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Technologies of Mobile Communication

Monika Margilaj

University for Business and Technology

Faculty of Computer Sciences and Engineering

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Monika Margilaj

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Student: Monika Margilaj

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Supervisor:Dr. Xhafer Krasniqi

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ABSTRACT

Long-Term Evolution (LTE) is a new technology recently specified by 3GPP-Third Generation Partnership Project on the way towards fourth-generation mobile. This thesis presents the main technical features of this technology as well as its performances in terms of peak bit rate and average cell throughput, among others. LTE entails a big technological improvement as compared with the previous 3G standards.[1]However, this thesis also demonstrates that LTE performances do not fulfill the technical requirements established by ITU-R to classify one radio access technology as a member of the IMT-Advanced family of standards. Thus, this thesis describes the procedure followed by 3GPP to address these challenging requirements. Through the design and optimization of new radio access techniques and a further evolution of the system, 3GPP is laying down the foundations of the future LTE-Advanced standard, the 3GPP candidate for 4G.

[1].www.hindawi.com/journals/special issues/432727.pdf

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GLOSSARY OF ACRONYMS

1xDO Rev0– Data Optimized Revision 0 is an evolution of the CDMA IS-2000 standard and supports higher data rates of 2.4Mbps (downlink) and 153kbps (uplink).

1xDo RevA- Data Optimized Revision A is an enhancement of the 1xDO Rev0 standard and supports higher data rates of 3.1Mbps (downlink) and 1.8Mbps (uplink).

2G– 2G is short term for second generation mobile communication networks. These systems were the digital mobile communication systems introduced in the 1990's. GSM and CDMA are examples of 2G systems.

3G – 3G is short term for third generation mobile communication networks. These systems, introduced in the mid 2000's, were created to handle demand for more data and higher bandwidth. UMTS and 1x DORev0/RevA are examples of 3G systems.

3GPP – Formed in 1998, the Third Generation Partnership Project fosters the development of 3G standards that descended from GSM.

3GPP-2- Formed in 1998, the Third Generation Partnership Project 2 fosters the development of 3G standards that descended from CDMA.

4G – 4G is short term for fourth generation mobile communication networks, a system that will supersede the 3G systems. These systems are going to be all-IP networks providing very high throughput and innovative services. LTE, UMB and WiMAX are examples of 4G systems.

ANSI- American National Standards Institute is a private non-profit organization that oversees the development of voluntary consensus standards for products, services, processes, systems, and personnel in the United States.

CAPEX– Capital expenditure are the expenditures towards purchase of new assets, technology or systems.

CDMA – Code Division Multiple Access is a radio access scheme used by IS-95 (aka CdmaOne) and IS-2000 (aka CDMA2000) standards.

EDGE - Enhanced Data rates for GSM Evolution is an extension of GSM systems with higher data transmission rates.

ETSI – The European Telecommunications Standards Institute is the official European telecommunications standards organization recognized by the European Union.

FDD– Frequency Division Duplexing refers to a transmission scheme that encompasses the transmitter and receiver operation at different carrier frequencies.

GSA- Global mobile Suppliers Association represents leading GSM/WCDMAHSPA/LTE suppliers worldwide.

GSM- Global System for Mobile communication is a 2G digital mobile communication standard.

HSDPA– High Speed Downlink Packet Access is an enhanced 3G (also known as 3.5Gor 3G+) mobile communication standard for enhanced data rates for network to device transmission.

HSUPA– High Speed Uplink Packet Access is an enhanced 3G (also known as 3.5G or

3G+) mobile communication standard for enhanced data rates for device to network transmission.

HSPA– High Speed Packet Access denotes a combination of HSUPA and HSDPA.

HSPA+- An evolution of HSPA with data rates enhancements.

IEEE- Institute of Electrical and Electronics Engineers is a non-profit professional association for the advancement of technology.

LSTI– LTE/SAE Trial Initiative is a global, collaborative technology trial initiativefocused on accelerating the availability of commercial and interoperable LTE mobilebroadband systems.

LTE – Long Term Evolution is a the 4th generation mobile communication technology designed to increase the capacity and speed of mobile networks. LTE is standardized by3GPP in its release 8.

NGMN- Next Generation Mobile Networks is an initiative by a world-wide group of leading mobile operators to provide a coherent vision for the mobile network technology evolution beyond 3G for the competitive delivery of mobile broadband wireless services.

OPEX – Operational expenditure is the on-going cost for running a product or system.

OSS –Open Source Software is a computer software for which the source code and certain other usage rights are provided under a software license to end user.

RAN– Radio Access Network is a component of the mobile communication network that sits between user equipment (handset) and core network. It encompasses a number of base transceiver stations.

SAE – System Architecture Evolution is the core network architecture of the LTE standard. SAE is simplified and based on an all-IP network. SAE can support mobility between radio access networks of legacy 3GPP standards. SAE also supports non-3GPPradio access networks as well.

SON– Self Organizing Networks is a set of requirements published in the form of use cases to enable automation in the operation of LTE radio access network.

TDD – Time Division Duplex refers to a transmission scheme that encompasses an asymmetric transmitter and receiver operation at the same carrier but using different timeslots.

UE– User Equipment is the term used for mobile terminals in LTE standard.

UMB– Ultra Mobile Broadband was the project to define a 4G mobile communication standard by 3GPP2. The project was halted in November 2008.

UMTS– Universal Mobile Telecommunications System is the 3G mobile communication system developed by 3GPP

W3C– The World Wide Web Consortium is an international consortium where member organizations, a full-time staff, and the public work together to develop Web standards. W3C's mission is to lead the World Wide Web to its full potential by developing protocols and guidelines that ensure long-term growth for the Web.

WiMAX – Worldwide Interoperability Microwave Access is a IEEE packet radio access standard.

WCDMA– Wideband Code Division Multiple Access is a radio access scheme for the air interface in 3G mobile communication networks (e.g. UMTS)

I INTRODUCTION

LTE (Long Term Evolution) is known as Release 8.LTE specifications are very stable, with the added benefit of small enhancements being introduced in Release 9, a Release that will be functionally toward in December 2009.Some motivations for creating this standard are to ensure the continuity of competitiveness of the 3G system for the future, demand for higher data rates and quality of service, packet switch optimized system, continued demand for cost reduction (CAPEX and OPEX), low complexity etc.[2]

The current generation of mobile telecommunication networks is collectively known as 3G (for “third generation"). Although LTE is often marketed as 4G, first-release LTE is a 3.9G technology since it does not fully comply with the IMT Advanced 4G requirements. The pre-4G standard is a step toward LTE Advanced, a 4th generation standard (4G) of radio technologies designed to increase the capacity and speed of mobile telephone networks.[3] LTE Advanced is backwards compatible with LTE and uses the same frequency bands, while LTE is not backwards compatible with 3G systems.

LTE Advanced is the evolution of LTE and is currently being standardized in 3GPP Release 10. LTE Advanced is the global 4G solution and the leading candidate to meet ITU’s IMT-Advanced requirements. LTE Advanced benefits includes the ability to leverage advanced topology networks; optimized heterogeneous networks with a mix of macro cells with low power nodes such aspicocells, femtocells and new relay nodes
LTE Advanced expected to be finalized in 2011.

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[2]www.scribd.com/doc/510458/Human-Resource-Management
[3]http://lazyproblogger.com/3gpp-lte-latest-standard-in-the-mobile-network/

1.1 Thesis goal

The main goal of this thesis is because we want to show the differences of mobile technologies and also their advancement whose today have taken a very big leap in the technology world.

Also considering that today each of us want to be in a step with technology m we think that notes below will be helpful to understand advantage and disadvantage of each mobile generation.

1.2 Research methodology

The compiler of thesis must have good knowledge on information technology field and to be ready for describing all data's from various sources which are included on notes below.

The data are based more in theoretical part which are based on various information that are presented online as e-booking, practice recording ,magazines and by collection of different literature by professors of Universities all over the world.

Resources concerned in this thesis are quite interesting and attractive to understand the main essence of mobile technology.

1.3 Chapter Review

Thesis is created on four chapters where which ones describes information for mobile technology.

First chapter contains information (introduction) for fourth generation such, its benefits, advantages and disadvantages

On second chapter there is description for mobile communication starting from the first one (1G) until last one fourth generation (4G) there is also described their standards, and their comparisons between each other.

On third chapter there is tutorial description for the 4G of mobile communication. There are their protocols and standards which are used on this technology. This chapter is forwarded fourth chapter which follow the newest technology such LTE Advanced.

II LITERATURE REVIEW

2 Mobile Communication

The world has seen a lot of changes in the realm of communication. Almost everyone possesses a mobile phone that functions nine to seven. Our handsets not only keep us connected with the world at large but also serve the purpose of entertainment gadget. From 1G to 2.5G and from 3G to 4G this world of telecommunications has seen a number of improvements along with improved performances with every passing day.

Mobile communication is provided via network infrastructure called “Cellular network”. This infrastructure enables integration of mobile telephony with PSTN (Public Switched Telecommunication Network).

The air broadband was always insufficient. It’s urged the need to find opportunity to re-use frequency belts and this could be achieved with cellular system. This means that one radio frequency channel can be used by more transmission in the same time, in condition to be separated from each other, to be avoided from interferences. This entire infrastructure has passed through 4 generations as shown on Fig.1.

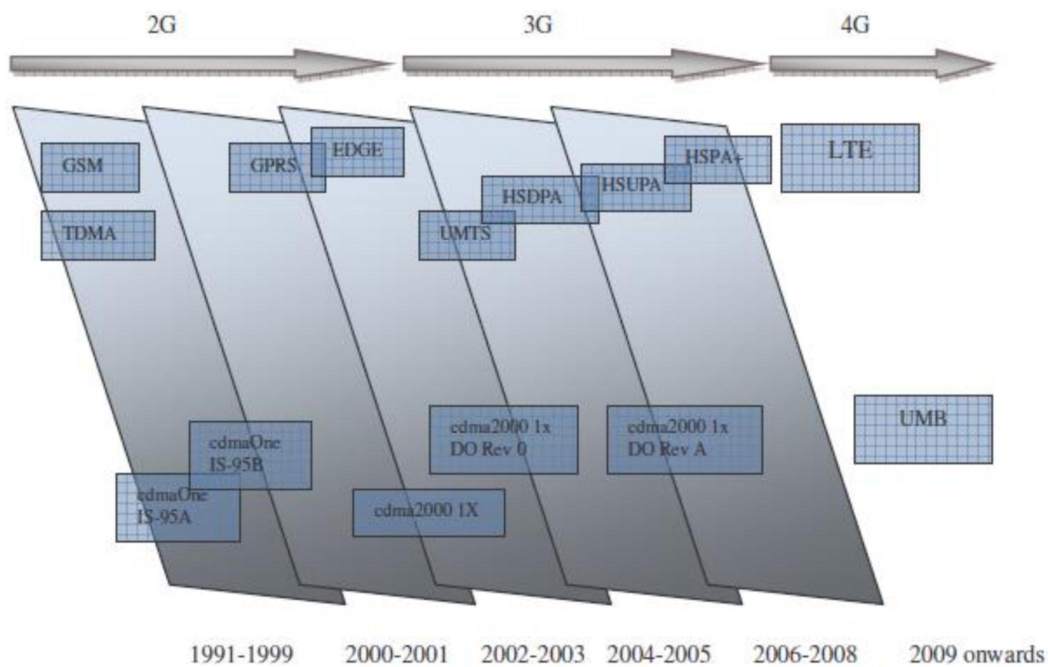

Figure 1:Evolution of mobile communication, [2]

2.1 1G First generation

1G first generation services were analogue services for cell phones. These were (and are) for voice only; the technology didn't provide for SMS or other data services.1G is circuit switched. This means that when you place a call, a connection is established for you, and is maintained until you hang up. You are billed for the duration of the call, regardless of how much talking occurred. This is appropriate for voice communication where one person or the other is talking at any point in time.

This is based on analogue technologies like the Advanced Mobile Phone System (AMPS) in North America or the Nordic Mobile Telephone (NMT) deployed in northern Europe. These systems are referred to as first Generation (1G) mobile communication standards. 1Gstandard were based on frequency division multiplexing i.e. each phone call utilizes separate radio channel.

2.2 **2G Second Generation**

2G Second Generation systems were significantly more efficient on the spectrum allowing for far greater mobile phone penetration levels; and 2G introduced data services for mobile, starting with SMS text messages. Standards followed and were utilizing digital technologies e.g. D-AMPS with Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA) and Global System for Mobile communication (GSM) using TDMA. TDMA was relatively better in terms of spectrum utilization and digital transmissions allow for more phone conversations in the same amount of spectrum.

2.3 **3G Third Generation**

3GThird Generation standards provided more robust technologies and better spectral efficiency. Global mobility and improvement in end-user experience by providing many categories of mobile services are some of the value propositions of 3Gstandards. This generation has to do with circuit switch and packet switch.

2.4 **4G Fourth Generation**

4G Fourth Generation demand for higher data rates and simplified networks is the premise for evolution of mobile communication networks to the 4G standards. It’s based all on IP networks, which has to do only with packet switch.

III BACKGROUND

3 4G Options and Technology

4G which stands as Fourth Generation is the upcoming next generation technology which will gradually replace its predecessor 3G out of the surface of the world. The 4G technology has promised to offer widespread, complete and invulnerable all-IP (Internet Protocol) based services. Examples of such services are high quality multimedia streaming, enhanced gaming services, super fast broadband Internet access, IP telephony and etc.

4G which is also be referred as "International Mobile Telecommunications Advanced" in short IMT Advanced promises to have a targeted maximum data speed up to around 100 mega bytes per second for outdoor users like instant access to Internet by mobiles or smart phones and for indoor users like the LAN (Local Area Network) users the data speed would be around 1 Giga bytes per second, for both the mobile or fixed stationed Internet users this type of higher speed, which has never before. Also up to 40 mega hertz of scalable bandwidth must be provided, according to ITU requirements. The frequency-domain equalization policy has removed the CDMA spectrum radio technology that was being used by the IS-95 and 3G stations.[4]

The reason behind the development of 4G is to provide accommodation for the required QoS and rate that was set as requirements by the advanced growth of current 3G applications such as, mobile TV, wireless broadband service, video chat, MMS (Multimedia Messaging Service) and also the famous HDTV content.[5] The fourth generation technology may also provide wireless LAN roaming and may also intermingle with systems that are used for digital video broadcasting.

[4]http://dev.qlotuspe.com/4g_technology.php
[5]http://www.itu.int/osg/spu/ni/futuremobile/Broadbandmobile.pdf

3.1 Objectives of 4G

Here are the main objectives that 4G will offer when is fully developed.

- 100Mbps would be the normal data rate for the users who are not stationary and moving at high speeds and 1Gbps would be the maximum data rate when the user is indoor or at a fixed position.
- Bandwidth flexibility, between 5 to 20 mega hertz maximum up to 40 mega hertz
- Worldwide roaming over multiple networks and flawless connectivity
- System spectral efficiency downlink up to 3 bit/s/Hz/cell and for fixed or indoor usage 2.25 bit/s/Hz/cell
- All-IP based network means packet switched network

3.2 Characteristics of 4G

4G must improve upon the ability of 3G technologies to provide coverage and capacity at a given price point. It must be more spectrally efficient and provide a cost per bit that is significantly lower than today's voice networks, perhaps roughly equivalent to that of wired DSL services. Low latency (also roughly equivalent to that of wired broadband) is also part of the definition.[6] Support for native IP protocols is also important and consensus suggests that 4G should be able to support user rates equivalent to DSL or cable modems (256 kbps to 1 Mbps downstream). In other words, 4G must be capable of reducing cost to operators and translating the desktop experience to the mobile world.

An important element to 4G should be an IP-centric cellular WAN (not WLAN) that eliminates circuit switching and distributes switching intelligence throughout the network rather than to a centralized location. 4G must also improve upon the performance of existing cellular networks (measured by coverage, capacity and cost per bit). All in all, 4G characteristics should include:

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[6] http://findarticles.com/p/articles/mi_m0NUH/is_14_36/ai_95791469/

- IP core network (no circuit switching)
- Decentralized (pushes intelligence away from center)
- Greater spectral efficiency than 3G
- Significantly lower cost per bit than 3G
- Latencies comparable to a wired network
- Native IP support and a user experience roughly equivalent to consumer DSL or cable modems. Demand for higher data rates and simplified networks are the premise for evolution of Mobile communication networks to the 4G standards.

There were three competing standards in this space: LTE from 3GPP, Ultra Mobile Broadband (UMB) from 3GPP2 and 802.16e-2005 (mobile Worldwide Interoperability Microwave Access (WiMAX) from IEEE.[7]

All of those standards have very similar features, offering high data rates and a similar network architecture. However, they vary in terms of their adoption by various service providers around the world. UMB developments are halted due to a lack of adoption.

WiMAX has gained popularity in the fixed broadband access segment, but adoption by mobile communication service providers is much lower. The LTE standard has emerged as clear winner among the 4G mobile communication standards. Major Service providers around the world have outlined plans to adopt LTE as their choice of next generation of service.[8]

[7]http://media.wiley.com/product_data/excerpt/0X/04706968/047069680X.pdf
[8]http://lazure2.wordpress.com/2011/06/18/china-mobile-repositioning-for-td-lte-with-full-content-and-application-aggregation-services-3g-hspa-level-is-to-create-momentum-for-that/

4 WiMAX

WiMAX belongs to the IEEE (Institute of Electrical and Electronics Engineers) family of standards and refers to as IEEE 802.16 standard. It enhances the WLAN (IEEE 802.11) by extending the wireless access to Wide Area Network (WAN) and Metropolitan Area Network (MAN). [9]

OFDMA (orthogonal frequency-division multiple access) is used as physical layer radio access technology in the downlink and uplink. Initial versions of WiMAX, IEEE 802.16-2004 (fixed WiMAX) supports fixed and nomadic access, while IEEE 802.16-2005 (mobile WiMAX) supports enhanced QoS (Quality of Service) and mobility up to 120 km/h. Mobile WiMAX uses IP based services to provide downlink peak data rates up to 75 Mbps.[10] WiMAX supports LOS (Line-of-Sight) and NLOS (Near-Line-of-Sight) propagations across 10 GHz to 66 GHz and 2 GHz to 11 GHz respectively.

4.1 WiMAX Architecture

The WiMAX Architecture is based on a network reference model to define end-to-end WiMAX Network, as shown on Fig.2.

4.1.1 Network Reference Model (NRM)

The NRM defines the entire WiMAX network. It ensures interoperability between various WiMAX enabled devices and operators.[11] The network architecture is based on IP Services and it can be logically divided into three parts; Mobile Station, Access Service Network and Connectivity Service Networks.

[9]http://searchmobilecomputing.techtarget.com/definition/IEEE-802-Wireless-Standards-Fast-Reference
[10]http://www.ijccr.com/November2011/5.pdf
[11]http://www.scribd.com/doc/56071451/92/Network-Reference-Model-NRM

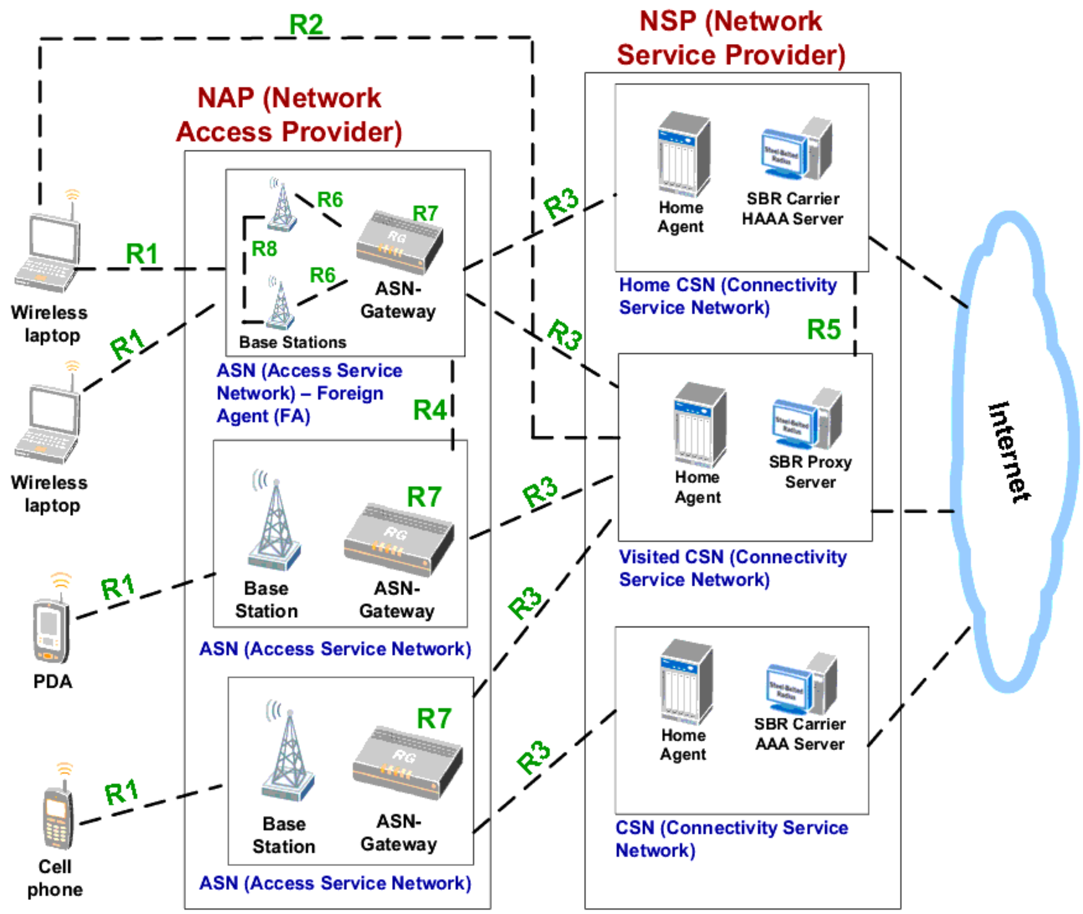

Figure 2: WiMAX Architecture, [5]

Mobile Station (MS) is used to access network.

Access Service Network (ASN) is comprised of ASN GWs (Gateways) and BSs to form Radio Access Network (RAN) at the edge.[12]

Base Station (BS) provides air interface to MS. In addition, BS is responsible for handoff triggering, radio resource management, enforcement of QoS policy, Dynamic Host Control Protocol (DHCP) proxy, session management, key management and multicast group management.

[12]http://www.scribd.com/doc/56071451/92/Network-Reference-Model-NRM

Access Service Network Gateway (ASN-GW) acts as layer 2 traffic aggregation point within an ASN. In addition, ASN-GW performs AAA (Authentication, Authorization and Accounting) client functionality,[13] establish and manage mobility tunnel with BSs, foreign agent functionality for mobile IP and routing towards selected Connectivity Service Network (CSN).

Connectivity Service Network (CSN) provides IP connectivity to internet, PSTN (Public Switched Telephone Network), ASP (Application Service Provider) and corporate networks. It also provides core IP functions, CSN is owned by the Network Service Provider (NSP), and is comprised of AAA servers, Mobile IP Home Agent (MIP-HA), Operation Support Systems (OSS) and gateways.[14] AAA servers are used to authenticate devices, users and specific services. CSN has those responsibilities: IP Address Management; Mobility, roaming and location management between ASNs; Roaming between NSPs by Inter-CSN tunneling.

4.1.2 Data Rates

Peak data rates of LTE and WiMAX depend upon multiple antenna configurations and modulation scheme used. Peak data rates of LTE and WiMAX are shown below.

	Downlink (DL)	**Uplink (UL)**
WiMAX	75 Mbps	25 Mbps
LTE	100 Mbps	50 Mbps

Table 1: Peak data rates of LTE and WiMAX, [4]

[13] http://media.wiley.com/product_data/excerpt/79/04707219/0470721979.pdf
[14] http://www.eetimes.com/design/signal-processing-dsp/4016258/The-nuts-and-bolts-of-WiMAX-Part-VII

5 Ultra Mobile Broadband (UMB)

Ultra-Mobile Broadband the next generation evolution for CDMA2000 providing high data transfer speeds and using both OFDM and MIMO.

Ultra-Mobile Broadband, UMB is the name for the next evolution for the CDMA2000 cellular telecommunications system which is run under the auspices of 3GPP2. The UMB cellular system provide very much faster data transfer speeds, and enables the system to compete with other mobile broadband systems including WiMAX and Wi-Fi.[15]

UMB system was to be based upon Internet (TCP/IP) networking technologies running over a next generation radio system, with peak rates of up to 280 Mbit/s.

The UMB IP based structure follows the trend of packet based data and internet protocol and its architecture is designed so as to support a huge variety of services. UMB technology is able to offer a better performance for so many of the newer services by providing valuable services, say like ultra high speed, low latency, delivering low rate, quicker data transfer with a very high speed, increasing system capacity and passing the way for newer spectrums and yet more applications.

5.1 UMB Features

- Significantly higher data rates & reduced latencies using FL advanced antenna techniques
- MIMO, SDMA and Beam forming
- Higher RL sector capacity with quasi-orthogonal reverse link
- Increased cell edge user data rates using adaptive interference management
- Dynamic fractional frequency reuse

[15] http://www.radio-electronics.com/info/cellulartelecomms/3gpp2/umb-ultra-mobile-broadband.php

- Distributed RL power control based on other cell interference
- Real time services enabled by fast seamless L1/L2 handoffs
- Independent RL & FL handoffs provide better air link and handoff performance[16]
- Power optimization through use of quick paging and semi-connected state
- Low-overhead signaling using flexible air link resource management
- Fast access and request using RL CDMA control channels
- New scalable IP architecture supports inter-technology handoffs
- New handoff mechanisms support real-time services throughout the network and across different air link technologies
- Fast acquisition and efficient multi-carrier operation through use of beacons
- Multi-carrier configuration supports incremental deployment & mix of low-complexity & wideband devices[17]

CDMA2000 contains:

- CDMA2000 1x
- Technology CDMA2000 1x EV-DO (Evolution Data Optimized)
- Technology UMB (Ultra Mobile Broadband) CDMA2000 can operate in frequency belts as follows:450 MHz, 800 MHz, 1700 MHz, 1900Mhz and 2100 MHz

5.1.1 CDMA2000 1x

This is an advanced version of CDMA2000 and provides transmission speeds up to 307 kbps for a single channel of 1.25 MHz, as shown on Fig.3.

[16]http://www.answers.com/topic/ultra-mobile-broadband
[17]http://dictionary.sensagent.com/ultra+mobile+broadband/en-en/

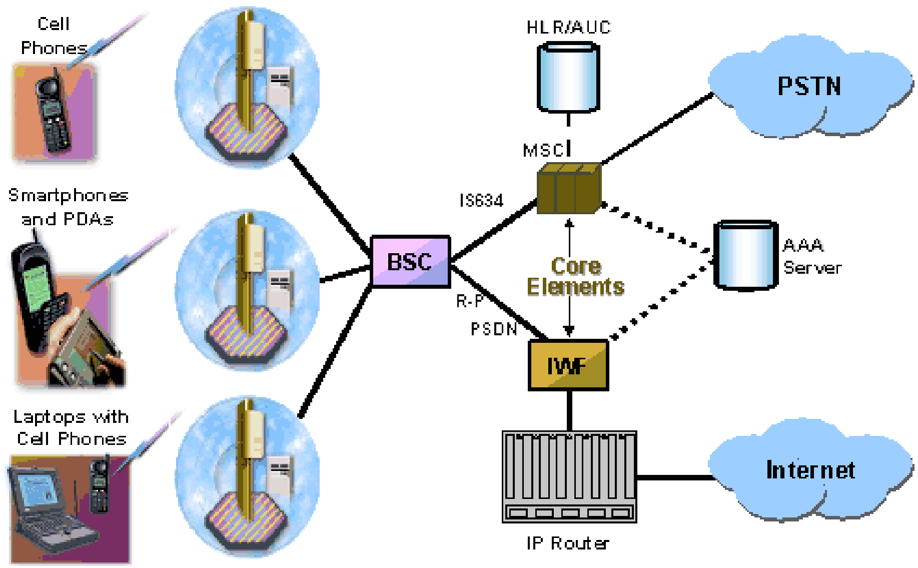

Figure 3: CDMA2000 1x,[1]

5.1.2 CDMA2000 1x EV-DO (Evolution Data Optimized)

This technology offers speed more than 2Mbit/s

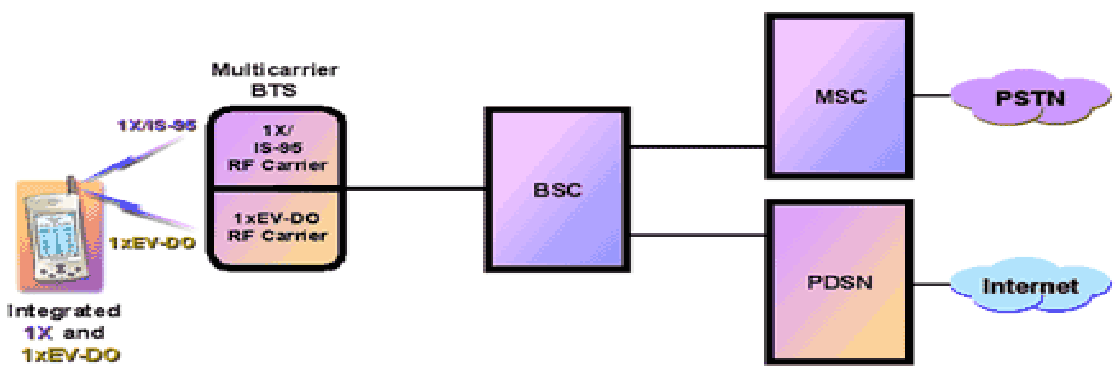

Figure 4: This technology has some version,[1]

6 Long Term Evolution (LTE)

The Long Term Evolution (LTE) comes from 3GPP. The Third Generation Partnership Project which devised the idea for this new standard. After UMTS (Universal Mobile Telephone System) project, which also is the project of 3GPP standard, comes in implementation before choosing Wideband Code Division Multiple Access (W-CDMA) for the Radio Access Network (RAN).[18]Then several candidates studied this technology and achieving to LTE which is evolutionary step towards Fourth Generation (4G) mobile communication systems.

The system which has to do with LTE, have in taken consideration the combination of two projects, known as EPS (Evolved Packet System) such as: The UMTS RAN which contains two main components: UTRA and UTRAN, than SAE (System Architecture Evolution) which is also the project of 3GPP.

UTRA (UMTS terrestrial Radio Access) is the air interface which includes (UE) user equipment.

UTRAN (UMTS Terrestrial Radio Access Network) includes Radio Access Controller (RNC) and the base stations known as Node B.
SAE has to do with all IP packets only Core Network (CN) known as EPC.

The Long Term Evolution (LTE) has some benefits such:

- Higher throughput and lower latency for data access
- Lowering the cost per bit traffic
- Enable a richer mobile service environment and

[18]http://www.telenor.com/en/resources/images/telektronikk-2010.01_tcm28-56065.pdf

- Provides the efficient usage of limited available spectrum[19]

Considering that LTE has to do in mobile communication, the service providers, operate the networks using two different families of standards: 3GPP based on 2th generation, 2.5 generation,3 generation such (GSM- Global System for Mobile) (Edge –Enhanced Data Rats for GSMA Evolution) Universal Mobile Telecommunications System (UMTS), High Speed Downlink Packet Access (HSDPA), High Speed Packet Access (HSPA+)), and 3GPP-2 based (i.e. (Code Division Multiple Access (CDMA IS-95), CDMA IS-2000, 1x Data Only Revision 0 (1xDO Rev0), 1x Data Only Revision A (1xDO RevA)).

Both families of standards were set to evolve to separate fourth generation technologies; the 3GPP family to LTE and the3GPP-2 family to Ultra Mobile Broadband (UMB). New wireless standard Institute of Electrical and Electronics Engineers (IEEE) 802-16e1 was proposed by IEEE in 2005.[20]

Most of the North American networks are based on the 3GPP-2 standards and Europe has deployment of networks that are based on the 3GPP standards. Here, we can conclude adoption of a single standard (i.e. LTE) by both, 3GPP based and non-3GPP based, service providers.

6.1 **LTE architecture**

The architecture of mobile communication networks consists of a Radio Access Network(RAN) and an Evolved Packet Core (EPC). Evolved Universal Terrestrial RAN (EUTRAN) is another name for RAN,Fig.5. SAE is the name for EPC as well. Collectively, the evolved network is known as Evolved Packet System (EPS).

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[19] www.umts-forum.org/component/.../Itemid,12/

[20] http://kunz-pc.sce.carleton.ca/Thesis/GurpreetThesis.pdf

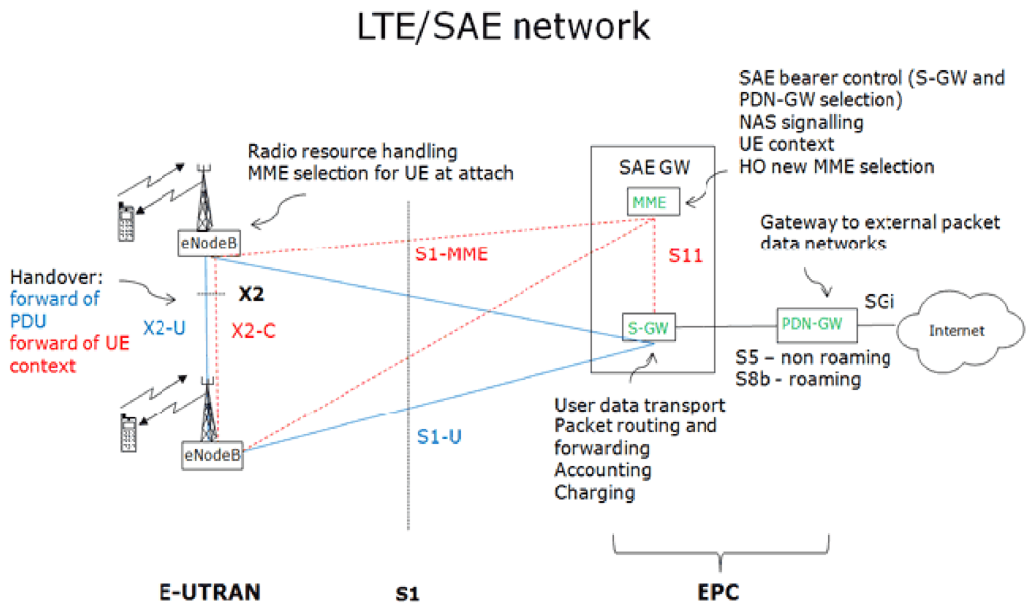

Figure 5: LTE/SAE Network,[6]

Network can be split into two parts: a radio access network part and a core network part. Functions like modulation, header compression and handover belong to the access network, whereas other functions like charging or mobility management are part of the core network. In case of LTE, the radio access network is E-UTRAN and the core network EPC.

6.1.1 Radio Access Network

The radio access network of LTE is called E-UTRAN and one of its main features is that all services, including real-time, will be supported over shared packet channels. This approach will achieve increased spectral efficiency which will turn into higher system capacity with respect to current UMTS and HSPA. An important consequence of using packet access for all services is the better integration among all multimedia services and among wireless and fixed services.

The main philosophy behind LTE is minimizing the number of nodes. Therefore the developers opted for single-node architecture. The new base station is more complicated than the Node B in WCDMA/HSPA radio access networks, and is consequently called eNB (Enhanced Node B). The eNBs have all necessary functionalities for LTE radio access network including the functions related to radio resource management.

6.1.2 Core Network

The new core network is a radical evolution of the one of third generation systems and it only covers the packet-switched domain. Therefore it has a new name: Evolved Packet Core.

Following the same philosophy as for the E-UTRAN, the number of nodes is reduced. EPC divides user data flows into the control and the data planes. A specific node is defined for each plane plus the generic gateway that connects the LTE network to the internet and other systems. The EPC comprises several functional entities.[21]

Evolved Node B (eNodeB):

- Functions for Radio Resource Management
- IP header compression and encryption of user data stream
- Selection of an MME at UE attachment when no routing to an MME can be determined from the information provided by the UE
- Routing of User Plane data towards Serving Gateway
- Scheduling and transmission of paging messages (originated from the MME)
- Scheduling and transmission of broadcast information (originated from the MME or O&M)

[21]www.hindawi.com/journals/specialissues/432727.pdf

- Measurement and measurement reporting configuration for mobility and scheduling

Mobility Management Entity (MME)

The MME manages mobility, UE identities and security parameters. MME functions include:

- NAS signaling and related security
- Inter CN node signaling for mobility between 3GPP access networks
- Idle mode UE tracking and reach ability (including control and execution of paging retransmission)
- Tracking area list management
- GW selections (Serving GW and PDN GW selection)
- MME selection for handovers with MME change
- Roaming (terminating S6a towards home HSS)
- SGSN selection for handover to 2G or 3G 3GPP access networks
- HRPD access node selection for handovers to/from HRPD
- Authentication
- Bearer management functions including dedicated bearer establishment
- Lawful Interception of signaling traffic
- Support for Single Radio VCC and CS Fallback for 2G/3G and 1xRTT CDMA[22]

Serving Gateway (SGW)

The Serving Gateway is the node that terminates the interface towards EUTRAN. For each UE associated with the EPS, at a given point of time, there is one single Serving Gateway. Serving GW functions include:

- The local Mobility Anchor point for inter-eNodeB handover

[22]http://lte.alcatel-lucent.com/locale/en_us/downloads/LTE_poster.pdf

- Mobility anchoring for inter-3GPP mobility (terminating S4 and relaying the traffic between 2G/3G system and PDN Gateway). This is sometimes referred to as the 3GPP Anchor function
- EUTRAN idle mode downlink packet buffering and initiation of network triggered service request procedure
- Transport level packet marking in the uplink and the downlink, e.g. setting the DiffServ Code Point, based on the QCI of the associated EPS bearer
- Accounting on user and QCI granularity for inter-operator charging
- Lawful Interception
- Packet routing and forwarding

Packet Data Network Gateway (PDN Gateway)

The PDN Gateway is the node that terminates the SGi interface towards the PDN. If a UE is accessing multiple PDNs, there may be more than one PDN GW for that UE. PDN GW functions include[23]:

- Policy enforcement
- Per-user based packet filtering (by e.g. deep packet inspection)
- Charging support
- Lawful Interception
- UE IP address allocation
- Packet screening
- DHCP functions[24]

Evolved Packet Data Gateway (ePDG):

[23]http://www.motorola.com/web/Business/Solutions/Industry%20Solutions/Service%20Providers/Wireless%20Operators/LTE/_Document/Static%20Files/6834_MotDoc_New.pdf
[24]tp.3gpp2.org/TSGX/.../TSG.../23401-141-clean%20FYI.doc

The ePDG is the primary element responsible for interworking between the EPC and untrusted non-3GPP networks, such as a wireless LAN. The ePDG uses Proxy Mobile IPv6 (PMIPv6) to interact with the PGW when the UE is in an untrusted non-3GPP system. The ePDGis involved in the Policy and Charging Enforcement Function (PCEF), meaning it manages QoS, flow-based charging data generation, gating, deep packet inspection, and other functions.

6.2 Fundamentals of Radio Access

Enhanced air interface: LTE is based on OFDM (Orthogonal Frequency Division Multiplexing).Here are some combination for downlink and uplink, such : OFDMA for downlink, and SC-FDMA (Single Carrier Frequency Division Multiple Access) for uplink. All OFDM schemes split the available spectrum into thousands of extremely narrowband carriers, each carrying a part of the signal.[25]

Efficiency of OFDM is further enhanced with higher order modulation schemes such as64QAM, and sophisticated FEC (Forward Error Correction) schemes such as tail biting, convolution coding and turbo coding, alongside complementary radio techniques like MIMO and Beam Forming with up to four antennas per station. [26]The result of these radios interface features is significantly improved radio performance, yielding up to five times the average throughput of HSPA. Downlink peak data rates are extended up to a theoretical maximum of 300 Mbit/s per 20 MHz of spectrum.

High spectral efficiency: LTE's greater spectral efficiency allows service providers to support more customers within their existing and future spectrum allocations, with a reduced cost of delivery per bit.

[25]http://www.skydsp.com/publications/4thyrthesis/chapter1.htm
[26]www.umts-forum.org/component/.../Itemid,12

Flexible radio planning: LTE can deliver optimum performance in a cell size of up to 5Km. It is still capable of delivering effective performance in cell sizes of up to 30 km radius, with more limited performance available in cell sizes up to 100 km radius.[27]

Reduced latency: By reducing round-trip times to 10ms or even less (compared with 40–50ms for HSPA), LTE delivers a more responsive user experience. These permit interactive, real-time services such as high-quality audio and videoconferencing and multi-player gaming.

An all-IP environment: One of the most significant features of LTE is its transition to a 'flat', all-IP based core network with a simplified architecture and open interfaces.
Conversion of the existing core network architecture to an all-IP system is carried out in the LTE standard that enables more flexible service provisioning plus simplified interworking with fixed and non-3GPP mobile networks.

Co-existence with legacy standards and systems: LTE users will be able to make voice calls from their terminal and have access to basic data services even when they are in areas without LTE coverage. LTE therefore allows smooth, seamless service handover in areas of HSPA, WCDMA or GSM/GPRS/EDGE coverage. Furthermore, LTE supports not only intra-system and intersystem handovers, but inter-domain handovers between packet-switched and circuit-switched sessions.

6.2.1 Multiple Input Multiple Output (MIMO)

One of the most important means to achieve the high data rate objectives for LTE is multiple antenna transmission.[28]MIMO is one of the most popular Advanced Antenna Technologies. The salient features of MIMO is that it offers higher throughput for a given

[27]http://www.slideshare.net/MASITMacedonia/viktor-nastev-broadband-strategy-tmmk
[28]http://www.hindawi.com/journals/wcn/2009/354089/

bandwidth and higher link range for a given power value. In MIMO the transceiver and receiver have multiple antennas giving MIMO multiple flavors based on the number of antennas present on each side.[29]

However, the key idea is that a transmitter sends multiple streams on multiple transmit antennas and each transmitted stream goes through different paths to reach each receiver antenna as shown in Fig.7.The different paths taken by the same stream to reach multiple receivers allow canceling errors using superior signal processing techniques. MIMO also achieves spatial multiplexing to distinguish among different symbols on the same frequency. MIMO thus helps in achieving higher spectral efficiency and Link reliability.

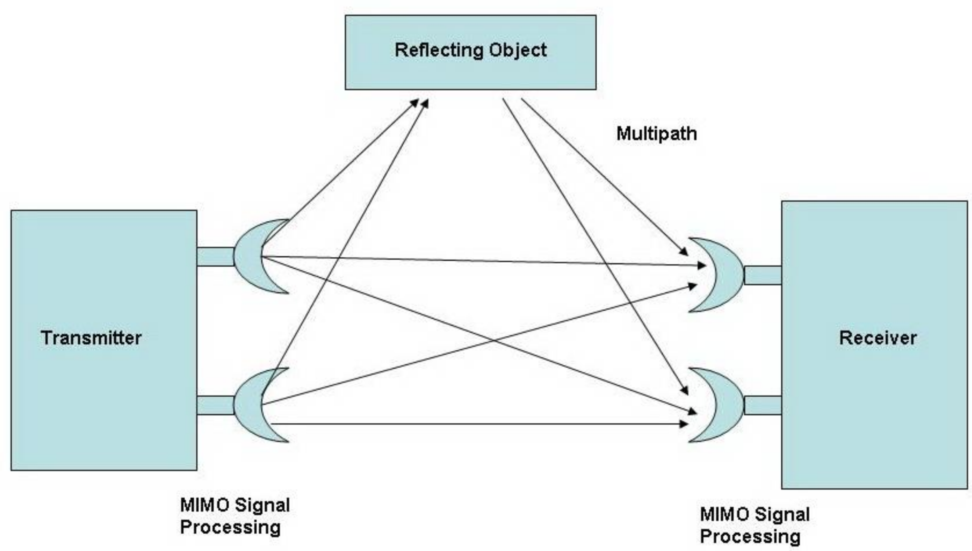

Figure 6: MIMO processing signal,[12]

6.2.2 Turbo Coding

In order to correct bit errors, introduced by channel variations and noise, channel coding is utilized. In case of the LTE downlink shared channel (DL-SCH) a turbo encoder with rate 1/3 is used, followed by a rate matching to adapt the coding rate to the desired level. In

[29]http://www.cs.wustl.edu/~jain/cse574-08/ftp/lte/index.html

each sub frame of 1 ms, one or two (with multi codeword MIMO) code words can be coded and transmitted.[30]

6.2.3 Hybrid ARQ with Soft Combining

Hybrid ARQ with soft combining is a technique that deals with the retransmission of data in case of errors. In an ARQ scheme, the receiver uses an error-detecting code to check if the received packet contains errors or not. The transmitter is informed by a NACK or ACK respectively. In case of a NACK, the packet is retransmitted.[31]

6.3 LTE air interfaces[32]

The main interfaces in LTE are Uu, S1-MME, X2, S1-U, S11 and S5.

- **LTE Uu**

  This is the air interface between UE and eNB. LTE layer 1 is dealt with later. RRC is the protocol that is used for communication between UE and eNB. Above RRC there is a NAS layer in UE. This NAS layer terminates at MME and eNB shall silently pass the NAS messages to MME.

- **LTE S1-MME**

  eNB and MME communicate using this IP interface. S1-AP is application layer interface. The transport protocols used here is SCTP (Stream Control Transmission Protocol).

[30] http://dacaso.webs.upv.es/publications/2009_VTC_MAC_Layer_Performance_LTE_DL.pdf
[31] http://dacaso.webs.upv.es/publications/2009_VTC_MAC_Layer_Performance_LTE_DL.pdf
[32] http://gsmcommunications.blogspot.com/2010/12/lte-interfaces-and-protocols.html

- **LTE X2:**

This interface is used by a eNB to communicate to other eNB. This again is a IP interface with SCTP as transport. X2-AP is the application protocol used by eNBs to communicate.

- **LTE S11**

An IP interface between MME and SGW! GTPv2 is the protocols used at the application layer. GTPv2 runs on UDP transport. This interface must and should runGTPv2.

- **LTE S5**

This is the interface between SGW and PGW. This again is an IP interface and has two variants. S5 can be a GTP interface or PMIP interface. PMIP variant is used to support non-trusted 3GPP network access.

- **LTE S1-U**

User plane interface between eNB and SGW! GTP-U v1 is the application protocol that encapsulates the UE payload. GTP-U runs on UDP. All the above IP interfaces can be of IPv4 or IPv6. Few interfaces can be of IPv4 and few can be of IPv6. From the specification side there are no restrictions. eNB and UE have control plane and data plane protocol layers. Data enters processing chain in the form of IP packets on one of the SAE bearers, as shown on Fig.7.

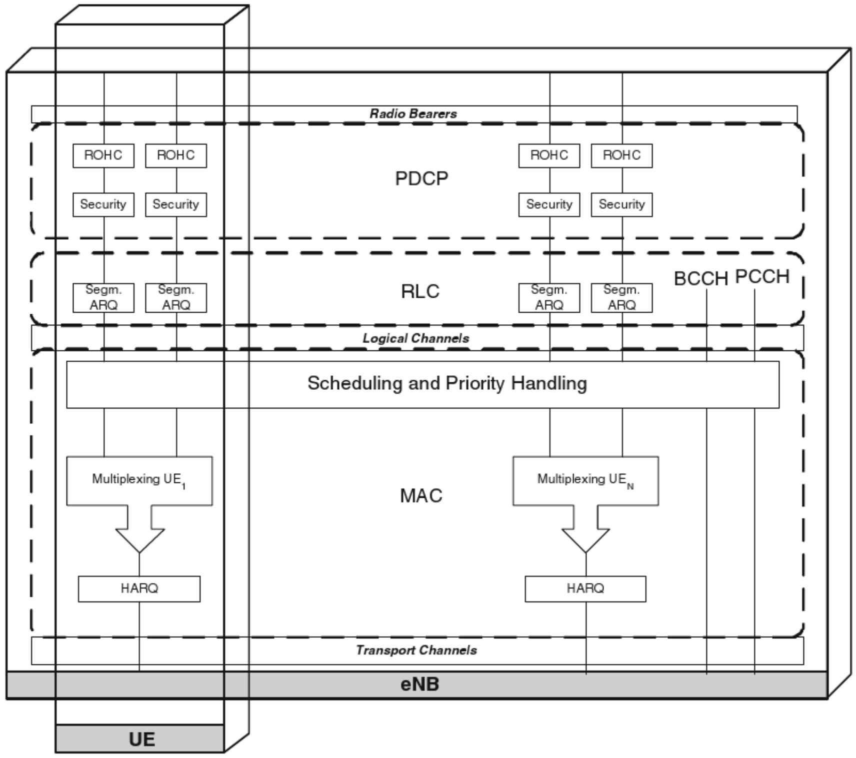

Figure 7: LTE Radio Interface, [11]

6.4 LTE Stack Protocol

It consists of 3 layers:

- Physical Layer
- Mac Layer
- RRC Layer

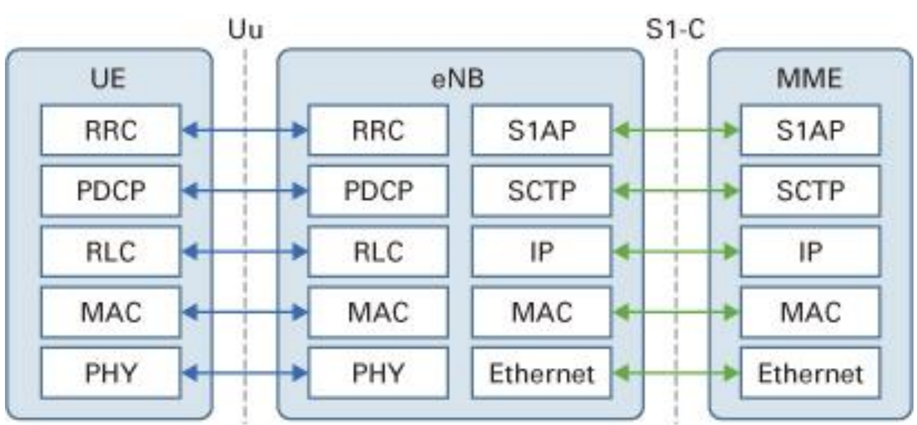

Figure 8: C-plane Protocol Stack on Uu (UE/eNB) and S1-C (eNB/MME), [9]

The LTE Physical Layer is a highly efficient means of conveying both data and control information between an enhanced base station (eNodeB) and mobile user equipment (UE). The LTE PHY employs some advanced technologies that are new to cellular applications.

These include Orthogonal Frequency Division Multiplexing (OFDM) and Multiple Input Multiple Output (MIMO) data transmission. In addition, the LTE PHY uses Orthogonal Frequency Division Multiple Access (OFDMA) on the downlink (DL) and Single Carrier – Frequency Division Multiple Access (SC-FDMA) on the uplink (UL).Although the LTE describe both Frequency Division Duplexing (FDD) and Time Division Duplexing (TDD) to separate UL and DL traffic.[33]

6.4.1 LTE Physical Layer

First Layer is designed to meet the following goals:

- Support scalable bandwidths of 1.25, 2.5, 5.0, 10.0 and 20.0 MHz
- Peak data rate that scales with system bandwidth
- Downlink (2 Ch MIMO) peak rate of 100 Mbps in 20 MHz channel
- Uplink (single Ch Tx) peak rate of 50 Mbps in 20 MHz channel
- Supported antenna configurations
- Downlink: 4x2, 2x2, 1x2, 1x1
- Uplink: 1x2, 1x1
- Spectrum efficiency
- Downlink: 3 to 4 x HSDPA Rel. 6
- Uplink: 2 to 3 x HSUPA Rel. 6
- 5. Latency
- C-plane: <50 – 100 msec to establish U-plane

[33] http://www.freescale.com/files/wireless_comm/doc/white_paper/3GPPEVOLUTIONWP.pdf

- U-plane: <10 msec from UE to server
- Mobility
- Optimized for low speeds (<15 km/hr)
- High performance at speeds up to 120 km/hr
- Maintain link at speeds up to 350 km/hr
- Coverage
- Full performance up to 5 km
- Slight degradation 5 km – 30 km
- Operation up to 100 km should not be precluded by standard

6.4.2 LTE MAC Second Layers

The LTE Layer 2, consist of comprehensive implementation of LTE MAC,RLC and PDCP protocol sub-layers. Features include:

MAC (Media Access Control) –All LTE transport channels with optional MBMS

- Mapping between logical channels and transport channels
- Multiplexing-Demultiplexing of SDUs
- Traffic volume measurement reporting
- Error correction through HARQ
- Priority handling between logical channels of one UE and a number of UEs by means of dynamic scheduling
- Transport format selection and padding

RLC (Radio Link Control) –UM, TM, AM nodes

- Transfer of upper layer PDUs supporting acknowledged mode (AM) or unacknowledged mode (UM) and transparent mode (TM) data transfer
- Error Correction through ARQ

- Segmentation of SDUs and Re-segmentation of PDUs
- Concatenation of SDUs for the same radio bearer
- In-sequence delivery of upper layer PDUs
- Duplicate Detection, SDU discard as well as protocol error detection and recovery

PDCP Packet Data Convergence Protocol– IP header compression based on Robust Header Compression (ROHC) ciphering and integrity protection of transmitted data.

- eNodeB functionality
- Transfer of use plane data
- Transfer of control plane data
- Header compression
- Ciphering
- Integrity Protection
- Completely Multi-threaded stack; part of Trillium Multi-Core family (Add-On)
- Extensive debugging and error checking facilities
- Features a minimized memory footprint ideal for femto and pico cell applications.
- Conforms to Trillium Advanced Portability Architecture (TAPA)
- Benefits of licensing Trillium Protocol Software

6.4.3 LTE RRC Third Layer

RRC is used in the control plane of the LTE-Uu interface protocol stack.

- eNodeB functionality
- Broadcast of system information
- RRC connection establishment/release/re-establishment
- RRC connection reconfiguration
- Paging, cell creative /deletion
- Uplink(UL)/Downlink(DL) information transfer
- Handovers and measurements

- Completely Multi-threaded stack, part of the Trillium Multi-Core Family
- Conforms to Trillium Advanced portability Architecture (TAPA)
- Benefits of licensing Trillium Protocol Software

6.5 **Channels of LTE**

LTE channels are separated into 3 groups: Physical, Logical and Transport channels.

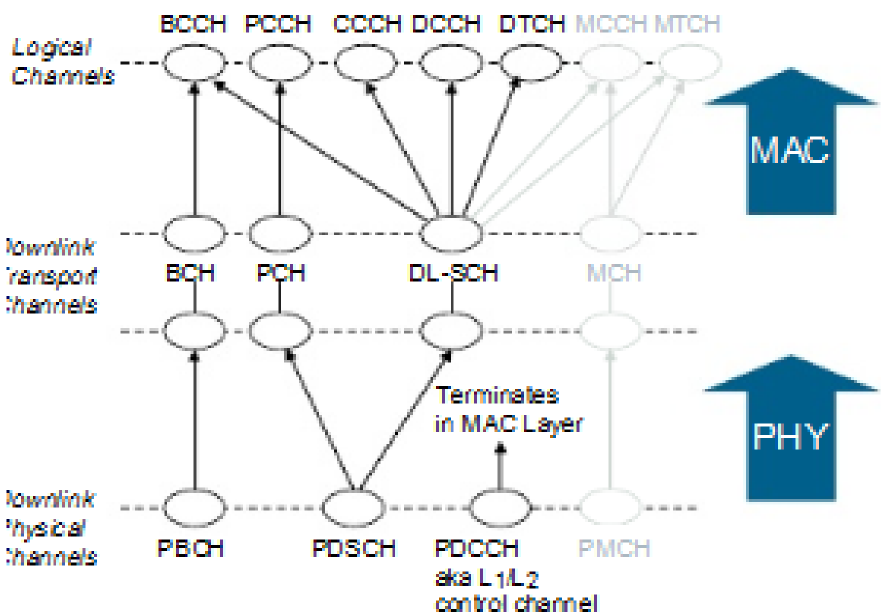

Figure 9: LTE Channels, [11]

6.5.1 Physical Channels

Three different types of physical channels are defined for the LTE downlink. One common characteristic of physical channels is that they all convey information from higher layers in the LTE stack. This is in contrast to physical signals, which convey information that is used exclusively within the PHY layer. LTE DL physical channels are:

Downlink physical channels:

- Physical downlink shared channel (PDSCH):Carries the DL-SCH and PCH. DL-SCH contains actual user data.
- Physical downlink control channel (PDCCH):Informs the UE about the resource allocation of PCH and DL-SCH, and HARQ information related to DL-SCH. Carries the uplink scheduling grant.
- Physical HARQ indicator channel (PHICH):Carries ACK/NACKs in response to uplink transmissions.
- Physical control format indicator channel (PCFICH):Informs the UE about the number of OFDM symbols used for the PDCCHs, transmitted in every sub frame.
- Physical broadcast channel (PBCH):The coded BCH transport block is mapped to four sub frames within a 40 ms interval.

Uplink Physical Channel

- Physical uplink shared channel (PUSCH): Carries the UL-SCH, ACK/NACK and CQI. UL-SCH contains actual user data.
- Physical uplink control channel (PUCCH): Carries ACK/NACKs in response to downlink transmission. Carries CQI (Channel Quality Indicator) report and SR (Scheduling Request).
- Physical random access channel (PRACH): Carries random access preamble.

6.5.2 Logical Channels[34]:

Each logical channel type is defined by the type of information to be transferred. Logical channels are separated into two groups:

- Control Channels (for the transfer of control plane information)
- Traffic Channels (for the transfer of user plane information).

6.5.2.1 Control Channels

Control channels are used for transfer of control plane information only. The control channels offered by MAC are:

- Broadcast Control Channel (BCCH): A downlink channel for broadcasting system control information.
- Paging Control Channel (PCCH): A downlink channel that transfers paging information and system information change notifications. This channel is used for paging when the network does not know the location cell of the UE.
- Common Control Channel (CCCH):Channel for transmitting control information between UEs and network. This channel is used for UEs having no RRC connection with the network.
- Dedicated Control Channel (DCCH): A point-to-point bi-directional channel that transmits dedicated control information between a UE and the network. Used by UEs having an RRC connection.

6.5.2.2 Traffic Channels:

Traffic channels are used for the transfer of user plane information only. The traffic channels offered by MAC are:

- Dedicated Traffic Channel (DTCH): A Dedicated Traffic Channel (DTCH) is a point-to-point channel, dedicated to one UE, for the transfer of user information. A DTCH can exist in both uplink and downlink.

[34] http://www.privateline.com/3G/WCDMA.pdf

- Multicast Traffic Channel (MTCH) (from Release 9):A point-to-multipoint downlink channel for transmitting traffic data from the network to the UE. This channel is only used by UEs that receive MBMS.

6.5.3 Transport Channels[35]

Downlink transport channel types are:

- Broadcast Channel (BCH) characterized by: Fixed, pre-defined transport format and requirement to be broadcast in the entire coverage area of the cell
- Downlink Shared Channel (DL-SCH) characterized by: Support for HARQ, support for dynamic link adaptation by varying the modulation, coding and transmit power, possibility to be broadcast in the entire cell, possibility to use beam-forming, support for both dynamic and semi-static resource allocation, support for UE discontinuous reception (DRX) to enable UE power saving.
- Paging Channel (PCH) characterized by: Support for UE discontinuous reception (DRX) to enable UE power saving (DRX cycle is indicated by the network to the UE), requirement to be broadcast in the entire coverage area of the cell, mapped to physical resources which can be used dynamically also for traffic/other control channels.
- Multicast Channel (MCH) (from Release 9) characterized by: Requirement to be broadcast in the entire coverage area of the cell, support for MBSFN combining of MBMS transmission on multiple cells, support for semi-static resource allocation e.g., with a time frame of a long cyclic prefix.

Uplink transport channel types are:

- Uplink Shared Channel (UL-SCH) characterized by: Possibility to use beam forming (likely no impact on specifications), support for dynamic link adaptation by varying

[35] http://cp.literature.agilent.com/litweb/pdf/5989-8139EN.pdf

the transmit power and potentially modulation and coding, support for HARQ, support for both dynamic and semi-static resource allocation.

- Random Access Channel(s) (RACH) characterized by: Limited control information, collision risk.

6.6 Frame Structure in LTE

FDD frame structure

The Fig.10 LTE frame has an overall length of 10 ms, this is then divided into a total of 20 individual slots. LTE Sub frames then consist of two slots - in other words there are ten LTE sub frames within a frame.

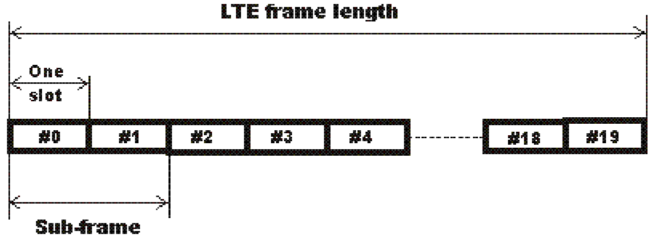

Figure 10: FDD LTE Frame Structure, [14]

TDD frame structure

The frame structure for the Fig.12 frames used on LTE TDD is somewhat different. The 10 ms frame comprises two half frames, each 5 ms long. The LTE half-frames are further split into five sub frames, each 1ms long.

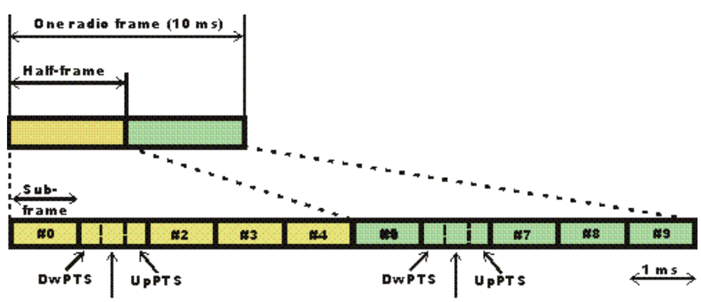

Figure: 11 TDDLTE Frame Structure, [14]

6.7 Analysis of LTE Performance

Different methods can be used to assess the performance of a mobile technology. Performance analysis requires the usage of simulation. Simulators are usually divided in two classes: link level simulators and system level simulators. Link level simulators are used to emulate the transmission of information from a unique transmitter to a unique receiver modeling the physical layer with high precision. [36]They include models for coding/decoding, MIMO processing, scrambling, modulation, channel, channel estimation and equalization, and so forth. System level simulators emulate the operation of a network with a number of cells and several users per cell including admission control, scheduling, and power control.

6.7.1 LTE Link Level Performance

This simulator contains the MIMO algorithms, the spatial channel models and modulation and coding schemes for LTE. The result of this simulator serves to evaluate the OFDM-MIMO LTE Link Level performance in different environments and create link level look-up tables to be used as an input for a future LTE system level simulator.
Concerning LTE downlink, different multi antenna configurations were modeled including SIMO1×2, MIMO 2×2 and MIMO 4×4.

In LTE downlink(Fig.12.)different multi antenna configurations were modeled including SIMO1×2, MIMO 2×2 and MIMO 4×4.The number of code words was 2 and the number of layers was equal to the number of transmit antennas, that is, 2 and 4 specified by the 3GPP. Additionally, the multiple channels among antennas were supposed uncorrelated. Control channel and signals overhead were taken into account and hence the first two OFDM symbols in each sub frame were reserved for control channels.

[36]http://upcommons.upc.edu/pfc/bitstream/2099.1/6978/1/AlbertSerra_MasterThesis.pdf

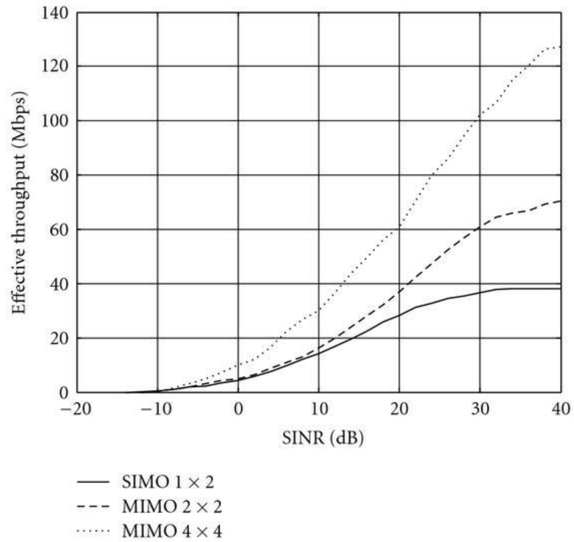

Figure 11: **Link level evaluation of throughput versus SINR in LTE downlink, [12]**

In the uplink, (Fig.13**)** were simulated configurations of two different multi antenna: SIMO 1×2 and SIMO1×4.

The multiple channels among antennas were supposed uncorrelated too. The MIMO scheme is not simulated here, because the LTE standard does not allow MIMO in uplink. In uplink only one codeword was considered specified by 3GPP.[37]Moreover, 12 of the 14 available SC-FDMA symbols in a sub frame were occupied by codified data since the other 2 were reserved for reference signals needed for the channel estimation at the receiver.

[37]www.hindawi.com/journals/specialissues/432727.pdf

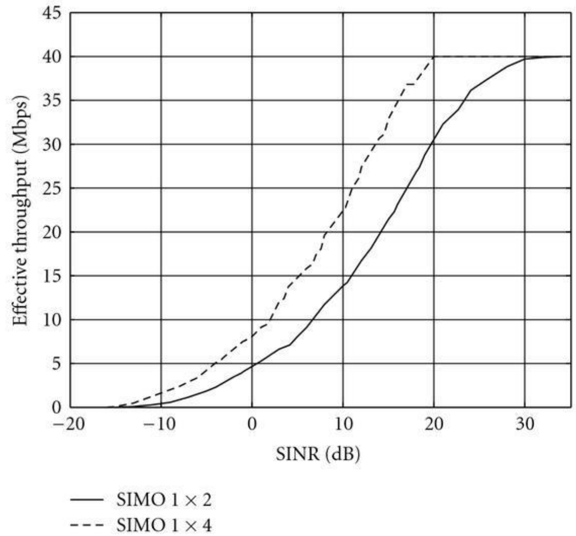

Figure 12: **Link level evaluation of throughput versus SINR in LTE uplink,[12]**

In both cases we can conclude that the maximum throughput isn't equal with throughput calculated before. The reason is threefold: the used bandwidth is not 20 MHz but 10 MHz, the highest coding rate used is 0.93 instead of 1 and downlink control signals overhead is assumed to be 2 OFDM symbols instead of 1.MIMO 4×4 scheme provides a clearly better performance than the other schemes for almost all the useful SINR margin.

Nevertheless, MIMO 2×2 scheme does not provide an important performance improvement until SINR reaches a value of 15 dB.

6.7.2 LTE, System Level Performance.

This level describes the statistics of system level. More important strategy here is: the cell spectral efficiency and the cell edge user spectral efficiency. The cell spectral efficiency is defined as the aggregate throughput of all users (the number of correctly received bits over a certain period of time) normalized by the overall cell bandwidth and divided by the number of cells. The cell edge user spectral efficiency is the 5% point of CDF of the user throughput normalized with the overall cell bandwidth. (Table.3)

Common parameters	
Bandwidth	10 MHz (50 RB)
Channel	Tapped delay line: EPA with 5 Hz Doppler frequency at link level.ETU at system level
Central frequency	2.5 GHz
MCS	CQI 1-15
Multiantenna	DL SIMO 1x2, MIMO 2x2 / 4x4
Schemes	UL SIMO 1x2/1x4
Control channels	DL 2 OFDM symbols per subframe
Overhead	UL Not considered
System level parameters	
Inter site distance (ISD)	500m
Cell deployment	3 sector cells, reuse 1
Pathloss	130.2+37.6log 10(d(km))dB
Shadowing	Lognormal, σ=8 dB
eNB transmission	46 dBm
Power	
Noise spectral density	-174 dBm/Hz
Scheduler	Proportional fair in time and frequency domains up to 5 UEs is scheduled per subframe
Mobility	Users moving at 30km/h

Table 2: Simulator of parameters, [12]

Dynamic system level simulators are used for calculating values of downlink. Here are used an ETU (Extended typical urban) channel. The scheduler operation follows the proposal of where scheduling algorithm is divided in two parts: one for the time domain and another for the frequency domain. For both domains a proportional fair approach has been used.

6.8 Handover and Roaming

Handover is an important function that maintains seamless connectivity when transitioning from one base station to another.[38] There are two types of handover: intra-RAT, which is

[38]http://www.faqs.org/patents/app/20100330993

within one radio access technology (i.e. LTE-to-LTE from one eNodeB to another), and inter-RAT between radio access technologies. Inter-RAT could be between LTE and GSM or 3G WCDMA, 3GPP2, WiMAX or even wireless LAN. These non-LTE handovers are being defined for LTE standard. These involve higher layers and often different radio modems, but call continuity is guaranteed with up to 100 milliseconds of disruption when a call is transferred using techniques such as mobile IP or operations in software layers above the modem stack.

Handover occurs in the active state; it is controlled by the network (the eNodeB).
The network uses measurements from the UE and its own knowledge of the network topology to determine when to handover a UE, and to which eNodeB. [39]Cell re-selection occurs in the idle state; it is controlled by the UE.

6.8.1 Handover Measurement

In single-radio architecture, it is challenging to monitor other networks while the receiver is active, because they are on different frequencies. The radio can only receive on one channel at a time. The radio needs to listen to other frequencies to determine if a better base station (eNodeB) is available.

In the active state, the eNB provides measurement gaps in the scheduling of the UE where no downlink or uplink scheduling occurs. Ultimately the network makes the decision, but the gap provides the UE sufficient time to change frequency, make a measurement, and switch back to the active channel.[40] This can normally occur in a few TTIs. This has to be coordinated with the DRX, which also causes the system to shut off the radio for periods of time to save power.

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[39]http://www.freescale.com/files/wireless_comm/doc/white_paper/LTEPTCLOVWWP.pdf
[40]http://ir.canterbury.ac.nz/bitstream/10092/3926/1/12624035_0909.IEEECS&T.pdf

IV Advance TECHNOLOGY

7 LTE Advanced

To enhance LTE features further to fulfill all IMT-Advanced requirements and hence become an IMT-Advanced technology, 3GPP has started a new Study Item on LTE-Advanced in March 2008.[41]

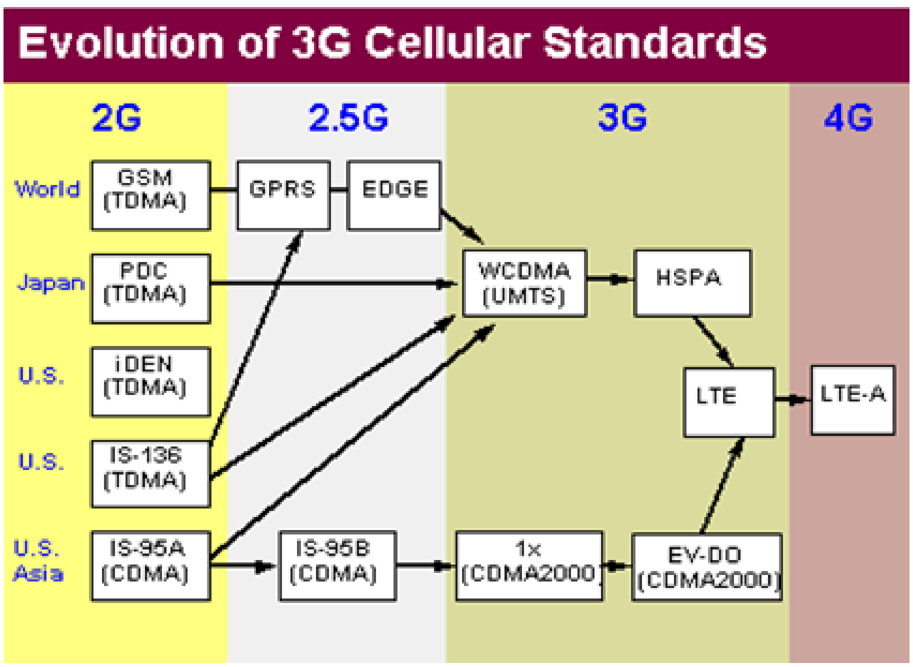

Figure 13:Evolution of 3GPP cellular standards, [6]

The **ITU Radio communication Sector** (**ITU-R**) is one of the three sectors of the International Telecommunication Union (ITU) and is responsible for radio communication. The ITU-R has started its evaluation process to develop the recommendations for the terrestrial components of the IMT Advanced radio interface. One

[41]http://www.tekna.no/ikbViewer/Content/787700/18%20LTE-Advanced%20Overview%20-%20Tor%20Leif%20Aarland.pdf

of the main competitors for this is the LTE Advanced solution.IMT Advanced reference the recommendation: to reach 100 Mb/s for mobile access and up to 1Gb/s for nomadic wireless access.

The 3GPP organized a workshop on IMT-Advanced where the following decisions were made[42]:

- Carrier and spectrum aggregation: The lack of contiguous spectrum for wider transmission bandwidths (to 100 MHz) forces the use of carrier aggregation to meet peak data rate and spectrum flexibility requirements. Aggregation of contiguous and non-contiguous component carriers is allowed.

- Enhanced uplink multiple accesses: The addition of N-times DFT-spread OFDM (also known as "clustered SC-FDMA") will satisfy increased data rate requirements while maintaining backward-compatibility with LTE.

- Higher order MIMO transmission: Up to 8x8 MIMO in the downlink and 4x4 MIMO in the uplink is used to reach peak data rates. Beam forming with spatial multiplexing is being considered to increase data rates, coverage, and capacity.

- Coordinated multipoint (CoMP) transmission and reception: This MIMO variant is intended to improve performance for high data rates, cell - edge throughput, and system throughput. Is being studied for Release 11.

- Relaying: In-channel relays receive, amplify, and retransmit downlink and uplink signals to improve coverage. More advanced relaying enables the use of some sub frames in a channel to carry backhaul traffic. The main use cases for relays are to

[42]http://www.ee.gatech.edu/research/labs/bwn/surveys/ltea.pdf

improve urban or indoor throughput, to add dead zone coverage, or to extend coverage in rural areas.

- Other proposals related to 4G LTE address the support needs of an increasingly heterogeneous network that combines macrocells, microcells, picocells, and femtocells, along with repeaters and relay nodes. The 4G LTE specifications also continue to focus on the use of femtocells and home base stations (eNBs) as a means of improving network efficiencies and reducing infrastructure costs.

7.1 LTE Advanced Requirements

Peak data rate

The system should target a downlink peak data rate of 1 Gbps and an uplink peak data rate of 500 Mbps.

Latency

C-Plane: The target for transition time from idle mode (with internet protocol (IP)address allocated) to connected mode should be less than 50 ms including the establishment of the user plane (excluding the S1 interface transfer delay).[43] The target for the transition from a "dormant state" to connected mode (i.e. discontinuous reception (DRX) sub state in connected mode) should be less than 10 ms (excluding the DRX delay).U-Plane: LTE-Advanced should allow for reduced U-plane latency compared to LTE Release 8.

[43]http://lteworld.org/wiki/lte-advanced

Spectrum efficiency

LTE-Advanced aims to support downlink (8x8 antenna configuration) peak spectrum efficiency of 30 bps/Hz and uplink (4x4 antenna configuration) peak spectrum efficiency of 15 bps/Hz. Additionally average spectrum efficiency targets have been set according to Table 1. Average spectrum efficiency is defined as the aggregate throughput of all users (the number of correctly received bits over a certain period of time) normalized by the overall cell bandwidth divided by the number of cells.

Cell edge user throughput

LTE-Advanced should allow cell edge user throughput to be as high as possible. The cell edge user throughput is defined as the 5% point of the cumulative density function(CDF) of the user throughput normalized with the overall cell bandwidth. .

Mobility

Mobility requirements have been formulated in comparison to LTE Release 8. The system shall support mobility across the cellular network for various mobile speeds up to 350km/h (or even up to 500km/h depending on the frequency band).[44] In comparison to LTE Release 8, the system performance shall be enhanced for 0 up to 10 km/h.

Spectrum flexibility

LTE-Advanced shall operate in spectrum allocations of different sizes including wider spectrum allocations than of LTE Release 8. The main focus for bandwidth solutions wider than 20MHz should be on consecutive spectrum. However aggregation of the spectrum for LTE-Advanced should take into account reasonable user equipment (UE) complexity. Frequency division duplex (FDD) and time division duplex(TDD) should be supported for existing paired and unpaired frequency bands, respectively

[44] http://www.mforum.ru/arc/20100429_1MA169_1E_MForum.pdf

7.2 LTE-Advanced Technical Proposals

LTE Release 8 can already fulfill some of the requirements specified for IMT-Advanced systems. However, it is also clear that there are more challenging requirements under discussion in the 3GPP, which would need novel radio access techniques and system evolution. The 3GPP working groups, mainly RAN1 working on the physical layer, are currently evaluating some techniques to enhance LTE Release 8 performance. This section offers an overview of some of these proposals:

The proposals could roughly be categorized into:

- Various concepts for Relay Nodes
- UE Dual TX antenna solutions for SU-MIMO and diversity MIMO
- Scalable system bandwidth exceeding 20 MHz, Potentially up to 100MHz
- Local area optimization of air interface
- Nomadic / Local Area network and mobility solutions
- Flexible Spectrum Usage
- Cognitive Radio
- Automatic and autonomous network configuration and operation
- Enhanced pre coding and forward error correction
- Interference management and suppression
- Asymmetric bandwidth assignment for FDD
- Hybrid OFDMA and SC-FDMA in uplink
- UL/DL inter eNB coordinated MIMO

7.2.1 Support of Wider Bandwidth

Support of larger bandwidth in LTE Advanced in 4G bandwidths up to 100MHz are foreseen to provide peak data rates up to 1 Gbps. In general OFDM provides simple means to increase bandwidth by adding additional subcarrier. Since the Release 8 UE capabilities only support 20MHz bandwidth (Fig.8) the scheduler must consider a mix of terminals.

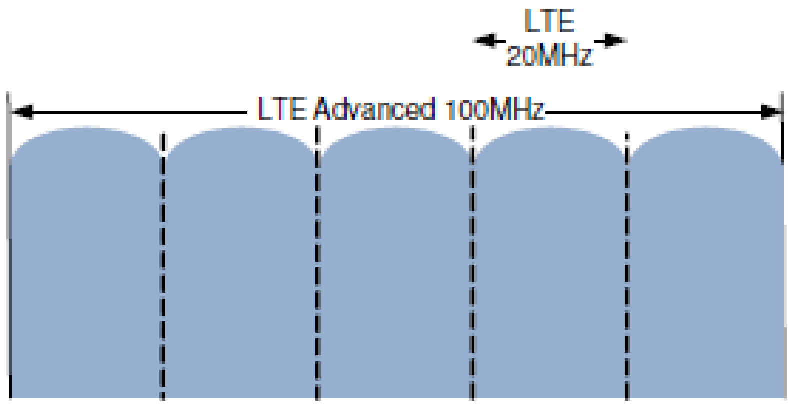

Figure 14: LTE Advanced Bandwidth,[8]

Concerning the resource allocation in the eNB and the backward compatibility, minimum changes in the specifications will be required if scheduling, MIMO, Link Adaptation and HARQ are performed over groups of carriers of 20MHz. For instance, a user receiving information in 100 MHz bandwidth will need 5 receiver chains, one per each 20 MHz block.

7.2.2 Coordinated Multiple Point Transmission and Reception

Coordinated multi point transmission and reception are considered for LTE-Advanced as one of the most promising techniques to improve data rates, hence increasing average cell throughput. It consists in coordinating the transmission and reception of signal from/to one UE in several geographically distributed points. [45]So far, the discussions have focused on classifying the different alternatives and identifying their constraints.

Potential impact on specifications comprises three areas: feedback and measurement mechanisms from the UE, preprocessing schemes and reference signal design. Remote

[45]http://www1.ericsson.com/res/thecompany/docs/journal_conference_papers/wireless_access/VTC09S_MC_HSPA.pdf

Radio Requirements (RREs) using optical fiber should be used in LTE-A as effective technique to extend cell coverage, as shown on figure below (Fig.16).

Layer 1 relays with non-regenerative transmission, that is, repeaters can also be used for improving coverage in existing cell areas. Layer 2 and Layer 3 relays can achieve wide coverage extension through an increase in Signal to Noise Ratio (SNR).

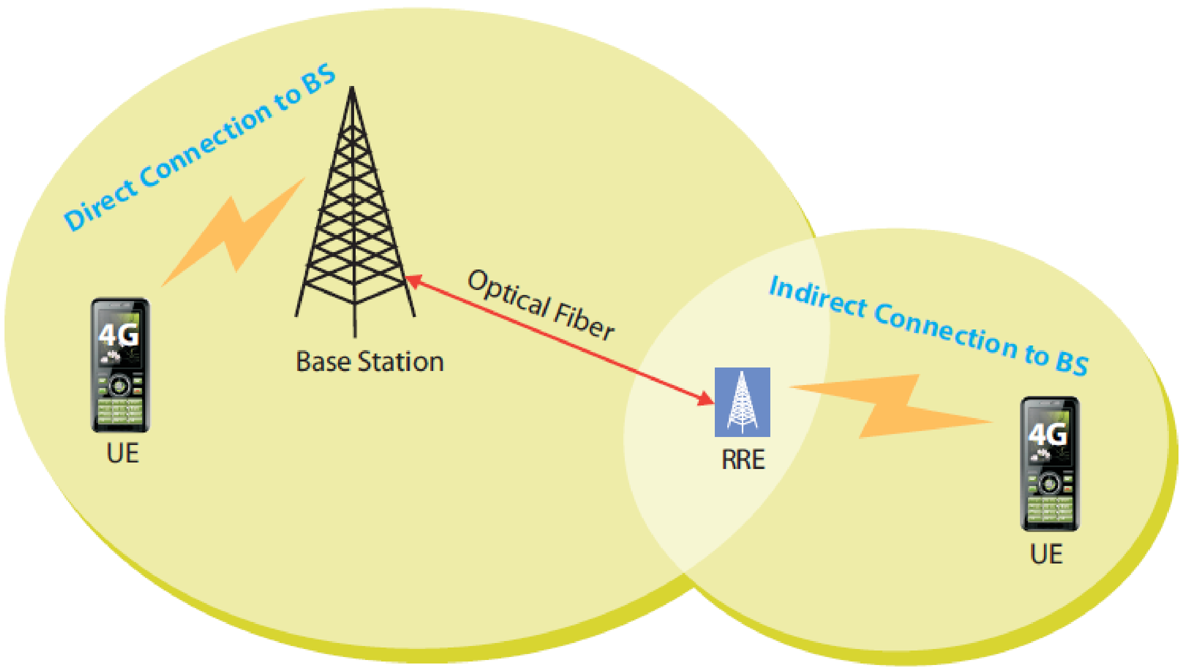

Figure 15: RRE using optical fibers, [15]

7.2.3 Relaying

LTE-Advanced extends LTE Release 8 with support for relaying in order to enhance coverage and capacity. In the case of relaying, the UEs communicate with the relay node which in turn communicates with a donor eNodeB also called an chore NodeB. The relay node is wirelessly connected to the donorcell of a donor eNodeB via the Uninterface, and UEs connect to the relay station via the Uu interface. The (anchor) eNodeB may, in addition to serving one or several relays, also communicate with non-relayed UEs directly according to the Release 8 specifications

7.2.4 Enhanced Multiple-Input Multiple-Output Transmission

Another significant element of the LTE-Advanced technology framework is MIMO, as in theory it offers a simple way to increase the spectral efficiency.[46] The combination of higher order MIMO transmission, beam forming or MultiUser (MU) MIMO is envisaged as one of the key technologies for LTE-Advanced. In LTE-A, the MIMO scheme has to be further improved in the area of spectrum efficiency, average cell through put and cell edge performances.

With multipoint transmission/reception, where antennas of multiple cell sites are utilized in such a way that the transmitting/receiving antennas of the serving cell and the neighboring cells can improve quality of the received signal at the UE/eNodeB and reduces the co-channel interferences from neighboring cells. Peak spectrum efficiency is directly proportional to the number of antennas used. In LTE-A the antenna configurations of 8x8 in DL (Downlink) and 4x4 in UL (Uplink) are planned, as shown on Fig.17.

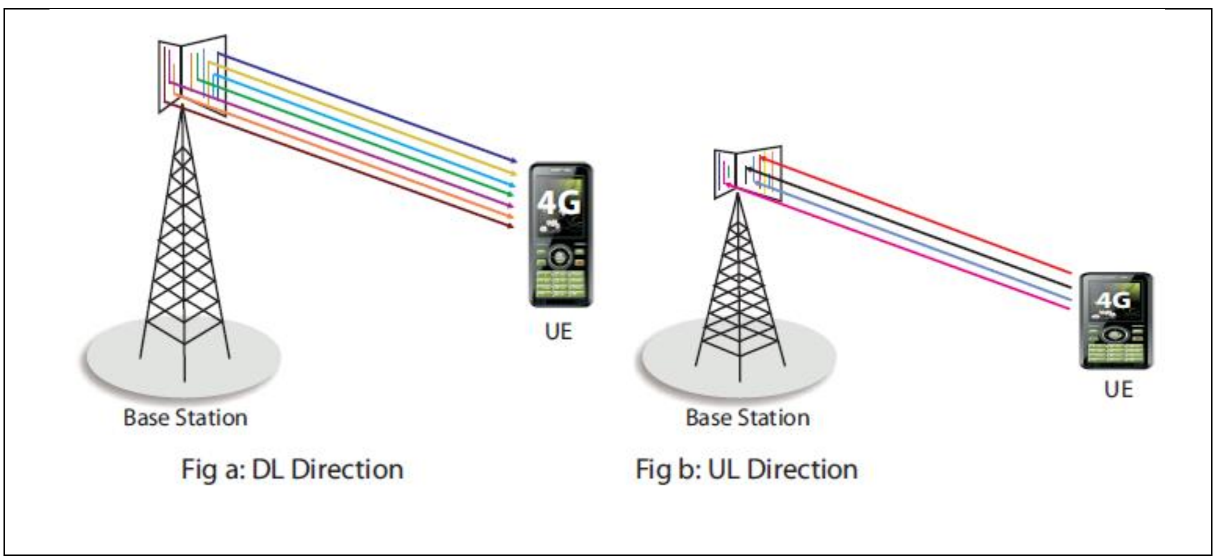

Figure 16: MIMO TX & Rx Schemes LTE-A,[15]

[46]http://www.docstoc.com/docs/69243685/Document-Title_-Enabling-Techniques-for-LTE-A-and-beyond

8 Comparison between LTE and LTE-Advanced

The comparison between those two technologies, are categorized in Table.3.

Technology	**Long Term Evolution – LTE**	**Long Term Evolution Advanced-LTE-A**
Peak data rate Down Link (DL)	150 Mbps	1Gbps
Peak data rate Up Link (UL)	75 Mbps	500 Mbps
Transmission bandwidth DL	20MHz	100 MHz
Transmission bandwidth UL	20MHz	40 MHz
Mobility	Optimized for low speeds (<15 km/hr) High performance at speeds up to 120km/hr. Maintain Links at speed up to 350 km/hr	Same as that in LTE
Coverage	Full performance up to 5km	Same as LTE requirement Should be optimized or deployment in local areas/micro cell environments
Scalable Band Widths	13,3,5,10 and 20MHz	Up to 20-100 MHz
Capacity	200 active users per cell in 5MHz	3 times higher than that in LTE

Table 2:Comparison of LTE and LTE –A, [15]

9 Analyze of technologies

Comparing pictures below you can see that there is dramatically change on physical view of each generation and of course on technical part there is going to be high modern technology over each generation. Pictures are just example (equipment) which belongs to each generation

All those generation are set of ITU which is specialized agency which agency is responsible for information and communication technology.

In 1979-1980 is introduced first mobile technology, which is called First generation known as 1G, Fig 18. The network belongs to this technology are analogue signals, Fig 17. The frequency for using to transmit voice calls are 150MHZ. Introducing was from NTT (Nippon Telegraph and Telephone) in Japan.

Figure 17: Phone of 1G Technology, [1]

The standard used on this technology was AMPS (Advanced Mobile Phone System (created by Bell Labs. The advantage of these standards was because the functionality of call setup was more flexible with strength signals and also frequency without interferences, because it operated in bandwidth of frequency of 800MHZ.

Seeing that 1G worked with analogue signals the needed was that technology to be more advanced, and from this generation we cross to a second generation known as 2G, Fig 18, which has to do with digital signals. The digital signal means that multiple data can be collect in one signal. This generation has to do with two standards TDMA and CDMA.

Figure 18: Phone of 2G Technology, [8]

TDMA (which GSM is based on it) separate signals into time slots, while CDMA decide for each user an extra code to communicate over physical channels (multiplex channels). After This generation there is also 2.5G, 2.75G till 3G. This technology is still used by some places in the world.

On third generation is that possibility that users to make cheap- free calls all over the world. 3G is more used on mobile phones, Fig 19. It is known also like a advanced multimedia access, high speed transmission and global roaming. With 3G the data can be transmitted as a packet switch with higher bandwidth. 3G is also known as IMT-2000. This generation contains all standards of 2G including special standards such: UMTS, W-CDMA, TD-SCDMA, HSPA+, and CDMA2000 which ensure the high data rate, wireless voice telephone, mobile internet access, video call and mobile TV.

Figure 19: Iphone of 3G Technology, [15]

Fourth generation known as a 4G ensure more bandwidth and services instead of 3G. Telecommunication business will have more perspective with this technology because it offers high data rate 100mb/s such are trains and cars, and about 1Gbit/s (LTE Advanced) for mobility communication (stationary users). Broadband of this technology is based all on IP and can be usable for wireless modems, laptop computers, and other mobile devices.

As we can see on descriptions on each mobile technology data rates start to be increased following their standards. So in 2008 is introduced release 8 known as LTE, then in 2010 is release 9 some enhancements of LTE, then in 2011 will come release 10 known as LTE Advanced which is compatible with LTE release 8.

Compliant of LTE and WiMax create e newest generation known as LTE Advanced which are official designation of IMT-Advanced.

It also must fulfill operators' demands like a reduced cost (per Mbit transmitted), compatibility with all 3GPP previous systems and a better service providing in terms of homogeneity, constant quality of the connection and smaller latency.

From the different mobile and wireless companies market trade for 2011 will be increased till 8.2million shipments all over the world, which cost is about 2 billion American dollars.

Figure 20: I-Phone Of 4G Technology,[3]

Till today are classified 49 operators for mobile all over the world which conclude that market trade of LTE Technology for 2011 will be increased till 8.2million shipments all over the world, which cost is about 2 billion American dollars. So mobile technology for companies which has to do with this nature such: Motorola, HTC, Android, Iphone, Fig 20, etc, predicted that till 2012 year to reach about 30 million users, this means that about 65% market trade will be increased as previous years.

As we seen on notes , wireless technology is doing very interesting and helpful job for every end users who implement this technology.

10 Conclusion

During reading a lot of materials about those advanced technologies LTE and LTE Advanced, it's clearly seen that both of them offer more enhanced functions than the others similar technologies.

LTE and LTE-Advanced enhance current deployments of 3GPP networks and enable significant new service opportunities. However, LTE's commercial success requires the availability of measurement solutions that parallel the standard's development.

But, taking into consideration that 4G isn't available yet in markets, the focus of this thesis was more on LTE rather than LTE Advanced. LTE is also known for higher throughput and lower latency for data access, as such achieving lower cost per bit traffic, richer mobile service environment and more efficient usage of limited available spectrum.

On the other side LTE –A is known for further increased data rates and lower latencies for all users in the cell, data rates scale with bandwidth—Up to 1 Gbps peak data rate. LTE-A as a system needs to take many features especially on physical layer and in network architecture, which will support larger bandwidth with flexible allocations, and coordinated base stations, MIMO.

It is believed that the initial intent of this thesis to describe these cutting edge technologies as part of evolution towards 4G mobile networks has been achieved and this thesis will serve as a useful source to different readers to better understand LTE and its evolving capabilities towards an All-IP service platform

REFERENCES

[1] Xhafer, Krasniqi (2010) Mobile communication, [Mobile and Personal communication Lecture 1, University of Business and Technology].27 March, last accessed on 15 September.

[2] WordPress 2.9.2, “4G Technology”,”technology4.net”, 2010, http://technology4g.net/, last accessed on 3 September

[3] Larry Swasey,” Telecommunications Americas”,”findarticles.com”, 2002, http://findarticles.com/p/articles/mi_m0NUH/is_14_36/ai_95791469/, last accessed on 29 September

[4] Paul Budde,” WiMAX vs. LTE”, CircleID, 2009, http://www.circleid.com/posts/20090310_wimax_vs_lte/, last accessed on 23 September

[5] Russell Hitchcock,” WiMAX”, “windowsnetworking.com”, 2009, http://www.windowsnetworking.com/articles_tutorials/WiMax-Part1.html, last accessed on 13 September

[6] LTE Architecture “E-UTRA and E-UTRAN Overall Description” http://www.3gpp.org/ftp/Specs/archive/36_series/36.300/, last accessed on 15 August

[7] Erik Dahlman, Stefan Parkwall, Johan Scold, Per Beming “3G Evolution, HSPA and LTE Broadband” 2nd edn, 2008, http://www.amazon.de/3G-Evolution-HSPA-Mobile-Broadband/dp/0123745381, last accessed on 10 August

[8] Moray Rumney "LTE and the Evolution to 4G wireless" 2009 first edn, Agilent Technologies, http://books.google.de/books?id=boePyryvxRAC&pg=PA194&lpg=PA194&dq, last accessed on 20 August

[9] Rohde & Schwarz, "Long Term Evolution {LTE)", 4mwireless.com", 2010, http://www.4mwireless.com/index.php, last access on 1 August.

[10] Moray Rumney," IMT-Advanced: 4G Wireless Takes Shape in an Olympic Year" agilent.com" 2008. www.agilent.com/go/journal,last accessed on 29 September

[11] Freescale Semiconductor, "LTE-Protocol Overview"," scribd.com", 2008, http://www.scribd.com/doc/18094043/LTE-Protocol-Overview, last accessed on 29 August

[12] David Martín-Sacristán, "On the Way towards Fourth-Generation Mobile: 3GPP LTE and LTE –Advanced","hindawi.com", August 2009, http://www.hindawi.com/journals/wcn/2009/354089.html, last accessed on 15 September

[13] Kevin Flynn, "3GPP Partners propose IMT- Advanced Radio Technology","3gpp.org", 2009, http://www.3gpp.org/3GPP-Partners-propose-IMT-Advanced, last accessed on 10 September

[14] Resources and analysis for electronics engineers, "LTE Advanced for IMT 4G","radio- electronics.com" 2009, http://www.radio-electronics.com/info/cellulartelecomms/lte-long-term,last accessed on September 22

[15] K.N Shantha Kumar, Madhu Kata, Paruchuri Chaitanya, Dinesh Mukkollu, “LTE-Advanced: Future of Mobile Broadband”,”TCS.com” 2009, http://www.tcs.com/SiteCollectionDocuments/White%20Papers/EIS_Whitepaper Advanced_Future_of_Mobile_broadband_09_2009.pdf, last accessed on October 1

[16] www.hindawi.com/journals/special issues/432727.pdf

[17] www.scribd.com/doc/510458/Human-Resource-Management

[18] http://lazyproblogger.com/3gpp-lte-latest-standard-in-the-mobile-network/

[19] http://dev.qlotuspe.com/4g_technology.php

[20] http://www.itu.int/osg/spu/ni/futuremobile/Broadbandmobile.pdf

[21] http://findarticles.com/p/articles/mi_m0NUH/is_14_36/ai_95791469/

[22] http://media.wiley.com/product_data/excerpt/0X/04706968/047069680X.pdf

[23] http://lazure2.wordpress.com/2011/06/18/china-mobile-repositioning-for-td-lte-with-full-content-and-application-aggregation-services-3g-hspa-level-is-to-create-momentum-for-that/

[24] http://searchmobilecomputing.techtarget.com/definition/IEEE-802-Wireless-Standards-Fast-Reference

[25] http://www.ijccr.com/November2011/5.pdf

[26] http://www.scribd.com/doc/56071451/92/Network-Reference-Model-NRM

[27] http://www.scribd.com/doc/56071451/92/Network-Reference-Model-NRM

[28] http://media.wiley.com/product_data/excerpt/79/04707219/0470721979.pdf

[29] http://www.eetimes.com/design/signal-processing-dsp/4016258/The-nuts-and-bolts-of-WiMAX-Part-VII

[30] http://www.radio-electronics.com/info/cellulartelecomms/3gpp2/umb-ultra-mobile-broadband.php

[31] http://www.answers.com/topic/ultra-mobile-broadband

[32] http://dictionary.sensagent.com/ultra+mobile+broadband/en-en/

[33] http://www.telenor.com/en/resources/images/telektronikk-2010.01_tcm28-56065.pdf

[34] www.umts-forum.org/component/.../Itemid,12/

[35] http://kunz-pc.sce.carleton.ca/Thesis/GurpreetThesis.pdf

[36] www.hindawi.com/journals/specialissues/432727.pdf

[37] http://www.motorola.com/web/Business/Solutions/Industry%20Solutions/Service

[38] http://www.skydsp.com/publications/4thyrthesis/chapter1.htm

[39] www.umts-forum.org/component/.../Itemid,12

[40] http://www.slideshare.net/MASITMacedonia/viktor-nastev-broadband-strategy

[41] http://www.hindawi.com/journals/wcn/2009/354089/

[42] http://www.cs.wustl.edu/~jain/cse574-08/ftp/lte/index.html

[43] http://dacaso.webs.upv.es/publications/2009_VTC_MAC_Layer_Performance_LTE

[44] http://dacaso.webs.upv.es/publications/2009_VTC_MAC_Layer_Performance_LTE

[45] http://gsmcommunications.blogspot.com/2010/12/lte-interfaces-and-protocols.html

[46] http://www.freescale.com/files/wireless_comm/doc/white_paper/3GPPEVOLUTIO

[47] http://www.privateline.com/3G/WCDMA.pdf

[48] http://cp.literature.agilent.com/litweb/pdf/5989-8139EN.pdf

[49] http://upcommons.upc.edu/pfc/bitstream/2099.1/6978/1/AlbertSerra_MasterThesis.

[50] www.hindawi.com/journals/specialissues/432727.pdf

[51] http://www.faqs.org/patents/app/20100330993

[52] http://www.freescale.com/files/wireless_comm/doc/white_paper/LTEPTCLOVWW

[53] http://ir.canterbury.ac.nz/bitstream/10092/3926/1/12624035_0909.IEEECS&T.pdf

[54] http://www.tekna.no/ikbViewer/Content/787700/18%20LTE-Advanced%20Overview%20-%20Tor%20Leif%20Aarland.pdf

[55] http://www.ee.gatech.edu/research/labs/bwn/surveys/ltea.pdf

[56] http://lteworld.org/wiki/lte-advanced

[57] http://www.mforum.ru/arc/20100429_1MA169_1E_MForum.pdf

[58] http://www1.ericsson.com/res/thecompany/docs/journal_conference_papers/wireles

[59] http://www.docstoc.com/docs/69243685/Document-Title_-Enabling-Techniques-for-LTE-A-and-beyond