 4 reception indicator for second previous SuperFrame
b11	= slot 5 reception indicator for second previous SuperFrame
b12	= slot 6 reception indicator for second previous SuperFrame
b13	= slot 7 reception indicator for second previous SuperFrame

b14	= slot 8 reception indicator for second previous SuperFrame
b15	= slot 9 reception indicator for second previous SuperFrame
b16-17	= reservation control for next SuperFrame
b18-b23	= CRC 6 parity

When the upstream data channel is a 256 kbit/s data channel, then only the first three slot reception indicators are valid. These slots indicators refer to the three available slots which span over two SuperFrame periods in the 256 kbit/s. When the upstream data rate is 1,544 Mbit/s, then the 9 slots are valid. When the data rate is 3,088 Mbit/s, the 9 slots of this field and the 9 slots of the following field are valid.

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 SuperFrame of the related downstream channel 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 (guard band for ranging operations).

Slot Boundary Definition field (b1-b6) - Slot types are assigned to upstream slots using bits b0-b6. The slots are grouped into regions within the SL-ESF 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 Fixed rate based slots. If a ranging slot is available within a SL-ESF it will consist of the first three slot times in the SL-ESF. A ranging slot is indicated by b0 = 1. The boundaries between the remaining regions of the SL-ESF are defined by b1-b6. The boundaries are defined as shown in table 12.

Table 12: Slot Boundary Definition field (b1-b6)

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

The boundary positions are defined by b1-b6 as shown in table 13.

Table 13: Boundary positions (b1-b6)

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

NOTE 1: Row = Contention based / Reserved region boundary

NOTE 2: Column = Reserved packet /Fixed rate based region boundary

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

EXAMPLE: b0 = 0, b1-b6 = 22: Contention (1-2), reserved (3-5), Fixed rate (6-9)

The remaining values of the Slot Boundary Definition Field are provided in table 14.

Table 14: Slot Boundary Definition Field

b1-b6 value	ranging control slots	contention slots	reservation slots	fixed rate slots
55	1-6	7-9	-	-
56	1-6	7-8	-	9
57	1-6	7	8-9	-
58	1-6	7	8	9
59	1-6	7	-	8-9
60	1-6	-	7-8	9
61	1-6	-	7	8-9
62	1-6	-	-	7-9
63	1-9	-	-	-

NOTE 1: For b1-b6 = 55 - 63, b0 shall be set to 1.

NOTE 2: For b1-b6 between 55 and 62, two ranging slots are provided (2 and 5). For b1-b6 = 63, three ranging slots are provided (2, 5 and 8).

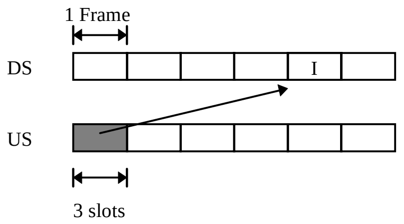
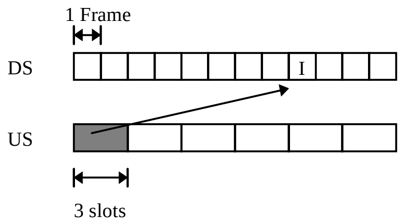
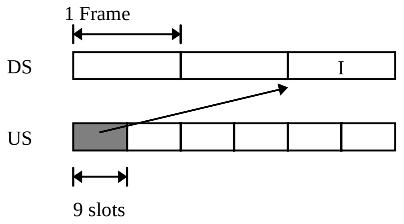
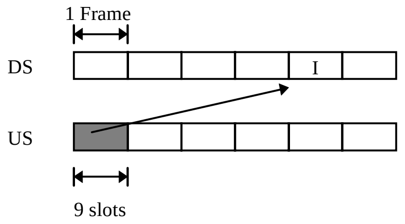
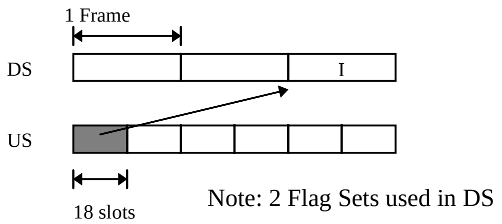
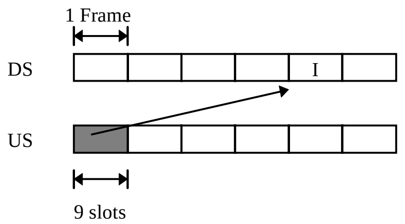
The values in tables 13 and 14 are derived from b1-b6 in the following manner:

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

When the upstream data channel is a 256 kbit/s data channel, then only the first three slot boundary positions are valid.

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 table 14. When the indicator is inactive ("0"), this indicates that either a collision was detected or no cell was received in the corresponding upstream slot.

Table 15: Relationship of US slot to DS Indicator

	1,544M Downstream	3,088 Downstream
256k		
1,544M		
3,088M		
	I indicates the US slot in which Indicators are sent. These indicators are for the DS slots in the shaded area.	

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 contain a CRC 6 parity value calculated over the previous 18 bits. The CRC 6 parity value is described in the SL-ESF frame format subclause 5.3.1.1.

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.

Trailer bytes

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

5.3.2 Forward Interaction Path (Downstream IB)

The structure that is utilized when the downstream QAM channel is carrying MPEG2-TS packets is shown in figure 18.

4	3	2	3	26	26	40	40	40	4
MPEG Header	Upstream Marker	Slot Number	MAC Flag Control	MAC Flags	Ext. Flags	MAC mes-sage	MAC mes-sage	MAC message	rsrvc

Figure 18: Frame structure (MPEG-2 TS format)

where:

MPEG Header is the 4 byte MPEG-2 Transport Stream (TS) Header as defined in ISO 13818-1 [10] with a specific PID designated for MAC messages.

Upstream Marker is a 24-bit field which provides upstream QPSK synchronization information. The definition of the field is as follows:

bit 0: upstream marker enable (MSB)

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

bit 1-7: reserved

bit 8 - 23: upstream slot marker pointer

The slot marker pointer is a 16-bit integer which indicates the number of "symbol" clocks between the first symbol of the next Sync byte and the next 3 ms marker.

Slot Number is a 16-bit field which is defined as follows:

bit 0: slot position register enable (MSB)

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

bit 1-3: reserved

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

bit 5: odd parity

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

bit 6-15: upstream slot position register

The upstream slot position register is a 10 bit counter which counts from 0 to n with bit 6 the MSB. These bits are equivalent to M10-M1 in the case of OOB downstream. (See subclause 5.4 for more information on the functionality of the upstream slot position register)

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

b0-b2 = channel 1 flag field control
b3-b5 = channel 2 flag field control
b6-b8 = channel 3 flag field control
b9-b11 = channel 4 flag field control
b12-b14 = channel 5 flag field control
b15-b17 = channel 6 flag field control
b18-b20 = channel 7 flag field control
b21-b23 = channel 8 flag field control

Each of the above channel "x" flag field control fields are defined as follows:

channel x flag control (a,b,c)

bit a: 0 - channel x flag field disabled

1 - channel x flag field enabled

bit b,c: 00 - all flags valid for second previous 3 ms period

(out-of-band signalling equivalent)

01 - flags valid for 1st ms of previous 3 ms period

10 - flags valid for 2nd ms of previous 3 ms period

11 - flags valid for 3rd ms of previous 3 ms period

MAC Flags

MAC Flags is a 26-byte field containing 8 slot configuration fields (24 bits each) which contain slot configuration information for the related upstream channels followed by two reserved bytes. The definition of each slot configuration field is defined as follows:

b0	= ranging control slot indicator for next 3 ms period (MSB)
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 3 ms period
b18-b23	= CRC 6 parity

The slot configuration fields are used in conjunction with the MAC Flag Control field defined above. When the MAC Flag Control field designates that a 1 ms flag update is enabled:

1) the reception indicators refer to the previous 3 ms period (the bracketed term [second] is omitted from the definition);

2) only the reception indicators which relate to slots which occur during the designated 1 ms period are valid; and

3) the ranging control slot indicator, slot boundary definition field, and reservation control field are valid and consistent during each 3 ms period.

Extension Flags

Extension Flags is a 26-byte field which is used when one or more 3,088 Mb/s upstream QPSK links are used. The definition of the Extension Flags field is identical to the definition of the MAC Flags field above.

When 3,088 Mbit/s QPSK upstream links are used, Each 3,088 Mbit/s upstream channel utilizes two consecutive qpsk_slot_configuration fields. The definition of the first slot configuration field is unchanged. The definition of the second slot configuration field extends the boundary definition to slots 10 through 18, and the reception indicators cover slots 10 through 18.

MAC Message

The MAC Message field contains a 40-byte message, the general format defined in subclause 5.5.

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

5.3.3 Return Interaction Path (Upstream)

5.3.3.1 Slot Format

The format of the upstream slot is shown in figure 19 below. A Unique Word (UW) (4 bytes) provides a burst mode acquisition method. The payload area (53 bytes) contains a single message cell. The RS Parity field (6 bytes) provides t = 3 Reed-Solomon protection RS(59,53) over the payload area. The Guard band (1 byte) provides spacing between adjacent packets.

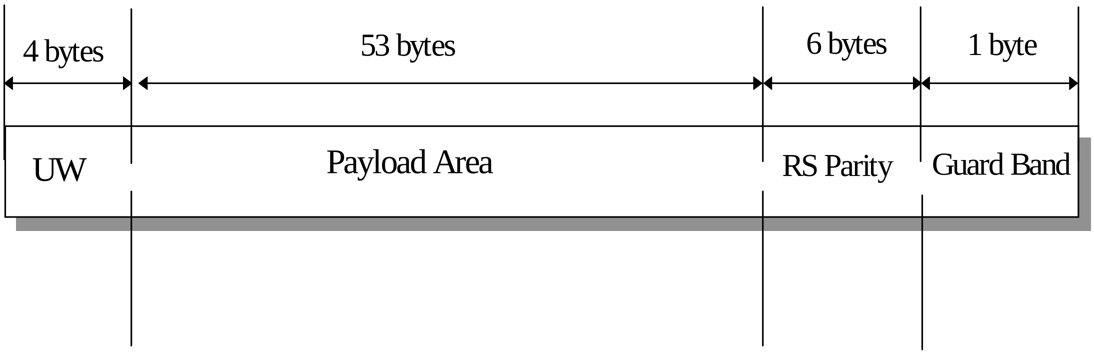


Figure 19: Slot format

The structure and field coding of the message cell shall be consistent with the structure and coding given in ITU-T Recommendation I.361 [8] for ATM UNI.

Unique Word

The unique word is four bytes long: CC CC CC 0D hex.

ATM Cell Structure

The format for each ATM cell structure is illustrated below. This structure and field coding shall be consistent with the structure and coding given in ITU-T Recommendation I.361 [8] for ATM UNI.

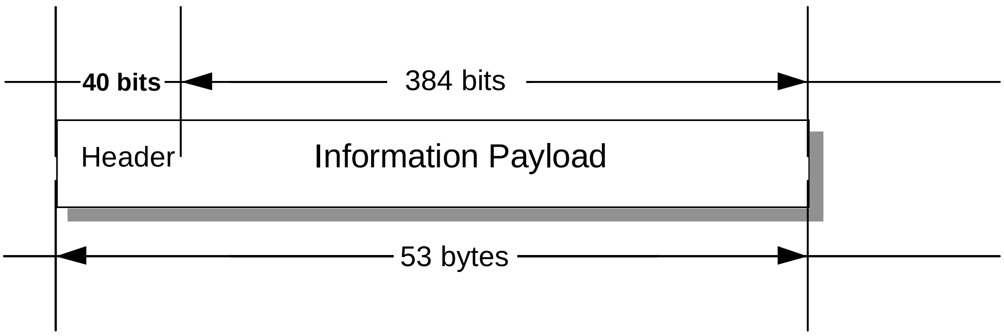


Figure 20: ATM cell format

Channel Coding

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 code word of (59,53).

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 = 02 hex

Field generator polynomial: $p(x) = x^8 + x^4 + x^3 + x^2 + 1$

Guard Band

The Guard Band is 1-byte long (4 QPSK symbols). It provides some extra protection against synchronization errors.

5.4 Slot timing assignment

5.4.1 Downstream slot position reference (Downstream OOB)

Upstream synchronization is derived from the downstream extended SuperFrame (OOB) by noting the slot positions as shown in table 16.

Table 16: Downstream slot position reference

Frame number	Bit number	Overhead bit	Slot Position reference
1	0	**M1**	Slot Position (note)
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	
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	
NOTE: The first slot position is also called the 3 ms time marker in the case of 1,544 Mbit/s rate downstream. For the 3,088 Mbit/s rate downstream, the 3 ms time marker only appears once every two SuperFrames. The M12 bit (see subclause 5.4) is used to differentiate between the two SuperFrames.			

5.4.2 Downstream slot position reference (Downstream IB)

Upstream synchronization is derived from the downstream extended SuperFrame (IB) by noting the 3 ms time Marker Downstream as shown in figure 21. From the bits of the upstream marker field contained in the MPEG-2 TS packet, the 3 ms time Marker is obtained by counting a number of symbol clocks equal to (b23-b8). This marker is equivalent to the first slot position of the SuperFrame for the OOB case.

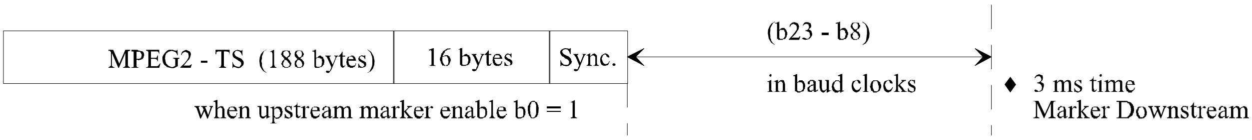


Figure 21: Position of the 3 ms time marker for IB signalling

In order to describe how the Upstream Marker is derived from the location of the 3 ms marker, consider the following system diagram.

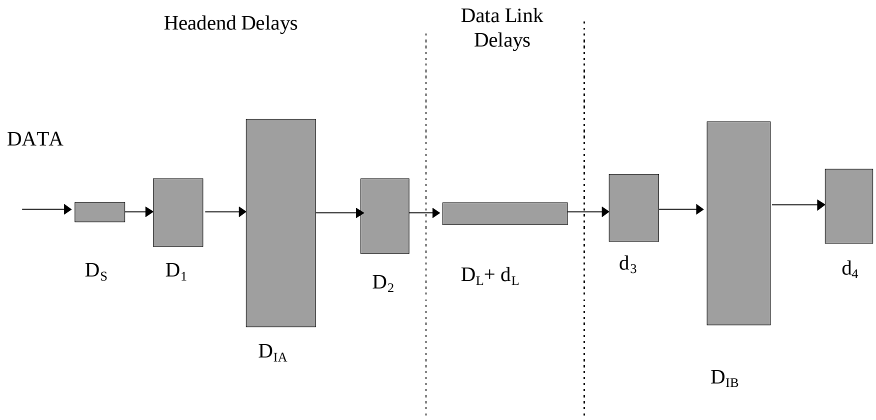


Figure 22: System Model for timing analysis

The delay between the location of the end of the Upstream Marker and the beginning of the next Sync byte, designated as D_S, is a constant value for each bit rate equal to the equivalent time of 194 bytes, or

(194×8 /x) symbol clocks, where

x = 4 for 16 QAM
6 for 64 QAM
8 for 256 QAM

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

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

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

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

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

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

The total interleave delay,

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

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

$D_I = 204 \times 8 \times \text{interleave\_depth} / \text{bit rate}$,

for example, if the modulation is QAM 64 with a baud rate of 5,0 Mbit/s,

$D_I = 204 \times 8 \times 12 / 30M = 652{,}8\ \mu s$ or 3,264 symbol clocks.

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

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

5.4.3 Upstream slot positions

Transmission on each QPSK upstream channel is based on dividing access by multiple NIU units by utilizing a negotiated bandwidth allocation slot access method. A slotting methodology allows the transmit slot locations to be synchronized to a common slot position reference, which is provided via the related downstream MAC control channel. Synchronizing the slot locations increases message throughput of the upstream channels since the 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 NIU. Since each NIU receives the downstream slot position reference at a slightly different time, due to propagation delay in the transmission network, slot position ranging is required to align the actual slot locations for each related upstream channel. The upstream slot rates are 6 000 upstream slots/s when the upstream data rate is 3,088 Mbit/s, 3 000 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 Guard Band)

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

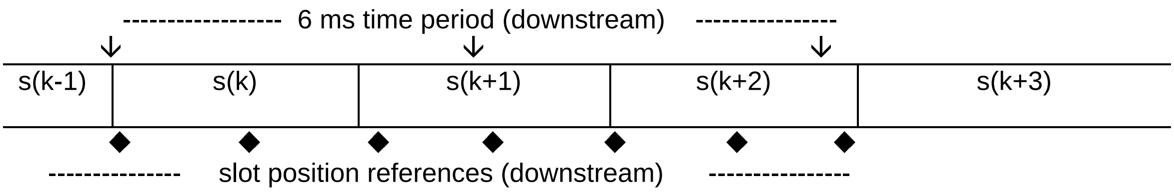
The M-bits in the SL-ESF serve two purposes:

- to mark the slot positions for the upstream Contention based and Contentionless based signalling links (see subclause 5.4);
- to provide slot count information for upstream message bandwidth allocation management in the NIU.

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

5.4.3.1 Rate 256 kbit/s

In the case where the upstream data rate is 256 kbit/s and the downstream OOB rate is 1,544 Mbit/s, the upstream slots are numbered as follows:



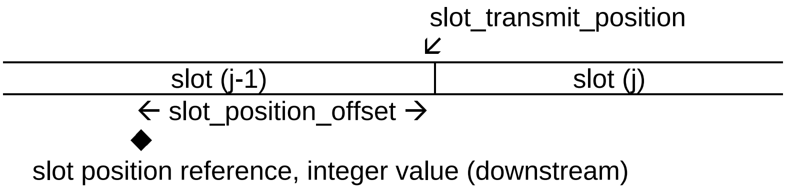
where k is a multiple of 3. In the case where the downstream OOB rate is 3,088 Mbit/s, there are 12 slot position references downstream during the transmission of 3 upstream packets. In the case of IB downstream, packet "k" is sent when the 3 ms time marker is received.

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

slot_transmit_position = slot_position_reference (integer) + slot_position_offset

where only the slot_position_references corresponding to integer values are valid and

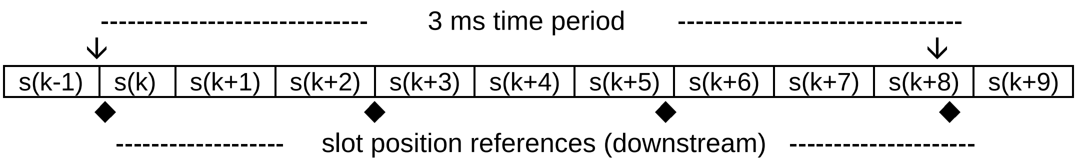
the slot_position_offset is derived from the Time_Offset_Value provided via the Range_and_Power_Calibration_Message in the MAC protocol.



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.

5.4.3.2 Rate 1,544 Mbit/s

In the case where the upstream data rate is 1,544 Mbit/s and the downstream OOB rate is 1,544 Mbit/s, the upstream slots are numbered as follows:



where k is a multiple of 9. In the case where the downstream OOB rate is 3,088 Mbit/s, there are 6 slot position references downstream during the transmission of 9 upstream packets. In the case of IB downstream, packet "k" is sent when the 3 ms time marker is received.

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

slot_transmit_position = slot_position_reference + slot_position_offset

where slot_position_offset is derived from the Time_Offset_Value provided via the Range_and_Power_Calibration_Message in the MAC protocol.

slot_transmit_position

↙

slot (j-1)	slot (j)

← slot_position_offset →

◆

slot position reference (downstream)

In the case where the upstream data rate is 1,544 Mbit/s, the actual slot transmission locations are given by

slot_transmission_location (k) = slot_transmit_position + (k × 512);

where k = 0,1,2; is the position of the slot with respect to the slot_transmit_position. This leaves a free time interval before the next slot_transmit_position occurs.

	slot_transmit_position ↙				slot_transmit_position ↙
	← position 0	← position 1	← position 2		
previous slot	slot k(0)	slot k(1)	slot k(2)		next slot
	512 bits	512 bits	512 bits		

5.4.3.3 Rate 3,088 Mbit/s

In the case where the upstream data rate is 3,088 Mbit/s and the downstream OOB rate is 1,544 Mbit/s, the upstream slots are numbered as shown below, where k is a multiple of 18.

← 3 ms time period →

s(k-1)	k	k+1	k+2	k+3	k+4	k+5	k+6	k+7	k+8	k+9	k+10	k+11	k+12	k+13	k+14	k+15	k+16	k+17	s(k+18)
	◆						◆						◆						◆

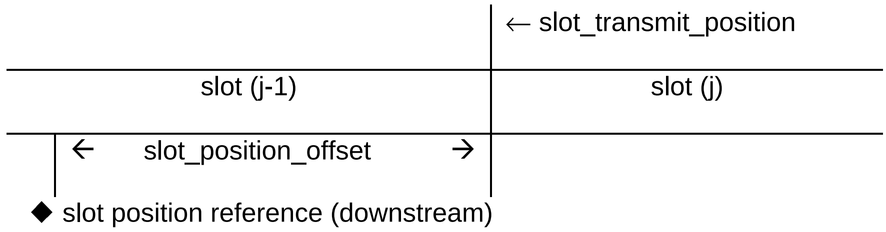
3 slot position references (downstream) per 3 ms time period

In the case where the downstream OOB rate is 3,088 Mbit/s, there are 6 slot position references downstream during the transmission of 18 upstream packets. In the case of IB downstream, packet "k" is sent when the 3 ms time marker is received.

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

slot_transmit_position = slot_position_reference + slot_position_offset

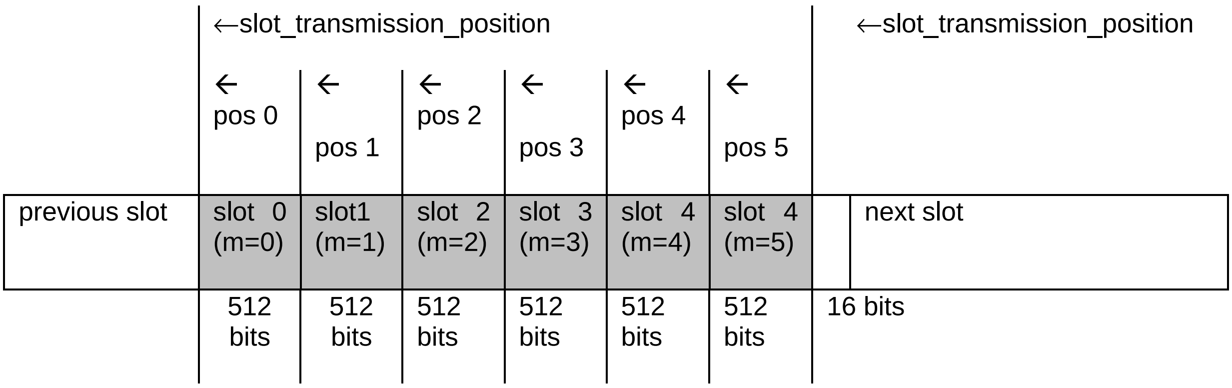
where slot_position_offset is derived from the Time_Offset_Value provided via the Range_and_Power_Calibration_Message.



In the case where the upstream data rate is 3,088 Mbit/s, the actual slot transmission locations are given by:

slot_transmission_location (m) = 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.



5.4.4 Slot position counter

Think of M-bits M10 - M1 as a register, called the upstream slot position register, which is used to generate an upstream slot position counter, 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 6 upstream slots per millisecond when the upstream data rate is 3,088 Mbit/s, 3 upstream slots per millisecond when the upstream data rate is 1,544 Mbit/s, and there is 0,5 upstream slot per millisecond when the upstream data rate is 256 kbit/s. The corresponding upstream slot rates are, therefore, 6 000 upstream slots/s when the upstream data rate is 3,088 Mbit/s, 3 000 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 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_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 = temp_upstream_slot_position_register;}
```

where, the M-bits will be defined as follows:

M1 - M10 =	10-bit ESF counter which counts from 0 to n with M10 the Most Significant Bit (MSB);
M11 =	odd parity for the ESF counter, i.e., M11 = 1 if the ESF_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".

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

5.5 MAC functionality

5.5.1 MAC Reference Model

The scope of this subclause 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 subclause focuses on the required message flows between the INA and the NIU for Media Access Control. These areas are divided into three categories: Initialization, Provisioning and Sign-On Management, Connection Management and Link Management.

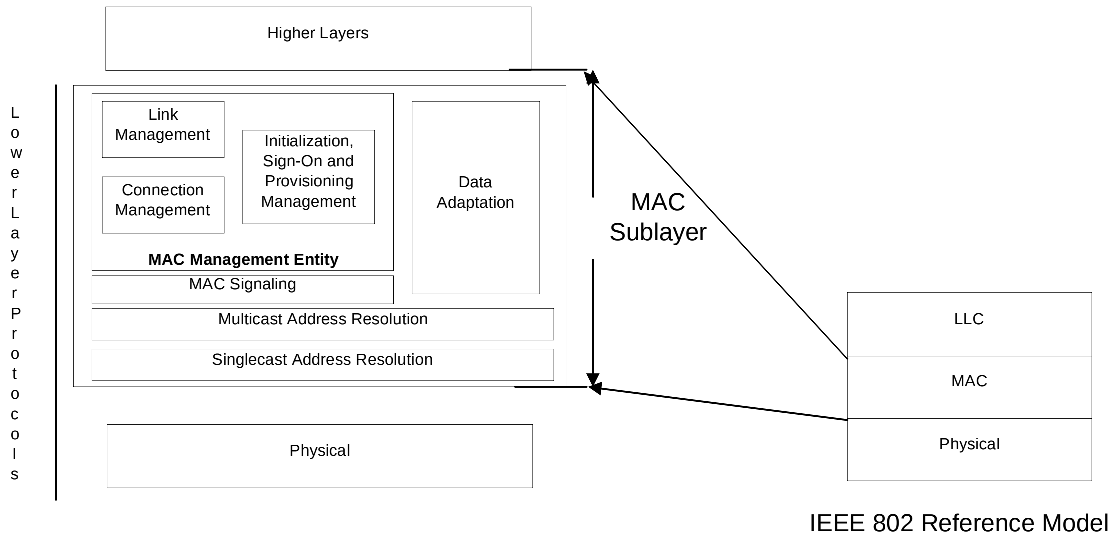


Figure 23: MAC Reference Model

5.5.2 MAC Concept

5.5.2.1 Relationship between higher layers and MAC protocol

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

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

- Grade A: Only one connection at a time can be handled by a NIU;

- Grade B: As many connections as needed, defined dynamically by the INA, following higher layers requests.

Bandwidth (time slots) does not need to be assigned immediately by the INA for a given connection. This means that a connection ID may exist at the NIU side without associated slot numbers.

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

A default connection is initiated by the INA when STBs are first turned on. This connection can be used to send data from higher layers leading to further interactive connections. This connection can be associated to a zero transmission rate (no initial bandwidth allocation).

5.5.2.2 Relationship between physical layer and MAC protocol

Up to 8 QPSK Upstream channels can be related to each downstream channel which is designated as a MAC control channel. An example of frequency allocation is shown in the figure 24. 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 ms 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 to perform MAC functions for each of these related upstream channels is transmitted via the downstream MAC control channel.

The Media Access Control Protocol supports multiple downstream Channels. In instances where multiple Channels are used, the INA shall specify a single OOB frequency called the Provisioning Channel, where NIU's perform Initialization and Provisioning Functions. If both 1,544 Mbit/s and 3,088 Mbit/s downstream OOB channels coexist on the network, there should be one provisioning channel with each rate. Also, in networks where IB NIUs exist, provisioning should be included in at least one IB channel. An aperiodic message is sent on each downstream control channel which points to the downstream Provisioning Channel. In instances where only a single frequency is in use, the INA shall utilize that frequency for Initialization and Provisioning functions.

The Media Access Control protocol supports multiple upstream channels. One of the upstream channels shall be designated the Service Channel. The Service Channel shall be used by NIU's entering the network via the Initialization and Provisioning procedure. The remaining upstream channels shall be used for upstream data transmission. In cases where only one upstream channel is utilized, the functions of the Service Channel shall reside in conjunction with regular upstream data transmission.

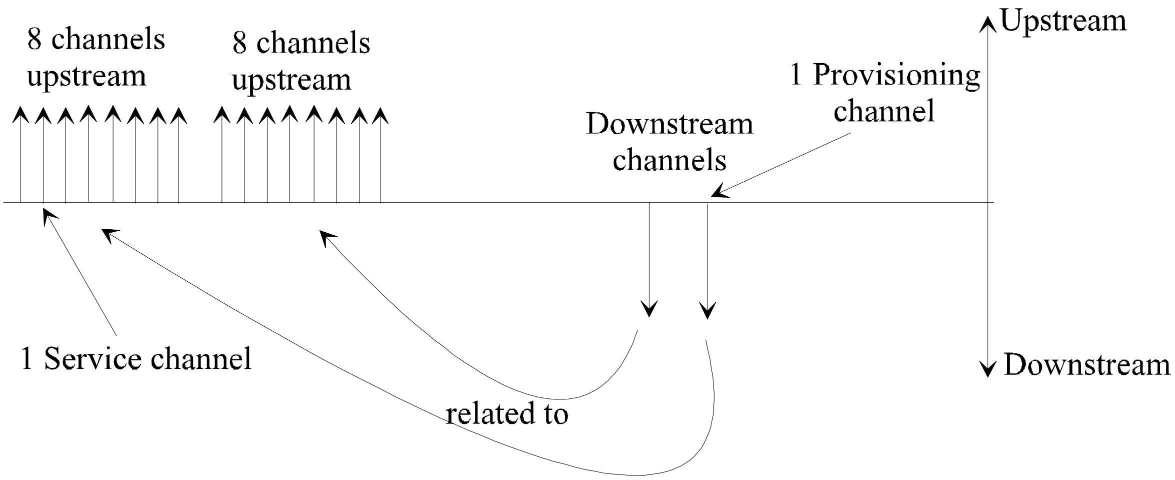


Figure 24: Example of frequency allocation

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

M10 - M1 is a 10-bit SuperFrame counter at the INA side, whereas the upstream slot position counter is an upstream slot counter at the NIUs side. The NIU slot position counter (M10 - M1 $\times$ 3 $\times$ m, where m = 3 for 1,544 Mbit/s and m = 6 for 3,088 Mbit/s) may be implemented as a 16-bit counter which is compared to the 16-bit slot numbers assigned by the INA in MAC messages (list assignment). When the counter value equals any assigned value, the NIU is allowed to send a packet upstream.

In the algorithm given in subclause 5.4.3, the counter value is refreshed every time M11 is received.

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

Different access modes are provided to the NIUs within access regions specified by information contained in the slot boundary fields of the downstream SuperFrames. The limits between access regions allow users to know when to send data on contention without risks of collision with contentionless type data. The following rules define how to select access modes:

- Data connections:

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

When the NIU shall send more cells than what was assigned by the INA, 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 INA). In that case, it shall wait for the slot reception indicator before it is allowed to send other cells with the same VPI/VCI value. The NIU 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 INA). If more cells shall be transmitted, the NIU shall send multiple requests for reservation access.

- MAC messages:

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

a) Contention Access

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

The Contention based technique is used for multiple subscribers that will have equal access to the signalling channel. It is probable that simultaneous transmissions will occur. For each ATM cell transmitted by the NIU, a positive acknowledgement is sent back by the INA, utilizing the reception indicator field, for each successfully received ATM cell. In contention based access mode, a positive acknowledgement indicates that a collision did not occur. A collision occurs if two or more NIUs attempt ATM cell transmission during the same slot. A collision will be assumed if a NIU does not receive a positive acknowledgement. If a collision occurs, then the NIU will retransmit using a procedure to be defined.

b) Ranging Access

`Ranging Access` indicates that the data is sent in a slot preceded and followed by slots not used by other users. These slots allow users to adjust their clock depending on their distance to the INA such that their slots fall within the correct allocated time. They are either contention based when the ranging control slot indicator **b0** received during the previous SuperFrame was 1 (or when b1-b6 = 55 to 63), or reserved if the INA indicates to the NIU that a specific slot is reserved for ranging.

c) Fixed rate Access

NOTE: Fixed rate is called TDMA in DAVIC.

`Fixedrate_Access` indicates that data is sent in slots assigned to the Fixed rate based access region in the upstream channel. These slots are uniquely assigned to a connection by the INA. No fixed rate access can be initiated by the NIU.

d) Reservation Access

`Reservation Access` implies that data is sent in the slots assigned to the reservation region in the upstream channel. These slots are uniquely assigned on a frame by frame basis to a connection by the INA. This assignment is made at the request of the NIU for a given connection.

5.5.2.5 MAC error handling procedures

Error handling procedures are under definition (Time out windows, retransmission, power outage, etc.).

5.5.2.6 MAC messages

The MAC message types are divided into the logical MAC states of Initialization, Sign-On, Connection Management and Link Management. Messages in Italic represent upstream transmission from NIU to INA. MAC messages are sent using Broadcast or Singlecast Addressing. Singlecast address shall utilize the 48-bit MAC address.

Table 17: MAC messages

Message Type Value		**Addressing Type**
	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]	
	MAC Link Management Messages	
0x27	*Idle Message*	Singlecast
0x40	Transmission Control Message	Scast or
0x41	Reprovision Message	Bcast
0x42	*Link Management Response Message*	Singlecast
0x43	Status Request Message	Singlecast
0x44	*Status Response Message*	Singlecast
0x45-0x5F	[Reserved]	Singlecast

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

- Upstream MAC messages:

AAL5 (as specified in ITU-T Recommendation I.363 [9]) adaptation shall be used to encapsulate each MAC PDU in an ATM cell. Upstream MAC information should be single 40 bytes cell messages.

- Downstream OOB MAC messages:

AAL5 (as specified in ITU-T Recommendation I.363 [9]) adaptation shall be used to encapsulate each MAC PDU in an ATM cell. Downstream OOB MAC information may be longer than 40 bytes.

- Downstream IB MAC messages:

Downstream IB MAC information is limited to 120 bytes long messages (A procedure to be able to send longer messages is under definition). No AAL5 layer is defined for MPEG-2 TS cells. MAC messages shall therefore be sent as explained in figure 25:

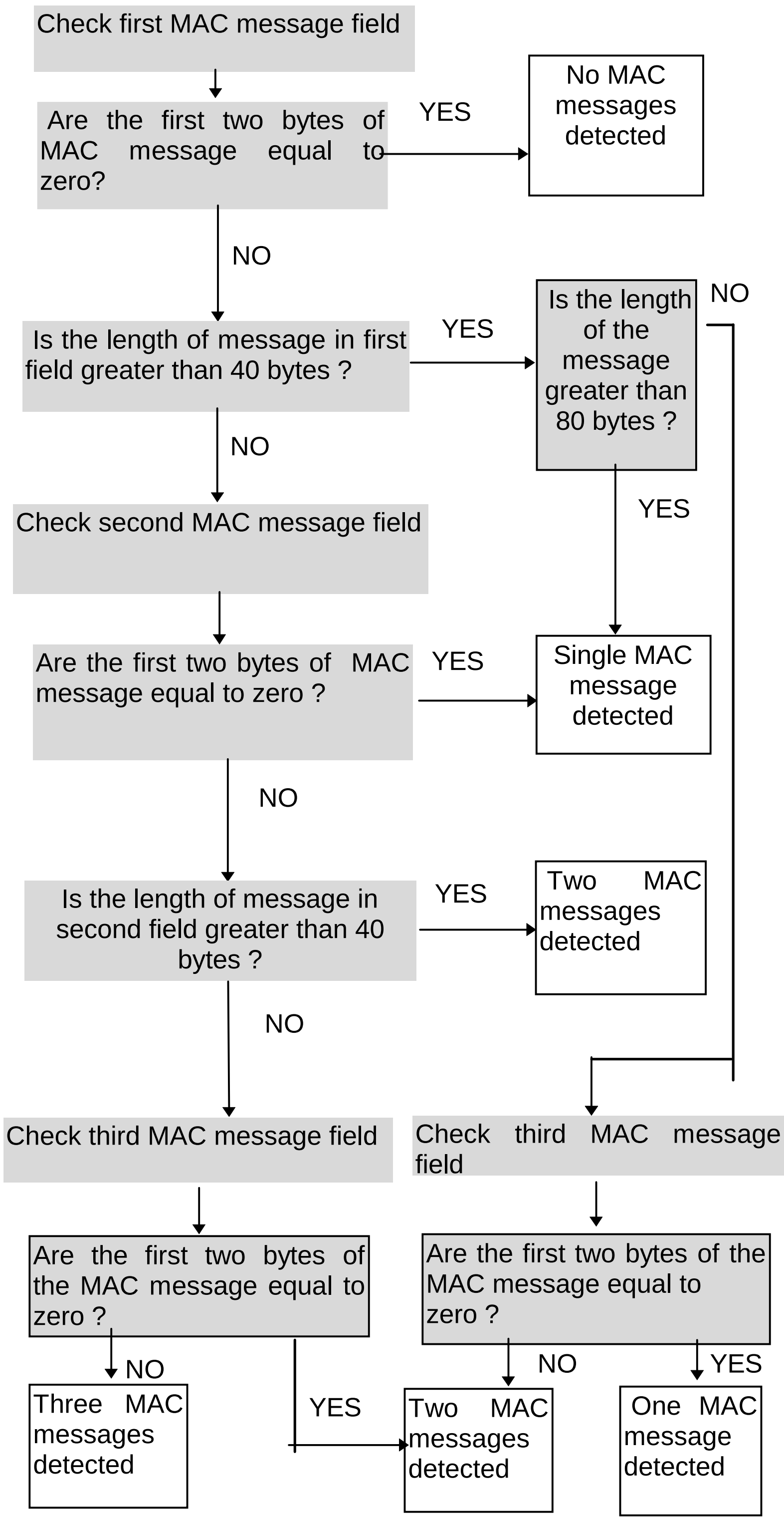


Figure 25: Algorithm when MAC message are sent IB Downstream

Since MAC related information is terminated at the NIU and INA a privately defined message structure will be utilized. The format of this message structure is illustrated in table 18.

NOTE 1: All messages are sent Most Significant Bit (MSB) first.

NOTE 2: Message 0x23 is not used in the present release of the MAC protocol.

NOTE 3: When no MAC_Address is specified in the message, it means that the message is sent broadcast. (Syntax_indicator = 000)

Table 18: MAC message structure

MAC_message(){	Bits	Bytes	Bit Number Description
Message_Configuration	**8**	**1**	
Protocol_Version	5		
Syntax_Indicator	3		
Message_Type	**8**	**1**	
if (syntax_indicator== 001) {			
MAC_Address	**(48)**	**(6)**	
}			
{			
MAC_Information_Elements ()		**N**	
}			

Protocol Version

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

Table 19: Protocol_version coding

Value	Definition
0	DAVIC 1.0 Compliant device
1	DAVIC 1.1 Compliant device
2-31	Reserved

Syntax Indicator

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

Enum Syntax_Indicator {No_MAC_Address ,MAC_Address_Included, reserved2..7};

MAC Address

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

<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 **Reservation_ID** }	**32** **16**	**4** **2**	

Connection ID

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

Reservation_ID

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

5.5.3 MAC Initialization and Provisioning

This subclause defines the procedure for Initialization and Provisioning that the MAC shall perform during Power-on or Reset.

1) Upon a NIU becoming active (i.e. powered up), it shall first find the current provisioning frequency. The NIU shall receive the **<MAC> Provisioning Channel Message**. This message shall be sent aperiodically 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 is to be utilized for Provisioning. Upon receiving this message, the NIU shall tune to the Provisioning Channel.

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

The figure 25 shows the signalling sequence.

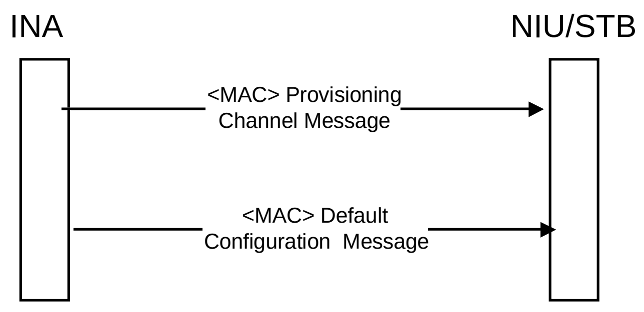


Figure 26: Initialization and Provisioning signalling

5.5.3.1 <MAC> Provisioning Channel Message (Broadcast Downstream)

The <MAC> PROVISIONING CHANNEL MESSAGE is sent by the INA to direct the NIU to the proper Out-of-band frequency where provisioning is performed. The format of the message is shown in table 20.

Table 20: Provisioning Channel Message Format

Provisioning_Channel_Message(){	Bits	Bytes	Bit Number / Description
Provisioning_Channel_Control_Field	8	1	
reserved	7		7-1:
provisioning_frequency_included	1		0: {no=0, yes=1}
if (provisioning_frequency_included) {			
Provisioning_Frequency	(32)	(4)	
DownStream_Type	8	1	
}			
}			

Provisioning Channel Control Field

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

Provisioning frequency included

`provisioning_frequency_included` is a boolean when set, indicates that a downstream OOB frequency is specified that the NIU 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 NIU provisioning occurs. The unit of measure is Hz.

Downstream Type

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

5.5.3.2 <MAC> Default Configuration Message (Broadcast Downstream)

The <MAC> DEFAULT CONFIGURATION MESSAGE is sent by the INA to the NIU. The message provides default parameter and configuration information to the NIU. The format of the message is shown in table 21.

Table 21: Default configuration message structure

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	**8**	**1**	
MAC_Flag_Set Service_Channel	5 3		7-3 2-0
Backup_Service_Channel_Frequency	**32**	**4**	
Backup_Service_Channel_Control_Field	**8**	**1**	
Backup_MAC_FlagSet Backup_Service_Channel	5 3		7-3 2-0
Service_Channel_Frame_Length [reserved]	**16**	**2**	unused here
Service_Channel_Last_Slot	**16**	**2**	
Max_Power_Level	**8**	**1**	
Min_Power_Level	**8**	**1**	
Upstream_Transmission_Rate	**3**	**1**	

Sign-On Increment Power Retry Count

`Sign_On_Incr_Pwr_Retry_ Count` is an 8-bit unsigned integer representing the number of attempts the NIU should try to enter the system at the same power level before incrementing its power level by steps of 0,5 dB.

Service Channel Frequency

`Service_Channel_Frequency` is a 32-bit unsigned integer representing the upstream frequency assigned to the service channel. The unit of measure is in Hz. This channel is identified as channel #0 for collision indications.

`MAC_Flag_Set` is an 5-bit field representing the MAC Flag set assigned to the service channel. In the OOB downstream timing, the eight sets of flags are assigned the numbers 0 ... 7. In the IB downstream timing, the 16 sets of flags are assigned the numbers 0 ... 15. In the case of a 3,088 Mbit upstream channel, this parameter represents the first of two successively assigned flag sets. This flag set indicates the x value the channel x associated to Rxa, Rxb, Rxc in the reception indicator fields.

`Service_Channel` is a 3-bit field which defines the channel assigned to the Service_Channel_Frequency.

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. This channel is identified as channel #1 for collision indications.

`Backup_MAC_Flag_Set` is an 5-bit field representing the MAC Flag set assigned to the backup service channel. In the OOB downstream timing, the eight sets of flags are assigned the numbers 0 ... 7. In the IB downstream timing, the 16 sets of flags are assigned the numbers 0 ... 15. In the case of a 3,088 Mbit upstream channel, this parameter represents the first of two successively assigned flag sets.

`Backup_Service_Channel` is a 3-bit field which defines the channel assigned to the Backup_Service_Channel_Frequency.

Service_Channel_Frame_Length [reserved]

Unused in this ETS.

Service Channel Last Slot

`Service_Channel_Last_Slot` is a 16-bit unsigned integer representing the last slot in the Service Channel frame that is used for contention based access. This number represents the largest slot value of the NIU slots counter (n $\times$ 3 $\times$ m, where n is defined in subclause 5.4.3).

Maximum Power Level

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

Minimum Power Level

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

Upstream Transmission Rate

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

```
enum Upstream_Transmission_Rate {Upstream_256K, Upstream_1-544M,
Upstream_3,088M, reserved3 ... 7};
```

5.5.4 Sign-On and Calibration

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

- The NIU shall tune to the downstream Provisioning channel and the upstream service channel with the information provided in the Initialization and Provisioning sequence.

- The NIU shall await the **<MAC> Sign-On Message** from the INA Entity. The NIU shall utilize Contention based entry on the service channel to access the network.

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

- The INA, upon receiving the Sign-On Response Message shall validate the NIU and send the **<MAC> Ranging and Power Calibration Message.**

- The NIU shall respond to the **<MAC> Ranging and Power Calibration Message** with the **<MAC> Ranging and Power Calibration Response Message.** The **<MAC> Ranging and Power Calibration Response Message** shall be transmitted on a Ranging Control Slot.

- The INA shall send the **<MAC> Initialization Complete Message** when the NIU is calibrated. The NIU is assumed to be calibrated if the message arrives within a window of 1,5 symbols (upstream rate) and a power within a window of 1,5 dB from their optimal value.

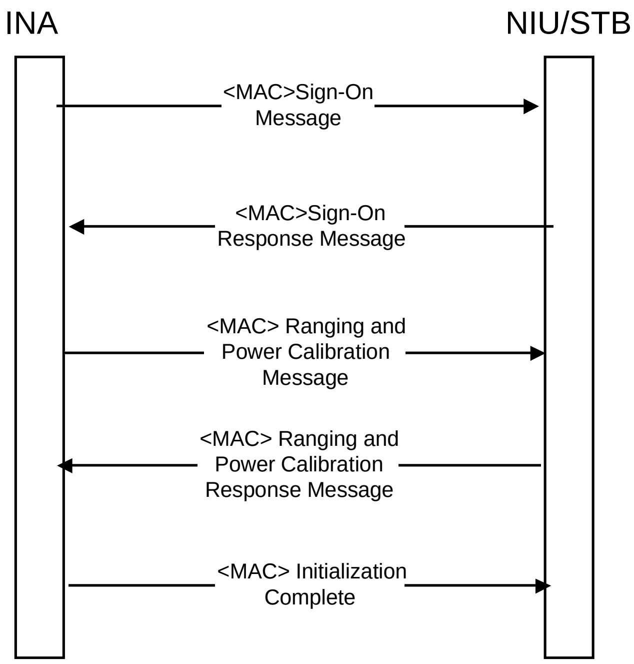


Figure 27: Ranging and Calibration Signalling

The figure 28 state diagram details the procedure described above:

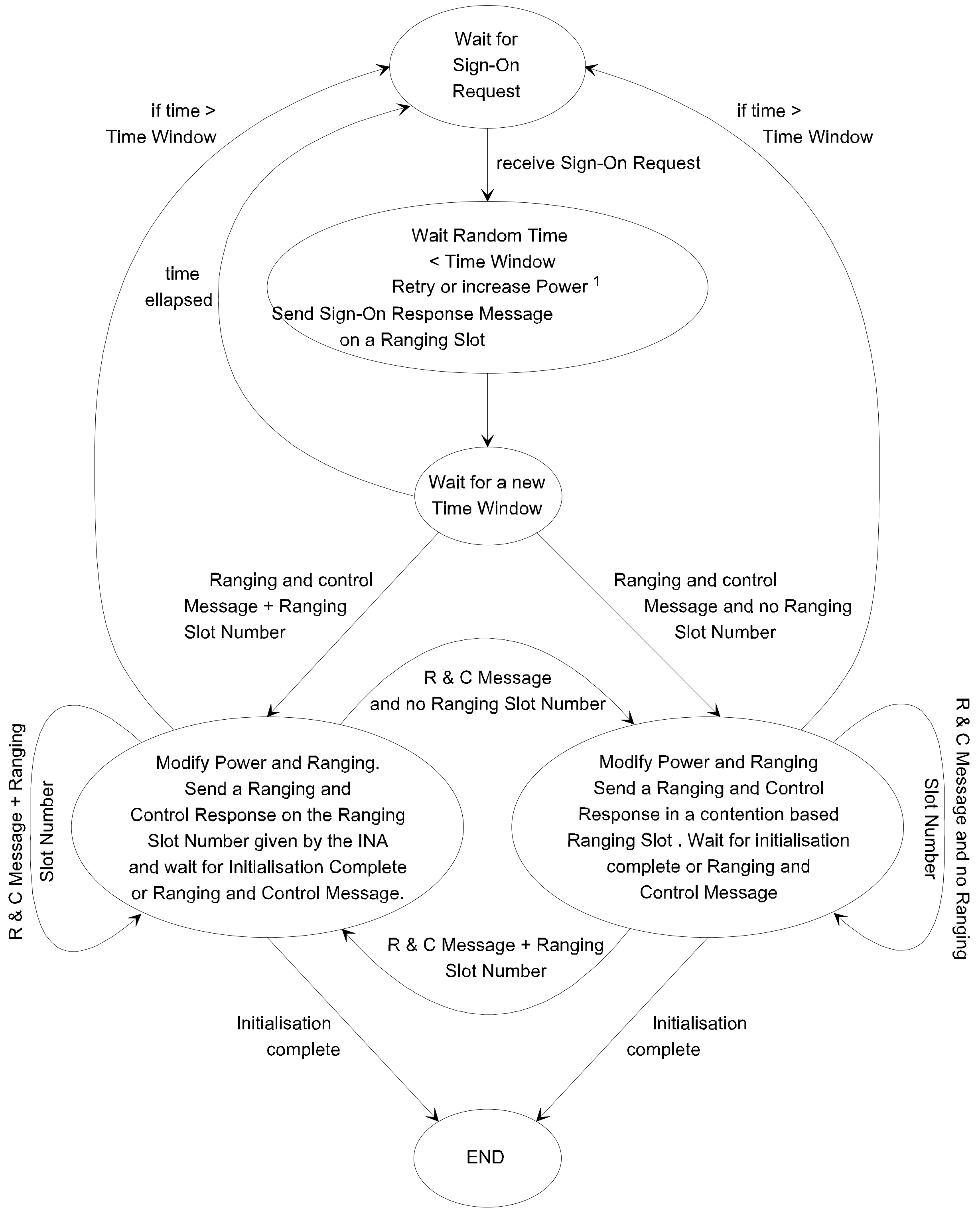


Figure 28: State Diagram for Ranging and Calibration

5.5.4.1 <MAC> Sign-On Request Message (Broadcast Downstream)

The <MAC> SIGN-ON REQUEST message is issued periodically by the INA to allow a NIU to indicate its presence in the network. The format of this subcommand is shown in table 22.

Table 22: Sign-On Message structure

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 NIU should respond to the SIGN-ON REQUEST only if its address matches the filter requirements specified in the message.

Response Collection Time Window

`Response_Collection_Time_Window` is a 16-bit unsigned integer that specifies the duration of time the NIU has to respond to the SIGN-ON REQUEST. The unit of measure is the millisecond (ms).

Address Position Mask

`Address_Position_Mask` is an 8-bit unsigned integer that indicates the bit positions in the NIU MAC address that are used for address filtering comparison. The bit positions are comprised between bit number 2^{Mask} and $2^{Mask}+7$. `Mask` = 0 corresponds to the 8 LSBs of the address, i.e., it represents the number of bits shifted to the left. The maximum value is 40.

Address Comparison Value

`Address_Comparison_Value` is an 8-bit unsigned integer that specifies the value that the NIU should use for MAC address comparison.

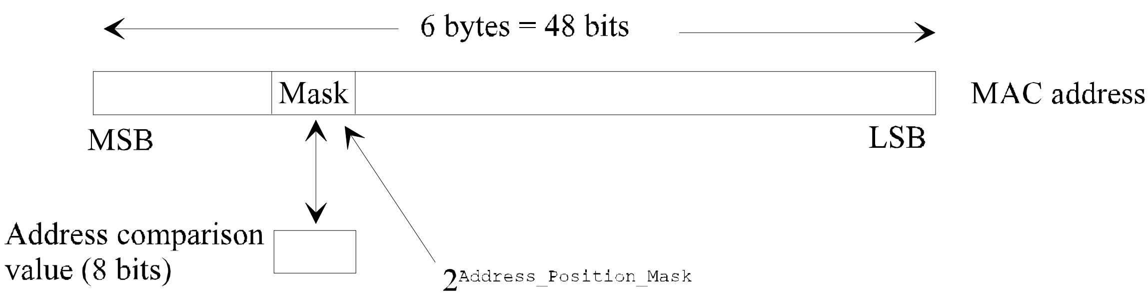


Figure 29: Position of Mask in MAC address

5.5.4.2 <MAC> Sign-On Response Message (Upstream Contention Ranging)

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

Table 23: Sign-On response Message structure

Sign-On_Response_Message(){	Bits	Bytes	Bit Number / Description
[reserved]	32	4	
[reserved]	16	2	
Retry_Count	8	1	
}			

Retry Count

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

5.5.4.3 <MAC> Range and Power Calibration Message (Singlecast Downstream)

The <MAC> RANGE AND POWER CALIBRATION MESSAGE is sent by the INA to the NIU to adjust the power level or time offset the NIU is using for upstream transmission. The format of this message is shown in table 24.

Table 24: Range and Power Calibration Message structure

Range_and_Power_Calibration_Message(){	Bits	Bytes	Bit Number / Description
Range_Power_Control_Field	8	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	(16)	(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 NIU should use to adjust its upstream Fixed rate based reference.

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 available.

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 (The NIU will adjust approximately its time offset to the closest value indicated by the Time_Offset_Value parameter, which implies that no extra clock is needed to adjust to the correct offset).

Power Control Setting

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

New output_power_level = current output_power_level + power_control_setting $\times$ 0,5 dB

Ranging Slot Number

Ranging_Slot_Number is a 16-bit unsigned integer that represents the reserved access Slot Number assigned for Ranging the NIU.

5.5.4.4 <MAC> Ranging and Power Calibration Response Message (Upstream reserved or contention Ranging)

The <MAC> RANGING AND POWER CALIBRATION RESPONSE Message is sent by the NIU to the INA in response to the <MAC> RANGING AND POWER CALIBRATION MESSAGE. The format of the message is shown in table 25.

Table 25: Range Request Response Message format

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

Power Control Setting

Power_Control_Setting is an 8-bit signed integer representing the upstream power level used by the NIU. It is a copy of the power control setting parameter received from INA.

5.5.4.5 <MAC> Initialization Complete Message (Singlecast Downstream)

This message has no message body. It indicates the end of the MAC Sign-On and Provisioning procedure.

5.5.5 Default Connection Establishment

Once a NIU has completed the Calibration State, it shall enter the Connection State. A low bit rate permanent connection is assigned to a NIU by the INA. After the initial calibration procedure, the INA provides a Default Connection to the NIU that the NIU shall utilize to communicate to the network. The message flow for such Connection Establishment is shown below.

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

2) The NIU, upon receiving the **<MAC> Connect Message** shall tune to the required upstream and downstream frequencies and send the **<MAC> Connect Response Message** confirming receipt of the message.

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

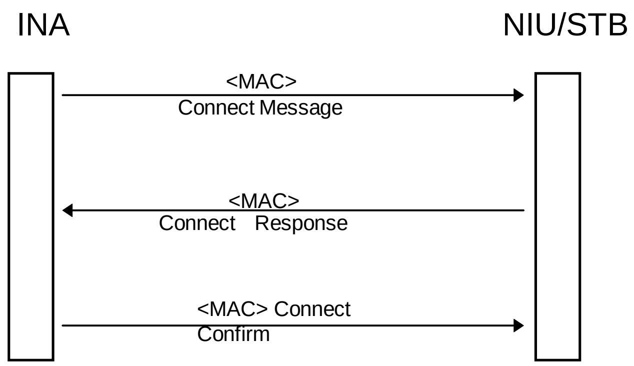


Figure 30: Connection signalling

5.5.5.1 <MAC> Connect Message (Singlecast Downstream)

Table 26: Connect Message Structure

Connect_Message (){	Bits	Bytes	Bit Number/ Description
Connection_ID	32	4	
Session_Number	32	4	
Resource_Number	16	2	
Connection_Control_Field	8	1	
Descriptor_Type	3		
Upstream_Channel_Number	3		
MAC_Control_Parameters	2		
Frame_Length	(16)	(2)	
Maximum_Contention_Access_Message_Length	(8)	(1)	
Maximum_Reservation_Access_Message_Length	(8)	(1)	
if(Descriptor_Type == DS_ATM_CBD){			
Downstream_ATM_CBD()	(64)	(8)	
}			
if(Descriptor_Type == DS_CBD_MPEG){			
Downstream_CBD_MPEG()	(48)	(6)	
}			
if(Descriptor_Type == US_ATM_Included){			
Upstream_ATM_CBD()	(64)	(8)	
}			
if(MAC_Control_Params == slot_list_assignment){			Fixed Rate Access
Number_Slots_Defined	(8)	(1)	
for (i=0;i<Number_Slots_Assigned; i++{			
Slot_Number	(16)	(2)	
}			
}			
if (MAC_Control_Params == cyclic_Assignment){			Fixed Rate Access
Fixedrate_Start	(16)	(2)	
Fixedrate_Dist	(16)	(2)	
Fixedrate_End	(16)	(2)	
}			

Connection ID

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

Session Number

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

Resource Number

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

Connection Control Field

`Connection_Control_Field` is an 8-bit unsigned integer that defines parameters and control for `Descriptor_Type`, `Upstream_Channel_Number` and `MAC_Control_Parameters`. This is partitioned across the 8-bits as shown below.

Table 27: Connection Control Field substructure

Bit 7	6	5	4	3	2	1	0
Descriptor_Type			Upstream_Channel_Number			MAC_Ctrl_Params	

54400.1 Descriptor Type

`Descriptor_Type` is a 3-bit unsigned integer that represents the connection descriptors present within the message. The values are defined in table 28.

Table 28: Descriptor Type substructure

Bit Number	Definition
7	When set indicates that upstream ATM Descriptor is present in the message
6	When set indicates that downstream MPEG Descriptor is present in the message
5	When set indicates that downstream ATM Descriptor is present in the message.

54400.1 Upstream Channel Number

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

54400.1 MAC Control Parameters

MAC_Control_Parameters is a 2-bit unsigned integer that indicates the type of upstream resources assigned in the connection.

Table 29: Control Parameter substructure

MAC_Control_Parameters	Definition
10	indicates a slot list is included
01	indicates a cyclical assignment
00	indicates contention based access only
11	[Reserved]

Frame length

`Frame_length` - This 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 Fixedrate_Start_slot and those which are multiples of Fixedrate_Distance from the Fixedrate_Start_slot within the Fixed rate access region.

Maximum contention access message length

`Maximum_contention_access_message_length` is an 8-bit number representing the maximum length of a message in 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

Table 30: ATM Connection Block Descriptor substructure

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

54402.1 Downstream Frequency

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

54402.1 Downstream Virtual Path Identifier

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

54402.1 Downstream Virtual Channel Identifier

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

54402.1 DownStream_Type

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

Downstream MPEG Connection Block Descriptor

Table 31: Downstream_CBD_MPEG substructure

Downstream_CBD_MPEG(){	Bits	Bytes	Bit Number / Description
Downstream_Frequency	32	4	
Program Number	16	2	
}			

54402.1 Downstream Frequency

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

54402.1 Program Number

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

Upstream ATM Connection Block Descriptor

Table 32: Upstream_CBD substructure

Upstream_ATM_CBD	Bits	Bytes	Bit Number / Description
Upstream_Frequency	32	4	
Upstream_VPI	8	1	
Upstream_VCI	16	2	
MAC_Flag_Set	5	1	7:3
Upstream_Rate	3		2:0
}			

54402.1 Upstream Frequency

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

54402.2 Upstream Virtual Path Identifier

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

54402.3 Upstream Virtual Channel Identifier

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

54402.4 MAC_Flag_Set

MAC_Flag_Set is a 5-bit field representing the MAC Flag set assigned to the connection. In the OOB downstream timing, the eight sets of flags are assigned the numbers 0 ... 7. In the IB downstream timing, the 16 sets of flags are assigned the numbers 0 ... 15. In the case of a 3,088 Mbit upstream channel, this parameter represents the first of two successively assigned flag sets.

54402.4 Upstream_Rate

Upstream_Rate is a 3-bit enumerated type indicating the data rate for the upstream connection { Upstream_256K, Upstream_1,544M, Upstream_3,088M, 3 ... 7 reserved}.

Number of Slots Defined

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

Slot Number

Slot_Number is a 16-bit unsigned integer that represents the Fixed rate based Slot Number assigned to the NIU.

Fixed rate Start

Fixedrate_Start - is a 16-bit unsigned number represents the starting slot within the fixed rate access region that is assigned to the NIU. The NIU may use the next Frame_length slots of the fixed rate access regions.

Fixed rate Distance

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

Fixed rate End

`Fixedrate_End` - is a 16-bit unsigned number indicates the last slot that may be used for fixed rate access. The slots assigned to the NIU, as determined by using the Fixedrate_Start_slot and Fixedrate_Distance, cannot exceed this number.

5.5.5.2 <MAC> Connect Response (Upstream contention, reserved or fixed rate access)

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

Table 33: Connect response message structure

Connect_Response(){	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 NIU Dynamic Connection.

5.5.5.3 <MAC> Connect Confirm (Singlecast Downstream)

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

Table 34: Connect Confirm message structure

Connect_Confirm(){	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 NIU Dynamic Connection.

5.5.6 Data connections

A connection is initiated by the INA using the <MAC> Connect Message explained in subclause 5.5.5.1. This message is either used to immediately assign time slots for a fixed rate connection or just to assign a connection ID and related parameters without time slot assignment. In particular, for reservation or contention access, no time slots are assigned in the Connect Message, but the connection ID shall be used in requests for slots by the NIU.

Connection assignment

The INA can assign other connections by using the **<MAC> Connect message** described previously. The NIU cannot request a connection, it shall be initiated by higher layers.

Connection Release

This subclause defines the MAC signalling requirements for connection release. The figure below displays the signalling flow for releasing a connection. The NIU cannot release a connection, this shall be initiated by higher layers. This message is thus initiated by the INA only.

1) Upon receiving the **<MAC> Release Message** from the INA, the NIU shall tear down the upstream connection established for the particular .

2) Upon teardown of the upstream connection, the NIU shall send the **<MAC> Release Response Message** on the default upstream channel.

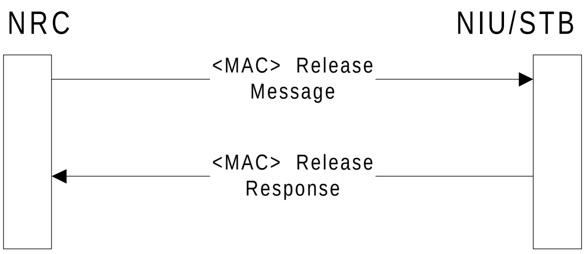


Figure 31: Connection release signalling

<MAC> Release Message (Singlecast Downstream)

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

Table 35: Release Message structure

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

54500.1 Connection ID

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

<MAC> Release Response (Upstream contention, reserved or fixed rate)

The <MAC> RELEASE RESPONSE MESSAGE is sent by the NIU to the INA to acknowledge the release of a connection. The format of the message is shown in table 36.

Table 36: Release Response Message structure

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

54500.1 Connection ID

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

5.5.6.1 Fixed rate access

Fixed rate access is provided by the INA using the <MAC> Connect Message.

5.5.6.2 Contention based access

The NIU shall use contention based slots specified by the slot boundary definition fields (Rx) to transmit contention based messages (see subclause 5.3). The format of contention based MAC messages is described by the MAC message format (see subclause 5.5.2.3).

5.5.6.3 Reservation access

This subclause defines the MAC signalling requirements for reservation access. The figure below displays the signalling flow for reserving an access.

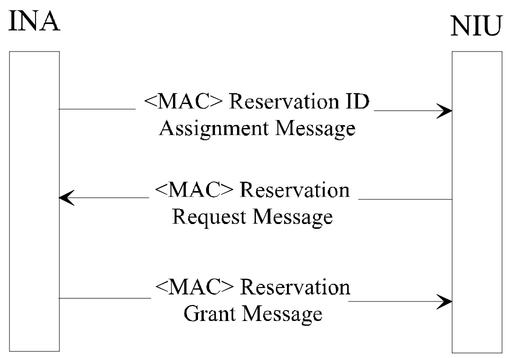


Figure 32: Reservation access signalling

1) The NIU shall wait for a `<MAC> Reservation ID Assignment Message` from the INA before it can request reservation access.

2) At any time when needed after receiving the reservation ID, the NIU can request a certain number of slots to the INA using the `<MAC> Reservation Request Message`.

3) The INA shall respond to that message using the `<MAC> Reservation Grant Message`.

4) If the NIU has not received the `<MAC> Reservation Grant Message` before the `Grant_Protocol_Timeout`, it shall send a `<MAC> Reservation Status Request` to the INA. This leads back to 3.

<MAC> Reservation ID Assignment Message (Singlecast Downstream)

The <MAC> Reservation ID Assignment Message is used to assign the NIU a Reservation_ID. The NIU identifies its entry in the Reservation_grant_message by comparing the Reservation_ID assigned to it by the Reservation_ID_assignment_message and the entries in the Reservation_Grant_message.

The format of the message is given in table 37.

Table 37: Reservation ID assignment message structure

Reservation_ID_assignment_Message (){	Bits	Bytes	Bit Number / Description
Connection_ID	32	4	
Reservation_ID	16	2	
Grant_protocol_timeout	16	2	
}			

54520.1 Connection ID

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

54520.1 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 NIU to identify the appropriate Reservation_Grant_Messages.

54520.1 Grant_protocol_timeout

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

<MAC> Reservation Request Message (Upstream contention, fixed rate or reserved)

Table 38: Reservation Request Message structure

Reservation_Request_message (){	Bits	Bytes	Bit Number / Description
Reservation_ID	16	2	
Reservation_request_slot_count	8	1	
}			

This message is sent from the NIU to the INA.

54520.1 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 NIU to identify the appropriate Reservation_Grant_Messages.

54520.1 Reservation Request Slot Count

Reservation_request_slot_count is an 8-bit unsigned number representing the number of slots requested by the NIU. This is the number of sequential slots that will be allocated in the reservation region of the upstream channel. The INA will respond with the Reservation_Grant message granting the request.

<MAC> Reservation Grant Message (Broadcast Downstream)

The <MAC> RESERVATION GRANT MESSAGE is used to indicate to the NIU which slots have been allocated in response to the Reservation Request message. The NIU identifies its entry in the

Reservation_grant_message by comparing the Reservation_ID assigned to it by the Reservation_ID_assignment_message and the entries in the Reservation_Grant_message.

The format of the message is given in table 39.

Table 39: Reservation Grant Message structure

Reservation_grant_message (){	Bits	Bit Number/ Description
Reference_slot	16	
Number_grants	8	
for (I=1; I<=Number_grants; I++){		
Reservation_ID	16	
Grant_Slot_count	4	
Remaining_slot_count	5	
Grant_control	2	
Grant_slot_offset	5	
}		
}		

54520.1 Reference_slot

`Reference_slot` is an 16-bit unsigned number indicating the reference point for the remaining parameters of this message. This represents a physical slot of the upstream channel. Since the upstream and downstream slots are not aligned, the INA shall send this message in a downstream slot such that it is received by the NIU before the Reference_slot exists on the upstream channel.

54520.1 Number_grants

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

54520.1 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 NIU to identify the appropriate Reservation_Grant_Messages.

54520.1 Grant_slot_count

`Grant_slot_count` is an 4-bit unsigned number representing the number of sequential slots currently granted for the upstream burst. Upon receipt of this message the NIU 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.

54520.1 Remaining_slot_count

`Remaining_slot_count` is a 5-bit unsigned number representing the remaining slots to be granted by the INA with subsequent grant messages. A value of 0x1f indicates that 31 or more slots will be made available in the future. A value of 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 NIU should monitor this count to determine if sufficient slots remain to satisfy current needs. Should additional slots be required because of lost grant messages or additional demand, additional slots should be requested using the Reservation_request_message. Additional Reservation_request_messages shall be sent only when the Remaining_slot_count is less than 15. To minimize contention on the upstream channel, the Reservation_request_message may be sent in one of the slots granted by the Reservation_grant_message.

54520.1 Grant_slot_offset

`Grant_slot_offset` is an 5-bit unsigned number representing the starting slot to be used for the upstream burst. This number is added to the Reference slot to determine the actual physical slot. Upon receipt of this message the NIU is assigned Grant_slot_count sequential slots in the reservation access region of the upstream channel.

<MAC> Reservation Status Request (Upstream contention, fixed rate or reserved)

The <MAC> RESERVATION STATUS REQUEST Message is used to determine the status of the outstanding grants to be assigned by the INA. This message is only sent after the Grant protocol time-out is exceeded. The INA will respond with the Reservation_grant_message (possibly without granting any slots) to inform the NIU of any remaining slots left to be granted. This allows the NIU to correct any problems should they exist such as issuing an additional request for slots or waiting patiently for additional grants.

The format of the message is given in table 40.

Table 40: Reservation status request message structure

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

54520.1 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 NIU to identify the appropriate Reservation_Grant_Messages.

54520.1 Remaining_request_slot_count

`Remaining_request_slot_count` is an 8-bit unsigned number representing the number of slots that the NIU is expecting to be granted.

5.5.7 MAC Link Management

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

- Power and Timing Management;
- Fixed rate Allocation Management;
- Channel Error Management.

5.5.7.1 Power and Timing Management

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

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

5.5.7.2 TDMA Allocation Management

To ensure optimum assignment of TDMA resources, the INA shall ensure the upstream allocation of TDMA resources for various connections remain intact when allocating resources to a new connection. However, in the event that reconfiguration is required to minimize fragmentation of resources, then the

INA shall dynamically reconfigure the upstream TDMA assignments to a NIU or group of NIUs. The **<MAC> Reprovision Message** is utilized to change previously established connection parameters.

<MAC> Reprovision Message (Singlecast Downstream)

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

Table 41: Reprovision Message structure

Reprovision_Message (){	Bits	Bytes	Bit Number / Descrip-tion
Reprovision_Control_Field	8	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_Cyclical_Assignment_Included	1		1: {no,yes }
New_Slot_List_Included	1		0: {no,yes }
if (Reprovision_Control_Field= New_Downstream_OOB_Frequency)			
New_Downstream_IB_Frequency	(32)	(4)	
if (Reprovision_Control_Field= New_Downstream_OOB_Frequency)			
New_Downstream_OOB_Frequency **DownStream_Type**	(32) 8	(4) 1	
New_Downstream_OOB_Frequency	(32)	(4)	
if (Reprovision_Control_Field= New_Frequency_Included)			
New_Upstream_Frequency **New_Upstream_Channel_Number** **reserved** **Upstream_Rate** **MAC_Flag_Set** **Reserved**	(32) 3 2 3 5 3	(4) 1 1 	 **7:5** **4:3** **2:0** **7:3** **2:0**
New_Upstream_Frequency	(32)	(4)	
if (Connection_Control_Field= New_Frame_Size_Included)			
New_Frame_Length	(16)	(2)	9-0: Unsigned
if (Reprovision_Control_Field= New_Slot_List){			
Number_of_Connections	(8)	(1)	
for(i=0;i<Number_of_Connections;i++){			
Connection_ID	(32)	(1)	
if(Reprovision_Control_Field == new_slot_list_included){			**Fixed Rate Access**
Number_Slots_Defined	(8)	(1)	

(continued)

Table 41 (concluded): Reprovision Message structure

Reprovision_Message (){	Bits	Bytes	Bit Number / Descrip-tion
for(i=0;i<Number_Slots_Assigned;i++){			
Slot_Number	(16)	(2)	
}			
if (Reprovision_Control_Field == new_cyclic_Assignment_included){			**Fixed Rate Access**
Fixedrate_Start	(16)	(2)	
Fixedrate_Dist	(16)	(2)	
Fixedrate_End	(16)	(2)	
}			

54610.1 Reprovision Control Field

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

54610.2 New Downstream OOB Frequency

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

54610.3 New Downstream IB Frequency

`New_Upstream_IB_Frequency` is a boolean that indicates that a new downstream IB frequency is specified in the message.

54610.4 New Upstream Frequency Included

`New_Upstream_Frequency_Include` is a boolean that indicates that a new upstream frequency is specified in the message.

54610.5 New Frame Length Included

`New_Frame_Length_Include` is a boolean that indicates that a new upstream frame is specified in the message.

54610.6 New Slot List Included

`New_Slot_List_Include` is a boolean that indicates that a new slot list is specified in the message.

54610.7 New Cyclical Assignment Included

`New_Cyclical_Assignment_Include` is a boolean that indicates that a new cyclical assignment is specified in the message.

54610.8 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.

54610.9 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 is an 8-bit enumerated type indicating the modulation format for the down stream connection { reserved, QPSK_1,544, QPSK_3,088, 3 ... 255 reserved}.

54610.10 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.

UpstreamStream_Rate is an 3-bit enumerated bype indicating the data rate for the upstream connection {Upstream_256K, Upstream_1,544M, Upstream_3,088M, 3 ... 7 reserved}.

MAC_Flag_Set is an 5-bit field representing the MAC Flag set assigned to the connection. In the OOB downstream timing ,the eight sets of flags are assigned the numbers 0 ... 7. In the IB downstream timing, the 16 sets of flags are assigned the numbers 0 ... 15. In the case of a 3,088 Mbit upstream channel, this parameter represents the first of two successively assigned flag sets.

54610.11 New Frame Length

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

54610.12 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.

54610.13 Slot Number

`Slot_Number` is a 16-bit unsigned integer that represents the Fixed rate based Slot Number assigned to the Network Interface Unit.

5.5.7.3 Channel Error Management

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

<MAC> Idle Message (Upstream fixed rate or reserved)

The **<MAC> Idle Message** is sent by the NIU within the STB to the INA at predefined intervals (between 1 and 10 minutes) when upstream connection buffers are empty.

Table 42: Idle Message structure

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

54620.1 Idle Sequence Count

`Idle_Sequence_Count` is a 8-bit unsigned integer representing the count of <MAC> IDLE MESSAGES transmitted while the NIU is Idle.

54620.2 Power Control Setting

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

5.5.7.4 Link Managment Messages

<MAC> Transmission Control Message (Singlecast or Broadcast Downstream)

The <MAC> TRANSMISSION CONTROL MESSAGE is sent to the NIU from the INA to control several aspects of the upstream transmission. This includes stopping upstream transmission, re-enabling transmission from a NIU or group of NIU's and rapidly changing the upstream frequency being used by a NIU or group of NIU's. To identify a group of NIU's 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 NIU shall compare its current frequency value to `Old_Frequency.` When unequal, the NIU shall switch to the new frequency specified in the message. When equal, the NIU shall ignore the new frequency and remain on its current channel.

Table 43: Transmission Control Message structure

Transmission_Control_Message(){	Bits	Bytes	Bit Number / Description
Transmission_Control_Field	**8**		
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 **New_Upstream_Channel_Number** **reserved** **Upstream_Rate** **MAC_Flag_Set** **Reserved**	**(32)** **3** **2** **3** **5** **3**	**(4)** **1** **1** 	 **7:5** **4:3** **2:0** **7:3** **2:0**
New_Upstream_Frequency	**(32)**	**(4)**	
}			
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	
}			
}			

54630.1 Transmission Control Field

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

54630.2 Stop Upstream Transmission

stop_upstream_transmission is a boolean when set indicates that the NIU should halt its upstream transmission.

54630.3 Start Upstream Transmission

start_upstream_transmission is a boolean when set indicates that the Network Interface Unit should resume transmission on its upstream channel. The NIU shall respond to the ranging and power calibration message regardless of the setting of the start_upstream_transmission bit.

54630.4 Old Frequency Included

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

54630.5 Switch Downstream OOB Frequency

switch_downstream_OOB_frequency is a boolean when set indicates that a new downstream OOB frequency is included in the message.

54630.6 Switch Upstream Frequency

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 NIU to stop transmission and change channel. This would be followed by the <MAC> TRANSMISSION CONTROL MESSAGE with the start_upstream_transmission bit set.

54630.7 Old Upstream Frequency

Old_Upstream_Frequency is a 32-bit unsigned integer representing the frequency that should be used by the NIU to compare with its current frequency to determine if a change in channel is required.

54630.8 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.

MAC_Flag_Set is an 5 bit field representing the MAC Flag set assigned to the connection. In the OOB downstream timing, the eight sets of flags are assigned the numbers 0 ... 7. In the IB downstream timing, the 16 sets of flags are assigned the numbers 0 ... 15. In the case of a 3,088 Mbit upstream channel, this parameter represents the first of two successively assigned flag sets.

UpstreamStream_Rate is an 3-bit enumerated bype indicating the data rate for the upstream connection {Upstream_256K, Upstream_1,544M, Upstream_3,088M, 3 ... 7 reserved}.

54630.9 Old Downstream OOB Frequency

Old_Downstream_OOB_Frequency is a 32-bit unsigned integer representing the frequency that should be used by the NIU to compare with its current frequency to determine if a change in channel is required.

54630.10 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 is an 8-bit enumerated type indicating the modulation format for the down stream connection { reserved, QPSK_1,544, QPSK_3,088, 3 ... 255 reserved}.

Link Management Response Message (Upstream contention, fixed rate or reserved)

The <MAC> LINK MANAGEMENT RESPONSE MESSAGE is sent by the NIU to the INA to indicate reception and processing of the previously sent Link Management Message. The format of the message is shown in table 44.

Table 44: Link Management Acknowledge Message Format

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

54630.1 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 shown in table 45.

Table 45: Link Management Message Number

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

<MAC> Status Request Message (Downstream Singlecast)

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

Table 46: Status Request Message structure

Status_Request(){	Bits	Bytes	Bit Number / Description
Status_Control_Field	8	1	
reserved	5		3-7:
Status_Type	3		0-2:{enum type}
}			

54630.1 Status Control Field

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

```
enum Status_Control_Field {Address_Params, Error_Params,
Connection_Params,Physical_Layer_Params, reserved4..7};
```

<MAC> Status Response Message (Upstream Contention, fixed rate or reserved)

The <MAC> STATUS RESPONSE MESSAGE is sent by the NIU in response to the <MAC> STATUS REQUEST MESSAGE issued by the INA. The contents of the information provided in this message will vary depending on the request made by the INA and the state of the NIU. The message shall be dissociated into separate messages if the resulting length of the message exceeds 40 bytes.

Table 47: Status Response Message Structure

Status_Response(){	Bits	Bytes	Bit Number/ Description
NIU_Status	32	4	
Response_Fields_Included	8	1	
reserved	4		`4-7:`
Address_Params_Included	1		`3:{no,yes}`
Error_Information_Included	1		`2:{no,yes}`
Connection_Params_Included	1		`1:{no,yes}`
Physical_Layer_Params_Included	1		`0:{no,yes}`
if (Response_Fields_Included == Address_Params_Included){			
NSAP_Address	(160)	(20)	
MAC_Address	(48)	(6)	
}			
if (Response_Fields_Included == Error_Information_Included){			
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	(32)	(4)	
Upstream_Frequency	(32)	(4)	
Downstream_Frequency	(32)	(4)	
}			
}			

54630.1 NIU Status

`NIU_Status` is a 32-bit unsigned integer that indicates the current state of the NIU.

```
NIU_Status { Calibration_Operation_Complete,
   Default_Connection_Established,
   Network_Address_Registered,
   ,reserved};
```

54630.2 Response Fields Included

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

54630.3 NSAP Address

`NSAP_Address` is a 20-byte address assigned to the NIU.

54630.4 MAC Address

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

54630.5 Number of Error Codes Included

`Number_Error_Codes_Included` is an 8-bit unsigned integer that indicates the number of error codes are contained in the response.

54630.6 Error Parameter Code

`Error_Parameter_Code` is a 8-bit unsigned integers representing the type of error reported by the NIU.

Table 48: Error Parameter Code

Error Parameter Code Name	Error Parameter Code
Framing_Bit_Error_Count	0x00
Slot_Configuration_CRC_Error_Count	0x01
Reed_Solomon_Error_Count	0x02
ATM_Packet_Loss_Count	0x03

54630.7 Error Parameter Value

`Error_Parameter_Value` is a 16-bit unsigned integers representing error counts detected by the NIU.

54630.8 Number of Connections

`Number_of_Connections` is an 8-bit unsigned integer that indicates the number of connections that are specified in the response. Specifically, if the number of connections is too large to have a MAC message with less than 40 bytes, it is possible to send separate messages with only the number of connections indicated in each message.

54630.9 ConnectionID

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

54630.10 Power Control Setting

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

54630.11 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.

54630.12 Upstream Frequency

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

54630.13 Downstream Frequency

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

Annex A (informative): Bibliography

For the purposes of this ETS, the following informative references apply:

- DVB-A008 (October 1995): "Commercial requirements for asymmetric interactive services supporting broadcast to the home with narrowband return channels".

- DAVIC 1.0 Specification: "DAVIC System Reference Model".

History

Document history		
February 1997	Public Enquiry	PE 9726: 1997-02-28 to 1997-06-27