

Mobile Telephony

Timo Ali-Vehmas and Yrjö Neuvo

5.1.1 Introduction

During the last one and half decades the world has become familiar with not only a new technology but also a phenomenon, Mobile Telephony. Mobile telephony is most often understood as cellular telephony but it actually includes a much wider range of technologies and services. During these years mobile telephony has developed from clumsy and heavy manually operated vehicle mounted radio telephones, to comprehensive systems that can be used by anybody almost anywhere and small but sophisticated devices that can connect people to people. Not even the sky is the limit for the mobile technology to develop, as mobile satellite systems will come to wide service during next 15 years.

Mobile telephony has its early roots equally and independently in North America, North Europe and in Japan. In these regions different systems were developed to fulfil local needs and under local regulative atmospheres. Today, enhanced versions of these early cellular networks form the backbone of the mobile telephony in the world.

North American AMPS (Advanced Mobile Phone System) is in largest use, not only in the USA and Canada, but also in South America and in several countries in the Pacific rim. Most subscribers in Europe are in TACS (Total Access Communications System) networks. TACS and its derivative E-TACS have their roots in AMPS. Largest TACS networks can be found in the United Kingdom and in Italy.

Another national network that has a strong position on its home market is the NTT network in Japan. The Japanese market has been quite different for many years because of the strong monopoly of the NTT. Only recently Japan has opened its markets and now there is also the so called J-TACS network operational in Japan.

The only first generation system providing international roaming is the Nordic Mobile Telephone (NMT) which has been developed in the Nordic countries and later has been adopted by several other countries (NMT has 450 MHz and 900 MHz versions). Most of these NMT operators have implemented automatic roaming between the networks.

In addition to these major systems several other systems have been developed; Netz C in Germany, Portugal and South Africa, Radiocom 2000 in France and so on.

Particularly in Europe there was a real patchwork of analog networks during the 1980's. Since it was obvious from the beginning that none of the first generation systems could have been accepted to become a pan European system, the CEPT initiated a new development that is now known as GSM, Global System for Mobile Communication. This process required about a decade from the start to commercial operation 1991 and several thousands of man-years of work. During that long period several test systems were developed to confirm the selected technologies. Also the standardisation process was transferred from CEPT to ETSI to widen the technological and financial basis of the process.

The large number of organizations involved in the development work was not the only challenge for GSM to overcome. The technological challenges were extremely demanding: all digital transmission, vocoder based speech source coding and requirements for signalling that materialised in the form of massive software and ASIC development projects in several companies all around the world. Later similar work started in the USA and Japan respectively; Telecommunications Industry Association (TIA) in the USA and RCR in Japan.

The starting point for digital mobile telephony in each of these regions was quite different and therefore it is quite obvious that different technology and market approaches were selected. In the USA there was no need for a brand new system, on the contrary, it was highly desirable to create a system that could coexist with the mighty AMPS network. The D-AMPS system, Digital and Dual mode AMPS was developed and documented as Interim Standard IS-54, which already has several revisions. However, it must be noted, that no other mobile telephone system standard except GSM is but an air interface specification. Only in the GSM system also the network interfaces have open standards for anybody to provide network elements.

The highly competing community of the telecommunications industry in the US could not be satisfied with a single standard. Two other major developments emerged. Narrow band AMPS, N-AMPS, introduced by Motorola, is a straight forward solution to provide a three fold capacity increase without any new principal technology. The other new candidate is technologically much more interesting since it introduced a totally new multiple access method for cellular, the Code Division Multiple Access method (CDMA). Earlier it had been used only in military or other specialised application.

In Japan the new digital standard has been developed primarily based on research activities by NTT. This standard, called RCR STD 27, has also its roots in national grounds. Many of the principal elements of the system are similar to either D-AMPS or to GSM but are modified and adjusted according to geographical, technological and political traditions and conditions of the country. The PDC (Personal Digital Communications) system is also based on a TDMA air interface.

Mobile telephony is actually much more than just cellular. The other technology offered for the general public is cordless telephony. Cordless telephones originally were just extensions to fixed PSTN, having radio access instead of physical wire. Since the early days of analogue cordless telephones (CT0) the development has gone through CT1 and CT2 to more advanced digital technologies such as DECT in Europe and Personal Handy Phone (PHP) in Japan, which actually in many respects closes the gap to cellular services by advanced features such as authentication, ciphering and also data services in the future.

The other section of Mobile Telephony, which in many ways is comparable to previous systems as technology but has very different users' requirements is Private Mobile Radio, PMR. Without going into detail it shall be recognised that from a technological (like DSP) point of view, there is much in common in the new digital trunked PMR systems and the current digital cellular systems. The most recent is the digital PMR specification in Europe, TETRA (Trans-European Trunked Radio).

The last and also the least developed sector of mobile telephony is mobile satellite communication. Currently there are some special systems for special needs. None of the current satellite telephone systems can be considered as personal telephony. In the future this may well be different if some of the currently planned personal satellite communications systems, such as Inmarsat P21, Iridium, Globalstar etc. are launched. However, the limited number of subscribers in any of the systems will limit the commercial potential of any such system and therefore mobile satellite telephony will be rather a complementary system to mainstream terrestrial mobile telephone systems.

In the future the integration of all these different mobile systems is evident. However, the air interfaces may in many cases be different for different systems because of different spectrum and service requirements. In some other cases these different systems will be more overlapping each other and for the customers of mobile telephony there will be many options to select. This development will be supported by the developing fixed networks and particularly concepts such as Intelligent Networking. Also it must be recognised that mobile communications networks often are based on state-of-the-art technologies and therefore provide at least the same amount of intelligence as any of their fixed counterparts. The integration of both mobile and fixed networks will finally form the future environment of telecommunication.

Regardless of any research and specification activities, the development of mobile telephony would have been quite different than experienced if thousands of enthusiastic engineers in hundreds of companies had not been able to materialise all their new ideas into physical designs of products. The development of size and performance of mobile communications equipment has been so rapid that it can only be compared to the fast decrease of the prices of this same equipment particularly on the markets which are open for competition. The customers, e.g. end-users of these systems do not consider standards and technologies to be important but features and services the systems can provide and total cost of the ownership.

When analysing the reasons for this extraordinary progress it can be seen quite easily that two technological key elements in this process have been Digital Signal Processing and Advanced embedded software and processing. Digital processing of physical signals as understood from a theoretical point of view is one step and its practical implementation as hardware and software is the other.

5.1.2 Usage

Today there are over ten million users in public cellular networks and another similar amount of users of cordless telephones and of other mobile telephone systems. In the early days most of the users were using their car phones but today more than 90% of the new subscribers select a hand portable or pocket phone when they buy a new mobile telephone.

Also the profile of the users today is quite different from what it was only a few years ago. Still in many markets and societies the mobile telephone is considered as a tool for a business man or a status symbol for wealthy people. In some areas where the penetration is about to exceed 10% this is quite different. For instance in Scandinavia quite ordinary people are using mobile telephones to widen the opportunities in their daily life. In Scandinavia the total cost of ownership is about the same or sometimes even below that of the fixed telephone and therefore the mobile telephones are used today by all groups of the society. In the Nordic countries mobile telephony is already becoming personal telephony in the office, at home and on the road.

Tailored tariffs for various groups of people have been the key promoter to this wide acceptance of mobile telephones. There are different tariff structures for low use subscribers such as elderly people or people having their vacation, that typically want to be reachable but do not call during office hours in the town centres. These tariffs are so low that any fixed service cannot compete. Also mobile centrex services are available covering the office or the town or the whole country depending on the needs of the subscribers. It has been recognised that once a person gets used to his/her personal communication tool, e.g. cellular telephone, he/she wants to use it anywhere regardless whether fixed telephone services are available in that location or not.

These type of behavioural patterns become even more dominating when very personalised additional services are available only via advanced mobile systems. Such services include messaging and other data services as well as advanced supplementary services such as call diverting and voice mail.

While many users today are quite happy if they have wide national coverage available, there is a larger and larger segment of subscribers that truly appreciate international roaming, particularly in Europe, where there are only national networks and at the same time European wide roaming of people is increasing because of, for instance, the development of the European Union.

The next very important step in this process is the extension of user's service profile from speech to data and further to modest multimedia during the next few years. This will be more visible for ordinary people than any high technology innovations deep in the networks. Multimedia will also require more than ever multitechnologies in the mobile terminals, both in ordinary telephones and in personal and portable digital assistants.

5.1.3 Evolutions and revolutions

When forecasting the future it is often useful first to backcast. The mobile telephony is right now living its first revolution, the digitalization. This revolution has taken different paths in Europe, Japan and in the USA and for good reasons. By analysing these reasons and their consequences we may start to draft the future.

It can be forecast that the next revolution requires quite significant forces, i.e. customers' needs and innovations and technical solutions to materialise. Also there must be very wide political will to influence positively for the revolution. On the other hand there will most likely be very strong evolution of the current systems and networks in any case before and parallel to any major revolution.

However, there will be developments which are part of the evolution, but which we can call revolutionary break throughs. Development of services will migrate towards multimedia and the best guess for the next revolution is actually evolutionary integration of several existing digital networks through interworking. This will not slow down the development of new services and introduction of new technologies. On the contrary, it will make the transition much easier and less risky.

Whatever new name or names will be used for this new generation of mobile telephony will be in the technologies we already know by names even today. Whether this will lead to global mobile telephony the answer is again the word: interworking. All global networks will interwork. The only question is: how. In the current European thinking the role of smart cards is very essential. One possibility to provide truly global roaming is to rely on the SIM roaming as will be implemented in GSM and PCN.

5.1.4 Basic concepts

When considering the role of digital signal processing in mobile telephony, the basic concepts are generic. None of the first generation analog systems have any feature that require any DSP at all. Even the modems and voice processors typically have been implemented using analog processing. Respectively, all second generation digital mobile telephone systems have DSP used in well defined sections of the system.

1. Source signal processing (audio [and video] source coding and decoding, pre-, and post-processing of those signals).
2. Modulation and demodulation and detection of the digital transmission.

3. Measuring and optimising the employment of radio resources (power control, frequency control and timing, also adaptive antennas).

The first section is what all the students in universities typically think when talking about DSP and its applications. This is an important section also because the major part of the processing complexity lies there. The source coding algorithms used in mobile telephones fall into two categories: waveform coders, such as Adaptive PCM (ADPCM is used typically in cordless telephones) and vocoders, such as CELP and VSELP or RPE-LPC (used in cellular phones). In vocoders Linear Prediction is the core of the processing. When coding video signal, then Discrete Cosine Transform (DCT) is an essential trick.

On top of the coding itself there are few a many pre- and post-filtering algorithms used to enhance the (perceived) quality of the signal. All kinds of linear and also nonlinear filter techniques are used.

Independently from specifications of mobile telephone systems, several kinds of accessories and additional functions have been introduced as well. One of the most promising such features is voice recognition, which independently of the methods and algorithms used is heavily relying on DSP.

The second section actually is the area that has given the characteristic name for all second generation systems, i.e. digital systems. Modulation, demodulation and detection are actually communications theory terms. In this area, however, most of the mathematical procedures are executed in the form of digital signal processing. Such procedures include several types of convolutions, correlations and filtrations. Some of the algorithms even carry names of famous experts of this field, such as Andrew Viterbi.

In radio communications many of the digital processing algorithms are adaptive. The need for adaptation is obvious due to the fast changing radio channel. Very robust algorithms are needed since they must work regardless of the wild behaviour of input signals.

The third section of digital signal processing used in mobile telephony can be described also using terms of control theory rather than communications theory. Automatic control functions for frequency source stability as well as for signal strength indication and gain setting in reception and power adjustment in transmission are typically variants of first and second order control loops, executed by the digital signal processing units of the mobile telephones.

Status of these control circuits, output of some special measurement processes and also status of detection algorithms of the receiver are used as basic information to initiate and complete the essential function of a mobile telephone network, the handover.

It is important to recognize that digital signal processing is used widely both in the terminals and in the network side. The aim of this chapter is to give an understanding on how DSP enters in mobile telephony by concentrating largely on the speech processing used in mobile telephony and on circuit structures for DSP. It is quite apparent that mobile terminals require a very high processing power accompanied by low power consumption both in standby and during operation.