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The Next Generation Broadband Wireless Communication Network (LTE)

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***Abstract*—The Next Generation Broadband Wireless Communication (3G & 4G) Cellular Networks use completely new physical layer signalling techniques. Some of the most important techniques introduced are Orthogonal Frequency Division Multiplexing (OFDM) based multiple access in Down-Link (DL) and Single Carrier Frequency Division Multiplexing based multiple access in Up-Link (UL) as used in 3GPP-Long Term Evolution (LTE).**

The access bandwidth is scalable from 1.4 MHz up to 20 MHz. Use of advanced Multiple Input Multiple Output (MIMO) antenna signalling procedures are also key features of beyond 3G systems.

However, high demand on data speed has pushed the operators to looking for 3.5G system. 3.99G networks are defined as long-term evolution for the existing 3G network and it will be based on OFDM and MIMO technologies. 4G networks were not yet defined, but requirement is to support heterogeneous networks at 100 Mbps mobility data speed.

Keywords: 4G, OFDM, MIMO

I. INTRODUCTION

Mobile networks have evolved through more than three generations, starting with the analogue or first-generation (1G) networks deployed in the early 1980s, and moving on to the digital second-generation (2G) networks de-ployed in the early 1990s. Operators started to deploy 3 G networks in 2001-03, and 3.5G networks from around 2005. Networks still in the design phase include 3.9G and 4G systems, which are expected to be deployed in the 2008-10 and 2010-20 timeframes, respectively.

The general principle behind this grouping is that mobile technologies are in the same generation if they have similar network characteristics and deployment time-lines.

The International Telecommunications Union (ITU), for example, uses a different approach when defining 3G, it groups technologies based on theoretical maximum connection speeds.

Motivated by the increasing demand for mobile broadband services with higher data rates and Quality of Service (QoS), 3GPP started working on two parallel projects, Long Term Evolution (LTE) and System Architecture Evolution (SAE), which are intended to define both the radio access network

1G	2G	2.5G	3G	3.5G	3.9G	4G
Early 1980	Early 1990s	Late 1990s	2001+	2005+	2005-09	2010-20

Fig.1: Generation Flow LTE

(RAN) and the network core of the system, and are included in 3GPP Release 8. LTE/SAE, also known as the Evolved Packet System (EPS), represents a radical step forward for the wireless industry that aims to provide a highly efficient, low-latency, packet-optimized, and more secure service. The main radio access design parameters of this new system include OFDM (Orthogonal Frequency Division Multiplexing) waveforms in order to avoid the inter-symbol interference that typically limits the performance of high-speed systems, and MIMO (Multiple-Input Multiple-Output) techniques to boost the data rates. At the network layer, an all-IP flat architecture supporting QoS has been defined

Performance and capacity–One of the requirements of LTE is that it should provide downlink peak rates of at least 100Mbps. In the first stage, the technology allows for speeds of over 300Mbps, and Ericsson has already demonstrated LTE peak rates over 1Gbps.

Simplicity–LTE supports flexible carrier bandwidths, from 1.4MHz up to 20MHz. LTE also supports both frequency division duplex (FDD) and time division duplex (TDD). So far, a large number of bands have been identified by 3GPP for LTE, and there are more bands to come. This means that an operator may introduce LTE in “new” bands where it is easiest to deploy 10MHz or 20MHz carriers.

Wide range of terminals – in addition to mobile feature phones, smartphones and MiFi’s, many computers and consumer electronic devices, such as laptops, notebooks and tablets, incorporate LTE embedded modules. Since LTE supports handover and roaming to existing mobile networks, all these devices can have ubiquitous mobile broadband coverage from day one. In summary, operators can introduce LTE

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flexibly to match their existing network, spectrum and business objectives for mobile broadband and multimedia services.

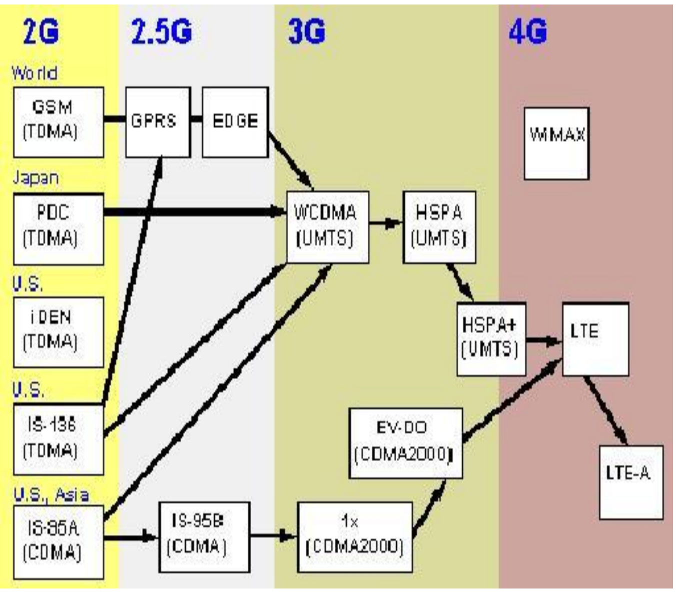

Fig.2: Evolution of LTE

First-generation (1G) mobile phones had only voice facility. These were replaced by second-generation (2G) digital phones with added fax, data, and messaging services. The third-generation (3G) technology has added multimedia facilities to 2G phones. And now talks are on for the next-generation mobile technology with more advanced features, i.e. 4G, which is expected to be available in the market by 2010.

II. EVOLUTION OF LTE

A. 1^{st} Generation (1G)

Mobile phones were based on the analogue system. The introduction of cellular systems in the late 1970s was a quantum leap in mobile communication, especially in terms of capacity and mobility. Semiconductor technology and microprocessors made smaller, lighter, and more sophisticated mobile systems a reality. However, these 1G cellular systems still transmitted only analogue voice information. The prominent ones among 1G systems were advanced mobile phone system (AMPS), Nordic mobile telephone (NMT), and total access communication system (TACS). With the introduction of 1G phones, the mobile market showed annual growth rate of 30 to 50 per cent, rising to nearly 20 million subscribers by 1990.

B. 2^{nd} Generation (2G)

Phones using global system for mobile communications (GSM) were first used in the early 1990s in Europe. GSM provides voice and limited data services, and uses digital modulation for improved audio Quality. Multiple digital systems**.** The development of 2G cellular systems was driven by the need to improve transmission quality, system capacity, and coverage. Further advances in semiconductor technology and microwave devices brought digital transmission to mobile communications.

Speech transmission still dominates the airways, but the demand for fax, short message, and data transmission is growing rapidly. Supplementary services such as fraud prevention and encryption of user data have become standard features, comparable to those in fixed networks.

Today, multiple IG and 2G standards are used in worldwide mobile communications. Different standards serve different applications (paging, cordless telephony wireless local loop, private mobile radio, cellular telephony, and mobile satellite communication) with different levels of mobility, capability, and service area. Many standards are used only in one country or region, and are incompatible.

GSM is the most successful family of cellular standards. It includes GSM900, GSM-railway (GSM-R), GSM1800, GSM1900, and GSM400. GSM supports around 250 million of the world's 450 million cellular subscribers, with international roaming in approximately 140 countries and 400 networks. The core network. This network links together all the cells into a single network, coordinates resources to hand over your call from one cell to another as you move, discovers where you are so that you can receive incoming calls, links to the fixed network so that you can reach fixed-line phones, and communicates with roaming partners. You can use your phone on other network links to the Internet, so you can reach Web servers and corporate systems worldwide to control and deliver services depending on your subscription profile. The 2G architecture. The existing mobile network consists of the radio access network (comprising cells and backhaul communications) and the core network (comprising trunks, switches, and servers). Mobile switching centres

(MSCs) are intelligent servers and the whole network is data-driven, using subscription and authentication information held in the home location register (HLR) and authentication centre (AuC). The standard services include circuit-switched voice, fax, and data, as well as voicemail and voicemail notification. Additional services include wireless application protocol (WAP), high-speed circuit-switched data (HSCSD), mobile location services (MLS), and cell broadcast. You can change to a new operator keeping your old phone number.

2.5G the mobile technology using general packet radio service (GPRS) standard has been termed as 2.5G. 2.5G systems enhance the data capacity of GSM and mitigate some of its limitations. GPRS adds packet-switched capabilities to existing GSM and TDMA networks. Working on the basis of emails, it sends text and graphics-rich data as packets at very fast speed. The circuit-switched technology has a long and successful history but it is inefficient for short data transactions and always-on service. The packet switched technology has grown in importance with the rise of the Internet and Internet protocol (IP). But as IP too has its own weaknesses, circuit-

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switched services are not going to disappear. Transmission control protocol (TCP) provides a virtual end-to end connection for reliability. Although Telnet is still used as a standard protocol for remote access to computer hosts, the main protocols in use today are HTTP for Web servers, SMTP for e-mail, and SNMP for network management. The GPRS (2.5G) core network and service characteristics. Although GPRS is an extension to the radio access network, it requires whole new packet based IP data links, servers, and gateways in the core network. Thus GPRS adds several new components besides changing the existing GSM or TDMA network. GPRS is important because it helps operators, vendors, content providers, and users prepare for 3G, as many concepts of GPRS live on in 3G, and we will need these enhancements to 2G networks for ten years or more. At the moment, wireless network technologies are somewhere between 2G and 2.5G.The second generation of mobile communications technology was all about digital PCS. The problem, however, was that much of the digital network was implemented for, or overlaid onto, proprietary networking equipment. Taken together, 2G and 2.5G technologies are far from seamless. These range from spread spectrum code-division multiple access (CDMA) in North America to narrow-spectrum time-division multiple access (TDMA) and GSM in Europe and Asia. In addition to these incompatibilities, both systems offer digital voice at a relatively low speed with very little bandwidth left over for data.

C. 3rd Generation (3G)

Technology adds multimedia facilities to 2G phones by allowing video, audio, and graphics applications. Over 3G phones, you can watch streaming video or have video telephony. The idea behind 3G is to have a single network standard instead of the different types adopted in the US, Europe, and Asia. These phones will have the highest speed of up to 2Mbps, but only indoors and in stationary mode. With high mobility, the speed will drop to 144 kbps, which is only about three times the speed of todays fixed telecom modems.3G cellular services, known as Universal Mobile Telecommunications System (UMTS) or IMT-2000, will sustain higher data rates and open the door to many Internet style applications.

The main characteristics of IMT-2000 3G systems are:

1. A single family of compatible standards that can be used worldwide for all mobile applications.
2. Support for both packet-switched and circuit-switched data transmission.
3. Data rates up to 2 Mbps (depending on mobility).
4. High spectrum efficiency.

IMT-2000 is a set of requirements defined by the International Telecommunications Union (ITU). 'IMT' stands for International Mobile Telecommunications, and '2000' represents both the scheduled year for initial trial systems and the frequency range of 2000MHz. The most important IMT-2000 proposals are the UMTS (W-CDMA) as the successor to GSM, CDMA2000 as the successor to interim-standard '95 (IS-95), and time-division synchronous CDMA (TDSCDMA) and UWC-136/EDGE as TDMA based enhancements to D-AMPS/ GSM—all of which are leading previous standards towards the ultimate goal of IMT-2000. UMTS increases transmission speed to 2 Mbps per mobile user and establishes a global roaming standard. The3G network perspective.

UMTS is a so-called 3G, broadband standard for packet-based transmission of text, digitised voice, video, and multimedia at data rates up to and possibly higher than 2 Mbps, offering a consistent set of services to mobile computer and phone users, no matter where they are in the world. Based on the GSM communication standard, UMTS, endorsed by major standards bodies and manufacturers, allows mobile users to have the constant access to the Internet and the same set of capabilities irrespective of their location. Users gain access through a combination of terrestrial wireless and satellite transmissions.

Until UMTS is fully implemented, users can have multi-mode devices that switch to GPRS or EDGE technology where UMTS is not yet available. Today's cellular telephone systems are mainly circuit-switched type, with connections always dependent on the circuit availability. With UMTS, the packet-switched connection using the IP means that a virtual connection is always available to any other end point in the network. This makes it possible to provide new services such as alternative billing methods (pay-per-bit, pay per-session, flat rate, symmetric bandwidth, and others). The higher bandwidth of UMTS also promises video conferencing and the virtual home environment.

In virtual home environment, a roaming user can have the same services as at home or in the office, through a combination of transparent terrestrial and satellite connections.

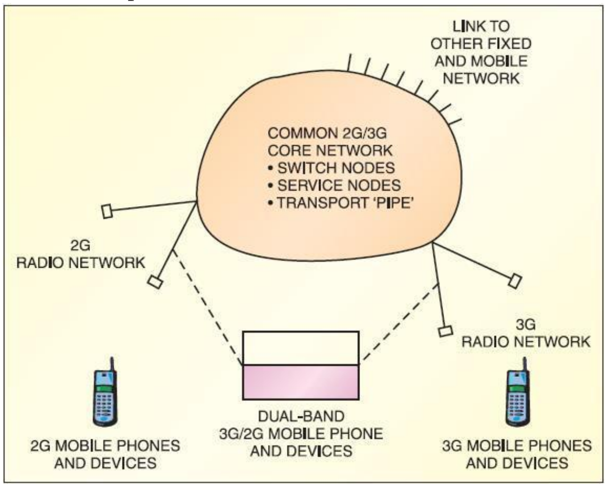

Fig.3: 3G Network

The difference between regular CDMA and W-CDMA.3G promises increased bandwidth, up to 384 kbps when the device holder is walking, 128 kbps in a car, and 2 Mbps in fixed applications. In theory, 3G would work over North American as well as European and Asian wireless air interfaces. A new air interface called enhanced data GSM

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environment (EDGE) has been developed specifically to meet the bandwidth needs of 3G. EDGE is a faster version of GSM wireless service. But the outlook for 3G is neither clear nor certain. Part of the problem is that network providers in Europe and North America currently maintain separate standards bodies. In addition to technical challenges, there are financial issues that cast a shadow over 3G's desirability.

D. 4^{th} Generation (4G)

The approaching 4G (fourth generation) mobile communication systems are projected to solve still-remaining problems of 3G (third generation) systems and to provide a wide variety of new services, from high-quality voice to high-definition video to high-data-rate wireless channels.

The term 4G is used broadly to include several types of broadband wireless access communication systems, not only cellular telephone systems. One of the terms used to describe 4G is MAGIC—Mobile multimedia, anytime anywhere, Global mobility support, integrated wireless solution, and customized personal service. As a promise for the future, 4G systems, that is, cellular broadband wireless access systems, have been attracting much interest in the mobile communication arena. The 4G systems not only will support the next generation of mobile service, but also will support the fixed wireless networks. This paper presents an overall vision of the 4G features, framework, and integration of mobile communication.

The features of 4G systems might be summarized with one word-Integration. The 4G systems are about seamlessly integrating terminals, networks, and applications to satisfy increasing user demands. The continuous expansion of mobile communication and wireless networks shows evidence of exceptional growth in the areas of mobile subscriber, wireless network access, mobile services, and applications. An estimate of 1 billion users by the end of 2003 justifies the study and research for 4G systems.

Vision of 4G this new generation of wireless is intended to complement and replace the 3G systems, perhaps in 5 to 10 years. Accessing information anywhere, anytime, with a seamless connection to a wide range of information and services, and receiving a large volume of information, data, pictures, video, and so on, are the keys of the 4G infrastructures. 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. Based on the developing trends of mobile communication, 4G will have broader bandwidth, higher data rate, and smoother and quicker handoff and will focus on ensuring seamless service across a multitude of wireless systems and networks. The key concept is integrating the 4G capabilities with all of the existing mobile technologies through advanced technologies. Application adaptability and being highly dynamic are the main features of 4G services of interest to users. These features mean services can be delivered and be available to the personal preference of different users and support the users' traffic, air interfaces, radio environment, and quality of service. Connection with the network applications can be transferred into various forms and levels correctly and efficiently. The dominant methods of access to this pool of information will be the mobile telephone, PDA, and laptop to seamlessly access the voice communication, high-speed information services, and entertainment broadcast services.

Figure 1 illustrates elements and techniques to support the adaptability of the 4G domain.

The fourth generation will encompass all systems from various networks, public to private; operator-driven broadband networks to personal areas; and ad hoc networks. The 4G systems will interoperate with 2G and 3G systems, as well as with digital (broadband) broadcasting systems. In addition, 4G systems will be fully IP-based wireless Internet. This allen compassing integrated perspective shows the broad range of systems that the fourth generation intends to integrate, from satellite broadband to high altitude platform to cellular 3G and 3G systems to WLL (wireless local loop) and FWA (fixed wireless access) to WLAN (wireless local area network) and PAN (personal area network),all with IP as the integrating mechanism. With 4G, a range of new services and models will be available. These services and models need to be further examined for their interface with the design of 4G systems. Figures 2 and 3 demonstrate the key elements and the seamless connectivity of the networks.

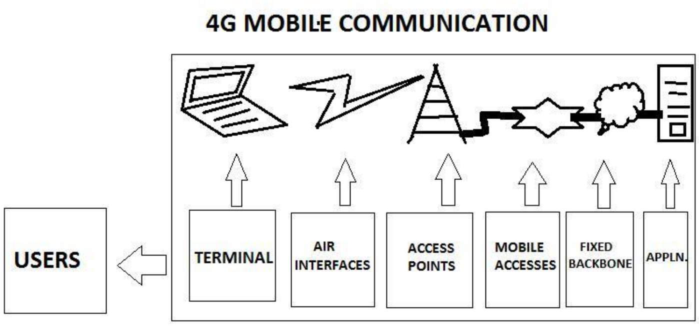

Fig.4: 4G Network

III. LTE (LONG TERM EVOLUTION)

A. OFDMA

Orthogonal Frequency Division Multiplexing (OFDM) not only provides clear advantages for physical layer performance, but also a framework for improving layer 2 performance by proposing an additional degree of free- dom. Using ODFM, it is possible to exploit the time domain, the space domain, the frequency domain and even the code domain to optimize radio channel usage. It ensures very robust transmission in multi-path environments with reduced receiver complexity.

OFDM also provides a frequency diversity gain, improving the physical layer performance .It is also compatible with other enhancement Technologies, such as smart antennas

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and MIMO.OFDM modulation can also be employed as a multiple access technology (Orthogonal Frequency Division Multiple Access; OFDMA).

In this case, each OFDM symbol can transmit information to/from several users using a different set of sub carriers (sub channels). This not only provides additional flexibility for resource allocation (increasing the capacity), but also enables cross-layer optimization of radio link usage.

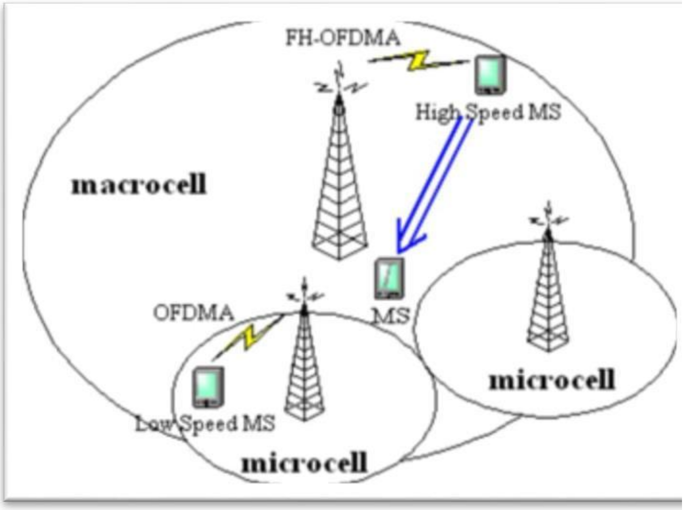

Fig.5: OFDMA Technique

B. MIMO TECHNIQUE

MIMO uses signal multiplexing between multiple transmitting antennas (space multiplex) and time or frequency. It is well suited to OFDM, as it is possible to process independent time symbols as soon as the OFDM waveform is correctly designed for the channel. This aspect of OFDM greatly simplifies processing. The signal transmitted by *m* antennas is received by *n* antennas. Processing of the received signals may deliver several performance Improvements range, quality of received signal and spectrum efficiency. In principle, MIMO is more efficient when many multiple path signals are received. MIMO is an acronym that stands for Multiple Input Multiple Output.

• It is an antenna technology that is used both in transmission and receiver equipment for wireless radio communication.

• There can be various MIMO configurations. For example, a 2x2 MIMO configuration is 2 antennas to transmit signals (from base station) and 2 antennas to receive signals (mobile terminal).

MIMO takes advantage of multi-path.

• MIMO uses multiple antennas to send multiple parallel signals (from transmitter).

• In an urban environment, these signals will bounce off trees, buildings, etc. and continue on their way to their destination (the receiver) but in different directions.

• "Multi-path" occurs when the different signals arrive at the receiver at various times.

• With MIMO, the receiving end uses an algorithm or special signal processing to sort out the multiple signals to produce one signal that has the originally transmitted data.

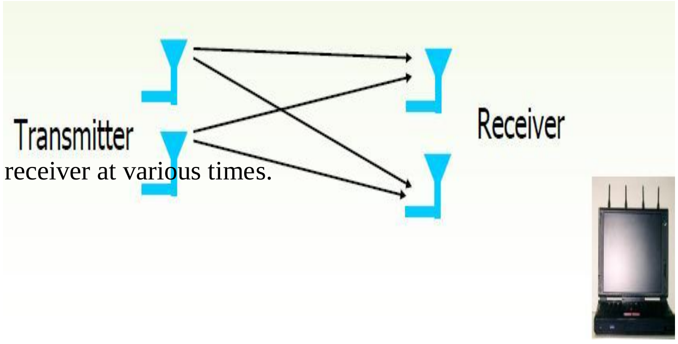

Fig.6: 2 X 2 MIMO

MIMO can be sub-divided into three main categories, precoding, spatial multiplexing or SM, and diversity coding. *Precoding* is multi-stream beamforming, in the narrowest definition. In more general terms, it is considered to be all spatial processing that occurs at the transmitter. In (single-stream) beamforming, the same signal is emitted from each of the transmit antennas with appropriate phase and gain weighting such that the signal power is maximized at the receiver input. The benefits of beamforming are to increase the received signal gain - by making signals emitted from different antennas add up constructively - and to reduce the multipath fading effect.

Spatial multiplexing requires MIMO antenna configuration. In spatial multiplexing, a high-rate signal is split into multiple lower-rate streams and each stream is transmitted from a different transmit antenna in the same frequency channel. Spatial multiplexing is a very powerful technique for increasing channel capacity at higher signal-to-noise ratios (SNR). The maximum number of spatial streams is limited by the lesser of the number of antennas at the transmitter or receiver.

Diversity Coding techniques are used when there is no channel knowledge at the transmitter. In diversity methods, a single stream (unlike multiple streams in spatial multiplexing) is transmitted, but the signal is coded using techniques called space-time coding. The signal is emitted from each of the transmit antennas with full or near orthogonal coding. Diversity coding can be combined with spatial multiplexing when some channel knowledge is available at the transmitter.

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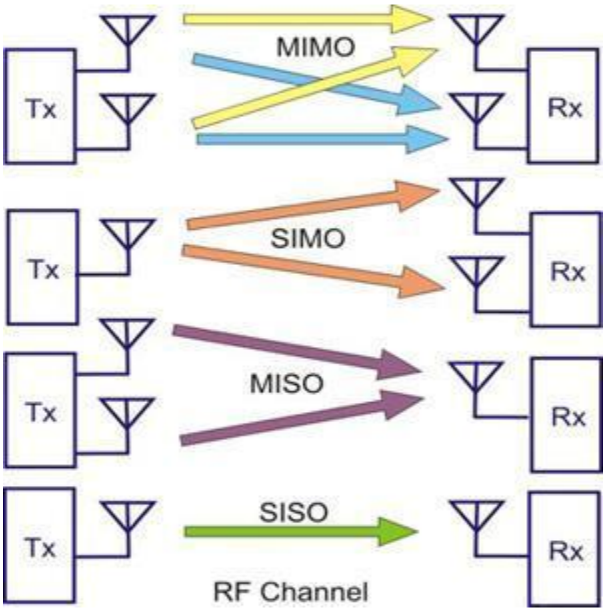

Fig.7: MIMO

UMTS Long Term Evolution (LTE) was introduced in 3GPP Release 8. The objective is a high data rate, low latency and packet optimized radio access technology. LTE is also referred to as E-UTRA (Evolved UMTS Terrestrial Radio Access) or E-UTRAN (Evolved UMTS Terrestrial Radio Access Network).

The basic concept for LTE in downlink is OFDMA (Uplink: SC-FDMA), while MIMO technologies are an integral part of LTE. Modulation modes are QPSK, 16QAM, and 64QAM. Peak data rates of up to 300 Mbps (4x4 MIMO) and up to 150 Mbps (2x2 MIMO) in the downlink and up to 75 Mbps in the uplink are specified.

Downlink

The following transmission modes are possible in LTE:

- Single antenna transmission, no MIMO
- Transmit diversity.
- Open-loop spatial multiplexing, no UE feedback required.
- Closed-loop spatial multiplexing, UE feedback required.
- Multi-user MIMO (more than one UE is assigned to the same resource block)
- Closed-loop precoding for rank=1 (i.e., no spatial multiplexing, but precoding is used)
- Beamforming.

C. WI-MAX

Its promises a peak data rate of 74 Mbps at a bandwidth of up to 20 MHz. Modulation types are QPSK, 16QAM, and 64QAM.

Downlink

The WIMAX 802.16e-2005 standard specifies MIMO in Wireless MAN-OFDMA mode. This standard defines a large number of different matrices for coding and distributing to antennas. In principle, two, three or four TX antennas are possible. For all modes, the matrices A, B, and C are available. In the "STC encoder" block, the streams are multiplied by the selected matrix and mapped to the antennas

Uplink

MIMO only different pilot patterns are used. Coding and mapping is the same like in non-MIMO case. In addition to single user MIMO (SU-MIMO) two different user can use the same channel (collaborative MIMO, MU-MIMO).

D. WLAN (802.11n)

WLAN as defined by the 802.11n standard promises a peak data rate of up to 600 Mbps at a bandwidth of 40 MHz. Modulation types are BPSK, QPSK, 16QAM, and 64QAM.

IV. Acknowledgement

As the history of mobile communications shows attempts have been made to reduce a number of technologies to a single global standard. Projected 4G systems offer this promise of a standard that can be embraced worldwide through its key concept of integration. Future wireless networks will need to support diverse IP multimedia applications to allow sharing of resources among multiple users. There must be a low complexity of implementation and an efficient means of negotiation between the end users and the wireless infrastructure. The fourth generation promises to fulfil the goal of PCC (personal computing and communication)—a vision that affordably provides high data rates everywhere over a wireless network.

4G is expected to be launched by 2010 and the world is looking forward for the most intelligent technology that would connect the entire globe.

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