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LTE Services

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Introduction

Long Term Evolution (LTE) is commonly marketed as fourth generation (4G). LTE and LTE Advanced have been recognized by International Telecommunications Union – Radiocommunications (ITU-R) and International Telecommunications Union – Telecommunications (ITU-T) as the principal solution for the future mobile communication networks standards. Thus, they are the framework of what marketing calls 4G and maybe also fifth generation (5G). They have registered logos:

Figure I.1. *LTE and LTE Advanced logo*

It seems interesting to look at the evolution of mobile communication systems from their appearance upto LTE. This move has obviously been driven by commercial motivations as well as by the extraordinary improvement of microelectronics, especially from

the 1960s to the present day. Functionalities, computing power and miniaturization have drastically progressed, while cost has constantly decreased.

I.1. Mobile communication systems: 0G, 1G, 2G, 3G, 4G and 5G

In this short introduction, many mobile communication systems will be omitted:

– military communications and public utilities communications;

– maritime and aviation communications;

– trunk systems and more generally all kinds of professional dedicated radio systems.

It does not mean that LTE will not have specific adaptations in order to fit the special requirements of such systems, especially for its radio interface, avoiding expensive developments being invested for a limited population of users.

Only public land mobile network (PLMN) will be considered: the so-called "4G" belongs to this category as long as LTE is used for public communication.

Also, the impressive list of various systems, which did not reach a high level of success, especially outside their country of origin, has been avoided.

The classification of mobile systems into generations is not strictly related to any given metrics or parameters. It corresponds to marketing considerations. Therefore, it is commonly agreed upon, both by industry and by academia, and hence conceived to be an unwritten standard.

I.1.1. *Rationale*

Mobile communications have always been a wish for most of the people. Of course, at the beginning, the mobile networks have been invested for precise applications, such as military communications or professional management. The introduction of PLMN came later. But

the requirements for mobile services are most common for public systems and more specific networks.

For a network addressing all citizens, the investment is very high, especially in research and development – millions of coded instructions have to be written and validated. Also, the precise areas where the service will be necessary have to be determined. Therefore, it is necessary to analyze what the customers are ready to pay for to avoid vain efforts and investments. Excluding applications that are just using the mobile network as a support, mobile services can be classified into three categories:

– Mobile telephony: the mobile subscriber wants to discuss in real-time with distant interlocutors, who are connected with either a fixed telephone or a mobile set. Telephony offers the possibility to get immediate up-to-date information as well as the means to discuss any difficult item. Up until now it has been the most "money making" application.

– Paging: by some means of collection of the information, the network offers the capacity to alert the mobile subscriber that something of interest is happening. The paging can be limited to a very simple binary signal – some tone or light – and the customer has to call an information center to get the message. It can also be accompanied by a short message, either written or vocal, giving the main details of the message. This paging is very popular and is now offered by the short message service (SMS) of Global System for Mobile communications (GSM) and further technologies. The SMS service is a "teleservice", which means that the operator must carry it to destination. The multimedia messaging service (MMS) delivers much richer information, but it is not as reliable, because the delivery of messages is not guaranteed by the network operator; it is supported by a "bearer service", the quality of service (QoS) is limited to the operator's commitment.

– The Internet, fax or any written dialog: in the latter case, the mobile network offers the possibility to carry the office environment of its customer anywhere. Like MMS, the Internet and Internet-like services are generally bearer services, which are sold with a certain grade of QoS.

For these services, the mobile network can provide two kinds of access:

– nomadic access: the service is available anywhere inside the coverage of the network, but the customer must be static or is allowed to move very little;

– full mobile access: the service is available when the customer is moving, eventually at any speed, again within the limits of the geographical coverage service.

The paradigm of mobile communications is simple to summarize:

– be able to be connected to and receive information from any calling party;

– be able to be connected to any called party;

– full bidirectional access and real-time exchange of information;

– be accessed anywhere, outdoor, indoor, in urban and rural environment;

– full bidirectional access at anytime.

Going into detail shows a lot of issues:

– size of the mobile device: devices such as smartphones or tablets such have limited space to support the broadband module; these days, the terminal can also be some communication part of a machine for machine to machine (M2M) communications;

– nature and content of information to be transmitted, i.e. full telephony, television or data transmission, bilateral or unilateral.

I.1.2. *Short history of mobile communications, milestones*

I.1.2.1. *0G*

The systems that allow customers to communicate on the move depend on electronics and microelectronics technology. Therefore,

before the mass production of semiconductors, only experimental services have been deployed. The first network appeared in the United States in 1940, with mobiles using electronic tubes for car mounted terminals. Connection to the called party was made by human operators, in a way similar to that ensured for maritime communications.

Between 1960 and 1980, quite a few mobile communication systems were designed and deployed for either telephony or paging. Most of the advanced countries installed a home-made network. These systems offered automatic dialing with a good communication quality, obtained with a frequency/phase modulation radio access network. The radio path consisted of narrow frequency channels – 30 kHz in Northern America and 25 kHz everywhere else in the world. With the advent of transistors, a few handheld mobiles were available, especially for paging.

Of course, the service was only operated by incumbent fixed telecommunication operators, which found a new service for wealthy customers.

These systems will be called 0G.

I.1.2.2. *1G*

During the 70s, some important innovations have brought a kind of revolution in the mobile communication world:

– computer driven frequency tuning (frequency synthesis) allowing us to reach with precision a given radio frequency channel among many with only one quartz oscillator. This technology opened the way to high-capacity systems in so-called analog technology – where each individual communication is allocated one (time division multiplex (TDM) or simplex) or two (frequency division duplex (FDD) or duplex) precise narrow band frequency channels – managing hundreds of radio frequencies instead of a few tens in the previous systems. With such a number of channels, the radio communication system becomes able to cope with a large number of customers. Also,

frequency synthetization opened a way for massive production of handheld terminals:

– standardization and generalization of Signaling System No. 7 (SS7) designed for telephony, mainly the international version of ISDN;

– availability of microcomputers and computing chips offering greater speed and power for real-time processing, thus allowing us to implement sophisticated encoding, error correction and new transmission standards.

All these innovations were applied to new designs including some important breakthroughs:

– localization of the mobile terminal, which could be done manually, and automatically realized, in order to have the ability to route incoming calls;

– detection of the need for changing the communication in progress from one radio base station (one "cell") to another due to degradation of the radio link quality, and execution of the "handover" (US: hand off) to the other base station/cell, which is selected to provide a good quality communication.

With all these new developments, the cost of R&D skyrocketed and only a few systems could be studied and deployed with a worldwide impact. Among them two standards will dominate the market:

– First, the advanced mobile phone system (AMPS), designed by the Bell Labs with a prototype rollout installed in Chicago in 1978, serving more than one thousand customers. AMPS has been the first system to offer real-time seamless handover. This network probably shows the best possible design for a system where each individual communication carried by an individual duplex frequency modulation (FM) (or phase modulation (PM)) channel, each channel being given a narrow frequency bandwidth. The main features were standardized by the American National Standard Institute (ANSI). This AMPS system has the particularity of being able to modify channel spacing and FM excursion very simply, which allowed us to adapt it to various

frequency configurations (channel spacing of 30 kHz in the USA and 25 kHz in Europe and Japan). This is achieved simply by modifying the clock frequency driving the network. In North America, it was the genuine AMPS (initially, A stood for American).

In Europe and Japan, it was a modified version with a 25 kHz channel spacing, called Total Access Communication System (TACS), Europe TACS (ETACS) and Japan TACS (JTACS)). Due to some specific US political process aiming at introducing competition, AMPS and TACS massive deployment was delayed to 1985.

– However, the Scandinavian countries joined their strengths and developed the Nordic Mobile Telephone (NMT) system. This standard is by far simpler than the AMPS/TACS in all aspects of the technology. The spread of NMT is somehow due to the above-mentioned American political process, which delayed the mass deployment of AMPS. NMT became available around 1982 and was immediately rolled out in all Scandinavian countries.

Nevertheless, due to its transnational origin, NMT introduced a very interesting feature: automatic international roaming.

Another cellular system of the first generation was designed and deployed in Germany (C-Netz) and France (Radiocom, 2000) and counted a few hundred thousand subscribers. There was also a Japanese home-made “cellular” system.

These systems and their unlucky competitors are considered to be 1G.

I.1.2.3. *2G*

In the 1980s, with the spectacular increase of the computing power of integrated circuits, technology continued to progress with many breakthroughs:

– Development of vocoders. In concordance with the design of very powerful processors. Instead of needing a bitrate of 64 kbps to correctly digitalize narrow band voice telephony as calculated from the ordinary Shannon sampling, a telephony 4 kHz analog signal can be coded with a very good quality with 12 kbps, and even 6 kbps

(GSM). For professional systems, vocoders provide a clear voice communication with a few hundred kilobits per second.

– Vocoders are the key to switch from analog FM (or PM) radio to full digital transmission for telephony. The compression of the voice signal is a question of processing power. Today, a very high quality sound can be coded with less than 10 kbps; and correct voice communications are now available for professional and military communications with a bitrate of less than 1 kbps.

– Development of identity chips. The 1G German C-Netz had introduced a device to dissociate the subscription from the mobile terminal hardware. Such chips make it possible to encrypt communications and protect customers' privacy. AMPS or NMT were identifying the mobile terminal by a number which was included inside it and was very easy to copy or modify; so, customers were often suffering from pirated use of their identity. Concerning the privacy of communications, 1G networks did not provide protection against eavesdropping.

In the meantime, continental European countries have been conscious of their technological backwardness compared with AMPS. In 1982 the "GSM" was created (at the beginning it was a "special mobile group" led by German FTZ and French Centre national d'études des télécommunications (CNET)), which was commissioned to study a revolutionary mobile system based on a fully digital radio access subsystem, since it was considered difficult to surpass AMPS as an analog system. This new system, also called GSM, passed through a lot of studies until 1991. Code division multiple access (CDMA), which was in the 1980s a spread spectrum technique in use for military purposes, was experienced in 1985. At that time, CDMA showed need for too much computing power, far over the performance of the available chips, thus a simpler process, time division multiple access (TDMA), was chosen.

In 1987, all countries of the European Union signed a Memorandum of Understanding (MoU), which was accepted