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THE EVOLUTION OF MODERN CELLULAR NETWORKS

Research Report

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Contents

1 The early history of wireless communication

Transferring information between far spaces across the world always meant a big challenge in the human history. There was some methods during the ancient times and the middle ages, like smoke signals, beacons or pigeon posts, but the speed and the reliability of the information transfer was not the most satisfactory.

The first big breakthroughs in the history of worldwide communication was the rapid spreading of the electrical telegraph networks starting from the middle of 19^{th} century. By 1902, as the result of laying several submarine communication cables, the telegraph system encircled the world. After that, at the early 20th century, the telephone started to take the place of the telegraph, and by the end of the century, it has become one of the most popular communication device all around the world.

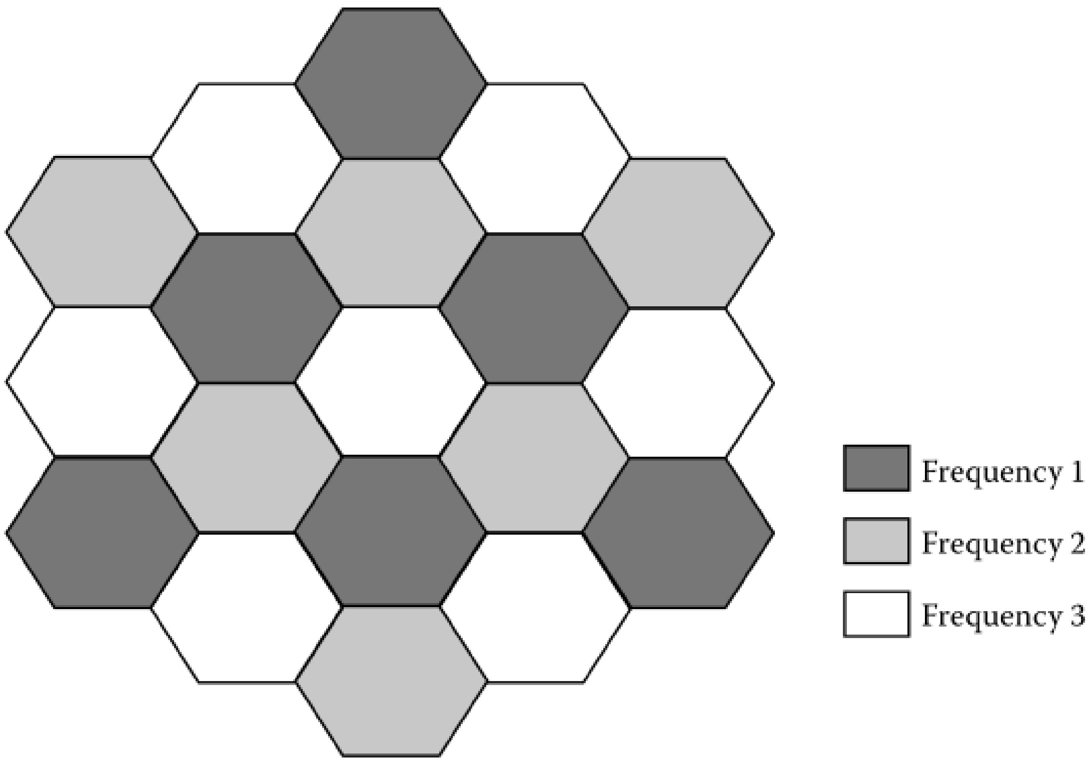
Beside the continuous improvement of cable communication, at the end of the 19^{th} century, Marconi stared to build a radio based wireless telegraphic system that would function the same as wired telegraphy. On 13 May 1897, Marconi transmitted the first wireless signals over water to Lavernock from Flat Holm, and the regular transatlantic radio-telegraph service was begun on 17 October 1907. Commercial radiotelephony for passengers on ships in the Atlantic was begun in 1929. By this time, radios were small and rugged enough to be installed in automobiles, and the first “land mobile” radio system was put into operation by the Detroit police in 1928. By 1934, there were 194 municipal police systems and 58 state police radio stations serving more than 5000 radio-equipped police cars. The age of mobile radio had begun.

Spectrum that could be exploited for practical systems was always in short supply, and mobile communication services were in competition with military and broadcast services for the available channels. As a result, most mobile radio channels were devoted to emergency and public service uses. Despite these difficulties, an early mobile telephone service was initiated in 1947, using several channels at 35 MHz. Additional channels were soon allocated at 150 MHz, and later at 450 MHz. Improved filtering and frequency stability allowed these channels to be narrowed, eventually creating a total of more than 40 channels for mobile telephony.

Early mobile telephone systems resembled broadcast systems, in that powerful transmitters were used to cover a distance of 20-30 miles from a high tower or rooftop.

These systems used analog modulation, and the calls in both directions were placed through a mobile operator.

For the better utilization of the ratio spectrum, and increasing of the covered areas, cellular networks has been constructed. In a cellular network, each cell uses a different set of frequencies from neighboring cells, to avoid interference and provide guaranteed bandwidth within each cell.



An example of a cellular communication network with frequency reuse factor 3

The first commercially automated cellular network (the 1G generation) was launched in Japan by NTT (Nippon Telegraph and Telephone) in 1979, initially in the metropolitan area of Tokyo. Within five years, the NTT network had been expanded to cover the whole population of Japan and became the first nationwide 1G network.

In 1981, the Nordic Mobile Telephone (NMT) system, simultaneous launched in Denmark, Finland, Norway and Sweden. NMT was the first mobile phone network to feature international roaming. In 1983, the first 1G network launched in the USA was Chicago-based Ameritech using the Motorola DynaTAC mobile phone. Several countries then followed in the early to mid-1980s including the UK, Mexico and Canada.

2 The era of digital cellular mobile networks

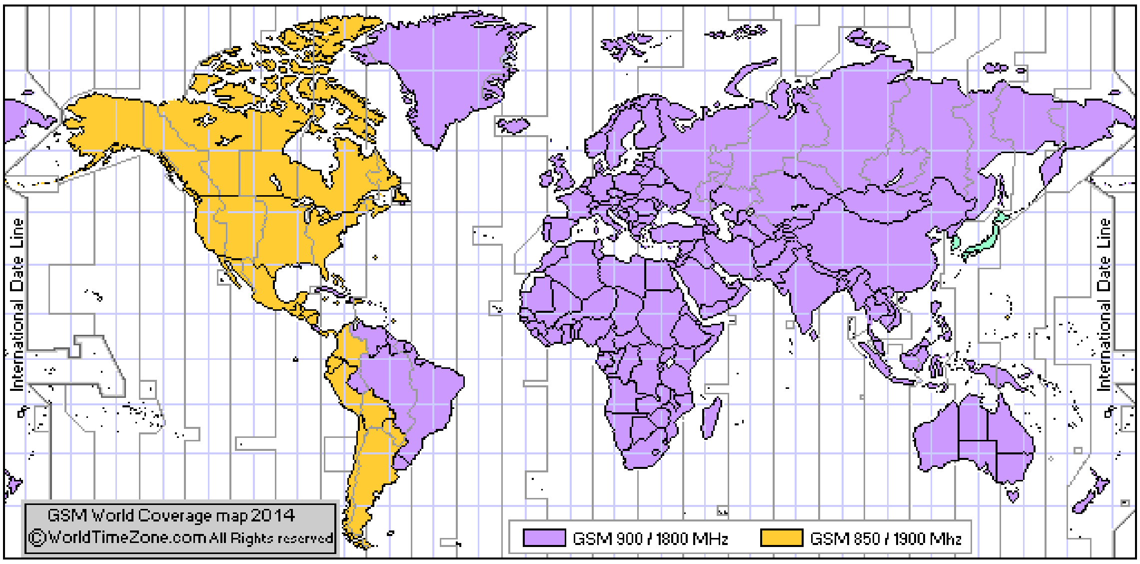
2.1 GSM

The second generation (2G) of the wireless mobile network was based on low-band digital data signaling. The most popular 2G wireless technology is known as Global Systems for Mobile Communications (GSM). The first GSM systems used a 25MHz frequency spectrum in the 900MHz band.

FDMA (Frequency Division Multiple Access), which is a standard that lets multiple users access a group of radio frequency bands and eliminates interference of message traffic, is used to split the available 25MHz of bandwidth into 124 carrier frequencies of 200 kHz each. Each frequency is then divided using a TDMA (Time Division Multiple Access) scheme into eight timeslots and allows eight simultaneous calls on the same frequency. This protocol allows large numbers of users to access one radio frequency by allocating time slots to multiple voice or data calls. TDMA breaks down data transmission, such as a phone conversation, into fragments and transmits each fragment in a short burst, assigning each fragment a time slot. With a cell phone, the caller does not detect this fragmentation.

Nokia 1011: the first mass-produced GSM phone

Today, GSM systems operate in the 900MHz and 1.8 GHz bands throughout the world with the exception of the Americas where they operate in the 1.9 GHz band. Within Europe, the GSM technology made possible the seamless roaming across all countries.



The used GSM frequencies around the world

2.2 UMTS

Projections of increasing demand for wide-area communications supporting new applications requiring high data rates led to the development of a new generation of cellular communication system in the late 1980s and the 1990s. These systems became known as 3rd Generation systems, aiming to fulfil the requirements set out by the International Telecommunication Union for the so-called IMT-2000 family. Broadly speaking, such systems aimed to achieve data rates up to 2 Mbps.

The 3rd Generation system which has become dominant worldwide was developed in the 3rd Generation Partnership Project (3GPP) and is known as the Universal Mobile Telecommunication System (UMTS). 3GPP is a partnership of six regional Standards Development Organizations covering Europe, Japan, Korea, North America, and China.

In contrast to the time division multiple access used by GSM, UMTS used a new paradigm in multiple access technology, being based on code division multiple access (CDMA) technology. CDMA permits several radios to share the same frequencies. Unlike TDMA, all radios can be active all the time, because network capacity does not directly limit the number of active radios. Since larger numbers of phones can be served by smaller numbers of cell-sites, CDMA-based standards have a significant economic advantage over TDMA-based standards, or the oldest cellular standards that used frequency-division multiplexing.

The first release of the UMTS specifications became available in 1999, and it was followed by extensions known as high-speed packet access (HSPA). The main stimulus for this was the rapid growth of packet data traffic, necessitating both much higher data rates and a switch from constant data-rate circuit-switched traffic (chiefly voice) toward Internet Protocol (IP)—based packet-switched traffic. The first enhancement was to the downlink, where high-speed downlink packet access (HSDPA) was introduced in Release 5 of the UMTS specifications, driven predominantly by the growth of Internet download traffic; this was followed in Release 6 by high-speed uplink packet access (HSUPA), as attention began to focus on services requiring a more symmetric uplink/downlink traffic ratio such as e-mail, file sharing (including photographs and videos), and interactive gaming.

2.3 LTE

The transition from circuit-switched mobile service provision to packet-switched is completed with the advent of the long-term evolution (LTE) of UMTS. Further growth in demand for packet data services, fueled by the arrival of mobile terminals with much more advanced capabilities for images, audio, video, e-mail, and office applications, led to the need for a further radical step in radio access network design.

3GPP took the first steps toward LTE at the end of 2004, when the industry came together to make proposals for the requirements and suitable technologies for the new system. In order to maximize its longevity, it was decided to embrace the opportunity to design a completely new radio access network architecture and radio interface, without being constrained by attempting to retain backward compatibility with the UMTS radio access network.

This meant that LTE was able to take advantage of the possibility of using much wider channel bandwidths (up to 20 MHz), partly facilitated by the allocation in 2007 of large new spectrum bands by the ITU for global use by “IMT”-designated systems, as well as exploiting advances in theoretical and practical understanding and processing capabilities. Targets were set for LTE to support at least 100 Mbps in the downlink and

50 Mbps in the uplink, with average and cell-edge spectral efficiencies in the range two to four times those provided by Release 6 HSPA.

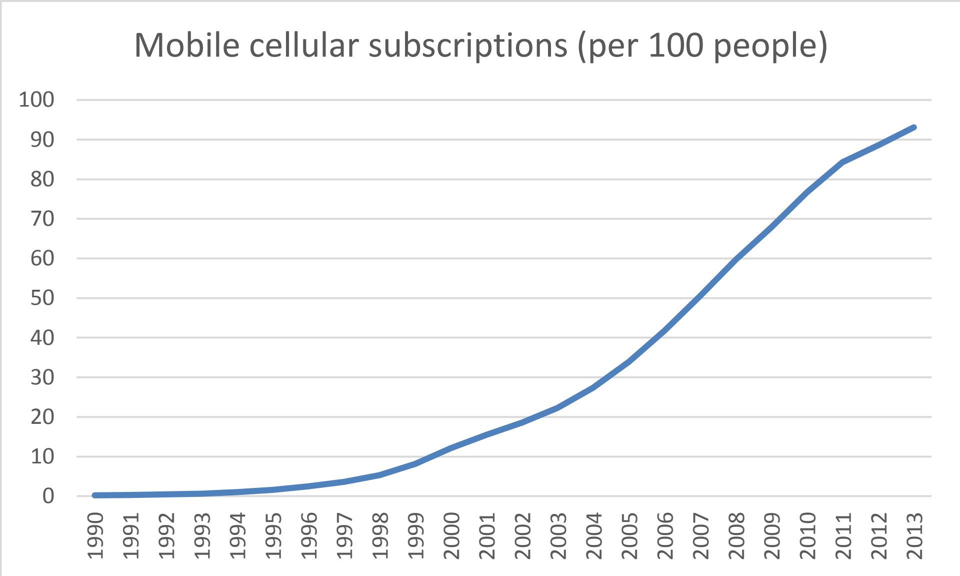
The LTE standard was finalized in December 2008, and the first publicly available LTE service was launched by TeliaSonera in Oslo and Stockholm on December 14, 2009 as a data connection with a USB modem. The LTE services were launched by major North American carriers as well, with the Samsung SCH-r900 being the world's first LTE Mobile phone starting on September 21, 2010.

Samsung SCH-r900

The evolution of LTE is LTE Advanced, which was standardized in March 2011.

3 The future of mobile networks

The rapid evolution of the cellular mobile networks in the last 25 years showed that it could be possible in the next few years for all the people around the world to use mobile communication:



Mobile cellular subscription around the world

In this situation, the future goals could be the improvement the reliability of the network to minimalize the service interruptions and the reducing of the cost per bit ratio.

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