RECOMMENDATION ITU-R F.1499

RADIO TRANSMISSION SYSTEMS FOR FIXED BROADBAND WIRELESS ACCESS BASED ON CABLE MODEM STANDARDS*

(Questions ITU-R 215/8 and ITU-R 140/9)

(2000)

CONTENTS

* This Recommendation is intended only for fixed BWA systems based on ITU-T Recommendation J.112, Annex B – Data over cable radio frequency interface. The Recommendation is complementary to ITU-T Recommendation J.116. This Recommendation and ITU-T Recommendation J.116 should be considered in their totality when implementing BWA systems.

Introduction

Local access and other high density radio-relay service planning and system deployments have rapidly accelerated in the last few years in many countries. This acceleration is due in large part to the trend towards increased demand and competition in the provision of high bit-rate local telecommunications and video distribution services. Because of cost and speed of deployment considerations, these developments are placing a major new focus on the provision of services directly to end users via fixed wireless access systems (FWA).

Current broadband wireless access (BWA) data rates over individual circuit paths range from about 1.5 Mbit/s to about 45 Mbit/s, and are expected to reach at least 310 Mbit/s within the next few years, as radios utilizing higher order modulation schemes become available (see Recommendation ITU-R F.758).

The variety of possible broadband FWA network configurations includes: conventional point-to-point (P-P), conventional point-to-multipoint (P-MP), and combinations thereof, e.g. P-P systems deployed in multi-sectored P-MP configurations. High density deployment of independent P-P links similarly results in clusters that assume the essential characteristics of P-MP deployment. An emerging system architecture is that of multipoint-to-multipoint (MP-MP), similar to mesh systems.

These broadband FWA systems are predominantly deployed in dense urban, suburban, and campus environments where transmission path elevation angles may reach up to about 40° to 60°. Links are regularly deployed on an on-demand basis to meet specific end-user requirements as they develop.

This Recommendation addresses fixed BWA systems, and this is based on ITU-T Recommendation J.112, Annex B – Data over cable radio frequency interface. A number of frequency bands in the range 2.5-66 GHz can be appropriate for these systems. This and other systems, which may be addressed in other recommendations, belong to the category of multimedia wireless systems (MWS). MWS are wireless systems which support information exchange of more than one type, such as text, graphics, voice, sound, image, data and video.

This Recommendation is complementary to ITU-T Recommendation J.116. This Recommendation and ITU-T Recommendation J.116 should be considered in their totality when implementing BWA systems.

Scope

This Recommendation is based on the standards approved and published by ITU-T for cable modems (specifically ITU-T Recommendation J.112, Annex B), but adapts the technical parameters for use in the wireless access environment, that is for BWA customer premises equipment (CPE) modems. The commonality is maximized to achieve economies of scale.

This Recommendation is complementary to ITU-T Recommendation J.116. This Recommendation and ITU-T Recommendation J.116 should be considered in their totality when implementing BWA systems.

References

The following ITU 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; all 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. Lists of the currently valid ITU Recommendations are regularly published.

Recommendation ITU-R F.755: Point-to-multipoint systems used in the fixed service

Recommendation ITU-R F.1402: Frequency sharing criteria between a land mobile wireless access system and a fixed wireless access system using the same equipment type as the mobile wireless access system

Recommendation ITU-R F.1400: Performance and availability requirements and objectives for fixed wireless access to public switched telephone network

Recommendation ITU-R F.1399: Vocabulary of terms for wireless access

Recommendation ITU-R F.1401:	Frequency bands for fixed wireless access systems and the identification methodology
ITU-T Recommendation H.222.0:	ISO/IEC 13818-1: 1996, Information technology – Generic coding of moving pictures and associated audio information: Systems
ITU-T Recommendation I.361:	B-ISDN ATM layer specification
ITU-T Recommendation I.363:	B-ISDN ATM adaptation layer (AAL) specification
ITU-T Recommendation J.83:	Digital multi-programme systems for television, sound and data services for cable distribution
ITU-T Recommendation J.110:	Basic principles for a worldwide common family of systems for the provision of interactive television services
ITU-T Recommendation J.111:	Network independent protocols for interactive systems
ITU-T Recommendation J.112:	Transmission systems for interactive cable television services
ITU-T Recommendation J.116:	Interaction channel for local multipoint distribution systems
ITU-T Recommendation V.21:	300 bits per second duplex modem standardized for use in the general switched telephone network
ITU-T Recommendation V.22:	1 200 bits per second duplex modem standardized for use in the general switched telephone network and on point-to-point 2-wire leased telephone-type circuits
ITU-T Recommendation V.22*bis*:	2 400 bits per second duplex modem using the frequency division technique standardized for use on the general switched telephone network and on point-to-point 2-wire leased telephone-type circuits
ITU-T Recommendation V.23:	600/1 200-baud modem standardized for use in the general switched telephone network
ITU-T Recommendation V.25:	Automatic answering equipment and general procedures for automatic calling equipment on the general switched telephone network including procedures for disabling of echo control devices for both manually and automatically established calls
ITU-T Recommendation V.32:	A family of 2-wire, duplex modems operating at data signalling rates of up to 9 600 bit/s for use on the general switched telephone network and on leased telephone-type circuits
ITU-T Recommendation V.32*bis:*	A duplex modem operating at data signalling rates of up to 14 400 bit/s for use on the general switched telephone network and on leased point-to-point 2-wire telephone-type circuits
ITU-T Recommendation V.34:	A modem operating at data signalling rates of up to 33 600 bit/s for use on the general switched telephone network and on leased point-to-point 2-wire telephone-type circuits
ITU-T Recommendation V.42:	Error-correcting procedures for DCEs using asynchronous-to-synchronous conversion
ITU-T Recommendation X.25:	Interface between Data Terminal Equipment and Data Circuit-terminating Equipment (DCE) for terminals operating in the packet mode and connected to public data networks by dedicated circuit
ITU-T Recommendation Z.100:	CCITT Specification and Description Language (SDL)

ISO/IEC:

ISO 8025: Information processing systems – Open Systems Interconnection – Specification of the Basic Encoding Rules for Abstract Syntax Notation One (ASN.1) (December, 1987)

ISO/IEC 8802-2: Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 2: Logical link control, 1994 (IEEE Std 802.2: 1994)

ISO/IEC 8802-3: Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical sublayer specifications, 1996 (IEEE Std 802.3: 1996)

ISO/IEC 10038: Information technology – Telecommunications and information exchange between systems – Local area networks – Media access control (MAC) bridges, 1993 (ANSI/IEEE Std 802.1D: 1993)

ISO/IEC 10039: Information technology – Open Systems Interconnection – Local area networks – Medium Access Control (MAC) service definition, 1991

ISO/IEC 15802-1: Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Common specifications – Part 1: Medium Access Control (MAC) service definition, 1995

IETF:

RFC-791: POSTEL, J. [September, 1981] Internet Protocol (MIL STD 1777). Internet Engineering Task Force (IETF).

RFC-826: PLUMMER, D. [November, 1982] Ethernet Address Resolution Protocol: Or converting network protocol addresses to 48-bit Ethernet address for transmission on Ethernet hardware.

RFC-868: HARRENSTIEN, K. and POSTEL, J. [May, 1983] Time Protocol. IETF.

RFC-1042: POSTEL, J. and REYNOLDS, J. [February, 1988] A Standard for the Transmission of IP Datagrams over IEEE 802 Networks. IETF.

RFC-1058: HEDRICK, C. [June, 1988] Routing Information Protocol. IETF.

RFC-1157: SCHOFFSTALL, M., FEDOR, M., DAVIN, J. and CASE, J. [May, 1990] A Simple Management Protocol (SNMP). IETF.

RFC-1350: SOLLINGS, K. [July, 1992] The TFTP Protocol (Revision 2). IETF.

RFC-1533: ALEXANDER, S. and DROMS, R. [October, 1993] DHCP Options and BOOTP Vendor Extensions. IETF.

RFC-1541: DROMS, R. [October, 1993] Dynamic Host Configuration Protocol. IETF.

RFC-1633: BRADEN, R., CLARK, D. and SHENKER, S. [June, 1994] Integrated Services in the Internet Architecture: An Overview. IETF.

RFC-1812: BAKER, F. [June, 1995] Requirements for IP Version 4 Routers. IETF.

RFC-2104: KRAWCZYK, H., BELLARE, M. and CANETTI, R. [February, 1997] HMAC: Keyed-Hashing for Message Authentication. IETF.

Definitions and abbreviations

Address resolution protocol (ARP): A protocol of the IETF for converting network addresses to 48-bit Ethernet addresses.

Asynchronous transfer mode (ATM): A protocol for the transmission of a variety of digital signals using uniform 53-byte cells.

Availability: Is the long-term ratio of the actual RF channel operation time to scheduled RF channel operation time (expressed as a per cent value) and is based on a bit error rate (BER) assumption.

Bridge Protocol Data Unit (BPDU): Spanning tree protocol messages as defined in ISO/IEC10038.

Broadcast addresses: A predefined destination address that denotes the set of all data network service access points.

Burst error second: Any errored second containing at least 100 errors.

BWA BTS modem: Broadband wireless access base transceiver station modem. One or more downstream demodulators and their corresponding upstream modulators.

BWA CPE modem: Broadband wireless access customer premises equipment modem.

Carrier hum modulation: The peak-to-peak magnitude of the amplitude distortion relative to the RF carrier signal level due to the fundamental and low-order harmonics of the power-supply frequency.

Carrier-to-noise ratio (*C*/*N*): The square of the ratio of the root mean square (r.m.s.) of the voltage of the digitally-modulated RF carrier to the r.m.s. of the continuous random noise voltage in the defined measurement bandwidth. (If not specified explicitly, the measurement bandwidth is the symbol rate of the digital modulation.)

Cross-modulation: A form of television signal distortion where modulation from one or more television channels is imposed on another channel or channels.

Customer: See end user.

Customer premises equipment (CPE): Equipment at the end user's premises; may be provided by the end user or the service provider.

Data link layer: Layer 2 in the open system interconnection (OSI) architecture; the layer that provides services to transfer data over the transmission link between open systems.

Downstream: The direction of transmission from the BTS to the subscriber.

Dynamic host configuration protocol (DHCP): An Internet protocol used for assigning network-layer (IP) addresses.

Dynamic range: The ratio between the greatest signal power that can be transmitted over a multichannel analogue transmission system without exceeding distortion or other performance limits, and the least signal power that can be utilized without exceeding noise, error rate or other performance limits.

End user: A human being, organization, or telecommunications system that accesses the network in order to communicate via the services provided by the network.

Errored second: Any one second interval containing at least one bit error.

Fibre distributed data interface (FDDI): A fibre-based LAN standard.

Fibre node: A point of interface between a fibre trunk and the coaxial distribution.

Forward channel: The direction of RF signal flow away from the BTS toward the end user; synonymous to downstream.

Group delay: The difference in transmission time between the highest and lowest of several frequencies through a device, circuit or system.

Guard time: Minimum time allocated between bursts in the upstream, referenced from the symbol centre of the last symbol of a burst to the symbol centre of the first symbol of the following burst.

Headend: The central location on the BWA network that is responsible for injecting broadcast video and other signals in the downstream direction. See also master headend, distribution hub.

Header: Protocol control information located at the beginning of a protocol data unit.

Impulse noise: Noise characterized by non-overlapping transient disturbances.

Interleave: An error correction method that enables the correction of burst noise induced errors.

Internet control message protocol (ICMP): An Internet network-layer protocol.

Internet protocol (IP): An Internet network-layer protocol, defined by the IETF.

Latency: The time, expressed in quantity of symbols, taken for a signal element to pass through a device.

Layer: A subdivision of the open system interconnection (OSI) architecture, constituted by subsystems of the same rank.

Local area network (LAN): A non-public data network in which serial transmission is used for direct data communication among data stations located on the user's premises.

Logical link control (LLC) procedure: In a LAN or a metropolitan area network (MAN), that part of the protocol that governs the assembling of data link layer frames and their exchange between data stations, independent of how the transmission medium is shared.

MAC service access point: is an attachment to a MAC-sublayer domain.

Mean time to repair (MTTR): the MTTR is the average elapsed time from the moment a loss of RF channel operation is detected up to the moment the RF channel operation is fully restored.

Media access control (MAC) address: The built-in hardware address of a device connected to a shared medium.

Media access control (MAC) procedure: In a subnetwork, that part of the protocol that governs access to the transmission medium independent of the physical characteristics of the medium, but taking into account the topological aspects of the subnetworks, in order to enable the exchange of data between nodes. MAC procedures include framing, error protection, and acquiring the right to use the underlying transmission medium.

Media access control (MAC) sublayer: The part of the data link layer that supports topology dependent functions and uses the services of the physical layer to provide services to the logical link control (LLC) sublayer.

Mini-slot: A mini-slot is an integer multiple of 6.25-μs increments. The relationship between mini-slots, bytes and time ticks is described in Section 6.

Multipoint Access: User access in which more than one terminal equipment is supported by a single network termination.

Multipoint connection: A connection among more than two data network terminations.

Network layer: Layer 3 in the OSI architecture; the layer that provides services to establish a path between open systems.

Network management: The functions related to the management of data link layer and physical layer resources and their stations across the data network supported by the hybrid fibre/coax system.

Open systems interconnection (OSI): A framework of ISO standards for communication between different systems made by different vendors, in which the communications process is organized into seven different categories that are placed in a layered sequence based on their relationship to the user. Each layer uses the layer immediately below it and provides a service to the layer above. Layers 7 through 4 deal with end-to-end communication between the message source and destination, and layers 3 through 1 deal with network functions.

Organizationally unique identifier (OUI): A three octet IEEE assigned identifier that OUI can be used to generate universal LAN MAC addresses and protocol identifiers per ANSI/IEEE Std 802 for use in local and metropolitan area network applications.

Packet identifier (PID): A unique integer value used to identify elementary streams of a program in a single- or multi-program MPEG-2 stream.

Physical (PHY) layer: Layer 1 in the OSI architecture; the layer that provides services to transmit bits or groups of bits over a transmission link between open systems and which entails electrical, mechanical and handshaking procedures.

Physical media dependent (PMD) sublayer: A sublayer of the physical layer which is concerned with transmitting bits or groups of bits over particular types of transmission link between open systems and which entails electrical, mechanical and handshaking procedures.

Program specific information (PSI): In MPEG-2, normative data necessary for the demultiplexing of transport streams and the successful regeneration of programs.

Program stream: In MPEG-2, a multiplex of variable-length digital video and audio packets from one or more program sources having a common time-base.

Protocol: A set of rules and formats that determines the communication behaviour of layer entities in the performance of the layer functions.

Quadrature amplitude modulation (QAM): A method of modulating digital signals onto a radio-frequency carrier signal involving both amplitude and phase coding.

Quaternary phase-shift keying (QPSK): A method of modulating digital signals onto a radio-frequency carrier signal using four phase states to code two digital bits.

Radio frequency (RF): Refers to electromagnetic signals typically in the range 5 to 40 000 MHz.

Reed-Solomon code: A forward error correction code located before interleaving that enables correction of errors induced by burst noise.

Return loss: The parameter describing the attenuation of a guided wave signal (e.g. via a coaxial cable) returned to a source by a device or medium resulting from reflections of the signal generated by the source.

Reverse channel: The direction of signal flow towards the BTS, away from the subscriber; equivalent to upstream.

Roll off: A coefficient of cosine roll off function that determines the frequency characteristics of the filter.

Routing information protocol (RIP): A protocol of the IETF for exchanging routing information about IP networks and subnets.

Service access point (SAP): The point at which services are provided by one layer, or sublayer, to the layer immediately above it.

Service data unit (SDU): Information that is delivered as a unit between peer service access points.

Simple network management protocol (SNMP): A network management protocol of the IETF.

Sublayer: A subdivision of a layer in the OSI reference model.

Subnetwork: Subnetworks are physically formed by connecting adjacent nodes with transmission links.

Subnetwork access protocol (SNAP): An extension of the LLC header to accommodate the use of IEEE 802 type networks as IP networks.

Subscriber: See end user.

Subsystem: An element in a hierarchical division of an open system that interacts directly with elements in the next higher division or the next lower division of that open system.

Systems management: Functions in the application layer related to the management of various OSI resources and their status across all layers of the OSI architecture.

Transit delay: The time difference between the instant at which the first bit of a PDU crosses one designated boundary, and the instant at which the last bit of the same PDU crosses a second designated boundary.

Transmission control protocol (TCP): A transport-layer Internet protocol which ensures successful end-to-end delivery of data packets without error, as defined by the IETF.

Transmission convergence sublayer: A sublayer of the physical layer that provides an interface between the data link layer and the PMD sublayer.

Transmission link: The physical unit of a subnetwork that provides the transmission connection between adjacent nodes.

Transmission medium: The material on which information signals may be carried; e.g. wireless, optical fibre, coaxial cable, and twisted wire pairs.

Transmission system: The interface and transmission medium through which peer physical layer entities transfer bits.

Transmit on/off ratio: In multiple-access systems, the ratio between the signal powers sent to line when transmitting and when not transmitting.

Transport stream: In MPEG-2, a packet-based method of multiplexing one or more digital video and audio streams having one or more independent time bases into a single stream.

Trivial file transfer protocol (TFTP): An Internet protocol for transferring files without the requirement for user names and passwords that is typically used for automatic downloads of data and software.

Type/length/value (TLV): An encoding of three fields, in which the first field indicates the type of element, the second the length of the element, and the third field the value.

Upstream: The direction from the subscriber location toward the BTS.

BC: Broadcast channel.

BRA: Basic rate access.

BTS: Base transceiver station. A BTS could contain multiple BTS modems.

BWA: Broadband wireless access.

CATV: Community antenna television (system).

CRC: Cyclic redundancy check, a method of error detection using cyclic code.

DA: Destination address.

DAVIC: Digital Audio-Visual Council.

DCE: Data communication equipment.

DOBSS: Data over BWA security system.

DTE: Data termination equipment.

DTMF: Dual tone multifrequency (dialling mode).

DVB: Digital video broadcasting.

EH or EHDR: Extended header.

FC: Frame control.

FDM: Frequency division multiplex.

FDMA: Frequency division multiple access.

FEC: Forward error correction.

FWA: Fixed wireless access.

GSTN: General switched telephone network.

GT: Global time.

HCS: Header check sequence.

HFC: Hybrid fibre/coax (HFC) system.

IC: Interaction channel.

IE: Information element.

IEC: International Electrotechnical Commission.

IEEE: Institute of Electrical and Electronic Engineers.

IETF: Internet Engineering Task Force.

INA: Interactive network adapter.

IQ: In-phase and quadrature components.

IRD: Integrated receiver decoder.

ISDN: Integrated services digital network.

ISO: International Organization for Standardization.

LEN: Length (in bytes unless otherwise stated).

LFSR: Linear feedback shift register.

LMCS: Local multipoint communication system.

LMDS: Local multipoint distribution system.

LSB: Least significant bit.

LT: Local time.

MAC: See media access control (MAC) procedure.

MCNS: Multimedia cable network system.

MMDS: Multi-channel multi-point distribution systems.

MPEG: Moving picture experts group.

MSAP: MAC service access point.

MSB: Most significant bit.

NIU: Network interface unit.

NSAP: Network service access point.

OoB: Out-of-band.

PM: Pulse modulation.

PSTN: Public switched telephone network.

QoS: Quality of service.

REQ: Request indicator.

RNG: Ranging.

RTD: Round trip delay.

SID: Service identifier.

SMATV: Satellite master antenna television.

SMS: Spectrum management system.

SNMP: Simple network management protocol.

STB: Set-top box.

STU: Set-top unit.

SYNC: Synchronization.

TC: Transmission convergence sublayer.

TDMA: Time division multiple access.

Tick: Time intervals that are the reference for upstream mini-slot definition and upstream transmission times.

TS: Transport stream.

UCC: Upstream channel change.

UCD: Upstream channel descriptor.

Conventions

Throughout this Recommendation, the words that are used to define the significance of particular requirements are capitalized. These words are:

MUST	This word or the adjective REQUIRED means that the item is an absolute requirement of this specification.
MUST NOT	This phrase means that the item is an absolute prohibition of this specification.
SHOULD	This word or the adjective RECOMMENDED means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighed before choosing a different course.
SHOULD NOT	This phrase means that there may exist valid reasons in particular circumstances when the listed behaviour is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behaviour described with this label.
MAY	This word or the adjective OPTIONAL means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.

Other text is descriptive or explanatory.

Considerations

ITU-T has developed Recommendations for cable modems, which can be used as the basis for wireless access systems in order to achieve economies of scale. In particular, Annex B of ITU-T Recommendation J.112 and ITU-T Recommendation J.83 – Digital multi-programme systems for television, sound and data services for cable distribution, are particularly applicable. The technical parameters can be adapted to the wireless environment rather than for a cable environment in order to support bidirectional data over BWA systems for interactive services.

Recommendation

The Radiocommunication Assembly recommends that the following requirements be used with radio transmission systems for fixed BWA based on cable modem standards (Annex B of ITU-T Recommendation J.112).

This Recommendation is complementary to ITU-T Recommendation J.116. This Recommendation and ITU-T Recommendation J.116 should be considered in their totality when implementing BWA systems.

1 General system requirements

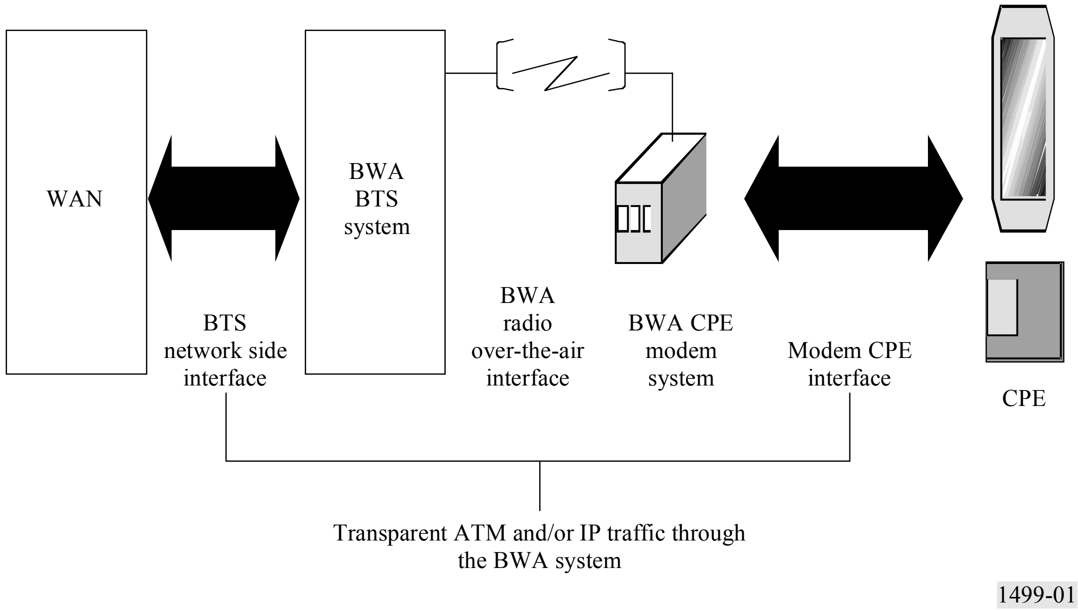
1.1 Service goals

The intended service will allow transparent bidirectional transfer of ATM and/or IP traffic, between the BWA BTS and customer locations, over a BWA network. This is shown in simplified form in Fig. 1.

The transmission path over the BWA system is realized at the fixed network side by a BWA BTS, and at each customer location by a BWA CPE modem. At the fixed network side, the interface to the BWA BTS system is called the BWA BTS – network-side interface (BTS-NSI) and is specified in MCNS3 (see Annex 1). At the customer locations, the interface is called the CPE-modem-to-customer-premises-equipment interface (CMCI) and is specified in MCNS4 (see Annex 1). The intent is for the BWA operators to transparently transfer ATM and IP traffic between these interfaces, including but not limited to datagrams, DHCP, ICMP and IP group addressing (broadcast and multicast).

FIGURE 1

Transparent ATM and/or IP traffic through the BWA system



1.2 Reference architecture

The reference architecture for the data-over-BWA services and interfaces is shown in Fig. 2.

1.3 Categories of interface specification

The basic reference architecture of Fig. 2 involves four categories of interface. These are being developed in phases:

1.3.1 Phase 1

Data interfaces – These are the CMCI (MCNS4 (see Annex 1)) and BTS-NSI (MCNS3 (see Annex 1)), corresponding respectively to the CPE-modem-to-CPE interface (for example, between the customer's computer and the BWA CPE modem), and the BWA BTS modem system network-side interface between the BWA BTS modem and the data network.

1.3.2 Phase 2

Operations support systems interfaces – These are network element management layer interfaces between the network elements and the high-level operations support systems (OSSs) which support the basic business processes, and are documented in MCNS5 (see Annex 1).

1.3.3 Phase 3

IF interfaces – The IF interfaces defined in this Recommendation are the following:

– between the BWA CPE modem and the CPE IF module;

– between the BTS modem and the BTS IF module.

1.3.4 Phase 4

Over the-air interface – The RF interfaces defined in this Recommendation are the following:

– between the BTS radio and the CPE radio in the downstream direction;

– between the BTS radio and the CPE radio in the upstream direction.

Security requirements

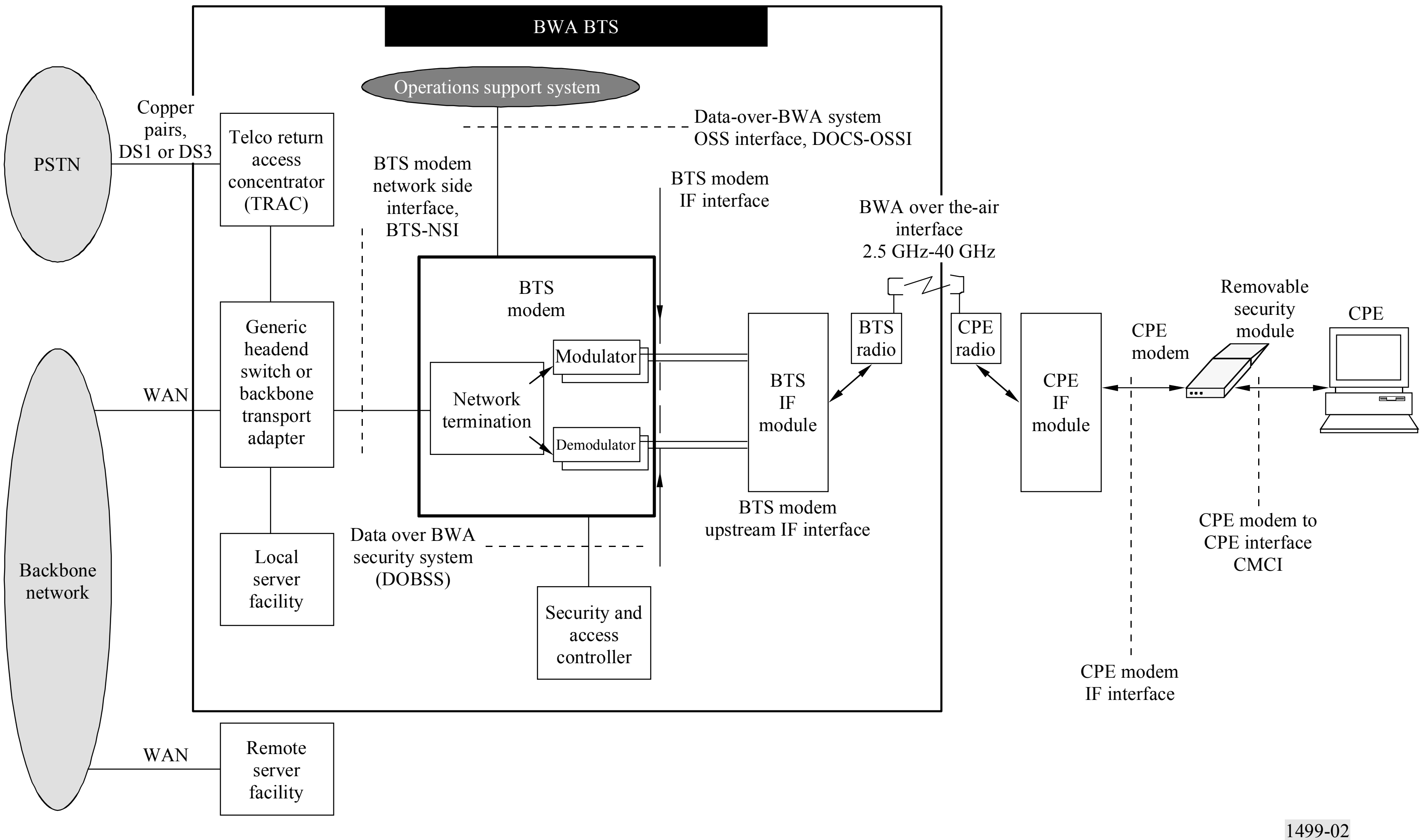
– The Data-over-BWA security system (DOBSS) is defined in MCNS2 (see Annex 1).

– The CPE removable security module (RSM) is defined in MCNS7 (see Annex 1).

– Baseline data-over-BWA security is defined in MCNS8 (see Annex 1).

FIGURE 2

Data-over-BWA reference architecture



1.4 Server location

This Recommendation refers to several servers which are central to the system operation (e.g. provision and security servers).

The message sequence charts used as examples within this Recommendation show sample message exchanges in which access to the servers is via the BTS modem.

2 Functional assumptions

This section describes the characteristics of a BWA network for the purposes of operation of the data-over-BWA system. The data-over-BWA system MUST operate satisfactorily in the environment described in this section.

2.1 BWA network

The BWA system uses TDMA. The key functional characteristics are the following:

– one- and two-way wireless transmission;

– downstream uses TDM;

– upstream uses TDMA;

– frequency bands between 2.5 to 66 GHz will be used;

– a BTS service area is called a cell, with a cell radius typically <15 km, depending on rain regions and the availability requirement;

– a cell may be divided into multiple sectors;

– the system must be able to combat rain fades of 30 dB and a fade rate of 5 dB/s.

2.2 Equipment assumptions

2.2.1 Frequency plan

Frequency bands between 2.5 GHz and 66 GHz (e.g. LMDS, LMCS and MMDS frequency bands) throughout the world are ideal for BWA applications. These types of systems form part of what is know as MWS. Considering the various RF bands to be used for BWA applications, it is desirable to define the IF for the interface between the modem units and the RF units, however the specific implementation of the IF is left to vendors.

2.2.2 Compatibility with other services

Some of the BWA frequency bands may be shared with satellite applications. In these cases, the mutual interference should be considered and engineered so that both systems will work with minimal performance degradation.

2.2.3 Fault isolation impact on other users

As the data-over-BWA system is a shared-media, point-to-multipoint (P-MP) system, fault-isolation procedures MUST take into account the potential harmful impact of faults and fault-isolation procedures on numerous users of the data-over-BWA and other services.

2.3 RF channel assumptions

The data-over-BWA system, configured with at least one set of defined physical-layer parameters (e.g. modulation, FEC, symbol rate, etc.) from the range of configuration settings described in this specification, must be capable of operating with a 1 500-byte packet loss rate of less than one per cent while forwarding at least 100 packets/s on BWA networks having characteristics defined in § 2.3.

2.3.1 Transmission upstream and downstream

The RF channel transmission characteristics of the BWA network in both the upstream and downstream directions are described in Table 1.

TABLE 1

Assumed upstream and downstream RF channel transmission characteristics

Parameter	Value
Frequency range	2.5-66 GHz (including the LMDS, LMCS and MMDS bands)
Upstream RF channel spacing (design bandwidth)	Up to 26 MHz
Downstream RF channel spacing (design bandwidth)	Up to 40 MHz
Propagation delay from the BTS to the most distant CPE	≤ 0.05 ms (typically much less)
Maximum rain attenuation	30 dB
Maximum rain fade rate	5 dB/s
Main transmission mechanism	Line-of-sight (LoS)

2.3.1.1 Availability

Typical BWA network availability is considerably greater than 99%.

2.4 Transmission levels

Define P_{1dBc} as the 1 dB compression point of the power amplifier output. The precise output power value will depend on specific link engineering.

Parameters	Value (dBm)
BTS transmit output power P_{1dBc}	>15
CPE transmit output power P_{1dBc}	>15

2.5 Power control requirements

No transmit power control is assumed in the downstream direction. Transmit power control is required in the upstream direction.

2.6 BER vs. *S*/*N* specifications

Due to various symbol rates allowed for the upstream and downstream directions, it is more convenient to specify BER versus *S*/*N*. The receive signal level threshold at a particular BER can be decided once the symbol rate and the receiver noise figure are known. The BER vs. *S*/*N* curves are shown in Figs. 3 to 5 for QPSK (4-QAM), 16-QAM and 64-QAM. Raw BER refers to BER without any FEC. BER with RS (204,188) is shown as an example.

2.7 Frequency inversion

Frequency inversion must be allowed in the transmission path in either the downstream or upstream direction. The modems should have the capability of correcting frequency inversions in the upstream and downstream paths.

FIGURE 3

BER vs. *S*/*N* performance for 64-QAM

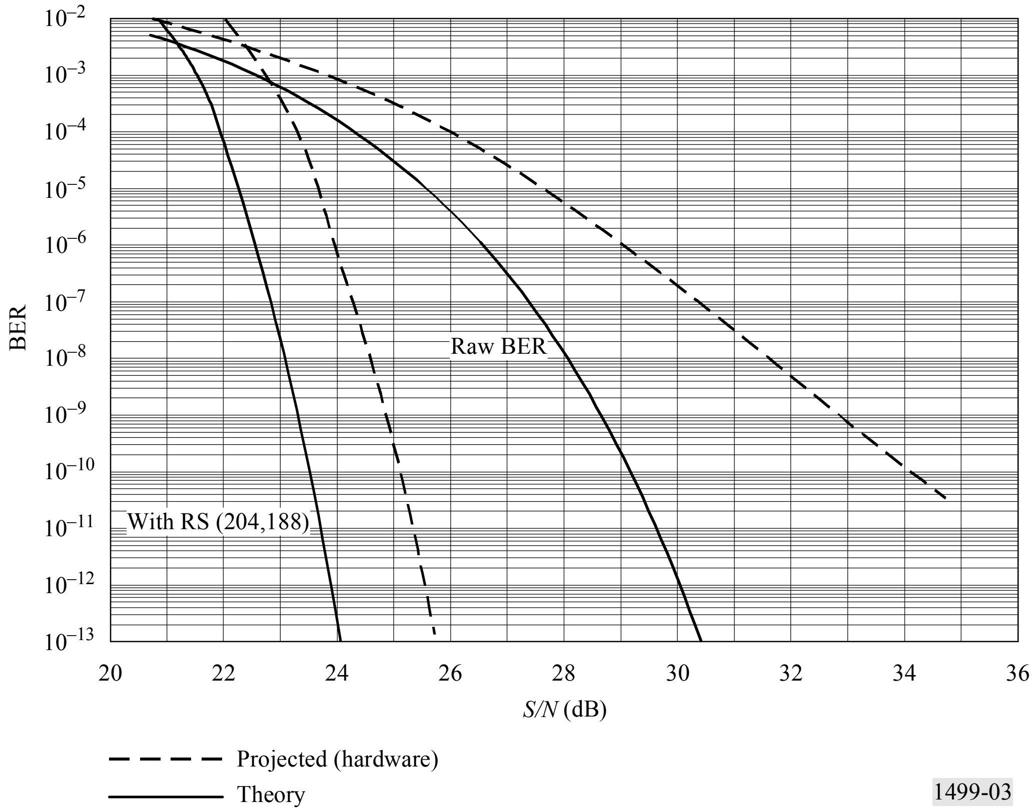


FIGURE 4

BER vs. *S*/*N* performance for 16-QAM

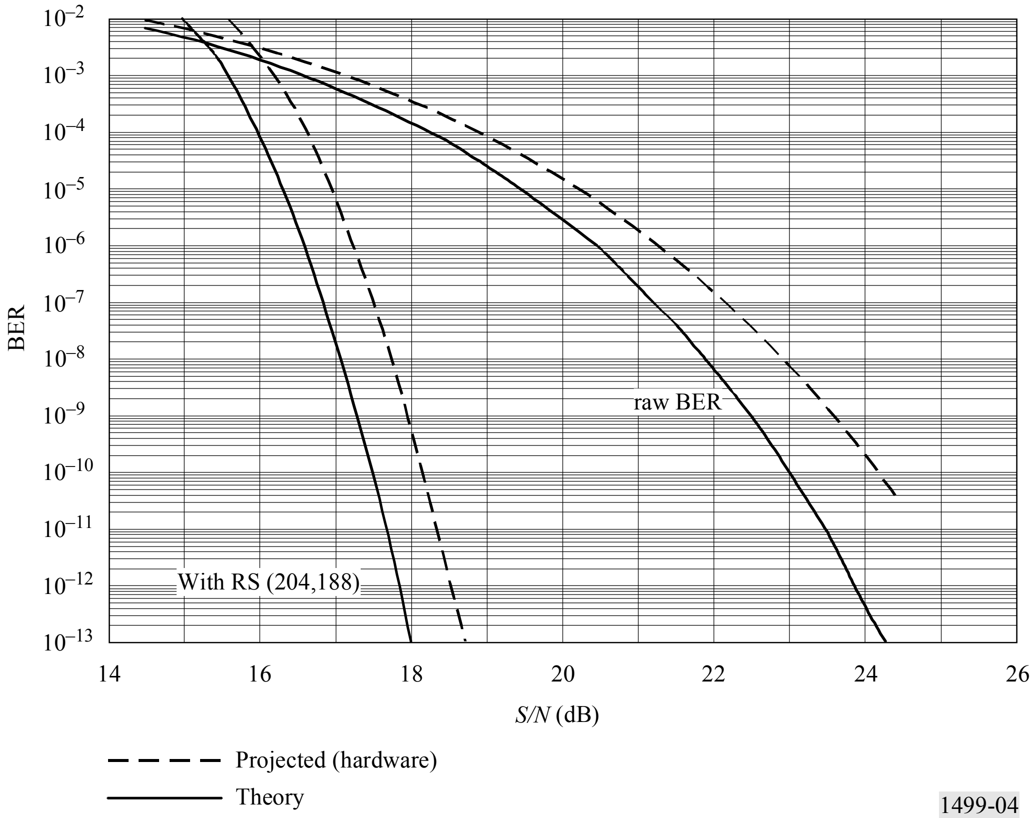
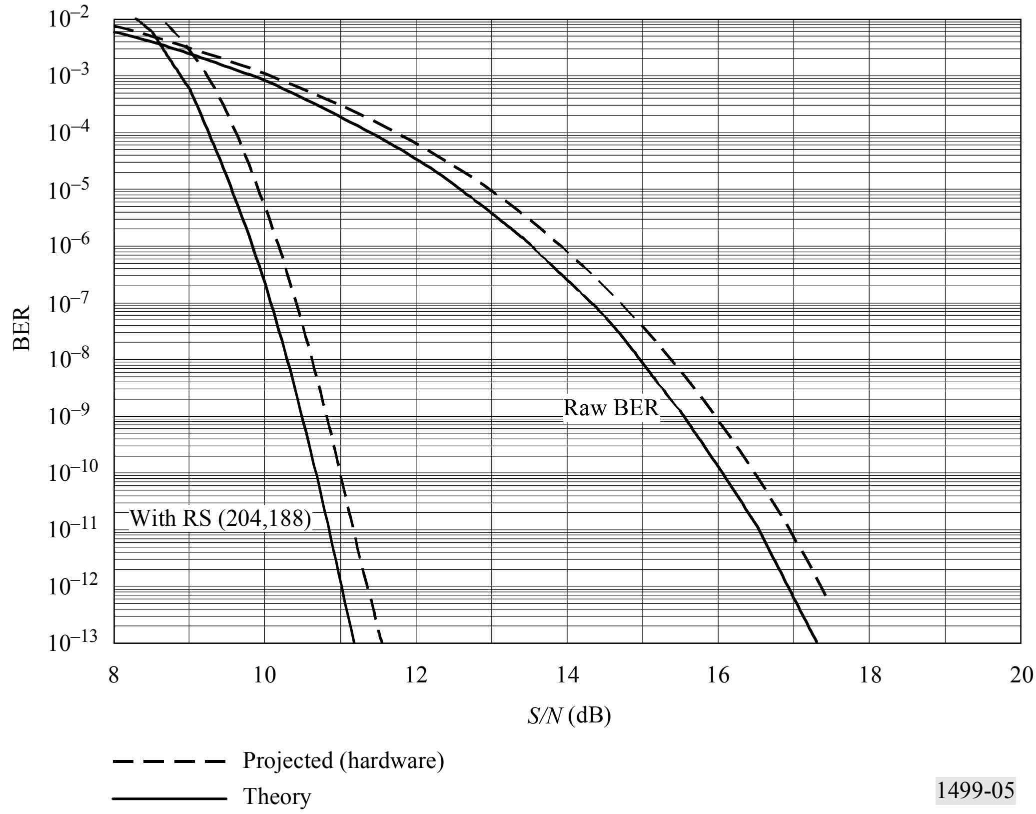


FIGURE 5

BER vs. *S*/*N* performance for QPSK (4-QAM)



3 Communication protocols

This section provides a high-level overview of the communication protocols that MUST be used in the data-over-BWA system. Detailed specifications for the physical media dependent, downstream transmission, and MAC sublayers are provided in § 4, 5 and 6 respectively.

3.1 Protocol stack

The BWA CPE modem and BWA BTS modem operate as forwarding agents and also as end-systems (hosts). The protocol stacks used in these modes differ as shown below.

The principle function of the BWA CPE modem system is to transmit IP packets transparently between the BWA fixed network side and the subscriber location. Certain management functions also ride on IP, so that the protocol stack on the BWA network is as shown in Fig. 6 (this does not restrict the generality of IP transparency between the BWA fixed network and the customer). These management functions include, for example, supporting spectrum management functions and the downloading of software.

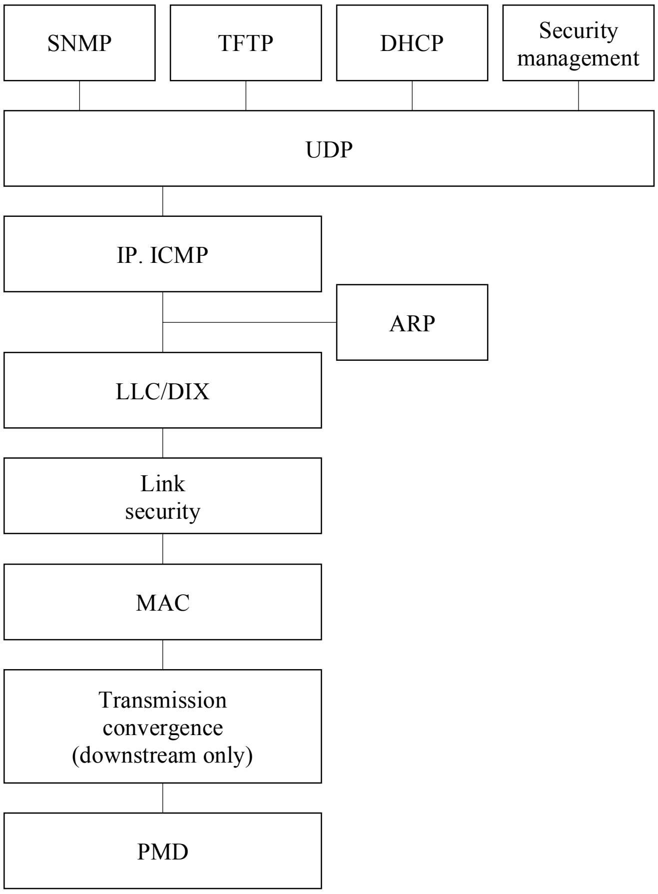
3.1.1 BWA CPE and BWA BTS modems as hosts

The BWA CPE and BWA BTS modems will operate as IP and LLC hosts in terms of IEEE Standard 802 IEEE 802 for communication over the BWA network. The protocol stack at the BWA CPE modem and BWA BTS modem over-the-air interfaces is shown in Fig. 6.

The BWA CPE modem and BWA BTS modem MUST function as IP hosts. As such, the BWA CPE modem and BWA BTS modem MUST support IP and ARP over DIX link-layer framing (see DIX). The BWA CPE modem and BWA BTS modem MAY also support IP and ARP over SNAP framing RFC-1042.

FIGURE 6

Protocol stack on the over-the-air interface



DIX: data interface transmitter

1499-06

The BWA CPE modem and BWA BTS modem also MUST function as LLC hosts. As such, the BWA CPE modem and BWA BTS modem MUST respond appropriately to TEST and exchange identification (XID) requests per ISO/IEC 8802-2.

3.1.2 Data forwarding through the BWA CPE and BTS modems

3.1.2.1 General

Data forwarding through the BWA BTS modem MAY be transparent bridging, or MAY employ network-layer forwarding (routing, IP switching) as shown in Fig. 7.

Data forwarding through the BWA CPE modem is link-layer transparent bridging, as shown in Fig. 7. Forwarding rules are similar to ISO/IEC 10038 with the modifications described in § 3.1.2.2 and 3.1.2.3. This allows the support of multiple network layers.

Forwarding of IP traffic MUST be supported. Support of other network layer protocols is OPTIONAL. The ability to restrict the network layer to a single protocol such as IP is REQUIRED.

Support for the 802.1d spanning tree protocol of ISO/IEC 10038 with the modifications described in § 3.1.2.3 is OPTIONAL for CPE modems intended for residential use. CPE modems intended for commercial use and bridging BTS modems MUST support this version of spanning tree. The CPE modem and BTS modem MUST include the ability to filter (and disregard) 802.1d BPDUs.

This specification assumes the CPE modems intended for residential use will not be connected in a configuration which would create network loops such as that shown in Fig. 8.

FIGURE 7

Data forwarding through the BWA CPE modem and the BWA BTS modem

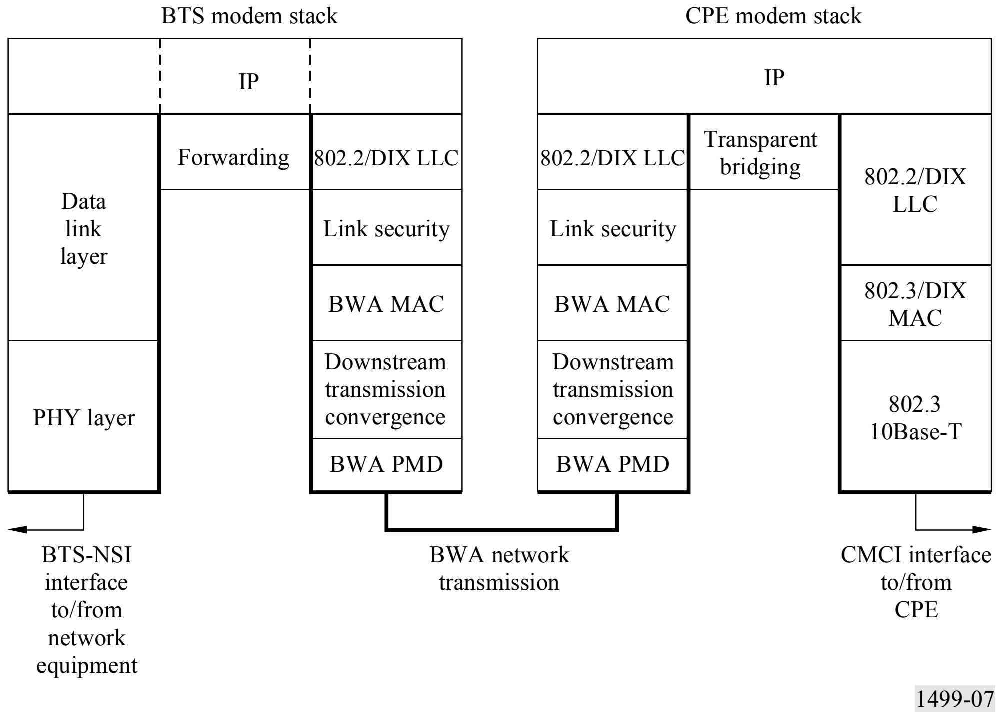
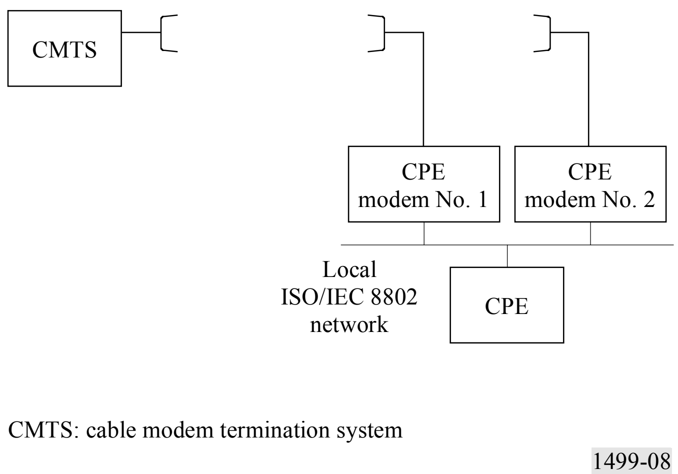


FIGURE 8

Example condition for network loops



3.1.2.2 BWA BTS modem forwarding rules

At the BWA BTS modem, if link-layer forwarding is used, then it MUST conform to the following general 802.1d guidelines:

– link-layer frames between a given pair of end-stations MUST be delivered in order;

– link-layer frames MUST NOT be duplicated;

– stale frames (those that cannot be delivered in a timely fashion) MUST be discarded.

The address-learning and address-aging mechanisms used are vendor-dependent.

If network-layer forwarding is used, then the BWA BTS modem should conform to IETF Router Requirements RFC-1812 with respect to its BWA BTS modem-RFI and BWA BTS modem-NSI interfaces.

Conceptually, the BWA BTS modem forwards data packets at two abstract interfaces: between the BWA BTS modem-RFI and the BWA BTS modem-NSI, and between the upstream and downstream channels. The BWA BTS modem MAY use any combination of link-layer (bridging) and network-layer (routing) semantics at each of these interfaces. The methods used at the two interfaces need not be the same.

Forwarding between the upstream and downstream channels within a MAC layer differs from traditional LAN forwarding in that:

– a single channel is simplex, and cannot be considered a complete interface for most protocol (e.g. 802.1d spanning tree, RIP per RFC-1058) purposes;

– upstream channels are essentially point-to-point, whereas downstream channels are shared-media;

– as a public network, policy decisions may override full connectivity.

For these reasons, an abstract entity called the MAC forwarder exists within the BWA BTS modem to provide connectivity between stations within a MAC domain (see § 3.2).

3.1.2.3 BWA CPE modem forwarding rules

Data forwarding through the BWA CPE modem is link-layer bridging with the following specific rules.

3.1.2.3.1 Address learning

– The BWA CPE modem MUST acquire Ethernet MAC addresses of connected CPE devices, either from the provisioning process or from learning, until the BWA CPE modem acquires its maximum number of CPE addresses (a device-dependent value). Once the BWA CPE modem acquires its maximum number of CPE addresses, then newly discovered CPE addresses MUST NOT replace previously acquired addresses. The BWA CPE modem must support acquisition of at least one CPE address.

– The BWA CPE modem MUST allow configuration of CPE addresses during the provisioning process (up to its maximum number of CPE addresses) to support configurations in which learning is not practical nor desired.

– Addresses provided during the BWA CPE modem provisioning MUST take preference over learned addresses.

– CPE addresses MUST NOT be aged out.

– On a BWA CPE modem reset (e.g. a power cycle), all learned and provisioned addresses MUST be discarded (they are not retained in non-volatile storage, to allow modification of user MAC addresses or movement of the BWA CPE modem). However, a BWA CPE modem MAY retain any provisioned addresses over a reset.

3.1.2.3.2 Forwarding

BWA CPE modem forwarding in both directions MUST conform to the following general 802.1d guidelines:

– link-layer frames between a given pair of end-stations MUST be delivered in order;

– link-layer frames MUST NOT be duplicated;

– stale frames (those that cannot be delivered in a timely fashion) MUST be discarded.

BWA-network-to-Ethernet forwarding MUST follow the following specific rules:

– frames addressed to unknown destinations MUST NOT be forwarded from the BWA port to the Ethernet port;

– broadcast frames MUST be forwarded to the Ethernet port;

– multicast frames MUST be forwarded to the Ethernet ports in accordance with filtering configuration settings specified by the BWA system operator's operations and business support systems.

Ethernet-to-BWA network forwarding MUST follow the following specific rules:

– frames addressed to unknown destinations MUST be forwarded from the Ethernet port to the CPE modem port;

– broadcast frames MUST be forwarded to the CPE modem port;

– multicast frames MUST be forwarded to the CPE modem port in accordance with filtering configuration settings specified by the BWA system operator's operations and business support systems;

– frames from source addresses other than those provisioned or learned as supported CPE devices MUST NOT be forwarded;

– if a single-user BWA CPE modem has learned a supported address, it MUST NOT forward data from a second source. Other (non-supported) CPE source addresses MUST be learned from the Ethernet port and this information used to filter local traffic as in a traditional learning bridge;

– if a single-user BWA CPE modem has learned A as its supported CPE device and learned B as a second device connected to the Ethernet port, it MUST filter any traffic from A to B.

3.2 The MAC forwarder

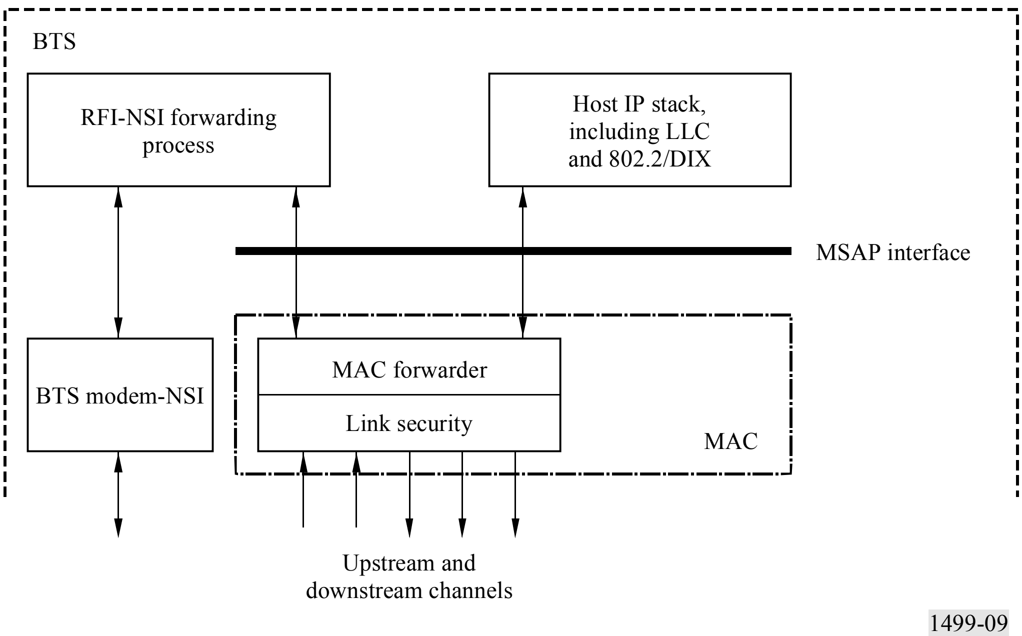
The MAC forwarder is a MAC sublayer that resides on the BWA BTS modem just below the MSAP interface, as shown in Fig. 9. It is responsible for delivering upstream frames to:

– one or more downstream channels;

– the MSAP interfaces.

FIGURE 9

MAC forwarder



In Fig. 9, the LLC sublayer and link security sublayers of the upstream and downstream channels on the BWA network terminate at the MAC forwarder.

The MSAP interface user MAY be the RFI-NSI forwarding process of the BWA BTS modem's host protocol stack.

Delivery of frames may be based on data-link layer (bridging) semantics, network-layer (routing) semantics, or some combination. Higher-layer semantics may also be employed (e.g. filters on UDP port numbers). The BWA BTS modem MUST provide IP connectivity between hosts attached to BWA CPE modems, and must do so in a way that meets the expectations of Ethernet-attached customer equipment. For example, the BWA BTS modem must either forward ARP packets or it must facilitate a proxy ARP service. The BWA BTS modem MAC forwarder MAY provide service for non-IP protocols.

Note that there is no requirement that all upstream and downstream channels be aggregated under one MSAP as shown above. The vendor could just as well choose to implement multiple MSAPs, each with a single upstream and downstream channel.

3.2.1 Example rules for data-link-layer forwarding

If the MAC forwarder is implemented using only data-link semantics, then the requirements in this section apply.

Delivery of frames is dependent on the DA within the frame. The means of learning the location of each address is vendor-dependent, and MAY include:

– transparent-bridging-like-source-address learning and aging;

– gleaning from MAC registration request messages;

– administrative means.

If the destination address of a frame is unicast, and that address is associated with a particular downstream channel, then the frame MUST be forwarded to that channel (see Note 1).

If the destination address of a frame is unicast, and that address is known to reside on the other (upper) side of the MSAP interface, then the frame MUST be delivered to the MSAP interface.

If the destination address is broadcast, multicast (see Note 2), or unknown, the frame MUST BE delivered to both the MSAP and to all downstream channels.

Delivery rules are similar to those for transparent bridging:

– frames from a specific source to a particular destination MUST be delivered in order;

– frames MUST NOT be duplicated;

– frames that cannot be delivered in a timely fashion MUST be discarded;

– the frame check sequence SHOULD be preserved rather than regenerated.

NOTE 1 – Vendors may implement extensions, similar to static addresses in 802.1d/ISO/IEC 10038 bridging, that cause such frames to be filtered or handled in some other manner.

NOTE 2 – The all-BTS multicast address (see Recommendation ITU-T J.116, Annex B) is an exception. 802.1d/ISO/IEC 10038 spanning tree bridge PDUs must be forwarded.

3.3 Network layer

As stated above, the purpose of the data-over-BWA system is to transport IP traffic transparently through the system.

The network layer protocol is the IP version 4, as defined in RFC-791, and migrating to IP version 6.

This Recommendation imposes no requirements for reassembly of IP packets.

3.4 Above the network layer

The subscribers will be able to use the transparent IP capability as a bearer for higher-layer services. Use of these services will be transparent to the CPE modem.

In addition to the transport of user data, there are several network management and operation capabilities which depend upon the network layer. These include:

– SNMP (RFC-1157), for network management;

– TFTP (RFC-1350), a file transfer protocol, for downloading software and configuration information;

– DHCP (DHCP RFC-1541), a framework for passing configuration information to hosts on a TCP/IP network;

– a security management protocol as defined in MCNS2 (see Annex 1).

3.5 Data link layer

The data link layer is divided into sublayers in accordance with IEEE 802, with the addition of link-layer security in accordance with MCNS2 (see Annex 1). The sublayers, from the top, are:

– LLC sublayer (Class 1 only);

– link-layer security sublayer;

– MAC sublayer.

3.5.1 LLC sublayer

The LLC sublayer MUST be provided in accordance with ISO/IEC 10039. Address resolution MUST be used as defined in RFC-826. The MAC-to-LLC service definition is specified in ISO/IEC 10039.

3.5.2 Link-layer security sublayer

Link-layer security MUST be provided in accordance with MCNS2 (see Annex 1) and MCNS8 (see Annex 1).

3.5.3 MAC sublayer

The definition, in detail, of the MAC sublayer and associated interfaces is provided in ITU-T Recommendation J.116, Annex B.

The MAC sublayer defines a single transmitter for each downstream channel – the BWA BTS modem. All BWA CPE modems listen to all frames transmitted on the downstream channel upon which they are registered and accept those where the destinations match the BWA CPE modem itself or CPEs reached via the BWA modem to CPE interface port. BWA CPE modems can communicate with other BWA CPE modems only through the BWA BTS modem.

The upstream channel is characterized by many transmitters (BWA CPE modems) and one receiver (the BWA BTS modem). Time in the upstream channel is slotted, providing for TDMA at regulated time ticks. The BWA BTS modem provides the time reference and controls the allowed usage for each interval. Intervals may be granted for transmissions by particular BWA CPE modems, or for contention by all BWA CPE modems. BWA CPE modems may contend to request transmission time. To a limited extent, BWA CPE modems may also contend to transmit actual data. In both cases, collisions can occur and retries are used.

ITU-T Recommendation J.116, Annex B describes the MAC-sublayer messages from the BWA BTS modem which direct the behaviour of the s on the upstream channel, as well as messaging from the BWA CPE modem to the BWA BTS modem.

3.5.3.1 Overview

Some of the MAC protocol highlights include:

– bandwidth allocation controlled by BWA BTS modem;

– a stream of mini-slots in the upstream;

– dynamic mix of contention- and reservation-based upstream transmit opportunities;

– bandwidth efficiency through support of variable-length packets;

– extensions provided for future support of ATM or other data PDU;

– class-of-service support;

– extensions provided for security as well as virtual LANs at the data link layer;

– support for a wide range of data rates.

3.5.3.2 MAC service definition

The MAC sublayer service definition is specified in ITU-T Recommendation J.116, Annex B.

3.6 PHY layer

The PHY layer is comprised of two sublayers:

– transmission convergence sublayer (present in the downstream direction only);

– PMD sublayer.

3.6.1 Downstream transmission convergence sublayer

The downstream transmission convergence sublayer exists in the downstream direction only. It provides an opportunity for additional services over the physical-layer bitstream. These additional services might include, for example, digital video. Definition of any such additional services is beyond the scope of this Recommendation.

This sublayer is defined as a continuous series of 188-byte MPEG ITU-T Recommendation H.222.0 packets, each consisting of a 4-byte header followed by 184 bytes of payload. The header identifies the payload as belonging to the data-over-BWA MAC. Other values of the header may indicate other payloads. The mixture of payloads is arbitrary and controlled by the BWA BTS modem.

The downstream transmission convergence sublayer is defined in § 5.

3.6.2 PMD sublayer

3.6.2.1 Overview

The PMD sublayer involves digitally modulated RF carriers over-the-air.

In the downstream direction, the PMD sublayer is based on ITU-T Recommendation J.83, with the exceptions called out in § 4.3, and includes these features:

– QPSK, 16- and 64-QAM modulation formats;

– up to 40 MHz occupied spectrum;

– RS block code and Trellis code defined per ITU-T Recommendation J.83;

– variable-depth interleaver supports both latency-sensitive and -insensitive data defined per ITU-T Recommendation J.83.

The features in the upstream direction are as follows:

– flexible and programmable BWA CPE modem under control of the BWA BTS modem;

– frequency agility;

– TDMA;

– QPSK and 16-QAM modulation formats;

– support of both fixed-frame and variable-length PDU formats;

– multiple symbol rates;

– programmable RS block coding;

– programmable preambles.

3.6.2.2 Interface points

Three RF interface points are defined at the PMD sublayer:

– downstream output on the BWA BTS modem;

– upstream input on the BWA BTS modem;

– CPE modem in/out at the BWA CPE modem.

Separate downstream output and upstream input interfaces on the BWA BTS modem are required for compatibility with typical downstream and upstream signal combining and splitting arrangements in BWA system.

4 PMD sublayer specification

4.1 Scope

This specification defines the electrical characteristics and protocol for a BWA CPE modem and BWA BTS modem. It is the intent of this specification to define an interoperable BWA CPE modem and BWA BTS modem such that any implementation of a BWA CPE modem can work with any BWA BTS modem. It is not the intent of this specification to imply any specific implementation.

4.2 Upstream

4.2.1 Overview

The upstream PMD sublayer uses a FDMA/TDMA burst modulation format, which provides variable symbol rates and two modulation formats (QPSK and 16-QAM). The modulation format includes pulse shaping for spectral efficiency, is carrier-frequency agile, and has selectable output power level. The PMD sublayer format includes a variable-length modulated burst with precise timing beginning at boundaries spaced at integer multiples of 6.25 μs apart.

Each burst supports a flexible modulation, symbol rate, preamble, randomization of the payload, and programmable FEC encoding.

All of the upstream transmission parameters associated with burst transmission outputs from the BWA CPE modem are configurable by the BWA BTS modem via MAC messaging. Many of the parameters are programmable on a burst-by-burst basis.

The PMD sublayer can support a near-continuous mode of transmission, wherein ramp-down of one burst MAY overlap the ramp-up of the following burst, so that the transmitted envelope is never zero. The system timing of the TDMA transmissions from the various BWA CPE modem MUST provide that the centre of the last symbol of one burst and the centre of the first symbol of the preamble of an immediately following burst are separated by at least the duration of several symbols. The guard time MUST be greater than or equal to the duration of five symbols plus the maximum timing error. Timing error is contributed by both the BWA CPE modem and BWA BTS modem. BWA CPE modem timing performance is specified in § 4. Maximum timing error and guard time may vary with BWA BTS modem from different vendors.

The upstream modulator is part of the BWA CPE modem which interfaces with the BWA network. The modulator contains the actual electrical-level modulation function and the digital signal-processing function; the latter provides the FEC, preamble prepend, symbol mapping, and other processing steps. This specification is written with the idea of buffering the bursts in the signal processing portion, and with the signal processing portion:

– accepting the information stream a burst at a time,

– processing this stream into a complete burst of symbols for the modulator, and

– feeding the properly-timed bursted symbol stream to a memoryless modulator at the exact burst transmit time.

The memoryless portion of the modulator only performs pulse shaping and quadrature upconversion.

At the demodulator, similar to the modulator, there are two basic functional components: the demodulation function and the signal processing function. Unlike the modulator, the demodulator resides in the BWA BTS modem and the specification is written with the concept that there will be one demodulation function (not necessarily an actual physical demodulator) for each carrier frequency in use. The demodulation function would receive all bursts on a given frequency.

NOTE 1 – The unit design approach should be cognizant of the multiple-channel nature of the demodulation and signal processing to be carried out at the headend, and partition/share functionality appropriately to optimally leverage the multi-channel application. A demodulator design supporting multiple channels in a demodulator unit may be appropriate.

The demodulation function of the demodulator accepts a varying-level signal centred around a commanded power level and performs symbol timing and carrier recovery and tracking, burst acquisition, and demodulation. Additionally, the demodulation function provides an estimate of burst timing relative to a reference edge, an estimate of received signal power, an estimate of *S*/*N*, and may engage adaptive equalization to mitigate the effects of multipath and IF circuit distortion. The signal-processing function of the demodulator performs the inverse processing of the signal-processing function of the modulator. This includes accepting the demodulated burst data stream and decoding, etc., and possibly multiplexing the data from multiple channels into a single output stream. The signal-processing function also provides the edge-timing reference and gating-enable signal to the demodulators to activate the burst acquisition for each assigned burst slot. The signal-processing function may also provide an indication of successful decoding, decoding error, or fail-to-decode for each codeword and the number of corrected RS symbols in each codeword.

4.2.2 Modulation formats

The upstream modulator MUST provide both QPSK and optionally 16-QAM and/or 64-QAM modulation formats.

The upstream demodulator MUST support QPSK, and optionally 16-QAM and/or 64-QAM.

4.2.2.1 Modulation rates

The upstream modulator MUST provide QPSK and the symbol rate must be selected from the following list: 160, 320, 640, 1 280, 2 560, 5 120, 10 240 and 20 480 ksymbols/s. The upstream modulator optional should provide 16-QAM and/or 64-QAM and the symbol rate must be selected from the following list: 160, 320, 640, 1 280, 2 560, 5 120, 10 240 and 20 480 ksymbols/s.

The upstream symbol rate MUST be fixed for each upstream frequency.

4.2.2.2 Symbol mapping

The modulation mode (QPSK or 16-QAM or 64-QAM) should be programmable. The symbols transmitted in each mode and the mapping of the input bits to the I and Q constellation MUST be as defined in Table 2. In the Table, I_1 is the MSB of the symbol map, Q_1 is the LSB for QPSK, and Q_0 is the LSB for 16-QAM. Q_1 and I_0 have intermediate bit positions in 16-QAM. The MSB MUST be the first bit in the serial data into the symbol mapper.

TABLE 2

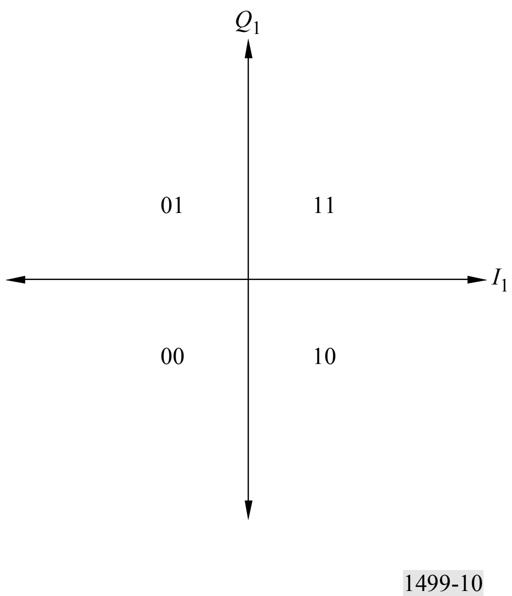
***I*/*Q* mapping**

QAM mode	Input bit definitions
QPSK	I_1 Q_1
16-QAM	I_1 Q_1 I_0 Q_0

The upstream QPSK symbol mapping MUST be as shown in Fig. 10.

FIGURE 10

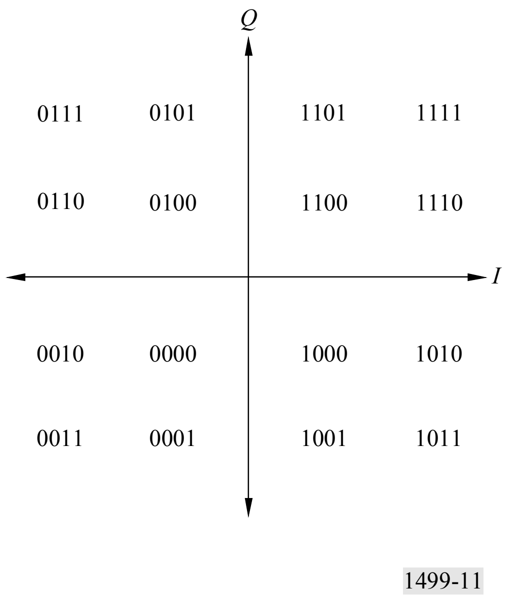
QPSK symbol mapping



The 16-QAM non-inverted (Gray-coded) symbol mapping MUST be as shown in Fig. 11.

FIGURE 11

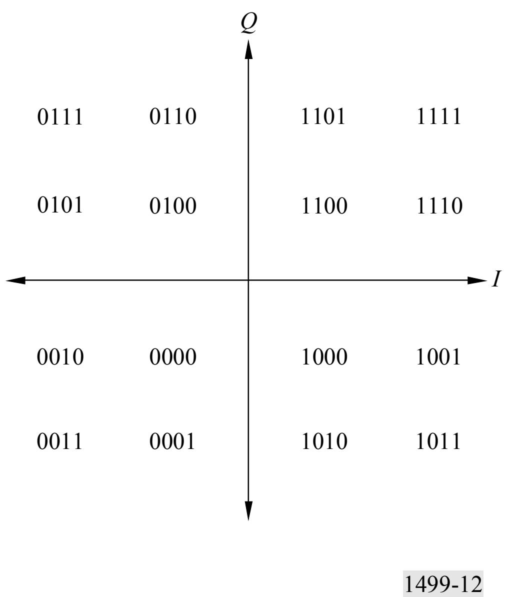
16-QAM Gray-coded symbol mapping



The 16-QAM differential symbol mapping MUST be as shown in Fig. 12.

FIGURE 12

16-QAM differential-coded symbol mapping



If differential quadrant encoding is enabled, then the currently-transmitted symbol quadrant is derived from the previously transmitted symbol quadrant and the current input bits via Table 3.

TABLE 3

Derivation of currently transmitted symbol quadrant

Current input bits *I*(1) *Q*(1)	Quadrant phase change (degrees)	MSBs of previously transmitted symbol	MSBs for currently transmitted symbol
00	0	11	11
00	0	01	01
00	0	00	00
00	0	10	10
01	90	11	01
01	90	01	00
01	90	00	10
01	90	10	11
11	180	11	00
11	180	01	10
11	180	00	11
11	180	10	01
10	270	11	10
10	270	01	11
10	270	00	01
10	270	10	00

4.2.2.3 Spectral shaping

The upstream PMD sublayer MUST support a 25% Nyquist square root raised cosine shaping.

The occupied spectrum MUST NOT exceed the channel widths shown in Table 4.

TABLE 4

Maximum channel width

Symbol rate (ksymbols/s)	Channel width (kHz)[(1)]
160	200
320	400
640	800
1 280	1 600
2 560	3 200
5 120	6 400
10 240	13 000
20 480	26 000

(1) Channel width is the –30 dB bandwidth.

4.2.2.4 Upstream frequency agility and range

The upstream PMD sublayer MUST support operation over the frequency range of 2.5-40 GHz edge to edge.

Offset frequency resolution MUST be supported having a range of ±350 kHz.

4.2.2.5 Spectrum format

The upstream modulator MUST provide operation with the format $s(t) = I(t) * \cos(\omega t) \pm Q(t) * \sin(\omega t)$, where t denotes time and ω denotes angular frequency.

4.2.3 FEC encode

The upstream modulator MUST be able to provide the following selections: RS codes over GF(256) with $T = 1$ to 10 or no FEC coding.

The RS generator polynomial MUST be supported:

$$g(x) = (x + \alpha^0)(x + \alpha^1)(x + \alpha^{2T-1})$$

The RS primitive polynomial MUST be supported:

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

The upstream modulator MUST provide codewords from 3 to 255 bytes in size. The uncoded word size can have a minimum of one byte.

In shortened last codeword mode, the BWA CPE modem MUST provide the last codeword of a burst shortened from the assigned length of k data bytes per codeword as described in § 4.2.10.1.2.

The value of T MUST be configured in response to the UCD from the BWA BTS modem.

4.2.4 Scrambler (randomizer)

The upstream modulator MUST implement a scrambler (shown in Fig. 13) where the 15-bit seed value MUST be arbitrarily programmable.

At the beginning of each burst, the register is cleared and the seed value is loaded. The seed value MUST be used to calculate the scrambler bit which is combined in an EXCLUSIVE OR (XOR) with the first bit of data of each burst (which is the MSB of the first symbol following the last symbol of the preamble).

The scrambler seed value MUST be configured in response to the UCD from the BWA BTS modem.

The polynomial MUST be $x^{15} + x^{14} + 1$.

4.2.5 Preamble prepend

The upstream PMD sublayer MUST support a variable-length preamble field that is prepended to the data after they have been randomized and RS encoded.

The value of the preamble that is prepended MUST be programmable and the length MUST be 0, 2, 4, ..., or 1 024 bits for QPSK and 0, 4, 8, ..., or 1 024 bits for 16-QAM. Thus, the maximum length of the preamble is 512 QPSK symbols or 256 QAM symbols.

The preamble length and value MUST be configured in response to the UCD message transmitted by the BWA BTS modem.

4.2.6 Burst profiles

The burst profiles are separated into two portions:

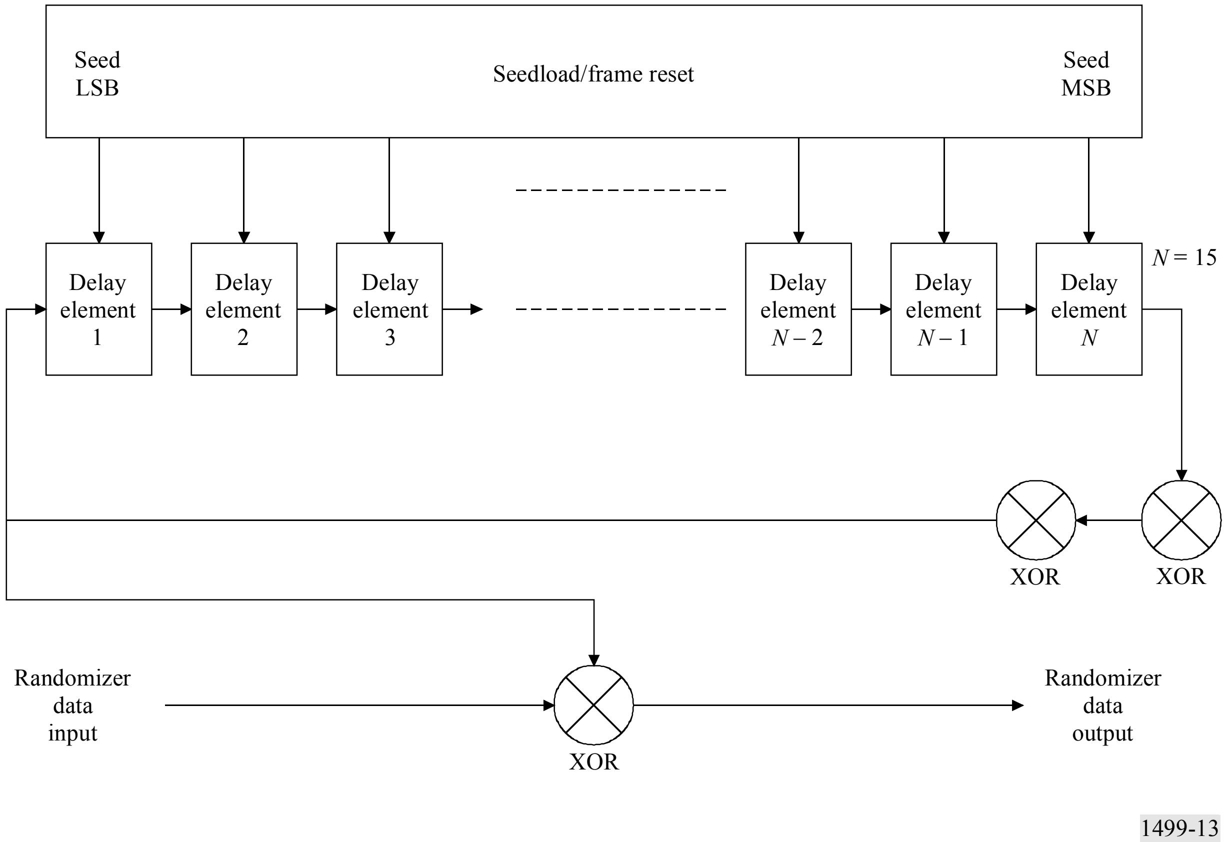
– channel burst parameters, which are common to all users assigned to a given channel using that burst type, and

– user unique parameters, which vary for each user even when using the same burst type on the same channel as another user (for example, power level).

In addition to these parameters, the assigned centre frequencies and mini-slot grants MUST also be provided by the BWA BTS modem.

FIGURE 13

Scrambler structure



The upstream PMD sublayer MUST support a minimum of four distinct burst profiles to be stored within the BWA CPE modem, with variable parameters as defined in Table 5. User unique parameters are defined in Table 6.

TABLE 5

Channel burst parameters

Parameter	Configuration settings
Modulation	QPSK, 16-QAM
Differential encoding	On/off
Symbol rate	8 configuration settings
Preamble length	0-1 024 bits (see § 4.2.5)
Preamble values	1 024 bits
FEC on/off	On/off
FEC codeword information bytes (*k*)	Fixed: 1 to 253 (assuming FEC on) Shortened: 16 to 253 (assuming FEC on)
FEC (*T* bytes)	0 to 10
Scrambler seed	15 bits
Burst length m mini-slots[(1)]	0 to 255
Last codeword length	Fixed, shortened
Guard time	5 to 255 symbols

(1) A burst length of 0 mini-slots in the channel profile means that the burst length is variable on that channel for that burst type. The burst length, while not fixed, is granted explicitly by the BWA BTS modem to the BWA CPE modem in the MAP.

TABLE 6

User unique burst parameters

Parameter	Configuration settings
Transmit power level(1) (minimum range) (at antenna flange)	–30 dBm to +20 dBm (QPSK), –27 dBm to +17 dBm (16-QAM), 1 dB steps
Offset frequency(1)	Range = ±350 kHz
Spectrum inversion	Normal, inverted
Ranging offset	0 to (2^{16} – 1), increments of 6.25 μs/64
Burst length (mini-slots) if variable on this channel (changes burst-to-burst)	1 to 255 mini-slots
Transmit equalizer coefficients(1) (advanced modems only)	Up to 64 coefficients; 4 bytes per coefficient: 2 real and 2 complex

(1) Values in Table apply for this given channel and symbol rate.

Ranging offset is the delay correction applied by the BWA CPE modem to the BWA BTS modem upstream frame time derived at the BWA CPE modem, in order to synchronize the upstream transmissions in the TDMA scheme. The ranging offset is an advancement equal to roughly the round-trip delay of the BWA CPE modem from the BWA BTS modem. The BWA BTS modem MUST provide feedback correction for this offset to the BWA CPE modem, based on reception of one or more successfully received bursts (i.e. satisfactory result from each technique employed: error correction and/or CRC), with accuracy within 1/2 symbol and resolution of 1/64 of the frame tick increment (6.25 μs/64 = 0.09765625 μs).

The BWA BTS modem sends adjustments to the BWA CPE modem, where a negative value implies the ranging offset is to be decreased, resulting in later times of transmission at the BWA CPE modem. The BWA CPE modem MUST implement the correction with resolution of at most 1 symbol duration (of the symbol rate in use for a given burst), and (other than a fixed bias) with accuracy within ±0.25 μs plus ±1/2 symbol owing to resolution. The accuracy of BWA CPE modem burst timing of ±0.25 μs plus ±1/2 symbol is relative to the mini-slot boundaries derivable at the BWA CPE modem based on an ideal processing of the timestamp signals received from the BWA BTS modem.

The BWA CPE modem MUST be capable of switching burst profiles with no reconfiguration time required between bursts except for changes in the following parameters:

– output power,

– modulation,

– symbol rate,

– offset frequency,

– channel frequency, and

– ranging offset.

For modulation, symbol rate, offset frequency and ranging offset, the BWA CPE modem MUST be able to transmit consecutive bursts as long as the BWA BTS modem allocates at least 25 symbols in between the last symbol centre of one burst and the first symbol centre of the following burst. The BWA CPE modem MUST implement, and have settled, changes in output power, modulation, symbol rate, or offset frequency 12.5 symbols or more before the symbol centre of the first symbol of a transmitted burst and 12.5 symbols or more after the symbol centre of the last symbol of a transmitted burst. Output power, modulation, symbol rate, offset frequency, channel frequency and ranging offset MUST NOT be changed until the BWA CPE modem is provided sufficient time between bursts by the BWA BTS modem.

If channel frequency is to be changed, then the BWA CPE modem MUST be able to implement the change between bursts as long as the BWA BTS modem allocates at least 25 symbols plus 100 ms between the last symbol centre of one burst and the first symbol centre of the following burst.

The channel frequency of the BWA CPE modem MUST be settled within the phase noise and accuracy requirements of § 4.2.9.5 and 4.2.9.6 within 100 ms from the beginning of the change.

If output power is to be changed by 1 dB or less, then the BWA CPE modem MUST be able to implement the change between bursts as long as the BWA BTS modem allocates at least 25 symbols plus 5 µs between the last symbol centre of one burst and the first symbol centre of the following burst.

If output power is to be changed by more than 1 dB, then the BWA CPE modem MUST be able to implement the change between bursts as long as the BWA BTS modem allocates at least 25 symbols plus 10 µs between the last symbol centre of one burst and the first symbol centre of the following burst.

The output power of the BWA CPE modem MUST be settled to within 0.1 dB of its final output power level:

– within 5 µs from the beginning of a change of 1 dB or less; and

– within 10 µs from the beginning of a change of greater than 1 dB.

The output transmit power MUST be maintained constant within a TDMA burst to within less than 0.1 dB (excluding the amount theoretically present due to pulse shaping, and amplitude modulation in the case of 16-QAM).

4.2.7 Burst timing convention

Figure 14 illustrates the nominal burst timing.

Figure 15 indicates worst-case burst timing. In this example, burst N arrives 1.5 symbols late, and burst $N + 1$ arrives 1.5 symbols early, but separation of 5 symbols is maintained; 8-symbol guardband shown.

At a symbol rate of R_S, symbols occur at a rate of one each $T_S = 1/R_S$ s. Ramp up and ramp down are the spread of a symbol in the time domain beyond T_S duration owing to the symbol-shaping filter. If only one symbol were transmitted, its duration would be longer than T_S due to the shaping filter impulse response being longer than T_S. The spread of the first and last symbols of a burst transmission effectively extends the duration of the burst to longer than $N \cdot T_S$, where N is the number of symbols in the burst.

4.2.8 Transmit power requirements

The upstream PMD sublayer MUST support varying the amount of transmit power. Requirements are presented for:

– the range of commanded transmit power;

– the step size of the power commands; and

– the accuracy (actual output power compared to the commanded amount) of the response to the command.

Power adjustments MUST be within the ranges of tolerances described below.

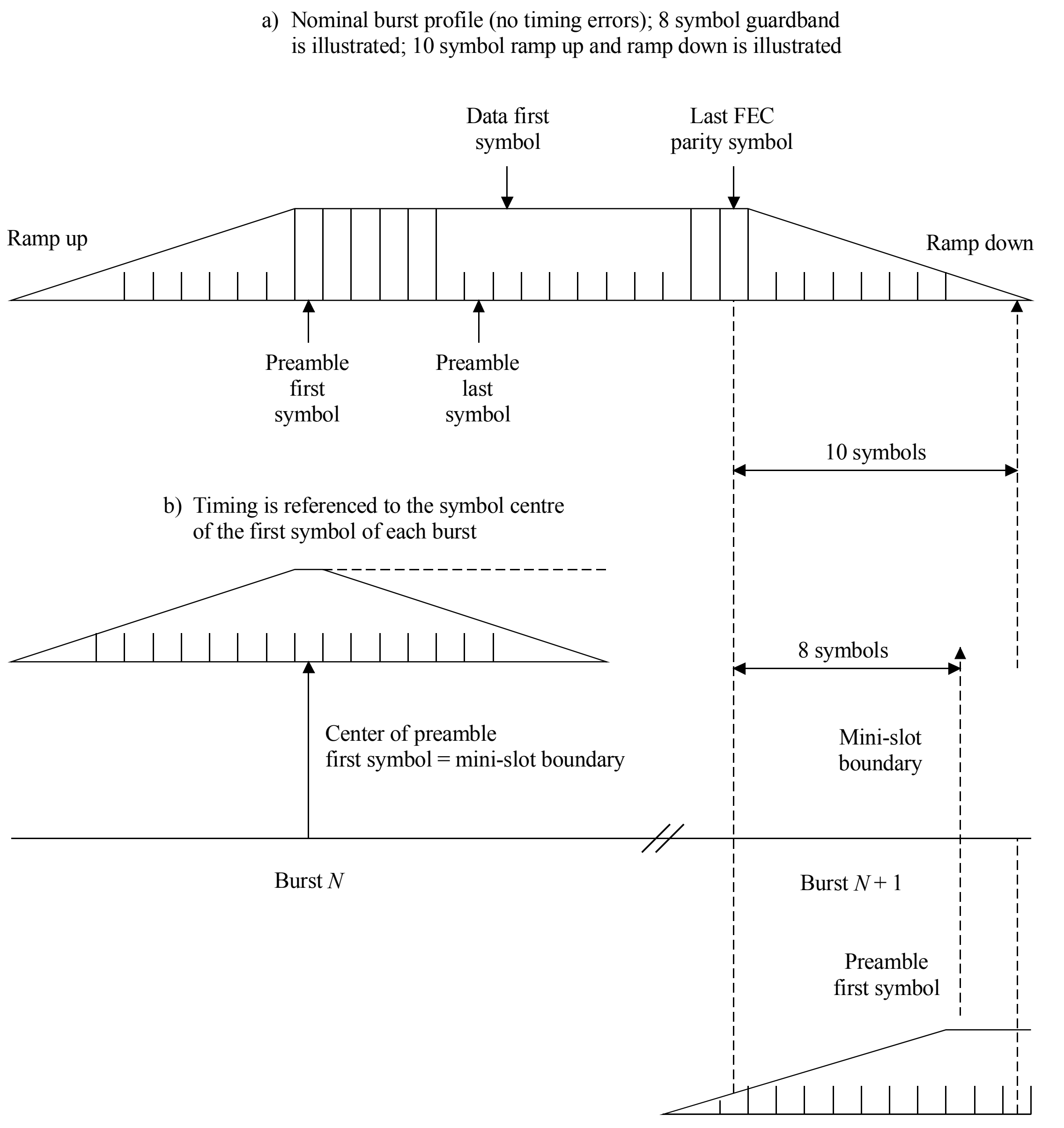
4.2.8.1 Output power agility and range

The output transmit power in the design bandwidth MUST be variable over the minimum range of –27 dBm to +17 dBm (16-QAM), –30 dBm to +20 dBm (QPSK), in 1 dB steps.

The absolute accuracy of the transmitted power MUST be ±2 dB, and step size accuracy ±0.4 dB. For example, the actual power increase resulting from a command to increase the power level by 1 dB in a BWA CPE modem's next transmitted burst MUST be between 0.6 dB and 1.4 dB.

FIGURE 14

Nominal burst timing



Note 1 – Ramp down of one burst can overlap ramp up of following burst even with one transmitter assigned both bursts.

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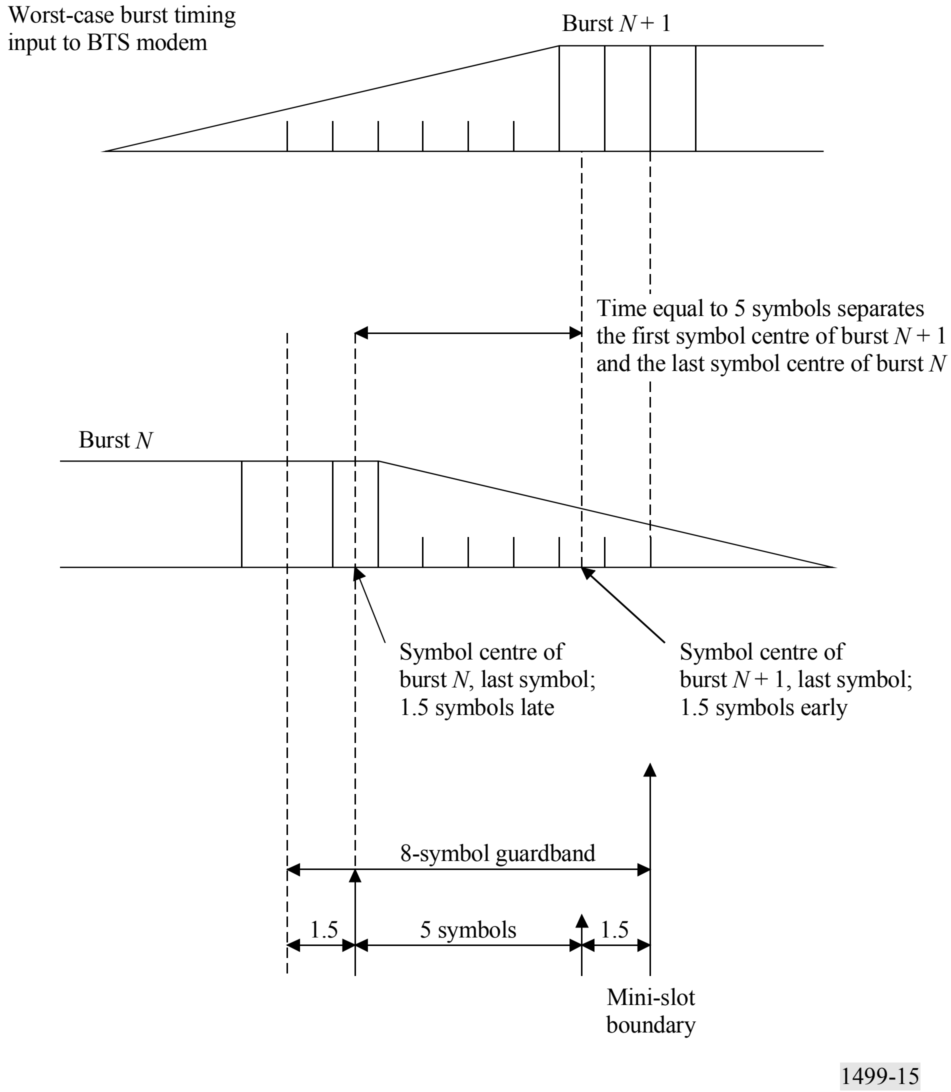
FIGURE 15

Worst-case burst timing



4.2.9 Fidelity requirements

4.2.9.1 Spurious emissions

The noise and spurious power MUST NOT exceed the levels given in Table 7. The measurement bandwidth is equal to the symbol rate (e.g. 160 kHz for 160 ksymbols/s) for the requirements. In addition to Table 7, the spurious emissions MUST meet local national and/or regional limits.

TABLE 7

Spurious emissions

Parameter	Transmitting burst (dBc)	Between bursts
Inband	–40	The greater of –72 dBc or –97 dBm
Adjacent band	–45	The greater of –72 dBc or –97 dBm

4.2.9.2 Spurious emissions during burst on/off transients

Each transmitter MUST control spurious emissions, prior to and during ramp up and during and following ramp down, before and after a burst in the TDMA scheme.

On/off spurious emissions, such as the change in voltage at the upstream transmitter output due to enabling or disabling transmission, MUST be no more than 100 mV, and such a step MUST be dissipated no faster than 2 μs of constant slewing. This requirement applies when the BWA CPE is transmitting at +20 dBm or more; at backed-off transmit levels, the maximum change in voltage MUST decrease by a factor of 2 for each 6 dB decrease of power level from +20 dBm, down to a maximum change of 7 mV at –4 dBm and below. This requirement does not apply to BWA CPE modem power-on and power-off transients.

4.2.9.3 BER

Overall modem performance MUST be within 1.5 dB of theoretical uncoded BER vs. C/N, at BER = 1×10^{-6}, for QPSK and 16-QAM.

4.2.9.4 Filter distortion

The following requirements assume that any pre-equalization is disabled.

4.2.9.4.1 Amplitude

The spectral mask MUST be the ideal square root raised cosine spectrum with α = 0.25, within the ranges given below:

$f_c - R_s/4$ Hz to $f_c + R_s/4$ Hz: –0.3 dB to + 0.3 dB

$f_c - 3R_s/8$ Hz to $f_c - R_s/4$ Hz, and $f_c + R_s/4$ Hz to $f_c + 3R_s/8$ Hz: –0.5 dB to 0.3 dB

$f_c - R_s/2$ Hz and $f_c + R_s/2$ Hz: –3.5 dB to –2.5 dB

$f_c - 5R_s/8$ Hz and $f_c + 5R_s/8$ Hz: no greater than –30 dB

where:

f_c: centre frequency

R_s: symbol rate.

4.2.9.4.2 Phase

$f_c - 5R_s/8$ Hz to $f_c + 5R_s/8$ Hz: group delay variation MUST NOT be greater than 100 ns.

4.2.9.5 Carrier phase noise

The upstream transmitter total integrated phase noise (including discrete spurious noise) MUST be less than or equal to –43 dBc summed over the spectral regions spanning 1 kHz to 1.6 MHz above and below the carrier.

4.2.9.6 Channel frequency accuracy

The BWA CPE MUST implement the assigned channel frequency within ±5 ppm over a temperature range of –40° to 75° C up to five years from date of manufacture.

4.2.9.7 Symbol rate accuracy

The upstream modulator MUST provide an absolute accuracy of symbol rates ±50 ppm over a temperature range of 0° to 40° C up to five years from date of manufacture.

4.2.9.8 Symbol timing jitter

Peak-to-peak symbol jitter, referenced to the previous symbol zero-crossing, of the transmitted waveform, MUST be less than 0.02 of the nominal symbol duration over a 2 s period. In other words, the difference between the maximum and the minimum symbol duration during the 2 s period shall be less than 0.02 of the nominal symbol duration for each of the eight upstream symbol rates.

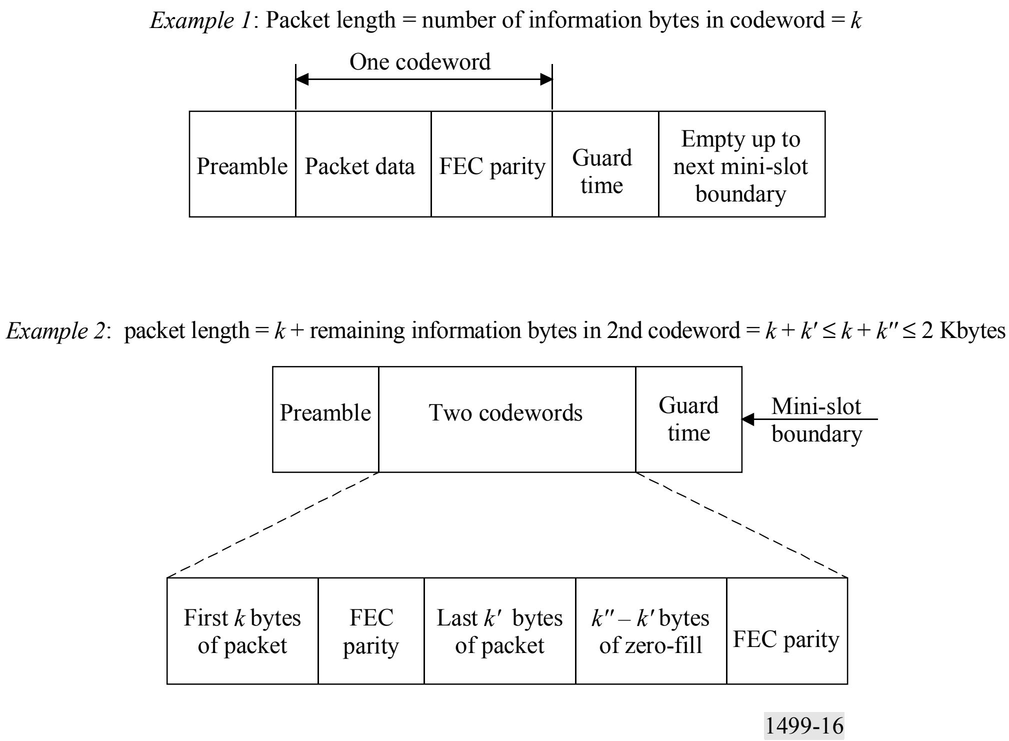
The peak-to-peak cumulative phase error, referenced to the first symbol time and with any fixed symbol frequency offset factored out, MUST be less than 0.04 of the nominal symbol duration over a 0.1 s period. In other words, the difference between the maximum and the minimum cumulative phase error during the 0.1 s period shall be less than 0.04 of the nominal symbol duration for each of the eight upstream symbol rates. Factoring out a fixed symbol frequency offset is to be done by using the computed mean symbol duration during the 0.1 s.

4.2.10 Frame structure

Figure 16 shows two examples of the frame structure: one where the packet length equals the number of information bytes in a codeword, and another where the packet length is longer than the number of information bytes in one codeword, but less than in two codewords. Example 1 illustrates the fixed codeword-length mode, and Example 2 illustrates the shortened last codeword mode. These modes are defined in § 4.2.10.1.

FIGURE 16

Example frame structures with flexible burst length mode



4.2.10.1 Codeword length

The BWA CPE modem operates in fixed-length codeword mode or with shortened codeword capability enabled. Shortened codeword capability is available with $k \geq 16$ bytes, where k is the number of information bytes in a codeword. With $k < 16$, shortened codeword capability is not available.

The following descriptions apply to an allocated grant of mini-slots in both contention and non-contention regions. (Allocation of mini-slots is discussed in § 6 of this Recommendation.) The intent of the description is to define rules and conventions such that BWA CPE modems request the proper number of mini-slots and the BWA BTS modem PHY knows what to expect regarding the FEC framing in both fixed codeword length and shortened last codeword modes.

4.2.10.1.1 Fixed codeword length

With the fixed-length codewords, after all the data are encoded, zero-fill will occur in this codeword if necessary to reach the assigned k data bytes per codeword, and zero-fill MUST continue up to the point when no additional fixed-length codewords can be inserted before the end of the last allocated mini-slot in the grant, accounting for FEC parity and guard-time symbols.

4.2.10.1.2 Shortened last codeword

As shown in Fig. 16, let k' = the number of information bytes that remain after partitioning the information bytes of the burst into full-length (k burst data bytes) codewords. The value of k' is less than k. Given operation in a shortened last codeword mode, let k'' = the number of burst data bytes plus zero-fill bytes in the shortened last codeword. In shortened codeword mode, the BWA CPE modem will encode the data bytes of the burst (including MAC header) using the assigned codeword size (k information bytes per codeword) until:

– all the data are encoded, or

– a remainder of data bytes is left over which is less than k.

Shortened last codewords shall not have less than 16 information bytes, and this is to be considered when BWA CPE modems make requests of mini-slots. In shortened last codeword mode, the BWA CPE modem will zero-fill data if necessary until the end of the mini-slot allocation, which in most cases will be the next mini-slot boundary, accounting for FEC parity and guard-time symbols. In many cases, only $k'' - k'$ zero-fill bytes are necessary to fill out a mini-slot allocation with $16 \leq k'' \leq k$ and $k' \leq k''$. However, note the following.

More generally, the BWA CPE modem is required to zero-fill data until the point when no additional fixed-length codewords can be inserted before the end of the last allocated mini-slot in the grant (accounting for FEC parity and guard-time symbols), and then, if possible, a shortened last codeword of zero-fill shall be inserted to fit into the mini-slot allocation.

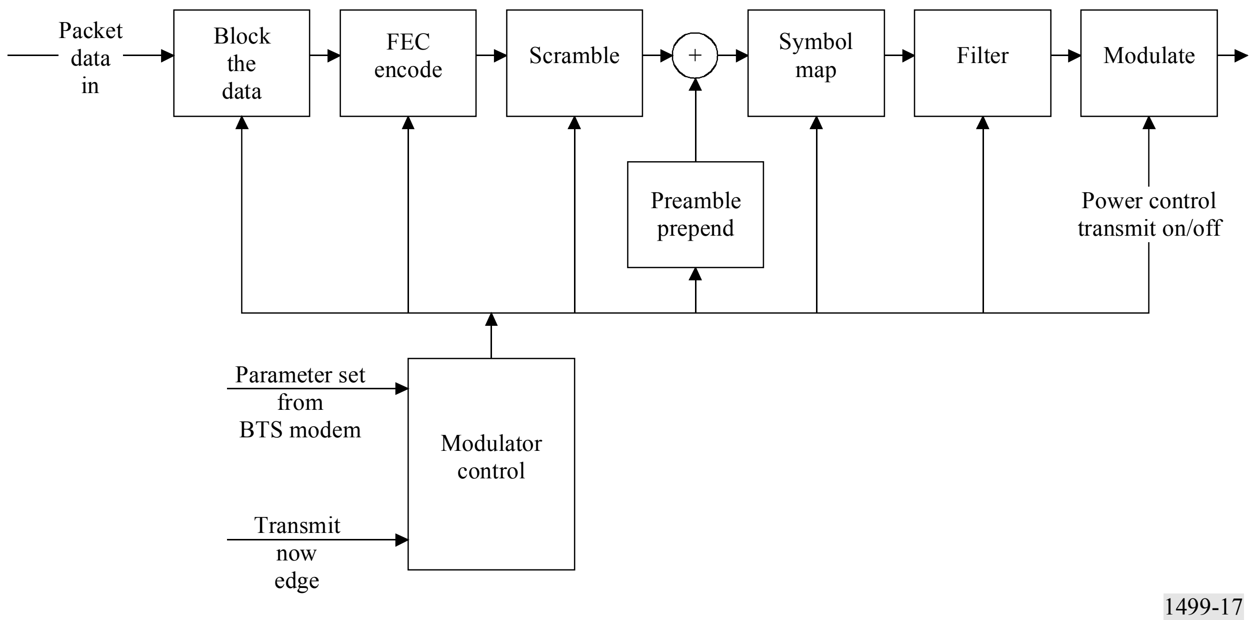
If, after zero-fill of additional codewords with k information bytes, there are less than 16 bytes remaining in the allocated grant of mini-slots, accounting for parity and guard-time symbols, then the BWA CPE modem shall not create this last shortened codeword.

4.2.11 Signal processing requirements

The signal processing order for each burst packet type MUST be compatible with the sequence shown in Fig. 17 and MUST follow the order of steps in Fig. 18.

FIGURE 17

Signal processing sequence



4.2.12 Upstream receiver input power characteristics

All CPEs MUST implement upstream power control so that the various bursts from different CPEs arrive at the BWA BTS with more or less the same power level. The objective receive signal at the BTS receiver depends upon the specific power control algorithm implemented. Once the objective receive signal level is defined, the demodulator MUST operate within its defined performance specifications with received bursts within ±6 dB of the nominal commanded received power.

FIGURE 18

TDMA upstream transmission processing

	Packet stream input
	⇓
Block the data	Separate packet into information blocks (= data bytes in one codeword)
	⇓
FEC encode	FEC encode (RS) each information block, using shortened codeword for last block if needed. FEC can be turned off
	⇓
Scramble	Scramble (see § 4.2.4)
	⇓
Preamble prepend	Preamble prepend symbols
	⇓
Symbol map	Symbol map the data stream into modulator symbols
	⇓
Filter	Filter symbol stream for spectral shaping
	⇓
Modulate	Modulate at precise times (QPSK; 16-QAM)
	⇓
	Output RF waveform bursts

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4.2.13 Upstream electrical output from the BWA CPE modem

The BWA CPE modem MUST output an RF modulated signal with the characteristics delineated in Table 8.

TABLE 8

Electrical RF output from BWA CPE

Parameter	Value
Frequency (GHz)	2.5 to 40
Minimum level range (one channel) (dBm)	–27 to +17 (16-QAM) –30 to +20 (QPSK)
Modulation type	QPSK and optionally 16-QAM and/or 64-QAM
Symbol rate (nominal) (ksymbols/s)	160, 320, 640, 1 280, 2 560, 5 120, 10 240 and 20 480
Bandwidth (kHz)	200, 400, 800, 1 600, 3 200, 6 400, 13 000 and 26 000
Output impedance (Ω)	50
Output return loss (dB)	>6

4.3 Downstream

4.3.1 Downstream protocol

The downstream PMD sublayer MUST conform to ITU-T Recommendation J.83, with the exceptions of 256-QAM and those called out in § 4.3.2. The downstream PMD sublayer MUST support QPSK, 16-QAM and optionally 64-QAM modulations and symbol rates and bandwidth defined in Table 10.

4.3.2 Scalable interleaving to support low latency

The downstream PMD sublayer MUST support a variable-depth interleaver with the characteristics defined in ITU-T Recommendation J.83, except those with latencies greater than 4 ms.

The interleaver depth, which is coded in a 4-bit control word contained in the FEC frame synchronization trailer, always reflects the interleaving in the immediately-following frame. In addition, errors are allowed while the interleaver memory is flushed after a change in interleaving is indicated.

Refer to ITU-T Recommendation J.83 for the control bit specifications required to specify which interleaving mode is used.

4.3.3 Downstream frequency plan

The downstream frequency should be in the range 2.5 to 40 GHz with channel bandwidth up to 40 MHz.

4.3.4 BWA BTS output electrical

The BWA BTS MUST output an RF modulated signal with the following characteristics defined in Table 9.

TABLE 9

BWA BTS RF output

Parameter	Value
Centre frequency, f_c	2.5 to 40 GHz ± 5 ppm
Transmit power level (at tx antenna flange) (dBm)	>10
Modulation type	QPSK, 16-QAM and optionally 64-QAM
Symbol rate, R_s	Up to 34.78 Msymbols/s
Nominal channel spacing	Up to 40 MHz
Frequency response	12%~18% square root raised cosine shaping
Spurious and noise	
Inband ($f_c \pm R_s/2$)	< –50 dBc in symbol rate bandwidth (R_s)
Adjacent channel ($f_c \pm R_s/2$) to ($f_c \pm 1,25 \cdot R_s/2$)	< –51 dBc in a bandwidth of $R_s/8$
Adjacent channel ($f_c \pm 1,25 \cdot R_s/2$) to ($f_c \pm 3 \cdot R_s/2$)	< –55 dBc, in 1.75 · R_s, excluding up to 3 spurs, each of which must be < –53 dBc when measured in a 10 kHz band
Next adjacent channel ($f_c \pm 3 \cdot R_s/2$) to ($f_c \pm 5 \cdot R_s/2$)	< –58 dBc in symbol rate bandwidth (R_s)
Output impedance (Ω)	50
Output return loss (dB)	>14

4.3.5 Downstream RF input to BWA CPE

The BWA CPE MUST accept an RF modulated signal with the following characteristics (see Table 10).

TABLE 10

RF input to BWA CPE

Parameter	Value
Centre frequency	2.5 to 40 GHz ± 5 ppm
Level range (one channel) (dBm)	–87 to –32
Modulation type	QPSK, 16-QAM and optionally 64-QAM
Symbol rate (nominal)	Up to 34.78 Msymbols/s
Bandwidth	Up to 40 MHz with 12%~18% square root raised cosine shaping
Input (load) impedance (Ω)	50
Input return loss (dB)	>14

4.3.6 BWA CPE modem BER performance

The BER performance of a BWA CPE modem MUST be as described in this section.

4.3.6.1 QPSK

4.3.6.1.1 QPSK BWA CPE modem BER performance

Implementation loss of the BWA CPE modem MUST be such that the BWA CPE modem achieves a post-FEC BER less than or equal to 1×10^{-8} when operating at a *C*/*N* of 10.8 dB or greater.

4.3.6.1.2 QPSK adjacent channel performance

Performance as described in § 4.3.6.1.1 MUST be met with digital signal at 0 dBc in the adjacent channels.

Performance as described in § 4.3.6.1.1, with an additional 0.2 dB allowance, MUST be met with digital signal at +10 dBc in the adjacent channels.

4.3.6.2 16-QAM

4.3.6.2.1 16-QAM BWA CPE modem BER performance

Implementation loss of the BWA CPE modem MUST be such that the BWA CPE modem achieves a post-FEC BER less than or equal to 1×10^{-8} when operating at a *C*/*N* of 17.8 dB or greater.

4.3.6.2.2 16-QAM adjacent channel performance

Performance as described in § 4.3.6.2.1 MUST be met with digital signal at 0 dBc in the adjacent channels.

Performance as described in § 4.3.6.2.1, with an additional 0.2 dB allowance, MUST be met with digital signal at +10 dBc in the adjacent channels.

4.3.6.3 64-QAM

4.3.6.3.1 64-QAM BWA CPE modem BER performance

Implementation loss of the BWA CPE modem MUST be such that the BWA CPE modem achieves a post-FEC BER less than or equal to 1×10^{-8} when operating at a *C*/*N* of 24.5 dB or greater.

4.3.6.3.2 64-QAM adjacent channel performance

Performance as described in § 4.3.6.3.1 MUST be met with digital signal at 0 dBc in the adjacent channels.

Performance as described in § 4.3.6.3.1, with an additional 0.2 dB allowance, MUST be met with digital signal at +10 dBc in the adjacent channels.

5 Downstream transmission convergence sublayer

5.1 Introduction

In order to improve demodulation robustness, facilitate common receiving hardware for both video and data, and provide an opportunity for the possible future multiplexing of video and data over the PMD sublayer bit stream defined in § 4, a sublayer is interposed between the downstream PMD sublayer and the data-over-BWA MAC sublayer.

The downstream bit stream is defined as a continuous series of 188-byte MPEG ITU-T Recommendation H.222.0 packets. These packets consist of a 4-byte header followed by 184 bytes of payload. The header identifies the payload as belonging to the data-over-BWA MAC. Other values of the header may indicate other payloads. The mixture of MAC payloads and those of other services is optional and is controlled by the BWA BTS modem.

Figure 19 illustrates the interleaving of data-over-BWA (DOC) MAC bytes with other digital information (digital video in the example shown).

FIGURE 19

Example of interleaving MPEG packets in downstream

Header = DOC	DOC MAC payload
Header = video	Digital video payload
Header = video	Digital video payload
Header = DOC	DOC MAC payload
Header = video	Digital video payload
Header = DOC	DOC MAC payload
Header = video	Digital video payload
Header = video	Digital video payload
Header = video	Digital video payload

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5.2 MPEG packet format

The format of an MPEG packet carrying BWA data is shown in Fig. 20. The packet consists of a 4-byte MPEG header, a pointer_field (not present in all packets) and the BWA payload.

FIGURE 20

Format of an MPEG packet

MPEG header (4 bytes)	pointer_field (1 byte)	BWA payload (183 or 184 bytes)

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5.3 MPEG header for BWA data-over-the-air

The format of the MPEG TS header is defined in § 2.4 of ITU-T Recommendation H.222.0. The particular field values that distinguish data-over-BWA MAC streams are defined in Table 11. Field names are from the ITU specification.

TABLE 11

MPEG header format for BWA data-over-BWA packets

Field	Length (bits)	Description
sync_byte	8	0x47; MPEG packet sync byte
transport_error_indicator	1	Indicates an error has occurred in the reception of the packet. This bit is reset to zero by the sender, and set to one whenever an error occurs in transmission of the packet
payload_unit_start_indicator	1	A value of one indicates the presence of a pointer_ field as the first byte of the payload (fifth byte of the packet)
transport_priority	1	Reserved; set to zero
PID (1)	13	Data-over-BWA well-known PID (0x1FFE)
transport_scrambling_control	2	Reserved, set to '00'
adaptation_field_control	2	'01'; use of the adaptation_field is NOT ALLOWED on the BWA PID
continuity_counter	4	Cyclic counter within this PID

(1) In the future, additional PIDs MAY be assigned to a BWA CPE modem.

The MPEG header consists of 4 bytes that begin the 188-byte MPEG packet. The format of the header for use on a BWA data-over-BWA PID is restricted to that shown in Table 11. The header format conforms to the MPEG standard, but its use is restricted in this specification to NOT ALLOW inclusion of an adaptation_field in the MPEG packets.

5.4 MPEG payload for BWA data-over-the-air

The MPEG payload portion of the MPEG packet will carry the BWA MAC frames. The first byte of the MPEG payload will be a pointer_field if the payload_unit_start_indicator (PUSI) of the MPEG header is set.

stuff_byte

This standard defines a stuff_byte pattern having a value (0xFF) that is used within the BWA payload to fill any gaps between the BWA MAC frames. This value is chosen as an unused value for the first byte of the BWA MAC frame. The FC byte of the MAC header will be defined to never contain this value. (FC_TYPE = 11 indicates a MAC-specific frame, and FC_PARM = 11111 is not currently used and, according to this specification, is defined as an illegal value for FC_PARM.)

pointer_field

The pointer_field is present as the fifth byte of the MPEG packet (first byte following the MPEG header) whenever the PUSI is set to one in the MPEG header. The interpretation of the pointer_field is as follows:

"The pointer_field contains the number of bytes in this packet that immediately follow the pointer_field that the BWA CPE modem decoder must skip past before looking for the beginning of a BWA MAC frame. A pointer field MUST be present if it is possible to begin a BWA frame in the packet, and MUST point to the beginning of the first MAC frame to start in the packet or to any preceding stuff_byte."

5.5 Interaction with the MAC sublayer

MAC frames may begin anywhere within an MPEG packet, MAC frames may span MPEG packets, and several MAC frames may exist within an MPEG packet.

Figures 21 to 24 show the format of the MPEG packets that carry BWA MAC frames. In all cases, the PUSI flag indicates the presence of the pointer_field as the first byte of the MPEG payload.

Figure 21 shows a MAC frame that is positioned immediately after the pointer_field byte. In this case, pointer_field is zero, and the BWA decoder will begin searching for a valid FC byte at the byte immediately following the pointer_field.

FIGURE 21

Packet format where a MAC frame immediately follows the pointer_field

MPEG header (PUSI = 1)	pointer_field (= 0)	MAC frame (up to 183 bytes)	stuff_byte(s) (0 or more)

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Figure 22 shows the more general case where a MAC frame is preceded by the tail of a previous MAC frame and a sequence of stuffing bytes. In this case, the pointer_field still identifies the first byte after the tail of Frame No. 1 (a stuff_byte) as the position where the decoder should begin searching for a legal MAC sublayer FC value. This format allows the multiplexing operation in the BWA BTS modem to immediately insert a MAC frame that is available for transmission if that frame arrives after the MPEG header and pointer_field have been transmitted.

FIGURE 22

Packet format with MAC frame preceded by stuffing bytes

MPEG header (PUSI = 1)	pointer_field (= *M*)	Tail of MAC frame No. 1 (*M* bytes)	stuff_byte(s) (0 or more)	Start of MAC frame No. 2

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In order to facilitate multiplexing of the MPEG packet stream carrying BWA data with other MPEG-encoded data, the BWA BTS modem SHOULD NOT transmit MPEG packets with the BWA PID which contain only stuff_bytes in the payload area. MPEG null packets SHOULD be transmitted instead. Note that there are timing relationships implicit in the BWA MAC sublayer which must also be preserved by any MPEG multiplexing operation.

Figure 23 shows that multiple MAC frames may be contained within the MPEG packet. The MAC frames may be concatenated one after the other or be separated by an optional sequence of stuffing bytes.

FIGURE 23

Packet format showing multiple MAC frames in a single packet

MPEG header (PUSI = 1)	pointer_field (= 0)	MAC frame No. 1	MAC frame No. 2	stuff_byte(s) (0 or more)	MAC frame No. 3

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Figure 24 shows the case where a MAC frame spans multiple MPEG packets. In this case, the pointer_field of the succeeding frame points to the byte following the last byte of the tail of the first frame.

FIGURE 24

Packet format where a MAC frame spans multiple packets

<table>
<tr><td>MPEG header (PUSI = 1)</td><td>pointer_field (= 0)</td><td>stuff_byte(s) (0 or more)</td><td colspan="2">Start of MAC frame No. 1 (up to 183 bytes)</td></tr>
<tr><td>MPEG header (PUSI = 0)</td><td colspan="4">Continuation of MAC frame No. 1 (184 bytes)</td></tr>
<tr><td>MPEG header (PUSI = 1)</td><td>pointer_field (= M)</td><td>Tail of MAC frame No. 1 (M bytes)</td><td>stuff-byte(s) (0 or more)</td><td>Start of MAC frame No. 2 (M bytes)</td></tr>
</table>

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The transmission convergence sublayer must operate closely with the MAC sublayer in providing an accurate timestamp to be inserted into the time synchronization message (refer to § 6).

5.6 Interaction with the PHY layer

The MPEG-2 packet stream MUST be encoded according to ITU-T Recommendation J.83, including MPEG-2 transport framing using a parity checksum as described in ITU-T Recommendation J.83.

5.7 MPEG header synchronization and recovery

The MPEG-2 packet stream SHOULD be declared in frame (i.e. correct packet alignment has been achieved) when five consecutive correct parity checksums, each 188 bytes from the previous one, have been received.

The MPEG-2 packet stream SHOULD be declared out of frame, and a search for correct packet alignment started, when nine consecutive incorrect parity checksums are received.

The format of MAC frames is described in detail in § 6.

6 MAC specification

The MAC protocol is specified in ITU-T Recommendation J.116, Annex B.

ANNEX 1

Data-over-BWA interface documents

A list of the texts in the data-over-BWA interface specifications family is provided below. For updates, please refer to URL http://www.cablemodem.com.

Specification	Designation	Title
MCNS1	SP-RFI	Radio Frequency Interface Specification, SP-RFI-I01-970326
MCNS2	SP-DOCSS	Data Over Cable Security System (DOCSS) Specification, SP-SSI-I01-970506
MCNS3	SP-CMTS-NSI	Cable Modem Termination System Network Side Interface Specification, SP-CMTS-NSI-I01-960702
MCNS4	SP-CMCI	Cable Modem to Customer Premises Equipment Interface Specification, SP-CMCI-I01-960702
MCNS5	SP-OSSI	Operations Support System Interface Specification, SP-OSSI-I01-970403
MCNS6	SP-CMTRI	Cable Modem Telco Return Interface Specification, SP-CMTRI-I01-970804
MCNS7	SP-RSM	Removable Security Module Specification, SP-RSM-D02-971004
MCNS8	SP-BDS	Baseline Data Over Cable Security Specification, SP-BPI-I01-970609

Key to designations:

SP: Specification

TR: Technical report (provides a context for understanding and applying the specification – documents of this type may be issued in the future).