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| Annex 7 to Working Party 5A Chair’s Report |
| PRELIMINARY DRAFT REVISION OF RECOMMENDATION ITU-R M.1801-2 |
| Radio interface standards for broadband wireless access systems, including mobile and nomadic applications, in the mobile service |

(Questions ITU-R 212-4/5 and ITU-R 238-2/5)

(2007-2010-2013)

Summary of the revision

In this revision the description of the IMT terrestrial radio interfaces has been replaced by references to the relevant ITU-R Recommendations to avoid duplication and other consequential amendments made throughout the draft revision, including updates of other annexes. The title of the Recommendation has been amended in accordance with the Radio Regulations (2020 Edition), which now identify certain frequency bands up to 71 GHz for the implementation of IMT. The organization of the draft revision has beenupdated in accordance with the mandatory [Format of ITU-R Recommendations](https://www.itu.int/oth/R0A0E000097).

Scope

This Recommendation provides specific radio interface standards for broadband wireless access[[1]](#footnote-2) (BWA) systems in the mobile service allocations. 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[[2]](#footnote-3).

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

Keywords

Broadband wireless access standards.

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](https://www.itu.int/rec/R-REC-M.1399) Vocabulary of terms for wireless access.

[Recommendation ITU-R M.1450](https://www.itu.int/rec/R-REC-M.1450/en) Characteristics of broadband radio local area networks.

[Recommendation ITU-R M.1457](https://www.itu.int/rec/R-REC-M.1457) Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)

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

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

[Recommendation ITU-R M.2012](https://www.itu.int/rec/R-REC-M.2012) Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications Advanced (IMT-Advanced).

[Recommendation ITU-R M.2150](https://www.itu.int/rec/R-REC-M.2150) Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2020 (IMT-2020).

Acronyms and abbreviations

AA Adaptive antenna

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

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

CQI Channel quality indicator

CS-OFDMA Code spread OFDMA

CTC Convolutional turbo code

DECT Digital enhanced cordless telecommunications

DFT Discrete Fourier transform

DLC Data link control

DS-CDMA Direct-sequence code division multiple access

DSSS Direct sequence spread spectrum

E-DCH Enhanced dedicated channel

ETSI European Telecommunication Standards Institute

FDD Frequency division duplex

FEC Forward-error correction

FER Frame error ratio

FHSS Frequency hopping spread spectrum

FSTD Frequency switched transmit diversity

FT Fixed termination

GoS Grade of service

GPRS General packet radio service

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

ICIC Inter-cell interference coordination

IEEE Institute of Electrical and Electronics Engineers

IETF Internet Engineering Task force

IP Internet protocol

LAN Local area network

LDPC Low density parity check

LLC Logic link control

LTE Long term evolution

MAC Medium access control

MAN Metropolitan area network

MIMO Multiple input multiple output

MS Mobile station

NLoS Non-line-of-sight

OFDM Orthogonal frequency-division multiplexing

OFDMA Orthogonal frequency-division multiple access

PAPR Peak-to-average power ratio

PDCP Packet data convergence protocol

PHS Personal handyphone system

PHY Physical layer

PMI Preferred matrix index

PT Portable termination

QAM Quadrature amplitude modulation

QoS Quality-of-service

RF Radio frequency

RLAN Radio local area network

RLC Radio link control

SC Single carrier

SC-FDMA Single carrier-frequency division multiple access

SDMA Spatial division multiple access

SISO Single input single output

SM Spatial multiplexing

SNP Signalling network protocol

TDD Time-division duplex

TDMA Time-division multiple access

TTA Telecommunications Technology Association

WiBro Wireless broadband

WirelessMAN Wireless metropolitan area network

WTSC Wireless Technologies and Systems Committee

WWINA Wireless wideband Internet access

XGP eXtended Global Platform

The ITU Radiocommunication Assembly,

considering

*a)* that the successful expansion of Internet connectivity over the past decades needs to continue and be accelerated[[3]](#footnote-4);

*b)* that standards facilitate interoperability and economies of scale, leading to the fulfilment of the United Nations’ 2030 Agenda for Sustainable Development Goals (SDGs)[[4]](#footnote-5),

recommends

that the radio interface standards in Annexes 1 to 9 should be used for BWA systems in the mobile service.

NOTE 1 – Annex 10 provides a summary of the characteristics of the standards found in Annexes 1 to 9

List of annexes

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[Annex 10](#a10) Key characteristics of standards

Annex 1

Broadband radio local area networks

Radio local area networks (RLANs) offer an extension to wired LANs utilizing radio as the connective media. They have applications in enterprise environments where there may be considerable savings in both cost and time to install a network; in residential environments where they provide low cost and flexible connectivity to multiple computers and other devices 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, and can be grouped as follows:

– IEEE 802. 11 Wireless LAN

– ETSI BRAN HIPERLAN

– ARIB HiSWANa.

# 1 IEEE 802.11 Wireless LAN

TheIEEE 802.11™ Wireless LAN Working Group has developed a standard for RLANs, IEEE Std 802.11‑2020, 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 employs the frequency hopping spread spectrum (FHSS) technique, direct sequence spread spectrum (DSSS) technique, orthogonal frequency division multiplexing (OFDM) technique, Beamforming and multiple input and multiple output (MIMO) technique.

The URL for the IEEE 802.11 Working Group is <http://www.ieee802.org/11>. IEEE Std 802.11‑2020 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[[5]](#footnote-6) HSWA[[6]](#footnote-7)

MMAC HSWA has developed and ARIB[[7]](#footnote-8) 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 IMT-2000 terrestrial radio interfaces are defined in [Recommendation ITU‑R M.1457](https://www.itu.int/rec/R-REC-M.1457/en) “Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)”.

Annex 3

IMT-Advanced terrestrial radio interfaces

The IMT-Advanced terrestrial radio interfaces are defined in [Recommendation ITU‑R M.2012](https://www.itu.int/rec/R-REC-M.2012/en) “Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications Advanced (IMT-Advanced)”.

Annex 4

IMT-2020 terrestrial radio interfaces

The IMT-2020 terrestrial radio interfaces are defined in [Recommendation ITU‑R M.2150](https://www.itu.int/rec/R-REC-M.2150/en) “Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2020 (IMT-2020)”.

Annex 5

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 only 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.

FIGURE 1

BWA standards harmonized for interoperability for frequencies below 6 GHz



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[[8]](#footnote-18). 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 ms. 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[[9]](#footnote-19) with better link connection to maximize spectral efficiency while fractional frequency reuse is achieved for edge users[[10]](#footnote-20) 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 V1.5.1: Broadband Radio Access Networks (BRAN); HiperMAN; physical (PHY) layer.

– ETSI TS 102 178 V1.5.1: 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 6

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) of the Alliance of Telecommunications Industry Solutions (ATIS), an American National Standards Institute (ANSI)‑accredited standards development organization, has developed an American National Standard that adheres to its adopted requirements for wireless wideband internet access (WWINA) systems. The WWINA air interface standard enables wireless portability and nomadic roaming subscriber services that complement the DSL and cable modem markets. This system is 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.

This air interface provides 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 interface optimizes the following performance attributes:

– system data speeds;

– system coverage/range;

– network capacity;

– minimum network complexity;

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

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

## 2.1 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 reuse 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 bit/s/Hz/cell.

## 2.2 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 1 describes the air interface functionality embodied in each layer. Each layer’s feature is briefly described below; more detailed overviews of key aspects are described in subsequent sections of this annex.

TABLE 1

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 2 summarizes the key elements of the HC-SDMA air interface.

TABLE 2

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/s |
| 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 |

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

Annex 7

“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.

XGP is the mobile BWA system which utilizes OFDMA, SC-FDMA/TDMA-TDD, and some more advanced features described below:

– Realization of always-connected environment at IP level

 The always-connected session at IP level that enables users to start up high‑speed transmission immediately is essential, taking into account the convenience of always‑connected environment provided in cable modem circumstance, etc.

– High transmission data rate

 It is also important to keep throughput to 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

 Highly efficient spectral utilization is necessary in order to avoid interruption of service applications by the shortage of frequency, due to the serious traffic congestion concentrated at a business district or downtown area.

In addition, it has the ability of highly efficient spectral utilization by adopting the latest technologies such as adaptive array antenna technology, space division multiple access technology and autonomous decentralized control technology. These three technologies also contribute to make cell designing plans unnecessary, and as a result, the cell radius down to less than 100 m is realized.

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, an offset of the base station from the intended building/position to an adjoining substitute building/position due to unsuccessful negotiations with the building owner, only causes inter-cell interferences which still lies within the range of a marginal error.

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

This issue is already solved with XGP 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.

XGP 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 XGP demonstrates advantage in the construction of micro-cell networks. It is also possible to form a network without being bothered with the interference problems that occur 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.

From the version 2 of XGP specifications, in addition to XGP original mode, Global Mode that referred to 3GPP specification (LTE TDD) has been added in order to attain the scale of merits provided by LTE. Therefore, XGP became substantially compatible with LTE TDD and can be regarded as a part of LTE community sharing a common eco-system.

The version 2 of XGP specifications also accommodates some specific requirements complying with regional or local regulations.

Taking a similar approach as for XGP specification, XGP Forum also introduced a new specification named sXGP (shared XGP) using 1.9 GHz private dedicated band which can also be used for BWA.

# 2 Detailed specification of the radio interface

The XGP radio interface has two dimensions for multiple access methods such as OFDMA, SC‑FDMA (controlled along frequency axis), and TDMA (controlled along time axis). OFDMA is an FDMA technique that divides a communications channel into a small number of equally spaced frequency bands, each of which carries a portion of the radio signal in parallel. These subcarriers are then transmitted simultaneously at different frequencies to the receiver. OFDMA have developed into a popular scheme for wideband digital communication.

Duplex method is TDD. TDD is not needed for paired spectrum channels and allows to devote resources to uplink and downlink asymmetrically, freeing capacity for up/downlink data-intensive applications.

The operation channel bandwidths supported by XGP are 1.25 MHz, 2.5 MHz, 5 MHz, 10 MHz, 20 MHz, 22.5 MHz, 25 MHz, 30 MHz and its modulation scheme supports BPSK, QPSK, 16-QAM, 64-QAM and 256-QAM. The subcarrier frequency spacing is 15 kHz and 37.5 kHz. The time-frame has 4, 8, 10, 16, 20 slots of 2.5 ms, 5 ms, 10 ms. Each slot can be used separately, or continuously by a single user, and moreover continuously in an asymmetric frame structure.

The frame structure image of XGP is shown in Fig. 2.

FIGURE 2

The frame structure image of XGP



XGP achieves efficient spectral utilization by some functions, such as adaptive array antenna, SDMA and MIMO.

Adaptive array antenna is a technique to make adaptive beam forming from a BS/MS to an MS/BS by combining signals of respective antennas. The adaptive array antenna uses multiple antennas and combines their signals (1) to adaptively form a beam to desired directions in order to avoid harmful interference from interferers and (2) to send the most suitable radio waves/signals to a specific terminal by using the formed beam. In XGP system that employs OFDMA SC‑FDMA/TDMA‑TDD schemes, this antenna technology is well-suited and can be effectively applied to both transmitter and receiver. It has a potential to increase XGP’s spectrum efficiency and to make it possible to cover a wider area with lower cost.

XGP Global Mode, which refers to TDD part of 3GPP technical specifications, specifies the air interface including the physical layer, MAC, RLC and PDCP layers and RRC layer related specifications. Due to the reference of the latest 3GPP release, XGP can now be compatible with 5G, which has been developed by 3GPP.

The key specifications of the radio interface are shown in Table 3.

TABLE 3

The key specifications of XGP

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| --- | --- | --- | --- |
| Characteristics | XGP | XGP compatible with NR | sXGP |
| Multiple access method | OFDMA, SC-FDMA/TDMA | OFDMA, SC-FDMA/TDMA | SC-FDMA/TDMA |
| Duplex method | TDD | TDD | TDD |
| Frequency band | 2.5 GHz (mainly) | 2.5 GHz (mainly) | 1.9 GHz (mainly) |
| Operation channel bandwidth | 1.4 MHz, 2.5 MHz, 5 MHz, 10 MHz, 20 MHz | 10 MHz, 20 MHz, 30 MHz, 40 MHz, 50 MHz | 1.4 MHz, 5 MHz |
| Frame duration | 2.5 ms, 5 ms, 10 ms | 10 ms, Sub-frame length 1 ms | 10 ms, Sub-frame length 1 ms |
| Modulation scheme | BPSK, QPSK, 16-QAM, 32-QAM, 64-QAM, 256‑QAM | BPSK, π, 2shift-BPSK, QPSK, 16-QAM, 64-QAM, 256‑QAM | BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM |
| Support for Beam-forming and MIMO | Yes | Yes | Yes |
| Peak channel transmission rate\*depending on the combination of conditions such as UL/DL configuration, modulation scheme and the number of MIMO | Uplink: up to 300 Mbit/s in 20 MHzDownlink: up to 600 Mbit/s in 20 MHz\*referring to 3GPP Standard | Uplink: depending on slot configuration and no. of aggregated component carriers (up to 16), 256QAM, 8-layers: from 17.9 to 64.6 Gbit/s Downlink: similarly, from 37 to 140.2 Gbit/s.\*referring to 3GPP Standard | Uplink: up to 75 Mbit/s in 5 MHzDownlink: up to 150 Mbit/s in 5 MHz\*referring to 3GPP Standard |

Standards

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

 “XGP Forum standards”

 <https://www.xgpforum.com/new_XGP/en/002/technical_specification.html>.

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

The ARIB standards of “eXtended Global Platform” are also available at the ARIB website.

 “ARIB STD-T95: Broadband Mobile Wireless Access System (XGP)”

 “ARIB STD-T118: OFDMA/TDMA TDD for digital cordless telephone (sXGP)”

 <https://www.arib.or.jp/english/std_tr/telecommunications/st_ej.html>.

The standards include Japanese regulation specifications as well as the system original specifications.

Annex 8

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 9

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 a frequency reuse 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

## 2.2 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.

## 2.1 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 the 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.

FIGURE 3

Frame structure for symmetric uplink and downlink



In Fig. 3, the 5 MHz band is divided into five 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 eight distributed sub-carriers. The CS-OFDMA TDD frame has a length of 10 ms, consisting of one preamble slot, one ranging slot, eight traffic slots and two 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 4.

TABLE 4

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 eight OFDMA symbols. The code spreading is performed on eight selected sub-carriers in each resource block with the eight 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 eight signals are then mapped onto the eight sub‑carriers. L is a loading factor of code spreading which is an integer variable equal to or less than 8. The scheme is illustrated in Fig. 4.

FIGURE 4

Code spreading with pre-coding matrix and its mapping onto sub-carriers



### 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 the 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. Eight QoS levels and eight 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 characteristics. 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/standardDetail?title=1800MHz%20SCDMA%E5%AE%BD%E5%B8%A6%E6%97%A0%E7%BA%BF%E6%8E%A5%E5%85%A5%E7%B3%BB%E7%BB%9F%20%E7%A9%BA%E4%B8%AD%E6%8E%A5%E5%8F%A3%E6%8A%80%E6%9C%AF%E8%A6%81%E6%B1%82&standardNum=YD%2FT%201956-2009%282017%29>.

Annex 10

Key characteristics of standards

Table 5 provides a summary of key technical characteristics of each standard.

TABLE 5

Key technical characteristics

| 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 5) | Flexible from 1.25 MHz up to 28 MHz.Typical bandwidths are:3.5, 5, 7, 8.75, 10 and20 MHz | Up:– QPSK-1/2, 3/4– 16-QAM-1/2, 3/4 – 64-QAM-1/2, 2/3, 3/4, 5/6Down:– QPSK-1/2, 3/4– 16-QAM-1/2, 3/4 – 64-QAM-1/2, 2/3, 3/4, 5/6 | CC/CTCOther options:BTC/LDPC | Up to 17.5 Mbit/s with SISOUp to 35 Mbit/s with (2 × 2) MIMOUp to 70 Mbit/s with (4 × 4) MIMO | Yes | Yes | TDD/FDD/HFDD | OFDMATDMA | 5 msOther options: 2, 2.5, 4, 8, 10, 12.5 and 20 ms | Mobile |
| ATIS-0700004.2005 high capacity-spatial division multiple access(HC-SDMA) (Annex 6) | 0.625 MHz | Up:– BPSK, QPSK,  8-PSK, 12-QAM,  16-QAM 3/4Down:– 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 |

TABLE 5 (*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) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eXtended Global Platform: XGP(Annex 7) | 1.25 MHz2.5 MHz5 MHz10 MHz20 MHz | Up and down:BPSKQPSK 16-QAM 64-QAM 256-QAM | Convolu-tional codeTurbo code (option) | Up:15 Mbit/sDown:55 Mbit/s(in case of 20 MHz, SISO, UL:DL=1:3) | Yes (option) | Yes (option) | TDD | OFDMA SC-FDMATDMA | 2.5 ms, 5 ms, 10 ms | Mobile |
| IEEE 802.11-2020 Subclause 16 (Formerly 802.11b) (Annex 1) | 22 MHz | Up and down:DQPSK CCKBPSK PBCC – 1/2QPSK PBCC – 1/2 | Uncoded/CC | 11 Mbit/s in 22 MHz | No | No | TDD | CSMA/CA | Variable frame duration | Nomadic |
| IEEE 802.11-2020Subclause 17 (Formerly 802.11a, 802.11j and 802.11y) (Annex 1) | 5 MHz10 MHz20 MHz | Up and down:64-QAM OFDM 2/3, 3/416-QAM OFDM –1/2, 3/4QPSK OFDM – 1/2, 3/4BPSK OFDM – 1/2, 3/4 | CC | 54 Mbit/s in 20 MHz | No | No | TDD | CSMA/CA | Variable frame duration | Nomadic |

TABLE 5 (*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 802.11-2020 Subclause 17 (Formerly 802.11g)(Annex 1) | 20 MHz | Up and down:64-QAM OFDM 2/3, 3/416-QAM OFDM – 1/2, 3/4QPSK OFDM – 1/2, 3/4BPSK OFDM – 1/2, 3/48-PSK PBCC – 2/364-QAM DSSS-OFDM – 2/3, 3/416-QAM DSSS-OFDM – 1/2, 3/4QPSK DSSS-OFDM – 1/2, 3/4BPSK DSSS-OFDM – 1/2, 3/4 | CC |  54 Mbit/s in 20 MHz | No | No | TDD | CSMA/CA | Variable frame duration | Nomadic |
| IEEE 802.11-2020 Subclause 18  (Formerly 802.11n) (Annex 1) | 20 MHz40 MHz | Up and down :64-QAM OFDM – 2/3, 3/4, 5/616-QAM OFDM –1/2, 3/4QPSK OFDM – 1/2, 3/4BPSK OFDM – 1/2 | CC and LDPC | 600 Mbit/s in 40 MHz | Yes | Yes | TDD | CSMA/CA | Variable frame duration | Nomadic |
| IEEE Std 802.11-2020(Clause 21, commonly knownas 802.11ac) | 20 MHz40 MHz80 MHz160 MHz80+80 MHz | Up and down:BPSK OFDM-1/2QPSK OFDM-1/2QPSK OFDM-3/416-QAM OFDM-1/216-QAM OFDM-3/464-QAM OFDM-2/364-QAM OFDM-3/464-QAM OFDM-5/6256-QAM OFDM-3/4256-QAM OFDM-5/6 | CC and LDPC | 6 933.3 Mbit/s in 160 MHz | Yes | Yes | TDD | CSMA/CA | Variable frame duration | Nomadic |
| IEEE Std 802.11-2020(Clause 23, commonly knownas 802.11ah) | 1 MHz2 MHz4 MHz8 MHz16 MHz | Up and down:BPSK OFDM-1/2 with 2x repetitionBPSK OFDM-1/2QPSK OFDM-1/2QPSK OFDM-3/416-QAM OFDM-1/216-QAM OFDM-3/464-QAM OFDM-2/364-QAM OFDM-3/464-QAM OFDM-5/6256-QAM OFDM-3/4256-QAM OFDM-5/6 | CC and LDPC | 346.7 Mbit/s in 16 MHz | Yes | Yes | TDD | CSMA/CA | Variable frame duration | Nomadic |
| IEEE Std 802.11ax-2021 | 20 MHz40 MHz80 MHz160 MHz80+80 MHz | Up and down:BPSK OFDM-1/2BPSK OFDM-3/4QPSK OFDM-1/2QPSK OFDM-3/416-QAM OFDM-1/216-QAM OFDM-3/464-QAM OFDM-1/264-QAM OFDM-2/364-QAM OFDM-3/464-QAM OFDM-5/6256-QAM OFDM-3/4256-QAM OFDM-5/61024-QAM OFDM-3/41024-QAM OFDM-5/6 | CC and LDPC | 9 607.8 Mbit/s in 160 MHz | Yes | Yes | TDD | CSMA/CA,Trigger-based access and OFDMA | Variable frame duration | Nomadic |
| ETSI BRAN HiperLAN 2(Annex 1) | 20 MHz | 64-QAM-OFDM16-QAM-OFDMQPSK-OFDMBPSK-OFDMboth 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 |

TABLE 5 (*continued*)

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 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) |
| 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 radio interface standards(Annex 2) | Refer to [Recommendation ITU‑R M.1457](https://www.itu.int/rec/R-REC-M.1457/en) “Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)” |
| IMT-Advanced radio interface standards(Annex 3) | Refer to [Recommendation ITU‑R M.2012](https://www.itu.int/rec/R-REC-M.2012/en) “Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications Advanced (IMT-Advanced)” |
| IMT-2020radio interface standards(Annex 4) | Refer to [Recommendation ITU‑R M.2150](https://www.itu.int/rec/R-REC-M.2150/en) “Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2020 (IMT-2020)” |
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| IEEE 802.20(Annex 8) | Flexible from 625 kHz, up to 20 MHz | Wideband mode:Up: QPSK, 8-PSK, 16-QAM, 64-QAMDown: QPSK, 8‑PSK, 16-QAM, 64‑QAM625 kHz mode:π/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 | TDDFDDHFDD | OFDMATDMA/ FDMA/ SDMA | Wideband mode: 0.911 ms  625 kHz mode: 5 ms | Mobile |

TABLE 5 (*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)** |
| YD/T 1956-2009Air interface of SCDMA broadband wireless access system standard(Annex 9) | 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.  |

1. “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)
2. *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)
3. State of Broadband Report 2021: Geneva: International Telecommunication Union and United Nations Educational, Scientific and Cultural Organization, 2021. License: CC BY-NC-SA 3.0 IGO. *Available:* https://www.itu.int/dms\_pub/itu-s/opb/pol/S-POL-BROADBAND.23-2021-PDF-E.pdf [↑](#footnote-ref-4)
4. <https://sdgs.un.org/2030agenda>. [↑](#footnote-ref-5)
5. Multimedia Mobile Access Communication Systems Promotion Council (now called “Multimedia Mobile Access Communication Systems Forum” or “MMAC Forum”). [↑](#footnote-ref-6)
6. High Speed Wireless Access Committee. [↑](#footnote-ref-7)
7. Association of Radio Industries and Businesses. [↑](#footnote-ref-8)
8. <http://www.wimaxforum.org/resources/technical-specifications>. [↑](#footnote-ref-18)
9. Users who are located towards the middle of a sector, far from the adjacent sectors. [↑](#footnote-ref-19)
10. Users who are located towards the edges of a sector, close to adjacent sectors. [↑](#footnote-ref-20)