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BSI Standards Publication

Information technology — Telecommunications and information exchange between systems — Local and metropolitan area networks — Specific requirements

Part 22: Cognitive Wireless RAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Policies and Procedures for Operation in the TV Bands

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Partie 22: Spécifications du contrôle d'accès du milieu sans fil cognitif (MAC) et de la couche physique (PHY) : Politiques et procédures pour le fonctionnement dans les bandes TV

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— *Part 1: Overview of Local Area Network Standards*

— *Part 2: Logical link control*

— *Part 5: Token ring access method and physical layer specifications*

— *Part 11: Wireless LAN medium access control (MAC) and physical layer (PHY) specifications*

— *Part 1X: Port-based network access control*

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— *Part 1AE: Media access control (MAC) security*

— *Part 1AR: Secure device identity*

— *Part 1AS: Timing and synchronization for time-sensitive applications in bridged local area networks*

— *Part 15-4: Wireless medium access control (MAC) and physical layer (PHY) specifications for low-rate wireless personal area networks (WPANs)*

This corrected version of ISO/IEC/IEEE 8802-22 incorporates the following corrections.

The abbreviation MAC has been corrected in the English title and the part title has been added for the French title.

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Abstract: This standard specifies the air interface, including the cognitive medium access control layer (MAC) and physical layer (PHY), of point-to-multipoint wireless regional area networks comprised of a professional fixed base station with fixed and portable user terminals operating in the VHF/UHF TV broadcast bands between 54 MHz to 862 MHz.
Keywords: broadband wireless access network, cognitive radio, fixed user terminals, IEEE 802.22, portable user terminals, radio spectrum sensing, regional area network, WRAN standards

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Introduction

This introduction is not part of IEEE Std 802.22-2011, IEEE Standard for Information Technology—Telecommunications and information exchange between systems—Wireless Regional Area Networks (WRAN)—Specific requirements—Part 22: Cognitive Wireless RAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Policies and Procedures for Operation in the TV Bands.

This standard specifies the air interface of broadband wireless access (BWA) systems for fixed and portable user terminals supporting multimedia services. The medium access control layer (MAC) supports a point-to-multipoint architecture. The MAC is structured to support a physical layer (PHY) specification especially suited for operation in TV broadcast bands while avoiding interference to the incumbent broadcast services.

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IEEE Standard for Information Technology—Telecommunications and information exchange between systems Wireless Regional Area Networks (WRAN)—Specific requirements

Part 22: Cognitive Wireless RAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Policies and Procedures for Operation in the TV Bands

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1. Overview

1.1 Scope

This standard specifies the air interface, including the cognitive medium access control layer (MAC) and physical layer (PHY), of point-to-multipoint wireless regional area networks comprised of a professional fixed base station with fixed and portable user terminals operating in the VHF/UHF TV broadcast bands between 54 MHz to 862 MHz.

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1.2 Purpose

This standard is intended to enable deployment of interoperable IEEE 802® multivendor wireless regional area network products, to facilitate competition in broadband access by providing alternatives to wireline broadband access and extending the deployability of such systems into diverse geographic areas, including sparsely populated rural areas, while preventing harmful interference to incumbent licensed services in the TV broadcast bands.

1.3 Reference application

The Wireless Regional Area Networks (WRANs) for which this standard has been developed are expected to operate primarily in low population density areas in order to provide broadband access to data networks. The WRAN systems will use vacant channels in the VHF and UHF bands allocated to the Television Broadcasting Service in the frequency range between 54 MHz and 862 MHz while avoiding interference to the broadcast incumbents in these bands. A typical application can be the coverage of the rural area around a village, as illustrated in Figure 1, within a radius of 10 km to 30 km from the base station depending on its EIRP and antenna height. The MAC can also accommodate user terminals located as far as 100 km with proper scheduling of the traffic in the frame when exceptional RF signal propagation conditions are present. With the PHY implemented in this standard, WRAN systems can cover up to a radius of 30 km without special scheduling.

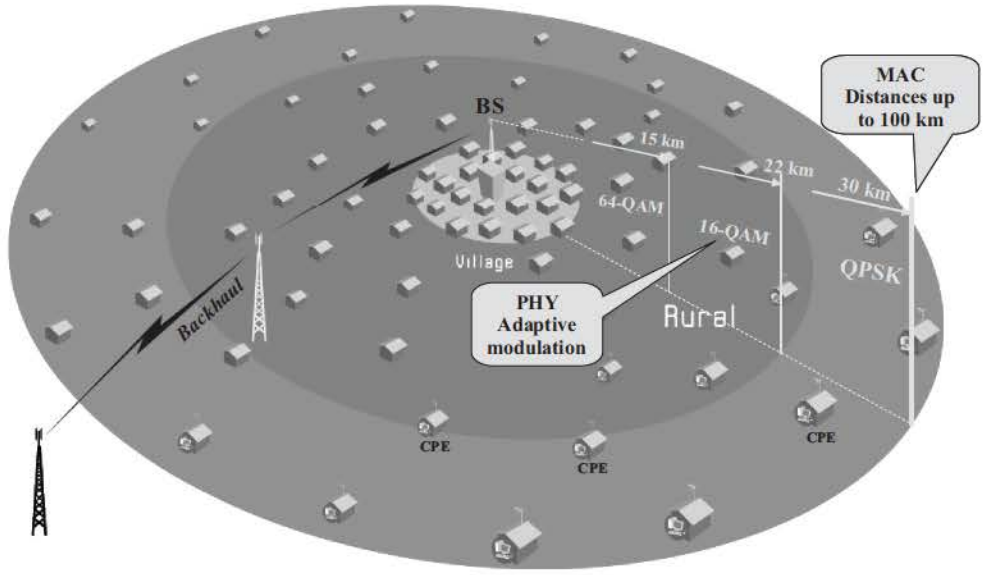


Figure 1 — An IEEE 802.22 WRAN cell with a base station and user terminals

A base station (BS) complying with this standard shall be able to provide high-speed Internet service for up to 512 fixed or portable customer premise equipment (CPE) devices or groups of devices within its coverage area assuming different quality of service (QoS) requirements for various CPEs, while meeting the regulatory requirements for protection of the incumbents.

The standard includes cognitive radio techniques to mitigate interference to incumbents, including geolocation capability, provision to access a database of incumbent services, and spectrum-sensing technology to detect the presence of incumbent services, other WRAN systems, and IEEE 802.22.1 wireless beacons.

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2. Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. At the time of publication, the editions indicated were valid. All standards and specifications are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the references listed below.

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ANSI X9.63-2001, Public Key Cryptography for the Financial Services Industry: Key Agreement and Key Transport Using Elliptic Curve Cryptography, November 2001.

IEEE Std 802®-2001, IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture.[2, 3]

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IEEE Std 802.22.1™-2010, IEEE Standard for Local and metropolitan area networks—Part 22.1: Methods to Enhance Protection of Low-Power, Licensed Device Operation in the TV Broadcast Bands from Harmful Interference from License-Exempt Devices Operating in those Bands.

FIPS 180-3, Secure Hash Standard (SHS), October 2008.[4]

FIPS 186-3, Digital Signature Standard (DSS), June 2009.

FIPS 197, Advanced Encryption Standard, November 2001.

IETF RFC 2437, PKCS #1: RSA Cryptography Specification Version 2.0, October 1998.[5]

IETF RFC 2578, "Structure of Management Information Version 2 (SMIv2)," K. McCloghrie, D. Perkins, J. Schoenwaelder, J. Case, M. Rose, S. Waldbusser, April 1999.

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IETF RFC 4492, Elliptic Curve Crytopgraphy (ECC) for Transport Layer Security (TLS), May 2006.

IETF RFC 5216, The EAP-TLS Authentical Protocol, March 2008.

IETF RFC 5246, The Transport Layer Security (TLS) Protocol Version 1.2, August 2008.

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[1] ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (http://www.ansi.org/).
[2] IEEE publications are available from the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, Piscataway, NJ 08854, USA (http://standards.ieee.org/).
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[4] FIPS publications are available from the National Technical Information Service (NTIS), U. S. Dept. of Commerce, 5285 Port Royal Rd., Springfield, VA 22161 (http://www.ntis.org/).
[5] Internet Requests for Comments (RFCs) are available on the World Wide Web at the following ftp site: venera.isi.edu; logon: anony¬mous; password: user's e-mail address; directory: in-inotes.

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IETF RFC 5280, Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile, May 2008.

IETF RFC 5281, Extensible Authentication Protocol Tunneled Transport Layer Security Authenticated Protocol Version 0 (EAP-TTLSv0), August 2008.

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U.S. FCC, ET Docket 08-260, "Second Report and Order and Memorandum Opinion and Order in the Matter of Unlicensed Operation in the TV Broadcast Bands," November 14, 2008.

U.S. FCC, ET Docket 10-174, "Second Memorandum Opinion and Order in the Matter of Unlicensed Operation in the TV Broadcast Bands," September 23, 2010.

[6] NIST SP 800-38D can be found at http://csrc.nist.gov/publications/nistpubs/800-38D/SP-800-38D.pdf.
[7] At the time this standard published, SEC 4 was still in draft form. The draft can be found at http://www.secg.org/. Alternately, users may contact the IEEE to obtain this draft.

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3. Definitions

For the purposes of this document, the following terms and definitions apply. *The IEEE Standards Dictionary: Glossary of Terms & Definitions* should be referenced for terms not defined in this clause.[8]

3.1 analog television: Radio frequency (RF) transmission of audio and video by analog signals [e.g., NTSC, PAL, SECAM) (see ITU-R Recommendation BT.470 [B50])].[9]

3.2 authenticator: An entity at one end of a point-to-multipoint Wireless Regional Area Network (WRAN) link that facilitates the authentication of the entity attached at the other end of that link.

3.3 backup channel: A channel that has been cleared [i.e., verified that no incumbent service will be affected by Wireless Regional Area Network (WRAN) operation in this channel] to immediately become the operating channel in case the WRAN needs to switch channel.

NOTE—See 10.2.2.[10]

3.4 base station (BS): Generalized equipment set providing connectivity, management and control of the customer premise equipment (CPE). The functionalities attributed to the BS, in the context of this standard, may be implemented by a device or a collection of devices.

3.5 broadcast connection: A connection established to transport MAC management messages and data from the base station (BS) to all of the CPEs in the cell on the downstream (DS).

3.6 burst: A two-dimensional segment of OFDM subchannels (frequency domain) and symbols (time domain). It may comprise multiple MAC PDUs that are encoded with the same physical modulation and coding.

3.7 candidate channel: A channel that, once cleared from potential harmful interference to incumbents, can become a backup channel.

NOTE—See 10.2.2.

3.8 carrier-to-noise ratio (CNR): Ratio of the power of a subcarrier to the noise power in a bandwidth corresponding to the subcarrier spacing for a set of system parameters as given in Table 199.

3.9 cell: An IEEE 802.22 cell (or simply, a cell) is formed by a single IEEE 802.22 BS and zero or more IEEE 802.22 customer premise equipments (CPEs) associated with and under control of this IEEE 802.22 BS. The coverage area of this cell extends up to the point where the signal received from the IEEE 802.22 BS is sufficient to allow IEEE 802.22 CPEs to associate and maintain communication with the BS.

3.10 channel: Refers to a specific physical radio frequency channel, a contiguous segment of spectrum in the TV broadcast frequency bands, which may be 6 MHz, 7 MHz, or 8 MHz wide depending on the relevant regulatory domains. *See also:* **logical channel**.

[8] *The IEEE Standards Dictionary: Glossary of Terms & Definitions* is available at http://shop.ieee.org/.
[9] The numbers in brackets correspond to those of the bibliography in Annex G.
[10] Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

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3.11 cognitive plane: The cognitive plane consists of all the entities in the IEEE 802.22 reference architecture that relate to cognitive functions. These cognitive functions are the spectrum manager/spectrum automaton, spectrum sensing function, the geolocation function and the security sublayer 2. The spectrum manager/spectrum automaton reside at the same level as the MAC common part sublayer in the data plane whereas the SSF and the geolocation function reside at the same level as the PHY in the data plane.

3.12 cognitive radio: A functionality of some wireless communication devices in which either a network or a wireless node can change the devices' transmission and/or reception parameters to communicate efficiently and to avoid interference with licensed or licensed-exempt users. This alteration of parameters is based on the active monitoring of several factors in the external and internal radio environment, such as radio frequency spectrum, location information, user behavior, network state, etc.

3.13 coexistence: State by which license-exempt wireless communication systems of various types can share a same RF transmission channel in a common area while minimizing harmful interference to each other by the use of appropriate means.

3.14 coexistence beacon: Series of bursts that is transmitted with the goal of improving self-coexistence among overlapping IEEE 802.22 cells, potentially improving coexistence among license-exempt wireless communication systems of various types if so equipped, regularly signaling the identity of the transmission device for potential interference resolution and enhancing geolocation ranging resolution between CPEs within a cell. The beacon is transmitted under the control of the BS during self-coexistence windows.

3.15 connection: Data path established between BS and CPE for transport of data.

3.16 customer premise or portable equipment (CPE): A generalized equipment set providing connectivity between a BS and a subscriber premise.

3.17 cyclic prefix (CP): The portion of an OFDM symbol used to absorb inter-symbol interference caused by transmission channel time dispersion. The cyclic prefix is actually a copy of the last portion of the symbol appended to the front of the same symbol. Its size is defined in terms of a ratio to the useful part of the OFDM symbol.

NOTE—See Table 200.

3.18 database service: Service officially operated under the rules of the local regulatory authority that provides a list of available channels and possibly the maximum EIRP allowable on these channels based on queries containing the geolocation of the Wireless Regional Area Network (WRAN) devices.

3.19 digital television: Radio frequency (RF) transmission of audio and video by digital signals (e.g., ATSC, DVB-T, ISDB-T) (see ITU-R Recommendation BT-798 [B52]).

3.20 downstream (DS): The direction of the transmitted signal from a base station (BS) to a CPE.

3.21 downstream channel descriptor (DCD): A medium access control (MAC) message that describes the PHY characteristics of a downstream burst.

3.22 downstream interval usage code (DIUC): An interval usage code specific to a downstream burst. *See also:* **interval usage code.**

3.23 downstream map (DS-MAP): A MAC message that defines the structure of the downstream subframe, i.e., burst locations in the time and frequency domain of the OFDM.

3.24 flow ID (FID): An identifier that identifies a particular flow of traffic assigned to a specific CPE or group of CPEs. *See also:* **station ID (SID).**

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3.25 frame: Basic time unit over which BS and CPEs communicate with each other. It is comprised of one downstream subframe, one upstream subframe and a self-coexistence window when present.

3.26 frame contention source (FC-SRC): A WRAN cell that is demanding additional spectrum resources (i.e., data frame transmission opportunities on a channel) and is initiating an interactive frame contention process with the target frame contention destination (FC-DST).

3.27 frame contention destination (FC-DST): A Wireless Regional Area Network (WRAN) cell that is the target of the frame contention request initiated by a frame contention source (FC-SRC), and is the occupier of the spectrum resources being requested by the frame contention source (FC-SRC).

3.28 frame contention number (FCN): Number randomly generated by the FC-SRCs and FC-DSTs for determining by contention the priority of frame access.

3.29 geolocation: The process of acquiring the location data of a device, determining its latitude and longitude, and producing the corresponding NMEA string.

3.30 harmful interference: Any emission, radiation or induction that endangers the functioning of a radio navigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunications service operating in accordance with the ITU and local Regulations. [See Article 1 of the ITU Radio Regulations, #1.169 and the FCC 47 CFR 15.3(m).]

3.31 IEEE 802.22.1 wireless beacon: An RF device that provides enhanced protection to licensed low power auxiliary devices such as those used in the production and transmission of broadcast programs [e.g., devices licensed as secondary under Title 47 of the Code of Federal Regulations (CFR) in the USA and equivalent devices in other regulatory domains] from harmful interference potentially caused by WRAN operation.

3.32 in-band: The operating channel (N) and its first adjacent channels (N–1 and N+1).

3.33 incumbents: Licensed transmission systems operating in the TV bands on a primary or secondary basis according to international and local regulatory rules.

3.34 interval usage code: A code identifying a particular burst profile that can be used for a downstream or upstream transmission interval.

3.35 logical channel: This is the channel number used by the MAC, and does not necessarily reflect a physical channel. This can be mapped into any representation as defined by the PHY. *See also:* **channel.**

3.36 MAC PDU: The smallest unit of transmission/reception to be processed by the MAC. It is comprised of the MAC header, the payload, and Cyclic Redundancy Check (CRC).

3.37 managed node: A node that collects and stores the managed objects in the format of a MIB that is made available to the network management system via the Simple Network Management Protocol (SNMP).

3.38 managed object: A specific characteristic, among many, of a managed device. Managed objects are comprised of one or more object instances, which are essentially variables. A managed object is also referred to as a MIB object or an object.

3.39 management connection: A connection established to transport MAC management messages and data between the BS and a particular CPE.

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3.40 Management Information Base (MIB): A collection of information that is organized hierarchically. MIBs are accessed using Simple Network Management Protocol (SNMP). They are comprised of managed objects that are identified by object identifiers.

3.41 multicast management connection: A connection established to transport MAC management messages and data from the BS to a particular group of CPEs on the DS.

3.42 multicast transport connection: A connection established to transport user data from the base station (BS) to a particular group of customer premise equipment (CPE) on the downstream (DS).

3.43 OFDM slot: A two-dimensional entity defined as one OFDM symbol by one subchannel.

3.44 operating channel: Channel being used by a WRAN system.

3.45 out-of-band: Any channel that is not in-band. *See also:* **in-band.**

3.46 protected contour: The regulator-defined boundary of an area within which a TV station is entitled to protection from harmful interference.

3.47 quiet period: A specific period of time during which the base station has scheduled a cessation of all transmission in its cell for the purpose of sensing.

3.48 RSSL: Received WRAN signal strength level at a base station or customer premise equipment (CPE).

3.49 RSSI: Received signal strength indication (estimate) on the sensing signal path or WRAN signal path in sensing mode 2 at a base station or customer premise equipment (CPE).

3.50 security association (SA): The set of security information a base station (BS) and one or more of its CPEs share in order to support secure communications. This shared information includes traffic encryption keys (TEKs) and the cipher suite that is to be applied to the SA.

3.51 security association identifier (SAID): An identifier shared between the base station (BS) and a customer premise equipment (CPE) that uniquely identifies a security association (SA).

3.52 security sublayer 1: Security functions for the Data/Control Plane.

3.53 security sublayer 2: Security functions for the Cognitive Plane.

3.54 self-coexistence: A state by which wireless communication systems of the same type can share a RF transmission channel in a common area while minimizing harmful interference to each other by the use of appropriate means. In the case of IEEE 802.22, this means coexistence of multiple nearby IEEE 802.22 cells.

3.55 sensing mode: A mode of operation of the spectrum sensing function that specifies the valid outputs of the spectrum sensing function.

3.56 service flow: Defines the QoS parameters for the PDUs that are exchanged on a connection, and provides a mechanism for upstream and downstream QoS management.

3.57 service flow identifier (SFID): A unique identifier for a service flow dealing with how higher layer packets/application sessions are mapped to their QoS requirements and scheduling constraints.

3.58 signal type array (STA): A one-dimensional array indicating which signal types the spectrum sensing function is to sense.

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3.59 spectrum manager: The spectrum manager is the cognitive function at the BS that will use the inputs from the database service based on the geolocation at the BS and the customer premise equipment (CPE), as well as the input from the spectrum sensing automaton (SSA) at the BS and the CPEs to decide on the channel to be used by the WRAN cell as well as the EIRP limits imposed on the specific WRAN devices.

3.60 spectrum sensing automaton: Cognitive function resident at the BS and the customer premise equipment (CPE) that includes essential features to allow autonomous and directed sensing at the BS and at the CPE as well as proper CPE operation when it is not under the control of a BS.

3.61 spectrum sensing function (SSF): The function that observes the RF spectrum for a defined set of signal types and reports the results of its observations.

3.62 station ID (SID): A unique identifier for a customer premise equipment (CPE) under the control of a BS. This can reflect a single CPE, or a group of CPEs (e.g., multicast group).

3.63 subchannel: The basic unit of a logical channel used for subcarrier allocation in both downstream and upstream. A subchannel is composed of 28 subcarriers (24 data and 4 pilot subcarriers).

3.64 subframe: Formed by a number of bursts transmitted in the same direction (e.g., downstream subframe, upstream subframe).

3.65 superframe: Group of 16 frames initiated by the transmission from the BS of the superframe preamble and the Superframe Control header (SCH).

3.66 Supplicant: An entity at one end of a point-to-multipoint Wireless Regional Area Network (WRAN) link that seeks to be authenticated by an Authenticator attached to the other end of that link.

3.67 symbol period: Fundamental unit of duration in the time domain that is equal to the duration of an OFDM symbol in the time domain.

NOTE—See Table 200.

3.68 time division duplex (TDD): A duplex scheme where upstream and downstream transmissions occur at different times but may share the same transmission channel.

3.69 transport connection: A connection established to transport user data between the BS and a particular CPE.

3.70 upstream: The direction of the transmitted signal from a customer premise equipment (CPE) to the BS.

3.71 upstream channel descriptor (UCD): A medium access control (MAC) message that describes the PHY characteristics of an upstream transmission burst.

3.72 upstream interval usage code (UIUC): An interval usage code specific to an upstream burst. *See also:* **interval usage code.**

3.73 upstream map (US-MAP): A MAC message that defines the media access parameters (i.e., burst start time, burst length and subchannel usage) for the OFDMA upstream subframe for the CPEs scheduled to transmit toward the BS.

3.74 wireless microphone: A wireless microphone with licensed use of the TV broadcast bands (e.g., Part 73 and 74 devices in the U.S.) and equivalent low-power auxiliary devices allowed under the rules of various regulatory domains.

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4. Abbreviations and acronyms

AAA	Authentication, Authorization, and Accounting
AAD	additional authenticated aata
AES	Advanced Encryption Standard
AK	authorization key
ARQ	Automatic Repeat Request
AU	antenna unit
BCC	binary convolutional coding
BE	best effort
BS	base station
BSN	block sequence number
BTC	Block Turbo Code
C-SAP	Control Service Access Point
CA	Certificate Authority
CBP	Coexistence Beacon Protocol
CC	confirmation code
CDMA	Code Division Multiple Access
CID	connection identifier
CINR	carrier-to-interference and noise ratio
CNR	carrier-to-noise ratio
CoS	class of service
CP	cyclic prefix
CPE	customer premise equipment
CPS	Common Part sublayer
CRC	Cyclic Redundancy Check
CS	Convergence sublayer
CS SAP	Convergence sublayer Service Access Point
CTC	Convolutional Turbo Code
CTR	Counter Mode Encryption
DAMA	Demand Assigned Multiple Access
DCD	Downstream Channel Descriptor
DFS	Dynamic Frequency Selection
DHCP	Dynamic Host Configuration Protocol
DIUC	Downstream Interval Usage Code
DS	downstream
DSA	Dynamic Service Addition
DSC	Dynamic Service Change
DSD	Dynamic Service Deletion
DSx	Dynamic Service Addition, Change, or Deletion
EAP	Extensible Authentication Protocol
ECC	Elliptic Curve Cryptography
EIRP	Effective Isotropic Radiated Power
FID	flow ID
FCH	Frame Control Header
FC-DST	Frame Contention Destination
FC-SRC	Frame Contention Source
FCN	Frame Contention Number
FDD	Frequency Division Duplex
FFT	Fast Fourier Transform
GCM	Galois Counter Mode
GMAC	AES-GCM Message Authentication Code
GMH	generic MAC header

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HCS	Header Check Sequence
IANA	Internet Assigned Numbers Authority
ID	identification
IDRP	Incumbent Detection Recovery Protocol
IE	information element
IETF	Internet Engineering Task Force
IFFT	Inverse FFT
IP	Internet Protocol
IUC	Interval Usage Code
LAN	Local Area Network
LBS	Location Based Service
LDPC	Low Density Parity Check Code
LLC	Link Layer Control
LSB	least significant bit
LTS	Long Training Sequence
M-SAP	Management Service Access Point
MAC	Medium Access Control Layer
MAC SAP	Medium Access Control Service Access Point
MIB	Management Information Base
MIC	Message Integrity Check
MPDU	MAC Layer Protocol Data Unit
MPEG	Moving Pictures Experts Group
MPFA	Maximum Probability of False Alarm
MPR	microphone protection radius (MPR)
MSB	most signification bit
MSDU	MAC Layer Service Data Unit
NCMS	Network Control and Management System
NCS	Network Control System
NMEA	National Marine Electronics Association
NMS	Network Management System
nrtPS	Non-real-time Polling Service
ODFC	on-demand frame contention
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access (To align with accepted usage, OFDMA is also used in this Standard to refer to the multi-user variant of OFDM.)
PAPR	Peak-to-Average Power Ratio
PDU	Protocol Data Unit
PER	Packet Error Rate
PHY	Physical Layer
PHY SAP	Physical Layer Service Access Point
PMP	point to multipoint
PN	Packet Number, also used for pseudo-noise
PPDU	Physical Layer Protocol Data Unit (PHY burst)
PRM	Protocol Reference Model
PSDU	Physical Layer Service Data Unit (equivalent to MPDU)
QAM	Quadrature Amplitude Modulation
QoS	quality of service
QPSK	Quadrature Phase-Shift Keying
RAN	Regional Area Network
ROHC	Robust Header Compression
RRM	Radio Resource Management
RS	Reed-Solomon
RSSL	Received WRAN Signal Strength
RSSI	Received Signal Strength Indication on the WRAN signal path or sensing path in sensing mode 2

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RTG	Receive/Transmit Transition Gap
rtPS	Real-time Polling Service
SA	security association
SAID	security association identifier
SAP	service access point
SBTC	Shortened Block Turbo Code
SCH	Superframe Control header
SCM	Security for Control and Management
SCW	self-coexistence window
SDU	Service Data Unit
SFID	service flow identifier
SID	station ID
SM	spectrum manager
SM-SSF SAP	Spectrum Manager, Spectrum Sensing Function Service Access Point
SM-GL SAP	Spectrum Manager, Geolocation Service Access Point
SNMP	Simple Network Management Protocol
SNR	signal-to-noise ratio
SPD	Secondary Protecting Device
SPA	Signal Present Array
SSA	Spectrum Sensing Automaton
SSF	Spectrum Sensing Function
STS	Short Training Sequence
STA	Signal Type Array
SWS	Sensing Window Specification
SWSA	Sensing Window Specification Array
TCP	Transmission Control Protocol
TDD	time division duplex
TDM	Time Division Multiplex
TDMA	Time Division Multiple Access
TEK	Traffic Encryption Key
TFTP	Trivial File Transfer Protocol
TPC	Transmit Power Control
TTG	Transmit/Receive Transition Gap
TU	Time Unit corresponding to a nominal sampling period, (see Table 199)
TRU	transceiver unit
UCD	Upstream Channel Descriptor
UCS	urgent coexistence situation
UGS	Unsolicited Grant Service
UIUC	Upstream Interval Usage Code
US	upstream
WG	working group
WGS	World Geodetic System
WRAN	Wireless Regional Area Network

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5. System architecture

5.1 Reference architecture

The IEEE 802.22 reference architecture is depicted in Figure 3 and Figure 4. A unique characteristic of this architecture is its cognitive components. Spectrum availability in the TV bands can be fragmented, i.e., some channels can be occupied by incumbents in an area (see Figure 2) while others can be available for WRAN transmission, and this availability can vary in time. As shown in Figure 2, channel 3 is allocated to the IEEE 802.22 WRAN system, while channels 1 and 5 are in use by overlapping IEEE 802.22 cells. Channels 2, 4, and 6 would be available for more WRAN services in the area. Also, proper frequency separation is enforced in order to protect incumbent services using cognitive radio techniques—the air interface must be frequency agile, must adjust to the fragmented and time-varying spectrum availability, and must avoid interference to the TV band incumbent services. The required functional capabilities of these cognitive radio techniques are established in this standard (see Clause 10). In particular, the cognitive components of the system architecture must keep track of multiple channels, know which of these channels are occupied by incumbents and which can be used for WRAN transmission, allow for dynamic frequency selection, and avoid interference to incumbents on a real-time basis.

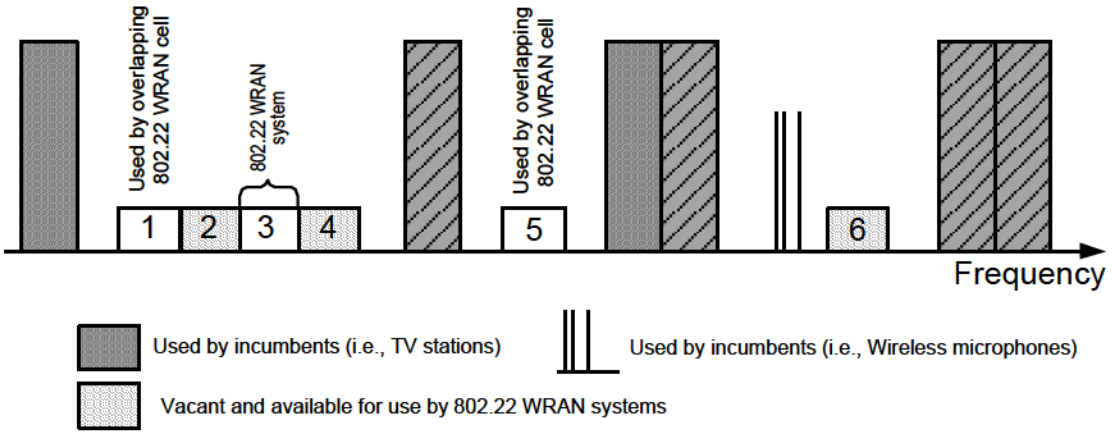


Figure 2 — Illustrative diagram of spectrum allocations in TV bands

The Protocol Reference Model (PRM), shown in Figure 3 and Figure 4, keeps the usual data and management/control plane functionality intact, while creating a new cognitive plane to support the cognitive radio capabilities. The data plane must carry the normal data as well as the management and control information. Figure 3 and Figure 4 show the PRMs at the BS and at the CPE respectively.

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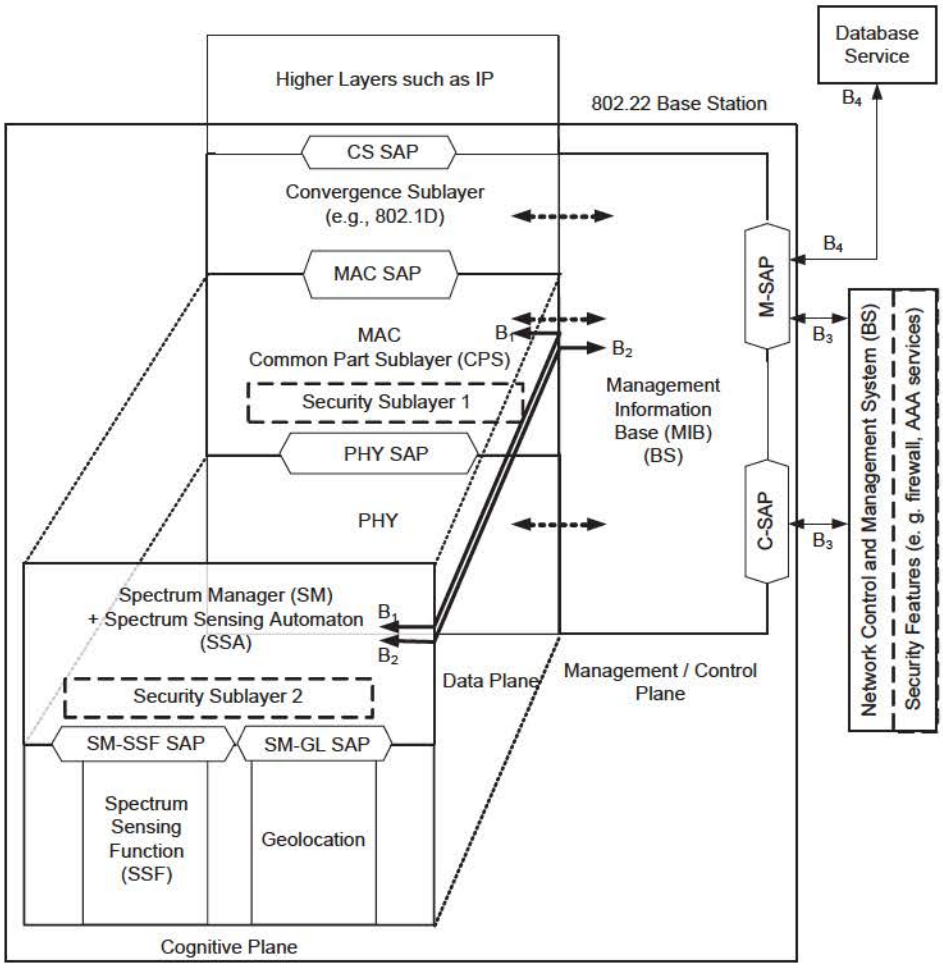


Figure 3 — Protocol Reference Model (PRM) of the IEEE 802.22 BS

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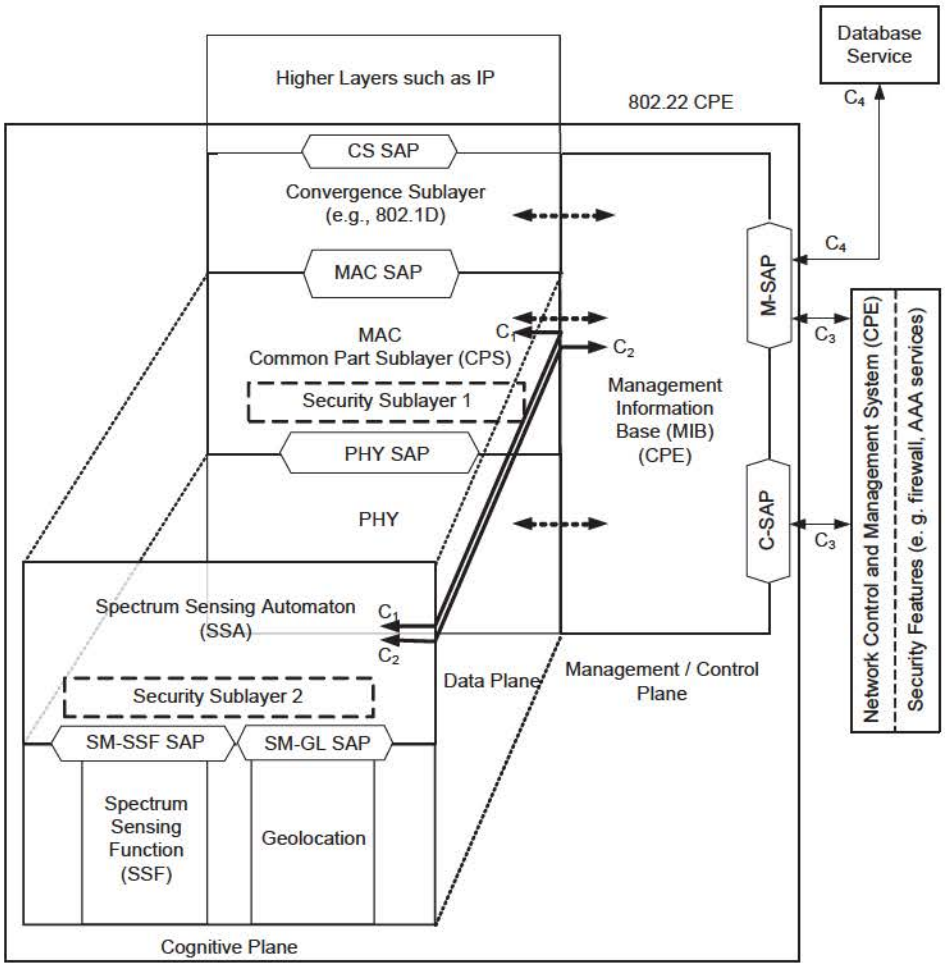


Figure 4 — Protocol Reference Model (PRM) of the IEEE 802.22 CPE

5.1.1 Data plane

The data plane consists of the Physical Layer (PHY), the Medium Access Control (MAC) layer and the Convergence sublayer (CS). Service Access Points (SAPs) are added in between these layers to allow modularization of the system where different components may be disjointed and/or from different vendors. A SAP is provided with a well-defined interface or set of primitives to exchange the information, by virtue of which these different components can talk to each other.

The Data & Control/Management plane of the MAC shall be comprised of three sublayers: service-specific CS, the MAC Common Part sublayer (CPS), and the security sublayer 1. The service-specific CS shall provide transformation or mapping of external network data that is received through the CS SAP, into MAC Service Data Units (SDUs) and data that is received by the MAC CPS through the MAC SAP. This transformation or mapping shall include classifying external network SDUs and associating them to the proper MAC service flow identifier (SFID) and flow identifier (FID). Multiple CS specifications are provided for interfacing with various protocols. The internal format of the CS payload is unique to the CS, and the MAC CPS is not required to understand the format of or parse any information from the CS payload.

The MAC Common Part sublayer shall provide the core MAC functionality of system access, connection establishment, and connection maintenance. The data that the MAC layer receives from the various CSs

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through the MAC SAP shall be classified to particular MAC connections. An example of the MAC CPS service definition is given in Clause 6. QoS is applied to the transmission and scheduling of data over the PHY. The MAC security sublayer 1 shall provide mechanisms for authentication, secure key exchange, encryption, etc. Data, PHY control, and monitoring statistics (spectrum sensing, RSSI, RSSL, etc.) shall be transferred between the MAC CPS and the PHY via the PHY SAP.

5.1.2 Management/control plane

The management/control plane shall consist of the Management Information Base (MIB). SNMP is used to communicate with the MIB database and some of its primitives may be used to manage the network entities (BS, CPE, switches, routers, etc.). The MIB primitives shall be used for system configuration, monitoring statistics, notifications, triggers, CPE and session management, Radio Resources Management (RRM), communication with the database service, spectrum sensing and geolocation reporting, etc. The MIB data may be obtained either from the network, pre-defined within the system, or obtained from another device (e.g., BS) after an exchange of information using SNMP over the communication medium.

5.1.3 Cognitive plane

The cognitive plane shall be comprised of the Spectrum Sensing Function (SSF), the Geolocation (GL) function, the Spectrum Manager/Spectrum Sensing Automaton (SM/SSA) and a dedicated security sublayer 2.

The SSF shall implement spectrum sensing algorithms and the GL module shall provide the information to determine the location of the IEEE 802.22 device (BS or CPE). The SSF and the GL modules are described in 10.7.4 and 10.7.5, respectively.

5.1.3.1 Spectrum Manager (SM)

The SM shall reside in the cognitive plane of the BS at the same layer as the MAC CPS in the data plane as shown in Figure 3. The SM shall maintain spectrum availability information, manage channel lists, manage quiet periods scheduling, and implement coexistence mechanisms. The SM shall also take requests from the MAC/PHY. For example, the MAC must inform the SM if an interference situation has been detected (e.g., with incumbents or other IEEE 802.22 cells) during normal operation in the channel. The SM must then take appropriate actions to resolve the issue such as moving to another channel (as specified in 10.2.3). In order to do this, the SM must first provide sufficient quiet period time for the CPEs to carry out in-band sensing (on channels N and N±1) to clear these channels within the specified channel monitoring requirement (see Annex A), and then keep an updated list of backup and candidate channels in a prioritized order and make sure that the CPEs have enough idle time to clear a sufficient number of backup channels. If an incumbent is found from the in-band sensing, the MAC shall use the informed response from the SM to perform the switching operation.

The SM has a key role in the overall architecture as it is the central point at the BS where all the information on the spectrum availability resulting from the database service and the spectrum sensing function is gathered. Based on this combined information, local regulations, and predefined SM policies (as specified in 10.2.5), the SM shall provide the necessary configuration information to the MAC, which shall remotely configure all the registered CPEs. Explicit connections B_1 and B_2 are shown in Figure 3 . This signifies that different kinds of information are exchanged between the SM and the MAC, and the SM and the MIBs. Connection B2 shall be used for configuration of the SM at the BS, transmission of the available channel list to the SM, as well as reporting the RF environment information via the MIBs. Connection B_1 shall be used by the SM to initiate channel move, to configure the SSA at the CPE (backup/candidate channel list, specific channels to be sensed, etc.) as well as to gather information from the CPEs (local sensing information, local geolocation information, etc.).

The functions of the SM are described in 10.2.

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5.1.3.2 Spectrum Sensing Automaton (SSA)

A simpler spectrum management entity, called Spectrum Sensing Automaton, is present at the BS and at the CPEs and independently implements specific procedures for sensing the RF environment at initialization of the BS and before the registration of a CPE with the BS. The SSA at the CPE shall also include essential features to allow proper operation when the CPE is not under the control of a BS such as independent procedures during initialization and channel change and, while the CPE is idle, the SSA shall conduct out-of-band sensing and report to the BS so that it can refresh the status of the channels in the backup/candidate channel list. At any other time, the SSA at the CPE is under the control of the SM. The SSA at the BS is also active when the BS is not transmitting to conduct out-of-band sensing. The SSA located at the BS can also carry-out sensing to clear channels when the base station is not transmitting. The functions of the SSA are described in 10.3.

Explicit connections C_1 and C_2 at the CPE are shown in Figure 4. Connection C2 shall be used to convey the environment monitoring information (e.g., list of service providers detected) via the MIBs to the CPE local interface in order to allow for the choice of the WRAN service by a professional installer through upper layers at the CPE. Connection C_1 shall be used to convey the local environment information such as sensing and geolocation to the BS.

5.1.3.3 Security sublayer 2

In addition to the security sublayer 1 at the data plane, security sublayer 2 is introduced in the cognitive plane. Security sublayer 2 enhances the security for the cognitive radio based access. The detailed operation of the security sublayers 1 and 2 are described in Clause 8. The functions of the security sublayers 1 and 2 must ensure spectrum and service availability; provide data and signal authentication; as well as ensure data, control and management message integrity, confidentiality and non-repudiation. The role of the security sublayer 2 is to provide enhanced protection to the incumbents as well as necessary protection to the IEEE 802.22 systems. If the IEEE 802.22.1 beacon has to be detected in the given regulatory domain and the transmission needs to be authenticated, the security sublayer 2 shall be used along with the security mechanism provided (ECC-based signature) to authenticate this beacon. Similarly, security sublayer 1 shall be used to authenticate a CBP packet originating from a neighboring cell CPE.

5.2 Management reference architecture

IEEE 802.22 network cells consist of a base station and up to 512 Customer Premise Equipment (CPE) devices or groups of devices. IEEE 802.22 networks may contain multiple cells. For multiple cells operation, interfacing with entities for management and control purposes is required. This standard refers to an abstract "black box" Network Control and Management System (NCMS) containing these entities. The NCMS allows the PHY/MAC layers specified in this standard to be independent of the network architecture, the transport network, and the protocols used at the backend and therefore allows greater flexibility. NCMS logically exists at the BS and CPE sides of the radio interface, termed NCMS (BS) and NCMS (CPE) respectively. Any necessary inter-BS coordination is handled through the NCMS (BS).

Figure 5 shows a management reference model for WRAN networks. It consists of a Network Management System (NMS), a Network Control System (NCS) and managed nodes. The BS and CPEs shall collect and store the managed objects (see 5.2.4) in the format as defined in the WRAN Management Information Base (MIB). The MIB is defined and specified in Clause 13. The Network Control System contains the service flow and the associated QoS information that is pre-populated in service classes at the BS and instantiated when a CPE requests services.

Interfaces B4 in Figure 3 and C4 in Figure 4 describe the interface between the CPE/BS and the database service. These interfaces are used to register with the database and request a set of available channels. Interfaces B3 in Figure 3 and C3 in Figure 4 describe the interface between the CPE/BS and the NCMS.

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The management information between the CPE and the BS may be carried over a secondary management connection. The management information can also be conveyed using the normal SNMP messages.

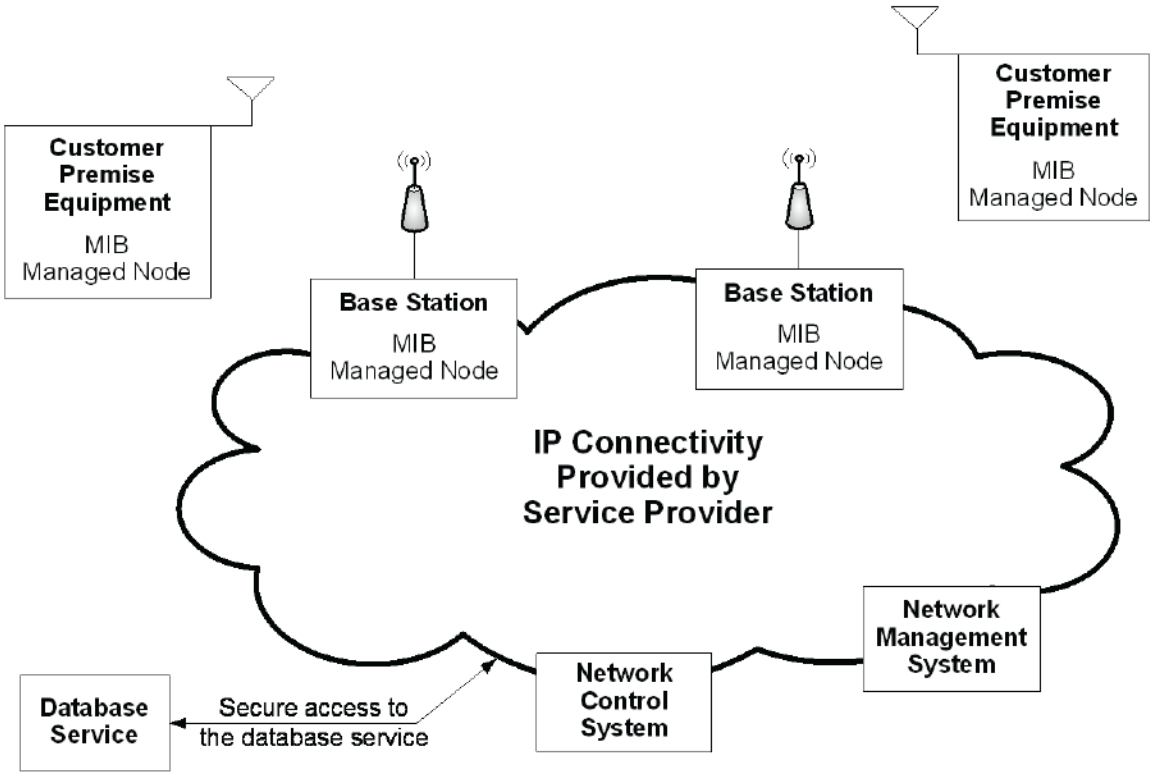


Figure 5 — Management reference model

Examples of services that may be provided by the NCMS include: Authentication, Authorization, and Accounting (AAA) services, Radio Resources Management (RRM) services, security services, Service Flow Management services, Location-Based services (LBS) management, and Network Management services.

5.2.1 PHY/MAC to NCMS interface

The NCMS is interfaced to the MAC and PHY layer entities of the CPE and BS through two Service Access Points (SAPs). The BS and CPE shall include a Control-SAP (C-SAP) and Management-SAP (M-SAP) that provide NCMS access to the control plane and management plane functions from upper layers. The M-SAP is used for less time sensitive Management plane primitives and the C-SAP is used for more time-sensitive Control Plane primitives. The C-SAP and M-SAP interfaces are described in 5.2.1.1 and 5.2.1.2. The NCMS uses the C-SAP and M-SAP to interface with the IEEE 802.22 managed nodes.

5.2.1.1 Management SAP (M-SAP)

The Management SAP may include, but is not limited to primitives related to the following:

- System configuration
- Monitoring statistics
- Notifications/Triggers
- Sensing and Geolocation reporting

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— Communication with the database service

5.2.1.2 Control SAP (C-SAP)

The Control SAP may include, but is not limited to primitives related to the following:

— Subscriber and Session management
— Security context management
— Radio Resource Management
— AAA server signaling, etc.

5.2.2 Network Reference Model

Figure 6 describes a simplified network reference model. Multiple CPEs may be attached to a BS. CPEs communicate to the BS over the U interface using a Basic Management Connection, a Primary Management Connection, or a Secondary Management Connection (see 7.2).

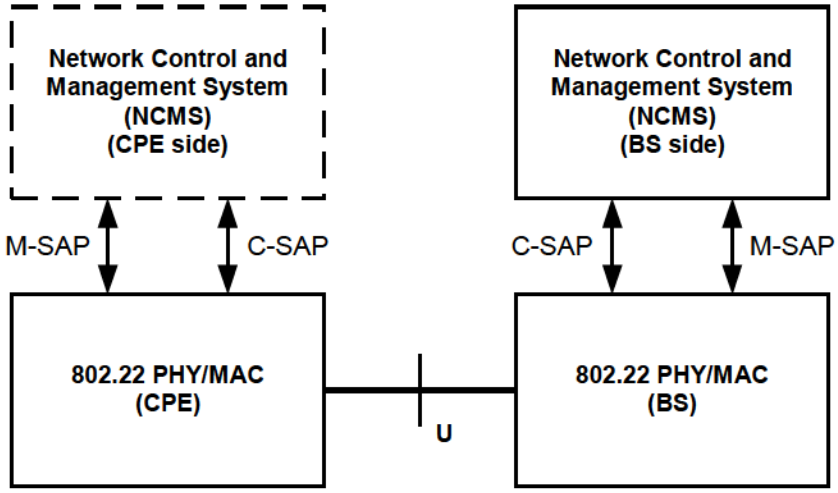


Figure 6 — IEEE 802.22 Network Reference Model

5.2.3 CPE and BS Interface

This standard observes the following correlation:

— MAC management PDUs that are exchanged on the basic management connection trigger or are triggered by primitives that are exchanged over the C-SAP.
— MAC management PDUs that are exchanged on the primary management connection trigger or are triggered by primitives that are exchanged over either the C-SAP or the M-SAP depending on the particular management or control operation.
— Messages that are exchanged over the secondary management connection trigger or are triggered by primitives that are exchanged over the M-SAP.

5.2.4 Managed objects

The definition of managed objects in this standard is expressed in IETF RFC 2578. It supports a management protocol agnostic approach, including SNMP.

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6. Packet Convergence sublayer

The Packet Convergence sublayer (CS) resides on top of the MAC Common Part sublayer (CPS). The CS shall perform the following functions using classification governed by rules (see 6.3.2 or 6.4.2) defined by the implementer/operator to process higher layer SDUs so they can be sent and received by the IEEE 802.22 BS and CPE. This process can be broken down into the following four steps, each utilizing the services of the MAC:

— Receiving higher-layer packet protocol data units (PDUs) from the higher layer

— Classifying the higher-layer PDUs into the appropriate connection

— Delivering the resulting CS PDUs to the MAC SAP associated with the service flow for transport to the peer MAC SAP

— Receiving the CS PDUs from the peer MAC SAP

The sending CS is responsible for delivering the MAC SDU to the MAC SAP. The MAC is responsible for delivery of the MAC SDU to peer MAC SAP in accordance with the QoS, fragmentation, concatenation, and other transport functions associated with the service flow characteristics of a particular connection. The receiving CS is responsible for accepting the MAC SDU from the peer MAC SAP and delivering it to a higher-layer entity.

The packet CS is used for transport of the following two packet-based protocols supported by this standard, i.e., IEEE Std 802.3 (Ethernet) and Internet Protocol (IP).

6.1 MAC SDU format

Once classified and associated with a specific MAC connection, a higher-layer PDU shall be encapsulated in a MAC SDU according to the format illustrated in Figure 7.

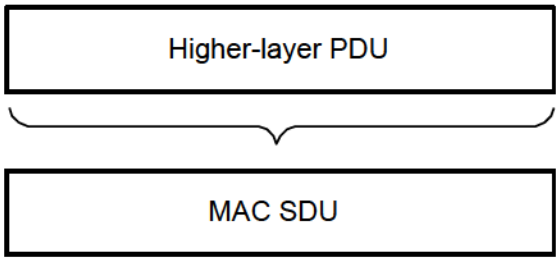


Figure 7 — MAC SDU format

6.2 Classification

Classification is the process by which a MAC SDU is mapped onto a particular connection for transmission between MAC peers. The mapping process associates a MAC SDU with a connection, which also creates an association with the service flow characteristics of that connection. This process facilitates the delivery of MAC SDUs with the appropriate QoS constraints.

A classification rule is a set of matching criteria applied to each packet entering the IEEE 802.22 network. It consists of some protocol-specific packet matching criteria (destination IP address, for example), a classification priority, and a reference to a flow identifier (FID, see 7.2). If a packet matches the specified packet matching criteria, it is then delivered to the SAP for delivery on the connection defined by the FID and the station identifier (SID, see 7.2) assigned to the CPE. Classification rules, which are to be defined by the WRAN operator, shall be downloadable to the BS and CPEs in a uniform and standardized format at

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the MIB level (see Clause 13) and shall be fully interoperable between the BS and CPEs. The service flow characteristics of the connection provide the QoS for that packet.

Several classification rules may each refer to the same service flow. The classification priority is used for ordering the application of classification rules to packets. Explicit ordering is necessary because the patterns used by classification rules may overlap. The priority needs not be unique, but care shall be taken within a classification priority to prevent ambiguity in classification. Downstream classification rules are applied by the BS to packets that it transmits and upstream classification rules are applied at the CPE. Figure 8 and Figure 9 illustrate the mappings discussed in the previous paragraph.

It is possible for a packet to fail to match the set of defined classification rules. In this case, the CS shall discard the packet.

The parameters for the classification rules shall be provided as MIB objects at the base station (see 13.1.3) and these parameters shall be downloaded from the BS to its associated CPEs for interoperability and consistency.

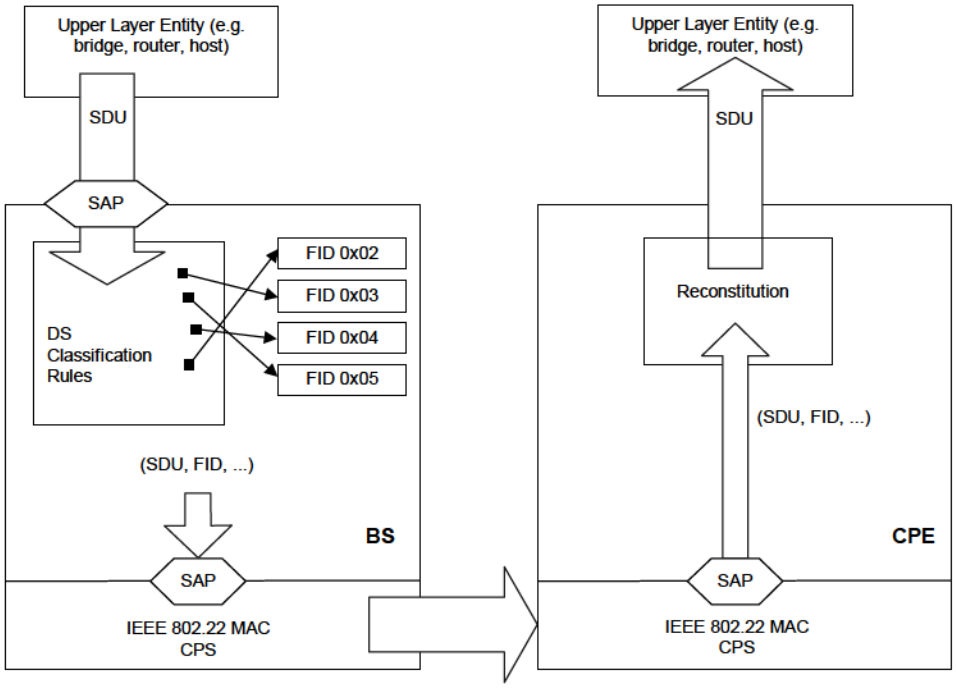


Figure 8 — Classification and FID mapping (BS to CPE)

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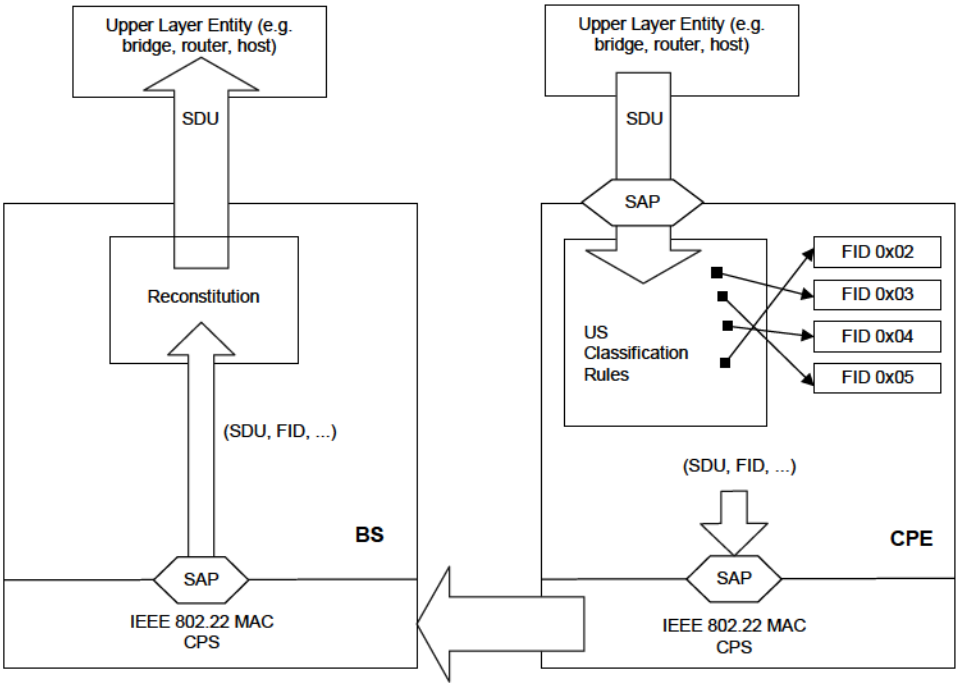


Figure 9 — Classification and FID mapping (CPE to BS)

6.3 IEEE 802.3/Ethernet-specific part

6.3.1 IEEE 802.3/Ethernet CS PDU format

An IEEE 802.3/Ethernet packet PDU is directly mapped to a CS PDU (MAC SDU).

6.3.2 IEEE 802.3/Ethernet CS classification rules

The following parameters are relevant for IEEE 802.3/Ethernet CS classification rules:

— IEEE 802.3/Ethernet and VLAN headers shall be processed by zero or more of the LLC classification parameters (see 7.7.8.9.18.3.8 to 7.7.8.9.18.3.12).

— For IP over IEEE 802.3/Ethernet, IP headers may be included in classification (see 7.7.8.9.18.3.2 to 7.7.8.9.18.3.7 and 7.7.8.9.18.3.14).

— For IP headers compressed with ROHC (IETF RFC 3095 [B27], IETF RFC 3749 [B31], IETF RFC 3243 [B28], IETF RFC 4995 [B36], IETF RFC 3843 [B32], IETF RFC 4996 [B37]) only the LLC parameters shall be used for classification (see 7.7.8.9.18.3.8 through 7.7.8.9.18.3.12).

Use of IP header compression (ROHC) is negotiated during registration (REG-REQ/RSP) and enabled during service flow setup.

6.4 IP specific part

This subclause applies when IP (IETF RFC 791 [B17], IETF RFC 2460 [B23]) is carried over the IEEE 802.22 network.

IPv6 CS requirements are only applicable if IPv6 support is enabled during registration.

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6.4.1 IP CS PDU format

An IP packet PDU is directly mapped to a CS PDU (MAC SDU).

6.4.2 IP classification rules

IP classification rules operate on the fields of the IP header and the transport protocol. Classification rules shall be the same as long as the MIB is defined. Classification rules will be downloaded from the BS to its associated CPEs for interoperability and consistency (see 6.2). IP classification rules shall be based on the IP classification parameters (see 7.7.8.9.18.3.2 through 7.7.8.9.18.3.7 and 7.7.8.9.18.3.14).

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7. MAC Common Part sublayer

This clause describes the MAC layer used by the IEEE 802.22 WRAN point-to-multipoint medium access control standard. The MAC provides tools for protection of TV bands incumbent services as well as for coexistence. The MAC is connection-oriented and provides flexibility in terms of QoS support. The MAC regulates downstream medium access by TDM, while the upstream is managed by using a DAMA/OFDMA system. In the MAC, the BS manages all the activities within its IEEE 802.22 cell and the associated CPEs are under the control of the BS.

7.1 General

In an IEEE 802.22 cell, multiple CPEs are managed by a single BS that controls the medium access. The downstream is TDM where the BS transmits and the CPE receives. The upstream transmissions, where the CPEs transmit and the BS receives, are shared by CPEs on a demand basis, according to a DAMA/OFDMA scheme. Depending on the class of service (CoS) utilized, a CPE may be issued continuing rights to transmit, or is dynamically allocated by the BS after receipt of a request from the CPE. The MAC supports unicast (addressed to a single CPE), multicast (addressed to a group of CPEs) and broadcast (addressed to all CPEs in a cell) services.

The MAC implements a combination of access schemes that efficiently control contention between CPEs within a cell and overlapping cells sharing the same channel while at the same time attempting to meet the latency and bandwidth requirements of each user application. This is accomplished through four different types of upstream scheduling mechanisms that are implemented using: unsolicited bandwidth grants, polling, and two contention procedures (i.e., MAC header and CDMA based). The use of polling simplifies the access operation and attempts to allow applications to receive service on a deterministic basis if it is required.

The MAC is connection-oriented, and as such, connections are a key component that require active maintenance and hence can be dynamically created, deleted, and changed as the need arises. A connection defines both the mapping between convergence processes at CPEs and BS and the related service flow (one connection per service flow). For the purposes of mapping to services on CPEs and associating varying levels of QoS, all data communications are instantiated in the context of a connection and this provides a mechanism for upstream and downstream QoS management. In particular, the QoS parameters are integral to the bandwidth allocation process as the CPE requests upstream bandwidth on a per connection basis (implicitly identifying the service flow). The BS, in turn, grants bandwidth to a CPE as an aggregate of grants in response to per-connection requests from the CPE.

7.2 Addressing and connections

Each IEEE 802.22 base station and CPE shall have a 48-bit universal MAC address, as defined in IEEE Std 802-2001. This address uniquely defines the base station and CPE from within the set of all possible vendors and equipment types. It is used as part of the authentication process by which the BS and CPE each verify the identity of the other at the time of network association. It is used as part of the authentication process by which the BS and CPE each verify the identity of the other at the time of network association. The BS MAC address is broadcast by the BS and is present in every CBP burst, being part of the Superframe Control header (SCH) data. Each WRAN device regularly broadcasts a CBP burst containing its Device ID and Serial Number. This is done as part of the device's self-identification process that helps identify potential interference sources to incumbent services and for coexistence purposes.

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Connections are identified by two items, a 9-bit station ID (SID) and a 3-bit flow ID (FID). The SID uniquely identifies a station that is under the control of the BS. A SID can be for a unicast station, when referencing a single CPE, or for a multicast station, when referencing a multicast group (of CPEs). A FID identifies a particular traffic flow assigned to a CPE. The tuple of SID and FID (SID | FID) forms a connection identifier (CID) that identifies a connection for the CPE. The SID is signaled in the DS/US-MAP allocation, and the FID is signaled in the generic MAC header (GMH) of a MAC PDU. This allows for a total of up to 512 stations, each with a maximum of eight flows that can be supported within each downstream and upstream channel.

At CPE initialization, three flows shall be dedicated for management connections (see 12.2) for the purpose of carrying MAC management messages and data between a CPE and the BS. The three flows reflect the fact that there are inherently three different levels of QoS for traffic sent on management connections between a CPE and the BS. The basic flow is used by the BS MAC and CPE MAC to exchange short, time-urgent MAC management messages; whereas, the primary management flow is used by the BS MAC and CPE MAC to exchange longer, more delay-tolerant MAC management messages (Table 19 specifies which MAC management messages are transferred on which type of connections). Finally, the secondary management flow is used by the BS and CPE to transfer more delay tolerant, standards-based (e.g., DHCP, TFTP, and SNMP) messages that are carried in IP datagrams. The secondary management flow may be packed and/or fragmented, similarly to the primary management except that no ARQ should be used for the latter since it is more time critical.

The FIDs for these connections shall be assigned according to the specification in 12.2. The same FID value is assigned to both upstream and downstream members of each connection.

The CID, which is a tuple of SID | FID, can be considered a connection identifier even for nominally connectionless traffic like IP, since it serves as a pointer to destination and context information.

Many higher-layer sessions may operate over the same wireless connection. For example, many users within a company may be communicating with Transmission Control Protocol (TCP)/IP to different destinations, but since they all operate within the same overall service parameters, all of their traffic is pooled for request/grant purposes. A service flow is a unidirectional flow of traffic (BS to CPE, or CPE to BS) that defines the mapping of higher-layer application service parameters (e.g., QoS) to a FID assigned to a particular CPE's unicast SID or multicast group (multicast SID).

The type of service and other current parameters of an application service are implicit in the SFID. A service flow definition may be accessed reading the appropriate service flow MIB (see 13.1.3) indexed by the SFID of the service flow assigned to a particular CPE.

Service flow, once established, may require active maintenance. The maintenance requirements vary depending upon the type of service connected. Modifiable service flows may require maintenance due to stimulus from either the CPE or the network side of the connection.

Service flow may also be terminated. This generally occurs only when a subscriber's service has changed or when the base station has not been able to communicate with the CPE. The BS or CPE can terminate a service flow.

Service Flow Management functions are supported through the use of static configuration and dynamic addition, modification, and deletion of service flow parameters and/or service flows themselves as described in 7.18.

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7.3 General superframe structure

The IEEE 802.22 WRAN system includes two operational modes: a normal mode and a self-coexistence mode. In normal mode, one WRAN cell occupies one channel and operates on all the frames in a superframe; while in self-coexistence mode, multiple WRAN cells share the same channel and each coexisting WRAN cell operates on one or several different frames exclusively.

When operating in normal mode, a WRAN cell shall transmit the Superframe Control header (SCH) at the beginning of the first frame of a superframe on the operating channel; when operating in self-coexistence mode, a WRAN cell shall transmit its SCH at the beginning of the first frame allocated to it in the superframe. The structure of the SCH for both normal mode and self-coexistence mode can be found in 7.5.1. A WRAN runs in normal mode by default and transits to self-coexistence mode when the WRAN can detect and decode an SCH or a CBP from an adjacent WRAN cell on its operating channel.

7.3.1 General superframe structure for normal mode

The superframe structure depicted in Figure 10 shall be used and the first frame shall be constituted of the following:

— A PHY superframe preamble, see Clause 9
— A PHY frame preamble, see Clause 9
— A Superframe Control header (SCH), see 7.5.1
— The rest of the first frame including its frame header and data payload

This first frame is then followed by 15 frames that each include a frame preamble, a frame header, and the data payload. See 7.4.

At the beginning of every superframe, the BS shall transmit the superframe preamble and the SCH on the operating channel using the modulation/coding specified in 9.4.1.2 and Table 202 respectively. In order to associate with a base station, a CPE must receive the SCH to establish communication with the BS. During each MAC frame, the BS shall manage the upstream and downstream operations, which may include ordinary data communication, measurement activities, coexistence procedures, and so on.

The superframe shall start with a superframe preamble, followed by the first frame preamble, the SCH, and finally the first frame payload. The first frame payload shall be reduced by two symbols with 1/4 cyclic prefix to keep the frame size consistent.

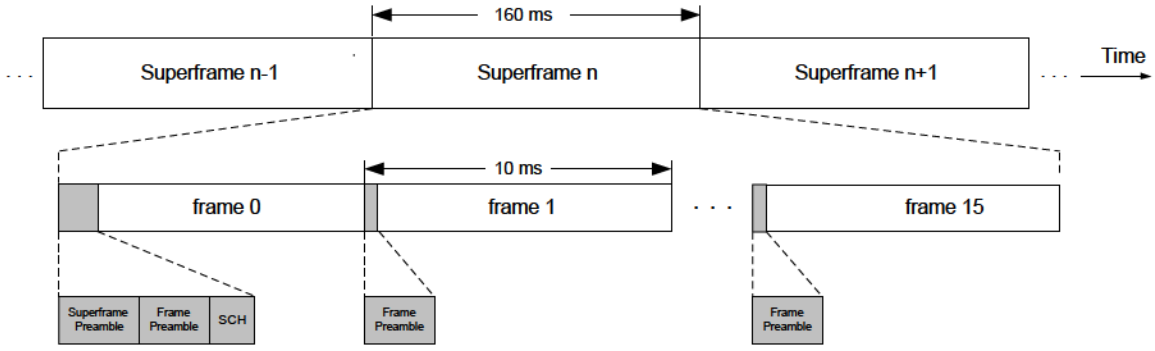


Figure 10 — General superframe structure

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7.3.2 General superframe structure for self-coexistence mode

The superframe structure in self-coexistence mode is shown in Figure 11. The self-coexistence mode is for the scenario when multiple BSs with overlapping coverage have to share the same channel. The frequency reuse factor cannot be maintained as one due to their mutual interference. In this case, these BSs shall share the channel on a per frame basis, i.e., each BS is allocated a subset of the frames of a superframe on a non-interference basis. The negotiation process of frame allocation can be found in 7.20.3.

In self-coexistence mode, the BS shall transmit its superframe preamble, frame preamble and SCH during the first active frame allocated to it. The BS and CPEs in a WRAN cell shall only transmit during the active frames allocated to that WRAN cell. They can only transmit during other frames when a self-coexistence window (SCW) has been scheduled. During the frames not allocated to the present cell, the BS and CPEs may monitor the channel for any transmission from neighboring WRAN cells to improve self-coexistence.

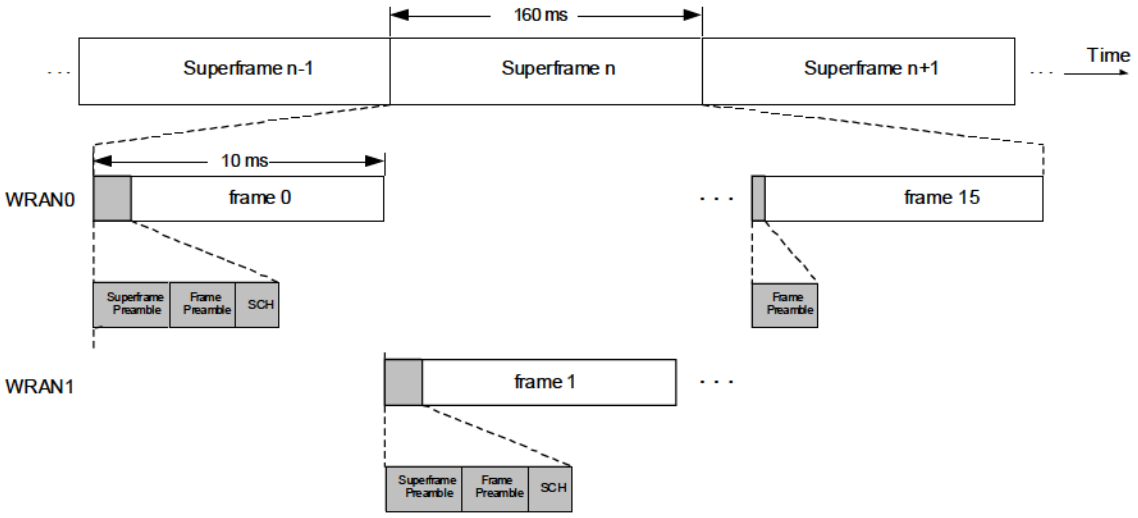


Figure 11 — General superframe structure in the self-coexistence mode

7.4 General frame structure

The top-down time division duplex (TDD) frame structure employed in the MAC is illustrated in Figure 12.

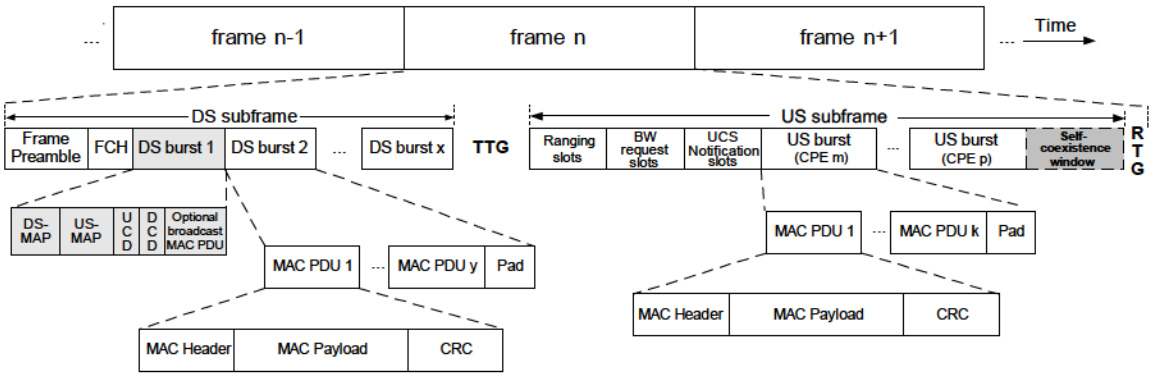


Figure 12 — MAC Frame structure

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As illustrated in Figure 12, a frame is comprised of two parts: a downstream (DS) subframe and an upstream (US) subframe. A portion of the US subframe may be allocated as a window to facilitate self-coexistence. This SCW may be scheduled by the base station at the end of the US subframe when necessary to allow transmission of opportunistic coexistence beacon protocol bursts. The SCW includes the necessary time buffers to absorb the difference in propagation delay between close-by and distant base stations and CPEs operating on the same channel. The boundary between the DS and US subframes shall be adaptive to adjust to the downstream and upstream relative capacity. The upstream subframe may contain scheduled upstream PHY PDUs, each transmitted from different CPEs for their upstream traffic. It may also include contention intervals scheduled for the following:

- CPE association (initial ranging)
- CPE link synchronization, power control and geolocation (periodic ranging)
- Bandwidth request
- Urgent coexistence situation (UCS) notification
- Quiet period resource adjustment

The definitions of the fields/messages are given in 7.6 and 7.7.

The PHY PDUs depicted in Figure 12 may be transmitted across several subchannels as shown in Figure 13, which depicts how a frame may be transmitted (in time and frequency) by the PHY layer.

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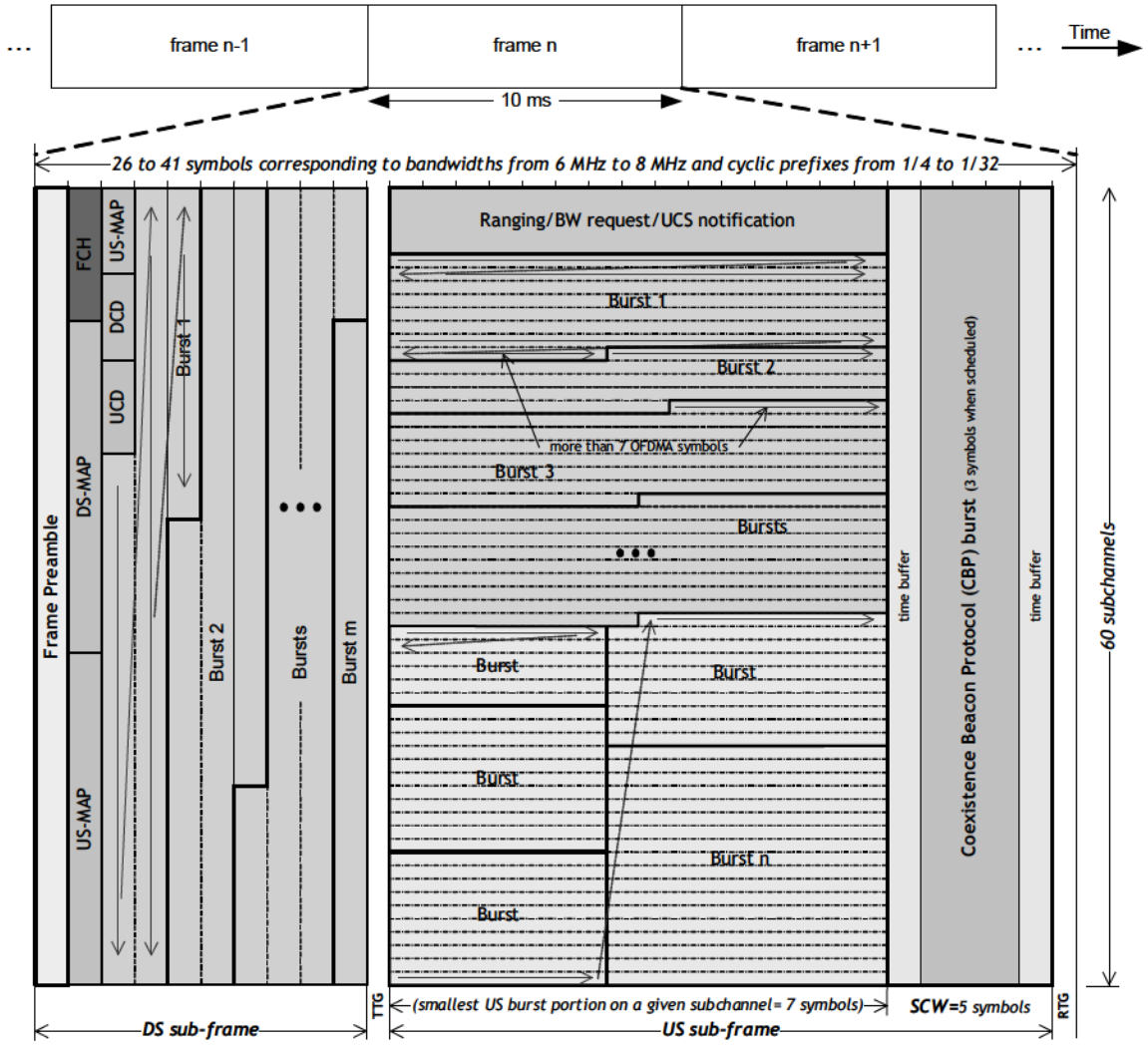


Figure 13 — Example of a time/frequency structure of a MAC frame

Figure 13 shows an example of the two-dimensional (time/frequency) structure of the MAC frame that shall consist of an integer number of fixed size OFDM slots. Each slot shall consist of one OFDM symbol by one subchannel (i.e., 1 OFDM slot = 1 symbol × 1 subchannel). To help understand Figure 13, the MAC packets are assumed to be structured in a linear TDM manner (see Figure 12) while the PHY packets are arranged in a two-dimensional time/frequency domain (symbol in the horizontal direction, logical subchannels in the vertical direction). For the FCH, the DS/US-MAP, the DCD, and UCD, as well as for the downstream payload, the MAC information is first laid vertically by subchannels then stepped horizontally in the time direction. This vertical layering allows early scheduling of DS bursts assigned to distant CPEs to compensate for propagation delays and to avoid potential interference at the CPE in the case of overlapping WRAN cells with different DS/US capacity split.

The MAC data elements from Figure 12, starting from the FCH and including the first broadcast burst, shall be entered into the second OFDM symbol, as shown in Figure 13, in the increasing order of logical subchannels until all logical subchannels are occupied. Then, the subsequent data elements, if they have not all been mapped, shall be placed in the same order on the following OFDM symbols. The balance of the last OFDM symbols shall be padded with zeros. The modulation and coding schemes for the padding zeros are defined by the DIUC for the last DS burst in the DS-MAP. Note that the DS-MAP indicates the length of the contiguous DS MAC elements, not their absolute position in the DS subframe.

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The MAC data elements that are contained in upstream bursts shall be mapped to the US subframe in a different order as shown in Figure 13. They are first mapped horizontally, OFDM symbol by OFDM symbol, in the same logical subchannel. Once a logical subchannel has been filled to the end of the upstream subframe, the balance of the MAC data elements shall be mapped to the next logical subchannel, in an increasing subchannel order. This process continues until all of the subchannels and symbols allocated to the burst are filled. If the quantity of MAC data elements is insufficient to fill an upstream burst so that an integer number of OFDMA slots is occupied once encoded, zero padding shall be inserted at the end.

Alternatively, the horizontal laying of the MAC data elements may fill one subchannel with at least 7 OFDM symbols at a time and continue on the following subchannels. However, when all logical subchannels have been filled, the next MAC data elements shall be placed in the first available logical subchannel in the following burst. The width of the last vertical burst will be between 7 and 13 symbols depending on the total number of symbols in the upstream subframe.

The long upstream packet structure, where a logical subchannel is completely filled before moving to the next subchannel, is used to maximize the allowed power per subcarrier for a given CPE EIRP limit, i.e., this horizontal laying reduces the EIRP required by the CPE for its upstream burst by minimizing the number of subchannels needed. In the upstream, the shorter burst alternative shown in Figure 13 is used to reduce latency by allowing advance of the US burst in the US subframe to give the base station time to react before the start of the next frame, at the cost of reduced transmit power and efficiency (e.g., video game near real-time versus transmission efficiency).

The format of the FCH MAC burst is described in 7.5.2. The FCH is modulated using the data mode selected (e.g., Mode 4 or 5, see Table 202) in the SCH. Binary convolutional coding (BCC, 9.7.2.1) shall also be applied to the FCH burst. The FCH specifies the burst profile and the length of either the DS-MAP, if transmitted, or the US-MAP. If neither, the DS-MAP nor the US-MAP is transmitted, the value shall be set to zero. The DS-MAP message, if transmitted, shall be the first MAC PDU in the burst following the FCH. A US-MAP message, if transmitted, shall immediately follow either the DS-MAP message, if transmitted, or the FCH. If DCD and UCD messages are transmitted in the frame, they shall immediately follow the DS-MAP and US-MAP messages. The symbols containing these broadcast MAC control messages shall be modulated using data mode 5 as described in Table 202 with the mandatory BCC mode (see 9.7.2.1).

In the upstream direction, if a CPE does not have any data to transmit in its US allocation, it shall transmit an US PHY burst containing a generic MAC header (see 7.6.1.1) with its basic FID, together with a Bandwidth Request subheader (see 7.6.1.2.1). This would allow the BS to reclaim this CPE's allocation in the following frames and use the resource for some other purpose.

The BS may schedule up to five types of contention windows (see 7.13): the Initial Ranging window is used for initializing the association; the periodic ranging window is used for regularly adjusting the timing and power at the CPE; the BW request window is for CPEs to request upstream bandwidth allocation from the BS; the UCS notification window is used by CPEs to report an urgent coexistence situation with incumbents; while the SCW is employed by CBP packets for signaling information to adjacent and overlapping WRAN cells for the purpose of self-coexistence, signal the device identification for resolving interference situations with incumbents when requested by local regulation, and for carrying out terrestrial geolocation between CPEs of the same WRAN cell. However, CBP burst transmissions for terrestrial geolocation purpose shall have lower priority than any other coexistence transmission on the CBP burst.

The SCW shall be scheduled at the end of the frame as depicted in Figure 13. The CBP packets are transmitted by selected CPEs or the BS, and carry information, among other things, about the IEEE 802.22 cell as a whole, the device that transmits it, as well as information to support the self-coexistence mechanism (see 7.20).

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A CBP packet shall be transmitted by each CPE associated to a base station as specified by the parameter "T34" in Table 272 for periodic identification of its device ID and serial number and the associated base station ID as may be required by local regulations (see Annex A).

Whenever a CPE is neither receiving nor sending data to its BS (idle state), it shall be capable of decoding CBP packets transmitted by nearby CPEs belonging to other WRAN cells, either on the same channel (N), or on adjacent channels (N±1), or on alternate channels (N±2 and beyond). This capability shall also be available at CPE initialization. In addition, BS frame synchronization is based on the absolute local start time of their superframe period to the start of every minute referenced to UTC as specified in 7.23. Hence, multiple co-located or nearby IEEE 802.22 cells can efficiently communicate with each other and align their SCW for CBP exchange as well as their quiet periods for sensing incumbents.

7.5 Control headers

As can be seen in Figure 10 and Figure 12, there are two mandatory control headers that provide essential information about the superframe (SCH) and the frame (FCH). The content and intent of each of these control headers is described in the following subclauses.

7.5.1 Superframe Control header

The SCH specification is shown in Table 1. Since the SCH decoding is critical, the SCH shall be transmitted using the modulation described in 9.4.2.1. The SCH provides information about the IEEE 802.22 cell, in order to protect incumbents, support self-coexistence mechanisms, and support the intra-frame and inter-frame mechanisms for management of quiet periods for sensing as described in 7.21.1.

Transmission of a SCH indicates that the WRAN cell is operating in one of the two possible modes: normal mode or self-coexistence mode. These are described in 7.3.

All bits indicated as "*Reserved*" in tables throughout this standard shall be transmitted as zeros unless otherwise explicitly specified.

Table 1— Superframe Control header format

Syntax	Size	Notes
Superframe_Control_Header_Format() {		One OFDM symbol long and transmitted with modulation/coding described in 9.4.2.1
BS_ID	48 bits	MAC address that uniquely identifies the BS transmitting the SCH.
Frame Allocation Map	16 bits	Indicates which frames in the present superframe are allocated to the BS transmitting the SCH.
Superframe Number	8 bits	Positive integer that represents the superframe number (modulo 256). This field shall be incremented by 1 upon every new superframe.
CP	2 bits	Cyclic Prefix Factor Specifies the size of the cyclic prefix used by the PHY in the frame transmissions in this superframe (see 9.1.1.1). Pre-determined values are 00: 1/4 T_{FFT} 01: 1/8 T_{FFT} 10: 1/16 T_{FFT} 11: 1/32 T_{FFT}
FCH Encoding Flag	2 bit	00: FCH packet encoded with PHY mode 5 (See Table 202) 11: FCH packet encoded with PHY mode 4
Self-coexistence Capability Indicator	4 bits	0000: no self-coexistence capability supported 0001: only Spectrum Etiquette 0010: Spectrum Etiquette and Frame Contention 0011–1111: *Reserved*
MAC version	8 bits	IEEE 802.22 MAC version to which the message originator conforms.

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Syntax	Size	Notes
		0x01: IEEE Std 802.22 0x02–0xFF: *Reserved*
Current Intra-frame Quiet Period Cycle Length	8 bits	Specified in number of superframes, it indicates the spacing between the superframes for which the intra-frame quiet period specification is valid. For example, if this field is set to 1, the Quiet Period Cycle repeats every superframe; if it is set to 2, the Quiet Period Cycle repeats every 2 superframes, etc. If this field is set to 0, no intra-frame quiet period is scheduled or the current intra-frame quiet period is cancelled.
Current Intra-frame Quiet Period Cycle Offset	8 bits	Valid only if Current Intra-frame Quiet period Cycle Length > 0. Specified in number of superframes, it indicates the offset from this SCH transmission to the beginning of the first superframe in the Current Intra-frame Quiet period Cycle Length.
Current Intra-frame Quiet period Cycle Frame Bitmap	16 bits	Valid only if Current Intra-frame Quiet Period Cycle Length > 0. Valid for each superframe identified by the Current Intra-frame Quiet Period Cycle Length, each bit in the bitmap corresponds to one frame within the superframe. If the bit is set to 0, no intra-frame quiet period shall be scheduled in the corresponding frame. If the bit is set to 1, an intra-frame quiet period shall be scheduled within the corresponding frame for the duration specified by the Current Intra-frame Quiet period Duration.
Current Intra-frame Quiet Period Duration	8 bits	Valid only if Current Intra-frame Quiet Period Cycle Length > 0. If this field is set to a value different from 0 (zero), it indicates the number of symbols starting from the end of the frame during which no transmission shall take place.
Claimed Intra-frame Quiet Period Cycle Length	8 bits	Specified in number of superframes, it indicates the spacing between the superframes for which the intra-frame quiet period specification claimed by a BS would be valid. For example, if this field is set to 1, the Quiet Period Cycle would repeat every superframe; if it is set to 2, the Quiet Period Cycle would repeat every 2 superframes, etc. If this field is set to 0, no intra-frame quiet period is claimed by the BS.
Claimed Intra-frame Quiet Period Cycle Offset	8 bits	Valid only if Claimed Intra-frame Quiet Period Cycle Length > 0. Specified in number of superframes, it indicates the offset from this SCH transmission to the time where the Claimed Quiet Period Cycle resulting from the inter-BS negotiation (see 7.21.2) shall become the Current Intra-frame Quiet Period Cycle.
Claimed Intra-frame Quiet period Cycle Frame Bitmap	16 bits	Valid only if Claimed Intra-frame Quiet Period Cycle Length > 0. Valid for each superframes identified by the Claimed Intra-frame Quiet Period Cycle Length, each bit in the bitmap corresponds to one frame within each specified superframe. If the bit is set to 0, no intra-frame quiet period will be scheduled in the corresponding frame. If the bit is set to 1, an intra-frame quiet period will be scheduled within the corresponding frame for the duration specified by Claimed Intra-frame Quiet period Duration.
Claimed Intra-frame Quiet Period Duration	8 bits	Valid only if Claimed Intra-frame Quiet Period Cycle Length > 0. If this field is set to a value different from 0 (zero): it indicates the number of symbols starting from the end of the frame during which no transmission will take place.
Synchronization Counter for Intra-frame Quiet Period Rate	8 bits	Valid only if Claimed Intra-frame Quiet Period Cycle Length > 0. This field is used for the purpose of synchronizing the Claimed Intra-frame Quiet Period rate among overlapping BSs in order to allow dynamic reduction of the Intra-frame Quiet Period rate. This Quiet Period rate is defined as the number of frames with quiet periods identified by the Cycle Frame Bitmap in the superframes designated by the Cycle Length, divided by this Quiet Period Cycle Length (see 7.21.2).
Synchronization Counter for Intra-frame Quiet Period Duration	8 bits	Valid only if Claimed Intra-frame Quiet Period Duration > 0. This field is used for the purpose of synchronizing the Claimed Intra-frame Quiet Period Durations among overlapping BSs in order to allow dynamic reduction of the Intra-frame Quiet Period Duration (see 7.21.2).

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