An Extensive Literature Survey on 4G WiMAX Systems with Multiple Antennas

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Abstract- The communication networks used today are wireless in nature. Wireless means transferring the signals without wires using radio waves, infra red etc. In wireless networks there is unlimited mobility; we can access the network services from almost anywhere. In wired networks we have the restriction of using the services in fixed area. The demand of wireless is increasing very fast as everybody wants to use the broadband services anywhere and anytime. The standardization of these wireless networks is also very important. The IEEE has developed many standards for different wireless networks. One of the most popular types of wireless networks is cellular networks. In cellular networks we divide the whole network into smaller cells and by this we can have more users in the network with better mobility and Quality of Service (QoS). Cellar networks are divided into different generations. The vision of broadband Internet access anywhere and anytime has appeared a distant dream, far from reality for the enormous majority of Personal Computers (PC), laptops and handheld users. WiMAX will be the most up to date wireless technology. WiMAX systems are likely to convey wireless broadband access to residential areas and customers in economical way.

Keywords – 4G wireless systems, WiMAX, LTE, OFDM, MIMO, multiple antennas.

I. INTRODUCTION

First generation (1G) cellular networks were introduced around 1980s. The first system was introduced in Japan. The first cellular network in Europe was built in Scandinavia in 1981 and it was known as Nordic Mobile Telephone (NMT). It uses the 450 MHz frequency band. This NMT system was also used in other parts of Europe as well. In America, Advance Mobile Phone System (AMPS) was used. The similarity between these two systems was that they were both analog. Second generation (2G) for cellular networks started in early 1990s. The first system was introduced in Europe as Global System for Mobile Communication (GSM). It was a digital system and nowadays it is used in more than two hundred countries with around 2.5 billion users. The purpose of this system was to have same system all over the world. GSM uses a frequency band of 900 MHz and 1800 MHz. GSM has many services like Short Messaging Services (SMS), Caller Identification, roaming etc. Enchantments were made in GSM when General Packet radio Service (GPRS) and Enhanced Data rates for GSM Evolution (EDGE) were introduced. These two systems increased the data rate in GSM. In America, CDMAone was used as a 2G technology.

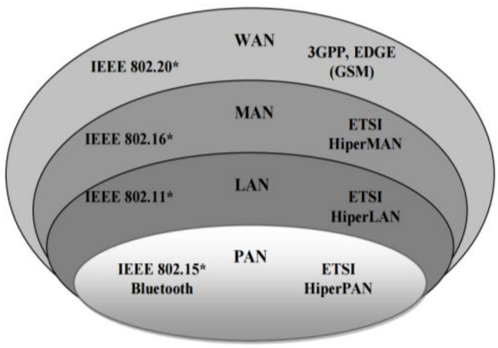

Fig. 1: IEEE and ETSI standards for wireless networks.

In the third generation (3G) cellular networks, Universal Mobile Telecommunication System (UMTS) was introduced. UMTS has higher data rates as compared to GSM while it enables more services like video conferencing, wireless television and wireless broadband as well. It has been designed to achieve the goal of global coverage. In America, CDMA 2000 was used as a 3G cellular technology. The fourth generation (4G) of cellular networks is currently under development and hopefully it will be available in 2012. It will be having a data rate of at least 10 Mbps. It will be having more efficient spectral resources and other services as well. WiMAX or Wireless Man is a 4G technology but some organizations refer it as a 3G technology. WiMAX is in implementation phase and it is the hottest wireless technology nowadays. WiMAX will be providing wireless internet anywhere and anytime.

In the 80's the first cellular system was implemented by NIPPON TELEPHONE AND TELEGRAPH, Tokyo, Japan. Analog modulation schemes were predominantly used. In the United States the Advanced Mobile Phone Systems (AMPS) became popular in the 80's. The bandwidth allocated was 40Mhz within the radio bandwidth of 800Mhz to 900Mhz. In 1988 additional 10Mhz of bandwidth was added for better performance. AMPS was using Frequency Modulation (FM) technique and only speech was transmitted. Later 1.5G was evolved providing an improvisation to 1G. Then consequently 2G came into market which used digital modulation schemes for transmission of speed and data. The remarkable thing in 2G was the ability to transmit data. Another notable thing was it was much efficient in spectrum and used multiple access techniques such as time division multiple access (TDMA), frequency division multiple access (FDMA) etc. In Europe the Global system for mobile communication started and became very popular for almost 20 years. Then the 3G (third generation) cellular system came into existence and it allows high speed data transmission as well as internet access. It also supported voice activated calls. Then the 4G system has become a hot topic. It ensures us data rate more than 100Mbps i.e. almost no waste of time and multi mega bit internet access. But the real challenge involved in 4G is how to design such a network. The conventional SISO (single input and single output) systems can never reach the barrier of 100Mbps.

The progress of communication technologies over the last century has been spectacular. In particular, the communication revolution that began with the invention of telephone by Bell continued with the invention of radio by Marconi. It was elevated to a whole new level by the introduction of other new technologies such as satellite and cellular networks. This revolution continues today with the widespread use of the Internet for data transfer and electronic correspondence as well as voice and video transmission. Recent techno- logical advancements in science and engineering have blurred the traditional boundaries between previously di®erent services such as the long distance telephone, radio and tele- vision broadcasting, and data transmission through the Internet. The number of Internet radio and television stations have increased signi¯cantly and continue to increase at a fast pace. Voice over IP technology has been successfully exploited by small corpora- tions to provide a cheaper alternative to traditional long distance phone services o®ered by established providers. These technological advancements and the growth in con- sumer's demands have tremendously increased the need for communication with high data rate, more reliability, power e±cient and cheaper wireless services. However, the radio spectrum available for new wireless systems is scarce and expensive, and therefore it is crucial to increase the channel capacity and reliability of current wireless systems

REQUIRMENT OF MIMO The typical aspirations of a system designer are high data rate, low bit error rate, low power consumption, low cost and easy study ability. The MIMO system ensures us very high data rates even more than 1Gbps while minimizing the bit error rate. By Shanon's theorem the rate of transmission is always less than or equal to the capacity. Practically it is less than the capacity. The capacity depends on the bandwidth of the channel and SNR of the channel. Both the bandwidth and signal to noise ratio are characteristics of the channel. The SNR can be improved either by reducing noise power or by increasing signal power. Reduction in noise power is not possible while increase in signal power requires more power for transmission which should be avoided for a good design. The improvement of bandwidth is not possible. There are techniques like OFDM (orthogonal frequency division multiplexing) which assure us efficient use of the channel i.e. spectral efficiency. But the use of multiple antennas at the transmitter and at the receiver that is use of MIMO meets the ongoing requirements in 4G. The bit error rate in MIMO is very less as compared to conventional SISO systems.

In conventional wireless communication systems, only one antenna is used at the trans- mitter and one at the receiver. This is defined as a SISO (Single Input Single Output) system. In 1948, Shannon worked on the fundamental capacity limit of this system [1]. Having a channel bandwidth W and SNR (Signal-to-noise ratio) over this bandwidth, Shannon stated that the maximum capacity C of the SISO system is

$$C = W\log_2(1 + SNR) \quad \text{bits/s}$$

It is noted from the above equation that the channel capacity can only be increased by an increase in bandwidth or signal power. On the one hand it is very expensive to occupy additional spectrum, and on the other hand, the signal power cannot be readily increased as the communication system is interference-limited. Many coding techniques have been developed over the years; from the initial work of Hamming [2], through to Low Density Check codes [3] and Turbo codes [4], and they are able to achieve a channel capacity close to the Shannon limit. Despite this, no coding scheme could overcome the channel capacity limitation of a traditional SISO system. During last decade, the Shannon capacity limit has been expanded by introducing multiple antennas at both the receiver and transmitter. The use of multiple antennas at both ends of a wireless communication system is called a MIMO (Multiple Input Multiple Output) system. Without increasing the bandwidth or signal power, the channel capacity of a MIMO system can be increased linearly with the number of the antennas under ideal conditions. In 1987, Winters First reported the capacity enhancement of the multi-antenna fading channels applying multiple antennas at both the transmitter and receiver [5]. Lately, the potential capacity of the MIMO system was theoretically demonstrated by Foschini and Gans [6, 7], and Telatar [8]. Since then, MIMO systems have attracted a considerable interest in both the academic and industry worlds, and tremendous efforts have been put into the research and development of MIMO systems [9{16]. The MIMO system can increase not only the channel capacity, but also the reliability (Quality of Service) of the wireless system by exploiting different coding schemes. The typical coding schemes, e.g. space time coding, spatial multiplexing and the combination of both schemes, are discussed in the following sections.

II. MISO Antenna Technique

In the MISO (Multiple-input Single-output) antenna technique, multiple antennas are used in the transmitter while a single antenna is used in the receiver. It is a comparatively new technology. This has been a favorite as only multiple antennas need to be installed in the base station (BS). Transmit diversity technique is used in case of MISO. In fig 2, a general diagram of MISO is shown.

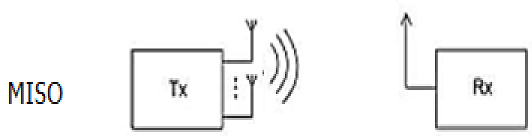

Fig. 2: MISO system

Transmit antenna diversity is a type of controlled diversity technique which provides spatial repetition of transmitted signals through different antennas. A method recognized as STC (Space Time Coding) is implemented at the transmitter with multiple antennas. STC permits the transmitter to transmit signals simultaneously in time and space, which means the information can be transmitted by multiple antennas at different times consecutively. Transmit diversity can be of two types, open loop and closed loop. In the open loop system, the knowledge of amplitude and phase characteristics of the channel is not needed at the transmitter, whereas in the closed loop system this knowledge is required.

Multiple-Input Multiple-Output

Multiple-Input Multiple-Output (MIMO) uses multiple antennas on both the transmitter and receiver. They have dual capability of combining the SIMO and MISO technologies. They can also increase capacity by using Spatial Multiplexing (SM). The MIMO method has some clear advantages over Single-input Single-output (SISO) methods. The fading is greatly eliminated by spatial diversity; low power is required compared to other techniques in MIMO.

III. LITERATURE REVIEW

Otilia Popescu. Dimitrie C. Popescu [1] This paper studies physical layer performance of LTE and WiMAX schemes used in fourth generation (4G) wireless communication systems when multiple antennas are employed in the receiver to provide diversity. Bit Error Rate (BER) plots obtained from simulations are presented to evaluate system performance with and without diversity and to do a side-by-side comparison of the two main 4G wireless technologies.

Sricharan, M.S., [2] Fourth generation wireless systems have the potential to change the way authors communicate and collaborate to accomplish business needs. The need of the hour is to provide a unified system that provides a seamless user experience on the move. Systems beyond IMT-2000 claim to have the capability to support services/applications that demand very stringent performance requirements. Standardization bodies are trying to achieve this by adopting cutting edge technologies and strategies that have evolved over the last few decades. WiMAX (802.16m) and LTE-Advanced (UMTS Release-10) are the mostly likely candidates to meet ITU defined IMT-Advanced performance goals. Both WiMAX and LTE have lot of technical similarities primarily on the radio access network side. Both have adopted an OFDMA based physical layer. Channel based scheduling algorithms; link adaptation techniques and hybrid ARQ are the common trait in these systems. Adaptive modulation and coding scheme (AMC) is another popular feature in this system which aims to exploit the channel conditions and assignment, to improve channel capacity. The performance of these systems is further augmented by embracing multiple antenna techniques. Flat network architecture and All-IP network are the buzzwords across standards to achieve throughput expansion and to reduce the capital and operational expenditure. The cutting edge technologies/strategies listed above are critical to achieve the performance target set through IMT-Advanced. This tutorial presentation would provide a detailed view of the important technologies behind 4G systems and how it's proposed to be implemented in IEEE-802.16m and LTE-Advanced.

Mahajan, S.; Jagannatham, A.K., [3] In this paper authors propose novel algorithms for optimal subcarrier power allocation towards video transmission in Orthogonal Frequency Division Multiple Access (OFDMA) based 4G wireless systems. A unique feature of the proposed schemes is that they employ diversity dependent subcarrier power distribution relying on a discrete wavelet transform (DWT) based hierarchical video decomposition. Another key aspect of the schemes is that they exclusively employ partial channel state information (CSI) feedback based on the order statistics of the allotted subcarriers in the OFDMA system. This significantly reduces the communication overhead required on the reverse link, thus reducing complexity and enhancing throughput. It is demonstrated that the paradigm of ordered subcarrier diversity based video distortion minimization can be formulated as a constrained convex cost minimization problem. Further, authors illustrate that this cost minimization reduces to a polynomial root computation under a suitable approximation. Closed form expressions are derived for the diversity based optimal power allocation scheme. Simulation results employing several video sequences for an OFDMA system demonstrate superior performance of the proposed optimal subcarrier power allocation schemes over equal power allocation.

Youngtaek Hong; Juneseok Lee; Jaehoon Choi,[4] In this research, a multi-band antenna for 4G wireless systems is proposed. The proposed antenna consists of a modified planar inverted-F antenna with additional branch line for wide bandwidth and a folded monopole antenna. The antenna provides wide bandwidth for covering the hepta-band LTE/GSM/UMTS operation. The measured 6-dB return loss bandwidth was 169 MHz (793 MHz-962 MHz) at the low frequency band and 1030 MHz (1700 MHz-2730 MHz) at the high frequency band. The overall dimension of the proposed antenna is 55 mm × 110 mm × 5 mm.

IV. PROBLEM IDENTIFICATION

In this paper authors presented a side-by-side comparison of 4G LTE and WiMAX systems with multiple antennas and receive diversity. In future work authors plan to study also the use of transmit diversity techniques for improving the performance of 4G wireless systems. Authors note that, while receiver diversity is mostly considered for mobile units, transmit diversity can be more suitable for base stations where open-loop techniques may be used in conjunction with Space-Time Block Codes (STBC), or closed-loop methods using channel feedback information may be implemented.

V. CONCLUSIONS

This research studies physical layer performance of LTE and WiMAX schemes used in fourth generation (4G) wireless communication systems when multiple antennas are employed in the receiver to provide diversity. Bit Error Rate (BER) plots obtained from simulations are presented to evaluate system performance with and without diversity and to do a sideby- side comparison of the two main 4G wireless technologies.

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