

RECOMMENDATION ITU-R M.1801

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

(Questions ITU-R 212/8 and ITU-R 238/8)

(2007)

1 Introduction

This Recommendation recommends specific standards for broadband wireless access¹ in the mobile service. These specific standards are composed of common specifications developed by standards development organizations (SDOs). Using this Recommendation, manufacturers and operators should be able to determine the most suitable standards for their needs.

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

2 Scope

This Recommendation identifies specific radio interface standards for BWA systems in the mobile service operating below 6 GHz. The standards included in this Recommendation are capable of supporting users at broadband data rates, taking into account the ITU-R definitions of “wireless access” and “broadband wireless access” found in Recommendation ITU-R F.1399².

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

3 Related ITU Recommendations

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

Recommendation ITU-R F.1399 – 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.1678 – Adaptive antennas for mobile systems.

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.

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.

4 Acronyms and abbreviations

AA	Adaptive antenna
ACK	Acknowledgement (channel)
AN	Access network
ARQ	Automatic repeat request
AT	Access terminal
ATM	Asynchronous transfer mode
BCCH	Broadcast control channel
BER	Bit-error ratio
BRAN	Broadband radio access network
BS	Base station
BSR	Base station router
BTC	Block turbo code
BWA	Broadband wireless access
CC	Convolutional coding
CDMA	Code division multiple access
CDMA-MC	Code division multiple access – multi carrier
CL	Connection layer
C-plane	Control plane
CTC	Convolutional turbo code
DECT	Digital enhanced cordless telecommunications
DLC	Data link control
DS-CDMA	Direct-sequence code division multiple access
DSSS	Direct sequence spread spectrum
E-DCH	Enhanced dedicated channel
EGPRS	Enhanced general packet radio service
ETSI	European Telecommunication Standards Institute
EV-DO	Evolution data optimized
FC	Forward channel
FCC	Forward control channel
FDD	Frequency division duplex
FEC	Forward-error correction
FER	Frame error rate
FHSS	Frequency hopping spread spectrum
FT	Fixed termination
GERAN	GSM edge radio access network

GPRS	General packet radio service
GPS	Global positioning system
HC-SDMA	High capacity-spatial division multiple access
HiperLAN	High performance RLAN
HiperMAN	High performance metropolitan area network
HRPD	High rate packet data
HSDPA	High speed downlink packet access
HS-DSCH	High speed downlink shared channel
HSUPA	High speed uplink packet access
I-CDMA	Internet code division multiple access
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task force
IP	Internet protocol
LAC	Link access control
LAN	Local area network
LDPC	Low density parity check
LLC	Logic link control
MAC	Medium access control
MAN	Metropolitan area network
MCSB	Multi-carrier synchronous beamforming
MIMO	Multiple input multiple output
MS	Mobile station
NLOS	Non-line-of-sight
OFDM	Orthogonal frequency division multiplexing
OFDMA	Orthogonal frequency division multiple access
OSI	Open systems interconnection
PDCP	Packet data convergence protocol
PHS	Personal handyphone system
PHY	Physical layer
PLP	Physical layer protocol
PT	Portable termination
QAM	Quadrature amplitude modulation
QoS	Quality-of-service
RAC	Reverse access channel
RF	Radio frequency
RLC	Radio link control

RLP	Radio link protocol
RTC	Reverse traffic channel
SC	Single carrier
SDMA	Spatial division multiple access
SDO	Standards development organization
SISO	Single input single output
SL	Security/session/stream layer
SM	Spatial multiplexing
SNP	Signalling network protocol
TCC	Traffic code channels
TDD	Time-division duplex
TDMA	Time-division multiple access
TDMA-SC	TDMA-single carrier
TD-SCDMA	Time-division-synchronized CDMA
U-plane	User plane
WirelessMAN	Wireless metropolitan area network
WWINA	Wireless widebands Internet access

5 Noting

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

6 Recommendation

The ITU Radiocommunication Assembly,

recommends

1 the radio interface standards in Annexes 1 to 5 as suitable for BWA systems in the mobile service operating below 6 GHz.

NOTE 1 – Annex 6 provides a summary of the characteristics of the standards found in Annexes 1-5.

Annex 1

Broadband radio local area networks

Radio local area networks (RLAN) offer an extension to wired LANs utilizing radio as the connective media. They have applications in commercial environments where there may be considerable savings in both cost and time to install a network; in domestic environments where they provide cheap, flexible, connectivity to multiple computers used in the home; and in campus and public environments where the increasing use of portable computers, for both business and

personal use, while travelling and due to the increase in flexible working practices, e.g. nomadic workers using laptop personal computers not just in the office and at home, but in hotels, conference centres, airports, trains, planes and automobiles. In summary, they are intended mainly for nomadic wireless access applications, with respect to the access point (i.e. when the user is in a moving vehicle, the access point is also in the vehicle).

Broadband radio local area network standards are included in Recommendation ITU-R M.1450, and can be grouped as follows:

- IEEE 802.11
- ETSI BRAN HIPERLAN
- ARIB HiSWANa

IEEE 802.11 has developed a set of standards for RLANs, 802.11-1999 (R2003), which have been harmonized with IEC/ISO³. The medium access control (MAC) and physical characteristics for wireless local area networks (LANs) are specified in ISO/IEC 8802-11:2005, which is part of a series of standards for local and metropolitan area networks. The medium access control unit in ISO/IEC 8802-11:2005 is designed to support physical layer units as they may be adopted dependent on the availability of spectrum. ISO/IEC 8802-11:2005 contains five physical layer units: four radio units, operating in the 2 400-2 500 MHz band and in the bands comprising 5.15-5.25 GHz, 5.25-5.35 GHz, 5.47-5.725 GHz and 5.725-5.825 GHz, and one baseband infrared (IR) unit. One radio unit employs the frequency hopping spread spectrum (FHSS) technique, two employ the direct sequence spread spectrum (DSSS) technique, and another employs the orthogonal frequency division multiplexing (OFDM) technique.

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 ISO/IEC 8802-11:2005, Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications.

MMAC⁴ **HSWA**⁵ 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 orthogonal frequency division multiplexing (OFDM) technique and TDMA-TDD scheme are used. It is capable of supporting multimedia applications by providing mechanisms to handle the quality-of-service (QoS). Restricted user mobility is supported within the local service area. Currently, only Ethernet service is supported.

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

Annex 2

IMT-2000 terrestrial radio interfaces

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

1.1 IMT-2000 CDMA Direct Spread⁷

The UTRAN radio-access scheme is direct-sequence CDMA (DS-SS) with information spread over approximately 5 MHz bandwidth using a chip rate of 3.84 Mchip/s. Advanced modulation (16QAM) and coding techniques (turbo codes) are used to provide high-speed packet access.

A 10 ms radio frame is divided into 15 slots (2 560 chip/slot at the chip rate of 3.84 Mchip/s). A physical channel is therefore defined as a code (or number of codes). For HS-DSCH (high-speed downlink packet access – HSDPA), E-DCH (high-speed uplink packet access – HSUPA) and associated signalling channels, 2 ms subframes consisting of 3 slots are defined. This technology achieves a channel transmission rate above 14 Mbit/s.

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

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.

⁷ See § 5.1 of Recommendation ITU-R M.1457.

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

1.2 IMT-2000 CDMA Multi-Carrier⁸

The cdma2000 radio interface provides two options: nX operation where multiple 1.25 MHz carriers are utilized or high-rate packet data 1X-EV-DO where a dedicated 1X RF channel is utilized.

The nX operation option supports 1.25 MHz bandwidth using a chip rate of 1.2288 Mchip/s or multi-carrier operation using multiple 1.25 MHz carriers. The radio interface is defined to carry a wide range of services to support both circuit-switched services (e.g. PSTN- and ISDN-based networks) as well as packet-switched services (e.g. IP-based networks). The radio protocol has been designed where several different services such as speech, data and multimedia can simultaneously be used in a flexible manner by a user and multiplexed on a single carrier. The defined radio-bearer services provide support for both real-time and non-real-time services by employing transparent and/or non-transparent data transport. The quality-of-service (QoS) can be adjusted in terms such as delay, bit-error probability and frame error rate (FER).

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

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

For high-rate packet data (1X-EV-DO) the forward CDMA channel, deployed on a dedicated 1X RF channel, consists of the following time-multiplexed channels: the pilot channel, the forward medium access control (MAC) channel, the control channel and the forward traffic channel. The forward traffic channel carries user data packets. The control channel carries control messages, and it may also carry user traffic. Each channel is further decomposed into code-division-multiplexed quadrature Walsh channels.

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

The forward traffic channel is a packet-based, variable-rate channel. The user data for an access terminal is transmitted at a data rate that varies from 38.4 kbit/s to 3.1 Mbit/s. The forward traffic channel and control channel data are encoded, scrambled and interleaved. The outputs of the channel interleaver are fed into a QPSK/8-PSK/16-QAM modulator. The modulated symbol sequences are repeated and punctured, as necessary. Then, the resulting sequences of modulation symbols are demultiplexed to form 16 pairs (in-phase and quadrature) of parallel streams. Each of the parallel streams are covered with a distinct 16-ary Walsh function at a chip rate to yield Walsh symbols at 76.8 ksymbol/s. The Walsh-coded symbols of all the streams are summed together to form a single in-phase stream and a single quadrature stream at a chip rate of 1.2288 Mchip/s. The resulting chips are time-division multiplexed with the preamble, pilot channel, and MAC channel chips to form the resultant sequence of chips for the quadrature spreading operation.

⁸ See § 5.2 of Recommendation ITU-R M.1457.

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

The reverse CDMA channel for 1X-EV-DO, deployed on a dedicated 1X RF channel, consists of the access channel and the reverse traffic channel. The access channel is used by the access terminal to initiate communication with the access network or to respond to an access terminal directed message. The access channel consists of a pilot channel and a data channel. The reverse traffic channel is used by the mobile station to transmit user-specific traffic or signalling information to the access network. The reverse traffic channel comprises a pilot channel, a reverse rate indicator (RRI) channel, a data rate control (DRC) channel, an acknowledgement (ACK) channel, and a data channel. The RRI channel is used to indicate the data rate transmitted on the reverse traffic channel. The RRI channel is time-multiplexed with the pilot channel. The DRC channel is used by the mobile station to indicate to the access network the supportable forward traffic channel data rate and the best serving sector on the forward CDMA channel. The ACK channel is used by the access terminal to inform the access network whether or not the data packet transmitted on the forward traffic channel has been received successfully.

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

1.3 IMT-2000 CDMA TDD⁹

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

The UTRA TDD radio interface has been developed with the strong objective of harmonization with the FDD component (see § 5.1) to achieve maximum commonality. This was achieved by harmonization of important parameters of the physical layer, and a common set of protocols in the higher layers are specified for both FDD and TDD, where 1.28 Mchip/s TDD has significant commonality with 3.84 Mchip/s TDD. UTRA TDD with the two options accommodates the various needs of the different Regions in a flexible way and is specified in a common set of specifications.

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

⁹ See § 5.3 of Recommendation ITU-R M.1457.

The radio-interface specification includes enhanced features for high-speed downlink packet access (HSDPA), allowing for high speed downlink packet-data transmission and simultaneous high-speed packet data and other services such as speech on the single carrier. This technology achieves a channel transmission rate above 10 Mbit/s.

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

1.4 IMT-2000 TDMA Single-Carrier¹⁰

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

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

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

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

1.5 IMT-2000 FDMA/TDMA¹¹

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

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

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

¹⁰ See § 5.4 of Recommendation ITU-R M.1457.

¹¹ See § 5.5 of Recommendation ITU-R M.1457.

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

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

- broadcast message control (BMC);
- connectionless message control (CMC);
- multibearer control (MBC).

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

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

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

Four types of MAC bearer are defined:

- Simplex bearer: a simplex bearer is created by allocating one physical channel for transmissions in one direction.
- Duplex bearer: a duplex bearer is created by a pair of simplex bearers, operating in opposite directions on two physical channels.
- Double simplex bearer: a double simplex bearer is created by a pair of long simplex bearers operating in the same direction on two physical channels.
- Double duplex bearer: a double duplex bearer is composed by a pair of duplex bearers referring to the same MAC connection.

A bearer can exist in one of three operational states:

- Dummy bearer: where there are normally continuous transmissions (i.e. one transmission in every frame).
- Traffic bearer: where there are continuous point-to-point transmissions. A traffic bearer is a duplex bearer or a double simplex bearer or a double duplex bearer.
- Connectionless bearer: where there are discontinuous transmissions. A connectionless bearer is either a simplex or a duplex bearer.

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

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

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

Annex 3

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

1 Overview of the radio interface

The IEEE standard 802.16 (including the 802.16e-2005 amendment), and ETSI HiperMAN standards define harmonized radio interfaces for the OFDM and OFDMA physical layers (PHY) and MAC (media access control)/DLC (data link control) layer, however the ETSI BRAN HiperMAN targets only the nomadic applications, while the IEEE 802.16 standard also targets full vehicular applications.

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

This type of system is referred to as a wireless metropolitan area network (WirelessMAN in IEEE and HiperMAN in ETSI BRAN). The word “metropolitan” refers not to the application but to the scale. The architecture for this type of system is primarily point-to-multipoint, with a base station serving subscribers in a cell that can range up to a few kilometers. 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.

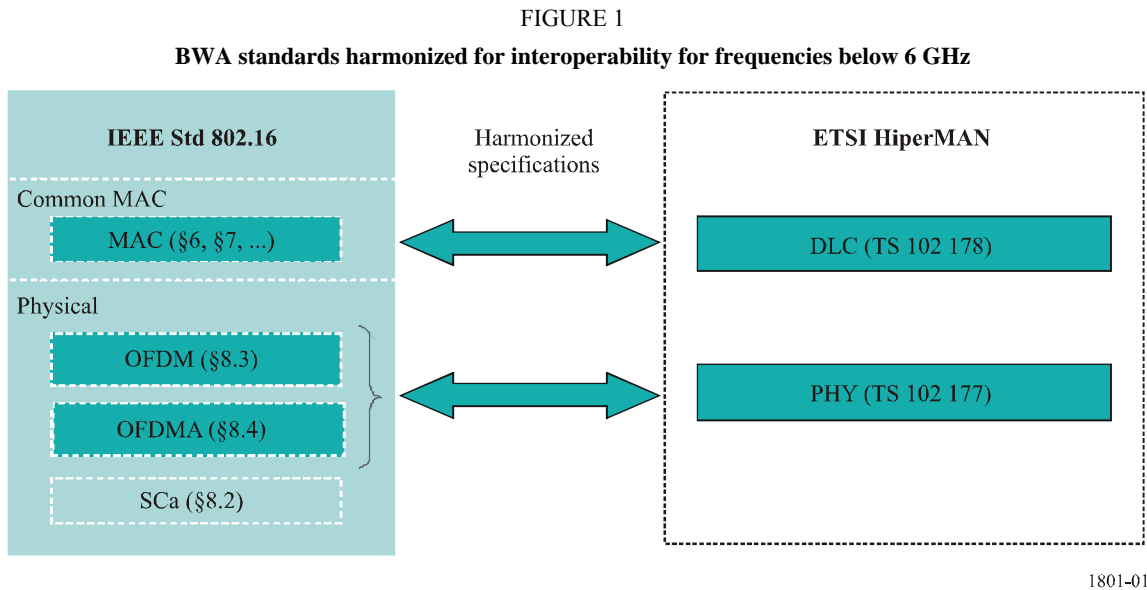
The radio interface supports a variety of channel widths and operating frequencies, providing a peak spectral efficiency of up to 3.5 bits/s/Hz in a single receive and transmit antenna (SISO) configuration.

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 quality-of-service (QoS).

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

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



The WiMAX Forum™, IEEE 802.16 and ETSI HiperMAN define profiles for the recommended interoperability parameters. IEEE 802.16 profiles are included in the main standards document, while HiperMAN profiles are included in a separate document. TTA (Telecommunications Technology Association) defines profile for WiBro (Wireless Broadband) service which is referred to WiMAX Forum profiles.

TTA maintains a standard TTAS.KO-06.0082/R1 for WiBro service, which is portable internet service in Korea. The standard is a subset of IEEE Std 802.16 including the IEEE 802.16e-2005 amendment and the IEEE 802.16-2004/Cor1 corrigendum.

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 Fixed and Mobile Broadband Wireless Access Systems.

IEEE Std 802.16 is an air interface standard for broadband wireless access (BWA). The base standard, IEEE Std 802.16-2004, address fixed and nomadic systems only. The amendment IEEE 802.16e-2005 enables combined fixed and mobile operation in licensed frequency bands below 6 GHz. The current IEEE 802.16 (including the IEEE 802.16e amendment) 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 multiple input multiple output (MIMO) and spatial multiplexing (SM) in uplink and downlink;
- adaptive MIMO switching between spatial multiplexing/space time block coding to maximize spectral efficiency with no reduction in coverage area;
- UL (uplink) collaborative spatial multiplexing for single transmit antenna devices;
- advanced beamforming and null steering.

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

Support for mobility

The standard supports BS and MS initiated optimized hard handover for bandwidth-efficient handover with reduced delay achieving a handover delay less than 50 msec. The standard also supports fast base station switch (FBSS) and Macro 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.

Re-use 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 re-use planning for spectrally efficient re-use factor 1, interference robust re-use factor 3 or optimal fractional re-use deployment scenarios.

In the case of re-use 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 users¹² with better link connection to maximize spectral efficiency while fractional frequency reuse is achieved for edge users¹³ to improve edge-user connection quality and throughput. The sub-channel re-use 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:

Base standard: <http://standards.ieee.org/getieee802/download/802.16-2004.pdf>

Amendment 802.16e: <http://standards.ieee.org/getieee802/download/802.16e-2005.pdf>

2.2 ETSI standards

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

- ETSI TS 102 177 v1.3.2: broadband radio access networks (BRAN); HiperMAN; physical (PHY) layer.
- ETSI TS 102 178 v1.3.2: broadband radio access networks (BRAN); HiperMAN; data link control (DLC) layer.

¹² Users who are located towards the middle of a sector, far from the adjacent sectors.

¹³ Users who are located towards the edges of a sector, close to adjacent sectors.

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

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

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

- all the PHY improvements related to OFDM and OFDMA modes, including MIMO for the OFDMA mode;
- flexible channelization, including the 3.5 MHz, the 7 MHz and 10 MHz raster (up to 28 MHz);
- scalable OFDMA, including FFT sizes of 512, 1 024 and 2 048 points, to be used in function of the channel width, such that the subcarrier spacing remains constant;
- uplink and downlink OFDMA (sub-channelization) for both OFDM and OFDMA modes;
- adaptive antenna support for both OFDM and OFDMA modes.

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

Annex 4

ATIS WTSC radio interface standards for broadband wireless access (BWA) systems in the mobile service

ATIS WTSC wireless wideband Internet access (WWINA) and other standards

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

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

- system data speeds;
- system coverage/range;
- network capacity;

- minimum network complexity;
- grade-of-service and quality-of-service management.

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

1 Overview of the radio interface

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

2 Detailed specifications of the radio interface

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

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

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

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

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

1 Overview of the radio interface

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

2 Detailed specifications of the radio interface

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

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

TABLE 1

Radio interface layer function

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

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

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

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

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

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

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

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

1 Overview of the radio interface

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

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 directionally processed channels. Adaptive modulation and channel coding, along with uplink and downlink power control, are incorporated to provide reliable transmission across a wide range of link conditions. Modulation, coding and power control are complemented by a fast ARQ to provide a reliable link. Fast, low-overhead make-before-break inter-cell handover is also supported. Authentication, authorization, and privacy for the radio access link is provided by mutual authentication of the terminals and access network, and by encryption.

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

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

TABLE 2

Air interface layers

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

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

TABLE 3

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

Quantity	Value
Duplex method	TDD
Multiple access method	FDMA/TDMA/SDMA
Access scheme	Collision sense/avoidance, centrally scheduled
Carrier spacing	625 kHz
Frame period	5 ms
User data rate asymmetry	3:1 down:up asymmetry at peak rates
Uplink time-slots	3
Downlink time-slots	3
Range	> 15 km
Symbol rate	500 kbaud/sec
Pulse shaping	Root raised cosine
Excess channel bandwidth	25%
Modulation and coding	<ul style="list-style-type: none"> – 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

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

1 Overview of the radio interface

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

2 Detailed specifications of the radio interface

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

- DLC is limited to data link control of the dedicated control channels. Dedicated traffic channels are not managed by the DLC.
- MAC – not the physical layer (PHY) – performs encoding/decoding for forward-error correction (FEC), encipherment/decipherment, symbol repetition/combining, and power control for quality-of-service (QoS).

TABLE 4

Air interface layers

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

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

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

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

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

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

Annex 5

“Next-generation PHS” for broadband wireless access (BWA) systems in the mobile service

1 Overview of the radio interface

PHS MoU Group, which is a standards development organization for personal handy phone systems (PHS), has developed “Next-generation PHS¹⁴” as one of the BWA (broadband wireless access) systems. “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.

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

- Enabling continuous connectivity at IP level
Considering the convenience of continuous connection provided on the cable modem circumstance, etc., the continuous connectivity at IP level that enables users to start high-speed transmission in a moment is essential.
- High transmission data rate
It is also important to keep throughput of some extent for practical use even in case that serious concentration of traffic occurs.
- High transmission data rate for uplink
Considering future demand of bidirectional broadband communication such as a videoconference, an uplink transmission data rate over 10 Mbit/s is considered to become still more important in the near future.
- High efficiency in spectral utilization
When serious traffic congestion occurs concentrically at a business district or downtown area, some problems by shortage of frequency would hamper many services. In order to avoid such situations, highly efficient spectral utilization is necessary.

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

- Adaptive array antenna technology and space division multiple access technology enable a frequency re-use factor of more than 4.
- Autonomous decentralized control technology contributes to make cell designing plans unnecessary, and as a result, the cell radius down to less than 100 m is realized.

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

Since “Next-generation PHS” adopts the autonomous decentralized control method, which enables several operators to share the same frequency band, more efficient spectral utilization would be realized.

¹⁴ “Next-generation PHS”, in the broad sense, can include enhanced a PHS system, that is a TDMA-TDD system.

“Next-generation PHS” is a system among BWA systems, whose service coverage areas consist of many micro-cells.

The radio interface of “Next-generation PHS” supports bandwidths from 1.25 MHz up to 20 MHz and up to 256QAM modulation to realize high transmission data rate for up/downlinks.

2 Detailed specification of the radio interface

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

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

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

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

TABLE 5
The basic elements of “Next-generation PHS”

Multiple access method	OFDMA/TDMA
Duplex method	TDD
Number of TDMA multiplexing	4
Number of OFDMA multiplexing	Depends on channel bandwidth
Operation channel bandwidth	1.25 MHz, 2.5 MHz, 5 MHz, 10 MHz, 20 MHz
Subcarrier frequency spacing	37.5 kHz
Number of FFT points (channel bandwidth: MHz)	32 (1.25), 64 (2.5), 128 (5), 256 (10), 512 (20)
Frame duration	5 ms
Number of slots	8 slots (4 downlink/4 uplink: symmetry)
Modulation method	BPSK, QPSK, 16-QAM, 32-QAM, 64-QAM, 256-QAM
Channel assign	Autonomous decentralized control
Basic cell size	Micro-cell
Connection technique	Sub-channel connection, slot connection
Technologies of efficient spectral utilization	Adaptive array antenna, SDMA, MIMO
Peak channel transmission rate/5 MHz (in case of SISO, symmetry)	Uplink: 8.0 Mbit/s Downlink: 11.2 Mbit/s

Standards: “Next-generation PHS” specification (A-GN4.00-01-TS) is available in electronic form at: <http://www.phsmou.org/about/nextgen.aspx>.

Annex 6

Table 6 provides a summary of key characteristics of each standard.

TABLE 6
Key technical parameters

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

TABLE 6 (continued)

Standard	Nominal RF channel bandwidth	Modulation/ coding rate ⁽¹⁾ – upstream – downstream	Coding support	Peak channel transmission rate per 5 MHz channel (except as noted)	Beam-forming support (yes/no)	Support for MIMO (yes/no)	Duplex method	Multiple access method	Frame duration	Mobility capabilities (nomadic/mobile)
ATIS-0700004.2005 high capacity-spatial division multiple access (HC-SDMA) (Annex 4)	0.625 MHz	Up: – BPSK, QPSK, 8-PSK, 12-QAM, 16-QAM 3/4 Down: – BPSK, QPSK, 8-PSK, 12-QAM, 16-QAM, 24-QAM 8/9	Convolutional and block code	Up: 2.866 Mbit/s × 8 sub-channels × 4 spatial channels = 91.7 Mbit/s Down: 2.5 Mbit/s × 8 sub-channels × 4 spatial channels = 80 Mbit/s	Yes	Yes	TDD	TDMA/FDMA/SDMA	5 ms	Mobile
T1.716/7-2000 (R2004) air interface standard for broadband direct sequence CDMA for fixed wireless PSTN access – Layer 1/ Layer 2 (Annex 4)	2 × 5 to 2 × 20 MHz (in 3.5 or 5 MHz increments)	Up: – QPSK, – 1/2 Down: – QPSK, – 1/2	Convolutional	Up: 1.92 Mbit/s Down: 1.92 Mbit/s	No	No	FDD	CDMA	19 ms max	Nomadic
Next-generation PHS (Annex 5)	1.25 MHz 2.5 MHz 5 MHz 10 MHz 20 MHz	Up and down: BPSK 1/2 QPSK 1/2, 3/4 16-QAM 3/4 32-QAM 4/5 64-QAM 5/6 256-QAM 7/8	Convolutional code Trellis code	Up: 8.0 Mbit/s Down: 11.2 Mbit/s (in case of SISO, symmetry)	Yes (option)	Yes (option)	TDD	OFDMA TDMA	5 ms	Mobile
IEEE 802.11-1999 (R2003) (802.11b) (Annex 1)	22 MHz	Symmetric up and down: DQPSK CCK BPSK PBCC – 1/2 QPSK PBCC – 1/2	Uncoded/CC	2.5 Mbit/s	No	No	TDD	CSMA/CA, SSMA	Variable frame duration	Nomadic

TABLE 6 (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 802.11-1999 (R2003) (802.11a) (Annex 1)	20 MHz	Symmetric up and down: 64-QAM OFDM 2/3, 3/4 16-QAM OFDM – 1/2, 3/4 QPSK OFDM – 1/2, 3/4 BPSK OFDM – 1/2, 3/4	CC	13.5 Mbit/s	No	No	TDD	CSMA/CA	Variable frame duration	Nomadic
IEEE 802.11-1999 (R2003) (802.11g) (Annex 1)	20 MHz	Symmetric up and down: 64-QAM OFDM 2/3, 3/4 16-QAM OFDM – 1/2, 3/4 QPSK OFDM – 1/2, 3/4 BPSK OFDM – 1/2, 3/4 8-PSK PBCC – 2/3 64-QAM DSSS-OFDM – 2/3, 3/4 16-QAM DSSS-OFDM – 1/2, 3/4 QPSK DSSS-OFDM – 1/2, 3/4 BPSK DSSS-OFDM – 1/2, 3/4	CC	13.5 Mbit/s	No	No	TDD	CSMA/CA	Variable frame duration	Nomadic
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 6 (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
IMT-2000 CDMA Direct Spread (Annex 2)	5 MHz	Up: QPSK Down: 16-QAM, QPSK	Convolutional turbo	Up: 5.7 Mbit/s Down: 14 Mbit/s	Yes	No (For inclusion in Rel-7)	FDD	CDMA	2 ms and 10 ms	Mobile
IMT-2000 CDMA Multi-Carrier (Annex 2)	1.25 MHz	Up: BPSK, QPSK, 8-PSK Down: 16-QAM, 8-PSK, QPSK	Convolutional/turbo	Up: 1.8 Mbit/s Down: 3.1 Mbit/s Per 1.25 MHz channel	Yes	No	FDD	CDMA	Down: 1.25, 1.67, 2.5, 5, 10, 20, 40, 80 ms Up: 6.66, 10, 20, 26.67, 40, 80 ms	Mobile
IMT-2000 CDMA TDD (Annex 2)	HCR: 5 MHz LCR: 1.6 MHz (high chip rate/low chip rate)	HCR Up: 16-QAM, QPSK LCR Up: 8-PSK, QPSK HCR Down: 16-QAM, QPSK LCR Down: 16-QAM, 8-PSK, QPSK	Convolutional turbo	HCR Up: 9.2 Mbit/s LCR Up: 2 Mbit/s/1.6 MHz carrier ⁽²⁾ HCR Down: 10.2 Mbit/s LCR Down: 2.8 Mbit/s/1.6 MHz carrier ⁽²⁾	Yes	No	TDD	HCR: TDMA/CDMA LCR: TD-SCDMA	HCR: 10 ms LCR: 5 ms	Mobile

TABLE 6 (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)
IMT-2000 TDMA Single-Carrier (Annex 2)	2 × 200 kHz 2 × 1.6 MHz	Up: – GMSK – 8-PSK – B-OQAM – Q-OQAM 0.329 – 1/1 Down: – GMSK – 8-PSK – B-OQAM – Q-OQAM 0.329 – 1/1	Punctured convolutional	Up: 16.25 Mbit/s 20.312 Mbit/s Down: 16.25 Mbit/s 20.312 Mbit/s	Not explicit but not precluded	Not explicit but not precluded	FDD TDD (for 1.6 MHz)	TDMA	4.6 ms 4.615 ms	Mobile
IMT-2000 FDMA/TDMA (Annex 2)	1.728 MHz	Up and down: GFSK $\pi/2$ -DBPSK $\pi/4$ -DQPSK $\pi/8$ -D8-PSK 16-QAM, 64-QAM	Depends on service: CRC, BCH, Reed-Solomon, Turbo	20 Mbit/s	Partial	Partial	TDD	TDMA	10 ms	Mobile

¹⁾ Including all applicable modes, or at least the maximum and the minimum.

²⁾ LCR TDD has a channelization equal to 1.6 MHz. In 5 MHz three LCR TDD carriers can be deployed. A 7.68 Mchip/s TDD option is also available. This requires 10 MHz bandwidth and provides double the data rates of HCR TDD.