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

Miscellaneous

Digital broadband delivery system: Out-of-band transport

ITU-T Recommendation J.184

(Formerly CCITT Recommendation)

ITU-T J-SERIES RECOMMENDATIONS

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ITU-T Recommendation J.184

Digital broadband delivery system: Out-of-band transport

Summary

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

Source

ITU-T Recommendation J.184 was prepared by ITU-T Study Group 9 (2001-2004) and approved under the WTSA Resolution 1 procedure on 9 March 2001.

FOREWORD

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ITU-T Recommendation J.184

Digital broadband delivery system: Out-of-band transport

1 Scope

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

2 Definitions

This Recommendation defines the following terms:

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

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

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

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

2.3 upstream: Transmission from terminal device to Headend.

2.4 downstream: Transmission from Headend to terminal device.

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

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

3 Requirements

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

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

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

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

3.1 Forward Data Channels (FDC)

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

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

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

3.2 Reverse Data Channels (RDC)

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

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

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

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

ANNEX A

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

A.1 Introduction

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

A.2 Acronyms

This annex uses the following acronyms:

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

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

A.3 References

Normative references

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

Normative reference list

- [1] IEEE 0802-1990, *Local and Metropolitan Area Networks: Overview and Architecture*, and ISO/IEC 10039:1991, *Information technology – Open Systems Interconnection – Local area networks – Medium Access Control (MAC) service definition*.
- [2] ITU-T H.222.0 (2000) | ISO/IEC 13818-1:2000, *Information technology – Generic coding of moving pictures and associated audio information: Systems*.

Bibliography

- [3] CableLabs: Data-Over-Cable-Service Interface Specifications (DOCSIS): Radio Frequency Interface Specification, *SP-RF1v1.1.I01-990311* (1999). <<http://www.opencable.com>>.
- [4] Digital Audio Visual Council 1.4 Specification Part 8, Lower Layer Protocols and Physical Interfaces. (<http://www.davic.org/>.)
- [5] CLARK (G.C.), CAIN (J.B.): Error-Correction Coding for Digital Communications, *Plenum Press*, (1981).

A.4 Out-of-band system specifications

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

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

This annex assumes that the reader has some:

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

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

A.5 Physical layer specification

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

A.5.1 Physical layer For OOB transmission

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

A.5.1.1 OOB transmission format

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

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

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

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

A.5.1.2 OOB coding scheme

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

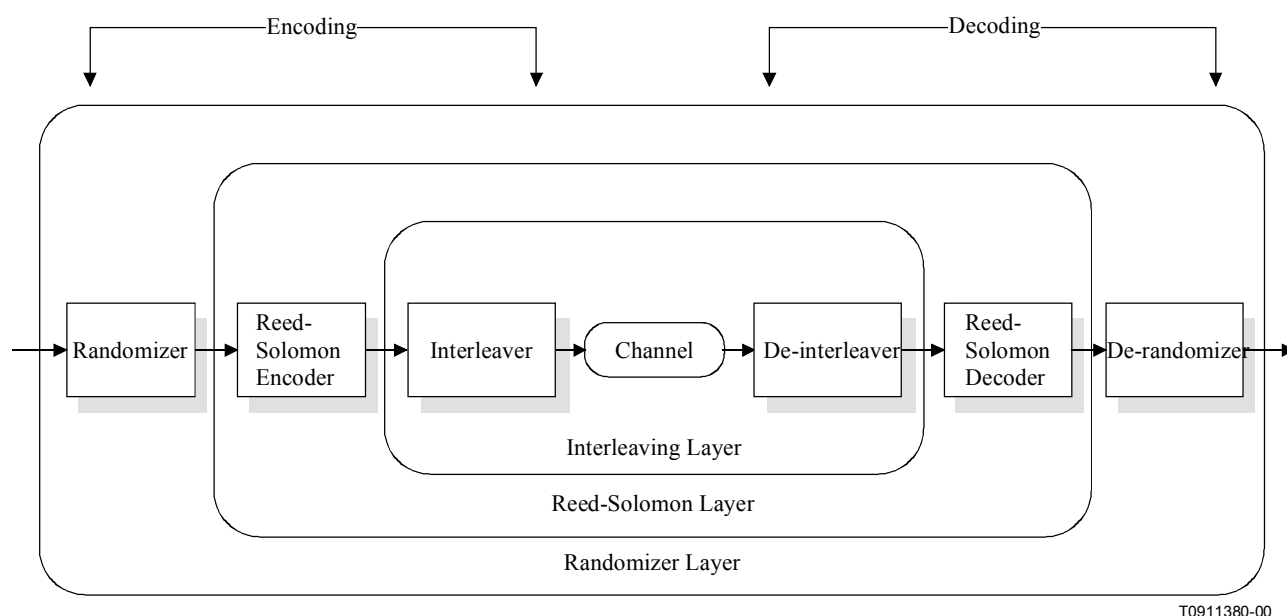


Figure A.1/J.184 – A block diagram for layers of coding in the OOB channel

A.5.1.2.1 OOB randomizer

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

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

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

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

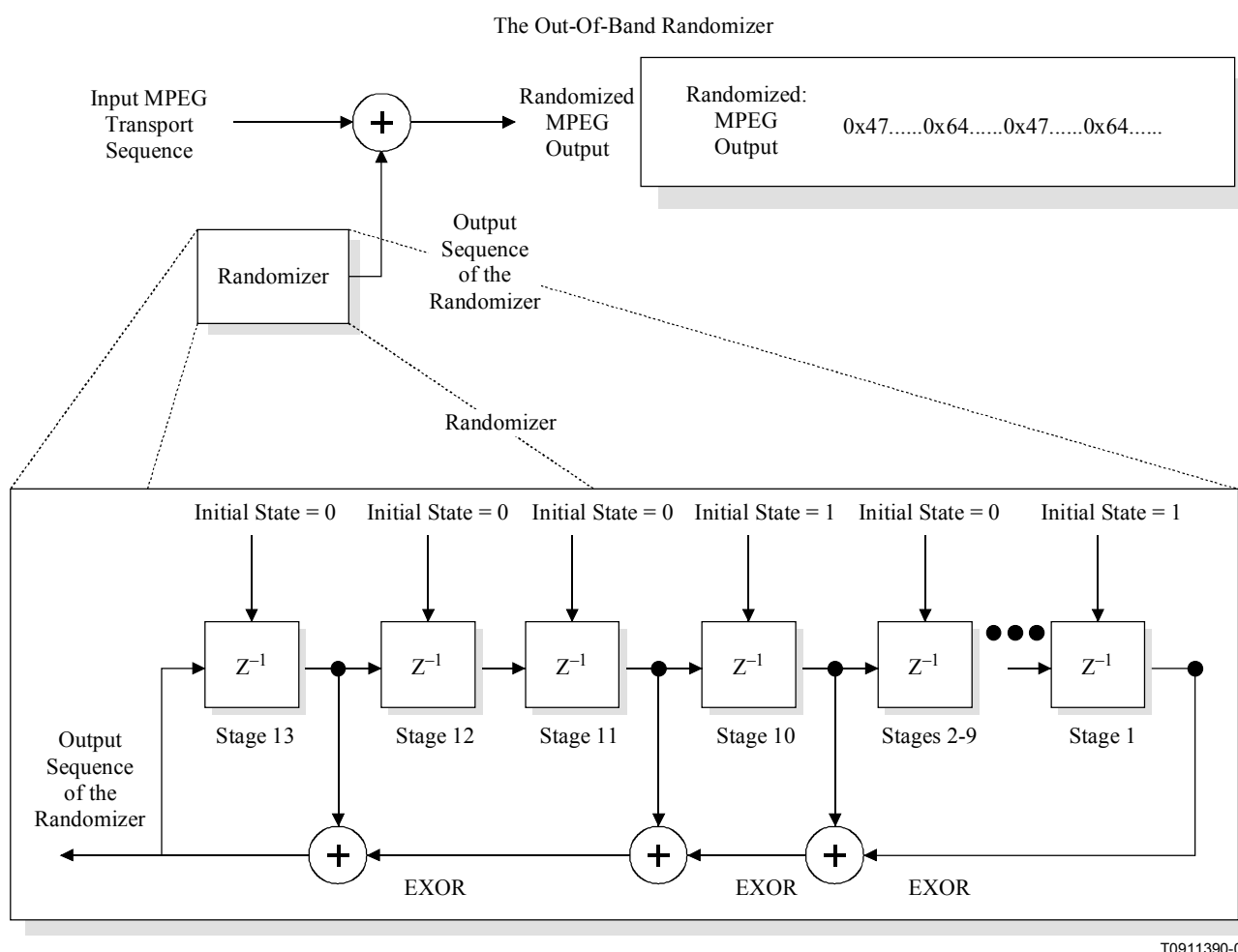


Figure A.2/J.184 – The out-of-band randomizer

A.5.1.2.2 Forward Error Correction Code

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

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

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

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

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

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

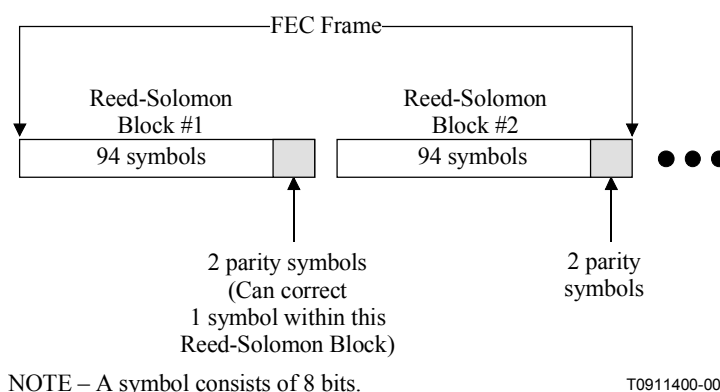
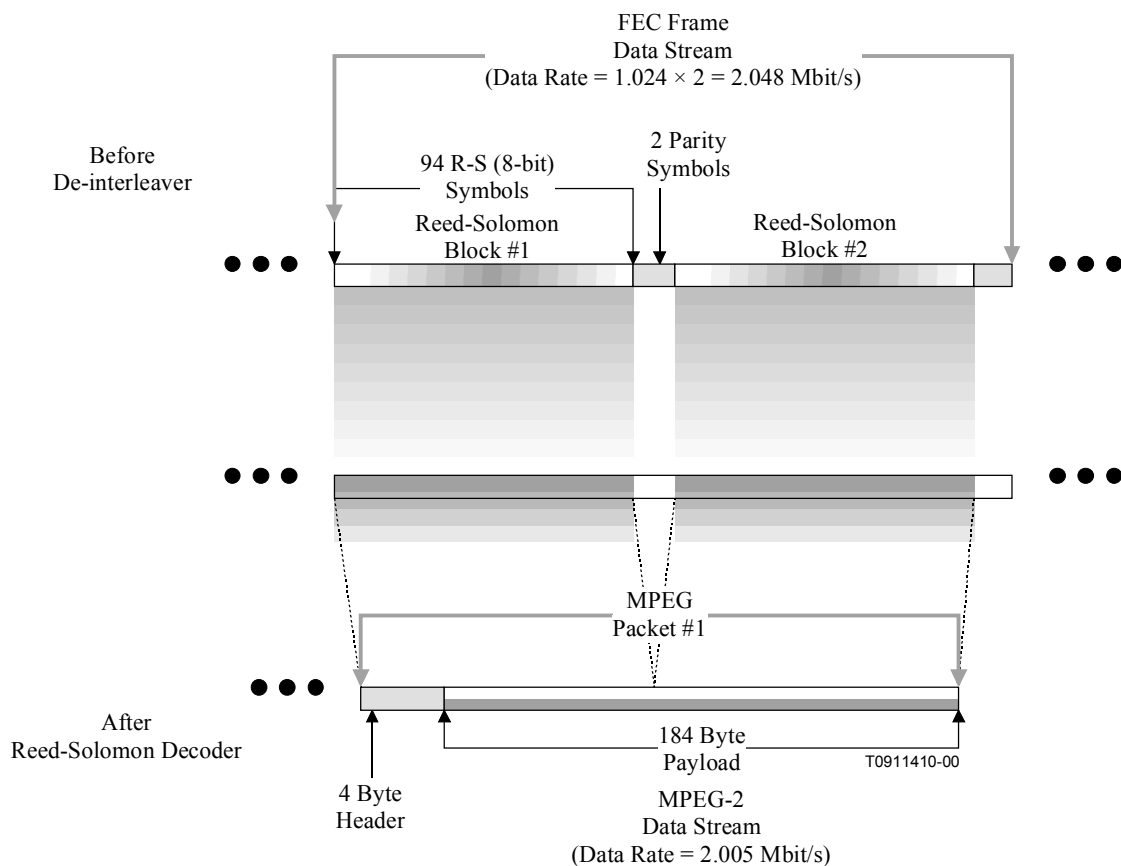


Figure A.3/J.184 – The OOB FEC frame packet format



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

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

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

A.5.1.2.3 OOB interleaver

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

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

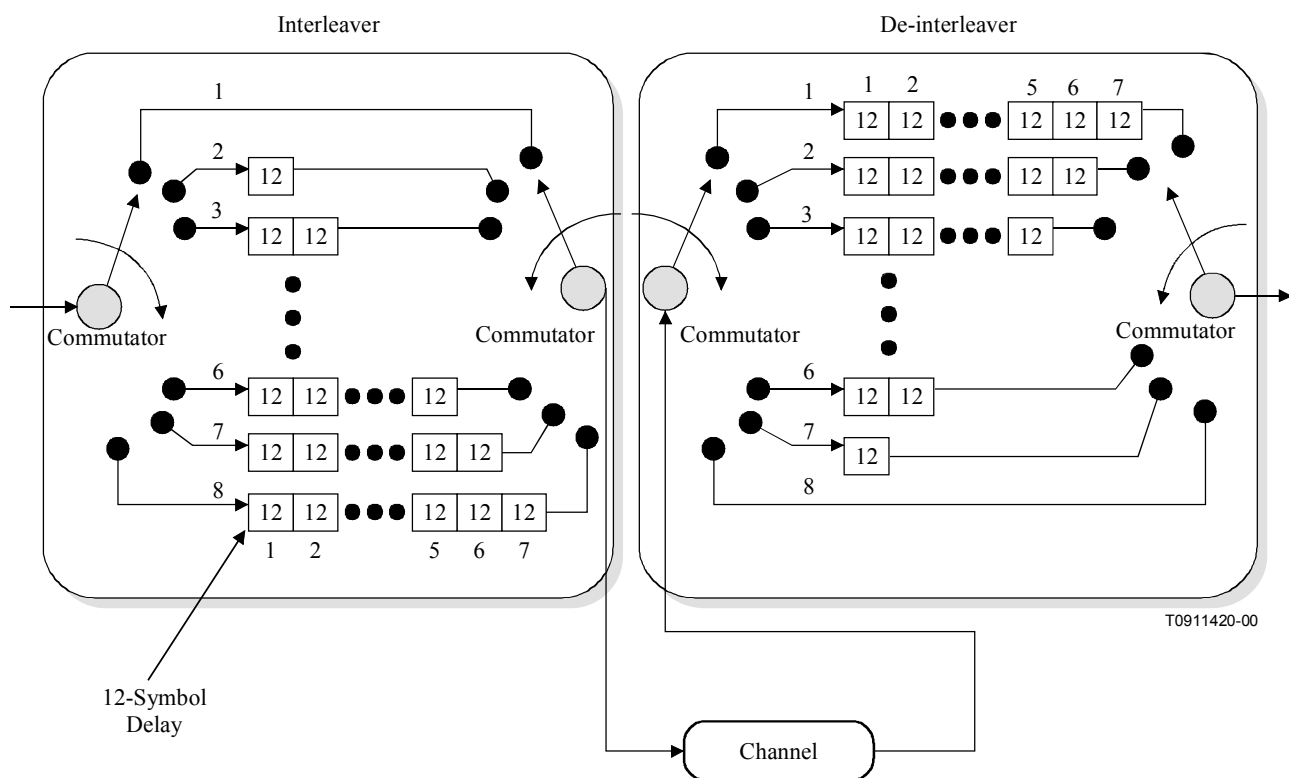


Figure A.5/J.184 – Out-of-band interleaving functional block diagram

A.5.1.3 OOB QPSK mapping

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

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

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

A.5.1.4 OOB modulator RF output

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

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

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

A.5.1.5 OOB carrier input power at receiver

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

A.5.2 Physical layer for return-path transmission

A.5.2.1 Return-path modem description

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

A.5.2.2 RF return path packet format

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

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

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

A.5.2.3 RF Return-Path Forward Error Correction

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

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

The generator polynomial for this FEC code is:

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

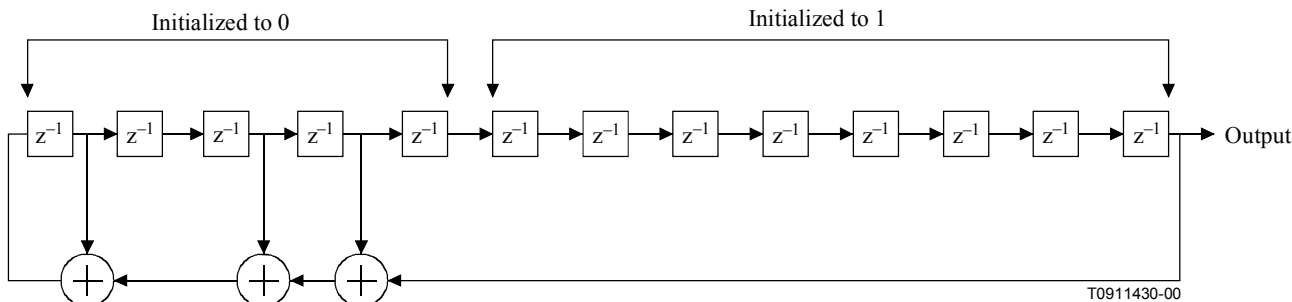
where α is a primitive element in GF(256).

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

A.5.2.4 RF return-path randomizer

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

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



A.5.2.5 RF return path modulator

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

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

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

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

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

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

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

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

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

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

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

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

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

The return-path modulator output specifications are summarized in Table A.9. It references to DOCSIS RFI specifications: *Radio Frequency Interface Specification* SP-RFIV1.1-I01-990311 [3]. As DOCSIS is still evolving with extended practices for more enhanced data features, the current implementation may be upgraded as future needs arise.

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

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

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

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

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

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

A.6 Data link layer

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

The Data Link Layer, along with its MAC (Media Access Control) sublayer, is responsible for transporting Network Layer PDUs between the Digital Terminal and the Headend. The layer also provides segmenting and reassembly of higher layer PDUs, e.g. network layer, as well as routing to the corresponding protocol stack. Additional information about general DLL and MAC functionality may be found in IEEE 802-1990, *Local and Metropolitan Area Networks: Overview and Architecture* [1], and ISO/IEC 10039:1991, *Information Technology – Open Systems Interconnection – Local Area Networks – Medium Access Control (MAC) service definition* [1].

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

A.6.1 Application PDU Processing

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

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

In the downstream direction, MPEG-2 transport packets are received and filtered based on PID values. Following this, Data Link Layer messages are reassembled, address filtered, and CRC checked. From an MPEG-2 point of view, Data Link Layer messages form an MPEG-2 private stream. The reassembly of those messages from the underlying MPEG-2 transport packets is as per

the MPEG-2 specification, using the Payload Unit Start Indicator bit in the MPEG-2 transport packet header. Those messages addressed to the Digital Terminal are processed by the Digital Terminal. For packets containing higher layer application PDUs, the PDU is extracted, reassembled and routed based on the Protocol ID field.

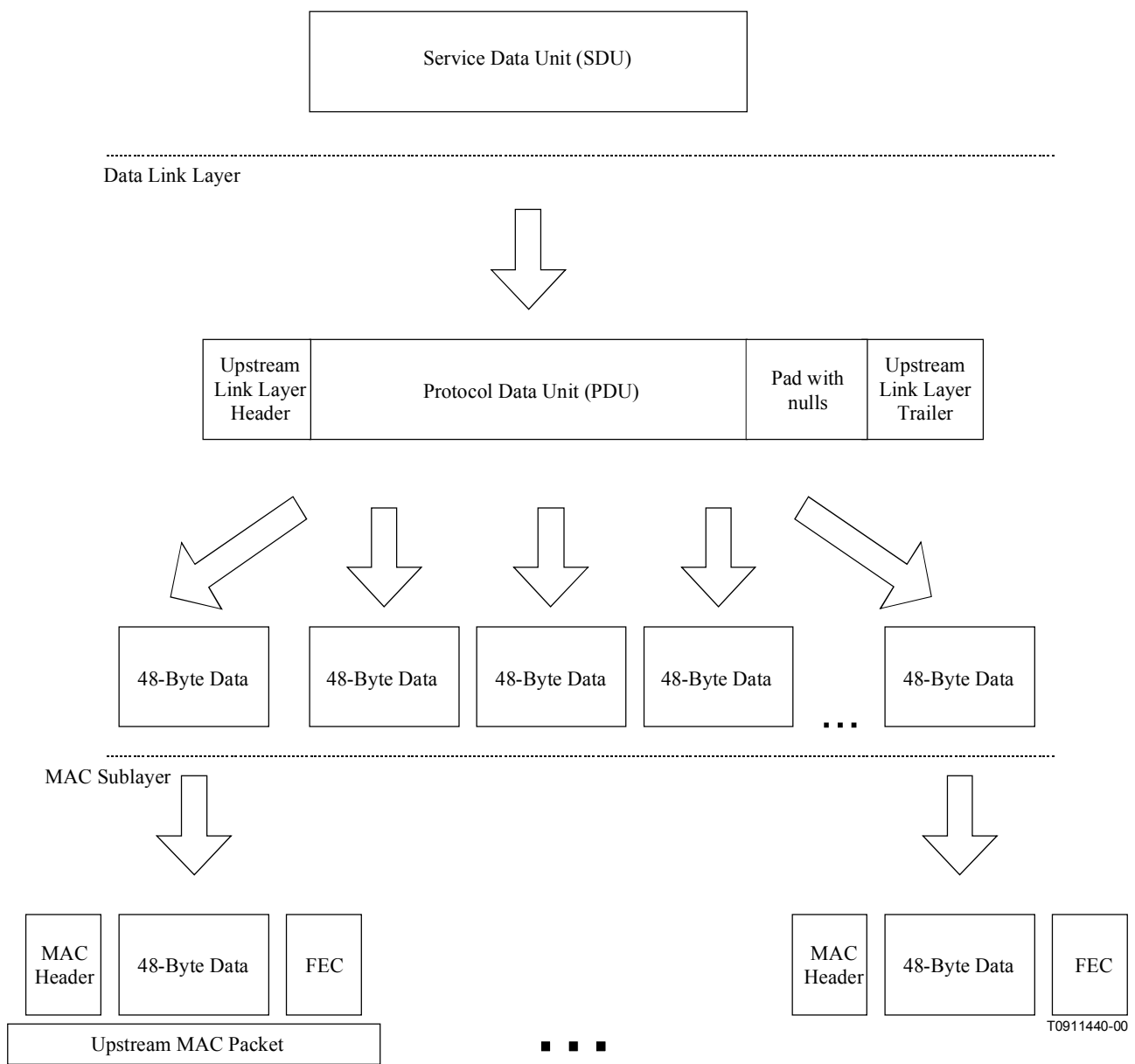


Figure A.6/J.184 – Upstream data link layer processing of application PDUs

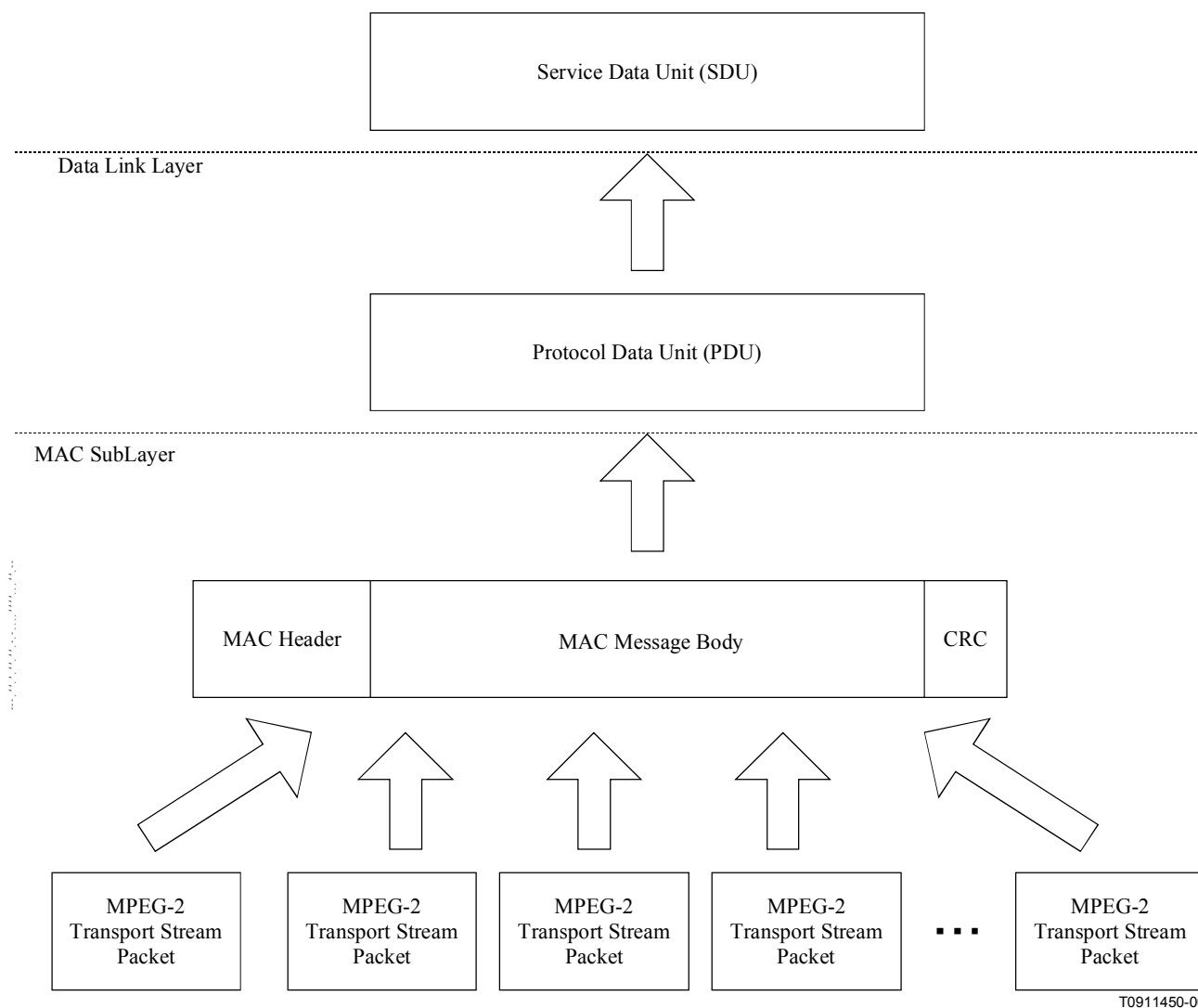


Figure A.7/J.184 – Downstream data link layer processing of application PDUs

A.6.2 Link layer headers/trailers

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

A.6.2.1 Upstream link layer header

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

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

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

Protocol_ID

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

Table A.11/J.184 – Protocol IDs

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

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

Msg_Length

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

CRC

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

A.6.2.2 Padding

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

A.6.2.3 Downstream link layer header

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

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

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

Protocol_ID

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

A.6.2.4 Upstream CRC function

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

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

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

A.6.2.5 Downstream CRC function

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

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

The initial seed for the calculation is 0xffffffff.

A.6.2.6 Acknowledgment protocol

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

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

The retry counter and the MAX_ACKNOWLEDGMENT_TIME are programmable.

A.6.3 Segmentation and reassembly

A.6.3.1 Upstream

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

A.6.3.2 Downstream

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

A.6.3.3 Maximum PDU sizes

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

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

A.6.4 MAC information transport

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

This clause focuses on the required message flows between the Headend and the Digital Terminal for Media Access Control. These messages are divided into three categories: Initialization, Provisioning and Sign-On Management, Connection Management and Link Management.

A.6.4.1 Downstream MAC Message Format

NOTE – All messages are sent most significant bit first.

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

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

Message_Type

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

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

Value	Message type
0x8E	Interactive Data
0x8F	MAC Signalling

Address_Type

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

Table A.13/J.184 – Address Types

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

Message_Length

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

Message_Type_Version_Field

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

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

A.6.4.2 Upstream packet format

The upstream packet format is as follows:

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

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

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

Message_Number

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

Sequence_Number

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

MAC_Control_Field

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

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

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

UPM_Address

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

Payload_Type (PT)

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

Ack_Required

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

Retry_Counter

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

Payload

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

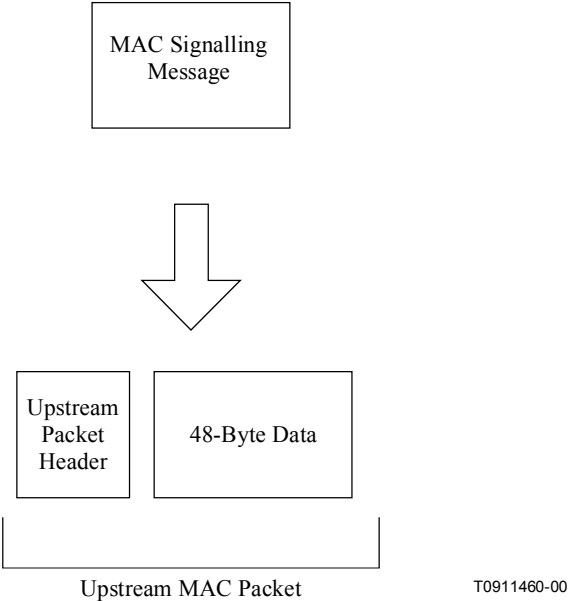
A.6.5 MAC signalling messages

A.6.5.1 MAC signalling message encapsulation

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

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

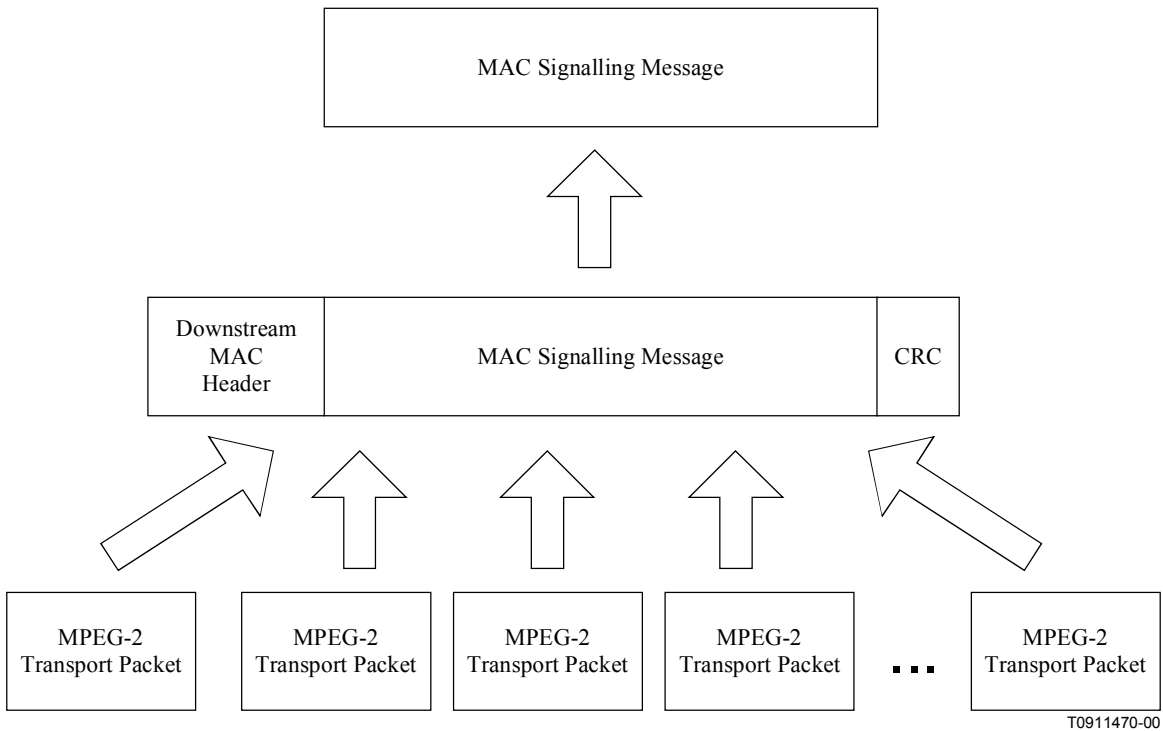
Figures A.8 and A.9 indicate the encapsulation for MAC Signalling Messages.



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

T0911460-00

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



T0911470-00

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

A.6.5.2 MAC signalling message format

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

NOTE – All messages are sent most significant bit first.

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

Protocol_Version

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

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

Syntax_Indicator

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

```
enum Syntax_Indicator    {    No_MAC_Address,
                           MAC_Address_Included,
                           Reserved 2..7    };
```

MAC_Address

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

A.6.5.3 ALOHA MAC Messages

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

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

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

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