Recommendation ITU-R M.1801-3
(02/2026)

M Series: Mobile, radiodetermination, amateur and related satellite services

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

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SM	Spectrum management
SNG	Satellite news gathering
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Note: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

RECOMMENDATION ITU-R M.1801-3*

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

(Questions ITU-R 212-4/5 and ITU-R 238-3/5)

(2007-2010-2013-2026)

Scope

This Recommendation provides specific radio interface standards for broadband wireless access (BWA) systems in the land 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[1].

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

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

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* This Recommendation should be brought to the attention of ITU-T Study Groups 2 and 15.

[1] *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.

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
SLB	SparkLink Basic
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

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 – Vocabulary of terms for wireless access.

Recommendation ITU-R F.1763 – Radio interface standards for broadband wireless access systems in the fixed service operating below 66 GHz.

Recommendation ITU-R M.1450 – Characteristics of broadband radio local area networks.

Recommendation ITU-R M.1457 – Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)

Recommendation ITU-R M.1678 – Adaptive antennas for mobile systems.

Recommendation ITU-R M.2012 – Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications Advanced (IMT-Advanced).

Recommendation ITU-R M.2150 – Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2020 (IMT-2020).

The ITU Radiocommunication Assembly,

considering

a)   that the successful expansion of Internet connectivity over the past decades needs to continue and be accelerated[2];

b)   that standards facilitate interoperability and economies of scale, leading to the fulfilment of the United Nations' 2030 Agenda for Sustainable Development Goals (SDGs)[3],

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

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[2] 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

[3] https://sdgs.un.org/2030agenda

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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

–   YD/T 4007 SLB.

1   IEEE 802.11 Wireless LAN

The IEEE 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.

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: https://www.etsi.org/standards-search, 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] HSWA[5]

MMAC HSWA has developed and ARIB[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.

4   YD/T 4007 SLB

YD/T 4007 known as SparkLink Basic (SLB) is developed for ultra-low latency, ultra-high speed, ultra-reliable and ultra-precisely synchronized wireless transmission. It can provide short-range wireless connectivity for smart vehicles, smart homes, smart terminals and smart manufacturing. The data rate is from 4.3 to 1249.0 Mbit/s for 20 MHz channel spacing. The radio interface defined in YD/T 4007 uses OFDMA as access method.

Annex 2

IMT-2000 terrestrial radio interfaces

The IMT-2000 terrestrial radio interfaces are defined in Recommendation ITU-R M.1457 – Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2000 (IMT-2000).

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[4]   Multimedia Mobile Access Communication Systems Promotion Council (now called "Multimedia Mobile Access Communication Systems Forum" or "MMAC Forum").

[5]   High Speed Wireless Access Committee.

[6]   Association of Radio Industries and Businesses.

Annex 3

IMT-Advanced terrestrial radio interfaces

The IMT-Advanced terrestrial radio interfaces are defined in Recommendation ITU-R M.2012 – 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 – 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 radio interface supports 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.

The broadband wireless access 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. 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
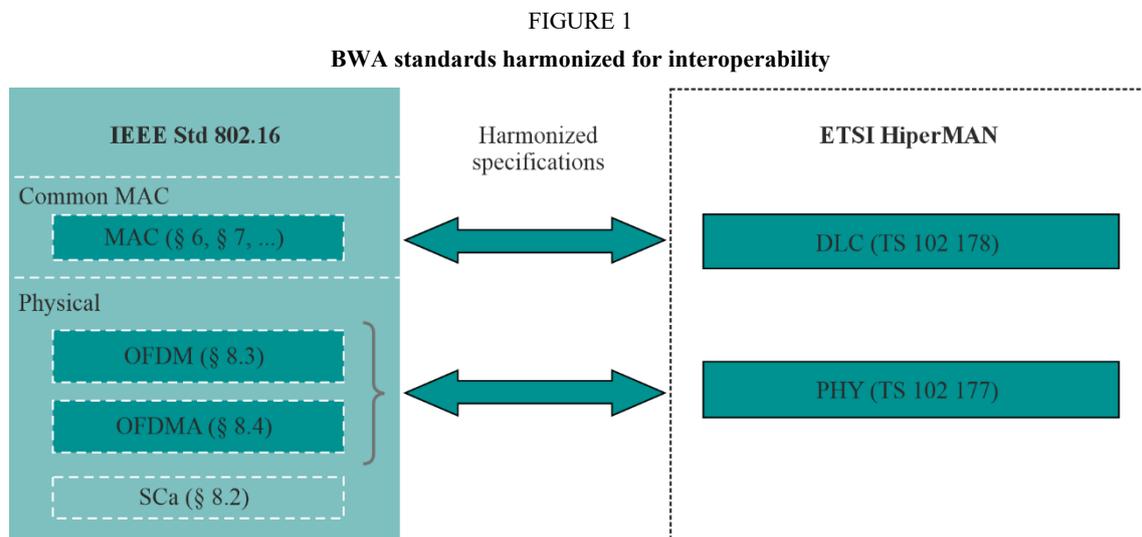
The WiMAX Forum™, IEEE 802.16 and ETSI HiperMAN define profiles for the recommended interoperability parameters. IEEE 802.16 profiles are included in the main standards document, while HiperMAN profiles are included in a separate document. TTA (Telecommunications Technology Association) defines the standard for WiBro service which is based on WiMAX Forum profile 1A[7]. 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 Recommendation ITU-R M.1457, § 5.6.1.1.1, as referenced in Annex 2.

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[7]   http://www.wimaxforum.org/TechSpec

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[8] with better link connection to maximize spectral efficiency while fractional frequency reuse is achieved for edge users[9] 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.

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[8]   Users who are located towards the middle of a sector, far from the adjacent sectors.

[9]   Users who are located towards the edges of a sector, close to adjacent sectors.

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: https://www.etsi.org/standards-search, 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
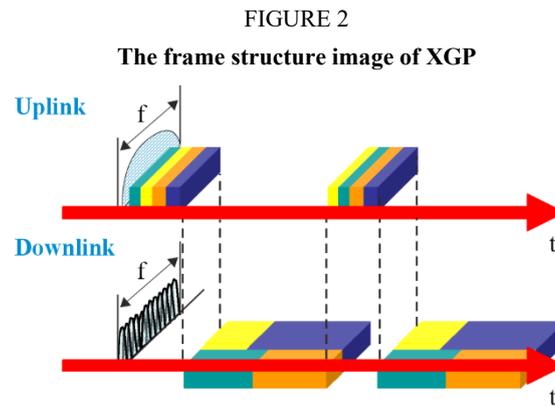
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XGP achieves efficient spectral utilization by some functions, such as adaptive array antenna, SDMA and MIMO.

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

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

TABLE 3 (*end*)

Characteristics	XGP	XGP compatible with NR	sXGP
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 MHz Downlink: 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), 256-QAM, 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 MHz Downlink: 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".

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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

## 2.1   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   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


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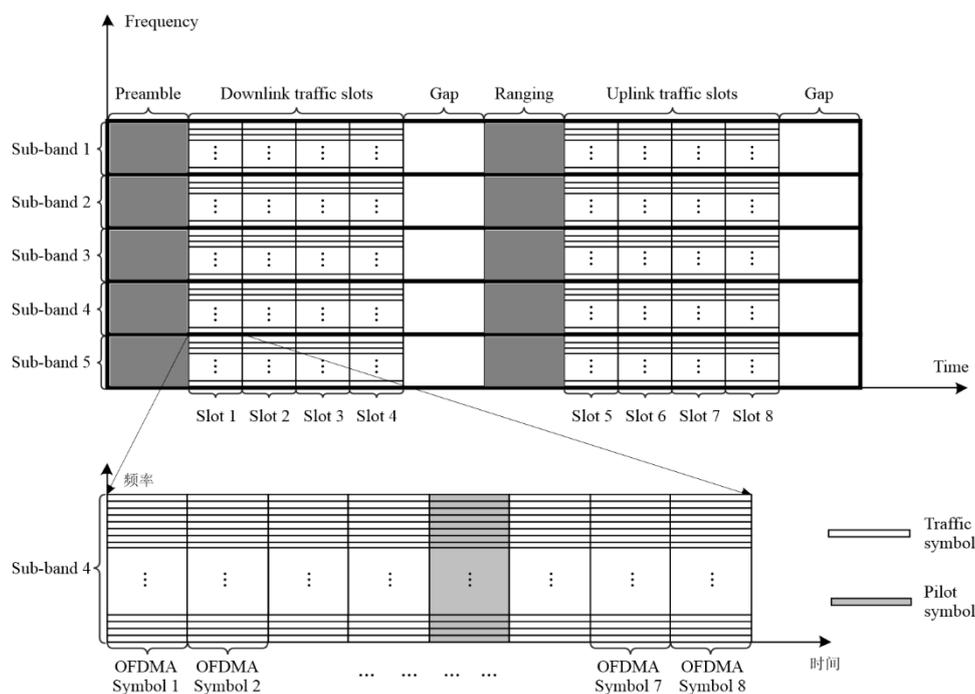
In Fig. 3, the 5 MHz band is divided into five sub-bands with each sub-band occupying 1 MHz. Each sub-band consists of 128 sub-carriers which are partitioned into 16 sub-channels; each sub-channel includes eight distributed sub-carriers. The CS-OFDMA TDD frame has a length of 10 ms, consisting of one 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 (kHz)	7.8125
CS-OFDMA symbol duration (µs)	137.5
Cyclic prefix duration (µs)	9.5
BS occupied bandwidth (MHz)	5
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

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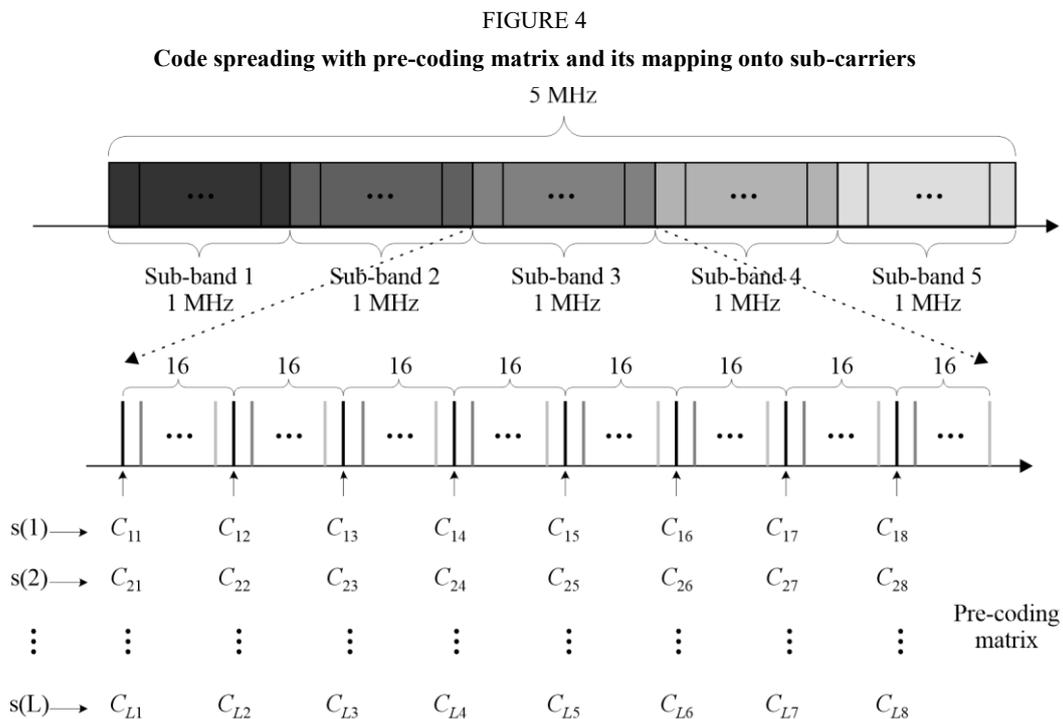
2.2.1   Multiple antenna technique

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)

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 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
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 3/4 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

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 MHz 2.5 MHz 5 MHz 10 MHz 20 MHz	Up and down: BPSK QPSK 16-QAM 64-QAM 256-QAM	Convolu-tional code Turbo code (option)	Up: 15 Mbit/s Down: 55 Mbit/s (in case of 20 MHz, SISO, UL:DL=1:3)	Yes (option)	Yes (option)	TDD	OFDMA SC-FDMA TDMA	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 CCK BPSK PBCC – 1/2 QPSK PBCC – 1/2	Uncoded/ CC	11 Mbit/s in 22 MHz	No	No	TDD	CSMA/ CA	Variable frame duration	Nomadic
IEEE 802.11-2020 Subclause 17 (Formerly 802.11a, 802.11j and 802.11y) (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	54 Mbit/s in 20 MHz	No	No	TDD	CSMA/CA	Variable frame duration	Nomadic

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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, 3/4 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	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 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	600 Mbit/s in 40 MHz	Yes	Yes	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 Std 802.11-2020 (Clause 21, commonly known as 802.11ac) (Annex 1)	20 MHz 40 MHz 80 MHz 160 MHz 80+80 MHz	Up and down: BPSK OFDM-1/2 QPSK OFDM-1/2 QPSK OFDM-3/4 16-QAM OFDM-1/2 16-QAM OFDM-3/4 64-QAM OFDM-2/3 64-QAM OFDM-3/4 64-QAM OFDM-5/6 256-QAM OFDM-3/4 256-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 known as 802.11ah) (Annex 1)	1 MHz 2 MHz 4 MHz 8 MHz 16 MHz	Up and down: BPSK OFDM-1/2 with 2x repetition BPSK OFDM-1/2 QPSK OFDM-1/2 QPSK OFDM-3/4 16-QAM OFDM-1/2 16-QAM OFDM-3/4 64-QAM OFDM-2/3 64-QAM OFDM-3/4 64-QAM OFDM-5/6 256-QAM OFDM-3/4 256-QAM OFDM-5/6	CC and LDPC	346.7 Mbit/s in 16 MHz	Yes	Yes	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 Std 802.11ax-2021 (Annex 1)	20 MHz 40 MHz 80 MHz 160 MHz 80+80 MHz	Up and down: BPSK OFDM-1/2 BPSK OFDM-3/4 QPSK OFDM-1/2 QPSK OFDM-3/4 16-QAM OFDM-1/2 16-QAM OFDM-3/4 64-QAM OFDM-1/2 64-QAM OFDM-2/3 64-QAM OFDM-3/4 64-QAM OFDM-5/6 256-QAM OFDM-3/4 256-QAM OFDM-5/6 1024-QAM OFDM-3/4 1024-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-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

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)
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	Convolutional	6-54 Mbit/s in 20 MHz	No	No	TDD	TDMA	2 ms	Nomadic
YD/T 4007 (Annex 1)	20 MHz 40 MHz 80 MHz 160 MHz	QPSK-OFDM 16-QAM-OFDM 64-QAM-OFDM 256-QAM-OFDM 1024-QAM-OFDM	Polar code	Peak rates of 1249.0 Mbit/s in 20 MHz	Yes	Yes	TDD	OFDMA	Variable frame duration	Mobile
IMT-2000 radio interface standards (Annex 2)	Refer to Recommendation ITU-R M.1457									
IMT-Advanced radio interface standards (Annex 3)	Refer to Recommendation ITU-R M.2012									
IMT-2020 radio interface standards (Annex 4)	Refer to Recommendation ITU-R M.2150									

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)
IEEE 802.20 (Annex 8)	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 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.

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