A Comparison and SWOT Analysis of Towards 4G Technologies: 802.16e and 3GPP-LTE

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Abstract—**In recent years, there has been a plenty of paradigm shifts occurring in the way people across the world could connect and collaborate. Nowadays, wireless connectivity is almost everywhere and getting highly affordable even for people who are in the bottom of the pyramid. However wireless connection is liable for several changes and challenges and therefore is far more complex to implement and sustain than a wired system. Now, with the cool arrival of third and fourth generation communication technologies, the inhibiting trends such as unpredictability, signal fading, latency, jitter etc., are gradually disappearing for the good. The fourth generation (4G) wireless networks are all set to turn the current networks into end-to-end IP networks. With the massive adoption of IPv6, every single device in the world will have a unique IP address thereby IP-based devices, networks and environments are going to shine in the days to unfurl. This significant transition enables everything tangible in our midst to join into the raging Internet bandwagon in order to be remotely monitored, managed and manipulated. If 4G is implemented correctly and comprehensively, it will truly and tantalizingly harmonize global roaming, high-speed connectivity, and transparent end-user performance on every mobile device in the world. 4G is set to deliver 100mbps to a roaming mobile device globally and up to 1gbps to a stationary device. This allows video conferencing, streaming picture-perfect video and much more. The maturity and stability of 4G technologies therefore breeds innovation at faster pace and hence possibilities for novel and people-centric services are huge.**

In this paper, we have highlighted the following critical issues for the leading wireless broadband standards such as WiMAX, Mobile WiMAX and 3GPP-LTE. This paper specifically discuss about the below-mentioned in detail.

- **The evolution of mobile service from the 1G (first generation) to 4G (Fourth Generation)**
- **The configuration details of Mobile WiMAX and LTE.**
- **Benefits and usage patterns of these systems**
- **Comparison and SWOT analysis for each of these standards in order to enable users to choose the best as per his requirements and preferences.**

Keywords-*WiMAX, 802.16e, 3GPP-LTE, SWOT*

I. INTRODUCTION

Wireless connectivity is increasingly pervasive and persuasive for enabling the true mobility. Anywhere anytime communication, computation and collaboration are the new norm being prescribed for every individual to be extremely productive. Competent and compact wireless technologies have emerged and evolved in order to fulfill the soaring expectations of businesses as well as end-users. Currently third-generation (3G) communication technologies are on the widespread usage across the continents, countries and counties and cities. WiMAX (both fixed and mobile) versions are being pampered and promoted vigorously by standard bodies, government agencies and mobile service providers as the best option for providing affordable and last-mile connectivity.

Next-Generation Communication Standard - Equipment manufacturers, product vendors, and researchers have already plunged into experimenting and espousing next-generation (4G) technologies. In a nutshell, accessing and availing information and Internet services anywhere, anytime, any device, any channel, and any media are becoming so common and casual these days with the maturity of wireless communication standards, infrastructures, and handy devices. Handheld terminals are undergoing real transformations in accommodating multiple functions through integration and miniaturization of hardware modules. The Internet is stuffed with a number of professional and personal services that could be accessed using any kind of portable, wearable, nomadic and wireless devices. Especially for video and other rich services, we need true broadband technologies. There is a silent yet strategic convergence happening in the mobile space. That is, video, voice and data are getting smoothly merged to be transmitted through a single channel without much latency and viewed in a single device with all clarity. Such kinds of real-time and seamless synchronization can be made possible with 4G technologies. Video on demand, global roaming, true interoperability among personal communication and assistive devices being produced by different makers are being demanded by people, who are on the know-how.

Therefore the future 4G infrastructures will consist of a set of various networks using IP (Internet protocol) as a common protocol so that users are in control because they will be able to choose every application and environment. The design is that 4G will be based on OFDM (Orthogonal Frequency Division Multiplexing), which is the key enabler of 4G technology. Other technological aspects of 4G are adaptive processing and smart antennas, both of which will be used in 3G networks and enhance rates when used in with OFDM. Currently 3G networks still send there data digitally over a single channel, OFDM is designed to send data over hundreds of parallel streams, thus increasing the amount of information that can be sent at a time over traditional CDMA networks. The 4G data rates will vary depending on the number of channels that are available, and can be used and technologies like adaptive processing, which detects interference on a channel and improves reception by actively switching channels to avoid interference.

4G networks will also use smart antenna technology, which is used to aim the radio signal in the direction of the receiver in the terminal from the base station. When teamed up with adaptive techniques, multiple antennas can cancel out more interference while enhancing the signal. The 4G plans are still years away, but transitioning from 3G to 4G should be seamless for customers because 4G will have evolved from 3G. Users won't even have to get new phones. Digital applications are getting more common lately and are creating an increasing demand for broadband communication systems. The technical requirements for related products are very high but solutions must be cheap to implement since we are essentially talking about consumer products. For Satellite and for Cable; such cost-efficient solutions are already about for the terrestrial link (i.e. original TV broadcasting) the requirements are so high that the 'standard' solutions are no longer an option. Orthogonal Frequency Division Multiplexing (OFDM) is a technology that allows transmitting very high data rates over channels at a comparable low complexity. Orthogonal Frequency Division Multiplexing is the choice of the transmission method for the European digital radio (DAB) and Digital TV (DVB-T) standard. Owing to its great benefit's OFDM is being considered for future broadband application such as wireless ATM as well.

II. TECHNOLGOY PATH

At the end of the 1940's, the first radio telephone service was introduced, and designed to users in cars to the public land-line based telephone network. Then, in the 1960 a system launched by Bell Systems, called IMTS, or, "Improved Mobile Telephone Service", brought quite a few improvements such as direct dialing and more bandwidth. The very first analog systems were based upon IMTS and were created in the late 60s and early 70s. The systems were called "cellular" because large coverage areas were split into smaller areas or "cells", each cell is served by a low power transmitter and receiver.

1G: 1G is first-generation wireless telephone technology. This generation of phones and networks is represented by the brick-sized analog phones introduced in the 1980's. Subsequent numbers refer to newer and upcoming technology.

2G: 2G phones use digital networks. Going all-digital allowed for the introduction of digital data services, such as SMS and email. 2G networks and their digital nature also made it more difficult to eavesdrop on mobile phone calls.

3G: 3G networks are an in between standard. 3G is seen more as pre4G instead of a standard of its own. The advantage 3G networks have over 2G networks is speed. 3G networks are built to handle the needs of today's wireless users. This standard of wireless networks increases the speed of internet browsing, picture and video messaging, and handheld GPS use.

4G: 4G (AKA Beyond 3G) is like the other generations in that its advantage lies in promised increased speeds in data transmission. There is currently no formal definition for 4G, but there are objectives. One of these objectives is for 4G to become a fully IP-based system, much like modern computer networks. The supposed speeds for 4G will be between 100 Mbit/s and 1 Gbit/s.

The evolution of Mobile service from the 1G (first generation) to fourth generation is discussed in this section and from Table-1 technology evolution began as follows:

Technology	**1G**	**2G**	**2.5G**	**3G**	**4G**
Design Began	1970	1980	1958	1990	2000
Implementation	1984	1991	1999	2002	2010+
Service	Analog Voice, Synchronous data to 9.6 kbps	Digital Voice, Short message	Higher Capacity, Packet data	Higher capacity, Broadband data up to 2 Mbps	Higher capacity, completely IP-oriented, multimedia, data to hundreds to megabits
Standards	AMPS, TACS, NMT, etc.	TDMA, CDMA, GSM, PDC	GPRS, EDGE, 1xRTT	WCDMA, CDMA2000	Single standard
Data Bandwidth	1.9kbps	14.4 kbps	384 kbps	2 mbps	200mbps
Multiplexing	FDMA	TDMA, CDMA	TDMA, CDMA	CDMA	CDMA
Core Network	PSTN	PSTN	PSTN, Packet network	Packet network	Internet

Legend:

1xRTT	= 2.5G CDMA data service up to 384 kbps
GSM	= global system for Mobile
AMPS	= advanced mobile phone service
NMT	= Nordic mobile telephone
CDMA	= code division multiple access
PDC	= personal digital cellular
EDGE	= enhanced date for global evolution
PSTN	= public switched telephone network
FDMA	= frequency division multiple access
TACS	= total access communications system
GPRS	= general packet radio system
TDMA	= time division multiple access
WCDMA	= wideband CDMA

Table1: History of Mobile Telephone Technologies

The Figure below shows the wireless technology evolution path for WiMAX and LTE toward to ITU defined Advance 4G Stands.

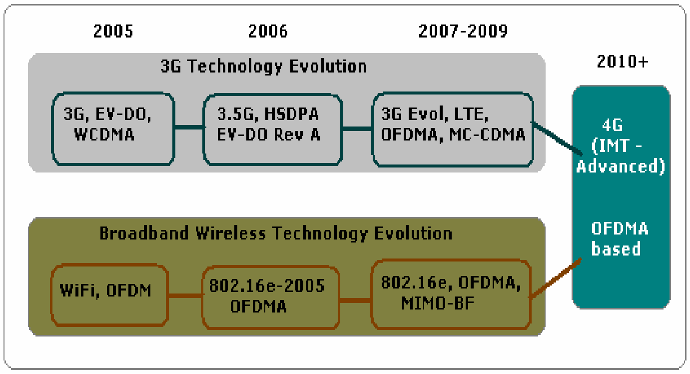

Figure-1: Evolution path of Mobile wireless technologies towards 4G

III. MOBILE WIMAX

The Mobile WiMAX (802.16e) standard can provide tens of megabits per second of capacity per channel from each base station (BS) with a baseline configuration. Many path-breaking features such as adaptive antennas, which can significantly improve the performance, are being embedded into WiMAX products. The high data throughput enables efficient data multiplexing and low data latency to deliver a host of people-centric services such as audio / video / web streaming, and wireless VoIP with high quality of service (QoS). Ultimately the pervasive Internet will become practical with the arrival of standards-compliant mobile WiMAX solutions.

The scalable architecture, high data throughput and low cost deployment make the mobile WiMAX standard an exciting solution for an astounding array of nimbler services. Hundreds of companies have contributed to the development of this technology and many firms have announced detailed product plans for this technology. This is an encouraging sign towards providing the always-on mobile Internet at very low subscription cost. The broad industry participation will ensure economies of scale that will help drive down the costs of subscription and enable the deployment of mobile internet services globally.

Mobile WiMAX (figure 2) is a broadband wireless solution that enables convergence of mobile and fixed broadband networks through a common wide-area broadband radio access technology and flexible network architecture. The mobile WiMAX Air Interface adopts Orthogonal Frequency Division Multiple Access (OFDMA) for improved multi-path performance in non-line-of-sight (NLOS) environments. Scalable OFDMA (SOFDMA) is introduced in the IEEE 802.16e to support scalable channel bandwidths from 1.25 to 20 MHz. There are a number of budding and blooming technologies, best-of-breed implementations, and other trend-setters in this happening field. This is a welcome indication for the dreamt ubiquitous computing world.

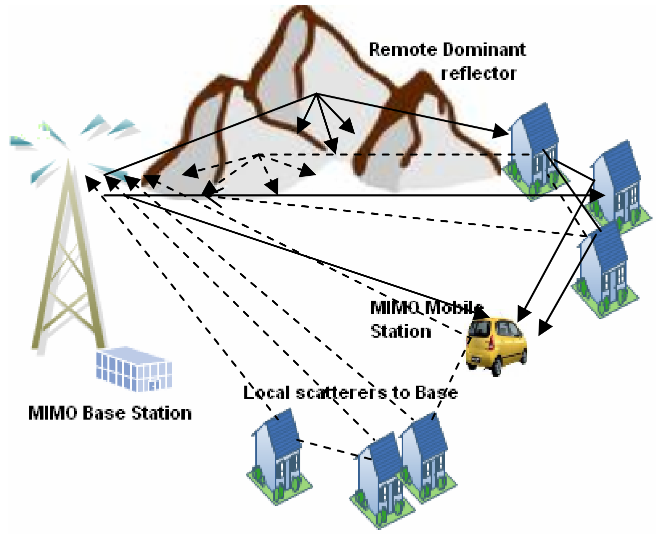

Figure 2 - Mobile WiMAX (802.16e)

IV. 3GPP- LTE

The growing commercialization of Global System for Mobile Communications (GSM) and its evolution such as Universal Mobile Telecommunications System (UMTS) with High Speed Packet Access (HSPA) have been the focus topic of 3GPP. The GSM / UMTS system is perhaps the most successful communications technology family and its evolution to beyond 3G becomes important issue for the next global mobile-broadband solution. In parallel to evolving HSPA, 3GPP is also specifying a new radio access technology in Release 8 known as LTE in order to ensure the competitiveness of UMTS.

LTE focuses to support the new Packet Switched (PS) capabilities provided by the LTE radio interfaces and targets more complex spectrum situations with fewer restrictions on backwards compatibility. Main targets and requirements for the design of LTE system have been captured in and can be summarized as follows.

Data Rate: Peak downlink rates of 100 Mbps and Uplink rates up to 50 Mbps for 20 MHz spectrum allocation, assuming 2 receive antennas and 1 transmit antenna at the terminal

Spectrum: Operation in both paired (Frequency Division Duplex / FDD mode) and unpaired spectrum (Time Division Duplex / TDD mode). Enabling deployment in many different spectrum allocations with scalable bandwidth of 5, 10, 15, 20 MHz, and better efficiency (downlink target is 3-4 times better than release 6 and uplink target is 2-3 times better than release 6)

Throughput: Mean user throughput per MHz is 3-4 times (downlink) and 2-3 times (uplink) better than release 6. Cell-edge user throughput is also expected to be improved by a factor 2 for uplink and downlink

Latency: Significantly reduced control-plane and user-plane requirements, i.e. less than 5ms in the transmission of an IP packet (user-plane), allow fast transition times of less than 100ms from camped state to active state (controlplane)

Costs: Reduced CAPEX and OPEX including backhaul for both operators and users, and effective migration from previous release shall be possible.

One of LTE requirement, as previously described, is to reduce the costs by simplifying the radio architecture. Therefore the number of nodes and interfaces in the network shall be reduced and it means that the 3GPP LTE Radio Access Network architecture need to group user plane functionalities into one network node called evolved Node B (eNB). The resulting radio architecture is commonly known as System Architecture Evolution (SAE) and is depicted on Figure 3 below.

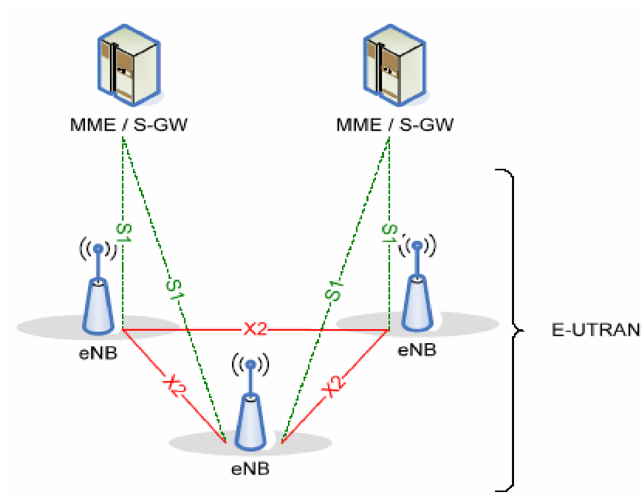

Figure 3: E-UTRAN overall architecture

As shown in the figure, the 3GPP LTE Radio Access Network (RAN) architecture is different from the one of the previous 3GPP releases. The main difference is that a significant part of the radio control functionality has been distributed to the so-called eNBs. Thus, it is possible to reduce latency with fewer hops in the media path and distribution of processing load into multiple eNBs.

V. 4G MARKET TREND

The primary 4G technologies of the future are expected to be Long Term Evolution (LTE), Ultra Mobile Broadband (UMB), and IEEE 802.16m WiMAX, the market research firm says. Research finds that 4G technologies will be OFDMA-based and will support 100 megabits per second for wide-area mobile applications. In addition, 4G technology roll-outs will most likely start between 2010 and 2012 from Fig-4, and mobile operators will deploy 4G slowly at first, and rely on their EV-DO or HSPA networks to provide for more ubiquitous coverage.

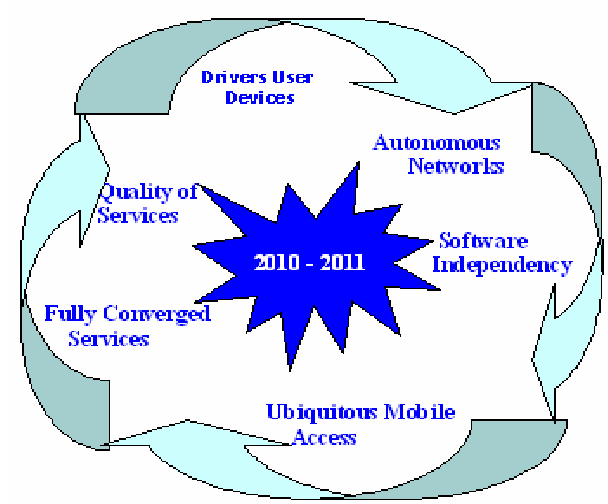

Figure 4: Key Elements of 4G

Mobile WiMAX is likely to have the most success among new market entrants looking to enter the market in the near term, such as landline operators seeking to include mobility in their service bundles. The worldwide broadband subscriber base has increased to nearly 250 million and the continued increase in broadband penetration will be an extremely important driver, as it is a vital requirement to enhance end user experience.

VI. A COMPARISON OF 802.16E AND 3GPP-LTE

We have studied various key elements of a comparison between the Mobile WiMAX and 3GPP-LTE standards as they converge to 4G broadband wireless access systems. This comparison focuses mainly on the physical layer aspects of the radio access technology of these two standards as given below Table2.

VII. SWOT ANALYSIS OF 802.16E AND 3GPP-LTE

We have studied the various properties and positives of each of these solutions as indicated below in the Table3:

CONCLUSION

In this paper, we have compared and compiled the various characteristics of each promising and potential wireless broadband technology. As indicated above, there are some critical shortcomings in the present-day3G technologies and hence technocrats and visionaries are betting and banking on the forthcoming 4G technologies in order to guarantee the envisioned goals behind true mobile broadband. As standardsbacked systems, solutions and services enable the seamless interoperability and spontaneous interaction, there will be more purposeful and real-time collaboration enhancing people productivity sharply.

Service providers as well as consumers are very optimistic about the grand success of next-generation communication technologies in realizing and releasing a stream of people-centric services in order to keep up their loyalty. On the other hand, professors and pundits are looking into the aspects of establishing unified, ubiquitous and autonomic communication. 4G standards are immensely contributing for these. Service orientation (SO) promises generation, deployment or delivery of design and run-time service composites, which are more people-aligned. A number of core and peripheral technologies converge with the happening space of telecommunication in order to make communication ambient and adaptive.

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AUTHORS PROFILE

Dr. C. Pathuru Raj (www.peterindia.net) has been working as a lead architect in the corporate research (CR) division of Robert Bosch. The previous assignment was with Wipro Technologies as senior consultant and was focusing on some of the strategic technologies such as SOA, EDA, and Cloud Computing for three years. Before that, he worked in a couple of research assignments in leading Japanese universities for 3.5 years. He has 8 years of IT industry experiences after the successful completion of his UGC-sponsored PhD in formal language theory / fine automata in the year 1997. He worked as a CSIR research associate in the department of computer science and automation (CSA), Indian institute of science (IISc), Bangalore for 14 memorable months. He has been authoring research papers for leading journals and is currently involved in writing a comprehensive and informative book on Next-Generation Service Oriented Architecture (SOA).

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Table 2: Comparison of IEEE802.16e and 3GPP-LTE

Aspect	WiMAX 802.16e	LTE
Network Equipment Availability	2007	2009
Standard Body	IEE & WiMAX Forum	3GPP
Spectrum Band Plan	TDD	FDD
Channel Bandwidth	3.5, 5, 7, 8.75,10 MHz	1.4 – 20MHz
Channel throughput	~3.5 Mbps/Hz downlink 35Mbps, 1 sector, 10MHz channel	~5.0 Mbps /Hz downlink 50Mbps, 1sector, 10MHz channel
Bit-rate/Site: DL UL	75Mbps (MIMO 2Tx 2Rx) 25Mbps	100Mbps (MIMO 2Tx 2Rx) 50Mbps
Mobility: Speed Handovers	Up to 120Km/H Optimized hard handovers supported	Up to 250 Km/H Inter-Cell soft handovers supported
MIMO: DL UL NO. of Code words	2Tx X 2Rx 1Tx X NRx (Collaborative SM) 1	2Tx X 2Rx 2Tx X 2Rx 2
Spectrum Type	Licensed	
Radio Technology DL & UL	Scalable OFDMA	
Antennas	MIMO & Advanced Antenna Techniques	
Core Technology	Flat, All IP	
Application Layer	IMS	
Application	VoIP, Data, Video	
Terminal Variety	Fixed CPE, Mobile Handsets, Data card	
Roaming framework	New (Work in process in WiMAX Forum)	Auto Through existing GSM/UMTS
Schedule forces: Standard completed Initial Deployment Mass Market	2005 2008 2009	2007 2010 1012

Table 3: SWOT Analysis of IEEE802.16e and 3GPP-LTE

SWOT	Mobile WiMAX (IEEE802.16e-2005)	3GPP-LTE (E-UTRAN)
Strengths	Economic Scalability and Cost Effective Solution	Latest emerging technologies and Higher data rates
	Business Flexibility and Student Communities	More efficient spectrum usage and Better end-user
	Space Age Technology	Can be made completely resistant to multi-path delay spread & Better suited to MIMO
Weaknesses	Spectrum issues have yet to be overcome	Sensitive to frequency errors, phase noise.
	security regulations for mobile WiMAX is not yet been solved	Doppler Shift as the sub carriers are closely spaced.
	Mobile WiMAX has yet to be made commercial	High peak-to-average power ratio (PAPR)
Opportunities	Mobile WiMAX makes it easy for developers to work toward a common interoperable technology.	Scalable bandwidth (defined by the number of sub carriers used),
	Mobile WiMAX systems are adaptive modulation, coding (AMC) and MIMO antenna technologies.	Radio channel emulation challenges in 3GPP LTE
	The high number of features and flexibility required in Mobile WiMAX	Long term evolution (LTE) is turning UMTS into a high- performance
Threats	Data and signal Loss.	Development of protocol stack for communication
	Difficulty of Compatibility, Security and Interference	Improving security
	Spectrum availability and quality is another critical issue	More difficult to operate at the edge of cells (CDMA uses scrambling codes to provide protection from inter-cell interference at the cell edges whereas OFDM has no such feature).