4G Wireless and International Mobile Telecommunication (IMT) Advanced

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Abstract:

IMT-Advanced is an evolving standard that is currently undergoing the standardization process. It promises the next generation mobile network with high data rates, seamless connectivity and mobile communication within heterogeneous networks. This paper discusses the requirements, details and emerging technologies of IMT-Advanced and its various aspects.

Keywords:

IMT Advanced, 4G, LTE, UMB, IEEE 802.16m.

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1. Introduction

The number of mobile subscribers is increasing and it is predicted that by the year 2020, mobile devices will be widely popular across the world [ITU05]. Thus the need arises for enhanced data rates to accomodate these users and to serve the ever evolving high speed mobile services. International Mobile Telecommunication-Advanced (IMT-Advanced) is an evolving standard by the ITU (Internation Telecommunications Union) that aims to provide the above mentioned aspects. It also promises seamless mobility making the network ubiquitous and many more features such as high quality mobile services, worldwide roaming, low cost services and applications across fixed as well as wireless networks and compatibility across radio access systems.

Section 1 gives a brief introduction followed by section 2 which describes various aspects of IMT-Advanced in detail. Section 3 gives an idea about the timeline of the implementation of this project whereas Section 4 describes the emerging technologies contending for a place in this standard. Finally, section 5 explains briefly the future plans that have been carved out for this project.

1.1 Background

The first generation (1G) of cellular networks came into existance in the early 1980s [Table 1]. TACS (Total Access Communication System) and AMPS (Advanced Mobile Phone System) were the two commonly used standards that provided analog transmission of voice in Europe and North America respectively. By the next decade the analog transmission was replaced by digital transmission using D-AMPS (Digital- Advanced Mobile Phone System) for a better , much clearer voice transmission. D-AMPS was eventually replaced by the newer 2G (Second Generation) technologies like GSM (Global System for Mobile Communication) and CDMA (Code Division Multiple Access). The 2.5 generation of technologies were a step further and supported data transmission along with voice. The 3G (Third Generation) of technologies absorbed the need for high data rates required for data transmssion and voice. The 3G technologies were standardized as IMT-2000 [ITU-R M.687] and the work on the 4G (Fourth Generation) technologies and its standardization is under progress by the name IMT-Advanced.

Table 1:Generations of Cellular Technologies

Generation	Year	Network	Technology	Data
1G	Early 1980s	Circuit switched	TACS,AMPS	Analog Voice
2G	Early 1990s	D-AMPS, GSM,CDMA	D-AMPS, GSM,CDMA	Digital Voice
2.5G	1996	Cicuit switched or Packet switched	GPRS, EDGE, EVDO, EVDV	Digital Voice + Data
3G	2000	Non IP, Packet switched / Circuit switched	WCDMA, CDMA2000	Digital Voice + High speed Data + video
4G	2012	IP based, Packet switched core network.	Not finalized.	Digital Voice, High speed Data , Multimedia, Security

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2.Overview of IMT-Advanced

IMT-Advanced proposes an all IP based network [Fig 1] with packet switched delivery for efficiently meeting the needs of the future generation networks like the high data rates (up to 100 Mbps for mobile nodes where as 1 Gbps for fixed or low mobility nodes), seamless mobility, availability of wide range of service to mobile users and expanding the services to maximum users over a large geographic area.

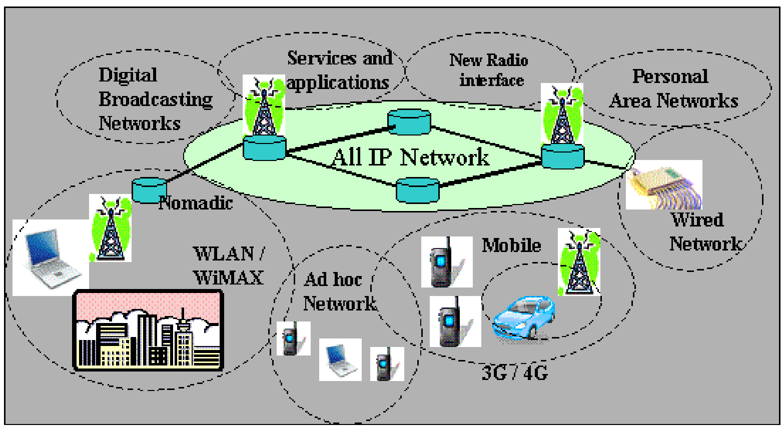

Figure 1: Convergence of various networks into one IP based network

It also proposes the convergence amongst the mobile, wireless, and wired netwotks. It has provisions for the QoS (Qaulity of Service) requirements as per users' demands.It promises to match the QoS to those of wired communication and supports global roaming. Handover between heterogenous networks will also be possible.

2.1 Requirements of IMT-Advanced

The heart of IMT-Advanced architechture consist of IP based global backbone network.Various networks such as the wired (PSTN - Public Switched Telephone Networks), LAN (Local Area Networks), IP based mobile network, cellular (3G), wireless (WiMAX - Worldwide Interoperability for Microwave Access), nomadic, ad hoc and sensor networks will be able to communicate with this core network.

IMT-Advanced will support improved performance with respect to use of spectrum, peak data rate, latency to support delay sensitive systems and the performance on the edge of a cell. It supports stationary (0 kmph) , pedestrians (10kmph) ,vehicular (120 kmph) and high speed vehicular (350 kmph) environments. Seamless application connectivity to mobile and other IP networks, efficient unicast services, multicast services and support to multiple radio interfaces are the other aspects of this standard.It also plans to support applications that conform to open standards and protocols. Seamless connectivity between the terminal and base station will be automatic and transparent to the user as it moves across mobile networks. Since the core network will be IP based the IMT-Advanced systems requires support for mobile IP.

Following are the technical requirements for air interface.

2.1.1 Channel access schemes

Channel access methods are transmission methods in which several stations can access a channel and send data over a time span. The new multiple access technologies will be backward compatible and must coexist with the IMT-2000 systems. Contention based multiple access methods will be supported. Flexibility, reuse and efficiency of spectrum are of importance while considering the access methods. These methods will be sufficient for broadband transmission and packet switching. Examples are OFDMA (Orthogonal Frequency Division Multiple Access), SC-FDMA (Single Carrier- Frequency Division Multiple Access), OFDM-TDMA (Orthogonal Frequency Division Multiplexing - Time Division Multiple Access), contention based.

Once the access method has been finalized the choice of modulation scheme is of equal importance and is influenced by various factors described below.

2.1.2 Modulation scheme and duplex methods

Modulation involves coding of data onto the carrier frequency by varying one or more of its basic characteristics. Modulation should support the efficient use of spectrum. Modulation with lower peak to average power ratio (PAPR) should be selected. The type of radio network and the spectrum efficiency requirements often influence the choice of modulation scheme. AMC (Adaptive Modulation and Coding) provides various modulation and coding scheme levels. Data modulation such as QPSK, 16QAM (Quadrature Amplitude Modulation), 64QAM, DAPSK (Differentially Amplitude and Phase Shift Keying) could possibly be supported.

Duplex Methods such as TDD, FDD (paired and unpaired frequency allocations), full and half-duplex FDD are supported. The uplink/downlink ratio is configurable. Symmetrical as well as asymmetrical operation is supported. In a symmetrical air interface, same bandwidth is occupied by both the downlink and uplink carrier waveforms. Whereas the downlink carrier waveform and the uplink carrier waveform occupies different channel bandwidth in a non-symmetrical air interface.

Duplex methods are independent of channel access technologies. Following the encoding scheme are the requirements for error control which are discussed below.

2.1.3 Error Control Coding Schemes

For reliable communication, implementation of advanced forward error correction coding scheme should be considered. Examples are Turbo codes [Berrou93] and LDPC (Low Density Parity Check) codes [Gallager62]. Hybrid ARQ (Automatic Repeat Request) is another technique for spectrum efficiency and reliable link.

2.2 Radio aspects for IMT-Advanced

A new radio interface technology will be introduced which will interoperate between heterogenous networks. Intelligent radio access as well as the use of software defined radio has been under consideration. The radio technology should operate in mutimode, mutiband and heterogeneous networks.

Advanced antenna techniques such as SDMA (Space Division Multiple Access), transmit diversity, MIMO (Multiple Input Multiple Output) and beam forming including multi-antenna capabilities at both the base station and at the mobile terminal (for uplink and downlink) will be supported. Minimum requirements for the configuration of antenna are:

Base station: Two transmit and two receive antennas. (2 x 2 configuration)
Mobile Station: One transmit and two receive antennas (1 x 2 configuration)

2.3 Bandwidth and Spectrum requirements for IMT-Advanced

Initially scalable bandwidths from 5 to 20 MHz will be supported. It will be extensible and support larger channel bandwidths as they become available. Efficient Spectrum sharing will be possible between different radio access technologies .Table 2 states the performance of a mobile device in an IMT Advanced system. While in low mobility a mobile device should get optimized performance where as a marginal degradation is expected during high mobility. Mobile devices should remain connected during high speeds.

It has also been estimated that by the year 2020 the spectrum requirements will increase to about 1280 (low user demand) -1720 MHz (High user demand).Since 750 MHz spectrum has already been identified for IMT-200 systems an additional spectrum of 530 MHz for low user demand and 970 MHz for high user demands must be identified [ITU-R]. Following candidate bands have been identified. Advantages and disadvantages of the candidate bands are described in Table 2.

Table 2: Candidate Bands and thier details

Spectrum	Current Use	Advantages	Disadvantages
410 - 430 MHz	Land mobile services-public protection and disaster relief	More coverage area, good propagation characteristics	Large antennas, limited band, capabilities of IMT-Advanced could downscale
450 - 470 MHz	Land mobile services-public protection and disaster relief	More coverage area, good propagation characteristics	Large antennas, limited band, capabilities of IMT-Advanced could downscale
470 - 806 MHz	Broadcasting services (Television and radio)	More coverage area, good propagation characteristics, upper band closer to IMT-2000. Therefore reduced complexity of Equipment	Large antennas, limited band, capabilities of IMT-Advanced could downscale
2300 - 2400 MHz	Fixed and mobile services	Band closer to IMT-2000. Simplifies development, planning and deployment of IMT systems in this band	Insufficient bandwidth, Used in other applications
2700 - 2900 MHz	Radar systems, aeronautical radio navigation	Band closer to IMT-2000. Simplifies development, planning and deployment of IMT systems in this band	Not feasible for IMT-2000 systems. Lots of interference from radars
3400 - 4200 MHz	Fixed services and fixed satellite services (FSS), fixed and mobile broadband wireless access systems, radiolocation.	Large bandwidth, smaller antenna size, relatively better propagation characteristics	interference mitigation measures are required

4400 - 4990 MHz	mobile service, FSS providing basic infrastructure telecommunication system, aeronautical mobile or for Fixed Services (FS) for long distance links, radio astronomy	Large bandwidth, smaller antenna size, multiple antenna techniques enabling high spectrum efficiency	largest frequency-dependent propagation loss adversely affecting high mobility

Source:[WINNER]

The table below (Table 3) states the spectrum allocation that was discussed for various countries in one of the meetings.

Table 3: Spectrum Allocation

Spectrum	Regions
450 - 470 MHz	Globally; individual administrations to decide
698 - 806 MHz	Americas and China, Korea, India, Japan, New Zealand, Papua New Guinea, Philippines, Bangladesh and Singapore
790 - 862 MHz	Europe and other Region 1 and 3 countries
2300-2400 MHz	Globally
3400-4200 MHz	IMT or mobile service

Source:[WRC07]

2.4 Handover

Handover can be defined as a change in channel of the ongoing connection in terms of time slot, spreading code, frequency, or combination of these while a call is in progress. For a continuous always-on service IMT-Advanced systems shall provide handover methods to facilitate continuous service to mobile terminals that are moving. This enables mobile terminals to maintain connectivity when moving between cells, systems, frequencies, and IP Subnets.

The handovers could be vertical (inter technology) or horizontal (intra technology).A vertical handover is often between different technologies. For example, a handover of a device from WiMAX service to 3G cellular service. A horizontal handover takes place within the same type of technology. A handover of a device between two cells of a mobile network is an example of a horizontal handover. Intra technology handover techniques are already in practice whereas inter technology handover faces many issues which need to be addressed such as service continuity, QoS, measurement reports, network discovery, network selection, security during handover, inter-technology handover initiation and control and power efficient network scanning.

Table 4: Performance and Mobility Support

Mobility	Performance
Low (0 - 15 km/h)	Optimized
High (15 - 120 km/h)	Marginal degradation
Highest (120 km/h to 350 km/h)	System should be able to maintain connection

Table 4 describes the performance requirements for mobility. For low mobility the perfomance should be optimized where as there should be minimal degradation during high mobility. For speeds greater than 120 km/h system should be able to maintain connection.

For conservation of power due to the limited power profile of the mobile terminals, stringent power useage is discussed below.

2.5 Power Efficiency and Quality of Service

Since the IMT-Advanced systems provide a wide range of symmetrical, asymmetrical and unidirectional services, QoS is an important issue. They provide management of QoS classes which will extend the support for applications such as VOIP(Voive over Internet Protocol), IPTV (IP Television), Interactive Gaming. The traffic will be prioritized based on the type of service and factors such as data rate, latency, packet error rate, jitter. Following are the QoS requirements that will be supported:

User QoS and policy requirements.
End-to-end QoS
Link layer QoS
Capability to distinguish between different service flows and satisfying the QoS for each flow.
Dynamic creation, modification and deletion of QoS flows
Admission control, traffic mapping and negotiation of QoS parameters

Table 5: Class of Service and their examples

Class of Service	Priority	Application Example
Background class	Lowest priority	file download, email download
Conversational class	Low priority	voice
Interactive class	High priority	Interactive web browsing, gaming
Streaming class	Highest priority	Real time video streaming

Table 5 above describes the class of services in which the traffic will be catagorized to support delay sensitive applications. Activities such has video, realtime streaming are categorized in streaming class which has the highest priority since these applications are delay sensitive where as the interactive class which includes applications such as gaming has higher priority than the conversational and background classes of services. These classes of service will help improve the QoS of IMT-Advanced systems.

2.6 Security Aspects

IMT-Advanced systems will be required to protect its resources from attacks as well as misuse. Protection from unauthorized access, denial of service as well as theft of service are just a few issues to name. Mutual authentication of base station as well as mobile station is required for data protection, integrity and privacy.An end to end security system will be implemented by using TLS (Transport Layer Security), SSL(Secure Sockets Layer) and IPSec (Internet Protocol Security). Security aspects include:

- Mutual Authentication
- Authentication / Credentials of user or device
- Data confidentiality
- Message Integrity and Origin authentication
- Maintain security asociation across networks without losing connection
- Protection against replay attacks
- Privacy and Integrity

Thus security forms an important part of any system including IMT-Advanced.

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3. Timeline

IMT-Advanced is still an evolving standard and hence most of the technologies that are to be a part of this standard are yet to be finalized. The work on IMT-Advanced [Fig 2] started around the year 2002 where the vision, definition and requirements were charted out. Currently the standard is evolving to accommodate the spectrum allocation requirements as well as reaching out for new radio access technologies. The IMT-Advanced system deployment is expected to be in place by the year 2012 and widely deployed by 2015.

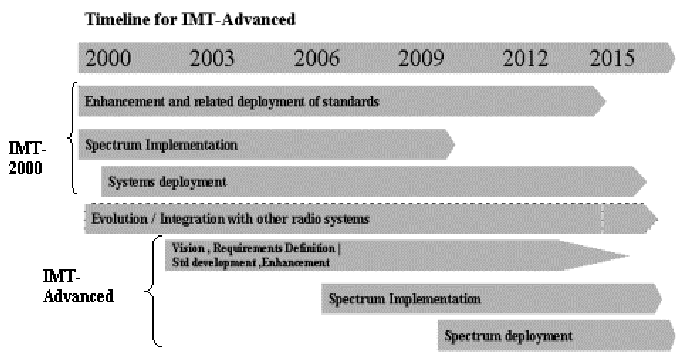

Fig 2 Timeline for the standardization of IMT-Advanced.

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4. Technologies for IMT Advanced

Since the IMT-Advanced vision was introduced in 2002 the telecommunication industry started work on IMT-Advanced and are developing technologies that meet this standards. LTE (Long Term Evolution), UMB (Ultra Mobile Broadband) and WiMAX are few technologies that are vying for a position in this standard. All these technologies being similar and contending, their time to market will be a crucial element in the popular acceptance of any of the above mentioned technologies.

3GPP plans for IMT advanced : LTE

3GPP (3rd Generation partnership project) is a consortium of telecommunication standards bodies that have proposed LTE. Feasibility studies on LTE and UTRAN (Universal Terrestrial Radio Access Network) began in December 2004 with the main objective of extending 3GPP services towards a packet based, low latency, high data rate radio-access network. The LTE system srchitecture consist of a core which is IP based [Fig 3]. Other radio access networks such as GERAN (GSM EDGE Radio Access Network), UTRAN, GPRS (General Packet Radio Systems). WLAN, ERAN (Evovled RAN) and other IP based networks co-exists and communicate with each other.

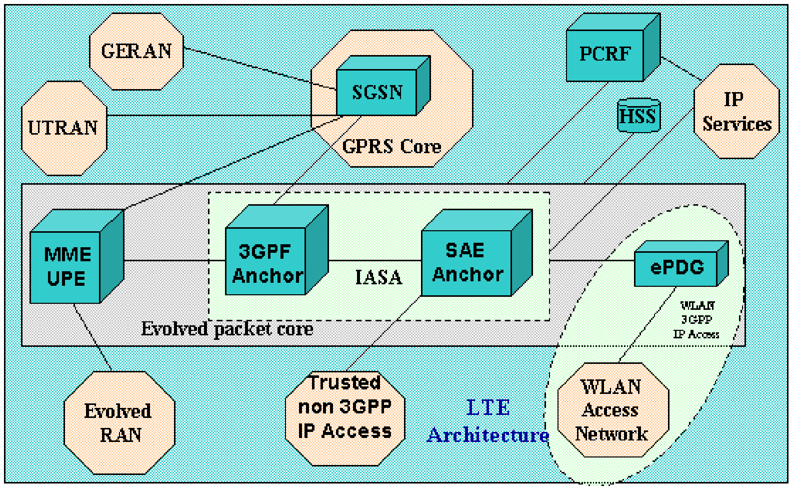

Fig 3: LTE System Architecture.

LTE promises peak data rates of 100 mbps and 50 mbps downlink and uplink respectively for 20 MHz spectrum allocation by using OFDM for downlink and SC-FDMA for uplink. It proposes to support data modulation schemes such as QPSK, 16QAM, and 64QAM for downlink where as uplink data-modulation schemes are (pi/2-shift) BPSK (Binary Phase Shift Keying), QPSK, 8PSK and 16QAM.Use of MIMO with up to four antenna supports at mobile as well as base stations. Turbo code for efficient error detection is used. In terms of mobility optimized speed for low mobility and high performance for higher mobility is assured. Depending on the frequency band mobility up to 500 km/h could be supported. Variable spectrum allocation from 1.25MHz to 20 MHz in both uplink and downlink directions will be supported. Co-existence with other 3GPP technologies like UTRAN, GERAN, GPRS as well as non 3GPP IP based networks is possible. LTE supports end to end QoS, load sharing, policy management across RATs (Radio Access Technologies). [LTE07]

Considerable amount of work has been put in to make this system less complex, affordable, bandwidth efficient and compatible for co-existence with other networks. Similarly on these lines UMB (Ultra Mobile Broadband) is being introduced by 3GPP2 (Third Generation Partnership Project 2) which is a collaboration of telecommunication companies established in 1998.

4.2 3GPP2 plans for IMT advanced : UMB

Ultra Mobile Wideband is the world's first IP based mobile broadband solution that has already been published which supports data rates up to 288 Mbps and low avearge latencies. It is expected that UMB will be commercially available by mid 2009. UMB promises high data rate, seamless mobility as well as low latency at affordable rates. Use of OFDMA technology along with advanced antenna techniques such as MIMO, SDMA and beamformaing make this technology bandwidth efficient. For always-on universal access UMB supports inter-technology hand-offs.

UMB promises peak data rates of 288 Mbps and 75 Mbps for downlink and uplink respectively for 20 MHz bandwidth.It suppports communication across fixed, pedestrian and mobile environments (greater than 300 km/h). It could be deployed in variable bandwidths from 1.25 MHz to 20 MHz and is designed to inter operate with the existing circuit switched networks.It will also support rich multimedia at high speeds. [UMB07]

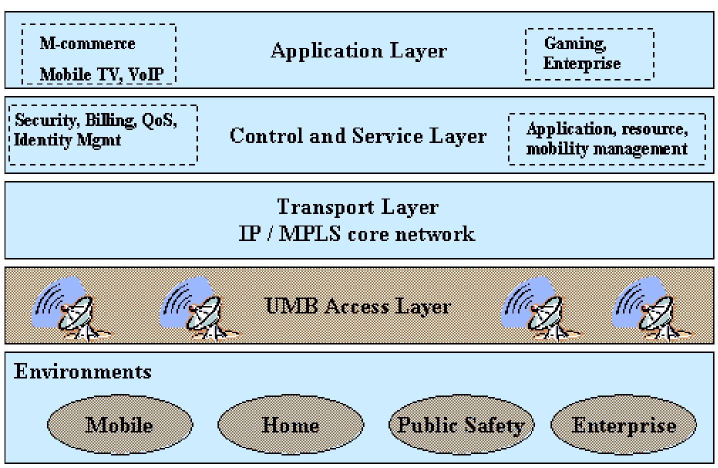

Fig 4 UMB Access Layers.

The access layers of UMB are shown in Fig 4. Various environments are supported by UMB such as home, mobile, public safety etc followed by the UMB access layer. IP based core network is present in the transport layer. Control and service layer provides the management functions such as resource and mobility management, security, billing and QoS. Finally the application layer providies many functions such as gaming, VoIP, mobile TV etc

4.3 WiMAX [IEEE 802.16m]

WiMAX is another technology that provides mobile broadband solution (802.16m). OFDMA based WiMAX will support scalable bandwidths from 5 to 20

MHz on operating frequencies lesser than 6 GHz. Its architecture will be flexible to support next generation mobile networks that are part of IMT-Advanced. It has support for seamless mobility across networks and QoS depending on the type of traffic. It will support TDD and FDD operational modes (paired and unpaired) as well as configurable UL / DL ratio. Advanced antenna techniques will be supported such as MIMO and beam forming. The peak data rates will exceed 130 Mbps for 20 MHz bandwidth. It will provide security and radio resource management (reporting and interference management). Enhanced multicast, broadcast and location based services will also be provided. High mobility and support for rich multimedia application, data and voice services are also included. 802.16m is being developed very close on the lines of IMT- Advanced specifications. [WiMAX]

Table 6 Comparison of WiMAX, LTE, UMB

Characteristics	**LTE**	**UMB**	**WiMAX (802.16m)**
Core Network	IP based	IP based	IP based
Peak data rates (for 20 MHz)	100 Mbps	288 Mbps	>130 Mbps
Access technology	OFDM, SC-FDMA	OFDMA	OFDMA
Advanced antenna techniques	MIMO	MIMO, SDMA, beam forming	MIMO, beam forming
Channel Bandwidth	1.25 to 20 MHz	1.25 to 20 MHz	5 to 20 MHz
Mobility support	500 km/h depending on frequency band	>300 km/h	350 km/h
Seamless mobility	Yes	Yes	Yes
Power saving	Yes	Yes	Yes
QoS	End to end	End to end	End to end
Handover	Vertical, horizontal	Vertical, horizontal	Vertical, horizontal
Time to Market	Under Development	Mid 2009	Under Development

Table 6 provides a brief comparison between the emerging technologies.

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5. Future Work

For further development of IMT-Advanced research should be carried out in new radio technologies, access methods and in the area of handover. Systems should be single sign on systems, which would make the handover easier.

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6. Summary

IMT- Advanced is an emerging standard with cutting edge technologies to support the ever growing mobile users and the increasing demands for high data rates. To make this standard a success still some research needs to be done in various areas. Various technologies are being developed by telecommunication companies to reach the ultimate requirement of this standard. Once the standardization process is complete lot of areas and aspects of IMT-Advanced will be clearer.

Table 7 Summary of IMT-Advanced

Characteristics	**Technology**
Deployment	2012-2015
Core networks	IP based
Band	Below 6GHz
Data rates	100 Mbps to 1 GHz
Access methods	OFDMA, SC- FDMA, OFDM-TDMA
Radio Interface	Cognitive radios, software defined radios.
Modulation	QPSK, 16QAM, 64QAM, DAPSK
Services provided	Rich multimedia, voice, high speed data.
Duplex methods	FDD(paired, unpaired), TDD
Error control	LDPC, turbo codes, HARQ
Handover	Seamless, vertical, horizontal, hard, soft

Table 7 summerizes the various IMT-Advanced aspects that have been described above. Many of these characteristics have not been finalized and hence technologies could be removed or added.

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List of Acronyms

3G	3rd Generation
3GPP	3rd Generation Partnership Project
3GPP2	3rd Generation Partnership Project 2
AMC	Adaptive Modulation Coding
BPSK	Binary Phase Shift Keying
CDMA	Code Division Multiplexing
DAPSK	Differentially Amplitude and Phase Shift Keying
DL	Downlink
EDGE	Enhanced Data for GSM Evolution
ERAN	Evolved Radio Access Network
EVDO	Evolution Data only
FDD	Frequency Division Duplex
FSS	Fixed Satellite Service
GERAN	GSM EDGE Radio Access Network
H-ARQ	Hybrid Automatic Repeat request
HO	Handover
IMT	International Mobile Telecommunication
IP	Internet Protocol
IPTV	Internet Protocol Television
ITU	International Telecommunication Union
LAN	Local Access Networks
LDPC	Low Density Parity Check
LTE	Long Term Evolution
MAC	Media Access Control
MIMO	(Multiple Input Multiple output)

OFDMA	Orthogonal Frequency Division Multiple Access
OFDM-TDMA	Orthogonal Frequency Division Multiplexing – Time Division Multiple Access
PDU	Protocol Data Unit
PSK	Phase Shift Keying
QAM	Quadrature Amplitude Modulation
QoS	Quality of service
QPSK	Quadrature Phase Shift Keying
RAN	Regional Access Networks
RAT	Radio Access Technology
SC- FDMA	Single Carrier – Frequency Division Multiple Access
SDMA	Space Division Multiplexing
TDD	Time Division Duplex
UL	Uplink
UMB	Ultra Mobile Broadband
UTRAN	Universal Terrestrial Radio Access Network
VOIP	Voice over IP
WiMAX	Worldwide Interoperability for Microwave Access

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