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| **Radiocommunication Study Groups** |  |
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|  | **DRAFT** |
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| **xx March 2011** |
| **English only**  **TECHNOLOGY ASPECTS** |
| Institute of Electrical and Electronics Engineers (IEEE) | |
| proposed modifications to THE WORKING DOCUMENT TOWARDS PDNR M.[IMT.RSPEC] | |

[Introduction to be inserted]

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| SWG IMT Specifications |
| WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW RECOMMENDATION ITU-R M.[IMT.RSPEC] |
| Detailed specifications of the terrestrial radio interfaces of IMT-Advanced |

# 1 Introduction

International Mobile Telecommunications-Advanced (IMT-Advanced) systems are mobile systems that include the new capabilities of IMT that go beyond those of IMT-2000. Such systems provide access to a wide range of telecommunication services including advanced mobile services, supported by mobile and fixed networks, which are increasingly packet-based.

IMT-Advanced systems support low to high mobility applications and a wide range of data rates in accordance with user and service demands in multiple user environments. IMT‑Advanced also has capabilities for high-quality multimedia applications within a wide range of services and platforms providing a significant improvement in performance and quality of service.

The key features of IMT-Advanced are:

– a high degree of commonality of functionality worldwide while retaining the flexibility to support a wide range of services and applications in a cost efficient manner;

– compatibility of services within IMT and with fixed networks;

– capability of interworking with other radio access systems;

– high-quality mobile services;

– user equipment suitable for worldwide use;

– user-friendly applications, services and equipment;

– worldwide roaming capability;

– enhanced peak data rates to support advanced services and applications (100 Mbit/s for high and 1 Gbit/s for low mobility were established as targets for research)[[1]](#footnote-1).

These features enable IMT-Advanced to address evolving user needs.

The capabilities of IMT-Advanced systems are being continuously enhanced in line with user trends and technology developments.

# 2 Scope

This Recommendation identifies the detailed terrestrial radio interface specifications of IMT‑Advanced.

These radio specifications detail the design features and design parameters of IMT-Advanced. This Recommendation includes the capability to ensure worldwide compatibility, international roaming, and access to high-speed data services.

*[Editor’s note: the previous paragraph might need additional consideration to reflect some of the views expressed, e.g., in Res 57, M.1822, and M.2133]*

# 3 Related ITU-R Recommendations and Reports

Recommendation ITU-R M.1036

Recommendation ITU-R M.1457

Recommendation ITU-R M.1579

Recommendation ITU-R M.1580

Recommendation ITU-R M.1581

Recommendation ITU-R M.1645

Recommendation ITU-R M.1768

Recommendation ITU-R M.1822

Recommendation ITU-T Q.1741

Recommendation ITU-T Q.1742

Report ITU-R M.2038

Report ITU-R M.2072

Report ITU-R M.2074

Report ITU-R M.2078

Report ITU-R M.2079

Report ITU-R M.2133.

Report ITU-R M.2134

Report ITU-R M.2135-1.

Report ITU-R M.[IMT.RADIO].

# 4 Acronyms and abbreviations

*[Editor’s Note: to be added]*

# 5 Notings and considerations

The ITU‑R Radiocommunication Assembly,

noting

a) Report ITU-R M.[IMT.RADIO] which contains the outcome and conclusions of Step 4 through 7 of the IMT-Advanced process, including the evaluation and consensus building, and provides the characteristics of the IMT-Advanced terrestrial radio interfaces,

considering

a) the possible involvement of several types of networks;

b) the increasing technical developments and opportunities;

c) the need of many users for services which are not bounded by geography or operators;

d) the necessity of priority services (e.g. emergency calls shall be supported as higher priority than other commercial services);

e) that the services supported by IMT will be operated in an environment which requires recognition of the following factors:

e-1) low cost: Users want diverse, affordable, and convenient mobile services. Such demands will be realized by development of technology that will reduce the cost per packet;

e-2) large effective bandwidths: to support the very high data rates that will likely be required by the various services offered, allowances must be made for either much larger single carrier bandwidths (even as spectral efficiencies increase) or aggregation of RF carriers;

e-3) high data rate: services such as video phone, streaming, and video-on-demand, which are currently available via wired networks will be required to be supported via wireless networks with higher broadband capacity with anytime, anywhere availability;

e-4) convergence: the rapid development of information technology (IT), including the Internet, has resulted in the aggregation and convergence of various networks and digital devices. In addition to the aggregation of data and voice, the integration of wired and wireless communications is ongoing;

e-5) wide range of terminals: a wide range of terminals is desired for future mobile services. Some users may need an affordable voice-centric terminal while other users would prefer a versatile mobile phone that could provide not only traditional functions like telephony, but also utilities such as a digital camera, music and movie player, map guidance, e-Wallet, etc. For connecting to the electric, electronic, and mechanical machine surrounding user, short-range communication devices could be merged to the terminals.

# 6 Recommendation

The ITU Radiocommunication Assembly,

recommends

1) the radio interface specifications in the Annexes below as the terrestrial radio interfaces of IMT-Advanced:

Annex A: Specification of the *LTE-Advanced*[[2]](#footnote-2) radio interface technology

Annex B: Specification of the *WirelessMAN-Advanced*[[3]](#footnote-3) radio interface technology;

2) the detailed information provided or referenced in these Annexes as the complete set of standards for the terrestrial radio interfaces of IMT-Advanced.

**Annex A  
  
Specification of the *LTE-Advanced*[[4]](#footnote-4) radio interface technology**

**Background**

IMT-Advanced is a system with global development activity and the IMT-Advanced terrestrial radio interface specifications identified in this Recommendation have been developed by the ITU in collaboration with the ***GCS Proponents*** and the ***Transposing Organizations***. It is noted from document ITU-R IMT-ADV/24, that:

- The ***GCS Proponent*** must be one of the ***RIT/SRIT Proponents*** for the relevant technology, **and** must have legal authority to grant to ITU-R the relevant legal usage rights to the relevant specifications provided within a GCS corresponding to a technology in Recommendation ITU‑R M.[IMT.RSPEC]

- A ***Transposing Organization*** must have been authorized by the relevant ***GCS Proponent*** to produce transposed standards for a particular technology, **and** must have the relevant legal usage rights.

It is further noted that **GCS** ***Proponents*** and ***Transposing Organizations*** must also qualify appropriately under the auspices of ITU-R Resolution 9-3 and the ITU-R “Guidelines for the contribution of material of other organizations to the work of the Study Groups and for inviting other organizations to take part in the study of specific matters (Resolution ITU-R 9-3)”.

The ITU has provided the global and overall framework and requirements, and has developed the Global Core Specification jointly with the ***GCS Proponent***. The detailed standardization has been undertaken within the recognized ***Transposing Organizations*** which operate in concert with the ***GCS Proponent***. This Recommendation therefore makes extensive use of references to externally developed specifications.

This approach was considered to be the most appropriate solution to enable completion of this Recommendation within the aggressive schedules set by the ITU and by the needs of administrations, operators and manufacturers.

This Recommendation has therefore been constructed to take full advantage of this method of work and to allow the global standardization time‑scales to be maintained. The main body of this Recommendation has been developed by the ITU, with each Annex containing references pointing to the location of the more detailed information.

This Annex A contains the detailed information developed by the ITU and “ARIB, ATIS, CCSA, ETSI, TTA, and TTC on behalf of 3GPP” (the ***GCS Proponent)*** and [TBD] (the ***Transposing Organizations)***. Such use of referencing has enabled timely completion of the high-level elements of this Recommendation, with change control procedures, transposition, and public enquiry procedures being undertaken within the external organization.

The detailed specifications received from “ARIB, ATIS, CCSA, ETSI, TTA, and TTC on behalf of 3GPP” (the ***GCS Proponent)*** and [TBD] (the ***Transposing Organizations)*** have generally been adopted unchanged, recognizing the need to minimize duplication of work, and the need to facilitate and support an on-going maintenance and update process.

This general agreement, that the detailed specifications of the radio interface should to a large extent be achieved by reference to the work of external organizations, highlights not only the ITU’s significant role as a catalyst in stimulating, coordinating and facilitating the development of advanced telecommunications technologies, but also its forward-looking and flexible approach to the development of this and other telecommunications standards for the 21st century.

A more detailed understanding of the process for the development of this Recommendation may be found in Document ITU-R IMT-ADV/24.

**A.1 Overview of the radio interface technology**

*[Editor’s Note: to be filled with stakeholder’s input(s)]*

**A.2 Detailed specification of the radio interface technology**

Detailed specifications described in this Recommendation are developed around a “Global Core Specification” (GCS)[[5]](#footnote-5), which is related to externally developed materials incorporated by specific references for a specific technology. The process and use of the GCS, references, and related notifications and certifications are found as IMT-ADV/24[[6]](#footnote-6)

The standards contained in this section are derived from the global core specifications for IMT‑Advanced contained at <http://ties.itu.int/u/itu-r/ede/rsg5/xxxxx/xxx/xxxxxxxx/>. The following notes apply to the sections below, where indicated:

1) The [relevant][TBD] (the ***Transposing Organisations)*** should make their reference material available from their web site.

2) This information was supplied by the ***Transposing Organizations*** and relates to their own deliverables of the transposed global core specification.

*[Editor’s note: the above notes will be revisited when the final version of IMT.RSPEC will be finalised]*

*[Editor’s Note: to be filled with stakeholder’s input(s)]*

Annex B  
  
Specification of the WirelessMAN-Advanced[[7]](#footnote-7) radio interface technology

**Background**

IMT-Advanced is a system with global development activity and the IMT-Advanced terrestrial radio interface specifications identified in this Recommendation have been developed by the ITU in collaboration with the ***GCS Proponents*** and the ***Transposing Organizations***. It is noted from document ITU-R IMT-ADV/24, that:

- The ***GCS Proponent*** must be one of the ***RIT/SRIT Proponents*** for the relevant technology, **and** must have legal authority to grant to ITU-R the relevant legal usage rights to the relevant specifications provided within a GCS corresponding to a technology in Recommendation ITU‑R M.[IMT.RSPEC]

- A ***Transposing Organization*** must have been authorized by the relevant ***GCS Proponent*** to produce transposed standards for a particular technology, **and** must have the relevant legal usage rights.

It is further noted that **GCS** ***Proponents*** and ***Transposing Organizations*** must also qualify appropriately under the auspices of ITU-R Resolution 9-3 and the ITU-R “Guidelines for the contribution of material of other organizations to the work of the Study Groups and for inviting other organizations to take part in the study of specific matters (Resolution ITU-R 9-3)”.

The ITU has provided the global and overall framework and requirements, and has developed the Global Core Specification jointly with the ***GCS Proponent***. The detailed standardization has been undertaken within the recognized ***Transposing Organizations*** which operate in concert with the ***GCS Proponent***. This Recommendation therefore makes extensive use of references to externally developed specifications.

This approach was considered to be the most appropriate solution to enable completion of this Recommendation within the aggressive schedules set by the ITU and by the needs of administrations, operators and manufacturers.

This Recommendation has therefore been constructed to take full advantage of this method of work and to allow the global standardization time‑scales to be maintained. The main body of this Recommendation has been developed by the ITU, with each Annex containing references pointing to the location of the more detailed information.

This Annex B contains the detailed information developed by the ITU and “IEEE” (the ***GCS Proponent)*** and [TBD] (the ***Transposing Organizations)***. Such use of referencing has enabled timely completion of the high-level elements of this Recommendation, with change control procedures, transposition, and public enquiry procedures being undertaken within the external organization.

The detailed specifications received from “IEEE” (the ***GCS Proponent)*** and [TBD] (the ***Transposing Organizations)*** have generally been adopted unchanged, recognizing the need to minimize duplication of work, and the need to facilitate and support an on-going maintenance and update process.

This general agreement, that the detailed specifications of the radio interface should to a large extent be achieved by reference to the work of external organizations, highlights not only the ITU’s significant role as a catalyst in stimulating, coordinating and facilitating the development of advanced telecommunications technologies, but also its forward-looking and flexible approach to the development of this and other telecommunications standards for the 21st century.

A more detailed understanding of the process for the development of this Recommendation may be found in Document ITU-R IMT-ADV/24.

**B.1 Overview of the radio interface technology**

*[Editor’s Note: to be filled GCS Proponents’ input(s) – the text is anticipated to be approx 10 pages]*

The WirelessMAN-Advanced radio interface specification is developed by IEEE. A complete end-to-end specification based on WirelessMAN-Advanced developed by the WiMAX Forum is called WiMAX 2.

The following clauses provide an overview of the WirelessMAN-Advanced radio interface technology.

# B.1.1 Mobile Station State Diagram

The WirelessMAN-Advanced mobile state diagram (i.e., a finite set of states and procedures between which the mobile station transit when operating in the system to receive and transmit data) is shown in Figure 2:

* Initialization State: a state where a mobile station without any connection performs cell selection by scanning and synchronizing to a BS preamble and acquires the system configuration information through the superframe header.
* Access State: a state where the mobile station performs network entry to the selected base station. The mobile station performs the initial ranging process in order to obtain uplink synchronization. Then the MS performs basic capability negotiation with the BS. The MS later performs the authentication and authorization procedure. Next, the MS performs the registration process. The mobile station receives WirelessMAN-Advanced specific user identification as part of Access State procedures. The IP address assignment may follow using appropriate procedures.
* Connected State: a state consisting of the following modes: Sleep Mode, Active Mode, and Scanning Mode. During Connected State, the MS maintains at least one transport connection and two management connections as established during Access State, while the MS and BS may establish additional transport connections. In order to reduce power consumption of the MS, the MS or BS can request a transition to sleep mode. Also, the MS can scan neighbour base stations to reselect a cell which provides more robust and reliable services.
* Idle State: a state comprising two separate modes, paging available mode and paging unavailable mode. During Idle State, the MS may save power by switching between Paging Available mode and Paging Unavailable mode. In the Paging Available mode, the MS may be paged by the BS. If the MS is paged, it transitions to the Access State for its network re-entry. The MS performs location update procedure during Idle State.

Although both normal and fast network re-entry processes are shown as transition from the Idle State to the Access State in Figure 2, there are differences that differentiate the two processes. The network re-entry is similar to network entry, except it may be shortened by the providing the target BS with MS information through paging controller or other network entity over the backhaul.



Figure 2: Mobile Station State Diagram

# B.1.2 Overview of Physical Layer

# B.1.2.1 Multiple Access Schemes

WirelessMAN-Advanced uses OFDMA as the multiple-access scheme in downlink and uplink. It further supports both TDD and FDD duplex schemes including H-FDD operation of the mobile stations in the FDD networks. The frame structure attributes and baseband processing are common for both duplex schemes. The OFDMA parameters are summarized in Table 1. Tone dropping at both edges of the frequency band based on 10 and 20 MHz systems can be used to support other bandwidths. In Table 1, TTG and RTG denote transmit/receive and receive/transmit transition gaps, respectively.

# B.1.2.2 Frame Structure

A superframe is a collection of consecutive equally-sized radio frames whose beginning is marked with a superframe header. The superframe header carries short-term and long-term system configuration information.

In order to decrease the air-link access latency, the radio frames are further divided into a number of subframes where each subframe comprises of an integer number of OFDM symbols. The transmission time interval is defined as the transmission latency over the air-link and is equal to a multiple of subframe length (default is one subframe). There are four types of subframes: 1) type-1 subframe, which consists of six OFDM symbols, 2) type-2 subframe, which consists of seven OFDM symbols, 3) type-3 subframe which consists of five OFDM symbols, and 4) type-4 subframe, which consists of nine OFDM symbols. In the basic frame structure shown in Figure 3, superframe length is 20 ms (comprised of four radio frames), radio frame size is 5 ms (comprised of eight subframes), and subframe length is 0.617 ms.

Table 1: OFDMA Parameters

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Nominal channel bandwidth (MHz) | | | 5 | 7 | 8.75 | 10 | 20 |
| Sampling factor | | | 28/25 | 8/7 | 8/7 | 28/25 | 28/25 |
| Sampling frequency (MHz) | | | 5.6 | 8 | 10 | 11.2 | 22.4 |
| FFT size | | | 512 | 1024 | 1024 | 1024 | 2048 |
| Subcarrier spacing (kHz) | | | 10.94 | 7.81 | 9.76 | 10.94 | 10.94 |
| Useful symbol time Tu (µs) | | | 91.429 | 128 | 102.4 | 91.429 | 91.429 |
| CP  Tg=1/8 Tu | Symbol time Ts (µs) | | 102.857 | 144 | 115.2 | 102.857 | 102.857 |
| FDD | Number of OFDM  symbols per 5ms frame | 48 | 34 | 43 | 48 | 48 |
| Idle time (µs) | 62.857 | 104 | 46.40 | 62.857 | 62.857 |
| TDD | Number of OFDM  symbols per 5ms frame | 47 | 33 | 42 | 47 | 47 |
| TTG + RTG (µs) | 165.714 | 248 | 161.6 | 165.714 | 165.714 |
| CP  Tg=1/16 Tu | Symbol time Ts (µs) | | 97.143 | 136 | 108.8 | 97.143 | 97.143 |
| FDD | Number of OFDM  symbols per 5ms frame | 51 | 36 | 45 | 51 | 51 |
| Idle time (µs) | 45.71 | 104 | 104 | 45.71 | 45.71 |
| TDD | Number of OFDM  symbols per 5ms frame | 50 | 35 | 44 | 50 | 50 |
| TTG + RTG (µs) | 142.853 | 240 | 212.8 | 142.853 | 142.853 |
| CP  Tg=1/4 Tu | Symbol Time Ts (µs) | | 114.286 | 160 | 128 | 114.286 | 114.286 |
| FDD | Number of OFDM  symbols per 5ms frame | 43 | 31 | 39 | 43 | 43 |
| Idle time (µs) | 85.694 | 40 | 8 | 85.694 | 85.694 |
| TDD | Number of OFDM  symbols per 5ms frame | 42 | 30 | 37 | 42 | 42 |
| TTG + RTG (µs) | 199.98 | 200 | 264 | 199.98 | 199.98 |

The concept of time zones applies to both TDD and FDD systems. These time zones are time-division multiplexed across time domain in the DL to support both new and legacy mobile stations. For UL transmissions both time and frequency-division multiplexing approaches can be used to support legacy and new terminals. The non-backward compatible improvements and features are restricted to the new zones. All backward compatible features and functions are used in the legacy zones.



Figure 3: Basic Frame Structure

The support for multiple RF carriers can be accommodated with the same frame structure used for single carrier operation. All RF carriers are time aligned at the frame, subframe, and symbol level. Alternative frame structures for CP=1/16 and CP=1/4 are used that incorporate different number of OFDM symbols in certain subframes or different number of subframes per frame.

# B.1.2.3 Physical and Logical Resource Blocks

The downlink/uplink subframes are divided into a number of frequency partitions, where each partition consists of a set of physical resource units over the available number of OFDM symbols in the subframe. Each frequency partition can include localized and/or distributed physical resource units. Frequency partitions can be used for different purposes such as fractional frequency reuse (FFR). The downlink/uplink resource partitioning and mapping is illustrated in Figure 4.

# B.1.2.4 Downlink Symbol Structure

A physical resource unit (PRU) is the basic physical unit for resource allocation that comprises 18 contiguous subcarriers by Nsym contiguous OFDM symbols where Nsym is 6, 7, and 5 OFDM symbols for type-1, type-2, and type-3 subframes, respectively. A logical resource unit (LRU) is the basic logical unit for distributed and localized resource allocations. A logical resource unit comprises of 18×Nsym subcarriers.

Distributed resource units (DRU) are used to achieve frequency diversity gain. A distributed resource unit contains a group of subcarriers which are spread across a frequency partition as shown in Figure 4. The size of the distributed resource units is equal to that of physical resource unit. Localized or contiguous resource units (CRU) are used to achieve frequency-selective scheduling gain. A localized resource unit comprises a group of subcarriers which are contiguous across frequency. The size of the localized resource units is equal to that of the physical resource units. To form distributed and localized resource units, the subcarriers over the OFDM symbols of a subframe are partitioned into guard and used subcarriers. The DC subcarrier is not used. The used subcarriers are divided into physical resource units. Each physical resource unit contains pilot and data subcarriers. The number of used pilot and data subcarriers depends on MIMO mode, rank and number of multiplexed MS, as well as the number of OFDM symbols within a subframe.

The PRUs are first subdivided into sub-bands and mini-bands where a sub-band comprises four adjacent PRUs and a mini-band comprises one PRU. The sub-bands are suitable for frequency selective allocations as they provide a contiguous allocation of PRUs in frequency. The mini-bands are suitable for frequency diverse allocations and are permuted in frequency. The downlink subcarrier to resource unit mapping process is defined as follows as illustrated in Figure 4.

The subcarrier permutation defined for the downlink distributed resource allocations spreads the subcarriers of the DRU across all the distributed resource allocations within a frequency partition. After mapping all pilots, the remaining used subcarriers are used to define the DRUs. To allocate the LRUs, the remaining subcarriers are paired into contiguous subcarrier-pairs. Each LRU consists of a group of subcarrier-pairs.



Figure 4: Illustration of the Downlink/Uplink Subcarrier to Resource Unit Mapping where Pi denotes the i-th Frequency Partition

# B.1.2.5 Uplink Symbol Structure

Similar to the downlink symbol structure, a physical resource unit is defined as the basic physical unit for resource allocation that comprises 18 consecutive subcarriers by Nsym consecutive OFDM symbols where Nsym is 6, 7, 5 and 9 OFDM symbols for type-1, type-2, type-3, and type-4 subframes respectively. A logical resource unit is the basic logical unit for distributed and localized resource allocations and its size is 18 × Nsym subcarriers for data transmission. The subcarriers of an OFDM symbol are partitioned into Ng,left left guard subcarriers, Ng,right right guard subcarriers, and Nused used subcarriers. The DC subcarrier is not used. The Nused subcarriers are divided into PRUs. Each PRU contains pilot and data subcarriers. The number of pilot and data subcarriers depends on MIMO mode, rank and number of mobile stations multiplexed, and the type of resource allocation; i.e., distributed or localized resource allocations as well as the type of the subframe.

The uplink distributed units comprise a group of subcarriers which are spread over a frequency partition. The size of distributed unit is equal to logical resource blocks. The minimum unit for constructing a distributed resource unit is a tile. The uplink tile sizes are 6 subcarriers by Nsym OFDM symbols. The localized resource unit is used to achieve frequency-selective scheduling gain. A localized resource unit contains a group of subcarriers which are contiguous across frequency. The size of the localized resource unit equals the size of the logical resource units for localized allocations, i.e., 18 subcarriers by Nsym OFDM symbols.

The PRUs are first subdivided into sub-bands and mini-bands, where a sub-band comprises N1 adjacent PRUs and a mini-band consists of N2 adjacent PRUs, where N1 =4 and N2 =1. The sub-bands are suitable for frequency selective allocations whereas the mini-bands are suitable for frequency diversity allocation and are permuted in frequency. The main features of resource mapping include support of CRUs and DRUs by frequency-division multiplexing, DRUs comprising multiple tiles which are spread across the distributed resource allocations to obtain frequency diversity gain, and FFR may be applied in the uplink. The uplink resource unit mapping process is illustrated in Figure 4. An inner permutation is defined for the uplink distributed resource allocations that spreads DRU tiles across the entire distributed resource allocations within a frequency partition. Each DRU in an uplink frequency partition is divided into 3 tiles of 6 adjacent subcarriers over Nsym symbols. The tiles within a frequency partition are collectively tile-permuted to obtain frequency diversity gain across the allocated resources.

The WirelessMAN-Advanced uplink physical structure supports both frequency and time division multiplexing of the new and the legacy system. A symbol structure based on the new PUSC subchannelization should be used in order to provide FDM-based legacy support. In that case, unlike the distributed structure, the new PUSC contains six tiles of 4 subcarriers by 6 symbols as shown in Figure 5.



Figure 5: New Uplink PUSC Structure for two Streams

# B.1.2.6 Modulation and Coding

The performance of adaptive modulation generally suffers from the power inefficiencies of multilevel modulation schemes. This is due to the variations in bit reliabilities caused by the bit-mapping onto the signal constellation. To overcome this issue, a constellation-rearrangement scheme is utilized where signal constellation of QAM signals between retransmissions is rearranged; i.e., the mapping of the bits into the complex-valued symbols between successive HARQ retransmissions is changed, resulting in averaging bit reliabilities over several retransmissions and lower packet error rates. The mapping of bits to the constellation point depends on the constellation-rearrangement type used for HARQ re-transmissions and may also depend on the MIMO scheme. The complex-valued modulated symbols are mapped to the input of the MIMO encoder. Incremental redundancy HARQis used in by determining the starting position of the bit selection for HARQ retransmissions.



Figure 6: Coding and Modulation Procedures

Figure 6 shows the channel coding and modulation procedures. A cyclic redundancy check (CRC) is appended to a burst (i.e., a physical layer data unit) prior to partitioning. The 16-bit CRC is calculated over the entire bits in the burst. If the burst size including burst CRC exceeds the maximum FEC block size, the burst is partitioned into KFB FEC blocks, each of which is encoded separately. If a burst is partitioned into more than one forward error correction (FEC) blocks, a FEC block CRC is appended to each FEC block before the FEC encoding. The FEC block CRC of a FEC block is calculated based on the entire bits in that FEC block. Each partitioned FEC block including 16-bit FEC block CRC has the same length. The maximum FEC block size is 4800 bits. Concatenation rules are based on the number of information bits and do not depend on the structure of the resource allocation (number of logical resource units and their size). The IEEE WirelessMAN-Advanced utilizes the convolutional turbo code (CTC) with code rate of 1/3. The CTC scheme is extended to support additional FEC block sizes. Furthermore, the FEC block sizes can be regularly increased with predetermined block size resolutions. The FEC block sizes which are multiple of seven are removed for the tail-biting encoding structure. The encoder block depicted in Figure 7 includes the interleaver.

Bit selection and repetition are used in WirelessMAN-Advanced to achieve rate matching. Bit selection adapts the number of coded-bits to the size of the resource allocation which may vary depending on the resource unit size and subframe type. The total subcarriers in the allocated resource unit are segmented to each FEC block. The total number of information and parity bits generated by FEC encoder are considered as the maximum size of circular buffer. Repetition is performed when the number of transmitted bits is larger than the number of selected bits. The selection of coded bits is done cyclically over the buffer. The mother-code bits, the total number of information and parity bits generated by FEC encoder, are considered as a maximum size of circular buffer. In case that the size of the circular buffer Nbuffer is smaller than the number of mother-code bits, the first Nbuffer bits of mother-code bits are considered as selected bits.

Modulation constellations of QPSK, 16QAM, and 64QAM are supported. The mapping of bits to the constellation point depends on the constellation-rearrangement (CoRe) version used for HARQ retransmission as described and further depends on the MIMO scheme. The QAM symbols are mapped into the input of the MIMO encoder. The sizes include the addition of CRC (per burst and per FEC block), if applicable. Other sizes require padding to the next burst size. The code rate and modulation depend on the burst size and the resource allocation.

Incremental redundancy HARQ (HARQ-IR) is used in WirelessMAN-Advanced by determining the starting position of the bit selection for HARQ retransmissions. Chase combining HARQ (HARQ-CC) is also supported and considered as a special case of HARQ-IR. The 2-bit sub-packet identifier (SPID) is used to identify the starting position. The CoRe scheme can be expressed by a bit-level interleaver. The resource allocation and transmission formats in each retransmission in the downlink can be adapted with control signalling. The resource allocation in each retransmission in the uplink can be fixed or adaptive according to control signalling. In HARQ re-transmissions, the bits or symbols can be transmitted in a different order to exploit the frequency diversity of the channel. For HARQ retransmission, the mapping of bits or modulated symbols to spatial streams may be applied to exploit spatial diversity with given mapping pattern, depending on the type of HARQ-IR. In this case, the predefined set of mapping patterns should be known to the transmitter and receiver. In downlink HARQ, the BS may transmit coded bits exceeding current available soft buffer capacity.

# B.1.2.7 Pilot Structure

# B.1.2.7.1 Downlink Pilot Structure

Transmission of pilot subcarriers in the downlink is necessary to allow channel estimation, channel quality measurement (e.g., CQI), frequency offset estimation, etc. To optimize the system performance in different propagation environments, WirelessMAN-Advanced supports both common and dedicated pilot structures. The classification of pilots into common and dedicated is done based on their usage. The common pilots can be used in distributed allocation by all mobile stations. Dedicated pilots can be used with both localized and distributed allocations. They are associated with user specific pilot index. The dedicated pilots are associated with a specific resource allocation, are intended to be used by the MSs allocated to specific resource allocation, and therefore shall be precoded or beamformed in the same way as the data subcarriers of the resource allocation. The pilot structure is defined for up to eight streams and there is a unified design for common and dedicated pilots. There is equal pilot density per spatial stream; however, there is not necessarily equal pilot density per OFDM symbols.



Figure 7: Downlink/Uplink Pilot Structures for 1, 2, 4, and 8 Streams for Type-1 Subframe

For the subframe consisting of 5 OFDM symbols, the last OFDM symbol is deleted. For the subframe consisting of 7 OFDM symbols, the first OFDM symbol is added as the 7th OFDM symbol. To overcome the effects of pilot interference among the neighbouring sectors or base stations, an interlaced pilot structure is utilized by cyclically shifting the base pilot pattern such that the pilots of neighbouring cells do not overlap.

# B.1.2.7.2 Uplink Pilot Structure

The uplink pilots are dedicated to localized and distributed resource units and are precoded using the same precoding as the data subcarriers of the resource allocation. The pilot structure is defined for up to 4 transmit streams for SU-MIMO and up to 8 streams for CSM. When pilots are power-boosted, each data subcarrier should have the same transmission power across all OFDM symbols in a resource block. The 18×6 uplink resource blocks use the same pilot patterns as the downlink counterpart. The pilot pattern for 6×6 tile structure is different and it is shown in Figure 7.

# B.1.2.8 Control Channels

Downlink control channels carry essential information for system operation. Depending on the type of control signalling, information is transmitted over different time intervals (i.e., from superframe to subframe intervals). The system configuration parameters are transmitted at the superframe intervals, whereas control signalling related to user data allocations is transmitted at the frame/subframe intervals.

# B.1.2.8.1 Downlink Control Channels

# Superframe Header

The superframe header carries essential system parameters and configuration information. The content of superframe header is divided into two segments; i.e., primary and secondary superframe headers. The primary superframe header is transmitted every superframe, whereas the secondary superframe header is transmitted over one or more superframes. The primary and secondary superframe headers are located in the first subframe within a superframe and are time-division-multiplexed with the advanced preamble. The superframe header occupies no more than 5 MHz bandwidth. The primary superframe header is transmitted using predetermined modulation and coding scheme. The secondary superframe header is transmitted using predetermined modulation scheme while its repetition coding factor is signalled in the primary superframe header. The primary and secondary superframe headers are transmitted using two spatial streams and space-frequency block coding to improve coverage and reliability. The MS is not required to know the antenna configuration prior to decoding the primary superframe header. The information transmitted in the secondary superframe header is divided into different sub-packets. The secondary superframe header sub-packet 1 (SP1) includes information needed for network re-entry. The secondary superframe header sub-packet 2 (SP2) contains information for initial network entry. The secondary superframe header sub-packet 3 (SP3) contains remaining system information for maintaining communication with the BS.

# Advanced MAP (A-MAP)

The advanced MAP (i.e., unicast control information) consists of both user-specific and non-user-specific control information. Non-user-specific control information includes information that is not dedicated to a specific user or a specific group of users. It contains information required to decode user-specific control signalling. User specific control information consists of information intended for one or more users. It includes scheduling assignment, power control information, and HARQ feedback. Resources can be allocated persistently to the mobile stations. Group control information is used to allocate resources and/or configure resources to one or multiple mobile stations within a user group. Within a subframe, control and data channels are frequency-division-multiplexed. Both control and data channels are transmitted on logical resource units that span over all OFDM symbols within a subframe.

Each DL subframe contains a control region including both non-user-specific and user-specific control information. All advanced MAPs share a time-frequency region known as A-MAP region. The control regions are located in every subframe. The corresponding UL allocations occurs L subframes later, where L is determined by A-MAP relevance. The coding rate is predetermined for non-user-specific information while it is indicated by superframe header for user-specific control information.

An advanced MAP (A-MAP) allocation Information Element (IE) is defined as the basic element of unicast service control. A unicast control IE may be addressed to one user using a unicast identifier or to multiple users using a multicast/broadcast identifier. The identifier is masked with CRC in the advanced MAP allocation information element. It may contain information related to resource allocation, HARQ, MIMO transmission mode, etc. Each A-MAP information element is coded separately. Non-user-specific control information is encoded separately from the user-specific control information. In the DL subframes, frequency partition for reuse-1 and/or frequency partition for power-boosted reuse-3 may contain an A-MAP region. The A-MAP region occupies the first few distributed resource units in a frequency partition. The structure of an A-MAP region is illustrated in Figure 8. The resource occupied by each A-MAP physical channel may vary depending on the system configuration and scheduler operation. There are different types of A-MAPs as follows:

* **Assignment A-MAP** contains resource assignment information which is categorized into multiple types of resource assignment IEs (assignment A-MAP IE). The minimum logical resource unit in the assignment A-MAP consists of 56 data tones. Assignment A-MAP IEs with less than 40 bits are zero-padded to 40 bits. Assignment A-MAP IEs with more than 40 bits are divided into several segmented IEs, each with 40 bits. Segments of an assignment A-MAP IE are separately coded and modulated and occupy a number of logically contiguous resource units. Assignment A-MAP IEs are grouped together based on channel coding rate after separate channel encoding of each IE. Assignment A-MAP IEs in the same group are transmitted in the same frequency partition with the same channel coding rate. Each assign­ment A-MAP group may occupy several logically contiguous resource units. The number of assignment A-MAP IEs in each assignment A-MAP group is signalled through non-user specific A-MAP in the same subframe. If two assignment A-MAP groups using two channel coding rates are present in an A-MAP region, assign­ment A-MAP group using lower channel coding rate is allocated first, followed by assignment A-MAP group using higher channel coding rate. For a segmentable assignment A-MAP IE (i.e., an assignment A-MAP IE that occupies more than one minimum logical resource unit using QPSK 1/2), each segment is counted as one assignment A-MAP IE.
* **HARQ Feedback A-MAP** contains HARQ ACK/NACK information for UL data transmission.
* **Power Control A-MAP** includes fast power control command to mobile stations.

There are different assignment A-MAP IE types that distinguish between DL/UL, per­sistent/non-persistent, single user/group resource allocation, basic/extended IE scenarios. Different types of assignment A-MAPs and their usage are shown in Table 2.

Table 2: Assignment A-MAP IE Types and Their Usage

|  |  |
| --- | --- |
| Assignment A-MAP IE Type | Usage |
| DL Basic Assignment | Allocation information for MS to decode DL bursts using contiguous logical resources |
| UL Basic Assignment | Allocation information for MS to transmit UL bursts using contiguous logical resources |
| DL Sub-band Assignment | Allocation information for MS to decode DL bursts using sub-band based resources |
| UL Sub-band Assignment | Allocation information for MS to transmit UL bursts using sub-band based resources |
| Feedback Allocation | Allocation or de-allocation of UL fast feedback control channels to an MS |
| UL Sounding Command | Control information for MS to request UL sounding transmission |
| CDMA Allocation | Allocation for MS requesting bandwidth using a ranging or bandwidth request codes |
| DL Persistent | DL persistent resource allocation |
| UL Persistent | UL persistent resource allocation |
| Group Resource Allocation | Group scheduling and resource allocation |
| Feedback Polling | Allocation for MS to send MIMO feedback using MAC messages or signalling headers |
| BR-ACK | Indication of decoding status of bandwidth request opportunities and resource allocation of bandwidth request header |
| Broadcast | Broadcast burst allocation and other broadcast information |



Figure 8: A-MAP Location and Structure (Example)

# B.1.2.8.2 Uplink Control Channels

# MIMO Feedback

MIMO feedback provides wideband and/or narrowband spatial characteristics of the channel that are required for MIMO operation. The MIMO mode, precoding matrix index, rank adaptation information, channel covariance matrix elements, and best subband index are examples of MIMO feedback information.

# HARQ Feedback

HARQ feedback (ACK/NACK) is used to acknowledge downlink data transmissions. The uplink HARQ feedback channel starts at a predetermined offset with respect to the corresponding downlink transmission. The HARQ feedback channel is frequency-division-multiplexed with other control and data channels. Orthogonal codes are used to multiplex multiple HARQ feedback channels. The HARQ feedback channel comprises three distributed mini-tiles.

# Bandwidth Request

Bandwidth requests are used to indicate the amount of bandwidth required by a user. Bandwidth requests are transmitted through indicators or messages. A bandwidth request indicator notifies the base station of an uplink grant request by the mobile station sending the indicator. Bandwidth request messages can include information about the status of queued traffic at the mobile station such as buffer size and quality of service parameters. Contention or non-contention based random access is used to transmit bandwidth request information on this control channel. The contention-based bandwidth request procedure is illustrated in Figure 9. A 5-step regular procedure or an optional 3-step quick access procedure is utilized. Steps 2 and 3 can be skipped in a quick access procedure. In step 1, the MS sends a bandwidth request (BW-REQ) indicator for quick access that may indicate information such as MS addressing and/or request size and/or uplink transmit power report, and/or QoS parameters, and the BS may allocate uplink grant based on certain policy.



Figure 9: Bandwidth Request Procedure

The bandwidth request channel starts at a configurable location with the configuration defined in a downlink broadcast control message. The bandwidth request channel is frequency-division-multiplexed with other uplink control and data channels. A BW-REQ tile is defined as 6 subcarriers by 6 OFDM symbols. Each BW-REQ channel consists of 3 distributed BW-REQ tiles. Multiple bandwidth request indicators can be transmitted on the same BW-REQ channel using code-division multiplexing.

# Channel Quality Indicators

Channel quality feedback provides information about channel conditions as seen by the user. This information is used by the base station for link adaptation, resource allocation, power control, etc. The channel quality measurement includes both narrowband and wideband measurements. The CQI feedback overhead can be reduced through differential feedback or other compression techniques. Examples of CQI include effective carrier to interference plus noise ratio (CINR), band selection, etc.

The default subframe size for transmission of uplink control information is 6 symbols. The fast feedback channel carries channel quality feedback and MIMO feedback. There are two types of uplink fast feedback control channels: a) primary and b) secondary fast feedback channels. The secondary fast feedback channel can be used to support CQI reporting at higher code rate and thus more CQI information bits. The fast feedback channel is frequency-division-multiplexed with other uplink control and data channels.

The fast feedback channel starts at a predetermined location, with the size defined in a downlink broadcast control message. Fast feedback allocations to a mobile station can be periodic and the allocations are configurable. The specific type of feedback information carried on each fast feedback opportunity can be different. The number of bits carried in the fast feedback channel can be adaptive. For efficient transmission of feedback channels a mini-tile is defined comprising 2 subcarriers by 6 OFDM symbols. One logical resource unit consists of 9 mini-tiles and can be shared by multiple fast feedback channels.

# Uplink Sounding Channel

The sounding channel is used by a user terminal to transmit sounding reference signals to enable the base station to measure uplink channel conditions. The sounding channel may occupy either specific uplink sub-bands or the entire bandwidth over an OFDM symbol. The base station can configure a mobile station to transmit the uplink sounding signal over predefined subcarriers within specific sub-bands or the entire bandwidth. The sounding channel is orthogonally multiplexed (in time or frequency) with other control and data channels. Furthermore, the base station can configure multiple user terminals to transmit sounding signals on the corresponding sounding channels using code-, frequency-, or time-division multiplexing. Power control for the sounding channel can be utilized to adjust the sounding quality. The transmit power from each mobile terminal may be separately controlled according to certain CINR target values.

# Ranging Channel

The ranging channel is used for uplink synchronization. The ranging channel can be further classified into ranging for non-synchronized and synchronized mobile stations. The ranging channel for non-synchronized mobile station(NS-RCH) is used for initial network entry and for handover to a target BS. The ranging channel for synchronized mobile station(S-RCH) is used for periodic ranging. In a femtocell, mobile stations shall perform initial ranging, handover ranging, and periodic ranging by using the S-RCH.

The ranging channel structures for non-synchronized mobile stations are shown in Figure 10.



Figure 10: Ranging Channel Structure for Non-synchronized Access

# Power Control

Power control mechanism is supported for downlink and uplink. Using downlink power control, user-specific information with dedicated pilot is received by the terminal with the controlled power level. The downlink advanced MAPs can be power-controlled based on the terminal uplink channel quality feedback.

The uplink power control is supported to compensate the path loss, shadowing, fast fading and implementation loss as well as to mitigate inter-cell and intra-cell interference. The base station can transmit necessary information through control channel or message to terminals to support uplink power control. The parameters of power control algorithm are optimized on system-wide basis by the base station and broadcasted periodically.

In high mobility scenarios, power control scheme may not be able to compensate the fast fading channel effect because of the variations of the channel impulse response. As a result, the power control is used to compensate the distance-dependent path loss, shadowing and implementation loss only.

The channel variations and implementation loss are compensated via open-loop power control without frequently interacting with the base station. The terminal can determine the transmit power based on the transmission parameters sent by the serving base station, uplink channel transmission quality, downlink channel state information, and interference knowledge obtained from downlink. Open-loop power control provides a coarse initial power setting of the terminal when an initial connection is established.

The dynamic channel variations are compensated via closed-loop power control with power control commands from the serving base station. The base station measures uplink channel state and interference information using uplink data and/or control channel transmissions and sends power control commands to the terminal. The terminal adjusts its transmission power based on the power control commands from the base station.

# B.1.2.9 Downlink Synchronization (Advanced Preamble)

WirelessMAN-Advanced utilizes a new hierarchical structure for the DL synchronization where two sets of preambles primary advanced preamble (PA-Preamble) and secondary advanced preamble (SA-Preamble) are transmitted (Figure 11). One PA-Preamble symbol and two SA-Preamble symbols exist within the superframe. The location of the A-Preamble symbol is specified as the first symbol of frame except for the last frame. PA-Preamble is located at the first symbol of second frame in a superframe while SA-Preamble is located at the first symbol of the first and the third frames. The PA-Preamblecarries infor­mation about system bandwidth and carrier configuration. The PA-Preamblehas a fixed bandwidth of 5 MHz. A frequency reuse of one is applied to the PA-Preamblein frequency domain. SA-Preamble is repeated once every two frames and spans the entire system bandwidth and carries the cell ID. A frequency reuse of three is used for this set of sequences to mitigate inter-cell interference. SA-Preamble carries 768 distinct cell IDs. The set of SA-Preamble sequences is partitioned and each partition is dedicated to specific BS type such as macro BS, femto BS, etc. The partition information is broadest in the secondary superframe header and AAI-SCD message.



Figure 11: Structure of the WirelessMAN-Advanced Advanced Preambles

# B.1.2.10 Multi-Antenna Techniques in WirelessMAN-Advanced

# B.1.2.10.1 Downlink MIMO Structure

WirelessMAN-Advanced supports several advanced multi-antenna techniques including single and multi-user MIMO (spatial multiplexing and beamforming) as well as a number of transmit diversity schemes. In single-user MIMO (SU-MIMO) scheme only one user can be scheduled over one (time, frequency, space) resource unit. In multi-user MIMO (MU-MIMO), on the other hand, multiple users can be scheduled in one resource unit. Vertical encoding utilizes one encoder block (or layer), whereas multi-layer encoding uses multiple encoders (or multiple layers). A layer is defined as a coding and modulation input path to the MIMO encoder. A stream is defined as the output of the MIMO encoder that is further processed through the beamforming or the precoder block. For spatial multiplexing, the rank is defined as the number of streams to be used for the user.



Figure 12: Illustration of Downlink MIMO Structure

The DL MIMO transmitter structure is shown in Figure 12. The encoder block contains the channel encoder, interleaving, rate-matching, and modulating blocks per layer. The resource mapping block maps the complex-valued modulation symbols to the corresponding time-frequency resources. The MIMO encoder block maps the layers onto the streams, which are further processed through the precoder block. The precoder block maps the streams to antennas by generating the antenna-specific data symbols according to the selected MIMO mode. The OFDM symbol construction block maps antenna-specific data to the OFDM symbols. The feedback block contains feedback information such as CQI or channel state information (CSI) from the MS. Table 3 contains information on various MIMO modes supported by the WirelessMAN-Advanced.

Table 3: DL MIMO Modes

|  |  |  |  |
| --- | --- | --- | --- |
| Mode Index | Description | MIMO Encoding Format | MIMO Precoding |
| Mode 0 | Open-Loop SU-MIMO (TX Diversity) | SFBC | Non-Adaptive |
| Mode 1 | Open-Loop SU-MIMO (Spatial Multiplexing) | Vertical Encoding | Non-Adaptive |
| Mode 2 | Closed-Loop SU-MIMO (Spatial Multiplexing) | Vertical Encoding | Adaptive |
| Mode 3 | Open-Loop MU-MIMO (Spatial Multiplexing) | Multi-layer Encoding | Non-Adaptive |
| Mode 4 | Closed-Loop MU-MIMO (Spatial Multiplexing) | Multi-layer Encoding | Adaptive |
| Mode 5 | Open-Loop SU-MIMO (TX Diversity) | Conjugate Data Repetition | Non-Adaptive |

The minimum antenna configuration in the DL and UL is 2x2 and 1x2, respectively. For open-loop spatial multiplexing and closed-loop SU-MIMO, the number of streams is constrained to the minimum of number of transmit or receive antennas. For open-loop transmit diversity modes, the number of streams depends on the space-time coding (STC) schemes that are used by the MIMO encoder. The MU-MIMO can support up to 2 streams with 2 transmit antennas and up to 4 streams for 4 transmit antennas and up to 8 streams for 8 transmit antennas. Table 4 summarized DL MIMO parameters for various MIMO modes.

Table 4: DL MIMO Parameters

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Number of Transmit Antennas | STC Rate per Layer | Number of Streams | Number of Subcarriers | Number of Layers |
| MIMO Mode 0 | 2 | 1 | 2 | 2 | 1 |
| 4 | 1 | 2 | 2 | 1 |
| 8 | 1 | 2 | 2 | 1 |
| MIMO Mode 1 and MIMO Mode 2 | 2 | 1 | 1 | 1 | 1 |
| 2 | 2 | 2 | 1 | 1 |
| 4 | 1 | 1 | 1 | 1 |
| 4 | 2 | 2 | 1 | 1 |
| 4 | 3 | 3 | 1 | 1 |
| 4 | 4 | 4 | 1 | 1 |
| 8 | 1 | 1 | 1 | 1 |
| 8 | 2 | 2 | 1 | 1 |
| 8 | 3 | 3 | 1 | 1 |
| 8 | 4 | 4 | 1 | 1 |
| 8 | 5 | 5 | 1 | 1 |
| 8 | 6 | 6 | 1 | 1 |
| 8 | 7 | 7 | 1 | 1 |
| 8 | 8 | 8 | 1 | 1 |
| MIMO Mode 3 and MIMO Mode 4 | 2 | 1 | 2 | 1 | 2 |
| 4 | 1 | 2 | 1 | 2 |
| 4 | 1 | 3 | 1 | 3 |
| 4 | 1 | 4 | 1 | 4 |
| 8 | 1 | 2 | 1 | 2 |
| 8 | 1 | 3 | 1 | 3 |
| 8 | 1 | 4 | 1 | 4 |
| MIMO Mode 4 | 4 | 2 and 1 a | 3 | 1 | 2 |
| 4 | 2 and 1 b | 4 | 1 | 3 |
| 4 | 2 | 4 | 1 | 2 |
| 8 | 2 and 1 a | 3 | 1 | 2 |
| 8 | 2 and 1 b | 4 | 1 | 3 |
| 8 | 2 | 4 | 1 | 2 |
| 8 | 1 | 8 | 1 | 8 |
| 8 | 2 and 1c | 8 | 1 | 7 |
| 8 | 2 and 1d | 8 | 1 | 6 |
| 8 | 2 and 1e | 8 | 1 | 5 |
| 8 | 2 | 8 | 1 | 4 |
| MIMO Mode 5 | 2 | 1/2 | 1 | 2 | 1 |
| 4 | 1/2 | 1 | 2 | 1 |
| 7 | 1/2 | 1 | 2 | 1 |

a 2 streams to one AMS and 1 stream to another AMS, with 1 layer each.

b 2 streams to one AMS and 1 stream each to the other two AMSs, with 1 layer each.

c 2 streams to one AMS and 1 stream each to the other six AMSs, with 1 layer each.

d  2 streams each to two AMS and 1 stream each to the other four AMSs, with 1 layer each.

e 2 streams each to three AMS and 1 stream each to the other two AMSs, with 1 layer each.

The stream to antenna mapping depends on the MIMO scheme that is used. The CQI and rank feedback are transmitted to assist the BS in rank adaptation, mode switching, and rate adaptation. For spatial multiplexing, the rank is defined as the number of streams to be used for each user. In FDD and TDD systems, unitary codebook based precoding is used for closed-loop SU-MIMO. An MS may feedback some information to the BS in closed-loop SU-MIMO such as rank, sub-band selection, CQI, precoding matrix index (PMI), and long-term channel state information.

The MU-MIMO transmission with up to two streams per user is supported. Beamforming is enabled with this precoding mechanism. WirelessMAN-Advanced has the capability to adapt between SU-MIMO and MU-MIMO in a predefined and flexible manner. Multi-BS MIMO techniques are also supported for improving sector and cell-edge throughput using multi-BS collaborative precoding, network coordinated beamforming, or inter-cell interference cancellation.

# B.1.2.10.2 Uplink MIMO

The block diagram of uplink MIMO transmitter is illustrated in Figure 13.



Figure 13: Illustration UL MIMO Structure

The BS will schedule users to resource blocks and determines the modulation and coding scheme (MCS) level and MIMO parameters (mode, rank, etc.). The supported antenna configurations include 1, 2, or 4 transmit antennas and more than two receive antennas. UL MIMO modes and parameters are contained in Table 5 and Table 6.

Table 5: UL MIMO Modes

|  |  |  |  |
| --- | --- | --- | --- |
| Mode Index | Description | MIMO Encoding Format | MIMO Precoding |
| Mode 0 | Open-Loop SU-MIMO (TX Diversity) | SFBC | Non-Adaptive |
| Mode 1 | Open-Loop SU-MIMO (Spatial Multiplexing) | Vertical Encoding | Non-Adaptive |
| Mode 2 | Closed-Loop SU-MIMO (Spatial Multiplexing) | Vertical Encoding | Adaptive |
| Mode 3 | Open-Loop Collaborative Spatial Multiplexing (MU-MIMO) | Vertical Encoding | Non-Adaptive |
| Mode 4 | Closed-Loop Collaborative Spatial Multiplexing (MU-MIMO) | Vertical Encoding | Adaptive |

Table 6: UL MIMO Parameters

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Number of Transmit Antennas | STC Rate per Layer | Number of Streams | Number of Subcarriers | Number of Layers |
| MIMO Mode 0 | 2 | 1 | 2 | 2 | 1 |
| 4 | 1 | 2 | 2 | 1 |
| MIMO Mode 1 | 1 | 1 | 1 | 1 | 1 |
| MIMO Mode 1 and MIMO Mode 2 | 2 | 1 | 1 | 1 | 1 |
| 2 | 2 | 2 | 1 | 1 |
| 4 | 1 | 1 | 1 | 1 |
| 4 | 2 | 2 | 1 | 1 |
| 4 | 3 | 3 | 1 | 1 |
| 4 | 4 | 4 | 1 | 1 |
| MIMO Mode 3 and MIMO Mode 4 | 1 | 1 | 1 | 1 | 1 |
| 2 | 1 | 1 | 1 | 1 |
| 2 | 2 | 2 | 1 | 1 |
| 4 | 1 | 1 | 1 | 1 |
| 4 | 2 | 2 | 1 | 1 |
| 4 | 3 | 3 | 1 | 1 |
| 4 | 4 | 4 | 1 | 1 |

The supported UL transmit diversity modes include 2 and 4 transmit antenna schemes with rate 1 such as space frequency block coding (SFBC) and 2 stream precoder. In FDD and TDD systems, unitary codebook-based precoding is supported. In this mode, the MS transmits a sounding reference signal in the UL to assist the UL scheduling and precoder selection in the BS. The BS signals the resource allocation, MCS, rank, preferred precoder index, and packet size to the MS. UL MU-MIMO enables multiple mobile stations to be spatially multiplexed on the same radio resources. Both open-loop and closed-loop MU-MIMO are supported. The mobile stations with single transmit antenna can operate in open-loop SU- or MU-MIMO mode.

# B.1.3 Overview of the WirelessMAN-Advanced MAC Layer

The following sections describe selected MAC features.

# 

# B.1.3.1 MAC Addressing

WirelessMAN-Advanced standard defines global and logical addresses for a mobile station that identify the user and its connections during a session. The MS is identified by the globally unique 48-bit IEEE extended unique identifier assigned by the IEEE Registration Authority. The mobile station is further assigned the following logical identifiers: 1) A station identifier during network entry (or network re-entry), that uniquely identifies the MS within the cell, and 2) a flow identifier that uniquely identifies the control connections and transport connections with the MS. A temporary station identifier is used to protect the mapping between the actual station identifier during network entry. A deregistration identifier is defined to uniquely identify the MS within the set of paging group identifiers, paging cycle, and paging offset.

# B.1.3.2 Network Entry

Network entry is the procedure through which a mobile station detects a cellular network and establishes a connection with that network. The network entry has the following steps (see Figure 15):

* Synchronization with the BS by acquiring the preambles
* Acquiring necessary system information such as BS and network service provider identifiers for initial network entry and cell selection.
* Initial ranging
* Basic capability negotiation
* Authentication/authorization and key exchange
* registration and service flow setup



Figure 14: Network Entry Procedures

# B.1.3.3 Connection Management and Quality of Service

A connection is defined as a mapping between the MAC layers of a BS and one (or several) MS. If there is a one-to-one mapping between one BS and one MS, the connection is called a unicast connection; otherwise, it is called a multicast or broadcast connection. Two types of connections are specified: control connections and transport connections. Control connections are used to carry MAC control messages. Transport connections are used to carry user data including upper layer signalling messages. A MAC control message is never transferred over transport connection, and user data is never transferred over the control connections. One pair of bi-directional (DL/UL) unicast control connections are automatically established when an MS performs initial network entry.

All the user data communications are in the context of transport connections. A transport connection is uni-directional and established with a unique flow identifier. Each transport connec­tion is associated with an active service flow to provide various levels of QoS required by the service flow. An MS may have multiple transport connections which have different set of QoS parameters, and each transport connection may have one or more sets of QoS parameters. The transport connection is established when the associated active service flow is admitted or activated, and released when the associated service flow becomes inactive. Transport connections can be pre-provisioned or dynamically created. Pre-provisioned connections are those established by system for an MS during the MS network entry. On the other hand, the BS or the MS can cre­ate new connections dynamically if required.

# B.1.3.4 MAC Header

WirelessMAN-Advanced specifies a number of efficient MAC headers for various applications comprising of fewer fields with shorter size compared to IEEE 802.16-2009 standard generic MAC header. The advanced generic MAC header consists of Extended Header Indicator, Flow Identifier, and Payload Length fields. Other MAC header types include two-byte short-packet MAC header, which is defined to support small-payload applications such as VoIP and is characterized by small data packets and non-ARQ connection, Fragmentation extended header, Packing extended header for transport connections, MAC Control extended header for control connections, and Multiplexing extended header that is used when data from multiple connections associated with the same security association is present in the payload of the MAC PDU.



Figure 15: Advanced Generic MAC Headers

# B.1.3.5 ARQ and HARQ Functions

An ARQ block is generated from one or multiple MAC service data units (SDUs) or MAC SDU fragment(s). ARQ blocks can be variable in size and are sequentially numbered.

WirelessMAN-Advanced uses adaptive asynchronous and non-adaptive synchronous HARQ schemes in the downlink and uplink, respectively. The HARQ operation is relying on an N-process (multi-channel) stop-and-wait protocol. In adaptive asynchronous HARQ, the resource allocation and transmission format for the HARQ retransmissions may be different from the initial transmission. In case of retransmission, control signalling is required to indicate the resource allocation and transmission format along with other HARQ necessary parameters. A non-adaptive synchronous HARQ scheme is used in the uplink where the parameters and the resource allocation for the retransmission are known a priori.

# B.1.3.6 Mobility Management and Handover

WirelessMAN-Advanced supports both network-controlled and MS-assisted handover (HO). As illustrated in Figure 16, the handover procedure may be initiated by either MS or BS; the final handover decision and target BS selection may be made either by the serving BS or the MS. The MS executes the handover or cancels the procedure through HO cancellation message. The network re-entry procedure with the target BS, as shown in Figure 16, may be optimized by target BS possession of MS information obtained from serving BS via core network. The MS may also maintain communication with serving BS while performing network re-entry at target BS as directed by serving BS.



Figure 16: WirelessMAN-Advanced Handover Procedure

# B.1.3.7 Power Management

WirelessMAN-Advanced provides power management functions including sleep mode and idle mode to mitigate power consumption of the mobile station. Sleep mode is a state in which an MS performs pre-negotiated periods of absence from the serving BS. The sleep mode may be enacted when an MS is in the connected state. Using the sleep mode, the MS is provided with a series of alternative listening and sleep windows. The listening window is the time interval in which MS is available for transmit/receive of control signalling and data. The WirelessMAN-Advanced has the capability of dynamically adjusting the duration of sleep and listening windows within a sleep cycle based on changing traffic patterns and HARQ operations. When MS is in active mode, sleep parameters are negotiated between MS and BS. The base station instructs the MS to enter sleep mode. MAC management messages can be used for sleep mode request/response. The period of the sleep cycle is measured in units of frames or superframes and is the sum of a sleep and listening windows. During the MS listening window, BS may transmit the traffic indication message intended for one or multiple mobile stations. The listening window can be extended through explicit or implicit signalling. The maximum length of the extension is to the end of the current sleep cycle.

Idle mode allows the MS to become periodically available for downlink broadcast traffic messaging such as paging message without registration with the network. The network assigns mobile stations in the idle mode to a paging group during idle mode entry or location update. If an MS is assigned to multiple paging groups, it may also be assigned multiple paging offsets within a paging cycle where each paging offset corresponds to a separate paging group. The assignment of multiple paging offsets to an MS allows monitoring of the paging messages at different paging offset when the MS is located in one of its paging groups. The distance between two adjacent paging offsets should be long enough so that the MS paged in the first paging offset can inform the network before the next paging offset in the same paging cycle occurs, thereby avoiding unnecessary paging in the next paging offset. The MS monitors the paging message during listening interval. The paging message contains identification of the mobile stations to be notified of pending traffic or location update. The start of the paging listening interval is calculated based on paging cycle and paging offset are defined in terms of number of superframes. The serving BS transmits the list of paging group identifiers (PGID) at the predetermined location at the beginning of the paging available interval. During paging available interval, the MS monitors the superframe header and if there is an indication of any change in system configuration information, the MS will acquire the latest system information at the next instance of superframe header transmission (i.e., next superframe header). To provide location privacy, the paging controller assigns Deregistration identifiers to uniquely identify the mobile stations in the idle mode in a particular paging group.

An MS in idle mode performs location update, if either of these conditions are met, paging group location update, timer based location update, or power down location update. The MS performs the location update when the MS detects a change in paging group by monitoring the PGIDs, which are transmitted by the BS. The MS periodically performs location update procedure prior to the expiration of idle mode timer. At every location update including paging group update, the idle mode timer is reset.

# B.1.3.8 Security

Security functions provide subscribers with privacy, authentication, and confidentiality across WirelessMAN-Advanced network. The PKM protocol provides mutual and unilateral authentication and establishes confidentiality between the MS and the BS by supporting transparent exchange of authentication and authorization (EAP) messages.

The MS and the BS may support encryption methods and algorithms for secure transmission of MAC PDUs. WirelessMAN-Advanced supports selectively confidentiality or integrity protection over MAC control messages. Figure 18 shows the functional blocks of WirelessMAN-Advanced security architecture.



Figure 17: Functional Blocks of WirelessMAN-Advanced Security Architecture

The security architecture is divided into security management and encryption and integrity logical entities. The security management functions include overall security management and control, EAP encapsulation/de-encapsulation, privacy key management (PKM) control, security association management, and identity/location privacy. To accomplish identity/location privacy, the MSID (i.e. MS MAC address) is not disclosed over the air even during network entry. BS assigns an STID to the MS which is securely transmitted to the MS so that the MS’s identity and location can be hidden. The encryption and integrity protection entity functions include encryption of user data and authentication, control message authentication, message confidentiality protection.

**B.2 Detailed specification of the radio interface technology**

Detailed specifications described in this Recommendation are developed around a “Global Core Specification” (GCS)[[8]](#footnote-8), which is related to externally developed materials incorporated by specific references for a specific technology. The process and use of the GCS, references, and related notifications and certifications are found as IMT-ADV/24[[9]](#footnote-9)

The standards contained in this section are derived from the global core specifications for IMT‑Advanced contained at <http://ties.itu.int/u/itu-r/ede/rsg5/xxxxx/xxx/xxxxxxxx/>. The following notes apply to the sections below, where indicated:

1) The [relevant][TBD] (the ***Transposing Organisations)*** should make their reference material available from their web site.

2) This information was supplied by the ***Transposing Organizations*** and relates to their own deliverables of the transposed global core specification.

*[Editor’s note: the above notes will be revisited when the final version of IMT.RSPEC will be finalised]*

*[Editor’s Note: to be filled with stakeholder’s input(s)]*

**B.2.1 WirelessMAN-Advanced Specification**

The WirelessMAN-Advanced specification is provided in Clause 16.1 of IEEE Std 802.16, as detailed in Section B.2.2. Anything in Section B.2.2 that is not mentioned in Clause 16.1 of IEEE Std 802.16 is excluded.

**B.2.2 IEEE Std 802.16**

**Standard for local and metropolitan area networks – Air interface for broadband wireless access systems**

This standard specifies the air interface, including the medium access control layer (MAC) and physical layer (PHY), of combined fixed and mobile point-to-multipoint broadband wireless access (BWA) systems providing multiple services. The MAC is structured to support multiple PHY specifications, each suited to a particular operational environment.

IEEE Std 802.16 is comprised of IEEE Std 802.16-2009, as amended by IEEE Std 802.16j, IEEE Std 802.16h, and IEEE Std 802.16m.

**B.2.2.1 IEEE Std 802.16-2009**

**Standard for local and metropolitan area networks – Part 16: Air interface for broadband wireless access systems**

This standard specifies the air interface, including the medium access control layer (MAC) and physical layer (PHY), of combined fixed and mobile point-to-multipoint broadband wireless access (BWA) systems providing multiple services. The MAC is structured to support multiple PHY specifications, each suited to a particular operational environment.

**B.2.2.2 IEEE Std 802.16j**

**Standard for local and metropolitan area networks – Part 16: Air interface for broadband wireless access systems – Amendment 1: Multiple relay specification**

This amendment updates and expands IEEE Std 802.16-2009, specifying physical layer and medium access control layer enhancements to IEEE Std 802.16 for licensed bands to enable the operation of relay stations. Subscriber station specifications are not changed.

**B.2.2.3 IEEE Std 802.16h**

**Standard for local and metropolitan area networks – Part 16: Air interface for broadband wireless access systems – Amendment 2: Improved coexistence mechanisms for license-exempt operation**

This amendment updates and expands IEEE Std 802.16, specifying improved mechanisms, as policies and medium access control enhancements, to enable coexistence among license-exempt systems and to facilitate the coexistence of such systems with primary users.

**B.2.2.4 IEEE Std 802.16m**

**Standard for local and metropolitan area networks – Part 16: Air interface for broadband wireless access systems – Amendment 3: Advanced air interface**

This amendment specifies the WirelessMAN-Advanced air interface, an enhanced air interface designed to meet the requirements of the IMT-Advanced standardization activity conducted by the ITU-R. The amendment is based on the WirelessMAN-OFDMA specification of IEEE Std 802.16 and provides continuing support for WirelessMAN-OFDMA subscriber stations.

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1. Data rates sourced from Recommendation ITU‑R M.1645. [↑](#footnote-ref-1)
2. Developed by 3GPP as *LTE Release 10 and Beyond (LTE-Advanced)*. [↑](#footnote-ref-2)
3. Developed by IEEE as the *WirelessMAN-Advanced* specification incorporated in IEEE Std 802.16 beginning with approval of IEEE Std 802.16m. [↑](#footnote-ref-3)
4. Developed by 3GPP as *LTE Release 10 and Beyond (LTE-Advanced)*. [↑](#footnote-ref-4)
5. A “GCS” (Global Core Specification) is the set of specifications that defines a single RIT, an SRIT, or a RIT within an SRIT. [↑](#footnote-ref-5)
6. ADV/24 is available on the ITU-R WP 5D web page under the link “IMT-Advanced documents” (http://www.itu.int/md/R07-IMT.ADV-C-0024/e [↑](#footnote-ref-6)
7. Developed by IEEE as the *WirelessMAN-Advanced* specification incorporated in IEEE Std 802.16 beginning with approval of IEEE Std 802.16m. [↑](#footnote-ref-7)
8. A “GCS” (Global Core Specification) is the set of specifications that defines a single RIT, an SRIT, or a RIT within an SRIT. [↑](#footnote-ref-8)
9. ADV/24 is available on the ITU-R WP 5D web page under the link “IMT-Advanced documents” (http://www.itu.int/md/R07-IMT.ADV-C-0024/e [↑](#footnote-ref-9)