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A Comparative Approach on WiMax and LTE Technologies

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***Abstract* — Wireless industry continues to change at very high speeds, tending to use the equipment more easily and safely and with a connection speed that tends to be higher and higher. Users of 3G wireless networks are looking forward to the launch of the new 4G standard. WiMax and LTE technologies are the main competitors in the mobile communication domain. This paper is a comparative study based on the first two level layers of the most innovative wireless and mobile technologies (WiMax and LTE), a technical comparative overview the parameters performances and the vulnerabilities of this technologies.**

***Index Terms* — 4G, Comparative Approaches, LTE, WiMax, Wireless**

I. INTRODUCTION

For years now on the market there was talk about WiMax technology being the next step in mobile data transmissions. It looks like the technology promoted by Intel will be set aside by the one from Universal Mobile Telecommunications System (UMTS) that comes with the alternative LTE (Long Term Evolution). This new technology enjoys the support of important companies in the communications market [1], support announced at Mobile World Congress held in Barcelona on February 11th, 2008. According to statistics, with the introduction of the 4th generation of communication technology (4G), mobile data traffic will increase by 300 times till 2015.

4G is an integrated system based entirely on IP technology, able to provide users with data, voice and multimedia services anywhere and anytime, with transfer rates up to 1Gb/s with high security and quality. The developing of the standard has as its main goals: meeting the need for broadband of the users of mobile broadband services; multimedia messaging services; digital video; HDTV and VOD; transfer rate between any two points in the world of 100Mb/s; interoperability with the existing mobile standards 2G, 3G, 3.5G; a nominal transfer rate of 1Gb/s for fixed users and 100Mb/s for mobile users; roaming and global connectivity across multiple networks and having an increased number of users on a single cell.

The fact that WiMax is already a standard and that LTE is still far from becoming a standard, gives WiMax a first advantage on the commercial market of the wireless broadband networks. The fight will be healed within the terminals and it will reflect heavily on its price. But LTE can't lose, worst case scenario it can't win, because of the considerable technological advantage over the WiMax technology.

LTE will cover the 2.1GHz spectrum, and the service suppliers will implement it without regards to pricing of the terminals. Those who will win the 3.5GHz spectrum will have the option to install the LTE technology on this frequency by taking the risk of investment in a technology that has no terminals.

It seems that all roads lead to LTE (Figure 1), the standard has known an impressive evolution over a short amount of time, being that is a software upgrade to the HSPA standard.

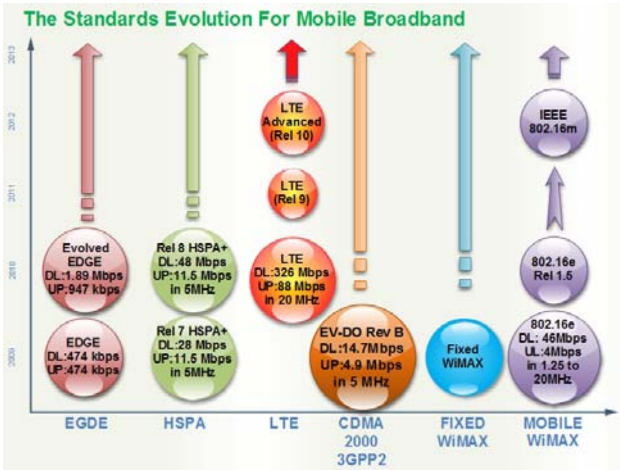

Fig. 1 The standards evolution for mobile broadband [2]

II. KEY ASPECTS OF LTE TECHNOLOGIES

For a better understanding of the LTE technologies we need to take a closer look at the first two level layers. At the first level we can find the Physical Layer, the transmissions on this level can be divided in downlink and uplink.

LTE uses for multiplexing OFDM technique (OFDMA for downlink and SC FDMA for uplink transmissions – this way it reduces PAPR – *Peak to Average Power Ratio*). The whole spectrum till 20MHz is managed by using FDD and TDD duplexing techniques [3]. The modulation formats for the downlink channels are QPSK, 16QAM, 64QAM. For achieving greater speaks it uses MIMO technology. The downlink OFDM spacing between the subcarriers is 15 KHz and the whole number of available subcarriers is 2048. The Base Station must transmit on only 72 subcarriers to the mobile device which is capable of receiving all of the 2048 subcarriers, because the transmission is split in intervals of 0.5ms, and sub frames of 1ms (a radio frame is 10ms).

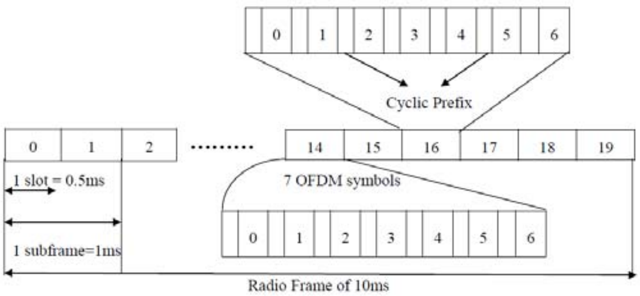

Fig. 2 Frame structure for LTE downlink and uplink

The uplink transmission uses QPSK or 16QAM modulation format (optionally it uses 64QAM). Using MIMO or SDMA the uplink speed may be increased depending on the number of antennas at the Base Station. This technology enables more than one mobile device to use the same resource (Figure 3).

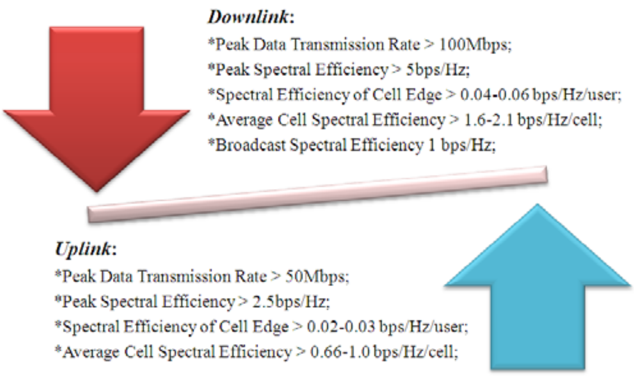

Fig. 3 LTE performance targets

The interface between the physical layer and MAC is defined by the transport channel. The bit scrambling, modulation, layer mapping, CDD precoding (Cyclic Delay Diversity) and resource elements have a defined algorithm for every physical channel. There are six channels for LTE physical layer downlink:

- ✓ PBCH (Physical Broadcast Channel) – uses QPSK modulation [4], the channel is used for carrying information about paging and control signaling mapped on four sub frames.
- ✓ PBFICH (Physical Control Format Indicator Channel) – is transmitted in each sub frame.
- ✓ PDCCH (Physical Downlink Control Channel) – uses QPSK modulation, and carries the ACK/NACK signals to the uplink channel.
- ✓ PHICH (Physical Hybrid ARQ Indicator Channel) – uses QPSK modulation; carries the ACK/NACK signals for automatic repeated request which uses a code that can correct some frame error.
- ✓ PDSCH (Physical Downlink Shared Channel) – uses QPSK, 16QAM and 64QAM modulation; transports data and multimedia services.
- ✓ PMCH (Physical Multicast Channel) - uses QPSK, 16QAM and 64QAM modulation and it is responsible for carrying multicast data.

The LTE physical uplink channels are:

- ✓ PRACH (Physical Random Access Channel) – A complex mathematical sequence (Zadoff-Chu) is used in order to generate the random access preamble [5].
- ✓ PUSCH (Physical Uplink Shared Channel) – uses QPSK, 16QAM and 64QAM modulation; in this channel the time domain SC-FDMA signals are generated for each antenna port.
- ✓ PUCCH (Physical Uplink Control Channel) – the channel contains uplink control information. This channel is mapped to the uplink control channel resource which is defined by a code and two resource blocks, consecutive in time, with hopping at slot boundary [4].

LTE uses MIMO (Multiple Input Multiple Output) technique in next generation mobile networks for increasing data rates, using for transmission two or four antennas in downlink. Multiple antennas can be used for high data rates in a matrix of 2x2 or 4x4 MIMO and for extending the coverage area beam-forming is used. In the uplink MIMO transmission is used MU-MIMO (Multi User- Multiple Input Multiple Output). The reception is supported by allocating the same time frequency resources to multiple user equipments, transmitting on a signal antenna. The closed loop transmit diversity is optional for user equipment and is supported only by FDD [6].

MAC Layer (Media Access Control) is the second layer level of the LTE technology and it is a part of the logical link layer of the radio protocol stock of LTE (Figure 4). The functions HARQ (Hybrid Automatic Repeat Request) of transmission and retransmission, multiplexing and de-multiplexing of logical channels, uplink and downlink scheduling are done by the MAC layer.

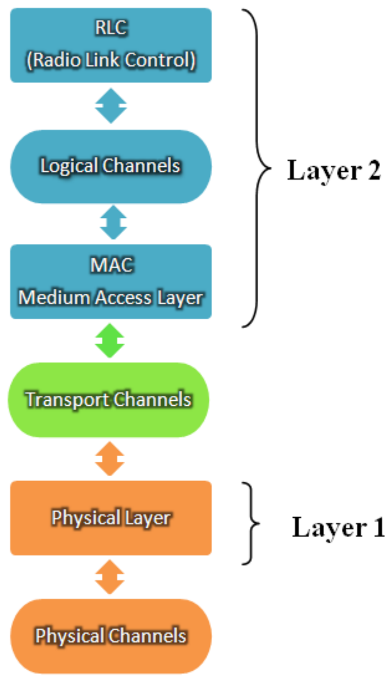

Fig. 4 LTE Protocol Stack

RLC layer sends data to the MAC layer. To these data there are added control elements and header MAC to form the MAC Single Data Unit. The MAC header is divided into sub headers which contain the length field and LCID (Logical Control Identification) which indicates the type of control elements used as type of the channel in the MAC payload field.

III. KEY ASPECTS OF WIMAX TECHNOLOGIES

Everyone has experienced the thrill of the high announced new standard WiMax, supported by Intel, and the disappointed that turned out to be.

WiMax is the abbreviation for Worldwide Interoperability for Microwave Access, and "Max" is used in order to express the very broad coverage provided by this standard. WiMax is similar to Wi-Fi and different all together, but it offers higher speeds and greater area coverage. This technology was designed to offer the same broadband access to wireless networks as the traditional cable connection. There are many advantages of using the WiMax standard: the ability for easy install on areas in which cable interfaces technology is hard to implement, low installation costs and the possibility to overcome the physical limitations traditional cable land line.

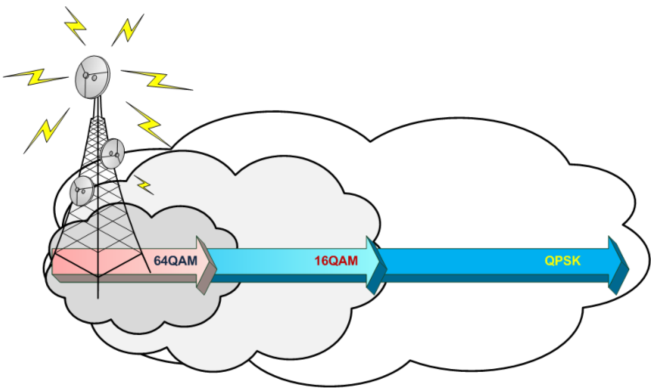

Fig. 5 Adaptive Modulations and Coding (AMC)

WiMax offers a set of technological improvements to wireless performance (throughput, coverage, indoor penetration). These improvements are: AMC (adaptive modulation and coding) which offers the highest available data rate based on link quality, sub channel division using SOFDMA (Scalable Orthogonal Frequency Division Multiple Access) – support bandwidths between 1.25 – 20 MHz, H-ARQ (Hybrid Automatic repeat Request), FEC (Forward Error Correction) and smart antennas that use MIMO and AAS (Adaptive Antenna System) [7]. WiMax has the advantage of using NLOS (Non-Line-of-Sight) technology, giving it grater coverage in rough terrain and indoors (supports high mobility up to 125 Km/h) [8].

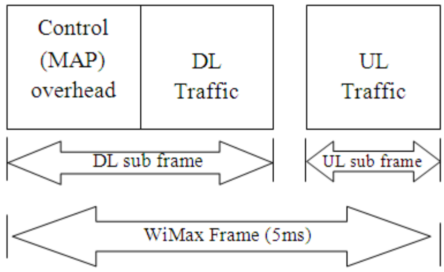

Fig. 6 Frame structure for WiMax

WiMax supports five physical layer interfaces depending on the modulation technique:

- ✓ WirelessHUMAN – TDD is used as a duplexing technique, it is used for the free frequency between 2-11GHz.
- ✓ WirelessMAN-OFDM – provides NLOS transmission.
- ✓ WirelessMAN-OFDMA – uses 2048 subcarriers for NLOS operation.
- ✓ WirelessMAN-SC – uses single carrier modulation technique in 10-66 GHz frequency band for LOS transmission.
- ✓ WirelessMAN-SCa – the same as WirelessMAN-SC with the difference that it operates in 2-11GHz.

The MAC layer is used as a transport layer between the physical layer and the upper layers. A key feature of the

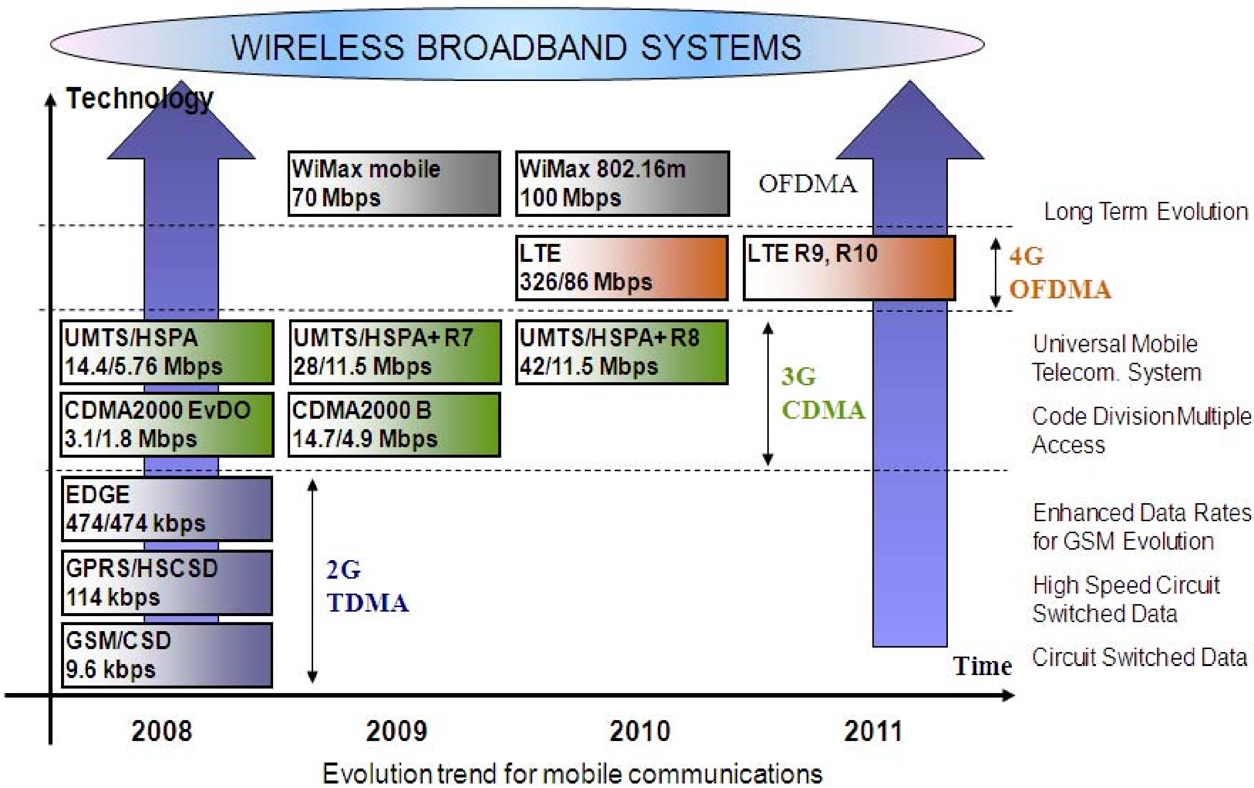

Fig. 7 Evolution trend for mobile communication

MAC layer is the support for transmission of variable length frames. There are three sub layers: SS (Security Sublayer), CPS (Common Part Sublayer), SSCS (Service Specific Convergence Sublayer).

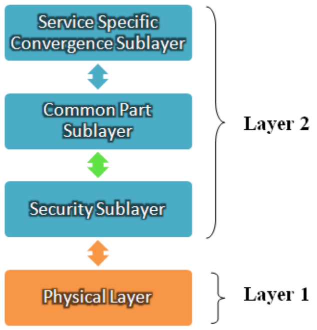

Fig. 8 Stack architecture of WiMax

WiMax supports two forms of MIMO systems. Open loop MIMO is used in order to increase the capacity and the range of WiMax. Closed loop MIMO contains information about the propagation channel and makes use of MRT (Maximum Ratio Transmission) to further enhance capacity and coverage area of WiMax.

IV. COMPARATIVE STUDY BETWEEN WIMAX AND LTE TECHNOLOGIES

High speed mobile wireless networks tend to rich a speed of 1 Gb/s, as shown in Figure 7 [9].

A technical comparison of LTE – WiMax is shown in Figure 9 and Figure 10 [10].

Aspect	LTE (3GPP R8)	WiMAX R 1.0 (16e)	WiMAX R 2.0 (16m)
Air Interface	DL: OFDMA UL: SC-FDMA	DL: OFDMA UL: OFDMA	DL: OFDMA UL: OFDMA
Duplexing	FDD, TDD	TDD	TDD, FDD
Mobility / Vehicular Speed	350 Km/H	60-120 Km/H	350 Km/H
Bandwidth	1.25, 1.6, 2.5, 5, 10, 15, 20 MHz	3.5, 5, 7, 8.75, 10 MHz	5, 10, 20, 40 MHz
Peak Data Rates	DL: 302 Mbps (4x4) UL: 75 Mbps (2x4) @ 20 MHz FDD	DL: 46Mbps (2x2) UL: 4Mbps (1x2) @ 10MHz TDD 3:1	DL > 350 Mbps (4x4) UL > 200 Mbps (2x4) @ 20 MHz FDD
Average Sector Spectral Efficiency	DL: 1.91 bps/Hz (2x2) UL: 0.72 bps/Hz (1x2)	DL: 1.91 bps/Hz (2x2) UL: 0.84 bps/Hz (1x2)	DL > 2.6bps/Hz (4x2) UL > 1.3bps/Hz (2x4)
Latency	Link layer < 5 mSec Handoff < 50 mSec	Link layer ~ 20 mSec Handoff 35-50 mSec	Link layer < 10 mSec Handoff < 30 mSec
VoIP Capacity	80 users / sector / FDD MHz	20 users / sector / TDD MHz	> 30 users / sector / TDD MHz

Fig. 9 Comparison between LTE and WiMax technologies

There are no devices available for LTE technology. On the other hand for WiMax there are multiple device models (USB dongles, MIDs, PC cards, smartphones, etc.). A number of mobile operators have secured a spectrum and support LTE. With WiMax the prices for delivering affordable and flexible broadband services are considerable lower than the LTE's.

WiMax is simpler to implement because it has a flat based network design with few protocols which are IETF based (Internet Engineering Task Force). LTE network design has many layers and specific protocols making it harder for implementation, being that is weight down by the 3G legacy network protocol.

Aspect	3GPP – LTE	Mobile WiMAX
Air Interface	OFDMA based QPSK – 64QAM	OFDMA based QPSK – 64QAM
Allocation Schemes	Contiguous allocation blocks	Multiple formats – PUSC, FUSC, AMC
Core Network	All-IP	All-IP
Persistent Allocations	Release 8.0	Release 1.5
Multicast/Broadcast	Release 9.0	Release 1.0
UL PAPR Reduction	SC-FDMA	N/A
Forward Error Correction	Control: CC, K=7, R=$^1/_3$ Data: CTC, K=4, R=$^1/_3$, 6144 bits/block	FCH: CC, K=7, R=½ Control+Data: CTC, K=4, R=$^2/_6$, 480 bits/block
H-ARQ	Incremental Redundancy	Release 1.0 – Chase Release 1.5 – Chase or IR
MIMO Models	Spatial Multiplexing Transmit Diversity (Alamouti, CDD) UE specific beam-forming	Spatial Multiplexing Transmit Diversity (Alamouti) CDD – R 1.5 UE specific beam-forming Collaborative UL SM
Multi Technology Support	GERAN, UTRAN, non-3GPP Non 3GPP: CDMA, WLAN, (WiMAX) PMIP and IMS/VCC	CDMA, GERAN, UTRAN, WLAN CMIP, PMIP, IMS

Fig. 10 Comparison between mobile LTE and WiMax technologies

For LTE there are used two types of frames GFS (Generic Frame Structure) used in FDD and AFS (Alternative Frame Structure) used in TDD. LTE offers TDD and FDD duplexing, giving operators better channel optimization – the synchronized speeds of download and upload is not mandatory. WiMax supports FDD and TDD frame structure, but the downlink and uplink subframes compromise the TDD frame. WiMax has the advantage over the FTTH (Fiber To The Home) technology, providing a cost effective infrastructure for multimedia services.

WiMax has the disadvantage that in high density areas the costs for data communications transmissions with high QoS increase exponentially. Another disadvantage is that has no certification.

When it comes to QoS the two technologies have different mechanisms supports. WiMax offers: UGS, ErtPS, BE, nrtPS, rtPS. LTE offers: AMBR, MBR, QCI, ARP, GBR.

WiMax supports idle and sleep mode connectivity and a mobility speed up to 120Km/h. LTE supports RRC-CONNECTED and RRC-IDLE modes and a mobility speed up to 350 Km/h.

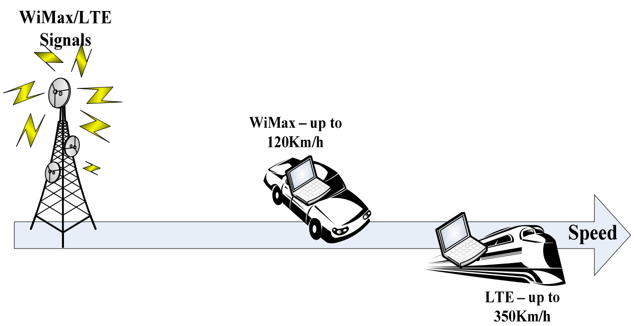

Fig.11 WiMax/LTE mobility speed

V. CONCLUSION

The two technologies are in competition for some market segments, in other the choice is clear for example fixed WiMax will probably replace at large scale Wi-Fi connections and will be preferred by ISPs for backhaul connections at low price. Even if there are similarities between them:

- both are using OFDM and MIMO,
- both regulations are covering fix and mobile communications,
- both are fully IP compatible and are supporting high data rates (360/80 Mbps for LTE 144/35 Mbps for WiMax)
- both include “best-effort” and priority based QoS scalable solutions [11].

For mobile wireless communications networks the choice is clear and the way to go is – LTE [12].

Original contributions of the paper are in the area of:

- comparative value of different technologies;
- the analysis on key aspects of the first two layer levels supports a better understanding of both technologies.
- this study leads to a general conclusion that LTE is the future for communications technologies.

Today’s trends for LTE and WiMax systems, for high-speed wireless access services, leads to a market battle for supremacy on communications domains. We conclude that LTE will win, in spite the fact that the standard for this technology hasn’t been lunched yet.

This study helps researchers who want to learn more on these innovative new technologies WiMax and LTE, about the way in which they work at the base levels.

Over all, the evolution trend is oriented toward an inter-network solution rather than a global communication system.

VI. FUTURE WORK

In our next papers we will present a study on WiMax and LTE on packet frames structure for downlink and uplink with a specific simulating software.

We will simulate wireless communication networks with the two technologies, WiMax and LTE, on high performance hardware to obtain maximum speeds for data transfer.

Future papers will analyze the effects of WiMax and/or LTE on live video streams, IPTV streams and multimedia.

VII. ACKNOWLEDGMENT

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