MCMC MTSFB TC G003:2015

TECHNICAL CODE

INTERNATIONAL MOBILE TELECOMMUNICATIONS - ADVANCED (IMT – ADVANCED) SYSTEM AND SPECIFICATIONS

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Celcom Axiata Berhad

DiGi Telecommunications Sdn Bhd

Orbitage Sdn Bhd

Packet One Networks (Malaysia) Sdn Bhd

U Mobile Sdn Bhd

Universiti Putra Malaysia (UPM)

Universiti Teknologi Malaysia (UTM)

Universiti Tenaga Nasional (UNITEN)

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FOREWORD

This technical code for International Mobile Telecommunications - Advanced (IMT – Advanced) System and Specifications ('this Technical Code') was developed pursuant to Section 185 of the Act 588 by the Malaysian Technical Standards Forum Bhd ('MTSFB') via its International Mobile Telecommunication Working Group.

This Technical Code serves to provide the guidelines for the International Mobile Telecommunications - Advanced (IMT-Advanced) system requirements and specifications for the terrestrial radio interface technologies.

The requirements outlined in this Technical Code are based on ITU-R M.2133 and M.2134 on the requirements and evaluation criteria for the development of IMT-Advanced and the technical performance for the radio interfaces.

This Technical Code shall continue to be valid and effective until reviewed or cancelled.

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INTERNATIONAL MOBILE TELECOMMUNICATIONS - ADVANCED (IMT – ADVANCED) SYSTEM AND SPECIFICATIONS

1. Scope

This Technical Code serves to provide the requirements for the International Mobile Telecommunications - Advanced (IMT-Advanced) system and the specifications for the terrestrial radio interface technologies.

The requirements outlined in this Technical Code are based on ITU-R M.2133 and M.2134 on the requirements and evaluation criteria for the development of IMT-Advanced.

In addition, details, features, parameters and specifications on the radio interfaces of IMT-Advanced are provided to ensure worldwide compatibility, international roaming, and access to high-speed data services. These are based on the two technologies developed by the industry that have been accorded the official designation of IMT-Advanced by ITU-R, namely “LTE-Advanced” and “WirelessMAN-Advanced.”

2. Normative References

The following normative references are indispensable for the application of this Technical Code. For dated references, only the edition cited applies. For undated references, the latest edition of the normative reference (including any amendments) applies

IEEE 802.16m, *Standard for local and metropolitan area networks – Part 16: Air interface for broadband wireless access systems – Amendment 3: Advanced air interface*

Report ITU-R M.2133, *Requirements, evaluation criteria and submission templates for the development of IMT-Advanced*

Report ITU-R M.2134, *Requirements related to technical performance for IMT-Advanced radio interface(s)*

Report ITU-R M.2198, *The outcome of the evaluation, consensus building and decision of the IMT-Advanced process (steps 4-7), including characteristics of IMT-Advanced radio interfaces*

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

3. Abbreviations

For the purposes of this Technical Code, the following abbreviation applies

ARQ	Automatic Repeat Request
BS	Base Station
CA	Carrier Aggregation
CC	Component Carrier
CP	Cyclic Prefix
C-plane	Control Plane
CQI	Channel Quality Indicator
CS	Circuit Switch

DL	Downlink
DRX	Discontinuous Reception
DwPTS	Downlink Pilot Time Slot
E-UTRA	Evolved UTRA
E-UTRAN	Evolved UTRAN
FDD	Frequency Division Duplex
GCS	Global Core Specification
GSM	Global System for Mobile communication
HARQ	Hybrid ARQ
ICIC	Inter-Cell Interference Coordination
IMT	International Mobile Telecommunication
IMTS	Improved Mobile Telephone System
IP	Internet Protocol
LTE	Long Term Evolution
MAC	Medium Access Control
MBMS	Multimedia Broadcast Multicast Service
MIMO	Multiple Input Multiple Output
MME	Mobility Management Entity
MS	Mobile Station
NACK	Negative Acknowledgement
OFDMA	Orthogonal Frequency Division Multiple Access
PCCH	Paging Control Channel
PCFICH	Physical Control Format Indicator Channel
PDCCH	Physical Downlink Control Channel
PDCP	Packet Data Convergence Protocol
PHICH	Physical Hybrid ARQ Indicator Channel
PHY	Physical layer
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
RF	Radio Frequency
RLC	Radio Link Control
RRC	Radio Resource Control
SCH	Synchronization Channel
SDP	Session Description Protocol
SeGW	Security Gateway
SFN	System Frame Number
TDD	Time Division Duplex
TTI	Transmission Time Interval
UE	User Equipment
UMTS	Universal Mobile Telecommunication System
UpPTS	Uplink Pilot Time Slot
UTRA	Universal Terrestrial Radio Access
UTRAN	Universal Terrestrial Radio Access Network

4. Requirements

4.1 Introduction

IMT systems are mobile broadband systems that include both IMT-2000 and IMT-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 that are increasingly packet-based.

To address evolving user needs, IMT-Advanced systems are designed with these key features:

a) 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;
b) Compatibility of services within IMT and with fixed networks;
c) Capability of interworking with other radio access systems;
d) High-quality mobile services;
e) User equipment suitable for worldwide use;
f) User-friendly applications, services and equipment;
g) Worldwide roaming capability; and
h) Enhanced peak data rates to support advanced services and applications (100 Mbit/s for high and 1 Gbit/s for low mobility)

4.2 Technical Requirements for IMT-Advanced

The followings outline the key technical requirements for IMT-Advanced as detailed by the IMT-Advanced Sub Working Group (SWG) Report ITU-R M.2133 and M.2134.

4.2.1 Requirements of compliance for services

Table 1. Requirements of compliance for services

Reference Section of Report ITU-R M.2133	Summary of compliance for services
4.2.4.1.1	Support of a wide range of services
4.2.4.1.1.1	Ability to support basic conversational service class
4.2.4.1.1.2	Support of rich conversational service class
4.2.4.1.1.3	Support of conversational low delay service class

4.2.2 Requirements of compliance for spectrum

Table 2. Requirements of compliance for spectrum

Reference Section of Report ITU-R M.2133	Summary of compliance for spectrum
4.2.4.2.1	Utilization of at least one band identified for IMT

4.2.3 Requirements of compliance for technical performance

Table 3. Requirements of compliance for technical performance

<table>
<tr><th>Reference Section of Report ITU-R M.2134</th><th colspan="4">Summary of compliance for technical performance</th></tr>
<tr><td rowspan="2"></td><td rowspan="2"></td><td colspan="2">Category</td><td>Required value</td></tr>
<tr><td>Test environment</td><td>Downlink or uplink</td><td></td></tr>
<tr><td rowspan="8">4.1</td><td rowspan="8">Cell spectral efficiency (bit/s/Hz/cell)</td><td rowspan="2">Indoor</td><td>Downlink</td><td>3</td></tr>
<tr><td>Uplink</td><td>2.25</td></tr>
<tr><td rowspan="2">Microcellular</td><td>Downlink</td><td>2.6</td></tr>
<tr><td>Uplink</td><td>1.8</td></tr>
<tr><td rowspan="2">Base coverage urban</td><td>Downlink</td><td>2.2</td></tr>
<tr><td>Uplink</td><td>1.4</td></tr>
<tr><td rowspan="2">High speed</td><td>Downlink</td><td>1.1</td></tr>
<tr><td>Uplink</td><td>0.7</td></tr>
<tr><td rowspan="2">4.2</td><td rowspan="2">Peak spectral efficiency (bit/s/Hz)</td><td rowspan="2">Not applicable</td><td>Downlink</td><td>15</td></tr>
<tr><td>Uplink</td><td>6.75</td></tr>
<tr><td rowspan="2">4.3</td><td rowspan="2">Bandwidth</td><td rowspan="2">Not applicable</td><td>Up to and including (MHz)</td><td>40</td></tr>
<tr><td>Scalability</td><td>Support of at least three bandwidth values</td></tr>
<tr><td rowspan="8">4.4</td><td rowspan="8">Cell edge user spectral efficiency (bit/s/Hz)</td><td rowspan="2">Indoor</td><td>Downlink</td><td>0.1</td></tr>
<tr><td>Uplink</td><td>0.07</td></tr>
<tr><td rowspan="2">Microcellular</td><td>Downlink</td><td>0.075</td></tr>
<tr><td>Uplink</td><td>0.05</td></tr>
<tr><td rowspan="2">Base coverage urban</td><td>Downlink</td><td>0.06</td></tr>
<tr><td>Uplink</td><td>0.03</td></tr>
<tr><td rowspan="2">High speed</td><td>Downlink</td><td>0.04</td></tr>
<tr><td>Uplink</td><td>0.015</td></tr>
<tr><td>4.5.1</td><td>Control plane latency (ms)</td><td>Not applicable</td><td>Not applicable</td><td>Less than 100 ms</td></tr>
<tr><td>4.5.2</td><td>User plane latency (ms)</td><td>Not applicable</td><td>Not applicable</td><td>Less than 10 ms</td></tr>
<tr><td rowspan="3">4.6</td><td rowspan="3">Mobility classes</td><td>Indoor</td><td>Uplink</td><td>Stationary, pedestrian</td></tr>
<tr><td>Microcellular</td><td>Uplink</td><td>Stationary, pedestrian, vehicular up to 30 km/h</td></tr>
<tr><td>Base coverage urban</td><td>Uplink</td><td>Stationary, pedestrian, vehicular</td></tr>
</table>

Table 3. Requirements of compliance for technical performance *(continued)*

Reference Section of Report ITU-R M.2134	Summary of compliance for technical performance			
		Category		Required value
		Test environment	Downlink or uplink	
		High speed	Uplink	High speed vehicular, vehicular
4.6	Mobility traffic channel link data rates (bit/s/Hz)	Indoor	Uplink	1
		Microcellular	Uplink	0.75
		Base coverage urban	Uplink	0.55
		High speed	Uplink	0.25
4.7	Intra-frequency hand-over interruption time (ms)	Not applicable	Not applicable	27.5
	Inter-frequency handover interruption time within a spectrum band (ms)	Not applicable	Not applicable	40
	Inter-frequency handover interruption time between spectrum bands (ms)	Not applicable	Not applicable	60
	Inter-system handover	Not applicable	Not applicable	Not applicable
4.8	Number of supported VoIP users (active users/sector/MHz)	Indoor	As defined in Report ITU-R M.2134	50
		Microcellular	As defined in Report ITU-R M.2134	40
		Base coverage urban	As defined in Report ITU-R M.2134	40
		High speed	As defined in Report ITU-R M.2134	30

4.3 IMT-Advanced Technologies

Due to the large effective bandwidths required to support the very high data rates required for the various services offered, IMT-Advanced technologies are able to take advantage of allowances in either much larger single carrier bandwidths (even as spectral efficiencies increase) or aggregation of different RF carriers.

The two technologies developed by the industry that have been accorded the official designation of IMT-Advanced by ITU-R, namely LTE-Advanced[1] and WirelessMAN-Advanced[2].

The detailed specifications of the terrestrial radio interfaces of IMT-Advanced are outlined and referenced in Section 5.

5. Technology Specifications

5.1 Overview of the Radio Interface

The radio interface is the interface between the UE and the base station and determines the manner in how wireless access is provided. In order for the complete compatibility between the UE and wireless network equipment of different manufacturers and operators, the radio interface must be completely defined and standardized.

The specifications of the radio interface have an important influence on spectrum efficiency, which dictate the capacity of the system and describe other functions such as how to manage interference, mobility, load and scheduling.

5.2 IMT Spectrum

The growth in Internet and IP services has created a surge in data growth in the recent years, and will continue to do so for years to come. This feeds the growing demand for wireless communications, resulting in higher data rates to meet user needs, and forms the basis for further development of IMT-2000 and IMT-Advanced.

Spectrum is inherent to wireless communications and technologies such as IMT-Advanced. Therefore, the ITU has produced a report ITU-R M.2078, *Estimated spectrum bandwidth requirements for the future development of IMT-2000 and IMT-Advanced* whereby it is calculated that in a lower market setting, a total spectrum bandwidth of 1280 MHz is required for the year 2020 to support pre-IMT, IMT-2000 (and its enhancements) and IMT-Advanced services; whereas in some countries with higher market settings this could go beyond 1720 MHz.

Due to the large effective bandwidths required to support the very high data rates needed for the various services offered, allowance/allocation for much larger single carrier bandwidths or aggregation of multiple RF carrier is critical for IMT-Advanced deployment.

In order to establish a guidance with regards to the IMT-Advanced standards for Malaysia and considering the objectives set forth in the scope, the principles for transmitting and receiving frequency arrangements for the terrestrial component of IMT systems are set forth in ITU-R Recommendation M.1036-4, *Frequency arrangements for implementation of the terrestrial component of International Mobile Telecommunications (IMT) in the bands identified for IMT in the Radio Regulations (RR)*.

[1] Developed by 3GPP as LTE Release 10 and Beyond (LTE-Advanced)

[2] Developed by IEEE as the WirelessMAN-Advanced specification incorporated in IEEE Std 802.16 beginning with approval of IEEE Std 802.16m

The frequency arrangements are recommended from the point of view of enabling the most efficient use of spectrum to deliver IMT services while minimizing the impact on other systems or services in the frequency bands and to facilitate the growth of IMT systems.

The identification of these frequencies does not prevent the local operators from deploying IMT systems in other frequencies not listed in the recommendation, nor does it restrict the deployment of IMT systems in these frequencies only but serves the purpose of promoting a globally harmonized frequency arrangement for IMT which brings about many benefits. The spectrum allocation that will be used in Malaysia shall be based on the Spectrum Plan and Standard Radio System Plans (SRSPs) published by Malaysian Communications and Multimedia Commission (MCMC).

5.3 LTE-Advanced

5.3.1 Introduction

LTE-Advanced is one of the recommended radio interfaces that meet the key requirements of IMT-Advanced. The following presents a description of the LTE-Advanced Radio Interface, based on that presented in the ITU-R Recommendation M.2012, *Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications Advanced (IMT-Advanced)*.

The specifications presented in this Technical Code are based on the technical specifications developed by 3GPP as specified and documented in 3GPP LTE Release 10 and beyond.

5.3.2 LTE- Advanced Radio Interface Technology

LTE-Advanced – LTE Release 10 consists of two defined radio interfaces:

a) A Frequency Division Duplex (FDD) interface; and
b) A Time Division Duplex (TDD) interface.

Both are evolutions of their LTE counterparts. This is to facilitate operation in both paired FDD and unpaired TDD spectrum. The TDD interface is also commonly referred to as TD-LTE Release 10 and Beyond or TD-LTE-Advanced. The TDD version has the added benefit of facilitating asymmetry through flexibility of downlink-uplink resource allocation. This is suitable for data communications which is typically asymmetric in resource use. The design of the two radio interfaces share much in common while still providing the flexibility of serving different spectrum arrangements. Each interface technology meets all the minimum requirements of IMT-Advanced.

LTE-Advanced can be considered to include and extend on the capabilities of LTE defined in 3GPP Release 8 and Release 9, in particular building on the defined system and core network specifications. LTE-Advanced will keep a central concept of interoperability, found in previous 3GPP releases, as well as maintaining key aspects of the 3GPP mobility solution including user services, connectivity, mobility and roaming, security, CODECs and media, operations and maintenance, charging, etc.

Both TDD and FDD versions support transmission bandwidths of up to 100 MHz, and will deliver peak data rates up to approximately 3.0 Gbps in the downlink and 1.5 Gbps in the uplink. As with LTE, the air interface is based on Orthogonal Frequency Division Multiple Access (OFDMA) in the downlink with a modification in the uplink to use Single Carrier FDMA (SC-FDMA). This is implemented in the uplink to facilitate a more efficient and cost-effective terminal design as it minimises the impact of the Peak-to-Average Power Ratio (PAPR) problem that is experienced in the downlink.

To facilitate forward error correction and to meet the stringent error demands of data traffic, Turbo coding at 1/3 rate is employed in conjunction with a Hybrid Automatic Repeat Request (Hybrid-ARQ) retransmission scheme. Modulation schemes supported are a Quadrature Phase Shift Keying

(QPSK), 16QAM, and 64QAM in both the downlink and uplink. As with LTE, to achieve the best balance of throughput and quality in a given channel condition, Adaptive Modulation and Coding (AMC) is implemented.

In LTE, it is the Base Station (or Evolved Node B (eNB)) that is responsible for the management and scheduling of the radio resources. Scheduling is done using both time and frequency domains, with the base station making the scheduling decision where a maximum frequency of once per Transmission Time Interval (TTI) – duration 1ms. In a scheduling period, the base station will allocate resources based on application of policy to traffic queuing/requesting resources in the downlink/uplink. The base station will allocate a number of Physical Resource Blocks (PRB) to each user.

Note that the details of the scheduling policy are not defined in the technical specifications and are vendor-specific.

The main new functionalities introduced in LTE-Advanced (Release-10) over LTE (Release-8) are

a) Carrier Aggregation (CA);
b) enhanced use of multi-antenna techniques; and
c) support for Relay Nodes (RN).

5.3.3 Carrier Aggregation (CA)

The most straightforward to increase capacity is by adding bandwidth. Since it is important to keep backward compatibility with R8 and R9 mobiles the increase in bandwidth in LTE-Advanced is provided through aggregation of R8/R9 carriers. Such spectrum compatibility is of critical importance for a smooth, low-cost transition to LTE-Advanced capabilities within the network and is similar to the evolution of Wideband Code Division Multiple Access (WCDMA) to High Speed Packet Access (HSPA). CA can be used for both FDD and TDD.

Bandwidth use and allocation is flexible in defined steps from a minimum of 1.4MHz up to a maximum of 100MHz. For bandwidths above 20MHz, LTE-Advanced uses carrier aggregation, which involves the simultaneous transmission of multiple component 20MHz carriers in parallel to/from the same mobile device Both a contiguous and non-contiguous use of component carriers is specified, where the non-contiguous bands can be taken from different frequency bands (e.g. 2600MHz, 2100MHz, 1800MHz, etc.)

The different implementation of Carrier Aggregation is illustrated in Figure 1, Figure 2 and Figure 3.

A list of existing and proposed work items on Carrier Aggregation is listed in Annex A.

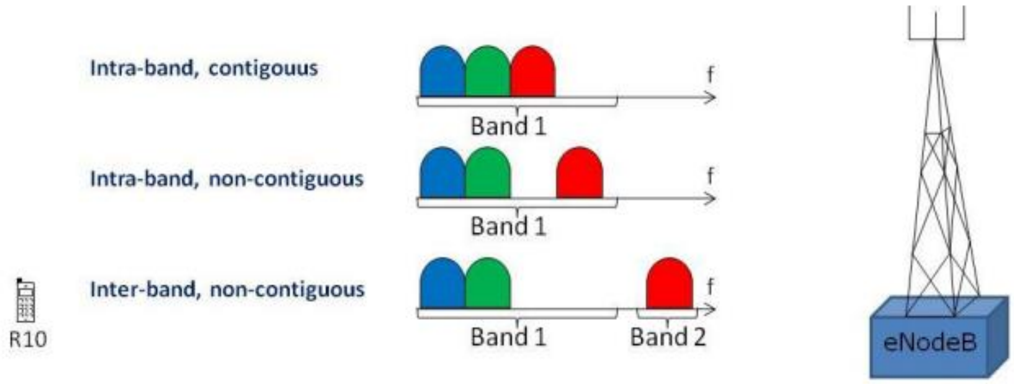

Figure 1. Carrier Aggregation – Intra and inter-band alternatives

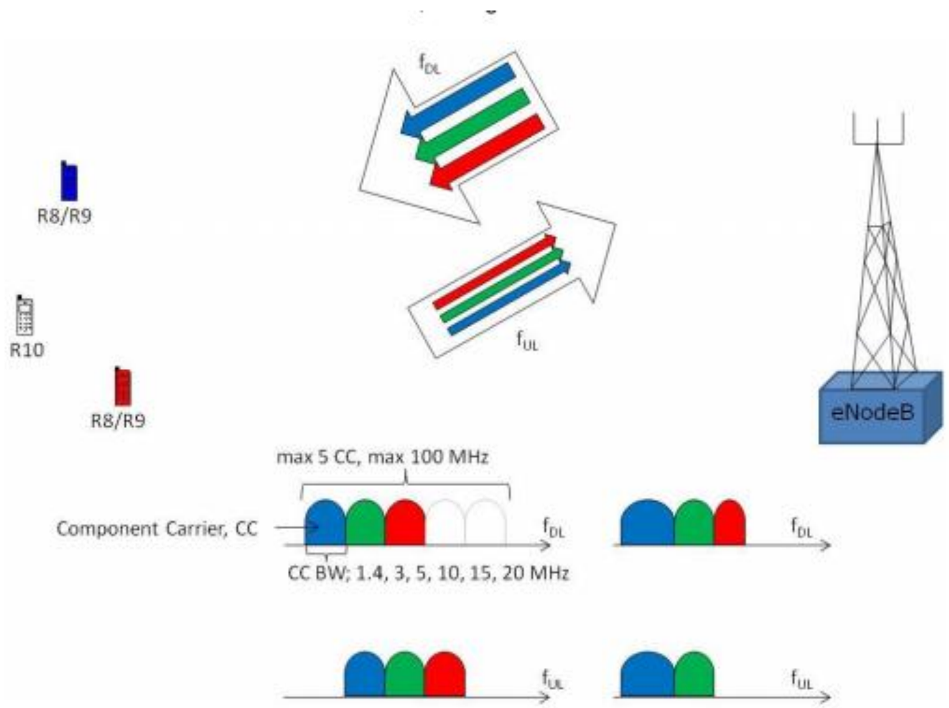

Figure 2. Carrier Aggregation in FDD[3]

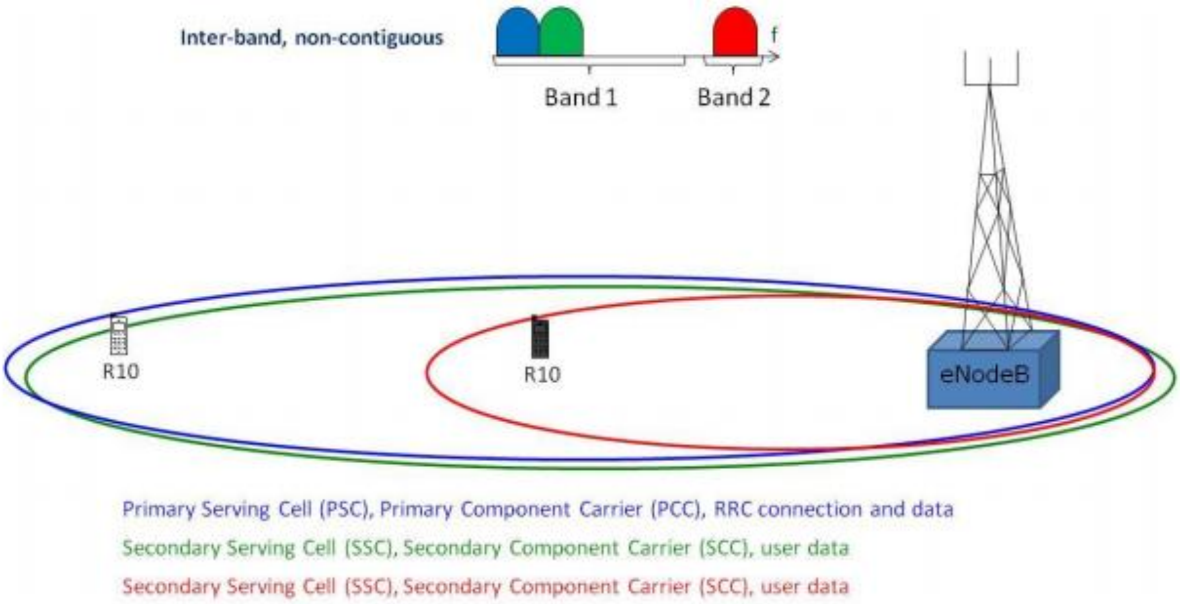

Figure 3. Inter-band Carrier Aggregation[4]

3 The R10 UE can be allocated resources Downlink (DL) and Uplink (UL) on up to five Component Carriers (CC). The R8/R9 UEs can be allocated resources on any ONE of the CCs. The Component Carriers (CCs) can be of different bandwidths

4 Inter-bank Carrier Aggregation where each CC corresponds to a serving cell. The different serving cells may have different coverage.

Inter-cell interference coordination (ICIC) is implemented to support a more dynamic and efficient use of frequency resources,. In this scheme, neighbouring cells exchange information, such as interference and power levels, with each other to allow dynamic management of interference and spectrum usage.

5.3.4 Multiple Input Multiple Output (MIMO) – or spatial multiplexing

LTE-Advanced uses multi-antenna transmission schemes to increase the speed of transmission. There are various different schemes defined, based around MIMO and beam-forming solutions. A major change in LTE-Advanced is the introduction of higher order MIMO; 8x8 in the DL and 4x4 in the UL.

5.3.5 Relay Nodes

A development in LTE-Advanced is the introduction of a relay function where low power base stations called relay nodes offer radio resources as usual to mobile devices, but uses LTE radio as a transmission layer to connect wirelessly to the radio access network. This enhances coverage and capacity at cell edges and can also be used to connect to remote areas without fibre connection.

The Relay Nodes is connected to the Donor eNB (DeNB) via a radio interface, Un, which is a modification of the E-UTRAN air interface Uu. Hence in the Donor cell the radio resources are shared between UEs served directly by the DeNB and the Relay Nodes.

5.3.6 Network Architecture

The LTE-Advanced radio-access network, known as the Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) consists of a flat architecture with a single network, the eNodeB (base station). The transmission is based on an end-to-end Internet Protocol (IP) architecture. The role of the eNodeB is to handle all functions related to the radio network for the cell(s) under its control. The eNodeB communicates with three other possible network elements, as follows:

Network Element	Interface
Mobility Management Entity (MME)	S1-c
Serving Gateway (S-GW)	S1-u
eNodeB	X2

A single eNodeB can be connected to multiple MMEs/S-GWs for the purpose of load sharing and redundancy.

The purpose of the X2 interface between eNodeBs is mainly for mobility and handover. During a handover the X2 is used to communicate signalling to the target eNodeB to prepare the handover, and also to carry user traffic between the eNodeBs while the handover is in progress to ensure no loss of data. Another use for the X2 interface is for Radio Resource Management (RRM) functions, in particular the ICIC.

The other two components that the eNodeB connects to are the MME and the S-GW. The MME is responsible for handling signalling towards both the eNodeB and the mobile device. It is a single point of contact which then coordinates with the remaining core network entities as well as communicating with other 3GPP and non-3GPP networks in the case of intersystem handovers. The S-GW acts as an anchor point for traffic between the access and core network. In the case of roaming, the S-GW will be located in the visited network. The architecture of the LTE-Advanced network is shown below in Figure 4.

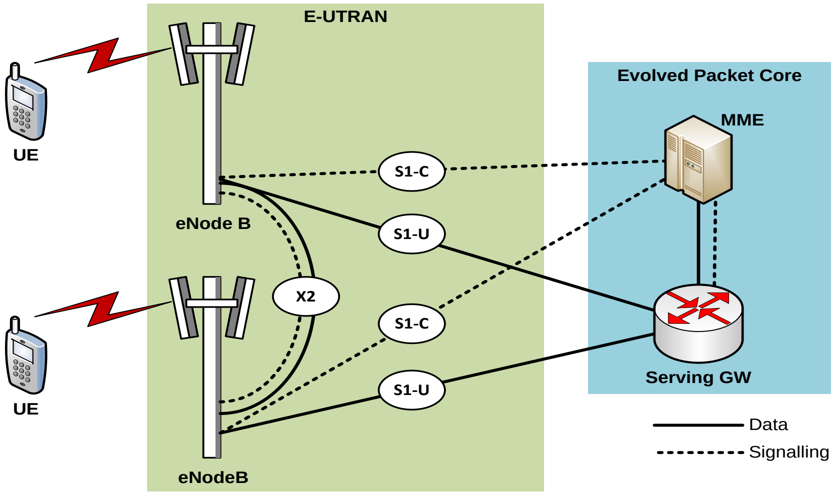

Figure 4. LTE-Advanced Network Architecture

5.3.7 Radio Protocol Architecture

The radio interface consists of a layered protocol architecture to facilitate the smooth transfer of data and signalling between the mobile device and LTE-Advanced network. The protocol stack is shown in Figure 5.

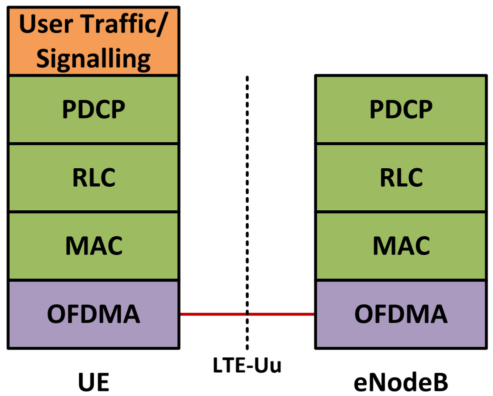

Figure 5. LTE-Advanced Radio Protocol Stack

On top of the OFDMA are three functions which constitute the "Layer 2" of the air interface. Layer 2 provides one or more Radio Bearers to higher layers to which IP packets are mapped according to their Quality-of-Service (QoS) requirements, i.e. different radio bearers carry different QoS, e.g. voice and data bearers. The functions provided by each of the layers are explained briefly in the next page.

Protocol	Main Functions
Packet Data Convergence Protocol (PDCP)	a) Header compression & decompression b) Data encryption c) Signalling integrity protection
Radio Link Control (RLC)	a) Segmentation & reassembly b) ARQ acknowledgement & retransmission (for Acknowledged Mode (AM) data) c) In sequence delivery of data
Medium access control (MAC)	a) UL/DL traffic scheduling

Protocol	Main Functions
	b) Control of Hybrid ARQ process & retransmissions c) QoS scheduling
Orthogonal Frequency Division Multiple Access (OFDMA)	a) Adaptive modulation & coding b) OFDMA signals c) Hybrid ARQ d) Resource Element mapping

5.3.8 Radio Channels

Radio channels defined for LTE-Advanced are grouped into logical, transport and physical channels. Logical channels define the “type” of information being carried, e.g. signaling, user traffic, etc. There are only two different types of Logical channel, either control (denoted xCCH) or traffic (denoted xTCH). Each of the channels is described in Table 4.

Table 4. LTE-Advanced Radio Channels

Channel Acronym	Channel	Direction	Description
BCCH	Broadcast Control Channel	DL	Broadcasting system control information
PCCH	Paging Control Channel	DL	Paging when the network is not aware of the location of the UE and for system information change notifications
CCCH	Common Control Channel	UL/DL	Transmission of control information between mobile devices and network when the UE has no RRC connection
DCCH	Dedicated Control Channel	UL/DL	Transmission of control information to/from a mobile device when the UE has a RRC connection
MCCH	Multicast Control Channel	DL	Transmission of control information required for reception of the MTCH
DTCH	Dedicated Traffic Channel	UL/DL	Transmission of user data to/from a mobile device
MTCH	Multicast Traffic Channel	DL	Downlink transmission of MBMS services

It should be noted that the type of logical channel has no relation with “how” the information is carried. Logical channels are the service offered by the MAC layer to the RLC layer map into transport channels as shown in Figure 6 for Downlink (D/L) and Figure 7 for Uplink (U/L). The DCI and UCI denote “Downlink Control Information” and “Uplink Control Information” respectively. These comprise of channels that exist only at the physical layer and provide format information and/or exchange control information, e.g. Hybrid ARQ acknowledgements.

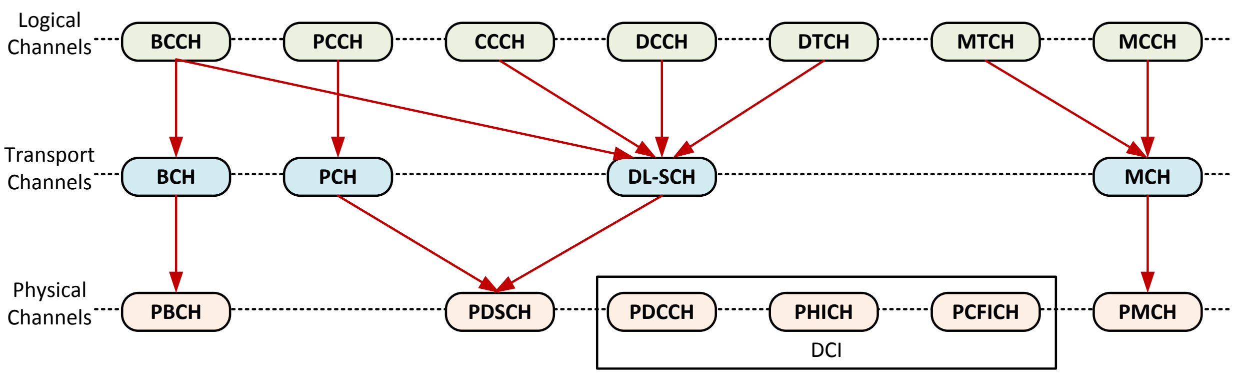

Figure 6. LTE-Advanced Downlink Channels

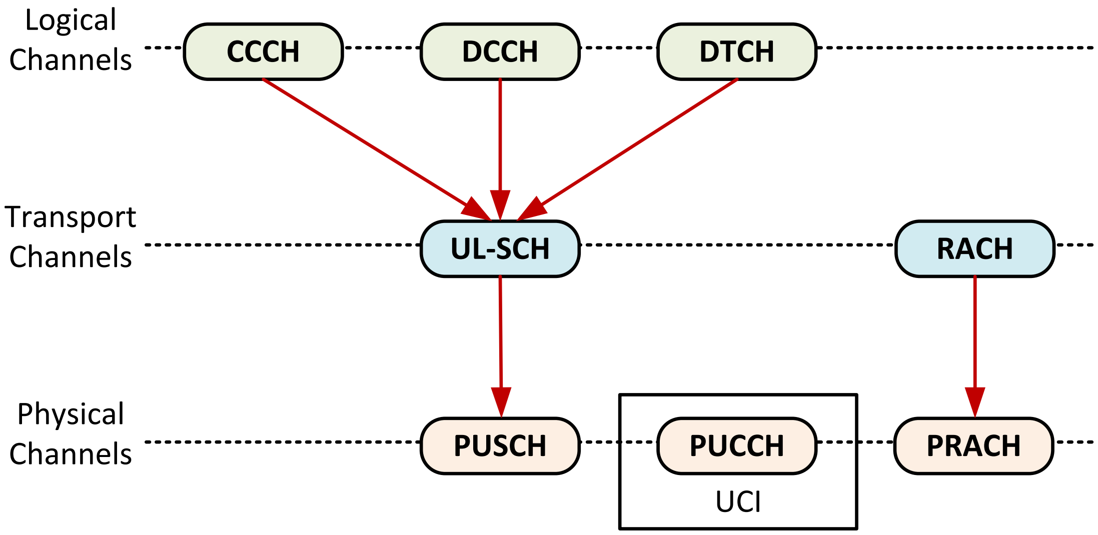

Figure 7. LTE-Advanced Uplink Channels

The MAC layer offers services to the physical layer as Transport Channels. A transport channel is defined by "how" and with "what characteristics", i.e. QoS, the information is transmitted over the radio interface. Data on a transport channel is organized into transport blocks which are passed to the physical layer in each 1ms Transmission Time Interval (TTI). In a given TTI, the MAC will send a maximum of one (or two for MIMO Spatial Multiplexing) transport blocks per component carrier. For each transport block, a Transport Format (TF) is defined which indicates its size, modulation scheme and antenna mapping. This TF is determined by the scheduler.

Table 5 and Table 6 describe the transport channels and physicals channels:

Table 5. LTE-Advanced Transport Channels

Channel Acronym	Channel	Direction	Description
BCH	Broadcast Channel	DL	Transmission of parts of the BCCH system information, more specifically the so called Master Information Block (MIB).

Table 5. LTE-Advanced Transport Channels *(continue)*

Channel Acronym	Channel	Direction	Description
PCH	Paging Channel	DL	Transmission of paging information from the PCCH logical channel. Supports discontinuous reception (DRX) to allow the mobile device to save battery power by only needing to wake up to listen to the PCH at predefined times.
DL-SCH	Downlink Shared Channel	DL	Main transport-channel type used for transmission of downlink data. Supports dynamic rate adaptation and channel-dependent scheduling, hybrid-ARQ with soft combining, and spatial multiplexing. Also supports DRX to reduce mobile device power consumption while still offering the user an “always-on” experience.
MCH	Multicast Channel	DL	Used to support MBMS and is scheduled according to a “semi-persistent” scheme, suitable for TV/Video broadcasting.
UL-SCH	Uplink Shared Channel	UL	Uplink counterpart to the DL-SCH, i.e. it is the uplink transport channel used for transmission of uplink data.
RACH	Random Access Channel	UL	Used in the uplink to reply to a paging message or to request that the user move to the RRC_CONNECTED state.

Table 6. LTE Physical Channels

Channel Acronym	Channel	Direction	Description
PBCH	Physical Broadcast Channel	DL	Cell and/or system specific information
PDSCH	Physical Downlink Shared Channel	DL	Transmission of user and control plane data services
PMCH	Physical Multicast Channel	DL	Transmission of control and user-plane broadcast services
PDCCH	Physical Downlink Control Channel	DL	Transmission of control information including resource allocation, transport format and HARQ related information
PCFICH	Physical Control Format Indicator Channel	DL	Indicates to the UE the control format (number of symbols comprising PDCCH, PHICH) of the current subframe
PHICH	Physical Hybrid ARQ Indicator Channel	DL	Carries the ACK/NACK information for UL (PUSCH) transmissions received at the eNodeB
PRACH	Physical Random Access Channel	UL	Sends a preamble which is used to trigger a random-access procedure (i.e. a user connection) in the eNodeB
PUSCH	Physical Uplink Shared Channel	UL	Carries both user data and higher layer control information
PUCCH	Physical Uplink Control Channel	UL	Carries control information from the UE including scheduling requests, CQI, HARQ ACK/NACK for PDSCH, etc.

5.3.9 Frame Structure

The transmission of information in LTE-Advanced is performed according to a strict time-domain structure consisting of 10ms radio frames for both FDD and TDD mode. Each radio frame consists of 10 sub-frames.

A sub-frame is a 1ms TTI and is the minimum scheduling period. A sub-frame consists of two 0.5ms slots, and each slot consists of either 6 or 7 symbols.

A symbol is the minimum modulation entity and each symbol has a cyclic prefix in front of it to mitigate the effects of multipath propagation. The number of bits represented by each symbol is dependent on the modulation scheme being used, e.g. a Quadrature Phase Shift Keying (QPSK) modulation scheme means each symbol represents two bits, etc.

The normal Cyclic Prefix (CP) frame has 7 symbols; an extended CP frame has a longer CP and only 7 symbols – this is for use in rural areas where the multipath propagation effects typically happen over a longer time period. The diagram, Figure 8, shows this frame hierarchy for the more common “normal CP” structure.

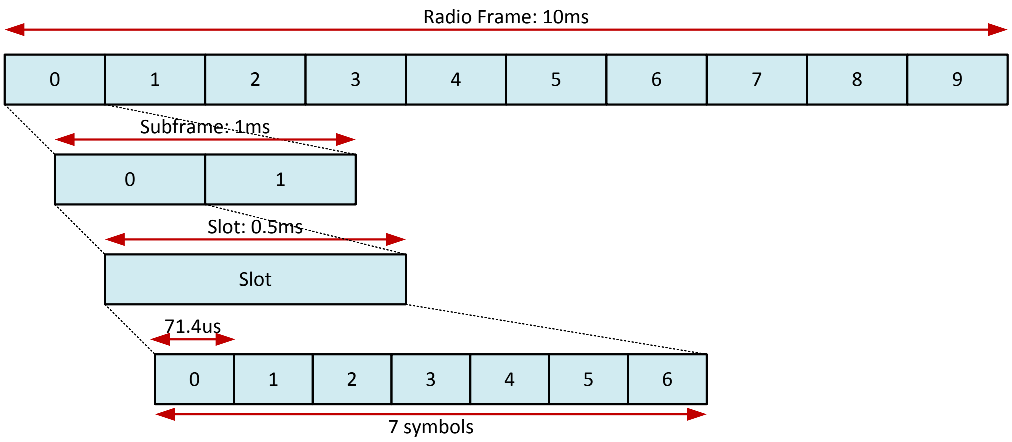

Figure 8. Radio Frame Structure

For FDD, this frame structure is used for both uplink and downlink with uplink and downlink being allocated different frequency channels as shown in Figure 9.

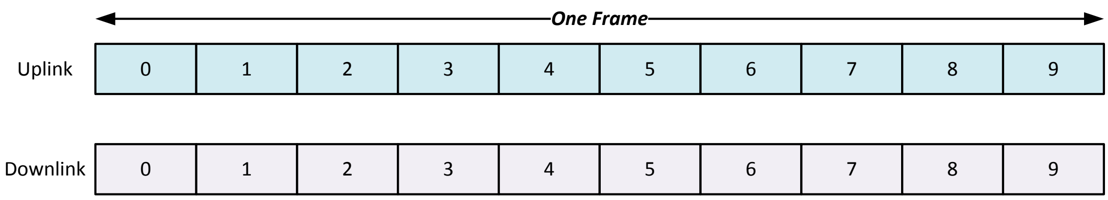

Figure 9. FDD Frame Format

For TDD, a single frequency channel is used and uplink and downlink are then separated in time. To accommodate this, some of the sub-frames facilitate the downlink to uplink transition by including a guard band & special pilot references, and thus cannot carry as much data. LTE-Advanced defines seven different TDD configurations with different ratios of UL & DL sub-frames as shown in Figure 10.

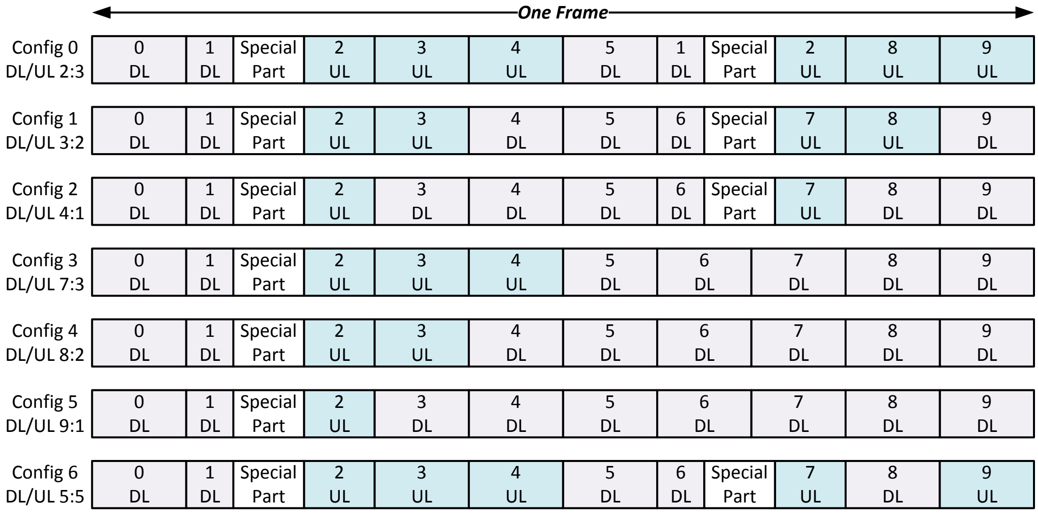

Figure 10 TDD Frame Options

The structure of the "special part" consists of a downlink part (DwPTS), a guard period (GP) where the actual DL-UL switch occurs and a uplink part (UpPTS). The DwPTS is still used for data but a reduced amount. The UpPTS is used for checking reference signals for channel sounding. The total length of DwPTS + GP + UpPTS is always 1ms though the individual lengths are configurable. This structure is show in Figure 11 below.

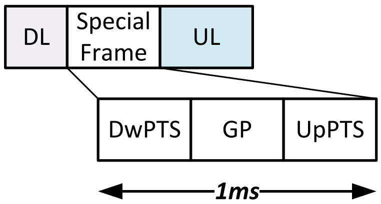

Figure 11. DL/UL transition sub-frame

5.3.10 Physical Layer

Information is carried at the physical layer in the format of "transport blocks". Before transmission, the transport block has a Cycle Redundancy Check (CRC) attached to check for errors, followed by forward error correction in the form of 1/3 rate Turbo coding. This protected data is then rate matched according to the adaptive coding scheme chosen. At this stage, the redundancy versions used by the Hybrid ARQ process are also created. The coded transport block is then modulated and transmitted. If spatial multiplexing MIMO is used, then the modulated data is mapped to the different antenna ports. During the connection life cycle, the modulation & coding scheme will change depending on link conditions, however the same modulation & coding scheme is used within the same TTI.

The first 1-3 symbols of the downlink frame is used to carry control information as mentioned, the number of symbols is indicated by the PCFICH channel. The control information provides the allocation of downlink and uplink resources to the UE (the PDCCH channel) as well as the Hybrid ARQ acknowledgements (the PHICH channel).

5.3.11 Mobility, Roaming and Quality of Service

3GPP has described the specifications related to mobility, roaming and quality of service (QoS) for LTE-Advanced in the below documents:

Feature	Document number	Description
Mobility and roaming	LTE Release 8 and 9	System and core network specifications address network, terminal service aspects required to provide an integrated mobility solutions including aspects such as user services, connectivity, interoperability, mobility and roaming, security, etc.
Mobility Management based on Mobile IPv6	TS 24.303	Signalling procedures for accessing the 3GPP Evolved Packet Core (EPC) network and handling the mobility between 3GPP and non-3GPP accesses via the S2c reference point defined in TS 23.402.
Mobility Management based on Mobile IPv4	TS 24.304	Stage 3 aspects for mobility management for User Equipment (UE) using IETF Mobile IPv4 foreign agent mode to access the EPC Network through trusted non-3GPP access networks.
Mobility Management Entity (MME)	TS 29.118	Circuit Switched Fallback (CS Fallback) in the Evolved Packet System (EPS) enables the provisioning of CS-domain services by reuse of CS infrastructure when the UE is served by E-UTRAN.
Evolved Packet System (EPS): Mobility Management Entity (MME) and Serving GPRS Support Node (SGSN) related interfaces based on Diameter protocol	TS 29.272	MME and SGSN related diameter-based interfaces towards Home Subscriber Server (HSS) and the MME and SGSN related diameter-based interface towards the Equipment Identity Register (EIR).
Proxy Mobile IPv6 (PMIPv6) based Mobility and Tunnelling Protocols	TS 29.275	Stage 3 of PMIPv6 based Mobility and Tunnelling Protocols used over PMIP-based S2a, S2b, S5 and S8 reference points defined in 3GPP RS 23.402.
QoS concept and architecture	TS 23.107	Framework for QoS in UMTS.
QoS parameter mapping	TS 29.213	Binding and mapping of QoS parameters among SDP, IMTS QoS parameters and QoS authorisation parameters.
Optimised handover procedures	TS 29.276	S101 interface supports procedures for Pre-registration, Session Maintenance and Active handoffs between E-UTRAN and High Rate Packet Data (HRPD) networks.

5.3.12 Detailed description of the radio interface technology

This standards document herewith provides an overview of the LTE-Advanced radio interface technology. The detailed specifications for the terrestrial radio interface of IMT-Advanced identified as LTE-Advanced have been listed in Annex C. It includes the key characteristics of LTE-Advanced and the additional capabilities of LTE-Advanced, both of which are continuously enhanced. The minimum version for the 3GPP standards listed as LTE-Advanced is Release 10.0.0 and will be superseded by newer versions (i.e. 10.x.y) as they become available. The most current release document can be obtained from 3GPP's internet site at http://www.3gpp.org/specifications.

5.4 WirelessMAN-Advanced

5.4.1 Introduction

The WirelessMAN-Advanced radio interface specification is specified in IEEE 802.16m.

The WirelessMAN-Advanced standard specifies the physical layer and the MAC layer of the radio access network. The specifications of both layers are, in principle, transposed from the Global Core Specification (GCS) provided by IEEE for ITU as WirelessMAN-Advanced technology.

The WirelessMAN-Advanced GCS consists of the body document, IEEE802.16-2009, with three amendment documents, i.e. IEEE802.16j-2009, IEEE802.16h-2010 and IEEE802.16m-2011. The core features of WirelessMAN-Advanced are described in IEEE802.16m-2011 document, while the supplement features are in the other three documents.

The WirelessMAN-Advanced System consists of the Mobile Station (MS), Access Service Network (ASN) and Connectivity Service Network (CSN) as shown in Figure 12. This standard specifies the radio interface for the WirelessMAN-Advanced System.

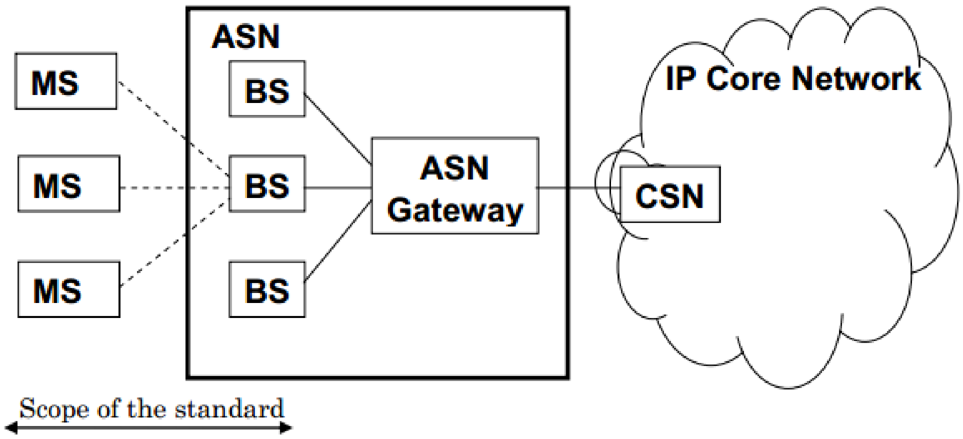

Figure 12. Configuration of WirelessMAN-Advanced System

5.4.2 Mobility

WirelessMAN-Advanced supports both network-controlled and MS-assisted handover (HO). The handover procedures may be initiated by either MS or BS. The MS executes the handover or cancels the procedure through HO cancellation message. The network re-entry procedures with the target BS may be optimised by target BS possession of MS information obtained from serving BS via core network.

5.4.3 Overview of Specifications

WirelessMAN-Advanced System specification is incorporated in IEEE Std 802.16. It is comprised of IEEE Std 802.16-2009, IEEE Std 802.16j-2009, IEEE Std 802.16h-2010, and IEEE Std 802.16m-2011.

In accordance with Clause 16.1.1 of IEEE Std 802.16, the WirelessMAN-Advanced GCS is specified in the clauses of IEEE Std 802.16 as indicated in Table 7.

Table 7. Description of the WirelessMAN-Advanced GCS

IEEE Std 802.16 Clause and Subject	IEEE Std 802.16-2009	IEEE Std 802.16j-2009	IEEE Std 802.16h-2010	IEEE Std 802.16m-2011
Clause 1.4: Reference models	Base specification		Amended	Amended
Clause 2: Normative references	Base specification		Amended	Amended
Clause 3: Definitions	Base specification	Amended	Amended	Amended
Clause 4: Abbreviations and acronyms	Base specification	Amended	Amended	Amended
Clause 5.2: Packet convergence sub layer	Base specification			Amended
Clause 16: WirelessMAN-Advanced air interface				Base specification
Annex R: MAC control messages				Base specification
Annex S: Test vectors				Base specification
Annex T: Supported frequency bands				Base specification
Annex U: Radio specifications				Base specification
Annex V: Default capability class and parameters				Base specification

5.4.4 Detailed Specifications

The detailed specifications of the WirelessMAN-Advanced System are listed in Annex C.

Annex A
(Normative)

List of current and proposed work items on Carrier Aggregation in 3GPP

Release 10

- Carrier Aggregation for LTE

Release 11

Inter-band Carrier Aggregation

- LTE Advanced Carrier Aggregation of Band 3 and Band 7
- LTE Advanced Carrier Aggregation of Band 4 and Band 17
- LTE Advanced Carrier Aggregation of Band 4 and Band 13
- LTE Advanced Carrier Aggregation of Band 4 and Band 12
- LTE Advanced Carrier Aggregation of Band 5 and Band 12
- LTE Advanced Carrier Aggregation of Band 7 and Band 20
- LTE Advanced Carrier Aggregation of Band 2 and Band 17
- LTE Advanced Carrier Aggregation of Band 4 and Band 5
- LTE Advanced Carrier Aggregation of Band 5 and Band 17
- LTE Advanced Carrier Aggregation of Band 3 and Band 20
- LTE Advanced Carrier Aggregation of Band 8 and Band 20
- LTE Advanced Carrier Aggregation of Band 1 and Band 7
- LTE Advanced Carrier Aggregation of Band 3 and Band 5
- LTE Advanced Carrier Aggregation of Band 4 and Band 7
- LTE Advanced Carrier Aggregation of Band 11 and Band 18
- LTE Advanced Carrier Aggregation of Band 1 and Band 18
- LTE Advanced Carrier Aggregation of Band 1 and Band 19
- LTE Advanced Carrier Aggregation of Band 1 and Band 21

Intra-band Carrier Aggregation

- LTE Carrier Aggregation Enhancements
- LTE Advanced Carrier Aggregation in Band 38
- LTE Advanced Carrier Aggregation in Band 41
- LTE Advanced Carrier Aggregation in Band 7

Release 12

Inter-band Carrier Aggregation

- LTE Advanced Carrier Aggregation of Band 3 and Band 5 with 2UL
- LTE Advanced Carrier Aggregation of Band 3 and Band 8
- LTE Advanced Inter-band Carrier Aggregation of Band 2 and Band 4

Intra-band Carrier Aggregation

- LTE Advanced Intra-band Non-Contiguous Carrier Aggregation in Band 25
- LTE Advanced Intra-band Non-Contiguous Carrier Aggregation in Band 3
- LTE Advanced Intra-band Non-Contiguous Carrier Aggregation in Band 4
- LTE Advanced Intra-band Contiguous Carrier Aggregation in Band 1

Annex B
(Normative)

Detailed specifications for the terrestrial radio interface IMT-Advanced as specified by 3GPP for LTE-Advanced

TS 25.460	UTRAN Iuant interface: General aspects and principles
TS 25.461	UTRAN Iuant interface: Layer 1
TS 25.462	UTRAN Iuant interface: Signalling transport
TS 25.466	UTRAN Iuant interface: Application part
TS 36.101	Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception
TS 36.104	Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception
TS 36.106	Evolved Universal Terrestrial Radio Access (E-UTRA); FDD repeater radio transmission and reception
TS 36.113	Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) and repeater ElectroMagnetic Compatibility (EMC)
TS 36.124	Evolved Universal Terrestrial Radio Access (E-UTRA); Electromagnetic compatibility (EMC) requirements for mobile terminals and ancillary equipment
TS 36.133	Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements for support of radio resource management
TS 36.171	Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements for Support of Assisted Global Navigation Satellite System (A-GNSS)
TS 36.201	Evolved Universal Terrestrial Radio Access (E-UTRA); LTE physical layer; General description
TS 36.211	Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation
TS 36.212	Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding
TS 36.213	Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures
TS 36.214	Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer; Measurements
TS 36.216	Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer for relaying operation
TS 36.300	Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2
TS 36.302	Evolved Universal Terrestrial Radio Access (E-UTRA); Services provided by the physical layer
TS 36.304	Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) procedures in idle mode
TS 36.305	Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Stage 2 functional specification of User Equipment (UE) positioning in E-UTRAN
TS 36.306	Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities
TS 36.307	Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements on User Equipments (Ues) supporting a release-independent frequency band
TS 36.314	Evolved Universal Terrestrial Radio Access (E-UTRA); Layer 2 – Measurements

TS 36.321 Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification

TS 36.322 Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Link Control (RLC) protocol specification

TS 36.323 Evolved Universal Terrestrial Radio Access (E-UTRA); Packet Data Convergence Protocol (PDCP) specification

TS 36.331 Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification

TS 36.355 Evolved Universal Terrestrial Radio Access (E-UTRA); LTE Positioning Protocol (LPP)

TS 36.401 Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Architecture description

TS 36.410 Evolved Universal Terrestrial Radio Access Network (E-UTRAN); S1 layer 1 general aspects and principles

TS 36.411 Evolved Universal Terrestrial Radio Access Network (E-UTRAN); S1 layer 1

TS 36.412 Evolved Universal Terrestrial Radio Access Network (E-UTRAN); S1 signalling transport

TS 36.413 Evolved Universal Terrestrial Radio Access Network (E-UTRAN); S1 Application Protocol (S1AP)

TS 36.414 Evolved Universal Terrestrial Radio Access Network (E-UTRAN); S1 data transport

TS 36.420 Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 general aspects and principles

TS 36.421 Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 layer 1

TS 36.422 Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 signalling transport

TS 36.423 Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 Application Protocol (X2AP)

TS 36.424 Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 data transport

TS 36.440 Evolved Universal Terrestrial Radio Access Network (E-UTRAN); General aspects and principles for interfaces supporting Multimedia Broadcast Multicast Service (MBMS) within E-UTRAN

TS 36.441 Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Layer 1 for interfaces supporting Multimedia Broadcast Multicast Service (MBMS) within E-UTRAN

TS 36.442 Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Signalling Transport for interfaces supporting Multimedia Broadcast Multicast Service (MBMS) within E-UTRAN

TS 36.443 Evolved Universal Terrestrial Radio Access Network (E-UTRAN); M2 Application Protocol (M2AP)

TS 36.444 Evolved Universal Terrestrial Radio Access Network (E-UTRAN); M3 Application Protocol (M3AP)

TS 36.445 Evolved Universal Terrestrial Radio Access Network (E-UTRAN); M1 data transport

TS 36.455 Evolved Universal Terrestrial Radio Access (E-UTRA); LTE Positioning Protocol A (LPPa)

TS 37.104 E-UTRA, UTRA and GSM/EDGE; Multi-Standard Radio (MSR) Base Station (BS) radio transmission and reception

TS 37.113 E-UTRA, UTRA and GSM/EDGE; Multi-Standard Radio (MSR) Base Station (BS) Electromagnetic Compatibility (EMC)

TS 37.141 E-UTRA, UTRA and GSM/EDGE; Multi-Standard Radio (MSR) Base Station (BS) conformance testing

Annex C
(Normative)

Detailed specifications for the terrestrial radio interface IMT-Advanced as specified by 3GPP for WirelessMAN-Advanced

- **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.

- **IEEE Std 802.16j-2009**
  Standard for local and metropolitan area networks – Part 16: Air interface for broadband wireless access systems – Amendment 1: Multihop 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.

- **IEEE Std 802.16h-2010**
  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.

- **IEEE Std 802.16m-2011**
  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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