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# 4G & 5G COMMUNICATION TECHNOLOGY

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## 5.1 INTRODUCTION

The rapid growth of wireless networks and services, accelerated by the third-generation mobile communication system, is ushering in the era of the fourth-generation mobile communication system and even further to fifth-generation. Wireless Communication systems are evolving to meet the ultimate goal, to allow 'anywhere, anytime, anything, by anyone' communication customized to a particular subscriber's preferences, location, and social behavior at a very high data rates transfer [1]. To reach this goal, much effort is still underway.

Technologies employed by 4G may include SDR (Software-defined radio) receivers, OFDM (Orthogonal Frequency Division Multiplexing), OFDMA (Orthogonal Frequency Division Multiple Access), MIMO (multiple input/multiple output) technologies, UMTS and TD-SCDMA. All of these delivery methods are typified by high rates of data transmission and packet-switched transmission protocols. 3G technologies, by contrast, are a mix of packet and circuit-switched networks [2].

When fully implemented, 4G is expected to enable pervasive computing, in which simultaneous connections to multiple high-speed networks provide seamless handoffs throughout a geographical area. Network operators may employ technologies such as cognitive radio and wireless mesh networks to ensure connectivity and efficiently distribute both network traffic and spectrum [2].

The main distinguishing factors between 3G and 4G will be data rates, services, transmission ways, access technology to the Internet, the compatibility to interface with wire-line backbone network, quality of service and security. The speeds of 3G can be up to 2Mbps, which is much slower than the speeds of 4G. For the service, 3G marketing is difficult to roam globally and interoperate across networks, yet 4G will be a global standard that provides global mobility and service portability so that service provider will no longer be limited by single-system. In other words, 4G should be able to provided very smooth global roaming ubiquitously with lower cost. A 5G communication system is envisioned as the real wireless world.

## 5.2 4G COMMUNICATION TECHNOLOGY

4G is being developed to accommodate the quality of service (QoS) and rate requirements set by forth coming applications like wireless broadband access, Multimedia Messaging Service, video chat, mobile TV, High definition TV content, DVB, minimal service like voice and data, and other streaming services for "anytime-anywhere".

The objectives of the 4G wireless communication standard are a spectrally efficient system (in bits/s/Hz and bit/s/Hz/site) [2], high network capacity with more simultaneous users per cell [2], a nominal data rate of 100 Mbit/s while the client physically moves at high speeds relative to the station [2], and 1 Gbit/s while client and station are in relatively fixed positions as defined by the ITU-R [2], a data rate of at least 100 Mbit/s between any two points in the world [2], smooth handoff across heterogeneous networks [2], seamless connectivity and global roaming across multiple networks [2], high quality of service for next generation multimedia support (real time audio, high speed data, HDTV video content, mobile TV, etc) [2], interoperability with existing wireless standards, and an all IP, packet switched network [2].

## 5.3 4G COMPONENT

### 5.3.1 Access Schemes

As the wireless standards evolved, the access techniques used also exhibited increase in efficiency, capacity and scalability. The first generation wireless standards used plain TDMA and FDMA. In the wireless channels, TDMA proved to be less efficient in handling the high data rate channels as it requires large guard periods to alleviate the multipath impact [2]. Similarly, FDMA consumed more bandwidth for guard to avoid inter carrier interference [2]. So in second generation systems, one set of standard used the combination of FDMA and TDMA and the other set introduced a new access scheme called CDMA. Usage of CDMA increased the system capacity and also placed a soft limit on it rather than the hard limit [2]. Data rate is also increased as this access scheme is efficient enough to handle the multipath channel [2]. This enabled the third generation systems to used CDMA as the access scheme IS-2000, UMTS, HSXPA, 1xEV-DO, TD-CDMA and TD-SCDMA. The only issue with the CDMA is that it suffers from poor spectrum flexibility and scalability [2].

Recently, new access schemes like Orthogonal FDMA, Single Carrier FDMA, Interleaved FDMA and Multi-carrier code division multiple access are gaining more importance for the next generation systems. WiMax is using OFDMA in the downlink and in the uplink. For the next generation UMTS, OFDMA is being considered for the downlink [2]. By contrast, IFDMA is being considered for the uplink since OFDMA contributes more to the PAPR related issues and results in nonlinear operation of amplifiers. IFDMA provides less power fluctuation and thus avoids amplifier issues [2]. Similarly, MC-CDMA is in the proposal for the IEEE 802.20 standard. These access schemes offer the same efficiencies as older technologies like CDMA. Apart from this, scalability and higher data rates can be achieved.

The other important advantage of the above mentioned an access technique is that they require less complexity for equalization at the receiver. This is an added advantage especially in the MIMO environments since the spatial multiplexing transmission of MIMO systems inherently requires high complexity equalization at the receiver [2]. In addition to improvements in these multiplexing systems, improved modulation techniques are being used. Whereas earlier standards largely used Phase-shift keying, more efficient systems such as 64QAM are being proposed for use with the 3GPP Long Term Evolution standards.

### 5.3.2 IPv6

Unlike 3G, which is based on two parallel infrastructures consisting of circuit switched and packet switched network nodes respectively, 4G will be based on packet switching only. This will require low-latency data transmission [2]. It is generally believed that 4th generation wireless networks will support a greater number of wireless devices that are directly addressable and routable. Therefore, in the context of 4G, IPv6 is an important network layer technology and standard that can support a large number of wireless-enabled devices. By increasing the number of IP addresses, IPv6 removes the need for Network Address Translation (NAT), a method of sharing a limited number of addresses among a larger group of devices [2].

In the context of 4G, IPv6 also enables a number of applications with better multicast, security, and route optimization capabilities. With the available address space and number of addressing bits in IPv6, many innovative coding schemes can be developed for 4G devices and applications that could aid deployment of 4G networks and services [2].

### 5.3.3 Advanced Antenna Systems

The performance of radio communications obviously depends on the advances of an antenna system, refer to smart or intelligent antenna. Recently, multiple antenna technologies are emerging to achieve the goal of 4G systems such as high rate, high reliability, and long range communications. In the early 90s, to cater the growing data rate needs of data communication, many transmission schemes were proposed. One technology, spatial

multiplexing, gained importance for its bandwidth conservation and power efficiency. Spatial multiplexing involves deploying multiple antennas at the transmitter and at the receiver [2].
Independent streams can then be transmitted simultaneously from all the antennas. This increases the data rate into multiple folds with the number equal to minimum of the number of transmit and receive antennas [2]. This is called MIMO (as a branch of intelligent antenna). Apart from this, the reliability in transmitting high speed data in the fading channel can be improved by using more antennas at the transmitter or at the receiver. This is called transmit or receive diversity. Both transmit/receive diversity and transmit spatial multiplexing are categorized into the space-time coding techniques, which does not necessary require the channel knowledge at the transmit [2]. The other category is closed-loop multiple antenna technologies which use the channel knowledge at the transmitter.

### 5.3.4 Software-Defined Radio (SDR)

SDR is one form of open wireless architecture (OWA). Since 4G is a collection of wireless standards, the final form of a 4G device will constitute various standards. This can be efficiently realized using SDR technology, which is categorized to the area of the radio convergence [2].

## 5.4 THE WORKING PRINCIPLES OF 4G

In the 4G wireless networks, each node will be assigned a 4G-IP address (based on IPv6), which will be formed by a permanent IP address and a dynamic address that represents its actual location. When a device (computer) in the Internet wants to communicate with another device (cell phone) in the wireless network, the computer will send a packet to the 4G-IP address of the cell phone targeting on its home address [3]. Then a directory server on the cell phone’s home network will forward this packet to the cell phone’s care-of address through a tunnel, mobile IP; moreover, the directory server will also inform the computer that the cell phone's care-of address (real location), so next packets can be sent to the cell phone directly [3]. The idea is that the 4G-IP address (IPv6) can carry more information than the IP address (IPv4) that we use right now. IPv6 means Internet Protocol Version 6 including 128 bits, which is 4 times more than 32bits IP address in IPv4. 32 bits IP address looks like this 216.37.129.9 or 11011000.00100101.10000001.00001001 (32 bits) [3]. However, the IP address in IPv6 version will be 4 times of IPv4; it looks like 216.37.129.9, 79.23.178.229, 65.198.2.10, 192.168.5.120. It includes 4 sets of IPv4 address defined in different functions and usages. In previous example for the case, the first set of the IP address (216.37.129.9) can be defined to be the "home address" purpose. It just likes the normal IP address that we use for addressing in the Internet and network [3]. The second set of the IP address (79.23.178.229) can be declared as the "care-of address"[3]. It is the address set up for the communication from cell phones to computers. After these addresses from cell and PC established a link, care-of address will instead of home address; it means that communication channel will switch from the first set to the second set of the IPv6 address. The third set of the IP address (65.198.2.10) can be signed as a tunnel (mobile IP address). It is the communication channel to wire-line network and wireless network. An agent, a directory sever, between the cell phones and PC will use this mobile IP address to establish a channel to cell phones. Then, the last set of IP address (192.168.5.120) can be local network address for virtual private network (VPN) sharing purpose [3]. In this rich data IP address, software can use them to distinguish different services and to communicate and combine with other network areas, such as computer (PC) and cell phones' network in the case of the example. Moreover, in 4G wireless network, not only has it IPv6 transmission protocol, but also be supported by OFDM, MC-CDMA, LAS-CDMA, UWB *7 and Network-LMDS [3].

## 5.5 5G COMMUNICATION TECHNOLOGY

5G is short for fifth-generation communication system, and is envisioned as the real wireless world. As usual, the next generation can be categorized two different view, which is evolutionary view and revolutionary view. For evolutionary view the beyond 4G (B4G) will be the complete version to enable the true World Wide Wireless Web (WWWW), i.e., either Semantic Web or Web 3.0 [4]. This view can be justified by the story of the 2G to 3G transition. In history, 3G completes digital modulation while 2G opens digital modulation [4]. In this view, it is assumed that 4G might still remain some more homeworks to complete true World Wide Wireless Web. For example, a highly flexible network such as a dynamic ad-hoc wireless network (DAWN) cannot be fully completed in 4G period and so, can be a remained homework. Therefore, flexible wireless networking can be a candidate for the beyond 4G system in this view. Advanced technologies including intelligent antenna, radio frequency agileness and flexible modulation are required to optimize ad-hoc wireless networks [4].

From the revolutionary view the 5G should make an important difference and add more services and benefit to the world over 4G [4]. 5G should be a more intelligent technology that interconnects the entire world without limits [4]. For example, an artificial intelligence robot with a wireless communication capability can be a candidate since Building up a practical artificial intelligence system is far beyond all current technologies.

### 5.5.1 Intelligent Antenna.

In radio, multiple-input and multiple-output, or MIMO, is the use of multiple antennas at both the transmitter and receiver to improve communication performance. It is one of several forms of smart antenna (SA), and the state of the art of SA technology.

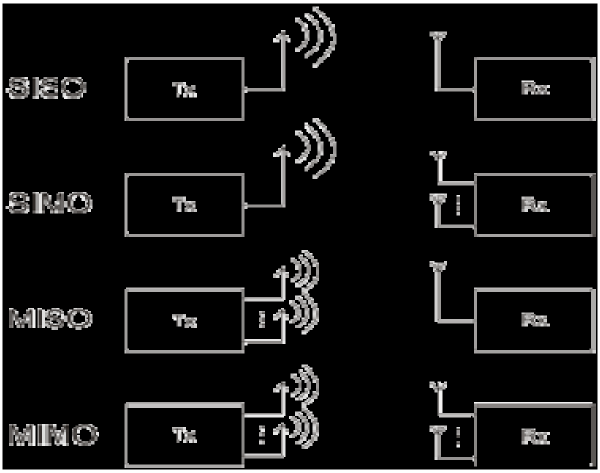


**Figure 5.1**. Understanding of SISO, SIMO, MISO and MIMO

Precoding is multi-layer beamforming in a narrow sense or all spatial processing at the transmitter in a wide-sense [5]. In single-layer beamforming, the same signal is emitted from each of the transmit antennas with appropriate phase and sometimes gain weighting such that the signal power is maximized at the receiver input [5]. The benefits of beamforming are to increase the signal gain from constructive combining and to reduce the multipath fading effect [5]. In the absence of scattering, beamforming results in a well defined directional pattern, but in typical cellular conventional beams are not a good analogy. When the receiver has multiple antennas, the transmit beam forming cannot simultaneously maximize the signal level at all of the receive antenna and precoding is used [5]. Note that precoding requires knowledge of the channel state information (CSI) at the transmitter.

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 [5]. If these signals arrive at the receiver antenna array with sufficiently different spatial signatures, the receiver can separate these streams, creating parallel channels for free [5]. Spatial multiplexing is a very powerful technique for increasing channel capacity at higher Signal to Noise Ratio (SNR) [5]. The maximum number of spatial streams is limited by the lesser in the number of antennas at the transmitter or receiver. Spatial multiplexing can be used with or without transmit channel knowledge.

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 [5]. The signal is emitted from each of the transmit antennas using certain principles of full or near orthogonal coding. Diversity exploits the independent fading in the multiple antenna links to enhance signal diversity. Because there is no channel knowledge, there is no beam forming or array gain from diversity coding [5].

Spatial multiplexing can also be combined with precoding when the channel is known at the transmitter or combined with diversity coding when decoding reliability is in trade-off.

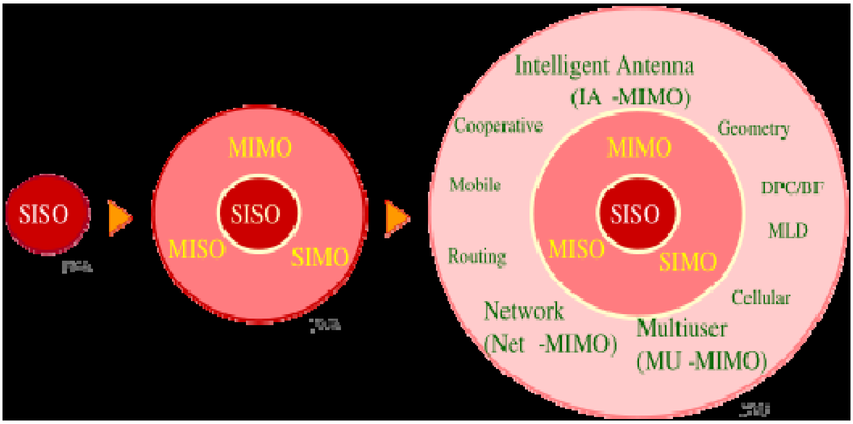


**Figure 5.2**. MIMO communication

### 5.5.2 Semantic Web

The Semantic Web is an evolving extension of the World Wide Web in which web content can be expressed not only in natural language, but also in a format that can be read and used by software agents, thus permitting them to find, share and integrate information more easily. It derives from W3C director Sir Tim Berners-Lee's vision of the Web as a universal medium for data, information, and knowledge exchange [6]. At its core, the semantic web comprises a philosophy, a set of design principles, collaborative working groups, and a variety of enabling technologies [6]. Some elements of the semantic web are expressed as prospective future possibilities that have yet to be implemented or realized. Other elements of the semantic web are expressed in formal specifications. Some of these include Resource Description Framework (RDF), a variety of data interchange formats (e.g. RDF/XML, N3, Turtle, N-Triples), and notations such as RDF Schema (RDFS) and the Web Ontology Language (OWL), all of which are intended to provide a formal description of concepts, terms, and relationships within a given knowledge domain [6].

Many files on a typical computer can be loosely divided into documents and data. Documents, like mail messages, reports and brochures, are read by humans. Data, like calendars, addressbooks, playlists and spreadsheets, are presented using an application program which lets them be viewed, searched and combined in many ways.

Currently, the World Wide Web is based mainly on documents written in Hypertext Markup Language (HTML), a markup convention that is used for coding a body of text interspersed with multimedia objects such as images and interactive forms. Metadata tags, for example <meta name="keywords" content="computing, computer studies, computer"><meta name="description" content="xxxx... "><meta name="author" content="xxxx"> provide a method by which computers can read the content of web pages [6].

The semantic web takes the concept further; it involves publishing the data in a language, Resource Description Framework (RDF), specifically for data, so that it can be manipulated and combined just as can data files on a local computer.HTML describes documents and the links between them. RDF, by contrast, describes arbitrary things such as people, meetings, or airplane parts.

The semantic web addresses this shortcoming, using the descriptive technologies Resource Description Framework (RDF) and Web Ontology Language (OWL), and the data-centric, customizable Extensible Markup Language (XML) [6]. These technologies are combined in order to provide descriptions that supplement or replace the content of Web documents. Thus, content may manifest as descriptive data stored in Web-accessible databases, or as markup within documents particularly, in Extensible HTML (XHTML) interspersed with XML, or, more often, purely in XML, with layout/rendering cues stored separately. The machine-readable descriptions enable content managers to add meaning to the content, i.e. to describe the structure of the knowledge we have about that content. In this way, a machine can process knowledge itself, instead of text, using processes similar to human deductive reasoning and inference, thereby obtaining more meaningful results and facilitating automated information gathering and research by computers.

The semantic web comprises the standards and tools of XML, XML Schema, RDF, RDF Schema and OWL. The OWL Web Ontology Language Overview describes the function and relationship of each of these components of the semantic web:

- XML provides an elemental syntax for content structure within documents, yet associates no semantics with the meaning of the content contained within [6].
- XML Schema is a language for providing and restricting the structure and content of elements contained within XML documents [6].
- RDF is a simple language for expressing data models, which refer to objects ("resources") and their relationships. An RDF-based model can be represented in XML syntax [6].
- RDF Schema is a vocabulary for describing properties and classes of RDF-based resources, with semantics for generalized-hierarchies of such properties and classes [6].
- OWL adds more vocabulary for describing properties and classes: among others, relations between classes (e.g. disjointness), cardinality (e.g. "exactly one"), equality, richer typing of properties, characteristics of properties (e.g. symmetry), and enumerated classes [6].
- SPARQL is a protocol and query language for semantic web data sources [6].

## 5.6 CONCLUSION

The intention of the paper is to focus on the concept of 4G and 5G within many aspects. The 4G system promises to bring the communication world with high data rates transfer, high quality service for multimedia support, seamless connectivity and global roaming across multiple networks. The component for 4G will be

OFDM, OFDMA, IPv6, advanced antenna system like MIMO and SDR. The 5G system is view as the real wireless system and the vision system for 5G are MIMO and semantic web.

Providing mobility architecture for 4G and for further generation (5G) networks is a very challenging task for the wireless research community. There are many issues involved in seamless mobility within a heterogeneous environment, which are yet to be dealt with, the most critical being security, End-to-End Reconfigurability, providing QOS and interoperability between different standards and synchronization of the networks globally. Further issues like mobile multimedia, handoff delay, adaptability and scalability and most importantly providing connectivity at vehicular speeds will play an important role in the design of efficient.

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