The Standardization of Mobile Systems from NMT to Mobile Internet

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Abstract. The paper presents how the 1G, 2G and 3G mobile system standards were created. The focus is on the strong contribution of different Nordic players: administrations, operators and manufacturers. It covers the years from 1970 to the end of the millennium. .

1 Introduction

This paper will tell the story how early mobile phone services with bulky vehicle mounted speech-only terminals have developed to the modern mobile Internet services, which are available practically everywhere with sleek smart phone devices. The focus is on how the standardization and global regulatory processes made this possible. The Nordic countries played a key role in this, and their early experiences later served as a model in European and international fora.

The time span is from the early NMT (Nordic Mobile Telephone) to 3G services, i.e. from 1970s to the end of the millennium. During these years major technical hardware developments (birth of microprocessors, digital signal processing etc.) were achieved, and without them the mobile Internet would still be a dream. These more hardware-oriented topics are not included in this paper.

2 The Cellular Systems from the First Generation (1G) to 3G

Before the 1G cellular systems 2-way mobile radios were used in e.g. military, maritime, aviation, and freight haulage services. All these equipments were of very different types and none of them could be described as mass market goods. One of the limiting factors for the mass markets is the availability of the frequencies. Frequencies are a natural resource like the farming land area which can be expanded only to a point. Higher and higher frequency bands were taken into use as new radio technologies evolved, but due to the physical laws of the radio

propagation these bands could not be used to wide area mobile services.

To overcome the capacity problem engineers in Bell Laboratories in late 1940s got the idea that radio towers can be arranged in a hexagonal pattern and this could support a telephone network. In these hexagonal cells the same frequency bands can be reused, depending on the cell radius and transmit power. By reducing the cell size and power levels and reusing the frequencies the network capacity can be increased considerably. But it took more than 30 years until cellular systems could be deployed commercially.

The 1G systems like NMT offered only speech services and some supplementary services not yet available in fixed networks. During 1970s data communication was used only very limited i.e. there was not yet any need for data services. Microprocessors were already available, and they were needed in the implementation of the 1G car phones which operated on the 450 MHz band.

At the same time (1981-82), when the NMT services were opened, Nordic administrations and the Netherlands proposed a 2G system which later became known as GSM. It was a digital system and in its specification data services were already recognized. The first GSM networks were officially opened in 1991, but due to technical implementation challenges the real commercial activities started a bit later. Originally GSM offered circuit switched 9.6 kbit/s data rate. Later during its evolution phase higher rate packet mode services were also made available. In this period users started to access their emails over GSM, but web surfing was not yet very common due to the high usage costs. One of the most interesting new services of GSM was Short Message Services (SMS). During its specification phase nobody could foresee its huge success and the sort of a revenue generator it became for the operators and service providers.

In 1988 the European Union started a technology research program called RACE (Research and Development in Advanced Communications Technologies). One of its work packages was called UMTS (Universal Mobile Telecommunication Services). Its work was continued in several fora. Later this was better recognized as 3G. The first networks were opened in 2001 but again the real business was slightly delayed. This system opened the doors to the explosive growth of mobile data services and to the mobile access to Internet.

It is interesting to note that the evolution steps from 1G, 2G to 3G each took about 10 years.

The evolution did not stop here. Afterwards 3.5G and 4G have materialized and today we see headlines of 5G. However, the generation gaps are not so big because the development nowadays is based more on gradual evolutionary steps.

3 The Standardization of NMT (Nordisk Mobiltelefon)

3.1 Early Steps

During the Midsummer 1969 the Nordic Telecommunications Conference was held in Kabelvåg on Lofoten, Norway. There were representatives from all 5 national Nordic telecom agencies. As in all meetings the last agenda item was "Any other business". Normally at this point meeting delegates pack their bags and quickly leave for refreshments and then go home. This time they did not do that, because the Swedish delegation had a proposal to start a long-term project to develop a new mobile telephone system. They argued that a similar service could be developed for all Nordic countries, and by sharing the development work and its results major economic benefits could be achieved. The meeting decided to set up a working group to study the issue.

3.2 Regulatory Hurdles

Before new mobile phone services could be opened several regulatory changes were needed. To own and use a radio transmitter a special license was required, because radio transmitters were considered as security risks. Although e.g. in Finland the same State Authority PTT issued the licenses and operated the telecom networks this question was difficult to resolve, because two different offices were involved. It might take weeks or even months until the operating permit could be issued and the customer should wait this period until he could begin to use the service.

The NMT working group set as a goal that the user could use the same terminals in all Nordic countries. This was another revolutionary idea, because importing a radio transmitter to another country had been very complicated. The assumption was that only spies could even think of doing it.

The Director Generals of the Nordic PTT's found a solution in 1976. Its principles facilitated international roaming with mobile telephones in a way that in those days was revolutionary:

- The user's national administration issues a license allowing the user to operate the terminal in all Nordic countries
- The fixed subscription fees must be paid to the national operator
- The call charges are paid to the country where the roaming user is making the calls.

One more terminal related topic was their ownership. In those days the end user equipment connected to a public network was in many countries owned by the operators and not by the user. This time the administrations decided that the subscribers could buy their terminals from the open market. This decision created a new competitive market which strongly helped to boost the sales. To do this a rigid

type approval system had to be created. The practical verification tests were done with a system simulator developed by a small Finnish company Insinööritoimisto Hakala. This method ensured that all the type approved terminals operated in an identical manner with the system simulator and later with real networks as well.

The availability of a new frequency band is always a major regulatory challenge in mobile telecommunication, because in practice all usable bands were already used by some service, and this time a common band had to be found in all Nordic countries. The adoption of 450 MHz band was decided. In Sweden this created a problem because that band was reserved for military purposes and Sweden had invested a lot for these equipment. After long negotiations a compromise was found: NMT service can use the 450 band in peace time, but if mobilization is required then military can grab half of the band for their purposes.

Later, when the 450 band became too congested due to traffic demand much higher than expected, NMT service was opened also on 900 MHz. During this transition the system specifications were also slightly changed. One of the most important changes was that at this time hand-portable mobile phones were allowed and their availability speeded up the growth of mobile telephony.

3.3 Standardization Topics

As mentioned earlier a working group started to explore the system principles. In January 1971 Mr Håkan Bokstam, the chairman of the working group, was able to write down 14 requirements for the system. These became better known as "14 commandments". This document became fundamentally important for the future of the mobile telecommunication. When comparing the requirements to modern days' systems they are all still valid although they were formulated more than 40 years ago. Some of the commandments included the words "if technically and economically feasible" because the group was unsure about the speed of the technology evolution. The "if" sentences could have been deleted, because the requirements could be and were implemented as proposed by the group.

The secretary of the group was Thomas Haug, originally Norwegian but working in Televerket, Sweden. He became later the chairman of the NMT group following the accidental death of Mr Bokstam. Mr Haug is undoubtedly one of the greatest

names in the standardization of mobile telecoms, and after finishing in NMT he was nominated as the chairman for the GSM group. He served in this position for several years and was a key person in guiding the GSM standardization in a very challenging technical and political environment. He was well known to interrupt the meetings for coffee breaks when no progress was made and ask the key figures to find a solution before the problem could be discussed again in the meeting. Dr.

Thomas Haug received in 2013 the US National Academy of Engineering the Charles Stark Draper Prize.

Traditionally the Telecom administrations had developed the standards behind the closed doors sharing the results only with e.g. the local industries. NMT was different. The group shared its results as much as possible with industrial players. By opening the precompetitive process it was possible to base the forthcoming technical standards on the results of the world wide knowledge.

The normal practice was that the radio systems were delivered as a whole by a single vendor. The NMT group also wanted to create competition in radio subsystems, so they specified the interface between the base stations and switching system. Now even smaller manufacturers were able to offer base stations. This approach created a very competitive base station market but e.g. in the US it took tens of years until the Base Station competition was opened. In NMT e.g. Nokia entered the mobile network business with base stations only.

As highlighted above the NMT group made superb results but in one aspect they failed badly: market estimates. Luckily the estimates were far too conservative. The assumption was that e.g. in Sweden there would be 45000 NMT subscribers in 10 years. After the service was opened it took less than two years to reach that number. The biggest challenge for the operators all the time was to cope with this phenomenal growth.

4 The Creation of the GSM standard (2G)

4.1 Early Steps

The basic goal was to create a new Pan-European system. This need was well understood because with the exception of NMT in Nordic countries, Holland and Switzerland all other European countries had their own national systems and there was no mutual interworking. International roaming in Central Europe was both technically and administratively impossible.

The work for a new system was started in 1982 in CEPT which is an organization of 26 mainly Western European PTT Administrations. Before that the World Administrative Radio Conference in 1979 had allocated a band on 900 MHz in Europe to a land mobile communications system.

A working group was established under the chairmanship of Thomas Haug to study the question. The group was called Groupe Spécial Mobile (GSM) and the same acronym was used as the name of the new system . Later the system was renamed to Global System for Mobile communications. As in NMT the charter of this group was left very open because the meeting had not a clear understanding what could be achieved.

Although the working environment was now far more challenging due to the conflicting national industrial politics, the experiences from the earlier NMT work were utilized. Now the 14 Commandments of NMT were rewritten as 12 Basic Requirements for GSM. The new ingredients were: the need for hand-portables, data services, interworking with data networks and voice security.

4.2 Political Challenges

The inner circle included the leaders of the French, German, Italian and UK delegations, but still the Nordic operators were carefully being listened to because the success of NMT was well recognized. It is worth noting that in the early stages no industry participants were allowed to attend the meetings. However, all the administrations informed unofficially their manufacturers.

As a European wide activity was going to be started the European Commission became active and wanted to fund the operation. This initiative was not welcomed because the CEPT thought that they had the talent and funds. However, when the EEC created the Frequency Directive for the 900 MHz band, it was recognized positively, because after that no other new system could use the 900 band. The non EEC countries of CEPT also followed the Directive. A representative of the Commission was allowed to attend the GSM meetings.

4.3 GSM Standardization Starts

CEPT delegates understood that at some point in time they had to publicize the work more but they wanted to make a few key decisions within this core group. One of the hot topics was the radio access method. To find the best solution a competition was arranged where the industry and research labs could also participate. A narrow band Time Division Multiplex Access (TDMA) system won the tests. This system was proposed by several Nordic industrial and research groups. The problem afterwards was that a Franco-German proposal based on a wide band solution had been agreed on highest political level in both countries. So, only an interim decision could be achieved, but after a few months the political objection was removed and the earlier decision could be ratified.

4.4 European Telecommunication Standards Institute (ETSI) is Created 1987

After the access method and a few other key issues were decided the standardization work moved to ETSI, where all interested parties could join with equal rights. The doors were opened also to non-European members. The birth of the GSM also made a big change in the operator business. Before the PTT's had operational monopolies which allowed them to e.g. invest in wide research activities like NMT. But when the GSM networks were opened telecommunication markets were also liberalized in

Europe, and the old monopolies suddenly had competitors in their home markets. In the competitive markets the incumbent operators now focused their activities on network operations and not on the new business creation.

Gradually the manufacturers took a leading role in ETSI GSM. Both Ericsson and Nokia had also been active earlier behind the curtains but now they got a more visible role. As both companies achieved a great market success with their GSM network and terminal products their opinions were carefully listened to, and in many cases the operator customers also supported their suppliers. However, the two companies did not dominate alone because there were strong competitors like Motorola, Siemens and Alcatel, who also had competent and innovative engineers in their teams. All these leading companies invested heavily in the standardization because they wanted to create as many essential patents as possible. These patent portfolios have later proved to be strategically very important. Companies like Apple and Google, who originally did not participate in the standardization of cellular systems, have had serious problems with incumbent patent owners when they issued iPhone and Android products. It has been said that the only reason for Google to buy Motorola was to grab its essential cellular patent portfolio.

4.5 Phased Approach

The original goal was that all the standards should be ready when the services were planned to open in July 1991. However, it was soon understood that this would not be possible and it was decided that the services should start with Phase 1 standards, and Phase 2 standards would be finished later. It turned out to be delayed to 1995. After that 3G would be the next step. However, based on several reasons Nokia made a proposal in 1993 that there was a lot of potential in the GSM platform which could be further developed. There was some opposition to the proposal but finally it was adopted. Major improvements were done in GSM such as enhanced speech codecs, high speed data, packet radio service.

The standardization of GSM was finished in 1997 after 15 years of intense work. But it paid well because GSM was a real success story in the history of telecommunications. From start pan-European service was the goal, but it finally ended as a global system with only a few white spots on the world map.

4.6 Other 2G Systems

Although the standardization culture is very different in the USA a similar beauty contest of the access method was arranged. Ericsson's TDMA was the winner there. But after the Qualcomm introduced their Code Division Multiplex Access CDMA system there was not a single system as in Europe but two competing systems. The TDMA , known as DAMPS (Digital Advanced Mobile Phone Service), standard had to be rewritten several times until it was ready in 1993. Nokia contributed actively in

the terminal related parts of the standard.

Japan also created their own 2G standard. Ericsson was again very active and the Japanese adopted their TDMA technology called JDC (later PDC). The Japanese were not able to export it outside their country. After this experience they decided that when the 3G was done they would partner with someone else in order not to repeat the limited success of PDC.

Later, in mid 90s, a new frequency band for Personal Communication Services (PCS) was made available in the USA. This opened the door for GSM in the USA. The standard had to be modified to the new environment and especially Nokia and Ericsson were very active in this process. After PCS services were opened there were three different network technologies based on GSM, DAMPS and CDMA.

5. The Focus moves to Mobile Data, 3G Systems are born

5.1 The Targets

In the late 1990s the ambition level was again raised in Europe: now we wanted to standardize a truly global system. It had to be based on the GSM evolution because the operators did not want to invest in a totally new system. The trick was how to tempt Koreans, Japanese and the US CDMA camp to work with us. The World Administrative Council had allocated a new global frequency band for this in 1982. So the corner stone was already laid down.

In 1990s Internet had already made its revolution and the new system had to provide similar user Internet experience as the users had in wireline networks.

As the goal was set higher so were the challenges. In this presentation only key parts of the history can be covered. Books have been written and a lot of academic research has been done about the creation of the 3G. The focus of this paper is again on what Scandinavians did and how important their role was.

5.2 Preparing for the “3G Beauty Contest”

As mentioned in section 2 the CEC funded several technology research programs. The projects attracted all main players. In a way we were killing the time, because nobody wanted to start the 3G standardization at this stage while there was still a lot of work to do with GSM. However, this gave the opportunity to operators, manufacturers and research labs to study new technologies and the possibility to create relevant patents. The CEC hoped that a consensus about the new 3G technology could be found in this process but it did not happen.

Japan had moved ahead with 3G faster than Europe, and their decisions had impact on us. Americans had already done their heavy lobbying in Japan and for a moment it

looked like Japan would go their way towards Qualcomm's CDMA 2000. However, Ericsson learnt about this and was able to turn Japan to Wideband CDMA technology which had far better chances to become a global system.

At this point Ericsson was alone with WCDMA in Europe and understood that alone they had no chances. So they contacted Nokia although at that time Nokia was favouring another technology, Wideband TDMA. Internal discussions started in Nokia and after a while they concluded that WCDMA would be a better choice for the global coverage and decided to support it. This technology was not new to Nokia, because it had earlier done related projects with the Oulu University of Technology.

It is worth pointing out that the manufacturers now were in the driver's seat and operators had the bystanders' role but, of course, in the final voting they had a lot to say. Nearly all subsidiaries of the Japanese industry in Europe supported WCDMA but all the other major manufacturers were against. They were supporting TD-CDMA (Time-Division CDMA), the system which was originally proposed by Siemens.

The management of Nokia, Ericsson and Siemens had several meetings where we tried to find a common solution. No real solution was found in these discussions. When the battle between the two competing groups intensified, the Commission became worried and tried to help but again without any success. The CEC was worried that the mobile market could be split in Europe, which would have been a major setback compared to the pan-European success with GSM.

In the agreement with Japan Nokia and Ericsson had set one major condition for their support: the protocols of the 3G core network must be based on GSM evolution ie. GSM Mobile Application Protocol. This was very difficult for the Japanese to accept because they had worked actively in the International Telecommunications Union (ITU) to develop another Broadband ISDN based solution. Finally when the Japanese understood how critical the situation was they gave up. There was some drama in this process. We had a trilateral meeting which at one point split into two groups: top management and technical experts. In the expert group Japanese members continued to promote their choice, but in the management meeting we were told that the precondition set by Nokia and Ericsson was accepted. Before the final vote this decision was made perfectly clear to everybody and it helped us very much.

We were surprised that Qualcomm and Lucent did not propose their CDMA 2000 for the vote. Those two companies stayed very quiet during the ETSI system selection process, although in the USA and in ITU they were promoting their choice aggressively.

5.4 UMTS Radio Access Decision in Paris, January 1998

In the final vote there were two main competitors WCDMA (Ericsson, Nokia) and TD CDMA (Siemens). The first one was widely supported by operators and administrations and the second one by manufacturers. The last discussions were

centered mostly around IPR (Intellectual Property Rights) issues and industrial politics (Europe vs Japan). This plenary meeting was the largest ETSI meeting ever, 1523 weighted votes given by 198 members in the indicative voting. Nobody abstained. WCDMA got the majority with 61,1% but this was too little because more than 71% was required. Now it was clear that a solution could not be found by voting. The key supporters of WCDMA and TD CDMA convened in their own closed meetings. During the night Ericsson and Nokia drafted a compromise proposal and this was accepted by Siemens and its allies. Next morning the main meeting continued with the final official vote. Actual voting was done so that the chairman noted that nobody opposed the compromise and nobody wanted to abstain i.e. he concluded that the meeting made a unanimous decision. This way all the participants were bound to accept the compromise solution. An option was made available for TD CDMA but it was never implemented. So in real life only WCDMA networks were made commercially available and all the WCDMA supporters got what they wanted.

5.5 Towards the Global Standard

The ETSI decision was a crucial step to create a global standard and now the actual standards drafting should start. It was evident that we needed all the other regional standards bodies to work together. One could not expect that Japanese, Chinese, Koreans and Americans could accept a standard written in Europe. ITU was not an option because manufacturers have no voting rights there and it was also considered too political.

In ETSI we decided to establish 3G Partnership Project (3GPP) to draft the standard. The group was made open to all global players. Once the standard text was approved in 3GPP it was afterwards sent to the regional standards bodies for the decision i.e. to be rubberstamped. 3GPP became a great success. Since the WCDMA services were opened we had a system available in all countries, where there are cellular services and global roaming with a single terminal is possible. This has been a benefit not only to the global travelers but to the ordinary users as well. The global mass markets lowered the network equipment and user terminal prices reducing considerably the end users' telecommunication costs.

A high level political problem popped up when the EU was preparing a UMTS Decision. The US State Secretary, Ms Albright reacted in a letter to Commissioner Bangemann claiming that the Decision draft is anti-competitive. After some arm-twisting a compromise was found. It did not have any commercial meaning and the WCDMA became practically the only 3G standard which was deployed in European networks.

6. Final Remarks

The evolution of the mobile networks did not stop at WCDMA but it was followed with e.g. HSPA, LTE. There has been a real need for huge capacity increases due to the explosive growth of the traffic generated by the smartphones. According to the statistics of the Global Mobile Suppliers Association (GSA), at the end of year 2013 there were almost 2 billion mobile broadband subscriptions, and the forecast for 2018 is about 5,6 billion subscriptions. According to Ericsson the growth of the data traffic was about 70% in 2013 while the voice traffic had hardly any growth.

When we were planning for 3G WCDMA we knew that 3G networks would provide a whole load of new services but nobody was able to forecast what we all experience today with our smartphone devices. “The 14 Commandments” written down 41 years ago guided the mobile systems standards creation to the birth of 3G WCDMA, but later the evolution of Internet technologies took over. At the same time the leadership has also moved from Europe to the USA and Asia although Ericsson and Nokia are still the two leading network suppliers.

This presentation is based mainly on my experiences from working in Nokia Corporation during years 1973 to 2007 and on the related books listed below.

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