Submission of IEEE to WP 5A, Edits to ITU-R M.1801-1

Sections edited address updates to IEEE 802.16 and IEEE 802.11 standards.

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| **Recommendation ITU-R M.1801-1**  **(04/2010)** |
| **Radio interface standards for broadband wireless access systems, including mobile and nomadic applications, in the mobile  service operating below 6 GHz** |
| **M Series**  **Mobile, radiodetermination, amateur**  **and related satellite services** |

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

# Policy on Intellectual Property Right (IPR)

ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Annex 1 of Resolution ITU-R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from <http://www.itu.int/ITU-R/go/patents/en> where the Guidelines for Implementation of the Common Patent Policy for ITU‑T/ITU‑R/ISO/IEC and the ITU-R patent information database can also be found.

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| Series of ITU-R Recommendations  (Also available online at <http://www.itu.int/publ/R-REC/en>) | |
| **Series** | Title |
| **BO** | Satellite delivery |
| **BR** | Recording for production, archival and play-out; film for television |
| **BS** | Broadcasting service (sound) |
| **BT** | Broadcasting service (television) |
| **F** | Fixed service |
| M | Mobile, radiodetermination, amateur and related satellite services |
| **P** | Radiowave propagation |
| **RA** | Radio astronomy |
| **RS** | Remote sensing systems |
| **S** | Fixed-satellite service |
| **SA** | Space applications and meteorology |
| **SF** | Frequency sharing and coordination between fixed-satellite and fixed service systems |
| **SM** | Spectrum management |
| **SNG** | Satellite news gathering |
| **TF** | Time signals and frequency standards emissions |
| **V** | Vocabulary and related subjects |

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| ***Note***: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.* |

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RECOMMENDATION ITU-R M.1801-1[[1]](#footnote-1)\*

Radio interface standards for broadband wireless access systems,   
including mobile and nomadic applications, in the mobile   
service operating below 6 GHz

(Questions ITU‑R 212/5 and ITU‑R 238/5)

(2007-2010)

# 1 Introduction

This Recommendation recommends specific standards for broadband wireless access[[2]](#footnote-2) in the mobile service. These specific standards are composed of common specifications developed by standards development organizations (SDOs). Using this Recommendation, manufacturers and operators should be able to determine the most suitable standards for their needs.

These standards support a wide range of applications in urban, suburban and rural areas for both generic broadband internet data and real-time data, including applications such as voice and videoconferencing.

# 2 Scope

This Recommendation identifies specific radio interface standards for BWA systems in the mobile service operating below 6 GHz. The standards included in this Recommendation are capable of supporting users at broadband data rates, taking into account the ITU‑R definitions of “wireless access” and “broadband wireless access” found in Recommendation ITU‑R F.1399[[3]](#footnote-3).

This Recommendation is not intended to deal with the identification of suitable frequency bands for BWA systems, nor with any regulatory issues.

# 3 Related ITU Recommendations

The existing Recommendations that are considered to be of importance in the development of this particular Recommendation are as follows:

[Recommendation ITU-R F.1399](http://www.itu.int/rec/R-REC-F.1399/en) – Vocabulary of terms for wireless access.

[Recommendation ITU-R F.1763](http://www.itu.int/rec/R-REC-F.1763/en) – Radio interface standards for broadband wireless access systems in the fixed service operating below 66 GHz.

[Recommendation ITU-R M.1678](http://www.itu.int/rec/R-REC-M.1678/en) – Adaptive antennas for mobile systems.

# 4 Acronyms and abbreviations

AA Adaptive antenna

ACK Acknowledgement (channel)

AN Access network

ARIB Association of Radio Industries and Businesses

ARQ Automatic repeat request

AT Access terminal

ATIS Alliance for Telecommunications Industry Solutions

ATM Asynchronous transfer mode

BCCH Broadcast control channel

BER Bit-error ratio

BRAN Broadband radio access network

BS Base station

BSR Base station router

BTC Block turbo code

BWA Broadband wireless access

CC Convolutional coding

CDMA Code division multiple access

CDMA-MC Code division multiple access – multi carrier

CL Connection layer

C-plane Control plane

CS-OFDMA Code spread OFDMA

CTC Convolutional turbo code

DECT Digital enhanced cordless telecommunications

DLC Data link control

DS-CDMA Direct-sequence code division multiple access

DSSS Direct sequence spread spectrum

E-DCH Enhanced dedicated channel

EGPRS Enhanced general packet radio service

EPC Evolved packet core

ETSI European Telecommunication Standards Institute

EV-DO Evolution data optimized

FC Forward channel

FCC Forward control channel

FDD Frequency division duplex

FEC Forward-error correction

FER Frame error rate

FHSS Frequency hopping spread spectrum

FT Fixed termination

GERAN GSM edge radio access network

GoS Grade of service

GPRS General packet radio service

GPS Global positioning system

HC-SDMA High capacity-spatial division multiple access

HiperLAN High performance RLAN

HiperMAN High performance metropolitan area network

HRPD High rate packet data

HSDPA High speed downlink packet access

HS-DSCH High speed downlink shared channel

HSUPA High speed uplink packet access

I‑CDMA Internet code division multiple access

IEEE Institute of Electrical and Electronics Engineers

IETF Internet Engineering Task force

IP Internet protocol

LAC Link access control

LAN Local area network

LDPC Low density parity check

LLC Logic link control

MAC Medium access control

MAN Metropolitan area network

MCSB Multi-carrier synchronous beamforming

MIMO Multiple input multiple output

MS Mobile station

NLoS Non-line-of-sight

OFDM Orthogonal frequency-division multiplexing

OFDMA Orthogonal frequency-division multiple access

OSI Open systems interconnection

PDCP Packet data convergence protocol

PHS Personal handyphone system

PHY Physical layer

PLP Physical layer protocol

PT Portable termination

QAM Quadrature amplitude modulation

QoS Quality-of-service

RAC Reverse access channel

RF Radio frequency

RLAN Radio local area network

RLC Radio link control

RLP Radio link protocol

RTC Reverse traffic channel

SC Single carrier

SC-FDMA Single carrier-frequency division multiple access

SCG Subcarrier group

SDMA Spatial division multiple access

SDO Standards development organization

SISO Single input single output

SL Security/session/stream layer

SM Spatial multiplexing

SNP Signalling network protocol

TCC Traffic code channels

TDD Time-division duplex

TDMA Time-division multiple access

TDMA-SC TDMA-single carrier

TD-SCDMA Time-division-synchronized CDMA

TTA Telecommunications Technology Association

U-plane User plane

WiBro Wireless broadband

WirelessMAN Wireless metropolitan area network

WTSC Wireless Technologies and Systems Committee

WWINA Wireless wideband Internet access

XGP eXtended Global Platform

# 5 Noting

Recommendation ITU‑R F.1763 recommends radio interface standards for broadband wireless access systems in the fixed service operating below 66 GHz.

The ITU Radiocommunication Assembly,

recommends

**1** that the radio interface standards in Annexes 1 to 7 should be used for BWA systems in the mobile service operating below 6 GHz.

NOTE 1 – Annex 8 provides a summary of the characteristics of the standards found in Annexes 1 to 7.

Annex 1  
  
Broadband radio local area networks

Radio local area networks (RLAN) offer an extension to wired LANs utilizing radio as the connective media. They have applications in commercial environments where there may be considerable savings in both cost and time to install a network; in domestic environments where they provide cheap, flexible, connectivity to multiple computers used in the home; and in campus and public environments where the increasing use of portable computers, for both business and personal use, while travelling and due to the increase in flexible working practices, e.g., nomadic workers using laptop personal computers not just in the office and at home, but in hotels, conference centres, airports, trains, planes and automobiles. In summary, they are intended mainly for nomadic wireless access applications, with respect to the access point (i.e., when the user is in a moving vehicle, the access point is also in the vehicle).

Broadband radio local area network standards are included in [Recommendation ITU‑R M.1450](http://www.itu.int/rec/R-REC-M.1450/en), and can be grouped as follows:

– IEEE 802.11

– ETSI BRAN HIPERLAN

– ARIB HiSWANa

# 1 IEEE 802.11

TheIEEE 802.11™ Working Group has developed a standard for RLANs, IEEE Std 802.11, which is part of the IEEE 802 series of standards for local and metropolitan area networks. The medium access control (MAC) unit in IEEE Std 802.11 is designed to support physical layer units as they may be adopted dependent on the availability of spectrum. IEEE Std 802.11 operates in the 2 400-2 500 MHz band and in the bands comprising 3 650‑3 700 MHz, 4.94-4.99 GHz, 5.03‑5.091 GHz, 5.15‑5.25 GHz, 5.25-5.35 GHz, 5.47‑5.725 GHz and 5.725‑5.850 GHz. IEEE Std 802.11 employs the frequency hopping spread spectrum (FHSS) technique, direct sequence spread spectrum (DSSS) technique, orthogonal frequency division multiplexing (OFDM) technique, and multiple input multiple outout (MIMO) technique.

Approved amendments to the IEEE 802.11-2012 base standard include Prioritization of Management Frames (IEEE 802.11ae), Video Transport Streams (IEEE 802.11aa). PHY and MAC amendments with available drafts include Very High Throughput 60 GHz (IEEE 802.11ad) and Very High Throughput below 6 GHz (IEEE 802.11ac).

The URL for the IEEE 802.11 Working Group is <http://www.ieee802.org/11>. The IEEE Std 802.11‑2012 standard and some amendments are available at no cost through the Get IEEE 802™ program at http://standards.ieee.org/about/get/, and future amendments will become available for no cost six months after publication. Approved amendments and some draft amendments are available for purchase at <http://www.techstreet.com/ieeegate.html>.

# 2 ETSI BRAN HIPERLAN

The HiperLAN 2 specifications were developed by ETSI TC (Technical Committee) BRAN (broadband radio access networks). HiperLAN 2 is a flexible RLAN standard, designed to provide high-speed access up to 54 Mbit/s at physical layer (PHY) to a variety of networks including internet protocol (IP) based networks typically used for RLAN systems. Convergence layers are specified which provide interworking with Ethernet, IEEE 1394 and ATM. Basic applications include data, voice and video, with specific quality-of-service parameters taken into account. HiperLAN 2 systems can be deployed in offices, classrooms, homes, factories, hot spot areas such as exhibition halls and, more generally, where radio transmission is an efficient alternative or complements wired technology.

HiperLAN 2 is designed to operate in the bands 5.15-5.25 GHz, 5.25-5.35 GHz and 5.47‑5.725 GHz. The core specifications are TS 101 475 (physical layer), TS 101 761 (data link control layer), and TS 101 493 (convergence layers). All ETSI standards are available in electronic form at: <http://pda.etsi.org/pda/queryform.asp>, by specifying the standard number in the search box.

ETSI TC BRAN has also developed conformance test specifications for the core HIPERLAN 2 standards, to assure the interoperability of devices and products produced by different vendors. The test specifications include both radio and protocol testing.

ETSI TC BRAN has worked closely with IEEE-SA (Working Group 802.11) and with MMAC in Japan (Working Group High Speed Wireless Access Networks) to harmonize the systems developed by these three fora for the 5 GHz bands.

# 3 MMAC[[4]](#footnote-4) HSWA[[5]](#footnote-5)

MMAC HSWA has developed and **ARIB[[6]](#footnote-6)** has approved and published, a standard for broadband mobile access communication systems. It is called HiSWANa (ARIB STD-T70). The scope of the technical specifications is limited to the air interface, the service interfaces of the wireless subsystem, the convergence layer functions and supporting capabilities required to realize the services.

The technical specifications describe the PHY and MAC/DLC layers, which are core network independent, and the core network-specific convergence layer. The typical data rate is from 6 to 36 Mbit/s. The OFDM technique and TDMA-TDD scheme are used. It is capable of supporting multimedia applications by providing mechanisms to handle the quality-of-service (QoS). Restricted user mobility is supported within the local service area. Currently, only Ethernet service is supported.

The HiSWANa system is operated in the 5 GHz bands (4.9-5.0 GHz and 5.15-5.25 GHz).

Annex 2  
  
IMT-2000 terrestrial radio interfaces

The section titles are taken from § 5 of Recommendation ITU‑R M.1457, additional updated information can be found there.

# 1 IMT-2000 CDMA Direct Spread[[7]](#footnote-7)

The UTRAN radio-access scheme is direct-sequence CDMA (DS-CDMA) with information spread over approximately 5 MHz bandwidth using a chip rate of 3.84 Mchip/s. Higher order modulation (64-QAM in downlink and 16-QAM in uplink), multiple input multiple output antennas (MIMO), improved L2 support for high data rates and coding techniques (turbo codes) are used to provide high-speed packet access.

A 10 ms radio frame is divided into 15 slots (2 560 chip/slot at the chip rate of 3.84 Mchip/s). A physical channel is therefore defined as a code (or number of codes). For HS-DSCH (high‑speed downlink packet access – HSDPA), E-DCH (high-speed uplink packet access – HSUPA) and associated signalling channels, 2 ms subframes consisting of 3 slots are defined. This technology achieves peak data rates approaching 42 Mbit/s for downlink and up to 11 Mbit/s for uplink. Large cell ranges (up to 180 km) can be achieved in good propagation conditions (e.g., desert, grassy and plain fields, coastal areas etc.).

For efficient support of always-on connectivity whilst enabling battery saving in the UE and further increasing the air interface capacity, the specifications also include the continuous packet connectivity feature (CPC). The CS voice services are supported over HSPA.

The radio interface is defined to carry a wide range of services to efficiently support both circuit‑switched services (e.g., PSTN- and ISDN-based networks) as well as packet-switched services (e.g., IP-based networks). A flexible radio protocol has been designed where several different services such as speech, data and multimedia can simultaneously be used by a user and multiplexed on a single carrier. The defined radio-bearer services provide support for both real‑time and non‑real‑time services by employing transparent and/or non-transparent data transport. The QoS can be adjusted in terms such as delay, bit-error probability, and frame error ratio (FER).

The radio access network architecture also provides support for multimedia broadcast and multicast services, i.e., allowing for multimedia content distribution to groups of users over a point‑to‑multipoint bearer.

E-UTRAN has been introduced for the evolution of the radio-access technology towards a high‑data-rate, low-latency and packet-optimized radio-access technology. E-UTRAN supports scalable bandwidth operation for spectrum allocations reaching from below 5 MHz up to 20 MHz in both the uplink and downlink. The radio access network architecture of E-UTRAN consists of the evolved UTRAN NodeBs (eNBs). eNBs host the functions for radio resource management, IP header compression and encryption of user data stream, etc. eNBs are interconnected with each other and connected to an evolved packet core (EPC).

In E-UTRAN, the uplink radio access scheme is based on single carrier FDMA, more specifically, DFTS-OFDM. The sub-carrier spacing is 15 kHz. The modulation scheme for the uplink is up to 16‑QAM and optionally 64-QAM. The downlink radio access scheme of E‑UTRAN is based on conventional OFDM using cyclic prefix. The OFDM sub-carrier spacing is 15 kHz. Single-user MIMO and multi-user MIMO with 2 and 4 transmit antennas are supported. Peak data rate of more than 300 Mbit/s can be achieved with a 20 MHz bandwidth, MIMO and higher order modulation up to 64‑QAM. In E-UTRAN each radio frame is 10 ms long, and the smallest time unit is one subframe of 1 ms. Uplink and downlink transmissions are separated in the frequency domain.

# 2 IMT-2000 CDMA Multi-Carrier[[8]](#footnote-8)

The CDMA multi-carrier radio interface provides two options: cdma2000 operation where one or three RF carriers are utilized or cdma2000 high rate packet data (HRPD) where one to fifteen RF carriers are utilized.

The cdma2000 operation option supports one or three 1.2288 Mchips/s RF carriers. The radio interface is defined to carry a wide range of services to support both circuit-switched services (e.g., PSTN- and ISDN-based networks) as well as packet-switched services (e.g., IP-based networks). The radio protocol has been designed where several different services such as speech, data and multimedia can simultaneously be used in a flexible manner by a user and multiplexed on a single carrier. The defined radio-bearer services provide support for both real-time and non‑real‑time services by employing transparent and/or non-transparent data transport. The QoS can be adjusted in terms such as delay, bit-error probability and FER.

The radio-interface specification includes enhanced features for simultaneous high-speed packet data and other services such as speech on the single carrier. In particular, features for enhanced reverse link have been introduced, allowing for improved capacity and coverage, higher data rates than the current uplink maximum, and reduced delay and delay variance for the reverse link.

The radio access network architecture also provides support for multimedia broadcast and multicast services, i.e., allowing for multimedia content distribution to groups of users over a point‑to‑multipoint bearer.

For cdma2000 HRPD, the forward link, deployed on one to fifteen RF carriers, consists of the following time-multiplexed channels: the pilot channel, the forward MAC channel, the control channel and the forward traffic channel. The forward traffic channel carries user data packets. The control channel carries control messages, and it may also carry user traffic. Each channel is further decomposed into code-division-multiplexed quadrature Walsh channels.

The cdma2000 HRPD MAC channel consists of two sub-channels: the reverse power control (RPC) channel and the reverse activity (RA) channel. The RA channel transmits a reverse link activity bit (RAB) stream. Each MAC channel symbol is BPSK-modulated on one of (sixty-four) 64-ary Walsh codewords.

The cdma2000 HRPD forward traffic channel is a packet-based, variable-rate channel. The user data for an access terminal is transmitted at a data rate that varies from 38.4 kbit/s to 4.9 Mbit/s per 1.2288 Mchip/s carrier. The forward traffic channel and control channel data are encoded, scrambled and interleaved. The outputs of the channel interleaver are fed into a QPSK/8‑PSK/16‑QAM/64-QAM modulator. The modulated symbol sequences are repeated and punctured, as necessary. Then, the resulting sequences of modulation symbols are demultiplexed to form 16 pairs (in-phase and quadrature) of parallel streams. Each of the parallel streams are covered with a distinct 16‑ary Walsh function at a chip rate to yield Walsh symbols at 76.8 ksymbol/s. The Walsh-coded symbols of all the streams are summed together to form a single in‑phase stream and a single quadrature stream at a chip rate of 1.2288 Mchip/s. The resulting chips are time-division multiplexed with the preamble, pilot channel, and MAC channel chips to form the resultant sequence of chips for the quadrature spreading operation.

The cdma2000 HRPD forward traffic channel physical layer packets can be transmitted in 1 to 16 slots. When more than one slot is allocated, the transmitted slots use 4‑slot interlacing. That is, the transmitted slots of a packet are separated by three intervening slots, and slots of other packets are transmitted in the slots between those transmit slots. If a positive acknowledgement is received on the reverse link ACK channel that the physical layer packet has been received on the forward traffic channel before all of the allocated slots have been transmitted, the remaining untransmitted slots are not transmitted and the next allocated slot is used for the first slot of the next physical layer packet transmission.

The cdma2000 HRPD reverse link, deployed on one to fifteen RF carriers, consists of the access channel and the reverse traffic channel. The access channel is used by the access terminal to initiate communication with the access network or to respond to an access terminal directed message. The access channel consists of a pilot channel and a data channel. The reverse traffic channel is used by the mobile station to transmit user‑specific traffic or signalling information to the access network. The cdma2000 HRPD reverse link traffic channel comprises a pilot channel, a reverse rate indicator (RRI) channel, a data rate control (DRC) channel, an acknowledgement (ACK) channel, and a data channel. The user data for an access terminal is transmitted at a data rate that varies from 4.8 kbits/s to 1.8 Mbits/s per 1.2288 Mchips/s carrier. The RRI channel is used to indicate the data rate transmitted on the reverse traffic channel. The RRI channel is time-multiplexed with the pilot channel. The DRC channel is used by the mobile station to indicate to the access network the supportable forward traffic channel data rate and the best serving sector on the forward CDMA channel. The ACK channel is used by the access terminal to inform the access network whether or not the data packet transmitted on the forward traffic channel has been received successfully.

For the enhanced HRPD access, physical layer H-ARQ (hybrid automatic repeat request), shorter frame sizes, fast scheduling/rate-control, and adaptive modulation and coding are implemented to increase the peak data rate and system throughput of the reverse link.

## 2.1 Ultra mobile broadband system

The ultra mobile broadband (UMB) system provides a unified design for full- and half-duplex FDD and TDD modes of operation with support for scalable bandwidths between 1.25 MHz and 20 MHz. The system is designed for robust mobile broadband access, and is optimized for high spectral efficiency and short latencies using advanced modulation, link adaptation, and multi‑antenna transmission techniques. Fast handoff, fast power control, and inter-sector interference management are used. Adaptive coding and modulation with synchronous H‑ARQ and turbo coding (LDPC optional) are used for achieving high spectral efficiencies. Sub-band scheduling provides enhanced performance on forward and the reverse link by exploiting multi‑user diversity gains for latency‑sensitive traffic.

The forward link is based on orthogonal frequency division multiple access (OFDMA) enhanced by multi-antenna transmission techniques including MIMO, closed loop beamforming, and space division multiple access (SDMA), with the maximum total spatial multiplexing order 4. Minimum forward link retransmission latency is approximately 5.5 ms and peak rate over 288 Mbit/s is achieved with 4th order MIMO in 20 MHz.

The reverse link is quasi-orthogonal. That is, it employs orthogonal transmission based on OFDMA, together with non-orthogonal user multiplexing with layered superposition or multiple receive antennas (SDMA). The reverse link also includes optional CDMA transmission for low‑rate traffic. Interference management is obtained through fractional frequency reuse. An optimized throughput/fairness trade-off is obtained through distributed power control based on other-cell interference. The reverse link employs a CDMA control segment and OFDMA control segment. The system employs fast access with reduced overhead and fast requests. The reverse link employs a broadband reference signal for power control, handoff decisions, and sub-band scheduling. UMB MAC design allows for a power efficient reverse link transmission by power limited terminals through scheduling. The reverse link retransmission latency is approximately 7.3 ms and the peak data rate is over 75 Mbit/s in a 20 MHz bandwidth (with single codeword quasi-orthogonal coding).

UMB is designed to operate in partly or fully asynchronous deployments, however, air interface is optimized to take advantage of inter-cell synchronization. Low overhead pilot channels (beacons) are introduced to enable low-complexity neighbour search and facilitate same frequency handoff as well as inter-frequency handoff with minimum interruption.

UMB also features power efficient operation modes to improve terminal battery life. Specifically, selected interlace mode is optimized for low-rate latency sensitive applications such as VoIP while a semi-connected state is designed to provide efficient DTX/DRX with a low duty cycle latency tolerant traffic.

# 3 IMT-2000 CDMA TDD[[9]](#footnote-9)

The universal terrestrial radio access (UTRA) time-division duplex (TDD) radio interface is defined where three options, called 1.28 Mchip/s TDD (TD-SCDMA), 3.84 Mchip/s TDD and 7.68 Mchip/s TDD can be distinguished.

The UTRA TDD radio interface has been developed with the strong objective of harmonization with the FDD component (see § 1.1) to achieve maximum commonality. This was achieved by harmonization of important parameters of the physical layer, and a common set of protocols in the higher layers are specified for both FDD and TDD, where 1.28 Mchip/s TDD has significant commonality with 3.84 Mchip/s TDD and 7.68 Mchip/s TDD. UTRA TDD with the three options accommodates the various needs of the different Regions in a flexible way and is specified in a common set of specifications.

The radio access scheme is direct-sequence code division multiple access. There are three chip‑rate options: the 3.84 Mchip/s TDD option, with information spread over approximately 5 MHz bandwidth and a chip rate of 3.84 Mchip/s, the 7.68 Mchip/s TDD option with information spread over approximately 10 MHz bandwidth and a chip rate of 7.68 Mchip/s and the 1.28 Mchip/s TDD option, with information spread over approximately 1.6 MHz bandwidth and a chip rate of 1.28 Mchip/s. The radio interface is defined to carry a wide range of services to efficiently support both circuit-switched services (e.g., PSTN- and ISDN-based networks) as well as packet-switched services (e.g., IP-based networks). A flexible radio protocol has been designed where several different services such as speech, data and multimedia can simultaneously be used by a user and multiplexed on a single carrier. The defined radio bearer services provide support for both real-time and non-real-time services by employing transparent and/or non-transparent data transport. The QoS can be adjusted in terms such as delay, BER and FER.

The radio-interface specification includes enhanced features for high-speed downlink packet access (HSDPA) and improved L2 support for high data rates, allowing for downlink packet-data transmission with peak data rates of 2.8 Mbit/s, 10.2 Mbit/s and 20.4 Mbit/s for the 1.28 Mchip/s, 3.84 Mchip/s and 7.68 Mchip/s modes respectively, and for simultaneous high-speed packet data and other services such as speech on the single carrier. Features for enhanced uplink have been introduced, allowing for improved capacity and coverage, higher data rates, and reduced delay and delay variance for the uplink.

The addition of higher order modulation (16-QAM) for the enhanced uplink, allows for peak data rates up to 2.2 Mbit/s, 9.2 Mbit/s and 17.7 Mbit/s for the 1.28 Mchip/s, 3.84 Mchip/s and 7.68 Mchip/s modes respectively. Support has been added for multi-frequency operation for the 1.28 Mchip/s UTRA TDD mode.

The radio access network architecture also provides support for multimedia broadcast and multicast services, i.e., allowing for multimedia content distribution to groups of users over a point-to-multipoint bearer.

E-UTRAN has been introduced for the evolution of the radio-access technology towards a high‑data-rate, low-latency and packet-optimized radio-access technology. E-UTRAN supports scalable bandwidth operation for spectrum allocations reaching from below 5 MHz up to 20 MHz in both the uplink and downlink. The radio access network architecture of E-UTRAN consists of the evolved UTRAN NodeBs (eNBs). eNBs host the functions for radio resource management, IP header compression and encryption of user data stream, etc. eNBs are interconnected with each other and connected to an evolved packet core (EPC).

In E-UTRAN, the uplink radio access scheme is based on single carrier FDMA, more specifically, DFTS-OFDM. The sub-carrier spacing is 15 kHz. The modulation scheme for the uplink is up to 16-QAM and optionally 64-QAM. The downlink radio access scheme of E‑UTRAN is based on conventional OFDM using cyclic prefix. The OFDM sub-carrier spacing is 15 kHz. Single-user MIMO and multi-user MIMO with 2 and 4 transmit antennas are supported. Peak data rate of more than 300 Mbit/s can be achieved with 20 MHz bandwidth, MIMO and higher order modulation up to 64‑QAM.

# 4 IMT-2000 TDMA Single-Carrier[[10]](#footnote-10)

This radio interface provides three bandwidth options for high-speed data, all using TDMA technology. The 200 kHz carrier bandwidth option (EDGE) utilizes 8-PSK or 32-QAM modulation with increased symbol rate with hybrid ARQ and achieves a channel transmission rate in dual-carrier mode of 1.625 Mbit/s or 3.25 Mbit/s while supporting high mobility. A 1.6 MHz bandwidth is provided for lower mobility environments which utilizes binary and quaternary offset QAM modulation with hybrid ARQ. This 1.6 MHz bandwidth option supports flexible slot allocation and achieves a channel transmission rate of 5.2 Mbit/s.

A rich broadcast or point-to-multipoint service known as multimedia broadcast/multicast service (MBMS) is provided. Point-to-multipoint services exist today which allow data from a single source entity to be transmitted to multiple endpoints. MBMS efficiently provides this capability for such broadcast/multicast services provided by the home environment and other value-added service providers (VASPs).

The MBMS is a unidirectional point-to-multipoint bearer service in which data is transmitted from a single-source entity to multiple recipients. It will also be capable of expanding to support other services with these bearer capabilities.

Multicast mode is interoperable with IETF IP multicast. This will allow the best use of IP service platforms to help maximize the availability of applications and content so that current and future services can be delivered in a more resource-efficient manner.

# 5 IMT-2000 FDMA/TDMA[[11]](#footnote-11)

The IMT-2000 radio interface for FDMA/TDMA technology is called digital enhanced cordless telecommunications (DECT).

This radio interface specifies a TDMA radio interface with time-division duplex (TDD). The channel transmission rates for the specified modulation schemes are 1.152 Mbit/s, 2.304 Mbit/s, 3.456 Mbit/s, 4.608 Mbit/s and 6.912 Mbit/s. The standard supports symmetric and asymmetric connections, connection-oriented and connectionless data transport. Using multicarrier operation with, for example, three carriers, allows bit rates up to 20 Mbit/s. The network layer contains the protocols for call control, supplementary services, connection oriented message service, connectionless message service and mobility management, including security and confidentiality services.

The radio access frequency channels as well as a time structure are defined. The carrier spacing is 1.728 MHz. To access the medium in time, a regular TDMA structure with a frame length of 10 ms is used. Within this frame 24 full slots are created, each consisting of two half-slots. A double slot has a length of two full slots, and starts concurrently with a full slot.

The modulation method is either Gaussian frequency-shift keying (GFSK), with a bandwidth-bit period product of nominally 0.5, differential phase shift keying (DPSK) or phase amplitude modulation (QAM). Equipment is allowed to use 4-level and/or 8-level and/or 16-level and/or 64‑level modulation in addition to 2-level modulation. This increases the bit rate of single radio equipment by a factor of 2 or 3 or 4 or 6. The 4-level modulation shall be /4-DQPSK, the 8‑level modulation /8-D8-PSK, the 16-level modulation 16-QAM and the 64‑level modulation 64‑QAM.

The MAC layer offers three groups of services to the upper layers and to the management entity:

– broadcast message control (BMC);

– connectionless message control (CMC);

– multibearer control (MBC).

The BMC provides a set of continuous point-to-multipoint connectionless services. These are used to carry internal logical channels, and are also offered to the higher layers. These services operate in the direction FT to PT, and are available to all PTs within range.

The CMC provides connectionless point-to-point or point-to-multipoint services to the higher layers. These services may operate in both directions between one specific FT and one or more PTs.

Each instance of MBC provides one of a set of connection-oriented point-to-point services to the higher layers. An MBC service may use more than one bearer to provide a single service.

Four types of MAC bearer are defined:

– Simplex bearer: a simplex bearer is created by allocating one physical channel for transmissions in one direction.

– Duplex bearer: a duplex bearer is created by a pair of simplex bearers, operating in opposite directions on two physical channels.

– Double simplex bearer: a double simplex bearer is created by a pair of long simplex bearers operating in the same direction on two physical channels.

– Double duplex bearer: a double duplex bearer is composed by a pair of duplex bearers referring to the same MAC connection.

A bearer can exist in one of three operational states:

– Dummy bearer: where there are normally continuous transmissions (i.e., one transmission in every frame).

– Traffic bearer: where there are continuous point-to-point transmissions. A traffic bearer is a duplex bearer or a double simplex bearer or a double duplex bearer.

– Connectionless bearer: where there are discontinuous transmissions. A connectionless bearer is either a simplex or a duplex bearer.

The MAC layer defines a logical structure for the physical channels. The user bit rate depends on the selected slot-type, modulation scheme, level of protection, number of slots and number of carriers.

The mandatory instant dynamic channel selection messages and procedures provide effective coexistence of uncoordinated private and public systems on the common designated frequency band and avoid any need for traditional frequency planning. Each device has access to all channels (time/frequency combinations). When a connection is needed, the channel is selected that, at that instant and at that locality, is least interfered of all the common access channels. This avoids any need for traditional frequency planning, and greatly simplifies the installations. This procedure also provides higher and higher capacity by closer and closer base station installation, while maintaining a high radio link quality. Not needing to split the frequency resource between different services or users provides an efficient use of the spectrum.

The latest specifications provide an update to “New Generation DECT”, where the main focus is the support of IP-based services. The quality of the speech service is further improved, by using wide‑band coding. The mandatory codec to provide interoperability over the air-interface is ITU‑T Recommendation G.722. Further optional codecs can be negotiated. In addition to voice‑over-IP, audio, video and other IP‑based services can be provided by “New Generation DECT”.

# 6 IMT-2000 OFDMA TDD WMAN[[12]](#footnote-12)

The IMT-2000 OFDMA TDD WMAN radio interface is based on the IEEE standard designated as IEEE Std 802.16, which is developed and maintained by the IEEE 802.16 Working Group on Broadband Wireless Access. It is published by the IEEE Standards Association (IEEE-SA) of the Institute of Electrical and Electronics Engineers (IEEE). The radio interface technology specified in IEEE Standard 802.16 is flexible, for use in a wide variety of applications, operating frequencies, and regulatory environments. IEEE 802.16 includes multiple physical layer specifications, one of which is known as WirelessMAN-OFDMA. OFDMA TDD WMAN is a special case of WirelessMAN-OFDMA specifying a particular interoperable radio interface. OFDMA TDD WMAN as defined here operates in both TDD and FDD.

The OFDMA TDD WMAN radio interface comprises the two lowest network layers – the physical layer (PHY) and the data link control layer (DLC). The lower element of the DLC is the MAC; the higher element in the DLC is the logical link control layer (LLC). The PHY is based on OFDMA supporting flexible channelizations including 5 MHz, 7 MHz, 8.75 MHz and 10 MHz bands. The MAC is based on a connection-oriented protocol designed for use in a point-to-multipoint configuration. It is designed to carry a wide range of packet-switched (typically IP‑based) services while permitting fine and instantaneous control of resource allocation to allow full carrier-class QoS differentiation.

The OFDMA TDD WMAN radio interface is designed to carry packet-based traffic, including IP. It is flexible enough to support a variety of higher-layer network architectures for fixed, nomadic, or fully mobile use, with handover support. It can readily support functionality suitable for generic data as well as time-critical voice and multimedia services, broadcast and multicast services and mandated regulatory services.

The radio interface standard specifies Layers 1 and 2; the specification of the higher network layers is not included. It offers the advantage of flexibility and openness at the interface between Layers 2 and 3 and it supports a variety of network infrastructures. The radio interface is compatible with the network architectures defined in ITU-T Recommendation Q.1701. In particular, a network architecture design to make optimum use of IEEE Standard 802.16 and the OFDMA TDD WMAN radio interface is described in the “WiMAX End to End Network Systems Architecture Stage 2-3”, available from the WiMAX Forum[[13]](#footnote-13).

Annex 3  
  
Harmonized IEEE and ETSI radio interface standards, for broadband   
wireless access (BWA) systems including mobile and nomadic   
applications in the mobile service

# 1 Overview of the radio interface

The IEEE Std 802.16-2009 and ETSI HiperMAN standards define harmonized radio interfaces for the OFDM and OFDMA physical layers (PHY) and MAC/data link control (DLC) layer, however the ETSI BRAN HiperMAN targets only the nomadic applications, while the IEEE Std 802.16‑2009 standard also targets full vehicular applications.

The use of frequency bands below 6 GHz provides for an access system to be built in accordance with this standardized radio interface to support a range of applications, including full mobility, enterprise applications and residential applications in urban, suburban and rural areas. The interface is optimized for dynamic mobile radio channels and provides support for optimized handover methods and comprehensive set of power saving modes. The specification could easily support both generic Internet-type data and real-time data, including applications such as voice and videoconferencing.

This type of system is referred to as a wireless metropolitan area network (WirelessMAN in IEEE and HiperMAN in ETSI BRAN). The word “metropolitan” refers not to the application but to the scale. The architecture for this type of system is primarily point-to-multipoint, with a base station serving subscribers in a cell that can range up to a few kilometres. Users can access various kinds of terminals, e.g., handheld phones, smart phone, PDA, handheld PC and notebooks in a mobile environment. The radio interface supports a variety of channel widths, such as 1.25, 3.5, 5, 7, 8.75, 10, 14, 15, 17.5 and 20 MHz for operating frequencies below 6 GHz. The use of orthogonal frequency division multiplexing (OFDM) and orthogonal frequency division multiple access (OFDMA) improves bandwidth efficiency due to combined time/frequency scheduling and flexibility when managing different user devices with a variety of antenna types and form factors. It brings a reduction in interference for user devices with omnidirectional antennas and improved NLoS capabilities that are essential when supporting mobile subscribers. Sub‑channelization defines sub-channels that can be allocated to different subscribers depending on the channel conditions and their data requirements. This gives the service providers more flexibility in managing the bandwidth and transmit power, and leads to a more efficient use of resources, including spectrum resources.

The radio interface supports a variety of channel widths and operating frequencies, providing a peak spectral efficiency of up to 3.5 bit/s/Hz in a single receive and transmit antenna (SISO) configuration.

The radio interface includes PHY as well as MAC/DLC. The MAC/DLC is based on demand-assigned multiple access in which transmissions are scheduled according to priority and availability. This design is driven by the need to support carrier-class access to public networks, through supporting various convergence sub-layers, such as Internet protocol (IP) and Ethernet, with full QoS.

The harmonized MAC/DLC supports the OFDM (orthogonal frequency-division multiplexing) and OFDMA (orthogonal frequency-division multiple access) PHY modes.

Figure 1 illustrates pictorially the harmonized interoperability specifications of the IEEE WirelessMAN and the ETSI HiperMAN standards, which include specifications for the OFDM and OFDMA physical layers as well as the entire MAC layer, including security.



The WiMAX Forum™, IEEE 802.16 and ETSI HiperMAN define profiles for the recommended interoperability parameters. IEEE 802.16 profiles are included in the main standards document, while HiperMAN profiles are included in a separate document. TTA (Telecommunications Technology Association) defines the standard for WiBro service which is based on WiMAX Forum profile 1A[[14]](#footnote-14). Although not explicitly included in Annex 2, the content of this standard, TTAK.KO‑06.0082/R2, including channelization of 8.75 MHz, is identical to one of the options in § 6 of Annex 2.

# 2 Detailed specification of the radio interface

## 2.1 IEEE 802.16

IEEE Standard for local and metropolitan area networks Part 16: Air Interface for Broadband Wireless Access Systems.

IEEE Std 802.16 is an air interface standard for broadband wireless access (BWA). It supports fixed, nomadic and mobile systems, and it enables combined fixed and mobile operation in licensed frequency bands below 6 GHz. The current IEEE Std 802.16-2009 is designed as a high-throughput packet data radio network capable of supporting several classes of IP applications and services based on different usage, mobility, and business models. To allow such diversity, the IEEE 802.16 air interface is designed with a high degree of flexibility and an extensive set of options.

The mobile broadband wireless technology, based on the IEEE-802.16 standard enables flexible network deployment and service offerings. Some relevant key standard features are described below:

Throughput, spectral efficiency and coverage

Advanced multiple antenna techniques work with OFDMA signalling to maximize system capacity and coverage. OFDM signalling converts a frequency selective fading wideband channel into multiple flat fading narrow-band subcarriers and therefore smart antenna operations can be performed on vector flat subcarriers. Major multiple antenna technique features are listed here:

– 2nd, 3rd and 4th, order MIMO and spatial multiplexing (SM) in uplink and downlink;

– adaptive MIMO switching between spatial multiplexing/space time block coding to maximize spectral efficiency with no reduction in coverage area;

– UL (uplink) collaborative spatial multiplexing for single transmit antenna devices;

– advanced beamforming and null steering.

QPSK, 16-QAM and 64-QAM modulation orders are supported both in uplink and downlink. Advanced coding schemes including convolution encoding, CTC, BTC and LDPC along with chase combining and incremental redundancy hybrid ARQ and adaptive modulation and coding mechanism enables the technology to support a high performance robust air link.

Support for mobility

The standard supports BS and MS initiated optimized hard handover for bandwidth-efficient handover with reduced delay achieving a handover delay less than 50 msec. The standard also supports fast base station switch (FBSS) and Marco diversity handover (MDHO) as options to further reduce the handover delay.

A variety of power saving modes is supported, including multiple power saving class types sleep mode and idle mode.

Service offering and classes of services

A set of QoS options such as UGS (unsolicited grant service), real-time variable rate, non-real-time variable rate, best effort and extended real-time variable rate with silence suppression (primarily for VoIP) to enable support for guaranteed service levels including committed and peak information rates, minimum reserved rate, maximum sustained rate, maximum latency tolerance, jitter tolerance, traffic priority for varied types of Internet and real time applications such as VoIP.

Variable UL and DL subframe allocation supports inherently asymmetric UL/DL data traffic.

Multiple OFDMA adjacent and diversified subcarrier allocation modes enable the technology to trade off mobility with capacity within the network and from user to user. OFDMA with adjacent subcarrier permutation makes it possible to allocate a subset of subcarriers to mobile users based on relative signal strength.

Sub‑channelization and MAP-based signalling schemes provide a mechanism for optimal scheduling of space, frequency and time resources for simultaneous control and data allocations (multicast, broadcast and unicast) over the air interface on a frame-by-frame basis.

Scalability

The IEEE-802.16 standard is designed to scale in different channel bandwidths from 1.25 to 28 MHz to comply with varied worldwide requirements.

Scalable physical layer based on the concept of scalable OFDMA enables the technology to optimize the performance in a multipath fading mobile environment, characterized with delay spread and Doppler shift, with minimal overhead over a wide range of channel bandwidth sizes. Scalability is achieved by adjusting the FFT size to the channel bandwidth while fixing the subcarrier frequency spacing.

Reuse planning

IEEE 802.16 OFDMA PHY supports various subcarrier allocation modes and frame structures such as partially used sub-channelization (PUSC), fully used sub-channelization (FUSC) and advance modulation and coding (AMC). These options enable service providers to flexibly perform wireless network reuse planning for spectrally efficient re-use factor 1, interference robust re-use factor 3 or optimal fractional reuse deployment scenarios.

In the case of reuse factor 1, although system capacity can typically increase, users at the cell edge may suffer from low connection quality due to heavy interference. Since in OFDMA, users operate on sub-channels, which only occupy a small fraction of the channel bandwidth, the cell edge interference problem can be easily addressed by reconfiguration of the sub-channel usage and reuse factor within frames (and therefore the notion of fractional reuse) without resorting to traditional frequency planning. In this configuration, the full load frequency re-use factor 1 is maintained for centre users[[15]](#footnote-15) with better link connection to maximize spectral efficiency while fractional frequency reuse is achieved for edge users[[16]](#footnote-16) to improve edge-user connection quality and throughput. The sub-channel reuse planning can be adaptively optimized across sectors or cells based on network load, distribution of various user types (stationary and mobile) and interference conditions on a per‑frame basis. All the cells/sectors can operate on the same RF frequency channel and no conventional frequency planning is required.

Security sublayer

IEEE 802.16 supports privacy and key management – PKMv1 RSA, HMAC, AES-CCM and PKMv2 – EAP, CMAC, AES-CTR, MBS security.

Standard

The IEEE standard is available in electronic form at the following address:

<http://standards.ieee.org/getieee802/download/802.16-2009.pdf>.

## 2.2 ETSI standards

The specifications contained in this section include the following standards for BWA, the last available versions being:

– ETSI TS 102 177 v1.3.2: broadband radio access networks (BRAN); HiperMAN; physical (PHY) layer.

– ETSI TS 102 178 v1.3.2: broadband radio access networks (BRAN); HiperMAN; data link control (DLC) layer.

– ETSI TS 102 210 v1.2.1: broadband radio access networks (BRAN); HiperMAN; System Profiles.

*Abstract:* The HiperMAN standard addresses interoperability for BWA systems below 11 GHz frequencies, to provide high cell sizes in non‑line-of-sight (NLoS) operation. The standard provides for FDD and TDD support, high spectral efficiency and data rates, adaptive modulation, high cell radius, support for advanced antenna systems, high security encryption algorithms. Its existing profiles are targeting the 1.75 MHz, 3.5 MHz and 7 MHz channel spacing, suitable for the 3.5 GHz band.

The main characteristics of HiperMAN standards, which are fully harmonized with IEEE 802.16, are:

– all the PHY improvements related to OFDM and OFDMA modes, including MIMO for the OFDMA mode;

– flexible channelization, including the 3.5 MHz, the 7 MHz and 10 MHz raster (up to 28 MHz);

– scalable OFDMA, including FFT sizes of 512, 1 024 and 2 048 points, to be used in function of the channel width, such that the subcarrier spacing remains constant;

– uplink and downlink OFDMA (sub-channelization) for both OFDM and OFDMA modes;

– adaptive antenna support for both OFDM and OFDMA modes.

*Standards:* All the ETSI standards are available in electronic form at: <http://pda.etsi.org/pda/queryform.asp>, by specifying in the search box the standard number.

Annex 4  
  
ATIS WTSC radio interface standards for BWA systems  
in the mobile service

# 1 ATIS WTSC wireless wideband internet access and other standards

The Wireless Technologies and Systems Committee (WTSC, formerly T1P1) of the Alliance of Telecommunications Industry Solutions (ATIS), an American National Standards Institute (ANSI)‑accredited standards development organization, has developed three American national standards that adhere to its adopted requirements for wireless wideband internet access (WWINA) systems as well as other standards applicable to nomadic wireless access. The WWINA air interface standards enable wireless portability and nomadic roaming subscriber services that complement the DSL and cable modem markets. These systems are optimized for high-speed packet data services that operate on a separate, data-optimized channel. The WWINA requirements specify a non-line-of-sight wireless internet air interface for full-screen, full-performance multimedia devices.

These air interfaces provide for portable access terminal (AT) devices with improved performance when compared to other systems that are targeted for high-mobility user devices. More specifically, the WWINA air interfaces optimize the following performance attributes:

– system data speeds;

– system coverage/range;

– network capacity;

– minimum network complexity;

– grade-of-service and quality-of-service management.

# 2 T1.723-2002 I‑CDMA spread spectrum systems air interface standard

## 2.1 Overview of the radio interface

The Internet code division multiple access (I‑CDMA) standard uses CDMA technology operating at a chip rate of 1.2288 Mcps and using a frequency assignment of 1.23 MHz similar to commercial CDMA cellular systems. QPSK/BPSK modulation along with turbo product code (TPC) and BCH forward-error correction and ARQ protocol ensure robust data delivery. Channel rasters of 12.5 kHz, 25 kHz, 30 kHz or 50 kHz are used to derive the centre channel transmit and receive frequencies to provide compatibility with current cellular FDD frequency assignments.

## 2.2 Detailed specifications of the radio interface

The I‑CDMA radio interface consists of three layers which follow the OSI model. These layers are the physical layer, the link layer comprising LAC and MAC, and the network layer.

The physical layer sends and receives packet data segments from the link layer. It provides forward-error correction (FEC) coding, interleaving, orthogonalization and spreading to allow code division multiple access, and modulation.

The link layer contains two sublayers: MAC and link access control (LAC). The MAC layer is responsible managing the physical layer resources for data services. The LAC layer is responsible for initiation of a link layer connection between the AT and the BSR (base station router). The link layer is responsible for segmentation and reassembly, data services, and ARQ error recovery.

The network layer receives user payload in the form of IP packets and processes those packets to and from the link layer. The network layer communicates to its peer entity over the I‑CDMA radio interface to provide the setup and control of the network layer functions. It provides AT configuration and management, connection maintenance, device authentication, user authentication support. The network layer also provides QoS support, session services and mobility support via mobile IP.

# 3 ATIS-0700001.2004 MCSB physical, MAC/LLC, and network layer specification

## 3.1 Overview of the radio interface

The MCSB (multi-carrier synchronous beamforming) standard uses a combination of CDMA technology and smart antennas to achieve a point-to-multipoint system with enhanced transmission quality in order to achieve broadband data rates in non-line-of-sight (NLoS) environments.

## 3.2 Detailed specifications of the radio interface

The MCSB radio interface consists of three layers which follow the OSI model. These layers are the physical layer, the data link layer comprising LLC and MAC, and the network layer:

As shown in Table 1, the physical layer defines modulation, multiplexing, time-division duplex (TDD) framing, power control, and timing synchronization. It treats both circuit-switched and packet-switched data in the same way.

TABLE 1

Radio interface layer function

|  |  |
| --- | --- |
| Layer | Function |
| Network layer (L3) | Packet classification/prioritization, bridging, OA&M |
| Data link (L2) | LLC: Segmentation/reassembly, resource management, selective retransmission error recovery |
| MAC: Segmentation/reassembly, resource management, forward‑error correction |
| Physical (L1) | Channelization, CDMA spreading, modulation, power control, synchronization |

The data link layer contains two sublayers: MAC and logic link control (LLC). The MAC layer is responsible for channel assignment, reassignment, release, and processing of data packets. The LLC layer processes both circuit-switched and packet-switched data. The LLC for circuit-switching packs and unpacks the control signal packets, processes them, and sets up the voice connection with an appropriate vocoder channel. The LLC for packet-switching implements the data framing and the selective retransmission error recovery protocol.

The network layer performs packet classification/prioritization, Ethernet bridging, and operation, administration and maintenance (OA&M) messaging, and is the interface to the core network.

The radio interface utilizes subcarriers of 500 kHz for the traffic/access/broadcast channels, while the sync channel utilizes subcarriers of 1 MHz. Therefore using a 5 MHz bandwidth, 10 subcarriers can be accommodated for the traffic/access/broadcast channels or 5 subcarriers for the synchronization channels. Each subcarrier has the capability of accommodating up to 32 traffic code channels (TCC).

Reed-Solomon forward-error correction coding is used and the data stream is modulated using QPSK, 8-PSK, 16-QAM, or 64-QAM. The data in each TCC are combined and then combined with other code channels for summation.

The reverse traffic channel can utilize a maximum of 2 or 4 contiguous subcarriers.

A frame period of 10 ms is used with a total number of symbols of 125 contained in the frame (including uplink and downlink). The forward traffic can occupy 55 + *n* \* 7 symbols while the resulting reverse traffic occupies 55 − *n* \* 7 symbols where *n* can range from 0 (symmetric) to 7.

# 4 ATIS-0700004.2005 high capacity-spatial division multiple access (HC-SDMA)

## 4.1 Overview of the radio interface

The HC-SDMA standard specifies the radio interface for a wide-area mobile broadband system. HC-SDMA uses TDD and adaptive antenna (AA) technologies, along with multi-antenna spatial processing algorithms to produce a spectrally efficient mobile communications system that can provide a mobile broadband service deployed in as little as a single (unpaired) 5 MHz band of spectrum licensed for mobile services. HC-SDMA systems are designed to operate in licensed spectrum below 3 GHz, which is the best suited for mobile applications offering full mobility and wide area coverage. Because it is based on TDD technology and does not require symmetrical paired bands separated by an appropriate band gap or duplexer spacing, systems based on the HC‑SDMA standard can easily be re-banded for operation in different frequency bands. The HC‑SDMA technology achieves a channel transmission rate of 20 Mbit/s in a 5 MHz licensed band. With its frequency re-use factor of *N* = 1/2, in a deployment using 10 MHz of licensed spectrum the 40 Mbit/s transmission rate is fully available in every cell in an HC-SDMA network, which is a spectral efficiency of 4 bits/s/Hz/cell.

## 4.2 Detailed specifications of the radio interface

The HC-SDMA air interface has a TDD/TDMA structure whose physical and logical characteristics have been chosen for the efficient transport of end-user IP data and to extract maximum benefit from adaptive antenna processing. The physical aspects of the protocol are arranged to provide spatial training data, and correlated uplink and downlink interference environments, for logical channels amenable to directive transmission and reception such as traffic channels. Conversely, channels not amenable to directive processing, such as paging and broadcast channels have smaller payloads and receive a greater degree of error protection to balance their links with those of the directively processed channels. Adaptive modulation and channel coding, along with uplink and downlink power control, are incorporated to provide reliable transmission across a wide range of link conditions. Modulation, coding and power control are complemented by a fast ARQ to provide a reliable link. Fast, low-overhead make-before-break inter-cell handover is also supported. Authentication, authorization, and privacy for the radio access link is provided by mutual authentication of the terminals and access network, and by encryption.

The HC-SDMA air interface has three layers designated as L1, L2, and L3.

Table 2 describes the air interface functionality embodied in each layer. Each layer’s features are briefly described below; more detailed overviews of key aspects are described in subsequent sections of this document.

TABLE 2

Air interface layers

|  |  |
| --- | --- |
| Layer | Defined properties |
| L1 | Frame and burst structures, modulation and channel coding, timing advance |
| L2 | Reliable transmission, logical to physical channel mapping, bulk encryption |
| L3 | Session management, resource management, mobility management, fragmentation, power control, link adaptation, authentication |

Table 3 summarizes the key elements of the HC-SDMA air interface.

TABLE 3

Summary of the basic elements of the HC-SDMA air interface

|  |  |
| --- | --- |
| Quantity | Value |
| Duplex method | TDD |
| Multiple access method | FDMA/TDMA/SDMA |
| Access scheme | Collision sense/avoidance, centrally scheduled |
| Carrier spacing | 625 kHz |
| Frame period | 5 ms |
| User data rate asymmetry | 3:1 down:up asymmetry at peak rates |
| Uplink time-slots | 3 |
| Downlink time-slots | 3 |
| Range | > 15 km |
| Symbol rate | 500 kbaud/sec |
| Pulse shaping | Root raised cosine |
| Excess channel bandwidth | 25% |
| Modulation and coding | – Independent frame-by-frame selection of uplink and downlink constellation + coding  – 8 uplink constellation + coding classes  – 9 downlink constellation + coding classes  – Constant modulus and rectangular constellations |
| Power control | Frame-by-frame uplink and downlink open and closed loop |
| Fast ARQ | Yes |
| Carrier and time-slot aggregation | Yes |
| QoS | DiffServ (Differentiated services) policy specification, supporting rate limiting, priority, partitioning, etc. |
| Security | Mutual AT and BSR authentication, encryption for privacy |
| Handover | AT directed, make-before-break |
| Resource allocation | Dynamic, bandwidth on demand |

# 5 T1.716/7-2000(R2004) air interface standard for broadband direct sequence CDMA for fixed wireless PSTN access – Layer 1/Layer 2

## 5.1 Overview of the radio interface

This radio interface uses direct sequence CDMA with chip rates defined from 4.16 Mchip/s to 16.64 Mchip/s resulting in RF bandwidths from 5 MHz to 20 MHz. FDD operation is defined with minimum uplink and downlink band separations of 40 to 60 MHz depending upon chip rate.

## 5.2 Detailed specifications of the radio interface

The broadband direct sequence CDMA radio interface consists of two layers; Layer 1 (L1) and Layer 2 (L2 – partitioned into MAC and DLC sublayers) which differ from the classical OSI model as shown in Table 4:

– DLC is limited to data link control of the dedicated control channels. Dedicated traffic channels are not managed by the DLC.

– MAC – not the physical layer (PHY) – performs encoding/decoding for forward-error correction (FEC), encipherment/decipherment, symbol repetition/combining, and power control for QoS.

TABLE 4

Air interface layers

|  |  |
| --- | --- |
| Layer | Function |
| Layer 2 (L2) | DLC: data link control of dedicated control channels |
| MAC: encoding/decoding, symbol repetition/combining, power control, encryption/decryption |
| Layer 1 (L1) | Channelization, CDMA spreading, modulation/demodulation, synchronization, RF combining/splitting |

Layer 1 provides physical channels (bearers) of 128 kbit/s. Multiple 128 kbit/s bearers can be aggregated to provide higher data rate services to an individual user. Layer 1 multiplexes multiple physical channels into the same RF spectrum by the use of direct-sequence spread spectrum with a distinct spreading sequence for each channel.

The data sequence for each physical channel modulates the spreading sequence, and the resulting sequence modulates the RF carrier. The chip rate of the spreading sequence determines the transmit bandwidth.

Pilot symbols are generated by Layer 1 as necessary and transmitted with the modulated data signals.

The DLC sublayer of Layer 2 provides control plane services. The DLC sublayer provides error control through a balanced link access protocol, designated LAPCc, based upon LAPC which in turn is based on LAPD (ITU‑T Recommendations Q.920 and Q.931). The control plane services provide a point‑to‑point service that operates in acknowledged mode. The point-to-point service includes the addressing, error control, flow control, and frame sequencing, multiplexing/demultiplexing of network layer information fields, and partitioning of DLC frames.

All the standards referenced to in this annex are available in electronic form at: <https://www.atis.org/docstore/default.aspx>.

Annex 5  
  
“eXtended Global Platform: XGP” for broadband wireless access (BWA) systems in the mobile service

# 1 Overview of the radio interface

XGP Forum, formerly known as PHS MoU Group, which is a standards development organization, has developed “eXtended Global Platform: XGP” as one of the BWA systems. “eXtended Global Platform” also known as “Next-generation PHS”, achieves high efficiency of spectral utilization mainly because of using micro-cells whose radii are much shorter than the typical mobile phone cells, as well as original PHS system.

“eXtended Global Platform” is the new mobile BWA system which utilizes OFDMA/TDMA-TDD, and some more advanced features described below:

– Enabling continuous connectivity at IP level

Considering the convenience of continuous connection provided on the cable modem circumstance, etc., the continuous connectivity at IP level that enables users to start high‑speed transmission in a moment is essential.

– High transmission data rate

It is also important to keep throughput of some extent for practical use even in case that serious concentration of traffic occurs.

– High transmission data rate for uplink

Considering future demand of bidirectional broadband communication such as a videoconference, an uplink transmission data rate over 10 Mbit/s is considered to become still more important in the near future.

– High efficiency in spectral utilization

When serious traffic congestion occurs concentrically at a business district or downtown area, some problems by shortage of frequency would hamper many services. In order to avoid such situations, highly efficient spectral utilization is necessary.

In addition, it has the ability of highly efficient spectral utilization by adopting the technologies described below:

– Adaptive array antenna technology and space division multiple access technology enable a frequency re-use factor of more than 4.

– Autonomous decentralized control technology contributes to make cell designing plans unnecessary, and as a result, the cell radius down to less than 100 m is realized.

Because many cells can basically overlap each other in the “eXtended Global Platform” system, a handset can access multiple cell stations around it at the same time. Therefore, this system is able to provide all users with continuous stable throughput by way of spreading traffic volume that might occur intensively and temporarily.

The autonomous decentralized control method is effective in order to construct micro-cell networks. The advantage of this method is its unexacting features of the installation position.

Mobile wireless systems generally require a relatively high level of accuracy in their installation position in order to avoid interference with other cells. In the case of macro-cell networks, a shift of the base station from the intended building to an adjoining substitute building due to unsuccessful negotiations with the building owner, only causes inter-cell interferences which still lies within the range of marginal error.

However, in the case of micro-cell networks, as such shifts cannot be dismissed as marginal error; readjustments of the surrounding cell designs are needed in some cases.

This concern is already solved with “eXtended Global Platform” system, as it has an interference resistant structure and does not require strict accuracy for the positioning of the base stations, promising less trouble for the construction of micro-cell networks.

Since “eXtended Global Platform” adopts the autonomous decentralized control method, which enables several operators to share the same frequency band, more efficient spectral utilization would be realized.

“eXtended Global Platform” is a system among BWA systems, which possesses a differentiating feature by flexibly utilizing micro-cell networks as well as macro-cells in order to resolve heavy traffic congestions in densely-populated areas.

The autonomous decentralized control method of “eXtended Global Platform” demonstrates advantage in the construction of micro-cell networks. It is also possible to form a network without distressing about the interference problems when the pico cell and the femto cell are similarly introduced with the same method. Moreover, as strict cell design is unnecessary for the macro-cell network construction, a simple network operation is possible, and regardless of the micro-cell or the macro-cell, it allows simple method operations for the installation of additional base-stations to the network.

The radio interface of “eXtended Global Platform” supports bandwidths from 1.25 MHz up to 20 MHz and up to 256QAM modulation to realize high transmission data rate for up/downlinks.

# 2 Detailed specification of the radio interface

The “eXtended Global Platform” radio interface has two dimensions for multiple access methods such as OFDMA (controlled along frequency axis) and TDMA (controlled along time axis). At the time axis, the time-frame format is the same as that of the original PHS which is a 5 ms symmetric frame. And at the frequency axis, using the method of OFDMA, a number of subcarriers would be allocated within the allowed whole bandwidth, depending on the user’s demand and the frequency circumstance at each time.

This radio interface can use some sorts of bandwidth, 1.25 MHz, 2.5 MHz, 5 MHz, 10 MHz, 20 MHz, and the subcarrier frequency spacing is 37.5 kHz. The time-frame has eight slots of 5 ms each, the consecutive 4 slots are for downlink, and other consecutive 4 slots are for uplink. Each slot of 4 slots can be used separately, of course, and also can be used continuously for one user, and moreover continuous using of over 4 slots is possible in asymmetry frame structure.

“eXtended Global Platform” achieves efficient spectral utilization by some functions, such as adaptive array antenna, SDMA and MIMO. It also has the functions of autonomous decentralized control method, dynamic channel assign technique to make microcell network, which is also effective for efficient spectral utilization.

The basic elements of the radio interface are shown in Table 5.

TABLE 5

The basic elements of “eXtended Global Platform: XGP”

|  |  |
| --- | --- |
| Multiple access method | OFDMA, SC-FDMA/TDMA |
| Duplex method | TDD |
| Number of TDMA multiplexing | 4 |
| Number of OFDMA multiplexing | Depends on channel bandwidth |
| Operation channel bandwidth | 1.25 MHz, 2.5 MHz, 5 MHz, 10 MHz, 20 MHz |
| Subcarrier frequency spacing | 37.5 kHz |
| Number of FFT points (channel bandwidth: MHz) | 32 (1.25), 64 (2.5), 128 (5), 256 (10), 512 (20) |
| Frame duration | 5 ms |
| Number of slots | 8 slots (4 downlink/4 uplink: symmetry) |
| Modulation method | BPSK, QPSK, 16-QAM, 64-QAM, 256‑QAM |
| Channel assign | Autonomous decentralized control |
| Basic cell size | Micro-cell |
| Connection technique | Sub-channel connection, slot connection |
| Technologies of efficient spectral utilization | Adaptive array antenna, SDMA, MIMO |
| Peak channel transmission rate/5 MHz (in case of SISO, symmetry) | Uplink: 9.85 Mbit/s Downlink: 10.7 Mbit/s |

The MAC layer of “eXtended Global Platform” has a very simple structure when seeing with the frequency axis and the time axis. This is because it is valued to keep continuously using the same frequency used between the base stations and terminals. As a result, a certain base station can monitor the frequency and timing used in the surroundings, and it is also able to choose to use the frequency and timing of best conditions. In addition, “eXtended Global Platform” has its uplink and downlink speed symmetric on the axis of time, which enables constant speed also for the uplink.   
By this, it enables real-time movie uploading and mobile video conference without inconvenience.

The MAC layer image of “eXtended Global Platform” is shown in Fig. 2.



Standards

The “eXtended Global Platform” specifications of XGP Forum are available in electronic  
form at its website:

“A-GN4.00-01-TS: eXtended Global Platform Specifications” <http://www.xgpforum.com>.

The ARIB (Association of Radio Industries and Businesses) has also standardized “eXtended Global Platform” for Japanese domestic use.

The ARIB standard of “eXtended Global Platform”, stated here as “Next-generation PHS”, is also available at the ARIB website.

“ARIB STD-T95: OFDMA/TDMA TDD Broadband Access System (Next Generation PHS) ARIB STANDARD” <http://www.arib.or.jp/english/index.html>.

The standard “ARIB STD-T95” includes Japanese regulation specifications as well as the system original specifications.

Annex 6   
  
IEEE 802.20: Standard air interface for mobile broadband wireless   
access supporting vehicular mobility

IEEE 802.20 is designed to provide IP-based broadband wireless (Internet) access in a mobile environment. The standard includes a wideband mode and a 625k-multicarrier mode. Time division duplexing is supported by both the 625k- MC mode and the wideband mode; frequency division duplexing is supported by the wideband mode.

# 1 System aspects

The 802.20 standard specifies requirements to ensure compatibility between a compliant access terminal (AT) and a compliant access node (AN) or base station (BS), conforming to properly selected modes of the standard.

The intent of the 802.20 standard is to permit either a fixed hierarchical backhaul structure (traditional to the cellular environment) or a more dynamic and non-hierarchical backhaul structure. The architecture of the 802.20 specification is intended to provide a backward compatibility framework for future service additions and expansion of system capabilities without loss of backward compatibility and support for legacy technology.

The wideband mode is based on OFDMA techniques and is designed to operate for frequency division duplex (FDD) and time division duplex (TDD) bandwidths from 5 MHz to 20 MHz. For systems having more than 20 MHz available, the wideband mode defines a suitable multicarrier mode that can accommodate larger bandwidths.

The 625k- MC mode is a TDD air interface that was developed to extract maximum benefit from adaptive, multiple-antenna signal processing. The 625k- MC mode enables wireless broadband access using multiple radio frequency (RF) carriers with 625 kHz carrier spacing that typically are deployed in channel block sizes of 5 MHz and up. The 625k- MC mode supports aggregation of multiple TDDD RF carriers to further increase the peak data rates available on a per user basis.

## 1.1 Wideband mode – physical layer features

The 802.20 wideband mode provides physical layer support based on OFDMA for both forward and reverse links. Supporting both FDD and TDD deployments, the PHY utilizes a similar baseband waveform for both, thereby reducing the number of technologies to be implemented by vendors. The specification provides modulation signal sets up to 64-QAM with synchronous HARQ, for both forward and reverse links, to improve throughputs in dynamic environments. To handle different environments, several different supported coding schemes include convolutional codes, turbo codes, and an optional LDPC scheme featuring performance comparable or better than turbo codes at all HARQ terminations.

Although the RL physical layer is based on OFDMA, a portion of the signalling from AT to AN takes place over a CDMA control segment embedded in certain subcarriers of the OFDM waveform. This unique feature enables robust and continuous signalling from AT to AN and can make use of soft handoff techniques, and other techniques developed for CDMA cellular transmission. The result is improved robustness of RL signalling, and continuity of the signalling channel even during transitions such as access and handoffs. Since the CDMA segment is “hopped” over the entire broadband channel, the AN can easily make broadband measurements needed for improved interference and resource management.

## 1.2 Wideband mode – multi-antenna techniques

From a system point of view, the 802.20 technology specifies several multi-antenna techniques for use with the FL. Both SISO and MIMO users can be supported simultaneously, thus optimizing the user experience to the best experience possible given channel conditions. For users close to the AP, MIMO enables very high data rate transmissions. Beamforming increases user data rates by focusing the transmit power in the direction of the user, thus enabling higher receive SINR at the AT. SDMA further increases sector capacity by allowing simultaneous transmissions to spatially separated users using the same sets of subcarriers. Thus beamforming in combination with MIMO and SDMA provides improved user data rates in both high and lower SINR regions.

## 1.3 625k – MC mode – air interface features

IEEE 802.20’s 625k-MC Draft Specification is an enhancement to the baseline specifications as given by High Capacity-Spatial Division Multiple Access (HC-SDMA) Radio Interface Standard (ATIS.0700004.2005) and is fully backward compatible to the commercially deployed systems based on HC-SDMA specifications.

The 625k-MC mode, which is uniquely designed around multiple antennas with spatial processing and spatial division multiple access (SDMA), enables the transfer of IP traffic, including broadband IP data, over a layered reference model as shown in Fig. 2. The physical (PHY) and data link layers (MAC and LLC) are optimally tailored to derive maximum benefit from spatial processing technologies: Adaptive antenna processing and SDMA: Enhanced spectral efficiency and capacity, and wider coverage while enabling the economic operation even when the available spectrum is as small as 625 kHz. Secondly, the physical and data link layers support higher data rates and throughputs by enabling multiple 625 kHz carrier aggregation – hence the name “625k-MC mode”.

<https://sbwsweb.ieee.org/ecustomercme_enu/start.swe?SWECmd=GotoView&SWEView=Catalog+View+(eSales)_Standards_IEEE&mem_type=Customer&SWEHo=sbwsweb.ieee.org&SWETS=1192713657>.

Annex 7   
  
Air interface of SCDMA broadband wireless access system standard

# 1 Overview of the radio interface

The standard radio interface defines TDD/code-spread OFDMA (CS-OFDMA) based physical layer and media access control (MAC)/data link control (DLC) layer. Packet data based, mobile broadband system built according to the standard radio interface supports a full range of applications, including best effort data, real-time multimedia data, simultaneous data and voice.

The radio interface is optimized for highly efficient voice, full mobility for voice and data, and high spectrum efficiency for single frequency deployment. Multiple antenna based techniques such as beam-forming, nulling and transmit diversity have been incorporated into the radio interface to provide better coverage, mobility performance and interference mitigation to support deployment with frequency re-use factor of *N* = 1.

The radio interface supports a channel bandwidth of a multiple of 1 MHz up to 5 MHz. Sub‑channelization and code spread, specially defined inside each 1 MHz bandwidth, provides frequency diversity and interference observation capability for radio resource assignment with bandwidth granularity of 8 kbit/s. The channelization also allows coordinated dynamic channel allocations among cells to efficiently avoid mutual interference. A system using 5 MHz bandwidth can support 120 concurrent users. Sub-channel and power assignments for multiple users are thus conducted based on both link propagation conditions and link interference levels.

The standard radio interface supports modulations of QPSK, 8-PSK, 16-QAM and 64-QAM for both uplink and downlink, giving rise to peak spectral efficiency of 3 bit/s/Hz for single transmit and single receive antenna configuration. The system employs TDD to separate uplink and downlink transmission. The ratio between uplink and downlink data throughput can be flexibly adjusted by changing the switching point of uplink and downlink.

The MAC/DLC performs user access control, session management and ARQ error recovery. It also conducts bandwidth assignments, channel allocation and packet scheduling for multiple users communications according to user bandwidth requests, user priorities, user QoS/GoS requirements and channel conditions.

# 2 General aspects of the radio interface

## 2.1 CS-OFDMA and frame structure

The standard radio interface employs CS-OFDMA as a key technique for both signal transmission and multiple accessing. CS-OFDMA is based on OFDMA technique. Like OFDMA, each user is allocated a dedicated set of time-frequency grids for communication such that no multiple access interference and multipath interference incur. However, unlike conventional OFDMA where each coded symbol is directly mapped to an allocated time-frequency grid, a vector of CS-OFDMA signal is generated by pre-coding a vector of coded symbols. The resulting CS‑OFDMA signal vector is then mapped onto multiple time-frequency grids which are spread out in time and frequency. In this way, signals are transmitted with intrinsic frequency and time diversity. The CS‑OFDMA and multiple accessing are best illustrated by the following frame structure.



In Fig. 1, the 5 MHz band is divided into 5 sub-bands with each sub-band occupying 1 MHz. Each sub-band consists of 128 sub-carriers which are partitioned into 16 sub-channels, each sub‑channel includes 8 distributed sub-carriers. The CS-OFDMA TDD frame has a length of 10 ms, consisting of 1 preamble slot, 1 ranging slot, 8 traffic slots and 2 guard slots. The ratio of uplink traffic slots to downlink slots can be configured. Each slot includes 8/10 consecutive OFDMA symbols. The basic CS-OFDMA signal parameters are listed in Table 6.

TABLE 6

Basic CS-OFDMA signal parameters

| Parameters | Values |
| --- | --- |
| FFT size | 1 024 |
| Sub-carrier spacing | 7.8125 kHz |
| CS-OFDMA symbol duration | 137.5 μs |
| Cyclic prefix duration | 9.5 μs |
| BS occupied bandwidth | 5 MHz |
| Number of guard sub-carriers | 32 |

All sub-carriers inside a sub-band and a slot form a resource block which contains 128 sub-carriers by 8 OFDMA symbols. The code spreading is performed on 8 selected sub-carriers in each resource block with the 8 sub-carriers uniformly distributed across the 1 MHz sub-band. A CS-OFDMA signal vector of size 8-by-1 is generated by left-multiplying a L-by-1 coded symbol vector by a pre‑coding matrix of size 8-by-L. The resulting 8 signals are then mapped onto the 8 sub-carriers. L is loading factor of code spreading which is an integer variable equal and less than 8. The scheme is illustrated in Fig. 4.



## 2.2 Key features of the standard radio interface

The standard radio interface provides an optimized framework to integrate PHY/MAC/DLC techniques such as advanced multiple antenna, adaptive loading factor and modulation, dynamic channel allocation, make-before-break handoff and QoS/GoS control. The mobile broadband system based on the standard radio interface offers deployment flexibility to meet various requirements on coverage, capacity and service.

### 2.2.1 Multiple antenna technique

The TDD/CS-OFDMA frame structure is amenable to apply multiple antenna techniques. With uplink and downlink beam-forming, the link quality and coverage is significantly improved while reducing inter-cell interference. The optimized spatial nulling technique enables the system to work under strong interference. Multiple beam-forming based signal transmit enhances the robustness of downlink link communication.

### 2.2.2 TDD

The TDD/CS-OFDMA frame structure supports flexible uplink and downlink throughput ratios 1:7, 2:6, 3:5, 4:4, 5:3, 6:2 and 7:1. TDD makes many un-paired spectrum usable for broadband access service. The standard radio interface is immune to BS-to-BS interference due to long distance, at the same time supports BS-to-terminal coverage larger than 80 km.

### 2.2.3 Adaptive loading factor and modulation

The radio interface supports the following modulation scheme for both uplink and downlink: QPSK, 8-PSK, 16-QAM and 64-QAM. The FEC employs shortened Reed-Solomon (31, 29) with fixed code rate 96/106. The channel dependent rate control is conducted by jointly adjusting modulation order and code-spreading loading factor according to the path loss, channel condition, bandwidth request and user Grade of Service (GoS) to achieve optimum system-wise spectral efficiency.

### 2.2.4 Dynamic channel allocation

The radio interface has incorporated intelligent interference detection and avoidance mechanism. The BS assigns channels for each terminal based on the real time uplink and downlink interference distribution observed by all terminals. In this way, each terminal can always communicate in the sub-channels with the least interference level. The technique combined with adaptive nulling technique, makes it feasible to deployment with frequency reuse factor equal to one.

### 2.2.5 QoS/GoS

The radio interface provides a QoS/GoS control mechanism to meet quality requirements of various classes of service. The mechanism is realized through QoS aware link adaptation, packet scheduling and GoS based bandwidth management. 8 QoS levels and 8 GoS grades are defined in the radio interface.

### 2.2.6 Mobility

The TDD/CS-OFDMA frame structure offers dynamic pilot assignment based on the terminal mobility characteristic. More pilots are assigned for sub-channels allocated for fast moving terminals in order to track fast varying channel. The radio interface supports make-before-break handoff by allowing the terminal to communicate with anchor BS and target BS simultaneously as a way of testing connection reliability before eventually switching to the target BS.

References

Technical Requirements for Air Interface of SCDMA Broadband Wireless Access System (YD/T 1956‑2009) <http://www.ccsa.org.cn/worknews/content.php3?id=2393>.

Annex 8  
  
Key characteristics of standards

Table 7 provides a summary of key characteristics of each standard.

TABLE 7

Key technical parameters

| Standard | Nominal RF channel bandwidth | Modulation/ coding rate(1)  – upstream  – downstream | Coding support | Peak channel transmission rate per 5 MHz channel (except as noted) | Beam-forming support (yes/no) | Support for MIMO (yes/no) | Duplex method | Multiple access method | Frame duration | Mobility capabilities (nomadic/ mobile) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| IEEE 802.16 WirelessMAN/ ETSI HiperMAN (Annex 3) | Flexible from 1.25 MHz up to 28 MHz.  Typical bandwidths are: 3.5,  5,  7,  8.75,  10 and 20 MHz | Up: – QPSK-1/2, 3/4 – 16-QAM-1/2, 3/4  – 64-QAM-1/2, 2/3,   3/4, 5/6  Down: – QPSK-1/2, 3/4 – 16-QAM-1/2, 3/4  – 64-QAM-1/2, 2/3,   3/4, 5/6 | CC/CTC Other options: BTC/ LDPC | Up to 17.5 Mbit/s with SISO  Up to 35 Mbit/s with (2 × 2) MIMO  Up to 70 Mbit/s with (4 × 4) MIMO | Yes | Yes | TDD/ FDD/ HFDD | OFDMA TDMA | 5 ms  Other options: 2, 2.5, 4, 8, 10, 12.5 and 20 ms | Mobile |
| T1.723-2002  I‑CDMA spread spectrum systems air interface standard (Annex 4) | 1.25 MHz | Up: – QPSK,  – 0.325-0.793  Down: – QPSK, – 0.325-0.793 | Block TPC BCH | Up: 1.228 Mbit/s  Down: 1.8432 Mbit/s | Not explicit but not preclu-ded | Not explicit but not preclu-ded | FDD | CDMA | Tier 1: 13.33 ms Tier 2: 26.67 ms | Nomadic |
| ATIS-0700001.2004 MCSB physical, MAC/LLC, and network layer specification (Annex 4) | 5 MHz | Up: – QPSK, 8-PSK – 16-QAM   R-S (18, 16)  Down:  – QPSK, 8-PSK – 64-QAM   R-S (18, 16) | Reed-Solomon (18, 16) | Up: 6.4 Mbit/s  Down: 24 Mbit/s | Yes | Not speci-fied | TDD | CDMA | 10 ms | Nomadic |

TABLE 7 (*continued*)

| Standard | Nominal RF channel bandwidth | Modulation/ coding rate(1)  – upstream  – downstream | Coding support | Peak channel transmission rate per 5 MHz channel (except as noted) | Beam-forming support (yes/no) | Support for MIMO (yes/no) | Duplex method | Multiple access method | Frame duration | Mobility capabilities (nomadic/ mobile) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ATIS-0700004.2005 high capacity-spatial division multiple access (HC-SDMA)  (Annex 4) | 0.625 MHz | Up: – BPSK, QPSK,   8-PSK, 12-QAM,   16-QAM 3/4  Down: – BPSK, QPSK,   8-PSK, 12-QAM,   16-QAM,   24-QAM 8/9 | Convolu-tional and block code | Up: 2.866 Mbit/s × 8 sub-channels ×  4 spatial channels = 91.7 Mbit/s  Down: 2.5 Mbit/s ×  8 sub-channels × 4 spatial channels =  80 Mbit/s | Yes | Yes | TDD | TDMA/FDMA/ SDMA | 5 ms | Mobile |
| T1.716/7-2000 (R2004) air interface standard for broadband direct sequence CDMA for fixed wireless PSTN access – Layer 1/ Layer 2 (Annex 4) | 2 × 5 to  2 × 20 MHz  (in 3.5 or 5 MHz increments) | Up: – QPSK,  – 1/2  Down: – QPSK, – 1/2 | Convolu-tional | Up: 1.92 Mbit/s  Down: 1.92 Mbit/s | No | No | FDD | CDMA | 19 ms max | Nomadic |
| eXtended Global Platform : XGP (Annex 5) | 1.25 MHz 2.5 MHz 5 MHz 10 MHz 20 MHz | Up and down: BPSK 1/2, 2/3 QPSK 1/2, 3/4 16-QAM 1/2, 3/4 64-QAM 4/6, 5/6 256-QAM 6/8, 7/8 | Convolu-tional code Turbo code (option) | Up: 9.85 Mbit/s  Down: 10.7 Mbit/s (in case of SISO, symmetry) | Yes (option) | Yes (option) | TDD | OFDMA SC-FDMA  TDMA | 5 ms | Mobile |
| IEEE 802.11-2012 Subclause 17  (Formerly 802.11b)  (Annex 1) | 22 MHz | Up and down: DQPSK CCK BPSK PBCC – 1/2 QPSK PBCC – 1/2 | Uncoded/ CC | 2.5 Mbit/s | No | No | TDD | CSMA/  CA | Variable frame duration | Nomadic |

TABLE 7 (*continued*)

| Standard | Nominal RF channel bandwidth | Modulation/ coding rate(1)  – upstream  – downstream | Coding support | Peak channel transmission rate per 5 MHz channel (except as noted) | Beam-forming support (yes/no) | Support for MIMO (yes/no) | Duplex method | Multiple access method | Frame duration | Mobility capabilities (nomadic/ mobile) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| IEEE 802.11-2012  Subclause 18 (Formerly 802.11a)  (Annex 1) | 5 MHz  10 MHz  20 MHz | Up and down:  64-QAM OFDM 2/3, 3/4  16-QAM OFDM –1/2, 3/4  QPSK OFDM – 1/2, 3/4  BPSK OFDM – 1/2, 3/4 | CC | 13.5 Mbit/s | No | No | TDD | CSMA/ CA | Variable frame duration | Nomadic |
| IEEE 802.11-2012 Subclause 19  (Formerly 802.11g) (Annex 1) | 20 MHz | Up and down: 64-QAM OFDM 2/3, 3/4 16-QAM OFDM – 1/2, 3/4 QPSK OFDM – 1/2, 3/4 BPSK OFDM – 1/2, 3/4 8-PSK PBCC – 2/3 64-QAM DSSS-OFDM – 2/3, 3/4 16-QAM DSSS-OFDM – 1/2, 3/4 QPSK DSSS-OFDM – 1/2, 3/4 BPSK DSSS-OFDM – 1/2, 3/4 | CC | 13.5 Mbit/s | No | No | TDD | CSMA/ CA | Variable frame duration | Nomadic |

TABLE 7 (*continued*)

| Standard | | Nominal RF channel bandwidth | | Modulation/ coding rate(1)  – upstream  – downstream | | Coding support | | Peak channel transmission rate per 5 MHz channel (except as noted) | | Beam-forming support (yes/no) | | Support for MIMO (yes/no) | | Duplex method | | Multiple access method | | Frame duration | | Mobility capabilities (nomadic/ mobile) | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| IEEE 802.11-2012  Subclause 20) (formerly 802.11n)  (Annex 1) | | 20 MHz  40 MHz | | Up and down :  64-QAM OFDM – 2/3, 3/4, 5/6 16-QAM OFDM –1/2, 3/4 QPSK OFDM – 1/2, 3/4 BPSK OFDM – 1/2 | | CC and LDPC | | 75 Mbit/s | | Yes | | Yes | | TDD | | CSMA/ CA | | Variable frame duration | | Nomadic | |
| IEEE 802.11ac | | 20 MHz  40 MHz  80 MHz  160 MHz  80+80 MHz | | Up and down,  256-QAM OFDM 2/3, ¾, 5/6  64-QAM OFDM – 2/3, 3/4, 5/6 16-QAM OFDM –1/2, 3/4 QPSK OFDM – 1/2, 3/4 BPSK OFDM – 1/2 | | CC and LDPC | | 216 Mbit/s | | Yes | | Yes | | TDD | | CSMA/CA | | Variable frame duration | | Nomadic |
| IEEE 802.11ad | | 2160 MHz | | Up and down,  Single Carrier :  DBPSK – ½  π/2-BPSK – ½, 5/8, ¾, 13/16, 13/28, 13/21, 52/63  π/2-QPSK – ½, 5/8, ¾, 13/16, 13/28, 13/21, 52/63, 13/14  π/2-16QAM – ½, 5/8, ¾  OFDM :  SQPSK – ½, 5/8  QPSK – ½, 5/8, ¾  16-QAM – ½, 5/8, ¾, 13/16  64-QAM – 5/8, ¾, 13/16, | | LDPC, RS, Block-Code, SPC | | 15.6 Mbit/s | | Yes | | No | | TDD | | Scheduled, CSMA/CA | | Variable frame duration | | Nomadic |
| ETSI BRAN HiperLAN 2 (Annex 1) | | 20 MHz | | 64-QAM-OFDM 16-QAM-OFDM QPSK-OFDM BPSK-OFDM  both upstream and downstream | | CC | | 6, 9, 12, 18, 27, 36 and 54 Mbit/s in 20 MHz channel (only 20 MHz channels supported) | | No | | No | | TDD | | TDMA | | 2 ms | | Nomadic | |
| ARIB HiSWANa (Annex 1) | | 4 × 20 MHz (5.15-5.25 GHz)  4 × 20 MHz (4.9-5.0 GHz) | | – BPSK 1/2 – BPSK 3/4 – QPSK 1/2 – QPSK 3/4 – 16-QAM 9/16 – 16-QAM 3/4 – 64-QAM 3/4 | | Convolu-tional | | 6-54 Mbit/s in 20 MHz | | No | | No | | TDD | | TDMA | | 2 ms | | Nomadic | |
| IMT-2000 CDMA Direct Spread (Annex 2) | | 5 MHz  (E-UTRAN)  1.4 MHz, 3 MHz,  5 MHz, 10 MHz, 15 MHz, 20 MHz | | Up:  QPSK,  16-QAM  Down:  16-QAM, QPSK, 64-QAM  (E-UTRAN) QPSK, 16-QAM, 64-QAM | | Convolu-tional turbo | | Up: 11.5 Mbit/s  Down: 42 Mbit/s  (E-UTRAN)  Up:  75.3 Mbit/s /  20 MHz(3)  Down:  302.7 Mbit/s /  20 MHz(3) | | Yes | | Yes | | FDD | | CDMA  (E-UTRAN) OFDM in DL  SC-FDMA in UL | | 2 ms and 10 ms  (E-UTRAN) 10 ms  Sub-frame length  1 ms | | Mobile | |

TABLE 7 (*continued*)

| Standard | Nominal RF channel bandwidth | Modulation/ coding rate(1)  – upstream  – downstream | Coding support | Peak channel transmission rate per 5 MHz channel (except as noted) | Beam-forming support (yes/no) | Support for MIMO (yes/no) | Duplex method | Multiple access method | Frame duration | Mobility capabilities (nomadic/ mobile) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| IMT-2000 CDMA Multi-Carrier  (Annex 2) | 1.25 MHz and 3.75 MHz (cdma2000)  1.25-20 MHz (cdma2000 HRPD) 1.25‑20 MHz, 153.6 kHz granularity  (UMB) | Up:  BPSK, QPSK, 8-PSK  Down:  QPSK, 8-PSK, 16‑QAM, (cdma2000)  QPSK, 8-PSK, 16‑QAM, 64-QAM (cdma2000 HRPD)  QPSK, 8-PSK, 16‑QAM, 64-QAM  (UMB) | Convolu-tional/ turbo  (cdma2000 and cdma2000 HRPD) Convolu-tional/ turbo/ LDPC (optional)  (UMB) | Up: 1.8 Mbit/s per 1.25 MHz channel  Down  3.1 Mbit/s Per 1.25 MHz (cdma2000)  Up: 1.8 Mbit/s per 1.25 MHz channel  Down:  4.9 Mbit/s  Per 1.25 MHz channel  (cdma2000 HRPD)Up: 75 Mbit/s for 20 MHz  Down:  228 Mbit/s for 20 MHz (UMB) | No  (cdma2000 and cdma2000 HRPD)  Yes (UMB) | No  (cdma2000 and cdma2000 HRPD)  Yes (UMB) | FDD  (cdma2000 and cdma2000 HRPD)  FDD/TDD (UMB) | CDMA  (cdma2000 and cdma2000 HRPD)  CDMA and  OFDMA  (UMB) | Down: 1.25, 1.67 2.5, 5, 10, 20, 40, 80 ms  Up: 6.66, 10, 20, 26.67, 40, 80 ms (cdma2000)  Down: 1.67, 3.33, 6,66,13.33,26.67  Up: 1.67, 6.66, 13.33, 20, 26.67 (cdma2000 HRPD)  Down: 0.911 ms  Up: 0.911 ms  (UMB) | Mobile |

TABLE 7 (*continued*)

| Standard | Nominal RF channel bandwidth | Modulation/ coding rate(1)  – upstream  – downstream | Coding support | Peak channel transmission rate per 5 MHz channel (except as noted) | Beam-forming support (yes/no) | Support for MIMO (yes/no) | Duplex method | Multiple access method | Frame duration | Mobility capabilities (nomadic/ mobile) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| IMT-2000 CDMA TDD (Annex 2) | 1.28 Mchip/sTDD option: Less than  1.6 MHz  3.84 Mchip/sTDD option: Less than  5 MHz  7.68 Mchip/s TDD option:  Less than 10 MHz  (E-UTRAN) 1.4 MHz, 3 MHz, 5 MHz,  10 MHz, 15 MHz and  20 MHz | 1.28 Mchip/s TDD option:  Up: 8‑PSK, QPSK,  16-QAM, Down: 8-PSK,  16-QAM, QPSK  3.84 Mchip/sTDD option:  Up: 16-QAM, QPSK  Down: 16-QAM, QPSK  7.68 Mchip/s TDD option:  Up: 16-QAM, QPSK  Down: 16-QAM, QPSK  (E-UTRAN) QPSK, 16-QAM,  64-QAM | Convolu-tional turbo | 1.28 Mchip/s TDD option:  Up: 2.2 Mbit/s /  1.6 MHz(2)  Down:  2.8 Mbit/s /  1.6 MHz(2)  3.84 Mchip/s TDD option:  Up: 9.2 Mbit/s Down: 10.2 Mbit/s  7.68 Mchip/s TDD option:  Up: 17.7 Mbit/s / 10 MHz Down:  20.4 Mbit/s /  10 MHz  (E-UTRAN)  Up: 75.3 Mbit/s / 20 MHz(3)  Down: 302.7 Mbit/s / 20 MHz(3) | Yes | No  (E-UTRAN)  Yes | TDD | TDMA/ CDMA  (E-UTRAN) OFDM in DL. SC-FDMA in UL | 1.28 Mchip/s TDD option:  10 ms  Sub-frame length: 5 ms  3.84 Mchip/s TDD option:  10 ms  7.68 Mchip/s TDD option:  10 ms  (E-UTRAN)  10 ms  Sub-frame length: 1 ms | Mobile |

TABLE 7 (*continued*)

| Standard | Nominal RF channel bandwidth | Modulation/ coding rate(1)  – upstream  – downstream | Coding support | Peak channel transmission rate per 5 MHz channel (except as noted) | Beam-forming support (yes/no) | Support for MIMO (yes/no) | Duplex method | Multiple access method | Frame duration | Mobility capabilities (nomadic/ mobile) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| IMT-2000 TDMA Single-Carrier (Annex 2) | 2 × 200 kHz 2 × Dual 200 kHz 2 × 1.6 MHz | Up: – GMSK – 8-PSK – QPSK, – 16-QAM,  – 32-QAM – B-OQAM – Q-OQAM 0.329 –   1/1  Down: – GMSK – 8-PSK – QPSK, – 16-QAM,  – 32-QAM  – B-OQAM – Q-OQAM 0.329 –   1/1 | Punctured convolu- tional code  Turbo code | Up: 16.25 Mbit/s 20.312 Mbit/s 40.625 Mbit/s  Down: 16.25 Mbit/s 20.312 Mbit/s 40.625 Mbit/s | Not explicit but not preclu-ded | Not explicit but not precluded | FDD | TDMA | 4.6 ms 4.615 ms | Mobile |
| IMT-2000 FDMA/TDMA (Annex 2) | 1.728 MHz | Up and down: GFSK π/2-DBPSK π/4-DQPSK π/8-D8-PSK 16-QAM, 64-QAM | Depends on service: CRC, BCH, Reed-Solomon, Turbo | 20 Mbit/s | Partial | Partial | TDD | TDMA | 10 ms | Mobile |
| IMT-2000 OFDMA TDD WMAN (Annex 2) | 5 MHz,  7 MHz,  8.75 MHz, 10 MHz | Up: – QPSK-1/2, 3/4 – 16-QAM-1/2, 3/4 – 64-QAM-1/2, 2/3,   3/4, 5/6  Down: – QPSK-1/2, 3/4 – 16-QAM-1/2, 3/4  – 64-QAM-1/2, 2/3,   3/4, 5/6 | CC/CTC Other options: BTC/ LDPC | Up to 17.5 Mbit/s with SISO  Up to 35 Mbit/s with (2 × 2) MIMO  Up to 70 Mbit/s with (4 × 4) MIMO | Yes | Yes | TDD  FDD | OFDMA | 5 ms | Mobile |

TABLE 7 (*end*)

| Standard | Nominal RF channel bandwidth | Modulation/ coding rate(1)  – upstream  – downstream | Coding support | Peak channel transmission rate per 5 MHz channel (except as noted) | Beam-forming support (yes/no) | Support for MIMO (yes/no) | Duplex method | Multiple access method | Frame duration | Mobility capabilities (nomadic/ mobile) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| IEEE 802.20  (Annex 6) | Flexible from 625 kHz, up to 20 MHz | Wideband mode:  Up: QPSK, 8-PSK, 16-QAM, 64-QAM  Down: QPSK, 8‑PSK, 16-QAM, 64-QAM  625 kHz mode:  Pi/2 BPSK, QPSK, 8‑PSK, 12‑QAM, 16‑QAM, 24‑QAM, 32‑QAM, 64‑QAM | Convolu-tional, Turbo, LDPC Code, parity check code, extended Hamming code | Peak rates of 288 Mbit/s DL and 75 Mbit/s UL in 20 MHz | Yes: SDMA, and beam-forming support on forward and reverse links | Yes: Single codeword and multi codeword MIMO support | TDD FDD  HFDD | OFDMA TDMA/ FDMA/ SDMA | Wideband mode: 0.911 ms    625 kHz mode: 5 ms | Mobile |
| YD/T 1956-2009  Air interface of SCDMA broadband wireless access system standard (Annex 7) | Multiple of 1 MHz up to 5 MHz | QPSK, 8-PSK, 16‑QAM, 64‑QAM | Reed-Solomon | 15 Mbit/s in 5 MHz | Yes | Yes | TDD | CS-OFDMA | 10 ms | Mobile |
| (1) Including all applicable modes, or at least the maximum and the minimum.  (2) In 5 MHz three 1.28 Mchip/s TDD carriers can be deployed.  (3) E-UTRAN supports scalable bandwidth operation up to 20 MHz in both the uplink and downlink. | | | | | | | | | | |

1. \* This Recommendation should be brought to the attention of ITU-T Study Groups 2 and 15. [↑](#footnote-ref-1)
2. “Wireless access” and “BWA” are defined in Recommendation ITU‑R F.1399, which also provides definitions of the terms “fixed”, “mobile” and “nomadic” wireless access. [↑](#footnote-ref-2)
3. *Broadband wireless access* is defined as wireless access in which the connection(s) capabilities are higher than the *primary rate*, which is defined as the transmission bit rate of 1.544 Mbit/s (T1) or 2.048 Mbit/s (E1). *Wireless access* is defined as end-user radio connection(s) to core networks. [↑](#footnote-ref-3)
4. Multimedia Mobile Access Communication Systems Promotion Council (now called “Multimedia Mobile Access Communication Systems Forum” or “MMAC Forum”). [↑](#footnote-ref-4)
5. High Speed Wireless Access Committee. [↑](#footnote-ref-5)
6. Association of Radio Industries and Businesses. [↑](#footnote-ref-6)
7. See § 5.1 of Recommendation ITU‑R M.1457. [↑](#footnote-ref-7)
8. See § 5.2 of Recommendation ITU‑R M.1457. [↑](#footnote-ref-8)
9. See § 5.3 of Recommendation ITU‑R M.1457. [↑](#footnote-ref-9)
10. See § 5.4 of Recommendation ITU‑R M.1457. [↑](#footnote-ref-10)
11. See § 5.5 of Recommendation ITU‑R M.1457. [↑](#footnote-ref-11)
12. See § 5.6 of Recommendation ITU‑R M.1457. [↑](#footnote-ref-12)
13. <http://www.wimaxforum.org/technology/documents/>. [↑](#footnote-ref-13)
14. [http://wimaxforum.org/imt‑2000/7/MRSv031.zip](http://wimaxforum.org/imt2000/7/MRSv031.zip). [↑](#footnote-ref-14)
15. Users who are located towards the middle of a sector, far from the adjacent sectors. [↑](#footnote-ref-15)
16. Users who are located towards the edges of a sector, close to adjacent sectors. [↑](#footnote-ref-16)