



**IEEE Standard for
Local and metropolitan area networks**

**Part 20: Air Interface for Mobile
Broadband Wireless Access Systems
Supporting Vehicular Mobility—
Physical and Media Access Control Layer
Specification**

IEEE Computer Society

Sponsored by the
LAN/MAN Standards Committee

IEEE
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New York, NY 10016-5997, USA
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Approved 12 June 2008

IEEE-SA Standards Board

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- TIA-1121.000—Overview for Ultra Mobile Broadband (UMB) Air Interface Specification
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- TIA-1121.002—MAC Layer for Ultra Mobile Broadband (UMB) Air Interface Specification
- TIA-1121.003—Radio Link Layer for Ultra Mobile Broadband (UMB) Air Interface Specification
- TIA-1121.004—Application Layer for Ultra Mobile Broadband (UMB) Air Interface Specification
- TIA-1121.005—Security Functions for Ultra Mobile Broadband (UMB) Air Interface Specification
- TIA-1121.006—Connection Control Plane for Ultra Mobile Broadband (UMB) Air Interface Specification
- TIA-1121.007—Session Control Plane for Ultra Mobile Broadband (UMB) Air Interface Specification
- TIA-1121.008—Route Control Plane for Ultra Mobile Broadband (UMB) Air Interface Specification
- TIA-1121.009—Broadcast-Multicast Upper Layers for Ultra Mobile Broadband (UMB) Air Interface Specification

Abstract: The technical requirements of this standard form a compatibility standard for mobile broadband wireless access systems. The standard ensures that a compliant access terminal (AT) or user terminal (UT) can obtain service through any access node (AN) or base station (BS) conforming to properly selected modes of this standard, consistent with equipment and operator requirements, thus providing a framework for the rapid development of cost-effective, multivendor mobile broadband wireless access systems. This compatibility standard is targeted for use in a wide variety of licensed frequency bands and regulatory environments.

This standard provides for future standardized extension capabilities. The architecture defined by this standard permits such expansion without the loss of backward compatibility.

Keywords: access node, access terminal, base station, broadband, LAN, local area networks, MAN, metropolitan area networks, user terminal, vehicular mobility, wireless access

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1. Scope

This standard specifies the physical and medium access control layers of an air interface for interoperable mobile broadband wireless access systems, operating in licensed bands below 3.5 GHz. The system is optimized for IP-data transport, with peak data rates per user in excess of 1 Mbps.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

3GPP2 C.R1001-F v1.0, Administration of Parameter Value Assignments for cdma2000TM Spread Spectrum Standards.¹

3GPP2 C.S0001, Introduction to cdma2000 Standards for Spread Spectrum Systems.

3GPP2 C.S0010-C v2.0, Recommended Minimum Performance Standards for cdma2000 Spread Spectrum Base Stations, March 2006.

3GPP2 C.S0011-C, Recommended Minimum Performance Standards for cdma2000 Spread Spectrum Mobile Stations, March 2006.

3GPP2 C.S0024, cdma2000 High Rate Packet Data Air Interface Specification.

3GPP2 C.S0057-B, Band Class Specification for cdma2000 Spread Spectrum Systems.

3GPP2 S.S0055A v2.0, Enhanced Cryptographic Algorithms.

3GPP2 S.S0078, Common Security Algorithms.

ATIS-0700004.2005, High Capacity-Spatial Division Multiple Access (HC-SDMA) Radio Interface Standard, September 2005.²

IEEE Std 802.1QTM, IEEE Standard for Local and Metropolitan Area Networks: 2 Virtual Bridged Local Area Networks.^{3, 4}

IEEE Std 802.2TM, IEEE Standard for Local Area Networks—Logical link control.

IEEE Std 802.3TM, IEEE Standard for 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 layer specifications.

IETF RFC 791, Internet Protocol.⁵

IETF RFC 2210, The Use of RSVP with IETF Integrated Services.

IETF RFC 2216, Network Element Service Specification Template, S. Shenker, J. Wroclawski, September 1987.

IETF RFC 2460, Internet Protocol, Version 6 (IPv6) Specification.

¹3GPP2 publications are available at <http://www.3gpp2.org/Public>.

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IETF RFC 2578, Structure of Management Information Version 2 (SMIPv2), April 1999.

IETF RFC 2579, Textual Conventions for SMIPv2, April 1999.

IETF RFC 2580, Conformance Statements for SMIPv2, April 1999.

IETF RFC 3056, Connection of IPv6 Domains via IPv4 Clouds, February 2001.

IETF RFC 3095, Robust Header Compression (ROHC): Framework and four profiles: RTP, UDP, ESP, and uncompressed.

IETF RFC 3748, Extensible Authentication Protocol, June 2004.

IETF RFC 4493, *The AES-CMAC Algorithm*, Song, JH., Poovendran, R., Lee, J., and Iwata, T., June 2006.

ITU-T Recommendation E.212, Identification Plan for Land Mobile Stations, 1988.⁶

NIST, Special Publication 800-38B, *Recommendation for Block Cipher Modes of Operation: The CMAC Method for Authentication*.

⁶ITU-T publications are available from the International Telecommunications Union, Place des Nations, CH-1211, Geneva 20, Switzerland/Suisse (<http://www.itu.int/>).

3. Definitions

For the purposes of this document, the following terms and definitions apply. *The Authoritative Dictionary of IEEE Standard Terms* [B1]⁷ should be referenced for terms not defined in this clause.

3.1 access network: Access network is a collection of access nodes (ANs).

3.2 access node (AN): The physical device that implements the MAC and PHY of one or more sectors in the network.

3.3 access probe: A sequence of signaling transmitted by the access terminal on the reverse access channel to establish a connection to the access network.

3.4 access sequence index: An identifier to distinguish an access terminal before a MACID is assigned to it. This is used for initial access.

3.5 access terminal (AT): A device providing data connectivity to a user. An access terminal may be connected to a computing device such as a laptop personal computer or it may be a self-contained data device such as a personal digital assistant.

3.6 acquisition pilot: The first TDM pilot in the superframe preamble. This is used for initial acquisition.

3.7 active set: A set of sectors maintained in an access terminal that are assigned a MACID to the access terminal.

3.8 band class: A set of frequency channels and a numbering scheme for these channels.

3.9 base layer: *See: layered modulation.*

3.10 base station (BS): The device in the access network that communicates over the air interface, via one or more sectors, with the user terminals. Base stations coordinate the management of the air interface attributes.

3.11 beacon: A deterministic signal used to indicate the presence of an access network to the access terminals.

3.12 beacon orthogonal frequency division multiplexing (OFDM) symbol: A number of OFDM symbols allocated for transmission of the forward beacon pilot channel per every two superframes.

3.13 beacon subcarrier group: A subset of subcarriers belonging to the set of usable subcarriers in a beacon OFDM symbol.

3.14 block: A set of subcarriers.

3.15 block resource channel: A channel in which the hop-ports are mapped to a group of adjacent subcarriers in units of tiles.

3.16 CDMA hopping zone: The set of subcarriers over which the CDMA subsegments can be transmitted on the Reverse Link.

3.17 CDMA segment: The collection of all CDMA subsegments in the reverse link.

⁷The numbers in brackets correspond to those of the bibliography in Annex B.

3.18 CDMA subsegment: A collection of fixed number of subcarriers in reverse link allocated for the transmission of code division multiple access channels.

3.19 channel interleaver: The entity that permutes a sequence of symbols before transmission.

3.20 channel quality indicator: A quantized measurement of Forward Link channel quality.

3.21 Code Division Multiple Access (CDMA): A technique for spread-spectrum multiple-access digital communications that creates channels through the use of unique code sequences.

3.22 code symbol: The output of an error-correcting encoder. Information bits are input to the encoder and code symbols are output from the encoder. *See:* **block code**, **convolutional code**, **turbo code**, and **LDPC code**.

3.23 common pilot: A pilot in the forward common pilot channel.

3.24 common segment: A set of hop-ports present in all forward link PHY frames containing all the common forward control channels, where the common forward control channels consist of all channels carried on the forward link control segment except the forward shared control channel. The common segment may contain the forward shared control channel under certain conditions.

3.25 constituent code: A component of turbo code. One of the two recursive convolutional codes. *See:* **turbo code** and **convolutional code**.

3.26 convolutional code: A type of error-correcting code. A code symbol can be considered as the convolution of the input data sequence with the impulse response of a generator function.

3.27 constraint length: A parameter of a convolutional code. Constraint length is equal to one more than the number of registers in the convolutional code. *See:* **convolutional code**.

3.28 Coordinated Universal Time (UTC): An internationally agreed upon time scale maintained by the Bureau International des Poids et Mesures (BIPM) used as the time reference by nearly all commonly available time and frequency distribution systems (e.g., WWV, WWVH, LORAN-C, Transit, Omega, and GPS).

3.29 cyclic code: Cyclic code is a special type of linear block code such that a cyclic shift of a codeword is also a codeword.

3.30 cyclic prefix: In OFDM, to avoid inter-symbol-interference, a segment of time-domain signal at the end of the OFDM symbol is copied to the beginning, so that after the multipath channel, the time-domain signal is still cyclic within the sampling period.

3.31 cyclic redundancy check (CRC): A class of linear error detecting codes, which generate parity check bits by finding the remainder of a polynomial division. *See:* **cyclic redundancy check (CRC) bits**.

3.32 cyclic redundancy check (CRC) bits: The CRC check applied to named channels.

3.33 Dedicated Pilot: Pilot in Forward or Reverse Dedicated Pilot Channel.

3.34 DFT Matrix: A matrix representation of Discrete Fourier Transform.

3.35 DFT-Precoded CDMA: A time-domain CDMA sequence is broken up into 8 different subsequences of length 128. Each of these subsequences is converted to a frequency domain sequence through a Discrete Fourier Transform (DFT) operation, and is called DFT precoded CDMA.

3.36 Discrete Fourier Transform: A transform that converts a time domain sequence into a discrete frequency domain sequence.

3.37 Displaced Subcarrier: A concept introduced in the CDMA segment hopping in Reverse Link and Forward Link Control Segment hopping in the Forward Link. *See:* **Nominal CDMA Segment** and **Nominal FLCS Block**.

3.38 distributed resource channel: A channel in which the hop-ports are mapped to distributed subcarriers.

3.39 downlink (DL): The radio connection with the BS transmitting and the UT receiving. The term is used interchangeably with the term *forward link* or *FL*.

3.40 downloadable codebook: A set of precoding matrices that can be downloaded.

3.41 effective antenna: An effective antenna may be a single physical antenna or a linear combination of multiple physical antennas that appear to the receiver as a single physical antenna.

3.42 Effective Isotropically Radiated Power (EIRP): The product of the power supplied to the antenna and the antenna gain in a direction relative to an isotropic antenna.

3.43 Effective Radiated Power (ERP): The product of the power supplied to the antenna and its gain relative to a half-wave dipole in a given direction.

3.44 Encoder Tail Bits: A fixed sequence of bits added to the end of a block of data to reset the convolutional encoder to a known state.

3.45 enhancement layer: *See:* **Layered Modulation**.

3.46 Erasure Sequence: A sequence transmitted on a channel to hold it in the absence of data.

3.47 Exponential Sequence: A sequence of length L , whose i^{th} element, $E_{\omega}L(i)$, is given by $E_{\omega}^L = e^{-2\pi j\omega i/L}$ where $0 \leq i < L$, and j denotes the complex number $(0, 1)$.

3.48 Fast Fourier Transform (FFT): The Fast Fourier Transform is a discrete Fourier Transform algorithm that reduces the number of computations needed. *See:* **Discrete Fourier Transform**.

3.49 Forward Acknowledgment Channel: A portion of a Forward Channel used for the transmission of acknowledgments from an access network to multiple access terminals in response to the data received on the Reverse Code Division Multiple Access/Orthogonal Frequency Division Multiple Access Data Channel.

3.50 Forward Acquisition Channel: A channel sent on the Forward Link preamble consisting of one Orthogonal Frequency Division Multiplexing symbol to help in the initial acquisition process.

3.51 Forward Beacon Pilot Channel: The Forward Beacon Pilot Channel is used to indicate the presence of the access network to access terminals on other carriers.

3.52 Forward Broadcast and Multicast Pilot Channel: The Forward Broadcast and Multicast Pilot Channel is an unmodulated signal transmitted by an access network to provide a phase reference for coherent demodulation of the Forward Broadcast and Multicast Services Channel.

3.53 Forward Broadcast and Multicast Services Channel: The Forward Broadcast and Multicast Services Channel is a Forward Link channel carrying broadcast and multicast data.

3.54 Forward Cell Null Channel: The Forward Cell Null Channel defines subcarriers that are blanked by all the sectors in a cell. These subcarriers are used to measure the out-of-cell interference level.

3.55 Forward Channel Quality Indicator Pilot Channel: A signal transmitted by an access network to provide a reference for the measurement of the signals from the various antennas.

3.56 Forward Common Pilot Channel: An unmodulated signal transmitted by an access network to provides a phase reference for coherent demodulation and a means for signal strength comparisons between access networks for determining when to handoff.

3.57 Forward Data Channel: A portion of a Forward Link that carries higher-level data and control information from an access network to an access terminal.

3.58 Forward Dedicated Pilot Channel: An unmodulated signal transmitted by an access network that provides a phase reference for coherent demodulation of block resource channels (BRCHs).

3.59 Forward Error Correction: A process whereby data is encoded with block, convolutional, concatenated, LDPC, or turbo codes to assist in error correction of the link.

3.60 Forward Fast Other Sector Interference Channel: A channel sent on the Forward Link that carries an indication of other sector interference.

3.61 Forward Interference over Thermal Channel: A channel sent on the Forward Link that is used to indicate interference levels in a given Reverse Link hop-port subzone to access terminals in other sectors.

3.62 forward link (FL): The radio connection with the AN transmitting and the AT receiving. The term is used interchangeably with the term *downlink* or *DL*.

3.63 Forward Link Control Segment: A set of hop-ports or subcarriers allocated to transmit control messages to access terminals. This occurs in every PHY frame in which the Forward Acknowledgment Channel, the Forward Start-of-Packet Channel, the Forward Shared Control Channel, the Forward Fast Other Sector Interference Channel, the Forward Interference over Thermal Channel, the Forward Pilot Quality Indicator Channel, or the Forward Power Control Channel are multiplexed.

3.64 Forward Link Control Segment Available Subcarrier: A subcarrier that can be used for transmitting the Forward Link Control Segment.

3.65 Forward Link Control Segment Block: Each block in a set of hop-port blocks allocated to the Forward Link Control Segment.

3.66 Forward Link Control Segment Hopping Zone: The Forward Link Control Segment usable tiles are divided into three groups. Each group is a Forward Link Control Segment Hopping Zone. Each tile in the Forward Link Control Segment hops within one zone.

3.67 Forward Link Control Segment Resource: Each symbol in a Forward Link Control Segment is designed to have a diversity level of three, by being transmitted at three different subcarriers. This three-tuple is called an FLCS Resource.

3.68 Forward Link Control Segment Usable Tile: Tiles that can be used for transmitting the Forward Link Control Segment.

3.69 Forward Link Serving Sector: The sector that transmits the Forward Data Channel to the access terminal.

3.70 Forward Other Sector Interference Channel: A channel sent on the forward link preamble consisting of two Orthogonal Frequency Division Multiplexing symbols to help in the initial acquisition process. In addition, these symbols also carry the other sector interference value that is received from the SFP MAC protocol.

3.71 Forward Pilot Quality Indicator Channel: A channel sent on the forward link that indicates the strength of the reverse link for a given access terminal.

3.72 Forward Power Control Channel: A channel sent on the forward link that carries commands for closed-loop control of Reverse Link transmit power.

3.73 Forward Preamble Pilot Channel: A signal transmitted by an access network to aid in acquiring the system.

3.74 Forward Primary Broadcast Control Channel: A Forward Link Channel transmitted on the preamble that carries deployment-wide static parameters like cyclic prefix duration, number of guard carriers, in addition to the superframe index.

3.75 Forward Quick Paging Channel: A channel sent on the forward link preamble to aid the access terminal in identifying when a page is sent to it.

3.76 Forward Reverse Activity Bit Channel: A channel sent on the forward link that carries a single bit that indicates the load on the Reverse Link of a given access network.

3.77 Forward Secondary Broadcast Control Channel: A Forward Link Channel transmitted on the preamble that carries sufficient information to enable the access terminal to demodulate forward link data from the PHY frames, e.g., information on hopping patterns, pilot structure, control channel structures, effective antennas, multiplexing modes.

3.78 Forward Shared Control Channel: A channel sent on the forward link that carries control information for the Forward Data Channel transmission, as well as for group resource assignments.

3.79 Forward Start-of-Packet Channel: A channel sent on the forward link that is used to indicate to an access terminal whether a persistent assignment is still valid or if it has expired.

3.80 Forward Superposed Channel Quality Indicator Pilot Channel: A pilot channel that helps in the channel quality feedback for the superposed traffic on the broadcast and multicast section.

3.81 Forward Superposed Data Channel: A portion of a forward link that carries higher-level data and control information from an access network to an access terminal sent as superposed traffic on the broadcast and multicast section.

3.82 Forward Superposed Dedicated Pilot Channel: A pilot channel that helps in the channel estimation for the superposed traffic on the broadcast and multicast segment.

3.83 Fractional Frequency Reuse: A frequency reuse scheme where some of the subcarriers have a reuse factor less than one, i.e., they are not used in all sectors.

3.84 frame: A basic timing interval in the system, comprising of eight Orthogonal Frequency Division Multiplexing symbols.

3.85 Galois field (GF): A Galois field is a finite algebraic field with p^n elements where p is a prime number.

3.86 generator function: A function used to define a convolutional code. *See:* **convolutional code.**

- 3.87 generator polynomial:** A polynomial form of the generator function. *See:* **generator function.**
- 3.88 Global Asynchronous:** A system setup where the superframe timing of all sectors need not be aligned.
- 3.89 Global Hopping:** A hop-permutation used in the Reverse Link OFDMA Segment such that hop-ports are permuted across all subzones in the Global Hopping Zone. *See:* **hop-permutation, hop-port, subzone,** and **Reverse Link OFDMA Segment.**
- 3.90 Global Positioning System (GPS):** A U.S. government satellite system that provides location and time information to users.
- 3.91 Global Synchronous:** A system setup such that the superframes timing of all sectors are aligned within a predefined time interval.
- 3.92 GroupID:** A bit pattern assigned to a set of access terminals to identify them for the purpose of group resource assignment.
- 3.93 Group Resource Assignment:** The method of assigning shared resources to a set of access terminals on the Forward Data Channel.
- 3.94 Guard Interval:** A time interval, inserted between symbols to avoid intersymbol interference.
- 3.95 Guard Subcarrier:** A tone carrying no data to avoid intersymbol interference.
- 3.96 Hadamard matrix:** A square matrix formed by 1 and -1 s. All columns (rows) are orthogonal to each other. The columns (rows) of the matrix are Walsh Sequences. *See* Walsh Sequence.
- 3.97 HARQ:** A technique to transmit a packet by splitting it into several parts, which are transmitted sequentially through retransmissions. After each retransmission, the receiver attempts to decode the packet using all the received subpackets, the success of which may be fed back to the transmitter. The transmission can be early terminated if early decoding is successful.
- 3.98 HARQ Retransmission Index:** A counter for HARQ retransmissions.
- 3.99 hash function:** A function that outputs a unique number given an input number.
- 3.100 Hierarchical Modulation:** *See:* **Layered Modulation.**
- 3.101 hopping:** A pattern of frequency assignments.
- 3.102 hop-permutation:** A time-varying mapping from hop-port to subcarriers. *See:* **hop-port** and **subcarrier.**
- 3.103 hop-port:** An indexing scheme for subcarriers in an OFDM symbol.
- 3.104 hop-port index:** An index to address hop-ports.
- 3.105 hop-port subzone:** A collection of hop-ports of a fixed given size. *See:* **hop-port.**
- 3.106 hop-sequence:** A sequence of hop-permutations.
- 3.107 initial access:** Procedure for the access terminal to set up a connection to the access network for the first time, i.e., without a MACID.
- 3.108 Initial Protocol Set Identifier:** This is used to identify the default protocol stack for each of the major revisions of the air interface standard. The access network includes values of the supported Initial Protocol

Set Identifier in overhead messages. Multiple Protocol Set Identifiers may map to a single Initial Protocol Set Identifier.

3.109 interlace: A portioning of forward link or reverse link frames. HARQ transmissions use PHY frames on a given interlace.

3.110 interleaving: The process of permuting a sequence of symbols.

3.111 Inverse Fast Fourier Transform: An algorithm to efficiently compute the Inverse Fourier Transform.

3.112 knockdown codebook: A type of precoding matrix set used in Space Division Multiple Access (SDMA) constructed from a set of universal matrices. *See:* **universal matrix**.

3.113 layered modulation: A method to map multiple (two) bit streams to points in modulation constellation. Bits from the first bit stream (base layer) select one of the non-overlapping sets of constellation points. Bits from the second bit stream (enhancement layer) select one of the constellation points in the selected set. The constellation of the enhancement layer may be rotated for performance enhancement.

3.114 Linear Block Code: A type of block code such that the sum of two codewords is another codeword. *See* Block Code.

3.115 Link Assignment Block (LAB): A message for resource assignment.

3.116 Link Assignment Block (LAB) segment: A Forward Link Control Segment containing only the Forward Shared Control Channel.

3.117 local hopping: A hop-permutation used in the Reverse Link OFDMA Segment such that the hop-ports are permuted within a subzone. *See:* **hop-permutation**, **hop-port**, **subzone**, and **Reverse Link OFDMA Segment**.

3.118 logical antenna: A set of linear combination of physical antennas.

3.119 logical channel: Any channel carrying signaling and higher layer data. A number of logical channels are often multiplexed to form a physical channel.

3.120 Low-Density Parity Check Code: A type of error-correcting code. The code is defined as the null space of a sparse parity-check matrix.

3.121 MAC layer identifier: A bit pattern assigned to an access terminal by the MAC Layer for identification.

3.122 mean input power: The total received calorimetric power measured in a specified bandwidth at the antenna connector, including all internal and external signal and noise sources.

3.123 mean output power: The total transmitted calorimetric power measured in a specified bandwidth at the antenna connector when the transmitter is active.

3.124 modulation order: A measure for the size of a modulation constellation, and is defined as $\log_2(M)$, where M is the number constellation points in the modulation process.

3.125 Modulation Symbol: For the Reverse CDMA Data Channel, the Reverse OFDMA Data Channel, the Forward Data Channel, the Forward Broadcast and Multicast Services Channel and the Forward Superposed

Channel, a modulation symbol is defined as the output of the QPSK/8-PSK/16-QAM/64-QAM modulator. For all other channels, a modulation symbol is defined as the input to the signal point mapping block and the output of the interleaver or the sequence repetition block, if present.

3.126 Modulo-2 Addition: An operation of two binary numbers with the output being the exclusive-or of the two inputs.

3.127 Multiple Codeword: A Multiple Input Multiple Output transmission mode where multiple codes are used to encode the packet being transmitted over the various antennas.

3.128 Multiple Input Multiple Output: An abstract mathematical model for multi-antenna communication systems where the transmitter has multiple antennas capable of transmitting independent signals and the receiver is equipped with multiple receive antennas.

3.129 mutually synchronous: A set of access networks whose timing is synchronized within a pre-specified limit.

3.130 Newly-Freed Subcarrier: A concept introduced in the CDMA segment hopping in Reverse Link and Forward Link Control Segment hopping in the forward link. *See:* **Nominal CDMA Subsegment** and **Nominal FLCS Block**.

3.131 Nominal CDMA subsegment: In the reverse link, the CDMA subsegments are designed to hop across the all available subcarriers. First, a set of subcarriers is assumed for the CDMA subsegments, which is defined as Nominal CDMA subsegments. The other hop-ports are mapped to available subcarriers not occupied by the Nominal CDMA subsegments. Then, the CDMA subsegments can be hopped to other locations. The subcarriers that the CDMA subsegments hop to are defined as Displaced Subcarriers, and the subcarriers that the CDMA subsegments leave are defined as Newly-Freed Subcarriers. The other hop-ports that originally map to the Displaced Subcarriers are adjusted to map to the Newly-Freed Subcarriers.

3.132 Nominal FLCS Block: In the forward link, the FLCS Blocks are designed to hop across the all available subcarriers. First, a set of subcarriers is assumed for the FLCS Blocks, which is defined as Nominal FLCS Blocks. The other hop-ports are mapped to available subcarriers not occupied by the Nominal FLCS Blocks. Then, the FLCS Blocks can be hopped to other locations. The subcarriers that the FLCS Blocks hop to are defined as Displaced Subcarriers, and the subcarriers that the FLCS Blocks leave are defined as Newly-Freed Subcarriers. The other hop-ports that originally map to the Displaced Subcarriers are adjusted to map to the Newly-Freed Subcarriers.

3.133 Orthogonal Frequency Division Multiple Access: A multi-user version of the Orthogonal Frequency Division Multiplexing digital modulation scheme. Multiple access is achieved in Orthogonal Frequency Division Multiple Access by assigning subsets of subcarriers to individual users.

3.134 Orthogonal Frequency Division Multiple Access (OFDMA) segment: The set of subcarriers used to transmit channels using OFDMA.

3.135 Orthogonal Frequency-Division Multiplexing (OFDM): A modulation technique that utilizes multiplexing based on orthogonal complex harmonic basis functions together with a cyclic prefix to allow multi-path resilience.

3.136 Orthogonal Frequency-Division Multiplexing (OFDM) Symbol: An Orthogonal Frequency Division Multiplexing symbol is comprised of individually modulated subcarriers that carry complex-valued data.

3.137 packet: A sequence of information bits to be transmitted by the Physical Layer.

3.138 Packet Error Detection: A method used to detect whether the received packet is in error. Usually, the data is encoded with a Cyclic Redundancy Check to aid in this detection. *See:* **Cyclic Redundancy Check**.

3.139 Packet Format: A specification of spectral efficiency, packet size, code rate and modulation order to be used for each transmission.

3.140 Packet Format Index: The index of Packet Format.

3.141 parity bits: Redundant bits added in an error-correcting code that help in detecting if a packet was demodulated properly.

3.142 parity symbol: Redundant symbols added in an error-correcting code that help in detecting if a packet was demodulated properly.

3.143 permutation function: A function that permutes a sequence of input bits, symbols, etc.

3.144 permutation matrix: A matrix form of the permutation function.

3.145 persistent assignment: An assignment that is valid until explicitly deassigned.

3.146 physical antenna: A radiating radio element.

3.147 Physical Layer: The part of the communication protocol between the access terminal and the access network that is responsible for the transmission and reception of data. The Physical Layer in the transmitting station is presented a frame and transforms it into an over-the-air waveform. The Physical Layer in the receiving station transforms the waveform back into a frame.

3.148 PilotID: A 10-bit quantity derived from the PilotPN and the IsSynchronous field of the Overhead Messages Protocol. PilotID is useful in distinguishing between two sectors with the same PilotPN provided that they have different values of the IsSynchronous field.

3.149 PilotPhase: A 9-bit quantity defined for use in modulating the Forward Other Sector Interference Channel. The PilotPhase of an access network depends on the superframe index and the PilotPN.

3.150 PilotPN: A 9-bit identifier used in the Physical Layer for differentiating between different sectors. Sectors with different PilotPNs transmit different acquisition pilots on the Forward Other Sector Interference Channel, which enables access terminals to monitor the signal strengths of the two sectors. Similarly, two sectors with different PilotPNs use different pseudo-random scrambling sequences on the Forward Data Channel.

3.151 power amplifier: An analog device that amplifies the radio frequency signal before sending it through the antenna.

3.152 Power density: The expected energy per modulation symbol, where “modulation symbol” refers to frequency domain (pre-IFFT) symbols, as defined in the Physical Layer specification. The “expected” power is used to cover the case of transmissions using non-constant modulus signal constellations. In all cases, the density shall be computed according to the parameters of the modulation symbols in the particular channel being specified.

NOTE—Note that this definition of power density is not true in the strictest sense because of cyclic prefix and windowing overheads. However, it provides a convenient method of communicating power levels to the Physical Layer Protocol. The construction of transmitted waveforms as a function of power densities is specified by the Physical Layer Protocol.⁸

3.153 preamble: *See: Superframe Preamble.*

⁸Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

- 3.154 precoder index:** The index to a precoding matrix in a set of precoding matrices.
- 3.155 precoding:** A method to beamform with multiple antennas to focus a spatial beam in a certain direction.
- 3.156 precoding matrix:** A matrix, whose columns determine the transmit vectors used for precoding during the Space Division Multiple Access operation.
- 3.157 Precoding Matrix Cluster:** A subset of precoding matrix set that cover the whole space. Different clusters of precoding matrices are used for the Space Division Multiple Access operation. *See:* **precoding matrix**.
- 3.158 preferred matrix:** A precoding matrix that the access terminal chooses for the future SDMA transmissions. *See:* **Precoding Matrix**.
- 3.159 Preferred Matrix Index:** The index to the preferred matrix used by access terminal to request the preferred matrix. *See:* **preferred matrix**.
- 3.160 Protocol Set Identifier:** Used to identify the subtype of each of the protocols in the protocol stack.
- 3.161 Pruned Bit Reversal Interleaver:** An interleaver such that the output ordering is the reverse of the binary representations of all input locations.
- 3.162 Pseudonoise (PN) Register:** A shift register structure used in the Pseudonoise (PN) sequence generator.
- 3.163 Pseudonoise (PN) sequence:** A periodic binary sequence.
- 3.164 Punctured Code:** An error-correcting code generated from another error-correcting code by deleting (i.e., puncturing) code symbols from the encoder output.
- 3.165 Radio Configuration:** A set of Broadcast and Multicast Serviced Channel transmission formats that are characterized by Physical Layer parameters such as Orthogonal Frequency Division Multiplexing symbol duration.
- 3.166 rank:** The number of effective antennas used in an MIMO transmission.
- 3.167 Rate-1/3 Concatenated Code:** A linear block code with 4 input bits and 12 output bits that can be interpreted as a concatenation of a rate-2/3 cyclic code and a rate-1/2 tail-biting convolutional code.
- 3.168 readymade codebook:** A type of precoding matrix set.
- 3.169 Recursive Convolutional Code:** A convolutional code that uses feedback.
- 3.170 Reed-Solomon Code:** A type of linear block code.
- 3.171 Reference Receive Power Density:** The reference receive power density used by the access terminal as the reference power density per subcarrier for comparing the strengths of different sectors, and is defined as

$$\frac{P_{\text{PBCH}}}{n_{\text{sc}}},$$

where

P_{PBCH} denotes the total received power of Forward Primary Broadcast Control Channel,

n_{sc} is the number of subcarriers carrying the Forward Primary Broadcast Control Channel in each OFDM symbol.

3.172 Reference Receive Power Level: The received power of the Forward Primary Broadcast Control Channel is used by the access terminal as a Reference Received Power Level for the transmitting sector.

3.173 Reference Transmit Power: The power at which the first OFDM symbol of the preamble (Forward Primary Broadcast Control Channel) is transmitted, and may vary from sector to sector.

3.174 reserved subzone: A forward link subzone that is reserved for non-unicast transmissions. A portion of this can be used for broadcast and multicast services. This subzone cannot be assigned to block resource channel and distributed resource channel zones.

3.175 Resource Multiplexing Mode: Methods to allocate forward link hop-ports to block resource channel and distributed resource channel zones.

3.176 ReuseIndex: PilotPhase mod 8. *See:* **PilotPhase**.

3.177 Reverse Access Channel: A Reverse Code Division Multiple Access Channel used by the access terminal for communicating with the access networks. The Access Channel is used for short signaling message exchanges, such as call originations, responses to pages, and registrations. The Access Channel is a slotted random access channel.

3.178 Reverse Acknowledgment Channel: A portion of a Reverse Orthogonal Frequency Division Multiple Access Channel used for the transmission of acknowledgments from an access terminal to multiple access networks in response to the data received on the Forward Packet Data Channel.

3.179 Reverse Acknowledgment Channel Partial-Tile: A contiguous set of eight subcarriers for a duration of two, four, or eight OFDM symbols that is used for the Reverse Acknowledgment Channel. The partial-tile is further divided into one, two, or four subtiles, each occupying a eight subcarriers by two OFDM symbols block.

3.180 Reverse Acknowledgment Channel Subtile: *See:* **Reverse Acknowledgment Channel Partial-Tile**.

3.181 Reverse Auxiliary Pilot Channel: An unmodulated signal transmitted in the Reverse Link CDMA segment by an access terminal in conjunction with the Reverse CDMA Data Channel. This channel provides a phase reference for coherent demodulation for demodulation of the Reverse CDMA Data Channel.

3.182 Reverse Code Division Multiple Access Dedicated Control Channel: A portion of a Code Division Multiple Access Reverse Link that carries control information and other feedback information from an access terminal to an access network.

3.183 Reverse Code Division Multiple Access Data Channel: A portion of a Code Division Multiple Access Reverse Link that carries higher-level data and control information from an access terminal to an access network.

3.184 Reverse Control Channel: A portion of a Reverse Link that carries control information from an access terminal to an access network.

3.185 Reverse Dedicated Pilot Channel: An unmodulated signal transmitted in the Reverse Link Orthogonal Frequency Division Multiple Access segment by an access terminal. This channel provides a phase reference for coherent demodulation of the Reverse Orthogonal Frequency Division Multiple Access Traffic Channels.

3.186 Reverse Code Division Multiple Access Control Channel: A portion of an Orthogonal Frequency Division Multiple Access Reverse Link that carries control information and other feedback information from an access terminal to an access network.

3.187 reverse link (RL): The radio connection with the AT transmitting and the AN receiving. The term is used interchangeably with the term *uplink* or *UL*.

3.188 Reverse Link Serving Sector: A sector to which the access terminal is scheduled to transmit its Reverse Link traffic data.

3.189 Reverse OFDMA Dedicated Control Channel Quarter-Tile: A resource spanning eight contiguous subcarriers in frequency and four contiguous OFDM symbols in time.

3.190 Reverse Orthogonal Frequency Division Multiple Access Control Channel: A portion of a OFDMA Reverse Link that carries control information and other feedback information from an access terminal to an access network.

3.191 Reverse Orthogonal Frequency Division Multiple Access Data Channel: A portion of a Orthogonal Frequency Division Multiple Access Reverse Link that carries higher-level data and control information from an access terminal to an access network.

3.192 Reverse Pilot Channel: An unmodulated signal transmitted in the Reverse Link Code Division Multiple Access segment by an access terminal. A reverse pilot channel may provide a phase reference for coherent demodulation and a means for signal strength measurement.

3.193 Reverse Traffic Channel: One or more code channels used to transport user and signaling traffic from the access terminal to the access network. *See:* **Reverse Code Division Multiple Access Data Channel** and **Reverse Orthogonal Frequency Division Multiple Access Data Channel**.

3.194 Rotational OFDM: A modulation technique in which a set of subcarriers are transformed through a rotational matrix for robustness in frequency selective fading channels.

3.195 route: Each InUse protocol stack instance is called a route.

3.196 Scrambling Algorithm: An algorithm that randomizes an input sequence using a pseudonoise sequence. The pseudonoise sequence is generated using a shift register structure whose initial state is given by a seed. *See:* **Seed**, **Shift Register**, and **Pseudonoise (PN) sequence**.

3.197 SDMA Subtree: A portion of the hop-ports used for SDMA transmissions. Typically, the channel tree contains multiple subtrees such that there is one subtree per SDMA cluster with one primary subtree. Identical hop patterns are used across the subtrees.

3.198 sector: One set of physical layer channels transmitted between base station and the user terminals within a given frequency assignment.

3.199 SectorSeed: An integer number used to initialize the state of the Pseudonoise generator that is sector specific.

3.200 Seed: An integer number used to initialize the state of the Pseudonoise generator.

3.201 SFNCellID: SFNCellID is a nine-bit quantity and is a field of the Overhead Messages Protocol. *See:* **SFNPhase**.

3.202 SFNID: A bit pattern assigned to a set of access networks that transmits data in a Single Frequency Network mode.

3.203 SFNPhase: In Synchronous mode, SFNPhase depends on the SuperframeIndex and is equal to $(\text{SFNCellID} + \text{SuperframeIndex}) \bmod 512$. In Asynchronous mode, SFNPhase is equal to SFNCellID.

3.204 Shared Control Channel Usable Hop-Port: A set of hop-ports that can be used for the transmission of the Forward Shared Control Channel.

3.205 Shift Register: A circuit formed by sequentially connected registers and feedback.

3.206 Silence Interval: A set of eight consecutive OFDM symbols (or multiples thereof) on the reverse link where no signal is transmitted by the access terminal.

3.207 Single Codeword: A Multiple Input Multiple Output transmission mode where a single code is used to encode the packet being transmitted over the various antennas.

3.208 Single Frequency Network: A set of sectors synchronously transmitting the same waveform on the same frequency assignment, with the exception of a sector-dependent delay and gain, within a specified frequency-division and time-division multiplexed channel.

3.209 Single Input Single Output: An abstract mathematical model for single-antenna communication systems where the transmitter has a single antennas capable of transmitting signals and the receiver is equipped with a single receive antenna.

3.210 Space Division Multiple Access: This technique spatially separates and multiplexes users through adaptive beamforming, thereby providing gains in system throughput by reducing interference across users.

3.211 Space Time Transmit Diversity: A technique to transmit multiple transformed versions of a data stream across a number of antennas and to exploit the various received versions of the data to improve the reliability of data-transfer.

3.212 Spatial Beam: A precoded transmission from a set of antennas used in Space Division Multiple Access, which typically creates a spatial pattern causing the transmission to be localized in a certain space.

3.213 subcarrier: Each frequency of the Discrete Fourier Transform.

3.214 subcarrier-symbol: One hop-port for the duration of one OFDM symbol. This is the smallest unit in the time-frequency grid and is the smallest unit that can be utilized to populate a modulation symbol.

3.215 subpacket: A subdivision of data packets whose size is subject to a pre-defined upper limit. Each subpacket may be independently encoded.

3.216 subzone: A set of subcarriers or hop-ports of given size, usually 64 or 128.

3.217 Supercast: A technique to overlay unicast data stream over the BCMCS data stream.

3.218 Superframe: A structure formed by a Superframe Preamble and multiple PHY frames. *See: Superframe Preamble and frame.*

3.219 Superframe Index: The index of Superframe.

3.220 Superframe Preamble: A collection of eight OFDM symbols transmitted at the beginning of each forward link superframe. *See: Superframe.*

3.221 System Time: The time reference used by the system. System Time is synchronous to UTC time (except for leap seconds) and uses the same time origin as GPS time. All access networks use the same System Time (within a small error tolerance). Access terminals use the same System Time, offset by the propagation delay from the access network to the access terminal. *See:* **Coordinated Universal Time.**

3.222 tail bit: *See:* **Encoder Tail Bit.**

3.223 Tail-biting Convolutional Code: A modified type of convolutional code, where the initial state of the trellis is selected such that the final state of the trellis is the same as the initial state. No tail bits are added.

3.224 TDM Pilot: The last three OFDM symbols in the Superframe Preamble. *See:* **Superframe Preamble.**

3.225 tile: A group of 16 hop-ports for the duration of 8 OFDM symbols. In the case of the Forward Superposed Channel, a tile may contain a different number of OFDM symbols as dictated by the Radio Configuration of supercast.

3.226 tile antenna: A linear combination of physical antennas, where the choice of the linear combination is fixed over each tile, but may vary from tile to tile.

3.227 tile segment: A portion of a tile used for defining FLCS resources. *See:* **tile.**

3.228 time reference: A reference established by the access terminal that is synchronous with the earliest arriving multipath component used for demodulation.

3.229 Turbo Code: A type of error-correcting code. A code symbol is based on the outputs of the two recursive convolutional codes (constituent codes) of the Turbo Code.

3.230 Turbo Interleaver: A component of Turbo Code. The information sequence is interleaved using the Turbo Interleaver before being input to the second constituent convolutional code. *See:* **Turbo Code** and **Constituent Convolutional Code.**

3.231 Universal Matrix: One or two matrices from which a Knockdown Codebook is constructed. Examples include the Identity matrix and the Fourier matrix.

3.232 uplink (UL): The radio connection with the user terminal transmitting and the base station receiving. The term is used interchangeably with the term *reverse link* or *RL*.

3.233 user terminal (UT): A device providing data connectivity to an end user device (EUD) user. A user terminal may be connected to a computing device, such as a laptop personal computer, or it may be a self-contained data device, such as a personal digital assistant.

3.234 vector channel quality indicator (VCQI): VCQI is used to convey extra channel quality information to the access network, beyond the information that is carried in the CQI channel defined by the Physical Layer.

3.235 Walsh chip: The shortest identifiable component of a Walsh function. There are 2^N Walsh chips in one Walsh function where N is the order of the Walsh function.

3.236 Walsh function: One of 2^N time orthogonal binary functions (note that the functions are orthogonal after mapping '0' to 1 and '1' to -1). The n^{th} Walsh function ($n = 0$ to $N - 1$) after the mapping to ± 1 symbols is denoted by $W_n N$.

3.237 Walsh sequence: *See:* **Walsh function.**

3.238 windowing function: A time domain function used to shape the amplitude of signal in the guard interval. *See:* **guard interval**.

3.239 zone: Either Distributed Resource Channel Zone or Block Resource Channel Zone in the forward link.

4. Abbreviations and acronyms

16-QAM	16-ary quadrature amplitude modulation
64-QAM	64-ary quadrature amplitude modulation
8-PSK	8-ary phase shift keying
AF	assured forwarding
AN	access node
ASMP	Active Set Management Protocol
AT	access terminal
ATI	access terminal identifier
BCMCS	Broadcast and Multicast Services
BE	best effort
BPSK	binary phase shift keying
BRCH	block resource channel
BSP	Basic Signaling Protocol
CDMA	Code Division Multiple Access
CQI	channel quality indicator
CRC	cyclic redundancy check
DFT	Discrete Fourier Transform
DL	downlink
DLC	Data Link Control
DRCH	distributed resource channel
DSCP	Differential Service Code Point
EF	expedited forwarding
EIRP	Effective Isotropically Radiated Power
ERP	Effective Radiated Power
FDD	Frequency Division Duplex
FFT	Fast Fourier Transform
FL	forward link
FLCS	Forward Link Control Segment
FLSS	Forward Link Serving Sector
GCL Sequence	Generalized Chirp Like Sequence
GF	Galois field
GH	global hopping
GPS	Global Positioning System
GRA	group resource assignment
IFFT	Inverse Fast Fourier Transform
IPSI	Initial Protocol Set Identifier
LAB	Link Assignment Block
LDPC Code	Low-Density Parity Check Code
LH	local hopping
LLC	Logical Link Control
LSB	least significant bit

MAC Layer	Medium Access Control Layer
MACID	MAC Layer Identifier
MCW	multiple codeword
MIMO	Multiple Input Multiple Output
MSB	most significant bit
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
OMP	Overhead Messages Protocol
PBRI	Pruned Bit Reversal Interleaver
PCI	Precoder Index
PDU	Protocol Data Unit
PF	packet format
PHY	Physical Layer
PN	Pseudonoise
PSI	Protocol Set Identifier
QPSK	quadrature phase shift keying
RC	radio configuration
RCC	Reverse Control Channel
RL	reverse link
RLC	Radio Link Control
RLP	Radio Link Protocol
RLSS	Reverse Link Serving Sector
RMU	RLC Message Unit
SAP	Service Access Point
SCW	single codeword
SDMA	Space Division Multiple Access
SE	Spectral Efficiency
SFN	Single Frequency Network
SISO	Single Input Single Output
SMB	Short Message Broadcast
SPF	Superframe Preamble
STTD	Space Time Transmit Diversity
TDD	Time Division Duplex
UL	uplink
UT	user terminal
UTC	Coordinated Universal Time or Temps Universel Coordonné <i>See</i> Coordinated Universal Time
VCQI	vector channel quality indicator
VoIP	Voice over Internet Protocol

5. General introduction

5.1 General

These technical requirements form a compatibility standard for mobile broadband wireless access systems. The requirements ensure that a compliant access terminal (AT) or user terminal (UT) can obtain service through any access network or base station (BS) conforming to properly selected modes of this standard, consistent with equipment and operator requirements, thus providing a framework for the rapid development of cost-effective, interoperable multivendor mobile broadband wireless access systems. This compatibility standard is targeted for use in a wide variety of licensed frequency bands and regulatory environments.

This standard omits details concerning a particular access network implementation. However, it is designed to allow both a fixed hierarchical backhaul structure or a more dynamic and non-hierarchical backhaul structure. The term *access network* itself is used throughout the document to remind the reader that both implementations are possible, and to avoid prejudicing one implementation over another. This standard is primarily oriented toward requirements necessary for the design and implementation of the access/user terminals. Thus, more detailed procedures are specified for access/user terminal operation in an effort to ensure a uniform response to all access networks.

This standard includes provisions for future service additions and expansion of system capabilities. The architecture defined by this standard permits such expansion without the loss of backward compatibility.

5.2 Modes of the standard

This standard specifies two modes of operation, a Wideband mode and a 625k-MC mode, both of which have their own distinct and optimized MAC and PHY layers. The Wideband mode is designed to operate for all Frequency division Duplex (FDD) and Time Division Duplex (TDD) bandwidths and is described in 5.4, Clause 2 through Clause 17, and Annex A. The 625k-MC mode is designed with 625 kHz carrier bandwidth supporting aggregation of multiple carriers for TDD operation only and is described in 5.5, Clause 18 through Clause 31, and Annex A.

This standard does not require any device to support multiple modes, and interoperability between terminals and access networks is only assured with each mode. This standard is designed to ensure multivendor interoperability of terminals and network equipment within each mode if that equipment fully complies with the procedures, message sequences, and protocols specified in this standard for each mode.

5.3 Requirements language

The words “shall” and “shall not” identify requirements to be followed strictly to conform to the standard and from which no deviation is permitted. The words “should” and “should not” indicate that one of several possibilities is recommended as particularly suitable, without mentioning or excluding others, that a certain course of action is preferred but not necessarily required, or that (in the negative form) a certain possibility or course of action is discouraged but not prohibited. The words “may” and “need not” indicate a course of action permissible within the limits of the standard. The words “can” and “cannot” are used for statements of possibility and capability, whether material, physical, or causal.

5.4 Wideband mode overview

For the Wideband mode, the specifications in this standard apply to both FDD and TDD, unless otherwise stated.

5.4.1 Architecture reference model

The Wideband architecture reference model is presented in Figure 1.

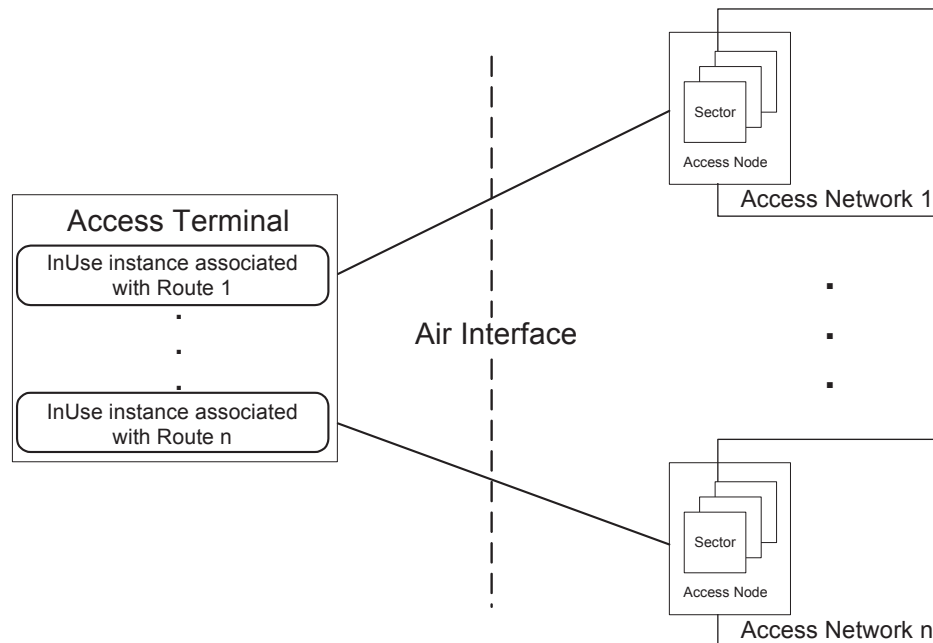


Figure 1—Wideband architecture reference model

The functional units of the reference architecture in Figure 1 are defined in the definition clause and included here for convenience of the reader:

- *access node (AN)*: The physical device that implements the MAC and PHY of one or more sectors in the network.
- *access network*: Access network is a collection of ANs.
- *access terminal (AT)*: A device providing data connectivity to a user. An access terminal may be connected to a computing device such as a laptop personal computer or it may be a self-contained data device such as a personal digital assistant.
- *forward link (FL)*: The radio connection with the AN transmitting and the AT receiving. The term is used interchangeably with the term *downlink* or *DL*.
- *reverse link (RL)*: The radio connection with the AT transmitting and the AN receiving. The term is used interchangeably with the term *uplink* or *UL*.
- *route*: Each InUse protocol stack instance is called a route.
- *sector*: One set of physical layer channels transmitted between the access network and the access terminals within a given frequency assignment.

The definition of InUse and InConfiguration Protocols is found in 5.4.9.

The reference model includes the air interface between the access terminal and the access node. The access terminal communicates with one or more access networks over the air interface. An access network may not support a radio link. An access network that does not have direct radio communication with the access terminal (either because the access network does not support a radio link or because the access network is not the current serving access network) can communicate with the access terminal by sending/receiving Route Protocol packets through the serving access network using the Inter-Route Tunneling Protocol of the serving access network.

The access terminal maintains an InUse instance of the protocol stack associated with each access network with which it is communicating. Each InUse protocol stack instance is called a route. The protocols used over the air interface are defined in this standard. This standard describes the interaction between one InUse instance at the access terminal and a corresponding InUse instance at one access network. Unless specified otherwise, access terminal and access network procedures are applicable only to the InUse instance being referenced. For example,

- “The access terminal shall transition to Inactive State” shall be interpreted to mean that “This InUse instance of the access terminal shall transition to the Inactive State”.

When a reference to more than one InUse instance is required, the reference is explicitly stated. For example,

- “If ExampleVariable is set to zero in all InUse instances at the access terminal, the access terminal shall issue an *Example* command,” shall be interpreted to mean that the instance of the protocol currently being referred to shall check ExampleVariable across all InUse instances, and issue the *Example* command if the condition is satisfied.

In procedural descriptions throughout the text describing operations in the Wideband mode, the AT and the AN shall perform the indicated steps in the sequence given, unless otherwise stated.

5.4.2 Protocol architecture

The air interface has been layered, with interfaces defined for each layer (and for each protocol within each layer). This allows future modifications to a layer or to a protocol to be isolated.

5.4.2.1 Layers

Figure 2 describes the layering architecture for each route of the air interface that carries unicast data. Each sublayer or plane consists of one or more protocols that perform the sublayer’s functionality.

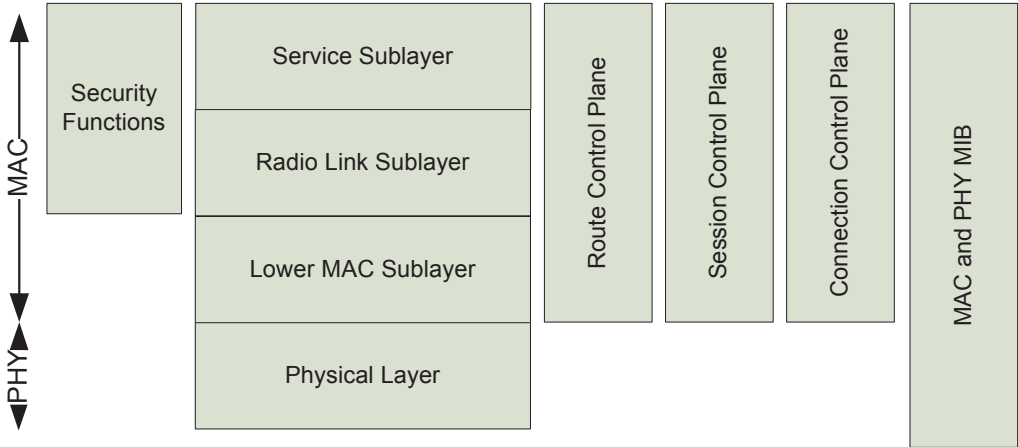


Figure 2—Unicast Route Layering architecture

The layers specified in Figure 2 are as follows:

- *Physical Layer*: The Physical Layer provides the channel structure, frequency, power output, modulation, and encoding specifications for the Forward and Reverse Channels. The Physical Layer protocol is defined in Clause 9.

- *Lower MAC Sublayer*: The Lower Medium Access Control (MAC) Sublayer defines the procedures used to receive and to transmit over the Physical Layer. The Lower MAC Sublayer is defined in Clause 8.
- *Radio Link Sublayer*: Protocols in the Radio Link Sublayer provide services such as reliable and in-sequence delivery of Application Sublayer packets, multiplexing of Application Sublayer packets, and Quality of Service (QoS) negotiation in support of applications. The Radio Link Sublayer is defined in Clause 7.
- *Service Sublayer*: The Service Sublayer provides support for multiple applications. It provides the Signaling Protocol for transporting air interface protocol messages. It also provides the Inter-Route Tunneling Protocol for transporting packets to/from other routes. Other examples of Service Sublayer protocols include the Extensible Authentication Protocol (EAP) Support Protocol for support of authentication, the Robust Header Compression (RoHC) Support Protocol for compressing the packet header, and protocols for transporting packets from other air interfaces. These Service Sublayer protocols are defined in Clause 6.
- *Connection Control Plane*: The Connection Control Plane provides air link connection establishment and maintenance services. The Connection Control Plane is defined in Clause 11.
- *Session Control Plane*: The Session Control Plane provides protocol negotiation and protocol configuration services. The Session Control Plane is defined in Clause 12.
- *Route Control Plane*: The Route Control Plane provides creation, maintenance, and deletion of routes. The Route Control Plane is defined in Clause 13.
- *Security Functions*: Security functions include functions for key exchange, ciphering, and message integrity protection. Security functions are defined in Clause 10.
- *MAC and PHY MIB*: For unicast transport, the MAC and PHY Management Information Base (MIB) provides usage statistics gathered from all protocols and management planes, e.g., access attempts, bytes successfully transferred, dropped connections. The MAC and PHY MIB is defined in Clause 17.

Figure 3 describes the layering architecture for a route of the air interface that carries broadcast-multicast service (BCMCS) data. Each layer or plane consists of one or more protocols that perform the layer's functionality.

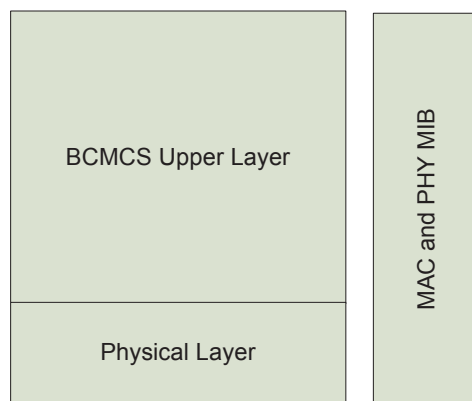


Figure 3—BCMCS Route Layering architecture

- *Physical Layer*: The Physical Layer provides the channel structure, frequency, power output, modulation, and encoding specifications for the BCMCS channel. The Physical Layer protocol is defined in Clause 9.
- *Broadcast-Multicast Service Upper Layer*: Besides the unicast routes, the air interface also defines a BCMCS Route that contains protocols in support of Broadcast-Multicast Service (BCMCS). BCMCS Upper Layer protocols are defined in Clause 14.

Each layer contains one or more protocols. Protocols use signaling messages or headers to convey state information to their peer protocols at the other side of the air-link. When protocols and applications send messages, they use the Signaling Protocol over the Radio Link Protocol to transmit these messages.

5.4.2.2 Protocols

Each sublayer specifies one or more protocol types. Protocols are associated with a type that denotes the type of the protocol (e.g., Access Channel MAC Protocol) and with a subtype that denotes a specific instance of a protocol (e.g., the Basic Access Channel MAC Protocol).

The following subclauses provide a brief description of protocols in each layer. A more complete description is provided in the introduction subclause of each layer.

5.4.2.2.1 Services Sublayer

The protocols of the Service Sublayer are illustrated in Figure 4 and described in the text following.

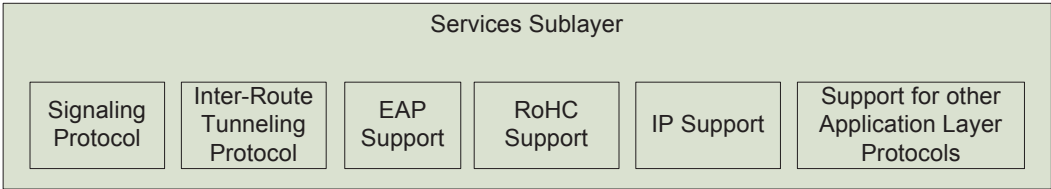


Figure 4—Services Sublayer Protocols

- *Signaling Protocol*: The Signaling Protocol provides message transmission services for signaling messages.
- *Inter-Route Tunneling Protocol*: The Inter-Route Tunneling Protocol provides transport of packets from other routes.
- Support for other Application Sublayer Protocols, such as EAP Support Protocol, RoHC Support Protocol etc., may create payload to be carried over this air interface. Examples of other protocols include IEEE 802.1Q C-VLAN frames IEEE 802.1Q and IEEE 802.3 Ethernet PDUs (see IEEE Std 802.3⁹).

⁹Information of references can be found in Clause 2.

5.4.2.2.2 Radio Link Sublayer

The protocols of the Radio Link Sublayer are illustrated in Figure 5 and described in the text following.

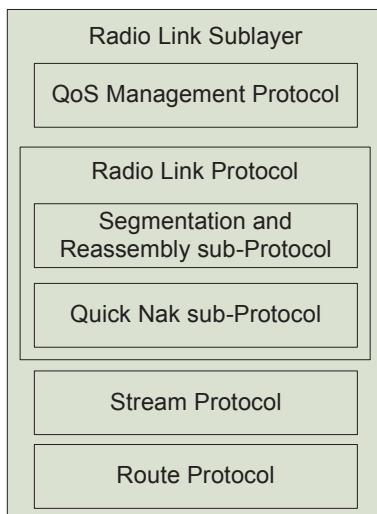


Figure 5—Radio Link Sublayer protocols

The Radio Link Sublayer defines the following four protocols:

- *Radio Link Protocol*: The Radio Link Protocol (RLP) is a bearer protocol that provides segmentation and re-assembly, ACK/NAK, retransmission, and duplicate detection for upper layer packets. The goal is to improve a voice-quality channel to provide packet-quality reliability.
- *Stream Protocol*: The Stream Protocol is a bearer protocol that identifies the stream on which the upper layer fragments are being carried.
- *Route Protocol*: The Route Protocol is a bearer protocol that identifies and routes Stream Protocol packets between the access terminal and the access network.
- *QoS Management Protocol*: The QoS Management Protocol provides negotiation of flow and filter specifications to provide appropriate Quality of Service (QoS) to application sublayer packets.

5.4.2.2.3 Lower MAC Sublayer

The protocols of the Lower MAC Sublayer are illustrated in Figure 6 and described in the text following.

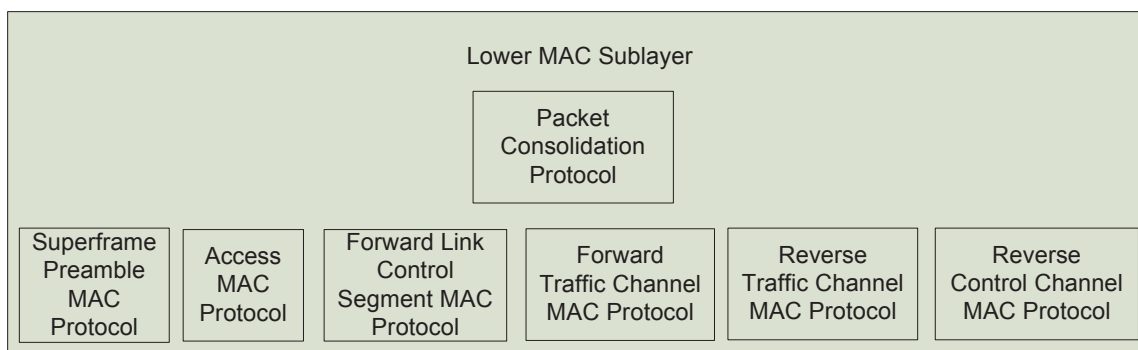


Figure 6—Lower MAC Sublayer Protocols

The Lower MAC Sublayer contains the following seven protocols:

- *Packet Consolidation Protocol*: Provides transmit prioritization and packet encapsulation for upper layer packets.
- *Superframe Preamble MAC Protocol*: Provides procedures followed by the access network to transmit and access terminal to receive the superframe preamble.
- *Access Channel MAC Protocol*: Provides the procedures followed by the access terminal to transmit, and by the access network to receive the Access Channel.
- *Forward Link Control Segment MAC Protocol*: Provides the procedures followed by the access network to transmit, and by the access terminal to receive the Forward Control Channel.
- *Forward Traffic Channel MAC Protocol*: Provides the procedures followed by the access network to transmit, and by the access terminal to receive the Forward Data Channel.
- *Reverse Control Channel MAC Protocol*: Provides the procedures followed by the access terminal to transmit, and by the access network to receive the Reverse Control Channel.
- *Reverse Traffic Channel MAC Protocol*: Provides the procedures followed by the access terminal to transmit, and by the access network to receive the Reverse Data Channel.

5.4.2.2.4 Physical Layer

The Physical Layer defines the Physical Layer Protocol as shown in Figure 7.

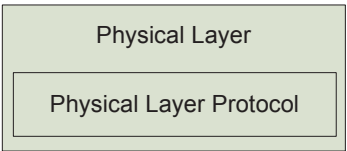


Figure 7—Physical Layer Protocol

- *Physical Layer Protocol*: Provides channel structure, frequency, power output, and modulation specifications for the forward and reverse links.

5.4.2.2.5 Security Functions

The protocols of the Security Function Sublayer are illustrated in Figure 8 and described in the text following.

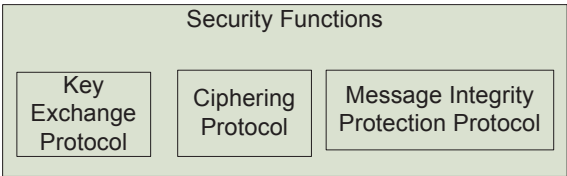


Figure 8—Security Protocols

- *Key Exchange Protocol*: Provides the procedures followed by the access network and the access terminal to generate security keys for message integrity protection and ciphering.
- *Message Integrity Protection Protocol*: Provides the procedures followed by the access network and the access terminal for integrity protection of signaling messages.
- *Ciphering Protocol*: Provides the procedures followed by the access network and the access terminal for ciphering traffic.

5.4.2.2.6 Connection Control Plane

The protocols of the Connection Control Plane Sublayer are illustrated in Figure 9 and described in the text following.

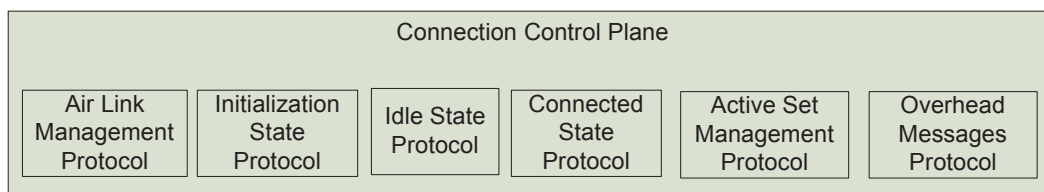


Figure 9—Connection Control Plane Protocols

The connection control plane contains the following six protocols used to manage connection state:

- *Air Link Management Protocol*: Provides the overall state machine management that an access terminal and an access network follow during a connection.
- *Initialization State Protocol*: Provides the procedures that an access terminal follows to acquire a network and that an access network follows to support network acquisition.
- *Idle State Protocol*: Provides the procedures that an access terminal and an access network follow when a connection is not open.
- *Connected State Protocol*: Provides the procedures that an access terminal and an access network follow when a connection is open.
- *Active Set Management Protocol*: Provides the means to maintain the air link between the access terminal and the access network.
- *Overhead Messages Protocol*: Provides broadcast messages containing information that is mostly used by Connection Control Plane protocols.

5.4.2.2.7 Session Control Plane

The protocol of the Session Control Plane Sublayer is illustrated in Figure 10 and described in the text following.

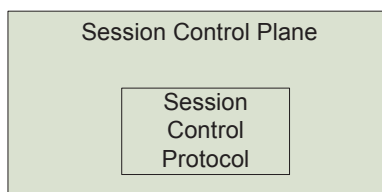


Figure 10—Session Control Plane Protocol

The session encapsulates all the state in the access network associated with an access terminal, whether connected, sleeping or even when powered down. The Session Control Plane contains one protocol as follows:

- *Session Control Protocol*: The Session Control Protocol provides negotiation and configuration of the protocols used in the session.

5.4.2.2.8 Route Control Plane

The protocol of the Route Control Plane Sublayer is illustrated in Figure 11 and described in the text following.

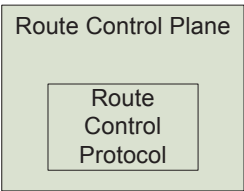


Figure 11—Route Control Plane Protocol

A route is an InUse instance of a protocol stack, used to communicate with a single access network. The route control plane contains one protocol as follows:

- *Route Control Protocol*: The Route Control Protocol performs creation, maintenance, and deletion of routes. The Route Control Protocol also performs management of access terminal identifier (ATI).

5.4.2.2.9 Broadcast-Multicast Service (BCMCS) Upper Layer Protocols

The protocols of the BCMCS Upper Layer Sublayer are illustrated in Figure 12 and described in the text following.

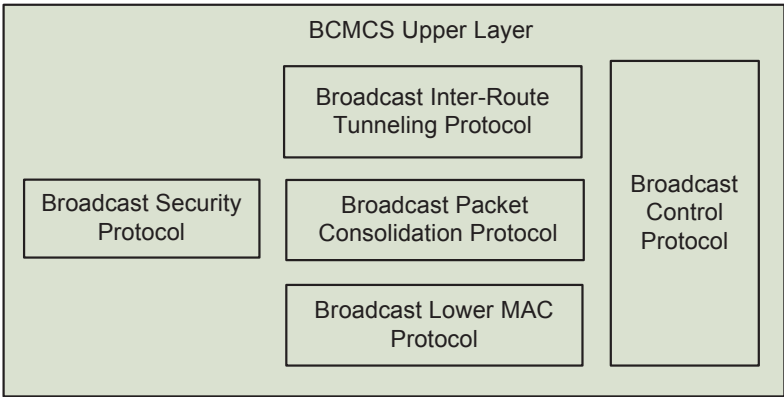


Figure 12—BCMCS Upper Layer Protocols

The following protocols in the BCMCS Upper Layer provide functions that offer broadcast-multicast service.

- *Broadcast MAC Protocol*: Defines the procedures followed by the access network to transmit, and by the access terminal to receive the BCMCS channel.
- *Broadcast Packet Consolidation Protocol*: Provides framing of BCMCS content packets and multiplexing of packets to be carried on the BCMCS channel.
- *Broadcast Inter-Route Tunneling Protocol*: Provides transport for packets from other routes.
- *Broadcast Security Protocol*: Provides ciphering of BCMCS content.
- *Broadcast Control Protocol*: Defines control procedures such as registration related to the BCMCS service.

5.4.2.2.10 Broadcast Physical Layer

The Broadcast Physical Layer is defined by the Physical Layer Protocol.

5.4.2.3 MIMO support

The air interface supports the following two modes of operation for the Lower MAC Sublayer and Physical Layer:

- Single-input-single-output (SISO) mode
- Multiple-input-multiple-output (MIMO) mode

The MIMO mode is divided into the following two sub-modes:

- Multiple codeword (MCW)
- Single codeword (SCW)

5.4.2.3.1 Access terminal requirements

All terminals shall support SISO mode. A MIMO-capable terminal shall support either the MIMO SCW or MCW sub-mode, and may operate, at a time, in either SISO mode or in one of the MIMO sub-modes. The MIMO mode requires at least two antennas at the access network and at least two antennas at the access terminal.

5.4.3 Channels

This standard refers to logical channels and physical channels. PHY (physical) channel names are in all uppercase, and MAC (logical) channels (typically on the reverse link) are displayed in all lowercase. A channel name consists of a prefix, an acronym, and a suffix. Table 1 shows the naming conventions for the channels in this standard. Special suffixes distinguish Pilot Channels (PICH) from Paging Channels.

Table 1—Channel naming conventions

Prefix	Acronym	Suffix
F = Forward Link R = Reverse Link (PHY) r = Reverse Link (MAC)	(derived from capitalized letters of the channel name) ACK = acknowledgement ACQ = acquisition A = access Aux = auxiliary C = CDMA O = OFDMA	CH = Channel PICH = Pilot Channel (PHY)

There is no particular criterion used to define a channel. Some channels have unique modulations and encodings, whereas other channels are simply a few bits taken from a larger transmission unit such as the superframe preamble. In some cases, a channel corresponds to a control loop in the air interface. Channel names reference important sets of bits sent in this air interface, which are referenced repeatedly in other parts of the standard.

The forward link consists of the following parts:

- Guard carriers are used to mitigate interference with adjacent channels to meet regulatory requirements.
- Pilot channels are used for channel estimation.

- The Superframe Preamble carries slowly changing (tens of milliseconds) information.
- A PHY frame (within a Superframe, about 1 ms in length) is the basic unit of transport, carrying the following:
 - 1) Control information including grants and acknowledgements, etc.
 - 2) A Traffic Channel (containing bearer frames)

A complete listing of forward link channels is given in Table 216.

The reverse link consists of the following parts:

- Guard carriers are used to mitigate interference with adjacent channels to meet regulatory requirements
- Reverse CDMA Channels
 - 1) Pilot channels that are used for a power reference signal
 - 2) Access channel (used by ATs attempting to connect)
 - 3) Dedicated Control Channels (with logical subchannels)
 - 4) CDMA Data Channel
- Reverse OFDMA Channels
 - 1) Pilot channel that is used for channel estimation
 - 2) Dedicated Control Channels (with logical subchannels)
 - 3) Reverse link acknowledgement channels
 - 4) Reverse link data channels

A complete listing of reverse link channels is given in Table 212.

On the reverse link, the control channels are normally carried via CDMA, not OFDMA, and so the reverse link is a hybrid design. Two of the reverse-link channels have logical channels, as described as follows:

- a) Reverse CDMA Dedicated Control Channel (R-CDCCH)
 - r-cqich (channel quality indicator channel)
 - r-reqch (request channel)
 - r-pahch (power amplifier headroom channel)
 - r-psdch (spectral density indication channel)
- b) Reverse OFDMA Dedicated Control Channel (R-ODCCH)
 - r-mqich (mimo quality indicator channel)
 - r-cqich (channel quality indicator channel)
 - r-reqch (request channel)
 - r-sfch (subband feedback channel)
 - r-bfch (beam feedback channel)

5.4.4 Management Information Base

This standard includes the definition of a Management Information Base (MIB) module for managing the MAC and PHY. The objects in this MIB are defined using the mechanisms specified in the Structure of Management Information (SMI). The MIB module specified is compliant to SMIv2, which is described in IETF RFC 2578, IETF RFC 2579, and IETF RFC 2580. The MIB is defined in Clause 17.

5.4.5 Protocol Interfaces

In the following, the generic term *entity* is used to refer to the access terminal and the access network. This standard defines a set of interfaces for communications between protocols in the same entity and between a protocol executing in one entity and the same protocol executing in the other entity.

Protocols in this standard have the following five types of interfaces:

- Headers and/or Trailers are added by a protocol to payload received from an upper layer protocol, and are used for communications between a protocol executing in one entity and the same protocol executing in the other entity.
- Messages are generated by a protocol and are transported using the Signaling Protocol. Messages are used for communications between a protocol executing in one entity and the same protocol executing in the other entity. Messages can be transmitted using Reliable or Best Effort (unreliable) delivery.
- Commands are used by a protocol to obtain a service from another protocol within the same access network or access terminal.
- Indications are used by a protocol to convey information regarding the occurrence of an event to another protocol within the same access network or access terminal. Any protocol can register to receive these indications.
- Public data is used to share information in a controlled way between protocols. Public data is shared between protocols in the same sublayer, between protocols in different sublayers and layers, and between protocols in different routes.

Commands and indications are written in the form of *Protocol.Command* and *Protocol.Indication*. For example, *AccessChannelMAC.Activate* is a command activating the Access Channel MAC, and *IdleState.ConnectionOpened* is an indication provided by the Idle State Protocol that the connection is now open. When the context is clear, the *Protocol* part is dropped (e.g., within the Idle State Protocol, *Activate* refers to *IdleState.Activate*).

Unless specified otherwise, a protocol registers for indications from other protocols in the same route. Unless specified otherwise, a protocol sends/receives commands to/from other protocols in the same route.

Most protocols support the following two commands:

- *Activate*, which commands the protocol to transition from the Inactive state to some other state.
- *Deactivate*, which commands the protocol to transition to the Inactive state. Some protocols do not transition immediately to the Inactive state, due to requirements on orderly cleanup procedures.

Other common commands are *Open* and *Close*, which command protocols to perform session open/close or connection open/close related functions.

Commands are always written in the imperative form, since they direct an action. Indications are always written in the past tense since they notify of events that happened (e.g., *OpenConnection* for a command and *ConnectionOpened* for an indication).

Headers, trailers, and messages are binding on all implementations. Commands, indications, protocol data, and procedures that are internal to the access network or access terminal are used purely as a device for a clear and precise specification. Access terminals and access networks can be compliant with this standard while choosing a different implementation that exhibits identical behavior.

5.4.6 Protocol data

Each protocols owns and acts on parameters that are called protocol data. Protocol data can have various properties:

- *Public*: Protocol data is said to be public if the value of the data is visible outside the protocol. Value of public data may be read by other protocols within the same route as well as by protocols in other routes.
- *Static (Dynamic)*: Protocol data is said to be static if the data must take the same value across the same Protocol Type in different routes and personalities. Since the value of static data is the same across routes and personalities, all static data must be public. Protocol data is said to be dynamic if the data may take different values in different routes or personalities.
- *Local common data*: Local common data is static data that is maintained only by the access terminal.
- *Attribute*: Protocol data is called an attribute if the value of the data can be negotiated between the access terminal and the access network using configuration services provided by the InUse instance of the Session Control Protocol. Attributes may be either soft or hard committable. An attribute is said to be soft committable if changes to values of the data can take effect without closing the route. In contrast, an attribute is said to be hard committable if the route must be closed and re-opened for changes in data values to take effect.
- *Session data*: Protocol data is said to be session data if it is part of the air interface session that could be copied from one access network to another. All attributes are session data. Session data is conveyed between access network through Session State Information Records.

5.4.7 Protocol states

When protocols exhibit different behavior as a function of the environment (if a connection is opened or not, if a session is opened or not, etc.), this behavior is captured in a set of states and the events leading to a transition between states.

Unless otherwise specifically mentioned, the state of the access network refers to the state of a protocol engine in the access network as it applies to a particular access terminal. Since the access network communicates with multiple access terminals, multiple independent instantiations of a protocol will exist in the access network, each with its own independent state machine.

Unless otherwise specifically mentioned, the state of the access terminal refers to the state of a protocol engine in the access terminal as it applies to a particular access network. Since the access terminal communicates with multiple access networks, multiple independent instantiations of a protocol will exist in the access terminal (one in each route), each with its own independent state machine.

Unless otherwise specifically shown, the state transitions due to failure are not shown in the figures.

Typical events leading to a transition from one state to another are the receipt of a message, a command, an indication, or the expiration of a timer.

When a protocol is not functional at a particular time, the protocol is placed in a state that is usually called the Inactive state. This state is common for most protocols.

Other common states are Open, indicating that the session, connection, or route (as applicable to the protocol) is open and Close, indicating that the session, connection, or route is closed.

If a protocol has a single state other than the Inactive state, that state is always called the Active state. If a protocol has more than one state other than the Inactive state, all of these states are considered active, and are given individual names.

5.4.8 Protocol Set Identifier

The Protocol Set Identifier is used to identify the subtype of each of the protocols in the protocol stack. The Initial Protocol Set Identifier is used to identify the default protocol stack for each of the major revisions of the air interface standard. The access network includes values of the supported Initial Protocol Set Identifier in overhead messages. Multiple Protocol Set Identifiers may map to single Initial Protocol Set Identifier.

5.4.9 InUse and InConfiguration protocol transport instances

A protocol instance can be either an InUse instance or an InConfiguration instance. A protocol or transport instance is InUse if it is currently being used to communicate between the access terminal and the access network. Otherwise, a protocol or transport instance is InConfiguration.

Each protocol specifies procedures and messages corresponding to the InUse and InConfiguration protocol instances. In general, the InConfiguration protocol instances use the services of the Session Control Protocol to perform attribute configuration. Typically, non-configuration procedures and messages are processed by the InUse protocol instances.

An InConfiguration instance of each protocol is created by the Session Control Protocol once the session configuration is initiated (e.g., in the Basic Session Control Protocol this occurs upon entering the AT Initiated state). The initialization procedures for an InConfiguration protocol instance are invoked upon creation of the InConfiguration protocol instance. InConfiguration protocol instances can be changed by the Session Control Protocol.

The configured InConfiguration instances can be stored. Stored protocol stacks configurations are called Personalities. The access terminal and access network can store multiple Personalities as part of the session (see 5.4.10 for a discussion of sessions).

The access terminal and the access network determine which Personality to use for every route. Once the access terminal and access network agree upon using a Personality, then that Personality is Committed to the InUse instance. Each InUse protocol defines a set of Hard Commit and Soft Commit procedures. The Commit procedures for a protocol are invoked by the InUse instance of the Session Control Protocol. Commit procedures are used to commit a stored Personality to the InUse instance. The initialization procedures for an InUse protocol instance are invoked upon creation of the InUse protocol instance.

5.4.10 Sessions and connections

A session refers to a shared state between the access terminal and the access network. This shared state stores one or more Personalities. Each Personality contains the protocols and protocol configurations that were negotiated and are used for communications between the access terminal and the access network.

Other than to open a session, an access terminal cannot communicate with an access network without having an open session.

A connection is a particular state of the air-link in which the access terminal is assigned dedicated communication channels.

During a single session the access terminal and the access network can open and close a connection multiple times.

5.4.11 Security

The air interface supports security functions, which can be used for integrity protection of signaling messages, encryption of signaling messages, and other traffic transported between the access terminal and the access network. Unless specified otherwise, all signaling messages shall be integrity protected.

5.4.12 Support for Quality of Service (QoS)

QoS parameters are established and maintained at upper layers on the protocol stacks (i.e., layers above the MAC layer) on a per IP flow (as defined in IETF RFC 2216) basis, between the access terminal and various infrastructure entities that participate in the establishment and delivery of services. The exact functionality and the employed protocols are outside the scope of this standard. From an air interface point of view, QoS related information is carried transparently by air interface messages between the AT and the AN, encapsulated in profiles. A profile is a data structure associated with an IP flow, that contains one or more QoS attribute sets. A QoS attribute set specifies either a standard setting of values for QoS parameters known as a flow profile and identified in 3GPP2 C.R1001-F v1.0., or an ad-hoc setting of values for specific QoS parameters, including traffic class, peak rate, bucket size, token rate, maximum latency, maximum IP packet loss rate, packet size, and sensitivity to jitter.

Each QoS attribute set is uniquely identified by an assigned ID, known as QoS_ATTRIBUTE_SET_ID. As specified in the Basic QoS Management protocol (see 7.2), the AN and AT synchronize with each other on the use of the QoS attribute sets by setting the selected QoS attribute set ids within the ProfileValue field transmitted in the air interface messages.

5.4.13 Route-Tunneling interface

Systems deploying Wideband mode may support a Route-Tunneling interface, to allow for rapid and efficient transfer of control and data between access networks. The Route-Tunneling interface’s control plane is assumed to be able to set up connections between at least two access networks, including support for the tunnel envisioned in the Inter-Route Tunneling Protocol (IRTP) of the Application Sublayer (see 6.3). The Route-Tunneling interface’s user plane is assumed capable of efficient transport of the IRTP payload, via the connection established by the control plane.

This standard does not require or specify any particular Route-Tunneling interface.

5.4.14 Message information

Each message definition contains information regarding channels on which the message can be transmitted, whether the message requires RLP reliable or best-effort delivery, the addressing modes applicable to the message, and whether AuthTag is required in the message. This information is provided in the form of a table, an example of which is given in Figure 13.

Channels			FTC	RTC	RLP		Best Effort
Addressing			Unicast		AuthTag	Required	

Figure 13—Sample message information

The following values are defined:

- a) Channels: This information field indicates the Physical Layer Channels on which this message can be transmitted. The sender of the message shall send the message only on the Physical Layer channel(s) indicated by this information field. Values are

- FTC for Forward Unicast Traffic Channel
- F-BCMCSCH for Forward Broadcast Multicast Services Channel
- RTC for Reverse Traffic Channel
- b) RLP: Radio Link Protocol requirements. The sender of the message shall send the message only using the RLP in the mode(s) indicated by this information field. Values are
 - Best Effort: the message is sent once and is subject to erasure
 - Reliable: erasures are detected and the message is retransmitted one or more times, if necessary
- c) Addressing: Addressing modes for the message. The sender of the message shall send the message only with an address type(s) indicated by this information field. Values are
 - Broadcast: if a broadcast address can be used with this message
 - Unicast: if a unicast address can be used with this message
- d) AuthTag: AuthTag requirements. The sender of the message shall send the message with AuthTag requirements indicated by this information field. Values are
 - Required: if this message shall not be sent without an AuthTag
 - Not Required: if an AuthTag is not required with this message
 - Required when key is available: if an AuthTag shall be sent with this message when Message Integrity Key for the channel carrying this message is available (e.g., FACMIKey[KeyIndex] is not set to NULL). See 10.3.5.1.6.

5.4.15 Notation

$A[i]$	The i^{th} element of array A. The first element of the array is $A[0]$.
$\langle e_1, e_2, \dots, e_n \rangle$	A <i>structure</i> with elements ' e_1 ', ' e_2 ', ..., ' e_n '. Two structures $E = \langle e_1, e_2, \dots, e_n \rangle$ and $F = \langle f_1, f_2, \dots, f_m \rangle$ are equal if and only if ' m ' is equal to ' n ' and e_i is equal to f_i for $i = 1, \dots, n$. Given $E = \langle e_1, e_2, \dots, e_n \rangle$ and $F = \langle f_1, f_2, \dots, f_m \rangle$, the assignment " $E = F$ " denotes the following set of assignments: $e_i = f_i$, for $i = 1, \dots, n$.
$S.e$	The member of the structure ' S ' that is identified by ' e '.
$M[i:j]$	Bits i^{th} through j^{th} inclusive ($i \geq j$) of the binary representation of variable M. $M[0:0]$ denotes the least significant bit of M.
	Concatenation operator. $(A B)$ denotes variable A concatenated with variable B.
$\times$	Indicates multiplication.
$\lfloor x \rfloor$	Indicates the largest integer less than or equal to x: $\lfloor 1.1 \rfloor = 1, \lfloor 1.0 \rfloor = 1$.
$\lceil x \rceil$	Indicates the smallest integer greater or equal to x: $\lceil 1.1 \rceil = 2, \lceil 2.0 \rceil = 2$.
$ x $	Indicates the absolute value of x: $ -17 = 17, 17 = 17$.
$\oplus$	Indicates exclusive OR (modulo-2 addition).
$\otimes$	Indicates bitwise logical AND operator.
$\min(x, y)$	Indicates the minimum of x and y.
$\max(x, y)$	Indicates the maximum of x and y.