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Functional Architecture of 4G Wireless Technologies

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ABSRRACT:

The development of broadband wireless access technologies in recent years was the result of growing demand for mobile Internet and wireless multimedia applications. Mobile communication plays a most important role in telecommunications industry.

Through a common wide-area radio-access technology and flexible network architecture WiMAX and LTE has enabled convergence of mobile and fixed broadband networks. Since January 2007, the IEEE 802.16 Working Group has been developing a new amendment of the IEEE802.16 standard (i.e., IEEE 802.16m) as an advanced air interface to meet the requirements of ITU-R/IMT-advanced for 4G systems as well as for the next-generation mobile network operators.

Next fourth generation (4G) mobile technology, promises the full mobility with high speed data rates and high-capacity IP-based services and applications while maintaining full backward compatibility. This paper explores 4G wireless system, its features and technologies to fulfill its requirement.

Keywords -

OFDMA, WiMAX, LTE, AAA, MS, BS, ASN, MME, HSS, QOS, AKA

1.1. **INTRODUCTION**

4G, short for fourth generation, is the fourth generation of mobile telecommunications technology, succeeding 3G. A 4G system must provide capabilities defined by ITU in IMT Advanced. Potential and current applications include amended mobile web access, IP telephony, gaming services, high-definition mobile TV, video conferencing, 3D television, and cloud computing.

Two 4G candidate systems are commercially deployed: the Mobile WiMAX standard (first used in South Korea in 2007), and the first-release Long Term Evolution (LTE) standard (in Oslo, Norway, and Stockholm, Sweden since 2009). It has however been debated if these first-release versions should be considered to be 4G or not, as discussed in the technical definition section below.

First generation (1G) a wireless network was basically analog cellular systems with circuit switched network architecture. The main challenges of these wireless networks were basic voice telephony, low capacity and limited local and regional coverage. The increased demand for high frequency ranges in the telecommunications sector caused development in analog to digital transmission techniques. In the early 1990s, second generation (2G), arrived to meet the capacity demands of burgeoning voice plus telephony, text messaging and limited circuit switched data services. By utilizing digital system, the signal can be compressed much more efficiently than analog system, allows transmitting more packets into the same bandwidth and propagates with less power.

1.2. FOURTH GENERATION NETWORKS

4G is short for Fourth (4th) Generation Technology. 4G Technology is basically the extension in the 3G technology with more bandwidth and services offers in the 3G. But at this time nobody exactly knows the true 4G definition. Some people say that 4G technology is the future technologies that are mostly in their maturity period. The expectation for the 4G technology is basically the high quality audio/video streaming over end to end Internet Protocol. If the Internet Protocol (IP) multimedia sub-system

movement achieves what it going to do, nothing of this possibly will matter. WiMAX or mobile structural design will become progressively more translucent, and therefore the acceptance of several architectures by a particular network operator ever more common. The main features of 4G services of interest to users are application adaptability and high dynamism user's traffic, radio environment, air interfaces, and quality of service.

1.3. NEED AND OPPURTUNIY FOR 4G

The use of the 4G service will be very similar to that of the 3G service whilst offering much higher data transfer rates and therefore allowing either more speed intensive applications or more users to experience good speeds whilst only connected through 1 carrier.
Applications could include:

- 4G Ultra high speed internet access - E-mail or general web browsing is available.

- 4G Data intensive interactive user services - Services such as online satellite mapping will load instantly.

- 4G Multiple User Video conferencing- subscribers can see as well as talk to more than one person.

- 4G Location-based services - a provider sends wide spread, real time weather or traffic conditions to the computer or phone, or allows the subscriber to find and view nearby businesses or friends whilst communicating with them.

- 4G Tele-medicines - a medical provider monitors or provides advice to the potentially isolated subscriber whilst also streaming to them related videos and guides.

1.4. WIMAX AND LTE AS NEXT GENERATION TECHNOLOGIES

Due to limitation in QOS and coverage range, Wi-Fi falls short as being wireless technology. The emergent 4G technologies such as WiMAX and LTE are stronger as compared to Wi-Fi. These technologies are having strong QOS and wider coverage. In some key aspect WiMAX and LTE resemble each other including operating in licensed spectrum bands, strong QOS support, wider coverage range.
Long Term Evolution (LTE) technology has been developed by the Third Generation Partnership Project (3GPP) as an improvement to the current Universal Mobile Telecommunications System is sometimes called 3.9G or Super 3G. Based on point-to-multipoint connections, both WiMAX and LTE telecommunications technologies provide broadband wireless service. Through Base Station (BS), mobile subscribers (MS) such as smart phones/laptops get connected to internet, while BS controls the channel access of mobile subscribers. Frequency-division duplex (FDD) as well as time-division duplex (TDD) systems are being supported by both WiMAX and LTE.
In TDD systems, a cell operates on the same frequency, with separation in time in uplink and downlink transmissions.
More specifically, with small guard intervals in between each 4G radio frame in TDD mode is divided into two sub frames: a downlink sub frame (i.e., transmission from BS to MS) followed by an uplink sub frame (i.e., transmissions from MS to BS) . Both WiMAX and LTE as operating network has its own specified network architecture .In WiMAX network, for special requirement a number of component are specified including BS(base station), AAA server, HA server ,ASN gateway some other components. Similarly in LTE networks a number of components are also specified including eNodeB, Serving Gateway PDN Gateway, MME, HSS.

1.4.1 Architecture of WiMAX network

The IEEE 802.16e-2005 standard provides the air interface for WiMAX but does not define the full end-to-end WiMAX network. The WiMAX Forum's Network Working Group (NWG) is responsible for developing the end-to-end network requirements, architecture, and protocols for WiMAX, using IEEE 802.16e-2005 as the air interface.
The Mobile WiMAX (IEEE 802.16e-2005) mobile wireless broadband access (MWBA) standard (also known as WiBro in South Korea) is sometimes branded 4G, and offers peak data rates of 128 Mbit/s downlink and 56 Mbit/s uplink over 20 MHz wide channels
The WiMAX NWG has developed a network reference model to serve as an architecture framework for WiMAX deployments and to ensure interoperability among various WiMAX equipment and operators.
The network reference model envisions unified network architecture for supporting fixed, nomadic, and mobile deployments and is based on an IP service model. Below is simplified illustration of IP-

based WiMAX network architecture. The overall network may be logically divided into three parts:

1. Mobile Stations (MS) used by the end user to access the network.
2. The access service network (ASN), which comprises one or more base stations and one or more ASN gateways that form the radio access network at the edge.
3. Connectivity service network (CSN), which provides IP connectivity and all the IP core network functions.

1.4.2 Architecture of LTE network

LTE also has IP based architecture .It is quite different from WiMAX in security mechanism. AKA is LTE authentication method .It cannot meet the enterprise security requirement and authenticate only identity (IMSI) and key in SIM card. An enhanced security method has been proposed which not only authenticate identity and key but also the enterprise certificates.

By using Orthogonal Frequency Division Multiple Access (OFDMA),for the highest category terminals LTE will be able to provide download rates of 150 Mbps for multi-antenna (2x2) multiple-input multiple-output (MIMO) . The non-compatibility of the 3G standards and demand for higher data rates has shifted industry focus to fourth generation (4G) wireless networks and it finally support data rates above 100 Mbps. It integrates all wireless networks. The high bandwidth provides an ideal mode for data transport. The Orthogonal Frequency Division Multiplexing (OFDM) and Orthogonal Frequency Division Multiple Access (OFDMA) effectively allocate network resources to multiple users and provide high quality video and audios. Moreover, 4G have better security and low latency data transmission. The 4G is an entirely packet-switched network with digital network elements .The 4G support global mobility and service portability.

Data Speed of LTE:-

Data speed of LTE (advanced):-

	LTE Advanced
Peak download	1 Gbit/s
Peak upload	500 Mbit/s

1.5. ORTHOGONAL FREQUENCY DIVISION MULTIPLEACCESS IN WIMAX AND LTE.

Orthogonal frequency division multiple access (OFDMA) has been recently recognized as an excellent multiple access technique for the next generation of downlink receivers. A multi-carrier transmission technique for high speed bi-directional wireless data communication. All the proposals which have been considered for the fourth generation (4G) wireless technologies has adopted orthogonal frequency division multiple access. WiMAX and LTE are the two main contenders in the 4G marketplace. The two standards those are likely to dominate the 4G

Wireless landscape is IEEE 802.16e based WiMAX and 3GPP based LTE. Orthogonal frequency division multiple access (OFDMA) is one of the common technologies used by both WiMAX and LTE.OFDMA is used both on the downlink (DL) and the uplink (UL) in WiMAX, whereas it is used only on the DL in LTE. There are several reasons for choosing OFDMA. Multipath handling capability, scalability of operation in different bandwidths, capability to handle different data rates. The ease with which it can be combined with multiple antennas techniques are some of the important reasons. In modern wireless systems support for higher data rates was a major requirement. For the above reasons, the use of OFDM has been considered to be suitable. To improve robustness and throughput, frequency diversity (FD) and channel feedback can be used effectively. Due to its ability to handle multipath, 4G cellular have adopted OFDM as the base technology. An integrated radio and core network catering to various services is envisaged for next generation wireless systems. The use of OFDMA technology helps resources to be split into smaller granular units which can be allocated for various services as required. OFDMA is considered vital for achieving high spectral efficiencies in 4G wireless systems because of its ability to integrate well with MIMO technology (also called as MIMO-OFDM).

	LTE
Peak download	100 Mbit/s
Peak upload	50 Mbit/s

1.6. USE OF OFDMA IN WIMAX AND LTE

A. Frame Structure

In WiMAX, frame duration of 5 ms along with time division duplexing (TDD) is used. The frame is partitioned into OFDM symbols (for e.g., 48) of which some are allocated for DL and the rest for UL transmissions. For preamble transmission, the first symbol in the frame is used. Sub channels are formed out of a group of subcarriers, used for control and data transmissions. To convey the DL and UL allocation, the base station (BS) announces a schedule every frame period (i.e., 5 ms). In LTE, sub frames of 1 ms duration is formed by dividing the frame duration of 10 ms. A sub frame is used to formed two slots of 0.5ms duration each. The BS schedules transmissions every 1 ms and the subcarriers formed resource blocks for allocation on the DL.

B. Subcarrier's resource mapping

In the frequency domain, subcarriers (also referred to as resource elements in LTE) are the smallest granular units and in the time domain, OFDM symbol duration is the smallest granular units. In an OFDM symbol, subcarriers are too large in number to handle in the allocation plane and hence groups of subcarriers are considered together. To minimize the signaling overhead while still achieving granularity in the achievable rates so as to support various services, a group of OFDM symbols are handled together.

C. Frequency Diversity

In WiMAX, in the PUSC (partially used subcarriers) sub channelization method, by grouping 24 subcarriers sub channels are formed which are present in different parts of the spectrum. This pseudorandom selection of the positions of the subcarriers over the entire band is dependent on the CELL_ID. Diversity based sub channelization method is used to send all the basic control messages. In LTE, for 7 OFDM symbols a RB (resource block) contains the same 12 contiguous subcarriers. However, to leverage FD (frequency diversity), another RB can be used in the second slot of the sub frame instead of using the same RB in the second part of the sub frame.

D. Multiuser Diversity

In WiMAX, to achieve multiuser diversity groups of contiguous subcarriers spread out over a few OFDM symbols in the BAMC method. The subcarriers are organized into groups of 9 contiguous subcarriers which are called as bins. A group of four bins are called as a band; each bin has 8 data and 1 pilot subcarrier. In one of these bands, the base station chooses 2 bins and for a BAMC slot it allocates the same bin over 3 consecutive OFDM symbols resulting in 48 data subcarriers. The most popular method needed for WiMAX certification is BAMC sub channelization method.
In LTE, the BTS chooses the RB to be used for sending data to a user. It uses the channel feedback from the mobile to schedule a RB for the user in a frame. The channel feedback in LTE sends configuration for the base station for its scheduled downlink. Typically in periodic feedback, 160 ms is the maximum gap between feedback messages and is 2 ms is the minimum duration between feedback messages. In a periodic feedback, the channel status report is requested by the BTS from the mobile. In LTE FD and MUD can be used simultaneously for different users whereas in WiMAX, FD and MUD based transmission cannot coexist in time.

E. Interference Diversity

In WiMAX, the formation of sub channel depends on the CELL_ID. The different users will have different sub channels. Hence, interference diversity is likely to experience by the user which is likely to give better performance than the dominant interferer case. Note that only in the case of PUSC transmissions interference diversity can be leveraged. For the BAMC transmissions, interference diversity cannot be used. In LTE, to the users RBs are allocated independent of the CELL_ID, across RBs of neighboring cells the interference on the DL won't be randomly distributed. Thus, in LTE, there is no interference diversity on the DL.

1.7. CHALLENGES

Managing Channel Quality

There is a lot of talk about how OFDM will provide very high broadband speeds on 4G wireless networks, but the truth is that the data throughput rate on a channel of given RF is bandwidth is limited by

channel quality, regardless of channel structure and coding. In urban areas where most of us will be using 4G services, channel quality is generally determined by levels of interference from other users of the same RF channel. As the channel is used more intensively within a given geographic area, interference levels rise. Indeed, managing mutual interference among users within a wireless network is the fundamental task in network design and optimization.

Individual user throughput expectations.

The second key challenge for 4G is related to the fact that a wireless data channel is a shared resource. Whatever throughput it delivers has to be shared by all simultaneous users of that channel. This fact is often glossed over in discussions of spectacular 4G bandwidths, but in my opinion it is really the elephant in the room when it comes to long-term prospects for 4G. A major problem in distinguishing between channel and individual throughput rates is typical usage patterns for Internet access have dramatically changed in the past few years and are still evolving rapidly. Not long ago, the most popular Internet applications (in terms of total demand) were "Web surfing" and e-mail. High bandwidth certainly enhances user experience for these sorts of activities, but on average, throughput is quite modest. This characteristic of high peak, moderate average user throughput demand is ideal for shared channels because it allows substantial numbers of simultaneous users to be served with satisfactory perceived speeds.

1.8. CONCLUSION

This paper presented a brief description of path to 4G networks, WiMAX and LTE Network architecture and OFDMA technology. It has been observed that the number of wireless broadband subscribers have passed the number of fixed broadband subscribers. So in a world going wireless, the technologies with higher throughputs get importance day by day. For a successful 4G network, coverage and capacity are essential parts. LTE-Advanced and WiMAX 802.16m the possible candidates for successful 4G deployments are LTE-Advanced and WiMAX 802.16m. So the technology is, it must be affordable in cost and worth deploying in throughput, coverage and capacity.

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