E 870

JOURNAL ON

COMMUNICATIONS

VOLUME XLVI SEPTEMBER-OCTOBER 1995

MOBILE COMMUNICATIONS

JOURNAL ON COMMUNICATIONS

A PUBLICATION OF THE SCIENTIFIC SOCIETY FOR TELECOMMUNICATIONS, HUNGARY

Editorial office
Budapest XIV. Ungvár u. 64-66.
1525 Budapest, P.O.Box 15.
Hungary, H-1525
Phone: (361) 251-1163
(361) 201-7471
Fax: (361) 251-9878
(361) 201-7471

Subscription rates
Hungarian subscribers
1 year, 12 issues 6000 HUF, single copies 650 HUF
Hungarian individual subscribers
1 year, 12 issues 960 HUF, single copies 110 HUF
Foreign subscribers
12 issues 150 USD, 6 English issues 90 USD, single copies 24 USD
Transfer should be made to the Hungarian Foreign Trade Bank, Budapest, H-1821, A/C No. MKKB 203-21411

EDITORIAL

The *MOBILE COMMUNICATIONS* issue is a significant milestone in the history of this journal.The topics discussed are especially timely and important in the development of the telecommunications services of Hungary and the complete Central and Eastern European region. In mobile communcations a very rapid development has been experienced in our country. First an NMT 450 system operated by the WESTEL Radiotelephone Ltd has been launched in 1990. In 1994 two GSM operators WESTEL 900 GSM Ltd. and Pannon GSM Co. received concessions to provide radiotelephone services in the 900 Mhz frequency band. Now the overall number of subscribers is more than 200 000 That is 10 % of the population served with telephone services relies on some kind of mobile communications.This high ratio is unprecedented in other countries. The importance of mobile communications services in the global Hungarian telecommunications market gives a special significance to this topic The experts working in this field and also those who are in some connection with this topic need a comprehensive and profound study clarifying the technical aspects of these services. The seminar was organized with the aim to emphasize the problems of technical development where Hungarian engineers have traditional merits.

With the choice of the seminar topics we wanted to cover all the important aspects of mobile communications development. The topics are as follows:

- System development
- System concepts
- Network planning
- Radio applications
- Services and tariffs
- Cellular infrastruture
- Mobile data
- Future systems

The papers of the issue are written by outstanding experts from Western companies and by knowledgeable specialists of the highly successful Hungarian companies. We are proud of the authors from Sweden, Norway, Finland, Germany and the United States giving a special flavour to this issue.

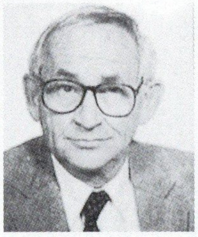
On the other hand we highly appreciate the efforts of the Hungarian authors giving a bright overview of our results in mobile communications Besides the managers and experts of the operators WESTEL Radiotelephon Co., WESTEL 900 GSM Ltd. and Pannon GSM Co., papers from the Technical University of Budapest, MATÁV Co. and the Hungarian State Railways contribute to the special value of this issue.

The issue concludes with a presentation by Rohde-Schwarz Co. the distinguished manufacturer of measuring systems for mobile communication.

In the organization of the seminar special help and advice was given by Thomas Haug and Petter Bliksrud. Their assistance is acknowledged hereby with sincere gratitude.

Finally the editor has to acknowledge the substantial moral and financial support given by the sponsors: Antenna Hungaria Co., Ericsson Ltd., MATÁV Co., Pannon GSM Co., WESTEL 900 GSM Ltd., Hungarian State Railways and the National Committee for Technological Development.

A. BARANYI



András Baranyi graduated in electrical engineering from the Technical University of Budapest in 1960. He received the PhD degree from the Hungarian Academy of Sciences in 1976. Since 1960, he has been with the Telecommunications Research Institute, Budapest. He has worked on circuit design of microwave FM systems, FM disortion equalization and transistor modelling problems. From 1973 to 1976, he was head of a section working on data communication. From 1980 to 1986, he was heading a department developing satellite communications systems. He has done research in the field of nonlinear circuit modelling and analysis. Presently he is studying the problems of optical-microwave interactions. He has given several courses at the Technical University of Budapest where he is an associate professor. In the academic years 1970-71 and 1980, he was research visitor in the US at the University of Maryland and at the University of California, Berkeley, respectively. He received the Academy Prize of the Hungarian Academy of Sciences in 1990. Since 1991, he is chief-editor of the Journal on Communications.

SYSTEM DEVELOPMENT

SHORT HISTORY OF THE WESTEL 900 GSM SYSTEM

A. SUGÁR

WESTEL 900 GSM MOBILE TELECOMMUNICATION LTD.
H-1117 BUDAPEST
KAPOSVÁR U. 5-7.

1. INTRODUCTION

WESTEL 900 GSM Mobile Telecommunication Ltd. started the pilot operation of its digital mobile radio telephone system and the construction of its nation-wide network nearly two years ago. Since then it has put four MSCs, four BSCs and more than 471 cells into operation. This infrastructure, which consists of Ericsson equipment/products only, allowed that GSM radio phones could be used on 72 percentage of Hungary's geographical territory. 89 percentage of all Hungarian citizens can make use of the up-to-date mobile services. Today already more than 100 thousand subscribers enjoy the mobility and safety provided by the WESTEL 900 GSM System.

2. SYSTEM DEVELOPMENT

The first milestone in the short history of WESTEL 900 was 15 December 1993 when the pilot mobile services were launched. Some 300 friendly users began to learn the use of the GSM system in the pilot system which consisted of one MSC, one BSC and 12 TRXs in six cells and which was put into operation in Budapest. The first service area offered by the system is shown in Fig. 1.

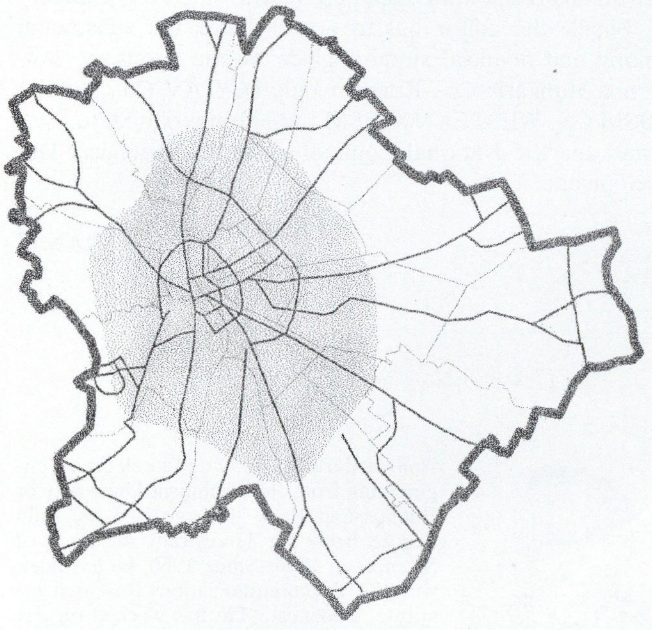


Fig. 1. Pilot system's coverage (12.17.93)

During the pilot operation the WESTEL 900 experts developed the procedures of system operation, quality parameters adjustment and correction, service definition and invoicing. The network was extended at an extremely quick pace.

The first real challenge and milestone was the launch of the commercial services on 31 March 1994. At the start 120 TRXs were operated in 60 cells in Budapest, while in April, 2 TRXs in 1 cell operated in Kecskemét. The service maps area is shown in Fig. 2. At that time already more than 1500 people used the WESTEL 900 digital mobile telephone system.

We introduced SIM authentication (Subscriber Identification Module), which serves subscriber safety and security, from the beginning, and some weeks later we were the first GSM operator to put the EIR (Equipment Identity Register) equipment checking system with all its functions into operation.

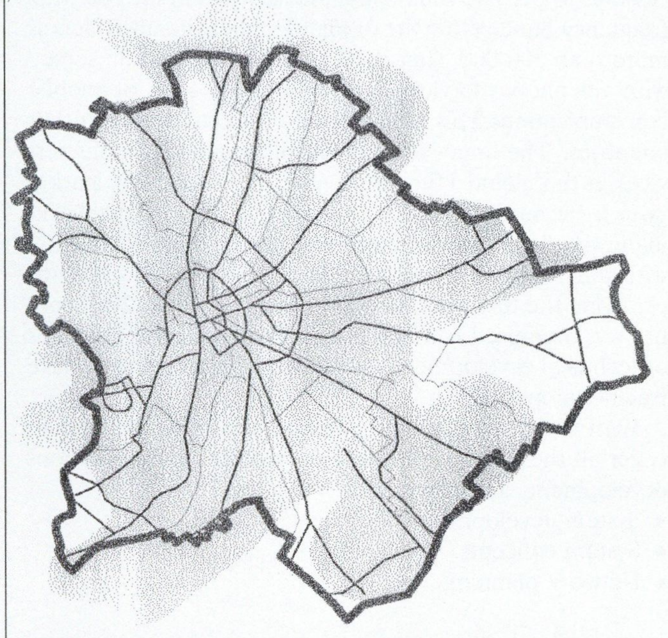


Fig. 2. Budapest coverage map at the beginning of commercial services (03.31.94)

With the launch of the commercial services we introduced two basic services, namely conversation calls and emergency calls. As regards supplementary services, call redirection and call restriction were available to our subscribers.

We put our first VMS (Voice Mail System) and SMS (Short Message Service) centers into operation also at the start. Each WESTEL 900 subscriber was given a free voice mailbox with a call redirection option. In this way our subscribers could be reached by leaving a message. We introduced this service in spite of the relatively small service area at the beginning. The system sent an SMS notification about the received messages as soon as it detected that the mobile phone had re-entered the network.

The number of WESTEL 900 subscribers has increased far more rapidly than expected and in not more than 8 months, on 6 December 1995, exceeded the magic 50-thousand limit. At this point our network struggled with a capacity shortage for a brief time. During a short period the capacities in the covered areas had to be extended to enable the handling of peak-hour traffic rather than increasing the service area. We put the second MSC-BSC center into operation in Székesfehérvár on 20 December 1994, and this center allowed the re-configuration of the network and resulted in a significant improvement in quality.

By connecting more and more cells, the service area has been extended continuously. A further increase in the number of subscribers, the introduction of new services and the continuous improvement of quality required further system expansion.

On 23 April 1995 the third MSC-BSC center was put into operation in Budapest, while the fourth such center was put into operation in Szolnok on 19 August 1995. This expansion provided for the connection of further base stations both in Budapest and in rural areas. Currently 598 TRXs are operated in 205 cells in Budapest, with 648 TRXs in 195 cells in rural areas. The current service is shown in Fig. 3.

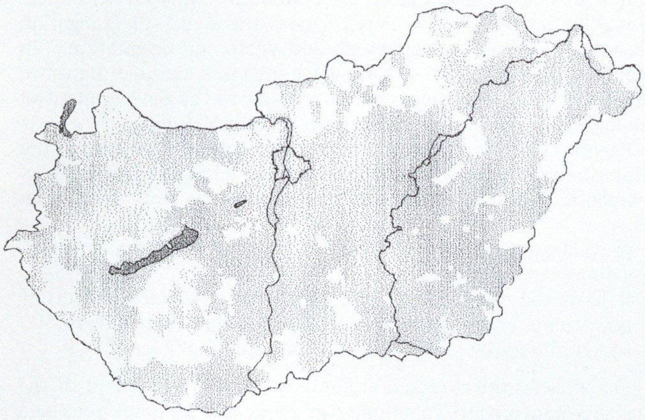


Fig. 3. Planned coverage at the end of the year '95

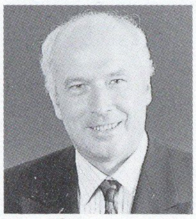
To introduce mobile data/fax services, we had to install a hardware/software module which co-operates with the PSTN network in the case of fax or data calls in each centre. We have introduced mobile originated and mobile terminated fax, as well as asynchronous data transmission services, in transparent and non-transparent quality, in the speed range of 1200 bps to 9600 bps.

In the meantime, we have put our second VMS and SMS centre into operation, partly to extend our voice mailbox capacity, and partly to introduce other mailbox services (business mailbox, mailbox to mailbox, faxbox services). The new SMS center is suitable for handling mobile originated short messages as well.

3. INTERNATIONAL ROAMING

The advantage of the GSM system over any other mobile radio telephone system is the possibility of international roaming. This service allows the subscribers of the operators with whom a co-operation agreement has been signed to use the services provided by the hosting network. WESTEL 900 signed its first roaming agreement with the Swiss PTT on 11 April 1994. Since then we have concluded such an agreement with nearly all European operators, but the WESTEL 900 GSM mobile phones can be used also in South Africa and Australia. Today our subscribers can originate and terminate calls from 41 networks in 30 countries.

It is important to note that the network was designed and the transmission system was built by the Hungarian experts of WESTEL 900. The continuous development and several re-configuration of the system took place in a commercial service network. Through the professional knowledge and competence of our experts, our subscribers noticed the work and corrections performed in the system (that is the continuous development activities) only through the extension of the service area and the improvement of call safety.



András Sugár is currently general manager of WESTEL 900 GSM Mobile Telecom Ltd. Before heading up the 900 system, he started WESTEL Radiotelephone Ltd., a 450 NMT joint venture between US WEST and the Hungarian Telecommunications Co. Before leading the WESTEL companies, he was deputy general director of Intercooperation and later managing director and deputy general manager of Transelektro, involved in trade, distribution and development of telecommunications as well. From 1980 to 1985, he worked at the Hungarian Commercial Counsellor's Office in New York as deputy commercial counsellor. From 1974 to 1980, he was with the Department for Trade Development of the Hungarian Ministry of Foreign Trade. Before that, he worked as an engineer developing FM radio transmitters for the Electromechanical Company. He speaks fluent English, German and sits on the board of the American Chamber of Commerce in Hungary and the Federation of Hungarian Industrialists. In 1993, he was elected a Leading Businessman in Europe by *The Wall Streat Journal*.

PANNON GSM SYSTEM DEVELOPMENT

A. GÁRDOS and GY. DROZDY

PANNON GSM TELECOMMUNICATIONS COMPANY
H-1134 BUDAPEST
VÁCI ÚT 37.

1. INTRODUCTION

In the following pages, Pannon GSM's brief history, its main business objectives, its system design, planning and installation, network and service quality management will be briefly described. The most important special features of our system and some of the most important problems and obstacles of our system development will be also shown.

2. BRIEF HISTORY OF PANNON GSM

In 1992, the Hungarian Minister of Transport, Communications and Water Management issued a tender for two mobile service operators using the Global System for Mobile Communications (GSM) standard. According to the Concession Agreement, these two companies would be responsible for installing and operating fully digitalized networks utilizing the 900 MHz frequency. After fierce competition, on the 26th of August 1994, the final result was announced: the first winner was Pannon GSM Telecommunications Ltd., the second winner was WESTEL 900 Telecommunications Ltd.

It is important to mention that the concession period is valid for 15 years, and there is a possibility to negotiate an extension of the Concession for an additional 7.5 years. This assures the winners of the tender that they can really plan for the future.

The roll-out requirements of the Concession Agreement determines the *minimum requirement* which was set up for the winners. Thanks to the intensive system development of both GSM companies we are fulfilling all requirements even to higher levels, than required by the Concession Agreement. In the middle of 1995 Pannon GSM reached 50 % of the geographical coverage and 70 % of the population coverage. These figures show a much higher percentage than the Concession Agreement's minimum requirements or our original plans which were attached to the Concession tender document and the first version of our business plan.

Pannon GSM today has 5 foreign owners and 4 Hungarian owners:

PPT Telecom	The Netherlands	(16.56 %)
Telecom A/S	Denmark	(16.56 %)
Nortelinvest AS	Norway	(14.49 %)
Telecom Finland	Finland	(14.49 %)
Telia International AB	Sweden	(14.49 %)
MOL Rt.	Hungary	(15.53 %)
Wallis Holding Kft.	Hungary	(5.18 %)
Antenna Hungária Co.	Hungary	(2.25 %)
Videoton Holding Co.	Hungary	(0.45 %)

There was a major capital increase in January 1995, when capital was increased by HUF 5,750 million from HUF 4,700 million. Today the capital of the company is HUF 10,450 million.

To give a brief summary of Pannon GSM's system development, the main events of the history of our system is as follows:

- The beginning of Pannon GSM System development was when a *test network* started to operate in Budapest with 8 base stations in December, 1993.
- The network in Budapest was *ready to operate* with 23 base stations on the 23rd of February, 1994.
- The *commercial service* started on the 28th of March, 1995.
- The network along the *M7 highway* and around *lake Balaton* was launched in June, 1994.
- By December 31st of 1994, the *area coverage* was extended to include all one digit highways, regional capitals and the lake Balaton. The sites were positioned so that handheld coverage could be obtained in the cities and handheld connected to external antenna coverage could be obtained along the roads. At the end of 1994 the *number of base stations on air* was around 150. Today this number is around 250.
- *Airtime per subscriber* per day on average is 2-3 times higher than in the West European GSM countries.
- We were the first to sign an *Interconnect Agreement* with MATÁV. Other Interconnect Agreements were signed with the two mobile phone operators, WESTEL 450 and WESTEL 900.
- System development can also be measured with the increasing number of *staff*: while in November 1993 only 4 people were working at Pannon GSM, today our company employs more than a hundred times more people.
- This intensive system development also requires a solid *financial background*. In April, 1995 Pannon GSM received a USD 115 million loan, which was at that time the greatest loan given to a Hungarian company by a group of private banks without any government or foreign guarantee.
- Today Pannon GSM provides all Phase 1 *services*, and it already provides a number of Phase 2 services: speech, call hold, call waiting, call barring, call forwarding, voice mail, calling line identification presentation, calling line identification restriction, DTMF (dual tone multi-frequency), short message service, data transmission and fax transmission.
- We have a wide range of *roaming partners*. We have roaming agreement with all major European operators, and also with some other non-European operators as well, like for example the two GSM operators of South Africa.

3. MAIN BUSINESS OBJECTIVES

The above mentioned few facts certainly indicate that Pannon GSM is to serve mobile communication in order to improve quality and efficiency of life and contribute to the economic growth of Hungary. We provide choice to strengthen free and fair competition throughout the telecommunications business. Our primary strategic orientation is to provide value to the Hungarian Business Community through advanced telecommunications services. The profile of the company is thus to meet the needs of Hungarian Business in terms of technology and customer orientation. In doing so we provide a tool with which business can operate more effectively, and by extension we contribute to the development of the market economy and the private sector in Hungary.

Pannon GSM's *primary aim* is to become and remain the telecommunications company of choice in Hungary for the governmental, business and institutional market, as well as individuals,

- providing high quality and cost effective mobile telecommunications services;
- fulfilling the requirements of each customer segment by setting new standards of excellence in customer services and care;
- and continuously striving for innovation and efficiency.

Our policies are directed at contributing to the interest of the Business and private community in Hungary, its employees and its shareholders, and acting in a beneficial relationship with our Hungarian and international business partners.

Pannon GSM's *strategy* is based upon the principle of allowing the business and private community to communicate at any place at any time with mobile telephony. The strategy is based upon the acquisition and retention of customers through continuous technical development (roll-out, capacity, services, state of the art billing and customer care) and continuous human development matching all communications and sales activities to the appropriate segment, channels and targets.

In order to achieve these goals Pannon GSM is building a GSM system which will be able to meet these aims. In the following, this system development will be briefly described, especially the four primary elements: system design, planning and installation, network management, and service quality management.

4. SYSTEM DEVELOPMENT

The most important determining factor of our system development plan is the Concession Agreement. It determined that the network has to be built first in Budapest, along the 1-digit highways, and in the county capitals. Since normal telephony is still a scarcity in Hungary, mobile telephone is used in place of normal phones, therefore great emphasis in system development concerning major cities is a very important difference, compared to the West European markets. For this reason it would have been better if the major cities would have got a bigger emphasis than the main roads. In this year we have greater freedom to plan. Today the development of the Budapest metropolitan area and the countryside cities have an increased emphasis.

Before we have a look at our network's most important characteristics and advantages the main principles of our system design, planning, installation, network and quality management is going to be introduced.

4.1. System design

The capacity of a GSM system is determined by the usage of the frequency band given to Pannon GSM by the Ministry. The capacity of the GSM system in Hungary with 2*8 MHz band for each of the two operators can give a total system capacity that can handle subscriber penetration exceeding 10 % of the population from a technical point of view. Subscriber distribution is of course not evenly spread over the geography of a country or a given city. In large cities, for example, the network has to be divided into geographical cells to increase the traffic capacity. (The size of the cells in the city center can be as small as 500 meters in diameter.) Dividing the network into smaller cells is a very costly method to increase traffic capacity, so new frequency bands would remarkably decrease the cost level of traffic capacity increase and could offer a cheaper service for the customers.

The total number of cells and sites is initially depending on the coverage requirements, later on the capacity requirements. The main goal of the site planning is to obtain a good handheld coverage in the populated areas. Handheld coverage is continuously improved so that in a couple of years more than 90 % of the country' s territory will have handheld coverage.

The connections between the network components, BTS (Base Transceiver Station), BSC (Base Station Controller) and MSC (Mobile Station Controller) will be based on digital microwave links and leased lines, including digital multiplexing equipment. Standard microwave equipment has been used for network design. The recommended transmission network topology consists of both stars and rings depending on the location and usage requirements. In short distance microwave transmission we use mainly 23 GHz and 34 GHz transmitters, and in some cases 15 GHz transmitters. We are in the process of installing a 6 GHz backbone system which provides a big capacity and big reliability connection between the BSCs and the BTSs.

Leased lines are used to interconnect the MSCs to the PSTN (Public Switched Telephone Network): to the Secondary Exchanges and to the International Exchanges. Leased lines and other PSTN related questions were settled in the Interconnect Agreement with MATÁV.

4.2. System Planning and Installation

There are three major *development target areas* in 1995 – Budapest, the major cities, and the main highways and roads.

- *Budapest* is totally covered, the most important task is to increase the capacity and the coverage quality.
- The *major cities* will be also covered by the end of 1995.
- Almost all *two digit roads* will be covered by the end of 1996.

There is a trend in Europe that mobile phones are having an increasing market share because of its immense technical capabilities. In Europe mobile phones are really becoming the complementary products of normal telephones. This tendency is also emerging in Hungary since the low level of normal telephone line supply. It seems that Hungary will be one of the countries where the mobile phone/normal phone ratio is above the international average. In the Budapest metropolitan area for example, the traffic parameters are much higher than expected and therefore this area is one of the most important issue in system development. In contrast with last year, this year we have concrete knowledge about the areas where our customers increasingly use our network. This means we do not have to make estimations to decide where to develop our network capacity, we utilize key figures about traffic, generated by our customers. This of course greatly increases the efficiency of the system development process, since we develop our network where customer demand requires it. In this sense customer demand is the most important input in our system development process.

Market demand is also the most important input in *coverage quality* improvement. At the beginning of Pannon GSM's history, after analyzing the Hungarian market, it was a fact that the network had to be planned for 2 W handheld phones, although the Concession Agreement recommended to plan our network for 8 W portable mobile phones. In the Pannon network, the 2 W handheld phones (in the most cases) can be used without external antennas. Because in Hungary mobile phones are used mostly in offices and other buildings, we had to adjust our network to our customers' demand, thus we are establishing an efficient indoor coverage in the urban areas. To achieve and improve coverage without the use of an external antenna, we continuously increase the number of base stations in order to meet our customers' needs. Of course at certain places no operator can provide 100 % coverage, since the physics of the 900 MHz radio waves. For example, in some cases the use of an external antenna is needed at ground floor or first floor flats, especially if the windows are facing a closed area and where the walls are extremely thick. For these cases, in order to increase coverage quality, Pannon GSM provides a wide scale of external antennas. Additionally, for our major customers we provide our special Repeater Program, which will be briefly described later on. In automobiles and buildings, in some cases coverage can be received only with external antennas. One of our primary aims is to continuously decrease the level of such areas, where coverage requires the use of external antennas.

4.3. Network and Quality Management

Network management functions are very important in order to be able to operate and maintain the network efficiently by keeping network availability at a maximum. For this reason, it is strategically important for Pannon GSM to have a continuous control over the network. In order to assure this, a centralized network management system based on the *Telecommunications Management Network (TMN) concept* is used. (The TMN concept was developed by the Consultative Committee on International Telegraphy and Telephony (CCITT)). TMN features ways to interconnect all infrastructure machines to a management network and ultimately to centralized sites where work stations enable the network management staff to control the whole system [1].

The GSM system has an *Operation Subsystem (OSS)*, which enables the operator to monitor and control the GSM network. OSS on the one hand is linked to major network elements, like for example the MSC, BSC, HLR, on the other hand OSS provides a man-machine interface for the operation personnel. The network element which is in contact with the BSS (Base Station System) and the NSS (Network Subsystem) machines is called *Operation and Maintenance Center (OMC)*. An OMC typically consists of a database for network data and a couple of workstations which are in charge of managing the OMC database and are in connection with other network elements. Pannon GSM's NOKIA OMC enables the operation personnel to overview the whole network's operation, including the quality of the network. Quality parameters are continuously checked, like for example traffic, congestion, handovers, dropped calls, interference, etc. The most important measurements provided by the OMC are: BSC-BTS measurements, MSC measurements and Home Location Register (HLR) measurements. Short Message Service Center (SMSC) measurements and Voice Mail System measurements are made separately, but these data are also carefully checked. Test car measurements are also important input figures to assess system operation [2]. Quality reports are provided at different levels, and for various time intervals. The continuous quality check helps to find bottlenecks and problematic areas. The OMC is also the basic element of the daily network maintenance. OMC, with on-line monitoring, continuously collects and displays alarms from all network elements and doing so, it allows the operator to detect, locate and correct the faults and breakdowns in the system [3].

4.4. Special Features of Pannon GSM's System

One of the most important advantage of our network is our main GSM system-equipment provider: *NOKIA*. The philosophy of the NOKIA system was the primary reason why Pannon GSM chose this system. The NOKIA system has distributed intelligence, which means that the functions are executed with many co-working microprocessors at both the switch center and the base station controller. The advantage of this method is that the system is more flexible, it can be easily extended, and at the same time it can provide an increased level of security. If a unit has any operation difficulty, its role is taken over by another unit. If a secondary unit also has any failure, other related units sustain system operation, due to the distributed intelligence system. This means that an operational failure of a certain unit only has a limited influence on the entire system.

Another significant advantage of the NOKIA system is that because its system is based on standard microprocessors, its software development abilities are in a leading position. The result of this advantage could be enjoyed by the Hungarian customers with many of our value added services, like for example the PANNON FAX and PANNON DATA services which were introduced very shortly after the world premiers. The calling line identification service was also introduced first in Hungary, but unfortunately we were ahead of our partner operators, and they did not cooperate with us. This means that today we can only provide this very popular service in our own network. We hope that MATÁV and the two WESTELs will be able to catch up in their service development and will cooperate with us in this matter. Calling line identification is a very popular value added service among other countries. In Sweden, for example, the public switched telephone network also introduced this service and they started to sell a quite cheap liquid crystal display where the called party can see the calling number. Last Christmas this was one of the most popular presents in Sweden.

Our *network planning system* is also supplied by NOKIA. The NPS/X NOKIA Planning System provides — among other features — coverage and interference calculations, automatic channel allocation, and a complex GSM simulation. The NPS/X planning system is connected with the NMS/X NOKIA Measuring System, which is capable of testing the whole network (e.g. coverage level measurement, test calls, etc.) and provide data to the planning system [4].

The use of *sectorized base stations* is also an advantage of the Pannon network. With a certain number of base stations, sectorized structures are the best solution to reach the best coverage and the largest capacity. Of course it needs greater investment efforts than other methods. Walking on the streets or driving a car, among base stations, sectorized base stations can be recognized by their special shapes: they look like big loudspeakers. The other main type of antennas, the omnidirectional antennas look like a simple metal bar. Pannon GSM has only a very few of them. Our base stations have three sectors in most cases, often two, or in a few cases only one sectors. A sector has two antennas. One antenna is a transmitter/receiver antenna, the other is only for receiving. In this sense, the two antennas provide spatial diversity, which is one of the best methods to minimize fading. Because of this effective fading minimization and proper power balance, if the customer's phone indicates coverage in our system, he will be able to originate a call with a greater probability, since the base station will receive his phone's signals with an increased probability.

The *antenna positioning* is also an advantage of the Pannon GSM network. In the urban areas, in most cases our antennas are positioned in a lower level: the antennas are not above the buildings, but if it is possible, in front of the building walls. Lower antenna positioning has two positive effects: it minimizes interference and because cells are smaller in size, lower antenna positioning increases capacity.

Our *base station towers* is also differentiation factors. The towers have a modular structure, the height of the modules is 10 meters. The height of the base station towers are between 30–90 meters. This modular system provides a low cost level, since it assures mass-production. The towers are hot-deep galvanized, which is a rather expensive method but the protection level is much higher, and because of this special galvanization method, the towers do not require regular maintenance, which also reduce costs. In the rural areas our antennas are quite high, in comparison with others, since the height of the towers increases the quality of the coverage, which is our main target [5].

The already mentioned *Repeater Program* is to extend the coverage area of some of our base stations. Repeaters provide a cost effective way of enhancing or supplementing coverage at areas where no considerable extra capacity is needed. Repeaters can enhance or supplement coverage mainly in office buildings, underground parkings, and in different outdoor applications, like for example in holes (dead spots), fringe areas (marginal coverage) and corridors (roads, tunnels). The advantages of using a repeater is that it is a cheap, cost efficient equipment, it does not require a transmission network, it can be quickly installed, and there is no need for allocating separate radio channels. The disadvantages of a repeater is that it does not provide additional capacity, it can overload the BTSs, it has a limited output power, so a limited coverage area can be only provided, and it can destroy quality at areas of almost equal field strength. The potential problems arising when using repeaters can be, and at Pannon GSM are avoided by careful planning. Altogether our Repeater Program is an effective tool to increase coverage areas where our customers' needs require it.

The *Microcell Program* is to increase the capacity and quality of the coverage. Pannon GSM has already several microcells in the urban areas where coverage and capacity need to be increased. Microcell applications are useful where the number of subscribers grow in such an amount, that the cell capacity is overloaded. In these cases the cell is splitted into smaller portions, so called microcells, thus multiplying the number of available channels. The importance of microcells will grow in the future, since the number of subscribers is steadily increasing in the urban areas.

There are several *other differences and special features* that distinguishes Pannon GSM's system from the other operators.

- In the idle mode, the parameters are set in such a way that the handset *batteries can operate longer*.
- We have a fully operational *Short Messages Service*, which provides both short message origination and termination. Pannon GSM customers can send or receive short messages, if the roaming partner's system is technically capable to transfer these messages.
- Forwarding a call to the voice mail in our system is done by the *Operator Controlled Call Forwarding* service, which provides a greater convenience than Normal Call Forwarding, which is widely used by other operators.
- Pannon GSM's customer friendly, flexible system called *Optimum Tariff System* does not require any calculations from the customer, and it does not require any choice between different tariff packages, since it automatically calculates the appropriate tariff, according to the customer's own call-time.

5. PROBLEMS AND OBSTACLES OF SYSTEM DEVELOPMENT

Pannon GSM system development is facing several (but strategically not severe) obstacles and problems, like for example:

- *difficulty in getting construction permissions*: the problem is that most of the municipalities would like to have GSM coverage in its city or territory, but they would like to have the base station to be set up out of their region, which is in most cases physically impossible. In many cases difficulty in getting construction permissions holds up our system development plans, preventing us to meet our customer's needs in a short time.
- some of our customers and some other people are afraid that the use of *GSM phones can be hazardous to ones health*. According to international research results, we can state that using the frequencies of mobile communications does not have any cancer risks, or cancer promoting effects, nor any other effects that are hazardous to our health. The international GSM community is trying its best to inform and convince GSM users and the public opinion, that using the GSM system does not harm the human body in any way [6].

6. CONCLUSIONS

As it can be seen from the above mentioned facts about Pannon GSM's system development, Pannon GSM's short history shows that with all our efforts we are developing a GSM system, which is to serve the Hungarian customers' needs on the long term. Having in mind, that our company did not benefit from any other mobile company's already installed infrastructure, so we had to build and develop our system from the absolute zero level, we think that the development of our system shows remarkable results, and can be compared with even the best international operators. We think that further concentrating on our customers' demands, we will be able to satisfy their needs, and we will be able to meet our primary aim: to provide outstanding value and choice to the Hungarian Business Community and the private sector as well.

REFERENCES

[1] M. Mouly, M.-B. Pautet: The GSM System for Mobile Communications. Michel Mouly, Marie-Bernadette Pautet, 1992.

[2] T. Rakó, O. Mikkelsen: Pannon GSM's Approach to Service Quality Assessment. To be published in *Híradástechnika*, 1995.

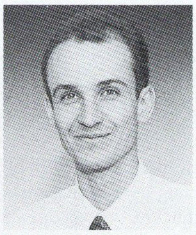
[3] T. Rakó, Gy. Drozdy: Introduction to the Global System of Mobile Communications. *Journal on Communications*, May-June, 1995.

[4] T. Rakó: Új szolgáltató a mobil távközlésben. Bemutatkozik a Pannon GSM Távközlési Rt. *Magyar Távközlés*, 1994.

[5] P. Sebestyén: Az állomások telepítése GSM-hálózatban. *Magyar Távközlés*, June 1995.

[6] Gy. Drozdy, A. Gárdos: Van-e káros biológiai hatása a cellás rádiótelefonoknak? *Magyar Távközlés*, June 1995.

Győző Drozdy is presently the director of External Affairs Department at Pannon GSM. He joined the company on September 2, 1993. Prior to his present position he had other responsible positions, e.g. Deputy Technical Director. Before that he lived in Finland from 1986, leading a GSM simulator project in the Technical Research Centre of Finland for Telecom Finland so he was involved in developing Telecom Finland GSM network. He holds the Bachelor of Sciences, the Master of Sciences degrees in electrical engineering and the Ph.D. from the Technical University of Budapest. He also wrote about 40 scientific publications.



Attila Gárdos finished his studies and received his diploma in economics at the Budapest University of Economic Sciences, Department of International Relations in 1993. He joined Pannon GSM in October 1994. He is secretary for conciliation issues in telecommunications at the Department of External Affairs.

NMT 450 SYSTEM DEVELOPMENT

M. PAPP

WESTEL RADIOTELEPHONE LTD.
H-1033 BUDAPEST
HUSZTI U. 32.

1. THE FIRST MOBILE CARRIER IN HUNGARY

The first cellular mobile service in Hungary — using the NMT 450 technology — was launched 5 years ago by WESTEL Radiotelephone Ltd. The owners of WESTEL are MATÁV Plc. & US West International.

2. WESTEL'S MILESTONES AND RESULTS

December 4, 1989	Company Foundation
October 15, 1990	Launching Mobile Telephone Service with 3 cells, 48 channels and 1 Digital Exchange
December 31, 1990	2.000 subscribers
December 31, 1992	3 Exchanges, NMT 450i SW-version, 22.000 subscribers
December 31, 1993	Countrywide service coverage with 167 cells, countrywide technical, sales and customer care networks, 40.000 subscribers
April 1, 1994	Starting Competition
September 1994	N°4 on the Hungarian top 200 list for 1993
December 31, 1994	236 cells, 4035 operating channels, 60.000 subscribers
Januar 1995	Launch of Voice Mail and Fax Mail Services
May 1995	Starting Audiotex and Fax-on-demand Services
September 1, 1995	325 cells, 4869 operating channels, 66.700 subscribers

3. TECHNICAL DEVELOPMENT OF THE NMT TERMINALS

Due to the rapid development of the radiotelephone equipment during the last four years

- the weight of the radiotelephone sets decreased from 5.2 kg to 35 dkg;
- without additional charge of the battery:
  - the sets are ready to operate for 96 hours (comparing to 6 hours),
  - while the user can talk continuously for 1 hour, or more(see Fig. 1).

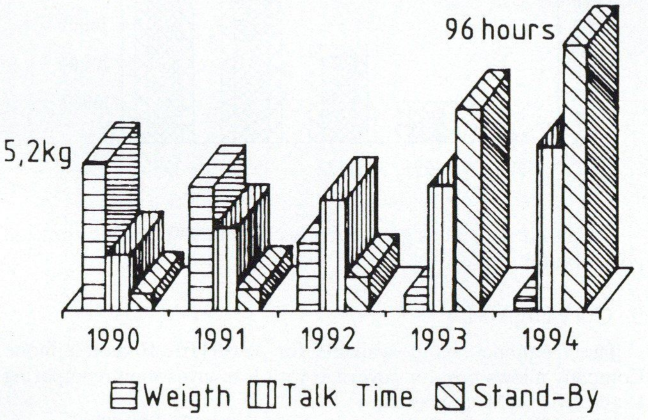


Fig. 1.

4. MARKET EVOLUTION

Privatization in Hungary accelerated the evolution of the market (see Table 1).

- Braking the monopoly of MATÁV Local Telephone Operators started to use the most up-to-date technology: digital exchanges, fiber optics.
- The backbone supplier MATÁV built PDH, SDH based network with new services to be introduce: ATM, Managed Data Network, Frame Relay, ISDN.
- Based on this background from the 900.000 small entrepreneurs some become dominant using enhanced telecommunications services.
- While in 1990 business users produced the main traffic for the radiotelephone service operator, today the mobile phone is on the consumer market.
- The insufficient capacity for landline users and the fast imple-

mentation of the radiotelephone services yield extremely high Minutes of Use figure in radiotelephony which is till high in Hungary comparing to other Western Countries.

Table 1.

1990	1995
Very poor landline service	Developing landline services
Many starting (hopeful) small business	A few stable, more changing business
HTC monopoly	Landline and mobile competition
Business market	Consumer market
Extremely high MoU	Still high, but decreasing MoU

5. DYNAMIC EVOLUTION: SUBSCRIBERS AND REVENUE

As we have seen the technical development of the NMT (and GSM) equipment in the world went through on a dynamic evolution during the past 5 years. The market situation in Hungary was also ideal for the mobile telephony business when WESTEL appeared on the telecommunications market.

WESTEL Radiotelephone Company recognized this attractive situation, and with intensive technical investment and marketing strategy gave space for a dynamic evolution.

The growth rate of subscriber number and revenue in each year was much higher than expected, so the investment returned soon (see Fig. 2).

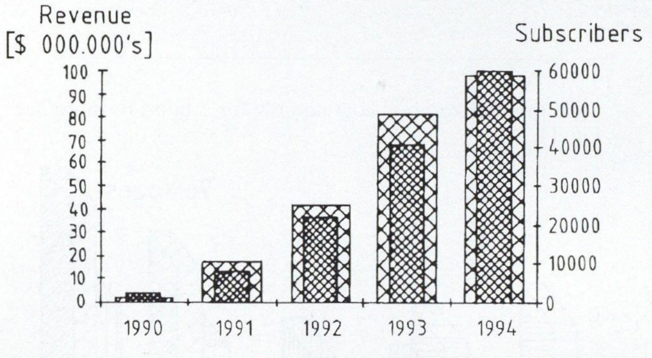


Fig. 2.

The GSM operators grew even faster, but will reach saturation point sooner.

6. COVERAGE

The frequency band available for WESTEL Radiotelephone Company allows greater coverage with less investment comparing to the two GSM operators.

With 15W transmitting power the geographical NMT coverage is more than 91 % of Hungary, which is equivalent to 97 % population coverage.

On the other hand the frequency band available for our concession company limits the use of our terminals for Hungary only. International roaming is not possible as the neighboring countries use different spectrum.

7. THE CHALLENGING ENVIRONMENT

The way of life within the Community has been changed, new legal regulations are in force (e.g. Concession, Telecommunications, Frequency Acts). Beside the social and economical changes the infrastructure developed very rapidly. The annual growth of telephone lines (landlines) is min. 15 % (regulation) and the privatized MATÁV and the LTO's will implement an extensive landline coverage. VSAT service providers, paging companies, audiotex service companies are trying to find their market place and share. The quality requirements are more serious day-by-day, quantity is no more enough.

Following the decision of the Hungarian Government and the tender process two GSM licence were issued in 1993. The operators — WESTEL 900 GSM & PANNON GSM — launched their services on the 1st of April 1994.

This is a serious challenge and WESTEL has to answer it.

8. ANSWERS FOR THE CHALLENGE

Beside the carefully developing core service in the competing environment WESTEL — as the matured operator — had time to make preliminary steps planning its future in advance.

Beside the current fruitful service WESTEL is prepared to introduce radio telecommunications services based on new technologies. Utilizing the experience and existing infrastructure new services can be implemented with less investment and within shorter period of time.

On the other hand most of the targeted services suffer from the lack of regulations and standardization causing open questions for the service providers.

The main lines of our answer are:

- NMT 450i System Development;
- Value Added Services;
- Total Quality Management;
- Proactive Marketing Policy;
- New Handheld Terminals;
- Diversification – New Mobile Services.

9. THE NMT 450i SYSTEM DEVELOPMENT IN 1995 (EXPECTED)

New radio cells:	98 pcs (41 %)
New radio channels:	965 pcs (24 %)
New microwave hops:	
• 8 Mbps – 20	
• 34 Mbps – 6	
• 140 Mbps – 7	
New Mobile Both-way Trunk Device (2 Mbps):	84 pcs
New investments	1.5 Billion HUF

10. VALUE ADDED SERVICES

Data transmission is the most evident network service on the NMT 450 system:

- *Vertical* data transmission is used between cellular modems such as AT&T Paradyne or Zyxel with 9.6 kbps effective speed.
- *Horizontal* data will be available for NMT users very soon when our new Data-Access Pad will operate.

WESTEL's *Voice-mail & Fax-mail* services were launched in January '95. The COMVERSE Trilogue Infinity System provides the maximum flexibility, availability, security and safety with its integrated HW & SW platform.

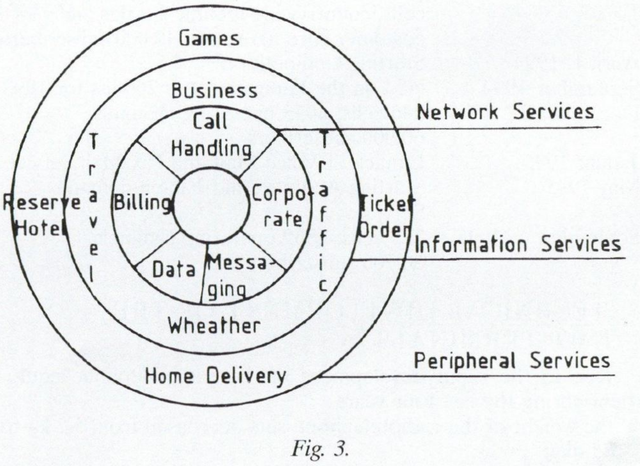


Fig. 3.

Our smallest and maybe kindest baby is the so called *"06 60 Voice Journal"*. This is an *audiotex and fax-on-demand* service based on the platform and features of our Voice-mail system.

It means that *we moved forward from the network services layer to the information service layer* (see Fig. 3). It is a *pioneering work*, because according to our information *this is the first audiotex among the NMT carriers and we can't find similar among the other European cellular service providers.*

The starting services of the *"06 60 Voice Journal"* are *traffic information, travel agencies' proposals, gardening information, business news, entrepreneur information, weather forecasts and WESTEL news for normal tariff or for free of charge.* The range of opportunities is unlimited, so several other services are under preparation.

11. TARIFF STRUCTURES

Only "future" radio telephone technology (like DECT) can compete in speech quality with the landline telephone service quality, but mobility is such a value for what customers are ready to spend more.

This is why mobile tariffs are higher comparing to normal PSTN prices.

The mobile operators use different tariff structure, introducing always changing price packaging. To compare these packages to each other is difficult even for a service supplier, but practically there is no great difference between them (see Table 2).

Table 2.

	WESTEL 450	WESTEL 900	PANNON GSM
Price packages	4	3	1
Connection Free (USD)	198	219	218
Monthly Fee min. (USD)	15	15	24
Monthly Fee max. (USD)	43	41	24
Free Minutes (min.)	0–200	0–75	0
Peak hours charge (cent/min)	14–29	14–27	19
Other hours charge (cent/min)	6–12	10–19	10
Off Peak hours charge (cent/min)	6	10–19	10

12. FUTURE IS MOBILE

Mobile communications represents one of the major areas for potential growth in the communications and information sector.

In the 1991–1993 time interval the number of cellular network subscribers has doubled in Europe.

From the studies undertaken mid-range estimates of the use of mobile communications in Europe suggest that there could be 40 million users by the year 2000 and up to 80 million users by 2010 and 20 % to 30 % of business users can be expected to have personal mobile communications by the year 2000.

The European forecasts for the fixed and mobile service providers' revenue are shown in the Fig. 4.

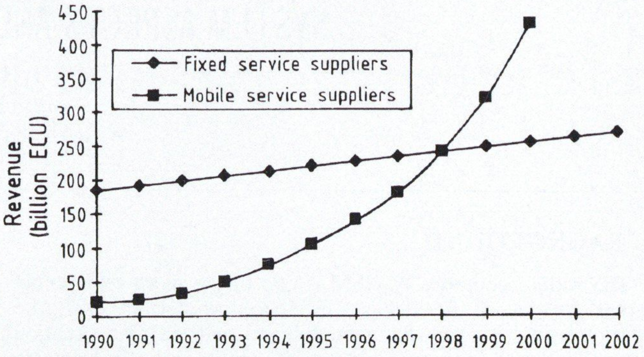


Fig. 4.

The planned investments of mobile communications in the European Union by 2000 (cumulated) is 27–45 MD ECU, which means 7–13 % of the total telecommunications investments.

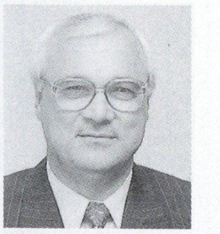
Value added services and data transmission will have enhanced role in mobile communications as well.

The Commission of the European Communities issued a document in Brussels on April 27 1994. This "GREEN PAPER" shows the common long term approach of the mobile and personal communications in the European Union.

Hungary would like to join the Union soon so the players of the Hungarian telecommunications market, so we have to take into consideration the contents of it seriously because the basic principles and action lines are identified, the opportunities are estimated in the document.

- Further liberalization is expected.
- Dual (Land and Satellite) Services take off.
- Share of GSM reaches 66 % (2000), FPLMTS (3rd generation) comes from 2000 (CDMA?).
- Number of Subscribers grows from 14.1 M (end of 1994) to 44.5 M by 2000 (source: ROMTEC), 60-65 M may be in 2005.
- In 1996-1997 new market opportunities revitalizes analogue vendors.
- Value Added Services (VAS) proliferate by multimedia information vendors.
- Terminal prices and tariffs continue to decrease.
- New user interface: voice control – Personal Communicator (multimedia).
- The Hungarian market size is 330 K (net) in 1996; 630 K (net) in 2000.

We have to prepare ourselves for more complex, integrated and interactive telecommunications and information service provision using decentralized systems which leads to the new Information Society.



Miklós Papp graduated at the Budapest Technical Universitys Faculty of Electrical Engineering at the Communications section in 1968. He started his carrier as a R&D engineer at the Finommechanikai Vállalat (Precision Mechanics Company). First he was tasked with the adaptation and implementation of postal broad-band microwave equipment then later he gained experience in the professional (military) mobile communications systems in addition to the civilian microwave technique. He was involved with the development of existing microwave equipment, satellite receivers and the microwave TV-signal distribution systems (AM micro). He was commissioned to India for a couple of years, where he had the opportunity to improve his English. The next step was the establishment of SAT-NET Műholdas Szolgáltató Kft. (SAT-NET Satellite Service Provider Co. Ltd.) by MATÁV which was a pioneer venture. He was the managing director of this venture for 2 years and led it successfully reaching a dominant position in the Hungarian market, worthy of the reputation and importance of MATÁV. He was appointed to the General Manager of WESTEL Radiotelephone Ltd. in December 1993.

SYSTEM CONCEPTS

SYSTEM ASPECTS AND PHILOSOPHY OF GSM

T. HAUG

TELIA AB
LINDVÄGEN 37
19170 SOLLENTUNA
SWEDEN

1. BACKGROUND

The wide acceptance of GSM is one of the more remarkable success stories of the 1990's. From a slow start in 1991, the development has gradually gained speed and led to a situation where over 100 operators in some 60 countries in- and outside Europe have accepted GSM as their standard for digital mobile communication. In addition, we have a number of operators in several countries that have opted for the GSM derivative DCS 1800 (in some cases transposed to the 1900 MHz range) as their standard for a Personal Communications Network. Considering this acceptance and the international roaming in GSM, it is no exaggeration to say that global mobile communications is becoming a reality.

There are several reasons for this success, such as

- the very high flexibility of GSM regarding introduction of new services;
- the feature of international roaming, a feature which was never before tried outside the Scandinavian countries, and which is very much in line with the present trends in the world towards open borders and international communication;
- the extremely high degree of security;
- the large number of data services implemented in the system, services which are no doubt going to be a valuable complement to the speech services;
- there is no other system that can claim to be a world standard, so that an operator who chooses GSM will not end up with an untried technology, nor will he have to install unique equipment which would forever tie him to one particular manufacturer;
- last but not least the weight of large numbers. The large volume production of GSM equipment, made possible by use of modern digital technique and strict standardization, has of course contributed significantly to the low cost and the acceptance of the system.

Since the topic of this session is "System Aspects", it might be appropriate to explain the philosophy behind some of the more important decisions that were taken, seen against the background of the environment at the time.

2. TERMS OF REFERENCE

The goal was to find the best compromise, in view of the expected applications of the system, between high spectrum economy, low cost, high speech quality and other conflicting requirements. The choice of analogue or digital technology was not mentioned in the terms of reference, but would have to be addressed in due course. It was agreed from the start that there must be the fullest possible utilization of recent developments, such as the ISDN, within the limits set by the radio environment. The system would have to offer the same or similar services as the fixed network. Furthermore, since the system would be introduced in competition with the first-generation systems such as TACS and NMT, it would at least have to be equal to those systems in a number of the following respects and superior in at least one of them:

- frequency economy;
- quality of speech transmission;
- cost of the mobile unit;
- cost of the system infrastructure;
- viability of handheld mobiles;
- ease of introduction of new services;
- security.

The air interface takes a particular position among the interfaces in the system, due to the fact that international roaming has always been considered as one of the great features of the system, one that obviously requires a standardized interface. It would have been possible to design a system in which nothing beyond the air interface was standardized, but it was realized that in order to meet the requirements for

- standardized ISDN-like service;
- close coordination with the multitude of different networks in Europe;
- drawing full use of CCITT SS7 and other novel features in the fixed networks;
- exchangeability of equipment, an important aim in this era of open borders;

it was necessary to go far beyond the air interface, so a number of interfaces in the network part had to be specified. The idea that there should be well standardized interfaces was a new principle in the field of mobile communications. Most previous systems were designed with proprietary interfaces, with the consequence that when an operator had installed a system from one manufacturer, he was permanently tied to that manufacturer for additions to the system. Furthermore, in order to secure competition between suppliers, an open structure with non-proprietary interfaces was considered essential.

One of the fundamental considerations was the range of services to be offered, since this choice would have a considerable impact upon the entire system. The first generation systems, NMT, TACS, AMPS etc. are basically telephone systems with radio access. However, an important strategic target of GSM is the mobile office of the person travelling for business, so it is essential to give users access to as many features of ISDN as possible. In addition to telephony, a wide range of services was therefore foreseen. This will no doubt lead to a much better utilization of the radio medium because of the high efficiency of data communication compared with speech.

3. ARCHITECTURE

Three distinct functional blocks can be defined (see Fig. 1):

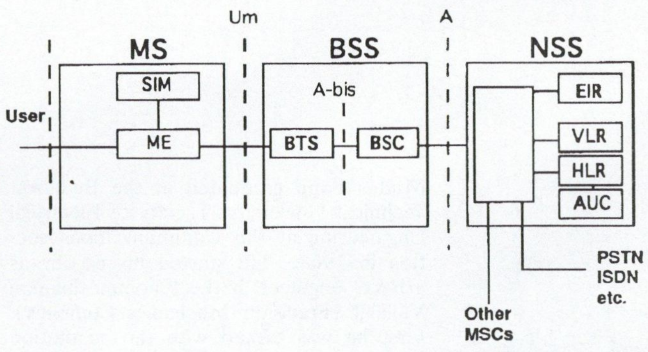


Fig. 1. GSM system architecture

The Mobile Station (MS) comprises two elements, the Mobile Equipment (ME) and the Subscriber Identity Module (SIM). The ME is an anonymous, non-customer related piece of mobile equipment which the user purchases from a dealer. The SIM is a smart card, issued at the time of subscription and containing a great deal of subscriber data. Thus, the user personalizes his ME into an MS by inserting the SIM.

The Base Station Subsystem (BSS) links the MSs in a certain area with the network subsystem of GSM. It consists of two functional blocks:

- Base Transceiver Station (BTS), containing the transmitter and receiver equipment and connected via the "A bis" interface to the;
- Base Station Controller (BSC), in effect a small switch in charge of the the switching functions in the BSS, i. e. controlling handover between cells and management of the radio channels. The reason for the split between the BTS and the BSC, an interface which might be considered to be an internal matter for the manufacturer, is that integration of the BTS and the BSC, attractive as it might be in a big city with dense traffic, would not be economical in sparsely populated areas where distances between the base stations are large and the traffic is low. By separating the two and defining their interface, a suitable solution even for such areas could be found, and at the same time the principle of open, competitive interfaces could be preserved for the two units.

The Network and Switching Subsystem (NSS) is the block which performs the switching in the system and also takes care of the communication with other networks, such as the PSTN, ISDN and others. The NSS also performs the necessary adaptation of both rates and protocols between GSM and the other networks. The central unit in the NSS is the Mobile Switching Centre (MSC), which communicates with the BSS through the "A" interface. It performs the switching functions for MSs located in a certain geographical area, allocates radio resources, commmunicates with the data bases in the system, etc.

Three functionally different data bases are used in connection with the handling of the traffic, i. e. the Home Location Register (HLR), the Visitor Location Register (VLR) and the Authentication Centre (AUC).

The HLR handles the management of the subcriber information such as the services, some location information enabling the routing of calls towards the area where the subscriber is currently roaming, the correspondence between the subscriber number used to call him from the telephone network and the ISDN number used in the GSM system, i. e. information of a medium and long-term character.

The VLR handles the information about the subscribers currently roaming in the area which the VLR controls. When a mobile station appears in a location area it starts a registration procedure, and the VLR stores the information required to control the mobile station and set up calls to and from the MS and keeps track of the movements of the subscriber, i. e. it handles information of a short-term character. Because of the very heavy flow of information between the VLR and the MSC these two units are usually integrated into one unit, but specifications exist for the case that they are separate entities.

When a mobile subscriber is called, its HLR must be interrogated to get the necessary information. If the call is coming from the telephone network, the interrogation cannot be done from that network so the call is routed to a specially appointed unit called the gateway MSC (GMSC), which may or may not be contain ordinary MSC functions, which performs the interrogation.

The AUC is a strongly protected data base handling the authentication and encryption keys, as will be shown later. It communicates mainly with the HLR.

A fourth data base, the Equipment Identity Register (EIR) is concerned with some administrative routines, such as tracking of faulty or stolen equipment, but has nothing to do with the traffic handling.

4. SERVICES

The GSM offers its customers a far wider range of services and features than any previous system.The Mobile Office is a target group of GSM, so GSM naturally offers a large number of data services. When fully equipped, the system will offer basically the same data services using the same terminals as the fixed network, within the limitations set by the radio path. In addition, there are some other services, such as the Short Message Service.

Using the ISDN definitions, GSM services are divided into three categories (see Fig. 2):

Fig. 2.

1. Bearer services, which provide transmission capability between access points. One example of this group is circuit switched synchronous data transmission.
2. Teleservices, which are based on the use of one or more bearer services, provide complete communication capability including terminal functions for communication between users. One example of this group is telephony.
3. Supplementary services, which have no meaning alone, but which are used to modify a tele- or bearer service. An example of this group is Call Forwarding On No Reply.

The use of data transmission in the fixed network is increasing, so GSM had to provide a wide variety of such services. The fact that GSM is a digital system made this easier. A reference configuration, showing the functional interfaces in an MS, is shown in Fig. 3. The Mobile Termination blocks, MT 0, 1 and 2, support functions in the radio interface (Um) and adapt the information flow to those required by the terminal functions at the access points 1 and 2 ("S" and "R" points). The simplest mobile termination is MT 0, an integrated arrangement of the terminal equipment and the mobile termination functions. An example of this basic station is a speech terminal for telephony. TE 1 and TE 2 are terminals with respectively ISDN and non-ISDN (example: V- or X-series) interfaces. If necessary, an adaptation equipment TA is converting a V or X interface to an ISDN interface.

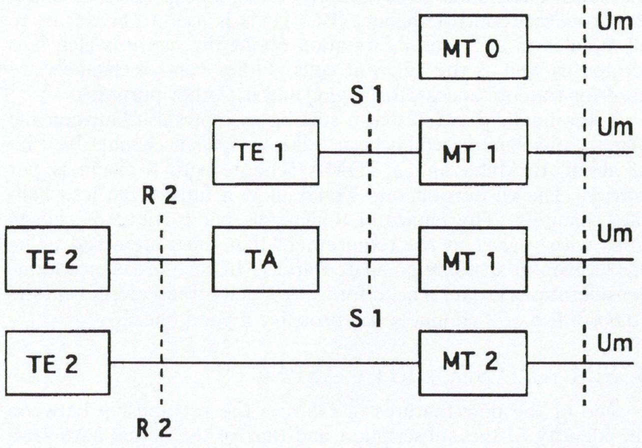


Fig. 3. GSM reference structure

5. RADIO ASPECTS

The air interface (Um) is the most important of all the interfaces in the system. Clearly, without a well standardized air interface, there cannot be international roaming, and it is also of crucial importance for spectrum economy and speech quality.

The terms of reference did not in any way direct us to base the system on digital modulation,- it was up to the committee to show the merits of digital modulation and to show that it would be superior to analog modulation. Probably nobody expected that the end result would be anything but digital, but the viability of this had to be shown in competition with the existing analogue systems, so extensive tests were performed.

It was decided in 1987 that the air interface should be based on digital techniques and on the TDMA access principle. The most important task was of course to secure the spectrum economy of the system, the crucial point of any system, and was also a very important point in the modifaction work done on the North American AMPS system, where work was going on to introduce digital modulation. However, the European situation was different in one important respect: While there was no new spectrum available in North America, and any modifications therefore had to fit in with the existing analogue system, the GSM band in Europe was by and large unused, so the designers had much more freedom.

Two main avenues were explored in order to improve the spectrum economy:

Firstly, the cell size had to be reduced in high-traffic areas, something which required a very fast handover process, since reduction of the cell size obviously led to a larger number of handovers. The TDMA is very well suited to such a fast handover. The reason is that since the mobile is occupied only part of the time with transmission and reception on its own channel, it can use the remaining time to monitor other channels. This is utilized in such a way that the mobile, when active, is scanning the frequencies of the broadcast channels of the adjacent cells (the channels being indicated to him by his own base station via its control channel) and thus it can have a full picture all the time of the relative field strengths of the base stations in the area, thereby enabling the mobile to make a fast decision concerning a handover.

Secondly, the reuse factor had to be improved by increasing the resistance to interference through the means of coding and error protection, and also by introduction of frequency hopping which averages the effects of interference. In addition, the interference level was reduced by power control or discontinuous transmission (activity detection), so that transmission is interrupted when the speaker is silent during a conversation.

One of the advantages in a time division system in mobile communications is that it makes it very easy for the designer to split the radio channel into many logical channels with different capacities, something which is very handy not only for increasing the traffic capacity but also for control of the system.

The system has two groups of logical channels, i. e. the traffic channels (TCH), for transmission of speech or data, and the control channels (CCH), used for signalling. One of these, the broadcast control channel (BCCH) is is used to broadcast to all mobiles in the area information about the cell in which it is located as well as the adjacent cells. Other control channels are used for random access, for paging and for other purposes.

It was finally decided that a suitable compromise between the many requirements would be a full-rate speech channel bit rate of about 16 kbit/s and a TDMA scheme with 8 channels per carrier. The chosen bit rate would allow a future split into half-rate channels. The choice of 8 channels per carrier was chosen i. e. with regard to the requirement that the system had to be viable even in sparsely populated areas. In such areas, economic considerations create a need for low-capacity transceivers, and the compromise of 8 channels was probably a good one.

6. SIM AND SECURITY ASPECTS

One of the new features of GSM is the relationship between the identity of the subscription and that of the actual hardware, the mobile equipment, ME. In most earlier systems, the identity of the equipment was permanently associated with that of the subscription. It might be possible to sell the equipment to somebody else, for sure, but the identity of the subscription, i. e. the number under which the station was called, was still permanently fixed in the mobile station. This is completely different in GSM, due to the introduction of the Subscriber Identity Module (SIM), which was mentioned above. The ME has no identity associated with the setting up of calls or any other traffic functions (although the identity of the ME may be used for tracing of stolen or misbehaving equipment), and cannot be used at all until a SIM is inserted. The SIM is handed to the subscriber at the time of subscription, and contains a number of parameters associated with the subscription. When it is inserted into the ME, the combination ME-SIM becomes a mobile station, MS, which thus assumes the identity associated with that particular subscription. If another SIM is inserted, the identity changes accordingly.

Among the advantages in this arrangement is that the ME can be used by any number of subscribers, who just insert their own SIM. Or conversely, that the owner of a SIM card can use it in any number of MEs if need be, for example if the ME that he uses regularly has to be repaired and he can borrow another one. Or if his ME is installed in his car and he goes abroad without it, he can just take his SIM along, and incoming calls will then be routed to him and outgoing calls will be charged to his account as if they were set up from his usual equipment.

The SIM contains a great deal of information. In the following the information elements which have to do with security are described.

Firstly, the SIM is PIN-code protected like many other credit cards. The effect of this is obvious. Secondly, the SIM is used in the authentication and encryption processes. This area is linked to the security functions in GSM, and I shall briefly explain how the information is protected in the system.

A radio system is inherently less secure than the fixed network, since the radio waves can be intercepted by anybody with the right kind of equipment. The security functions in GSM are the following:

- Authentication of the subscriber, i. e. a mechanism to secure that the identity given by the MS really is genuine, so that the operator is going to get his money. In earlier systems, insecure authentication functions have caused the operators great losses.
- Encryption of the subscriber generated information, whether speech or data. No public analogue system has an encryption function worth the name, so eavesdropping is always relatively easy.
- Subscriber identity protection, whereby even the identities exchanged on the radio path are encrypted. This makes it impossible to trace the whereabouts of a subscriber.

In the design of the security mechanisms, a serious problem was that although there are well known ways to protect information in fixed networks, the handling of security related information such as keys is difficult in a system where the subscribers roam freely across international borders, between a large number of networks and also communicate via radio.

A very simplifed outline of the security mechanisms are given in the following (see Fig. 4):

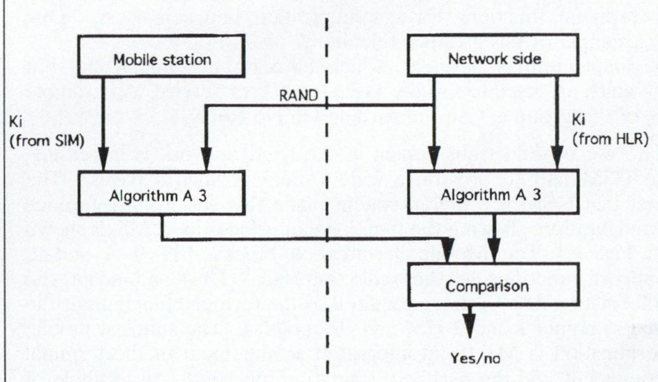


Fig. 4. Authentication mechanism

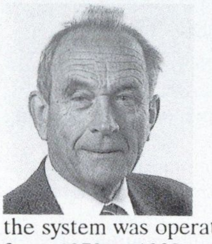
A secret key (Ki), which is kept secret even to the subscriber in question, is permanently stored in the SIM and in the AUC associated with the subscriber's HLR. It is never sent outside the home network and is thus not disclosed to other operators. When a subscriber wants to make a call, a random number (RAND) is generated by the AUC and sent to the mobile station, where it is put through a coding algorithm A3 together with the key Ki, and the same procedure is followed in the HLR. If the two results are identical, the MS is allowed to proceed.

After this process, agreement has to be reached between the mobile station and the fixed side as to the encryption key to be used. The same principle as above of mutual key setting is used even here, and the information used to create the encryption key is the secret key Ki plus the same random number as above, but a different algorithm (A8) is used. The result of this process is the encryption key, Kc. The encryption itself is quite straight forward and performed with the aid of a different algorithm, A5, which is kept secret and is entrusted to the MoU operators.

The next time authentication is needed, a new RAND is used. As a consequence, there will be a new Kc created. This would create a delay problem for an MS roaming outside its home area, since the transmission of keys and codes via international lines would take a long time in many cases. The problem is handled very simply by generating a number, say, 5, of triplets (RAND, SRES, Kc) which can be stored both in the home network and in the visited one. For each authentication a new set of triplets are taken from the storage, and new ones are requested when the supply is running low.

7. FINAL REMARKS

I think one of the most important conclusions that can be drawn from the GSM work is that international cooperation can be made to work if there is a strong common interest in producing results. The benefits of this are obvious, both the international roaming as well as the volume production gains that could be made through standardization were very important incentives for a cooperatitve spirit, and the results are far beyond any expectations in the early days.



Thomas Haug graduated from the Technical University of Norway in 1951. He has been working at Swedish Telecom (lately renamed Telia) since 1966, mostly in the fields of transmission and cellular mobile radio systems. He was with the Nordic Mobile Telephone Group, specifying the NMT system, from the start in 1970 until the system was operational in all Nordic countries in 1982, during from 1978 to 1982 as chairman of the group. He was chairman of the Pan-European GSM committee from its start in 1982 until his retirement in 1992. He is now working as a consultant to Telia.

MOBILE COMMUNICATIONS: DEVELOPMENT TRENDS AND IMPACT ON THE INFORMATION SOCIETY

L. PAP

TECHNICAL UNIVERSITY OF BUDAPEST
ELECTRICAL ENGINEERING AND INFORMATICS DEPARTMENT
H-1111 BUDAPEST
STOCZEK U. 2.

1. INTRODUCTION

In the second half of the 20th century, human civilization reached the limits of a new epoch by approaching the information society. In 1969, during the initial spectacular growth of third and fourth generation computer sciences, the following declaration has been issued by Herbert A. Simon: "During history of written evidence, three events strong enough to reshape mankind can be ascertained: the introduction of agriculture, the industrial revolution, and the computer revolution in the field of information processing." During the decades following this statement, this opinion has been justified by the revolutionary changes taking place around us: a new society is being created, witnessing a spectacular and ever increasing growth of information technology involving the establishment, processing, transmission and storage of information, this being the chief motive power during society's transformation process.

The organization of information society is focused on information, and instead of abundant material consumption, the general dominance of human intelligent creativity is now being emphasized. This kind of development results in several positive effects:

- industrial and economical innovation is accelerated;
- globalization of products and services is supported;
- novel company management methods become feasible;
- state bureaucracy methods are accelerated and changed;
- commercial and business relations are actively supported, thus increasing the competitivity and efficiency of the whole economy;
- the value of products and services is increased by applying informatics;
- learning and teaching is becoming more efficient.

All this means that by the dissemination of information technologies, new perspectives and new industrial branches are created, new relations between individuals and society are established, and by intruding into the private sphere of family life, the recreational and orientational activities of individuals and families are substantially modified. On the other hand, this accelerated development may well give rise to global social tensions as already witnessed in the course of history. Finally, due to the divergent levels of information processing and information transmission, an information gap may take shape between developed and developing regions, thus increasing further the economical and cultural disparities. Not by chance, everybody wants to board the "ship" of the information revolution, thus avoiding to fall behind and to be able to join countries which are successful in developing the infrastructure of information technology, and to establish general economical/social development.

The information infrastructure can be subdivided into four levels:

1. telecommunication infrastructure (telecommunication networks and voice-data-picture type services based on these networks);
2. information networks (computer processing, storage, data bases);

3. application of information (in large systems of state administration, educational, public health, traffic and industrial organizations);
4. information procedures (working style, private ways of living, social and economical values, legal regulations).

The first two and the second two are technological and social levels, respectively. In Eastern Europe of today, the establishment of the first two constitute the key issue, this being the pledge for the countries of this region for joining the economical, commercial, scientific and cultural organizations of continental dimensions.

This presentation is concerned with the technological basis and development trends of a substantial item in the telecommunications infrastructure, the so-called personal communication. This is in line with the future prospects as outlined in the Bangemann report prepared for the European Union Council, and as discussed in the so-called Green Book prepared for the European Parliament and the Commission of the European Communities.

2. DEVELOPMENT TRENDS OF MOBILE AND PERSONAL COMMUNICATIONS

During the last decade, three major trends have been responsible for the development of telecommunications:
1. Globalisztion, i.e. introduction of unified services covering whole continents or even the globe.
2. Integration, i.e. establishment of telecommunication networks capable of voice, picture and data transmission on a unified technical basis.
3. Mobility, i.e. introduction of telecommunication services enabling the subscriber to move arbitrarily over large areas without interrupting his connection to the network.

The importance of developing the telecommunication infrastructure has been strongly emphasized even in early conceptions on the information society. However, the underlying role of mobile and personal communication has only recently been recognized during the rapid development of modern mobile communications technologies during the last decade. It is obvious by now that within telecommunications, this segment is developing at the fastest rate, and in the report on "Europe and the global information society", mobile and personal communication are said to be the indispensable building blocks of the information society. Recent years witnessed a spectacular growth in the number of subscribers to mobile telephone systems. In Europe, more than 11 millions of people are using mobile telephones, and this number exceeds by more than 3 millions the prediction of the Green Book published in 1994. In addition, further mobile services such as pagers, trunked radios for dispatching purposes and mobile data transmission, are used by another 8 million people. It is expected that in the year 2000, the number of mobile subscribers in Europe will be over 40 million, reaching as much as 80 million in 2010 due to the ever increasing extension of personal communication services (PCS).

The market is governed by rapid technical development, business opportunities and falling prices. However, in Eastern Europe, equally important factors are the relative underdevelopment and slow growth rate of the public wired communication network. During recent years, countries with expanding mobile phone markets witnessed a subscriber growth rate between 30 to 40 per cent, and according to investigations, this trend seems to overcome economic recession.

Mobility and new services based on technological development have a decisive effect on the establishment of the information society. In European countries, advantages provided by the information society are thus available for all citizens and business ventures. Mobile communication and, in general, personal communication is becoming an everyday part of business life, with the range of participants extending from the manager of a multinational company to the local plumber or building contractor. Due to further price reductions, introduction of new technologies and decreasing recession, a substantial expansion of the huge mobile communication market is expected during the forthcoming years.

According to the Green Book, mobility is of great importance even for the entire European Union. On the one hand, the unimpeded flow and movement of products, people, services and capital values is directly enhanced by the mobility, and on the other hand, the development of communication networks and services may contribute to the establishment of the European information society, thus helping Europe to maintain a decisive role in today's global economical/social competition. The integration of voice, picture and data transmission, i.e. the introduction of new multimedia and online services will help to enhance the establishment of novel personal communication systems, thereby removing the traditional distinction between fixed and mobile networks and services. Mobile technologies are helping operators to reduce some of their service prices, and by co-operating with traditional communication service providers, these operators may then offer global services covering entire continents.

Within countries, the establishment of mobile communication systems contributes to increase employment and economic growth. In the Bangemann report, this is proved by the example of Germany where 300 thousand new jobs have been created within the mobile sector, and another 100 thousand new jobs within this sector are expected within the European Union.

The expansion of mobile communication is having a substantial effect on the entire telecommunication industry by the rapid increase of the number of subscribers and the traffic. This growth will have an effect even on the traffic of fixed networks because these are responsible to handle most of the mobile traffic.

Taking into account the success of cellular mobile telephone systems, some experts are expecting the subscriber density of mobile and personal networks to reach or even exceed the density of fixed networks. All this means that private and public capital investment is enhanced by mobile communication systems and services, so an increasing share of these systems and services will be realized in maintaining and expanding the communication services in underdeveloped regions.

Four basic objects have been formulated by the Commission of the European Communities:
- the development of mobile services, equipment and subscriber sets should be supported on the Community level;
- common principles should be elaborated to enhance the mobile infrastructure, the development of mobile networks, services and mobile subscriber sets;
- the transformation of the mobile communication market into a huge personal communication market should be promoted, emphasizing Pan-European services;
- the establishment of Trans-European networks and services should be supported, and during the development of the region, the interests of the European Community should be safeguarded.

In order to reach these goals, five substantial changes are proposed by the Green Book for eliminating obstacles in the development procedure:
- Abandonment of exclusive and special rights within the sector, definition of suitable authorization conditions;
- Abandonment of all restrictions of mobile services, regarding both independent service providers and mobile network service providers, applying to free offering of services authorized by individual licences, the provision of services in other EC member states, and helping users to have free access to these services by removing existing restrictions;
- Provision of complete freedom for operators of mobile networks so that they can operate and further develop their systems within the limits of valid authorizations. It should be noted here that the operator should be entitled to use the infrastructure of his own property or the property of a third party, or to share with someone his infrastructure;
- The right to offer, without restrictions, combined services via the fixed and mobile networks, including the rights of mobile operators or independent service providers to hand out offers for obtaining retail authorization of fixed services, further the removal of all restrictions preventing fixed network operators to enter the mobile market;
- Supporting Pan-European operation and services by mutual acceptance of mobile subscriber set type approvals, and by harmonizing the authorization and award procedures.

The above considerations show that in the countries of the European Community, the development of mobile and personal communication segment is regarded as a key domain so that Europe should have a good chance, also in this field, to compete with overseas countries.

3. TECHNOLOGICAL DEVELOPMENT OF MOBILE AND PERSONAL TELECOMMUNICATION

Regarding the infrastructure elements of the information society, i.e. telecommunications and computer techniques, the following technological trends are determinant:

- rapid growth of computer and graphics performance in microelectronic devices;
- dramatic price-per-performance improvement of microelectronic devices;
- abrupt transmission speed growth of communication systems;
- rapid expansion of computer networks, establishment of systems covering buildings, cities, countries and continents;
- intensive unification and standardization.

The development of mobile and personal communication is also based on this technological background. Mobile communication systems are characterized by utilizing wireless, primarily radio transmission so their large scale utilization requires procedures providing economical and efficient utilization of the radio frequency bands which are sparsely available. Following methods are utilized most frequently.

- efficient digital source encoding methods allowing the information (data, picture, voice) to be transmitted over the channel at the lowest possible bit rate, still yielding acceptable quality;
- bandwidth economizing modulation methods requiring sufficiently narrow bandwidth even with digital transmission, i.e. minimizing the bandwidth requirement of the customer;
- efficient trunking methods allowing a few radio channels to serve efficiently several low-traffic customers;
- up-to-date multiple access algorithms allowing efficient utilization of one or more communication channels by widely spread un-coordinated end users;
- the cellular principle, allowing the coverage of extended geographical areas by dividing the areas into cells, and by re-utilizing the already utilized frequency bands in widely scattered areas (cells).

Mobile communication systems can be classified to fall into two large groups, public and private systems. The following is a survey of the present status of technological development for both systems.

3.1. Public mobile communication systems

3.1.1. Cellular radio telephone systems

The present development of cellular mobile radio telephone systems is characterized by two trends:

- changeover from first generation analogue frequency division systems (NMT 450, NMT 900, TACS, C-Netz, D-Netz, Natel C, AMPS, N-AMPS, N-MATS, JTACS) to second generation digital systems (GSM, IS-54, IS-41, NMPTS);
- introduction of continental, even global unified systems (GSM).

An interesting feature of digital cellular system development is the competition between time division (TDMA) and code division (CDMA) systems. The first is represented by the highly successful GSM system of European origin while the second is exemplified by the Qualcom IC-41 system.

Following are the main advantages of second generation digital systems:

- higher transmission rate;
- easy identification of the user (SIM function);
- possibility to provide a wide range of value added services;
- higher spectral efficiency;
- better data protection and encryption facilities;
- Pan-European roaming facilities (for GSM);
- general improvement of services (for GSM).

It should be noted that the system capacity can be substantially increased by increasing the efficiency of source encoding and applying a micro-cellular structure. For GSM, the half bit rate voice encoding development is now in progress.

3.1.2. Cordless telephones

Several technical standards and frequency ranges are presently utilized for cordless telephones. During the early eighties, following the early solutions, the CT-1 analogue system operating in the 914 to 915 MHz and 959 to 960 MHz frequency bands has been introduced in Europe. Unfortunately, this latter band and the GSM band are overlapping.

The second generation CT-2 system, operating in the 864 to 868 MHz band, provides the so-called telepoint function, in addition to the conventional cordless operation. This means that a portable set is able to reach the public network via a public base station. In most European countries, the CT-2 system is used as a conventional cordless telephone system, but in a few areas, the telepoint application is also utilized.

The third generation of cordless phones is represented by the unified European DECT system operating in the 1880 to 1900 MHz band. In addition to the conventional cordless functions, several important additional services are provided by this system:

- cordless PABX;
- telepoint function;
- wireless local loop.

30 million users are expected to use the DECT system in Europe, and it is planned to be directly connected to the GSM and ISDN structures. Compared with the GSM system, the DECT system will be suitable to meet the short range, low mobility communication requirements.

3.1.3. Telepoint applications with public access

The telepoint function can be regarded as a special extension of a cordless telephone system with limited mobility. The system allows the user to reach the public network via a base station serving one or more subscribers. According to the original concept, the telepoint system, similarly to a phone booth, is suitable only for initiating calls from the subscriber set. However, the further developed variant is equally suitable for voice mail services and for calls from the public network to mobile telephones.

Within Europe, the telepoint functions are realised primarily by the CT-2 and DECT technologies. The system has become popular in The Netherlands, France and a few Far East countries.

3.1.4. Paging systems

The first generation of paging systems has been mainly applied in private small area networks. The requirement for defining, developing and introducing a unified European paging system operating in the 160 MHz frequency range has first appeared in the early nineties. Due to European harmonization effects, the ERMES system is suitable to cover large areas, and is thus able to provide public services. By 2010, seven per cent of the European population is expected to make use of the ERMES system.

3.1.5. Wireless local loop

The wireless local loop, used to connect the telephone subscriber to the public communication network by wireless devices, has following main advantages.

- Rapid installation procedure: the subscriber is connected to the public network without wired connection.
- Inexpensive installation, operation and maintenance.

The quality, performance and security of wireless local loop services are comparable with those of the wired network. Depending on the application field, two systems are used: urban systems with a distance range between 200 and 500 metres (by applying primarily CT-2 or digital cellular systems), and rural systems with ranges of up to 20 kilometres.

3.1.6. The concept of a universal mobile telecommunications system

The universal mobile telecommunications system (UMTS) is a third generation digital communications system. It is a further developed second generation system yielding multifunction services featuring:

- service provision over extended areas for private and office customers, fixed and moving customers, both in urban and rural environment;
- suitable to meet several requirements of portable sets, multimedia terminals and vehicle bound sets, and to interface with other terminal equipment;
- supports the Universal Personal Telecommunication (UPT) concept enabling a subscriber having a personal call number to access selected services even while moving, to place and receive calls with any fixed or mobile subscriber set, independently from his geographical position. These possibilities are only limited by the capacity of the subscriber set and the network, further by the regulations and restrictions of the service provider.

It should be noted that the introductory problems of UMTES are dealt with also by ITU under the headword Future Public Land Mobile Telecommunication Systems (FPLMTS).

3.2. Private mobile communications systems

3.2.1. Private mobile radio systems (PMR)

PMR systems have been developed for meeting primarily the requirements of small closed user groups. These groups are operating terminals installed generally in moving vehicles, and are able to establish half duplex links to the dispatcher centre. PMR systems can be classified to fall within two large groups, the independently operated small and medium size networks, and the networks providing services for customers. In Europe, the analogue trunked PMR (PAMR - Public Access Mobile Radio) system has been introduced in 1986. In this system, the applied trunking method allows efficient sharing of the available radio channels between customers, resulting in better bandwidth utilization as compared with simple monitoring systems.

Recent years witnessed great efforts aiming at the introduction and standardization of the unified digital Pan-European trunked system (TETRA - Trans-European Trunked Radio). TETRA is able to provide data and voice transmission services in the frequency bands of 380 to 400, 410 to 430 and 450 to 470 MHz allocated for whole Europe. The system is able to provide also roaming services, and in addition to public services, can also be applied - in a separate frequency band - for meeting security and civil requirements (police, border-guards, fire service etc.).

3.2.2. Mobile data networks

Several variants of low-speed data transmissions such as fax, data transmission via modems etc. are already provided by presently operating mobile communication systems. However, during recent years, the need to serve large user populations at low cost and high spectral efficiency by utilizing the benefits of packet switched transmission has become evident. The rapid spreading of portable personal computers has substantially increased these requirements. In Europe, perhaps the Mobitex system has been mostly utilized, together with other systems offering similar services. During the forthcoming years, the TETRA standard will provide unified solutions applicable to these services too.

3.2.3. Short range digital radio (DSRR)

Regarding the provided functions, the DSRR system (Digital Short Range Radio) is situated somewhere between the CB (Citizens Band) and the professional PMR system. It is dated back to the middle of the eighties, established to meet the requirements of inexpensive wireless communication links e.g. at the sites of industrial corporations, similarly to the Far East practice. The 900 MHz band has been allocated for this service by European authorities but the introduction of the service is now delayed by several factors, the most important one being the incompatibility of the GSM and the DSRR standard.

3.3. Survey of main development trends

The development trends in mobile communication, to be expected in the near future, can be summarized as follows.

- widespread usage of micro cellular radio telephone systems;
- development of personal communication networks (GSM extensions — DCS 1800, CDMA applications);
- general use of the wireless local loop;
- substantial increase of traffic in mobile networks;
- usage of the personal calling number (IN functions);
- introduction of global mobile services via satellite.

REFERENCES

[1] Green Paper, Toward the Personal Communication Environment, Commission of the European Communities, April 27, 1994.

[2] Europe and the global information society, Recommendation for the European Council, May 26, 1994.

[3] Report prepared for the European Parliament and for the Committee of the Commission of the European Community: discussions on the Green Book covering mobile and personal communications, November 23, 1994.

[4] Detailed Spectrum Investigation, Phase II, CEPT/ERC, Copenhagen 1995.

[5] National Informatics Strategy, Budapest, November 1994.

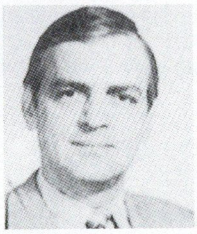
[6] Z. Haas: Mobile Communications Networks, Tutorial 3, *IEEE Globecom '94*, San Francisco, November 28 to December 2, 1994.

[7] Y. Masuda, The information society, OMIKK, 1988, p. 156.

[8] D. Maslmstrom: PCS Overview, US West Advances Technologies, pp. 541-624, 1995.

[9] H. Mitts: The Third Generation: Revolution or Evolution?, *Mobile Communication International*, Vol. 22, pp. 35-38, May 1995.

[10] M. Ellxmann: Mobility on Europe's Infobahn, *Mobile Communication International*, Vol. 22, pp. 35-42, May 1995.



László Pap graduated in 1967 at the Technical University of Budapest from the Telecommunication Branch of the Electrical Engineering Department. He received the candidate of sciences and the Academy doctor of sciences degrees in 1980 and 1992, respectively. Since 1992, he is a full university professor and head of the Telecommunications Department, and since 1994, dean of the Electrical Engineering and Informatics Department. His main interests include communication theory, encoding, modulation, synchronization, further mobile communications and the theory of modern telecommunication systems.

NETWORK PLANNING

NETWORK PLANNING IN WESTEL 900 GSM SYSTEM

A. KOLONITS

WESTEL 900 GSM MOBILE TELECOMMUNICATION LTD.
H-1117 BUDAPEST
KAPOSVÁR U. 5-7.

1. INTRODUCTION

The most spread technology for multiple access wireless communication systems is cellular. This general idea is suitable for phone and data network design anywhere if there is a need for two way communication with the terminals via common resources by multiple access. The mobile networks have some additional, network specific features because of the user's mobility. GSM as one realization of the cellular theory is in fact a product which can be bought on the market. Dimensioning the network from the input data is quite exact even statistical methods are often required and the process is very complicated. Meanwhile putting it into operation however significant deviations can be obtained between the planned and the actual behaviour of the network. The cellular network structure is the mostly influenced part of the system by local characteristics such as terrain, clutter, population distribution, traffic hot spots. The exact location and radiotechnical cell parameters have drastic effect on the size of coverage, the quality and the maximum system capacity. An unproperly located site can destroy the quality within 5—10 other cochannel cells beyond providing poor coverage and quality in its own surface. In such a case the frequency allocation can be performed via substantial capacity loss. What is the optimal location? This is not so obvious. When starting the network rollout maximum coverage is required using as few sites as possible. This is the financial pressure. Later when the system is maturing capacity is the most relevant issue. It means that avoiding interference small cells are required. So the same site should serve both for the short and long term requirements. Among these requirements we should consider the time and cost factors. Most often practical problems cause deviations from the original plan. It is hard work to find the optimal site location but to get and build there the site is also not obvious and easy. Site owners and local authorities are afraid of huge antenna masts, radiation and intermodulation hazards with cable TV. Very often the suitable site location is a deserted hilltop or a dense suburban area only with cottages and no high building in sight. Based on the interference calculations in regular cellular systems and our experience the maximum allowable deviation from the theoretical site location is 1/4 of the cell radius.

WESTEL 900 GSM network rollout started in december 1993. At the end of 1995 almost all the towns in Hungary will be indoor covered and using external antenna the subscribers can utilize the service countrywide according to the coverage map on Fig. 1, where the dark grey area represents 2 W mobile coverage with external antenna. The investment is continuing heavily. Our goal is to provide indoor coverage in every town and larger village and improve the coverage to handheld where it is currently only car mounted. After covering the highways and main roads we are working along the secondary roads. The subscriber number of WESTEL 900 exceeded 100.000 in the summer. The succes of our strategy is appreciated internationally because our company is noted among the large GSM networks wordwide. It should be emphasised that the radio network planning is a result of Hungarian development work. Our network planning staff have experience in planning the 450 MHz network. The accurate and proper geographical, economic observations, experience made it possible to achieve the great success of our company. To manage the planning and rollout with this high speed is based on the immediate feedback from the actual situation to the planning process and continuously monitoring and response to the changing demand or enviroment. Any little information and knowledge utilized by the planners has multipled benefits to the network quality and the costs.

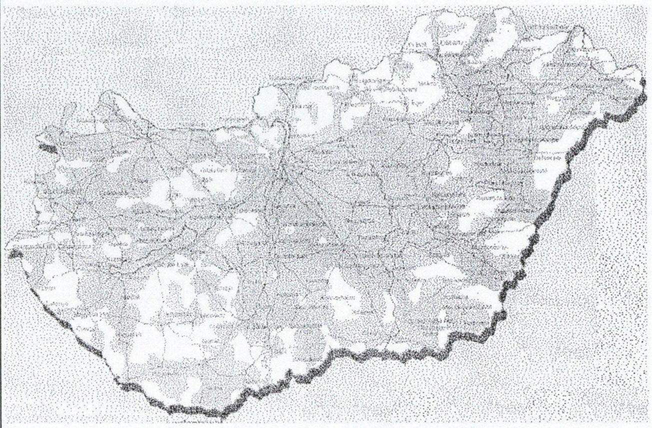


Fig. 1. Coverage area, December 1995

2. RADIO NETWORK PLANNING REQUIREMENTS

A mobile radio network always differs from a classical wireline random access communication network. The differences can be characterised in the followings:

a) The most important is that the spatial distribution of the subscribers is varying in time. It requires the dynamic reconfiguration of the system. A major event, fair or holiday season cause temporary traffic hot spots and the cell capacity should fit them. WESTEL 900 have so called mobile base stations which can help. These truck mounted containers with modular mast up to 30 m height are installed within few hours in a suitable location so the extra traffic can be handled in its region.

b) The end user behaviour can't be always characterized with Poisson distribution. Creating intelligent cell structure we can obtain higher trunking efficiency with higher capacity.

c) Multipath radiowave propagation is occuring resulting in different fading phenomena. Characterizing the coverage and interference calls for statistical calculations. The main features are the lack of line of sight and the multiple reflections in the micro enviroment. This latter can be described with Rayleigh distribution. The macro enviroment can be described with the log-normal distribution. The effect of the two phenomena can be seen on Fig. 2.
So the coverage and the interference limit values can be provided only in statistical way. The coverage for example is defined with the following median levels:

indoor coverage:	−76 dBm
handheld coverage:	−85 dBm
2W mobile with external antenna:	−94 dBm

d) GSM — as one realization of cellular systems — has some system specific features. One of them is the neighbouring channel spectrum overlapping. This requires additional constraint in the frequency planning that the neighbouring channels can't be allocated in neighbouring cells. Often not only the physical neighbour can cause difficulties at inhomogen circumstances. GSM is some 20 dB less sensitive for adjacent than cochannel. The 200 kbit/s data transmission rate is high enough to caues significant time dispersion problem. Substantial energy out of the equalizer window can't be treated. The main feature of the digital transmission mode is the abrubt transition to bad quality as the noise and interference level come close to the signal level. Bit error rate increases exponentially. In practice 1-2 dB level change very often can turn good quality to bad or vice versa. So the network should be fine tuned before putting into operation.

e) Our company's activity is based on the customer satisfaction, so the network planning should be based on the same. For the network planning department the main customer expectations are the followings:

- the service should be available "at any place" so the handheld coverage is an absolut must countrywide;
- mobile telephony exists for everybody, the future is mass market;
- subscriber trust; What does it mean? If someone buys a TV set than of course expect program on channels and trust that the standard won't change until a reasonable time. Buying a fridge you expect and trust uninterrupted mains in the wall outlet preventing the meal against deterioration. When a subscriber buys a mobile phone he trusts that he can use it according to the operator's coverage map.

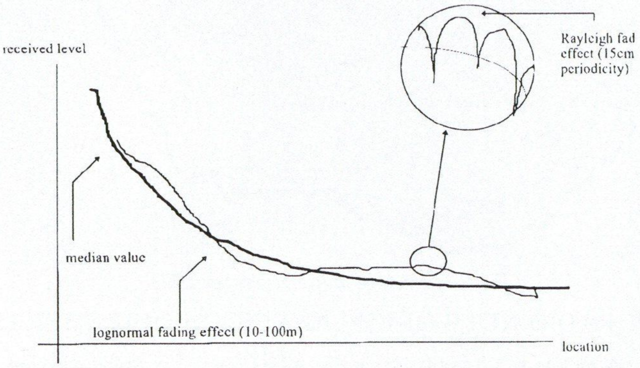


Fig. 2. Received level versus location in a multipath propagation environment

From the network planning point as the system matures cell splitting and power reduction comes. But the subscriber want to use continously the phone and doesn't care the increasing interference level. Huge and careful logistic task is needed to maintain the same service area.

3. CAD SYSTEM PLANNING

Our company has a Unix based planning system called Cellcad. The database is Hungary's 50x50 m resolution digital terrain model with clutter code. Population density is also provided. To help the overview the ordinary car road map is digitalized and fed into the computer. The prediction model is Okumura–Hata. The propagation curves can be approximated by the user via breakpoints even for individual cells if it is required. Delta plot shows the difference between prediction and measurement and suggests deviation. 2D or 3D view of terrain is possible with rotating or zoom. The coverage prediction process is the following:

1. Path profile creation into max. 720 direction. The length of the profile is tipically 20 km in Budapest and 110 km in the country. The height information is created via dual linear interpolation.
2. Effective antenna height determination for each point of the profile.
3. Pathloss calculation.
4. Conversion into quadratical matrix and additiv corrections with the actual station parameters (3D antenna pattern, ERP, direction, downtilt etc). Wave propagation calculation is done with uniform stations (100 W ERP omni).

The advantages of 4. is that interactive modifications can be done very quickly. For example a modification of the main direction is only involves linear recalculations in the 4. but the time consuming path profile calculations and database operations can be avoided. This makes the tool very helpful when preliminary tuning of a composite system can be done interactively.

Additional built in feature is the automatic frequency planning which creates a frequency allocation fullfilling the editable border conditions. These border conditions are the interference mean value and the corresponding location percent, priority order for alteration (absolute-preferred-none). Both co and adjacent channel interference can be calculated.

Report function is available in many cases so detailed statistics can be obtained about coverage area, interference percent, traffic distribution, capacity allocation etc.

The planning procedure is not based exclusively on the aforementioned CAD system. The computer can be as accurate as the data fed into it. In a heavy urban enviroment where cell radius is a few hundred meters and buildings, street orientation affect coverage the computer can't give accurate predictions. For microcell and accurate interference planning additional data is required. All the perpendicular or parallel street orientations, building heights, trees, metal materials fall outside the computer's considerations. Test measurements can be the solution in these cases. Our company has a Network Information System (NIS) which extracts the data from the BSC-s and MSC-s. Trends can be created to show the traffic growth and predict the optimum timing of capacity increment. Handover and call statistics help to tune the system. 15 minutes after an action the results can be checked in the NIS.

4. BUDAPEST NETWORK PLANNING

Special attention should be paid for the capital of Hungary where the 1/5 part of the Hungarian inhabitants live and the economy, business is focused. It is only a 600 square km area. In this area where 20 sites created coverage at the beginning now on 80 sites some 200 cells are operating. The average frequency reuse is 20 times, but at least 17. The ordinary cell radius in the city is around 500 m so the maximum deviation at site selection is 100–200 m. The inhomogenous propagation effects does not allow the implementation of a theoretical regular system. From cell planners' point of view the capital has the following main features:

a) The river Danube distributes the city right in the most dense downtown area causing an open area corridor with zero traffic. The propagation over water has much less loss than in the heavy urban area in the neighbourhood. Inhomogenous cell shapes don't allow the classic subdivision towards the outer districts.
b) Both east and west directions from the river the terrain height is growing which means long haul disturbance between the cells standing on the opposite edges of the capital. The hills are built in up to large heights but the cellular systems are basically two dimensional. So extreme height differences can't be handled by the system and higher cochannel interference may be expected because in three dimensional cases the classic interference calculations are not valid.
c) In the city center the high buildings with narrow streets cause extra high pathloss. In the outer districts the iron-concrete block of flats are source of shadowing and reflection.
d) The majority of the potencial traffic is concentrated into a 5x7 km area where the offices, business centres and car traffic density are the highest.

Due to the inhomogenous distributions mentioned above the cell structure should be "pre-distorted". The pre-distortion is trying to compensate the inhomogenous conditions and transform the network to a so called quasy regular system. Than in this quasy regular system the well known calculating methods can be used. So in the real network the site allocation doesn't fit to any raster and base stations ERP scaling is used to maintain the interference balance. Narrow vertical pattern antennas facing to the hills are downtilted to avoid longhaul interference. Dynamic power control is used in uplink and will be implemented in downlink also whenever it will be available. The discontinous transmission could be characterized statistically with difficulty but anyway we can say it is a helpful feature to increase network performance. We shouldn't forget about the conditions when propagation is not according to Okumura–Hata. In case of microcells basically different models can describe the effects. The line of sight propagation has much role and the antenna height/coverage gain function is also different. For these cases the Walfish–Ikegami model is more adequate however in-building coverage predictions are based on other empiric models and many test measurements. At the frequency planning we don't download directly the computer's results but only treat as a suggestion. Than corrections are made based on measurements and considerations which result in a different and more sophisticated frequency allocation and system tuning.

5. RURAL NETWORK PLANNING

The computer — due to the high resolution database — provides very accurate coverage and interference predictions because the cell radius is nominally 10–15 km where 50 m resolution is good enough. Utilizing the experience in the 450 MHz system planning it was obvious that during site selection we should consider the universal requirements for a cellular base station and not only for a GSM one. Than the structure would fit all cellular systems such as GSM 900, GSM 1800/DCS, NMT 450. Of course this is not possible in all cases but we examine it before any site selection. The typical site configuration in a rural enviroment is an omni station which can be seen on Fig. 3. In towns we start with sectors or prepare for sectorizing maybe we use overlay cells.

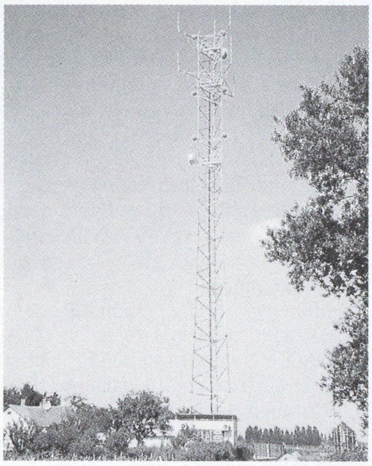


Fig. 3. Lajosmizse GSM + NMT

In the country border area due to strict restrictions in CEPT 20.08. rec. the average cell surface is 30–60 % compared to a normal cell. On a preferred channel the maximum allowed fieldstrength is only 19 dBμV/m which equal –118 dBm. If we compare it with our coverage limit of –94 dBm than it's obvious that the border area requires more sites than normally expected just from studying the terrain and clutter. On a non preferred channel the same limit already exists at the border line. The solution is installing sector cells facing into the country with moderated ERP. Extremely hard planning considerations exist along the northern border between Lábatlan and Salgótarján, here the terrain in Hungary is hilly but in Slovakie it is rather flat. So the effective antenna height is the largest to the disturbing direction and small into the useful direction.

To eliminate small coverage holes in valleys and villages sometimes we use repeaters. These duplex amplifiers decrease the pathloss additively. To avoid oscillations built-in circulators are implemented and the isolation between the donor and mobile antennas are 10–15 dB higher than minimum coupling loss. The ERP is somewhere between 0.5–5 W.

6. STRATEGIC PLANNING

The long term plans are based on the conviction that mobile telephony penetration just has been started. During a few years it becomes an ordinary tool in the everyday life such as happened with video and personal computer in the last decade. The market will be a mass market, more and more people can afford his own mobile phone. It calls for a network with capacity of many hundred thousands subscribers. Handheld is normal expectation so the external antenna usage remains negligible. That's why we aspire to provide indoor coverage and improve coverage within the existing service area. If the demand asks it we will cover the underground lines. Preliminary study plans are already examined. The main business, shopping, transportation centres should be covered with microcells to achieve high capacity. Today already available optically linked repeaters which help to increase not only coverage but capacity and oscillation free operational theory gives more freedom to the planner. Slow frequency hopping promises more capacity via moving to 3/9 clusters. Combining these with overlay cells substantially increases capacity with low cost. Unfortunatelly the current international experiences are not so encouraging. There are problems with mobiles and the interference supression is behind the expectations. The current cluster allocation at WESTEL 900 is based on the 4/12 pattern which can be seen on Fig. 4.

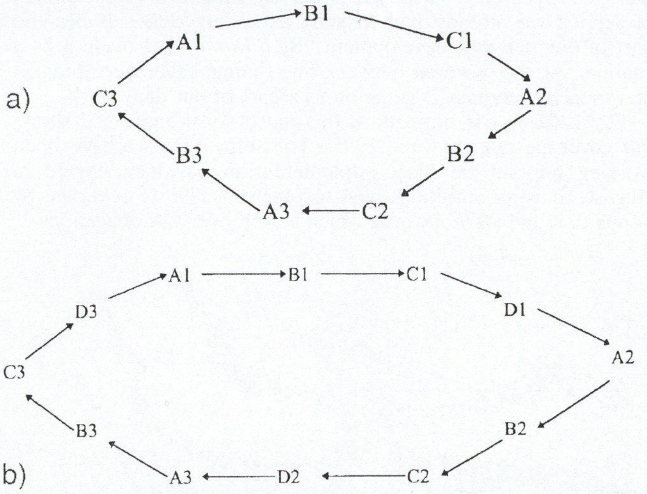
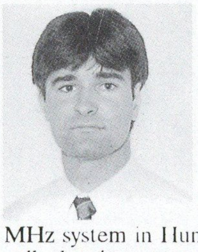


Fig. 4. a) 3/9 raster channel group allocation; b) 4/12 channel group allocation

The half rate transmission in its current stage is also not reassuring. If it comes to the market (it is supposed to be there at the end of this year) further question is that how many subscribers will buy a new handset. But there is one more capacity increment possibility. Awarding all GSM channels to the GSM operators in Hungary would increase the capacity exponentially. At the moment namely WESTEL and it's competitor are allowed to use 40–40 channels. In GSM extended channels are plannned so others also recognized this way of capacity increment. Generally we can tell that GSM is one of the most spectrum efficient utilization of the frequencies as natural resources and due to concessional and other fees provide a good income source for the state.

In not so far future GSM-DCS and GSM-DECT networks may be realized. These extremely advantageous common systems utilize optimally the much larger capacity of PCN.



András Kolonits graduated in electrical engineering in 1992 at the Technical University of Budapest. He started his work at WESTEL Radiotelephone Ltd. with operation and maintenance. Next year he moved to the system engineering department as a cell planner. Here he developed a new and cheap overlay cell solution which is currently widely used in the 450 MHz system in Hungary. Since 1994 he has been with 900 GSM cell planning manager. From 1993 he is a guest lecturer at the Széchenyi High School in Győr.

NETWORK PLANNING AT PANNON GSM

Z. BOGNÁR and L. BABITS

PANNON GSM TELECOMMUNICATIONS COMPANY
H-1134 BUDAPEST
VÁCI ÚT 37.

1. INTRODUCTION

Pannon GSM's network development had to start from scratch having no transmission infrastructure at all. Transmission network suitable for GSM purposes in our country was owned by MATÁV the only operating company of long distance telecom network in Hungary. In fact MATÁV is the half owner of our competitor. It was quite a challenge to build a network under rather tough Concession Agreement (CA) conditions. That was a costly and tiring deal. We managed to build a transmission network which served our coverage purposes only. That was an advantage and another one was that the whole network was in our company's hands.

The launch of service with low capacity base stations has been rather cost effective even though subcontractors had to work at our sites repeatedly. After one and a half months from the launch of service we already had to start extending cells. It became part of our network development. By now we have made it as a routine. At the moment network fine tuning, coverage extension and capacity increase is going on as a part of our daily work.

Fig. 1 shows our network at the end of 1994 and Fig. 2 shows our coverage map in June 1995. For some time we have been working on our '96 plan, implementation of which started in August. It is an ambitious plan to reach over 95 % coverage by population and 90 % by area which is well over CA obligations.

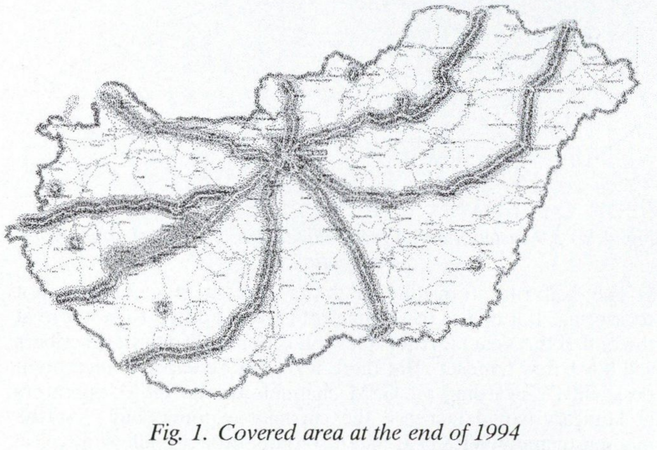


Fig. 1. Covered area at the end of 1994

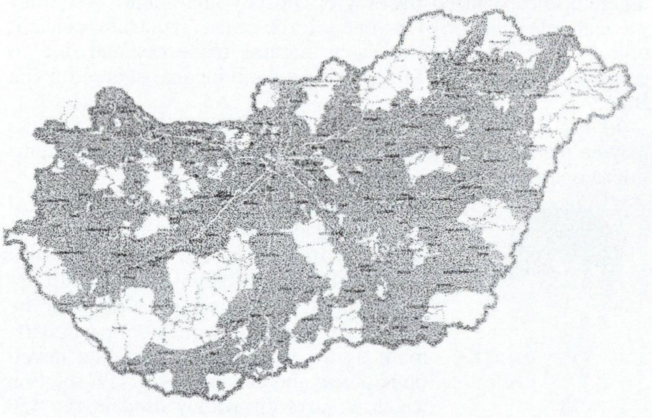


Fig. 2. Service area in June 1995

2. PANNON'S HISTORY

We do not claim we are the most authentic authors who can give a summary of Pannon's history and network development but we have been working in network development almost from the beginning. As it is generally known, our company was one of the winners of the bid announced by the Ministry of Transport, Telecommunication and Water Management of this country in 1993. The owners of the company are Scandinavian telecom companies (75 %) and the rest belongs to local investors. The development of the network started almost simultaneously with company organization according to CA. This was possible with a team which was fully committed to start a GSM service in this country within the given time limits. The work has been organized by 3-4 highly experienced elder experts and a group of young but skilled and highly educated and motivated guys. They were equipped with everything as tourists who intend to discover an unknown mountain. Though conditions were different from their home ones and time was extremely short, however, the task proved to be solved.

Hungarians joined the team right from the beginning. They have done organizational and installation work. Subcontractors offered their services to Pannon and network started to grow.

We found a special connection to Nokia, our major supplier. An outstanding support has been given to our network development right from the beginning.

The time schedule was really tough. According to the CA service had to be started not later then 1st of April 1994. The first call went through a base station before Christmas 1993. The Budapest Network of 22 base station was practically ready by mid February 1994. Commercial service started in the last days of March. During the 90 days a lot of tests have been done including roaming to Scandinavian countries.

MATÁV has been very co-operative in network interconnection issues.

The Scandinavian experts have been replaced several times and more and more Hungarians joined Pannon and though they took over an increasing part of the professional work the hard work and enthusiasm remained. The company started functioning more and more as a company.

3. RADIO NETWORK PLANNING

3.1. Coverage Planning

We have determined types of coverage to have easy references in daily work. Our coverage types expressed in measured values are:

Type 1. Countryside (with roof mounted antenna):	-102 dBm
Type 2. Highways (without roof mounted antenna):	- 92 dBm
Type 3. General city areas, handheld coverage:	- 87 dBm
Type 4. Business area, handheld coverage, indoor :	- 77 dBm

As a planning objective we took 95 % for rate of successful call attempts with normally terminated calls. In city coverage we have started with large coverage cells which decreased according to the traffic growth. In road coverage we have preferred to start service with rather high masts (60 – 80 m) and type 1. coverage. We have raised coverage by putting additional base stations between 2 succeeding one. This was a general rule but of course we had to deviate from it partly due to terrain constraints, partly due to MW transmission requirements. That was the reason why we used 'transmission only' sites. These high masts gave us a rather good starting condition to extend our coverage to branching roads and passed cities, villages. This way of network development, i.e. continuos rollout ensured an almost continous coverage along main roads for Pannon right from the beginning.

As a coverage prediction tool we have used Nokia NMS/X. The facilities and options it offers we can say are excellent. The accuracy it achieves depends on that of the terrain database and propagation model it uses. In rural area we can fully rely on it but in city area its accuracy is less due to insufficient resolution of our terrain database. It is using some version of Okumura – Hata and/or Walfish – Ikegami propagation model as most of the similar planning tools do.

3.2. Capacity Planning

Our development philosophy was to start with low capacity and make extensions according to the traffic growth. Traffic was higher than we had expected. We formed a quite good extension practice together with Nokia, which affected the selection of starting configuration. For instance it has led to the usage of sectorized antennas in most of the cases at city coverage. Due to low traffic for road coverage we used splitted cells. Planners receive regularly traffic information in a properly prepared format and based on these measurements they decide the type and the time of extension. As the network has grown quite big they will be given an even more sophisticated support in trend calculation and other prediction means. These gave us a rather cost-effective way of network development though we must admit there are base stations with lower traffic than what company owners would like to see.

At the beginning in our planning the traffic per subscriber was a high value similar to that what is used in fix telephony for rural areas. It was decreased by 1995 and even more decreased by 1996. Of course our company is conducting traffic profile studies but it is the matter of another paper.

3.3. Frequency Planning

Pannon has got 40 channels like our competitor WESTEL. This ensures 100 – 200 thousand subscribers. Though we have now just less than 60 thousand, frequency planning gives more and more work for our planners. Our Planning Tool gives a good start in frequency allocation but during implementation we have to deviate from its proposal . It is partly because of the border area in the countryside and the heavy traffic and terrain at the Budapest city area. These have almost turned traditional cluster structure and allocation routine into an empirical one which of course takes into account basic frequency reuse principles.

To ease our frequency burden we use all possible ways to improve coverage and increase capacity in city areas with good service quality. At 4 heavy traffic nodes in the Budapest network we have introduced 2-layer network model. With proper setting of BSS (base station and base station controller) parameters large area coverage cells act as umbrella cells which take over traffic only in case of microcells beneath them get overloaded or give help to mobiles to make handover while moving between microcells they cover.

At large we envisage half-rate, intelligent antennas, DCS 1800 but currently we must exploit the frequency range we have. Our difficulties are most severe in Budapest. It is due to the terrain here and of course heavy traffic concentration. On the top of Buda hills every frequency change can be indicated. To maximize traffic handling capability of the frequency range network dimensioning is one of the most important issues. The right antenna selection, screening by the proper selection of antenna location and position are the basic means in planners' hands to fulfil rollout within frequency channel set currently available for our company.

4. TRANSMISSION PLANNING

4.1. Access Network

As mentioned above we had to rely on our own background in transmission due to the lack of 2 Mb/s links from our base stations to BSC (base-station controller) and MSC (mobile switching centre). Due to the time constraint and availability of planning and installation facilities Pannon decided to establish microwave transmission routes for BTS-BSC level. This decision has led to long MW chains along main roads. These were quite long, the shortest was 80 km, the longest was over 300 km. Planners who have attempted to allocate planning objectives of medium grade links to such long links know it is a difficult task using E1, 4E1 capacity MW equipment. At the beginning we were given 15 GHz and 22 GHz (exclusive range allocation) to implement the lowest level transmission routes. We have also received an exclusive frequency range allocation in the 38 GHz range. With this equipment category it is hard to fulfil certain objectives (like Severely Errored Seconds or Total availability) laid down in ITU-T (CCITT) Recommendations G.821 and G.921 with reasonable antenna size and hop lengths of 20 – 25 km. These were the long sleeves as it is shown in Fig.1. Basically the branches functioned rather well despite of some human faults during operation.

As it can be seen our total transmission network was in fact an access network. As the traffic and the network have grown the solution has made our transmission planners more and more anxious.

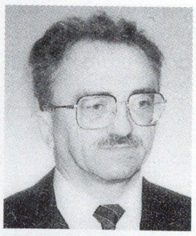
To ease the anxiety we have ordered MATÁV optical fiber links to certain interim points. By that move our small capacity MW links became no longer than 4 hops. Now in the planning phase it was easy to fulfil the objectives mentioned above. We used these MATÁV links at a lowest level of our infrastructure. We do not have availability figures of those due to the short time of usage.

The total length of our MW network comprision 2 Mb/s and 8 Mb/s links is over 3000 km.

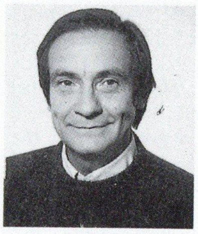
4.2. Backbone History

As mentioned above it became clear for us that relying on an access network in such a service and network dimensions is not possible any more. Our company has initiated the establishment of a backbone network to give a sound base for our transmission network, to make major reliability contribution to the service and all parts of it is under our company's control. It took a long time to get a licence to build a backbone network in the lower 6 GHz range but eventually we have received it. We belive our company is the first cellular operating company in Central-Europe which is constructing such a high capacity SDH backbone network.

The backbone program is in implementation phase. The first hops are under testing. Further loops are under planning and access network rearrangement studies are going on.



Zoltán Bognár received MSc degree in electronic engineering in 1962, in microwave engineering in 1967. He received doctoral degree in 1971 from the Technical University of Budapest. From 1962 to 1971 he was design engineer at Orion Radio Factory as a planning engineer. In 1971 he joined the PTT and made supervisory work for Hungarian Microwave Network. As an ITU expert he has made training for 2 years at PTC of Zambia. In 1980 he joined the Technical College of Transport and Telecommunication in Győr and headed the Radio Group there. Since beginning of 1994 he is the head of Radio Planning Group of Pannon GSM Company.



László Babits graduated in electrical engineering from the Technical University of Budapest in 1973. He received doctoral degree in 1984. He started his work at the antenna department of the Research Institute for Telecommunications (TKI). From 1985 to 1991 he was head of the antenna department and from 1991 to 1994 he was head of the microwave equipment department. In 1994 he joined to Pannon GSM Mobile Telecommunications Company as deputy manager of transmission systems. Presently he is manager of transmission systems.

RADIO APPLICATIONS

RADIO IN THE LOCAL LOOP

B. KIÁCZ

PKI TELECOMMUNICATIONS DEVELOPMENT INSTITUTE OF MATÁV
HUNGARIAN TELECOMMUNICATIONS COMPANY LTD.
H-1456 BUDAPEST
P.O.B. 2

1. DEFINITION

By definition the local loop is that part of the telephone network which lies between the telephone exchange or its remote stages and the subscriber terminals (telephone sets, faxes or modems). There is a great variety of different factors (terrain, network structure, density of customers, etc.) which requires different technical solutions in the local loop [1]. Traditionally the local loop was a pair of wires between the main distribution frame (MDF) of the local exchange and the telephone set. Now it means a complex network of all kinds of telecommunications technology ranging from copper wires to fibre optic cables. This paper deals only with radio systems which provide connection between the subscriber terminals and the MDF or DDF (digital distribution frame) of the local exchanges.

2. HISTORY

In the past few decades RLL was used mainly for satisfying special needs and was represented by so called VHF/UHF line extenders and point-to-multipoint rural microwave radio systems. The line extenders were applied mainly for the provision of government or payphone connections and utilized the radio spectrum rather inefficiently. Point-to-multipoint microwave systems represent good solutions in rural territories but they are not able to serve densely populated areas.

In the nineties some network operators started to use the spare capacity of their mobile networks in the rural areas for connecting telephone subscribers (e.g. Finland and Spain). This was also the time when the digital GSM (Global System for Mobile Communications) system appeared on the scene and the leading mobile system manufacturers started to work on RLL systems based on the "old" but field-proven analogue cellular technology. The current huge telephone developments in countries with poor telecommunications infrastructure is also giving a boost to the application of RLL.

As the liberalization of the telecommunications sector speeds up and the competition reaches the local telephone networks the manufacturers and the operators are forced to develop and apply new radio-based telecommunications systems because their lower costs and faster implementation. These new systems have been developed especially for RLL and therefore don't have any limitations compared to the wired local loop.

2.1. Standardization of RLL

Due to the relatively new demand for RLL the standardization of it is not too matured. There are two committees within ETSI (European Telecommunications Standards Institute) where work is in progress on RLL: RES3 and SMG. The RES3 Sub-Technical Committee has produced a working document [2] which gives a thorough analysis of the topic while work has only recently started in the SMG Technical Committee. RLL is a Phase 2+ Working Item in SMG which means that there will be a standard GSM-based solution for RLL in the second half of the decade. However, GSM in its current status can also be used for RLL purposes [3]. There are two relatively big projects in EURESCOM dealing with local loop networks (P303/P306) which have some contributions to the RLL developments as well.

It is important to note that the new concentrator and multiplexer interface specifications (V5.1 and V5.2) specified by ETSI [4] are very important for the spread of RLL. Nowadays the concentrator and multiplexer protocols are proprietary products of the exchange manufacturers and this situation makes the economical implementation of RLL systems made by other vendors than the particular switch rather difficult. If V5.1 and V5.2 interfaces were implemented in the majority of the switches, any kind of access systems having these interfaces could be used in the telephone networks based on the open standards and this could give a boost to the application of RLL systems.

3. APPLICATIONS OF RLL

RLL is a very flexible tool which can be used for several purposes. When, where and to which extent to apply RLL in the telephone network are questions which can only be answered after thorough analysis of such factors like costs, speed of implementation, operation and maintenance, flexibility, etc. This exciting analysis can be the subject of an other paper, here I would like to highlight only some typical applications of RLL.

- Utilization of the free capacity of an existing local exchange while the wired local loop network is not entirely available. In this case RLL is only an intermediate solution and can be removed or moved to another place when the wired network reaches the customers.
- Final implementation of the local loop network in regions where the costs of the wired solution are too high because of the terrain type, low subscriber density, long distances, etc. This solution is typically used in rural areas.
- Overlay network for quick satisfaction of new demands for telephone. In this case regional or country-wide RLL networks can be built which enables the telephone operator to connect new customers within one or two days.
- Replacement of party-lines when a new digital exchange is used instead of an old analogue one.
- Provision of telephone service at special events (e.g. exhibitions, sport events, etc.).

4. ADVANTAGES AND DISADVANTAGES OF RLL

RLL has several advantages over traditional wired networks. Some of them are summarized below.

- Quick implementation. RLL doesn't require civil works and ducting, in-building wiring at customer premises is not needed. Subscribers can be connected in some month thus generating more revenue for the operators.
- Easy reconfiguration. The location of RLL subscribers can be changed quickly and easily. If the RLL system is not needed any more the eqipment can be moved to another location. The transmission infrastructure built for RLL (e.g. microwave hops) can be used for the backbone network.
- Economical aspects. In sparsely populated areas and in certain geographical environments the price per subscriber line using RLL is less compared to the wired connections. Operation and maintenance costs are also lower. RLL systems are very reliable and less vulnerable then wired local loop networks.

RLL has some disadvantages which can be summarised as follows:

- Limited capacity. This depends on the available spectrum which is determined by the radio administrations.
- Technical limitations (in some systmes). This apply mainly for those older systems which are based on mobile networks.
- Noise and interference. Radio transmission and reception can be disturbed by non-wanted signals.

- Power supply of RLL terminals. Generally, the RLL terminals are operating from the 230 V mains network. If there is a mains failure, the user cannot have access to the system. Optional batteries can be provided in most systems to avoid this problem.

5. RLL TECHNOLOGIES

This clause provides a summary of the availble RLL solutions. Most of them are derived from existing mobile networks and therefore inherited the capabilities of the systems they are based on.

5.1. RLL systems based on cellular networks

Nowadays those RLL systems are the most important which are based on public land mobile networks (PLMNs) [10]. In these RLL systems the main elements of the radio system of the PLMN remains almost the same as in the mobile applications but the connection between the base station and the telephone network can be done in several ways. In RLL applications mobility functions (handover and roaming), which are essential in mobile networks, are not required and the subscribers can have access to the system typically only in the coverage area of one particular base station.

The subscreiber terminals consist of a standard transceiver of a mobile station connected to a line interface which provides telephone interface for the users. The terminals are usually table or wall mounted and are powered from the mains network.

The PLMN based RLL systems are very flexible, they can be used for all applications listed in clause 3. However, there are several limitations which has to be considered when applying some of these systems.

- Transparent line signalling. So as to reduce the use of radio resources most PLMN based RLL systems don't support transparent line signalling. This means that there is no direct connection to the local exchange during dialling. Dialling tones are transmitted from the RLL terminals and the connection towards the exchange is set up only after collecting the dialled digits. This can inhibit the application of some supplementary services and causes some delay at the call setup procedures. The transmission of the hookflash signal is also problematic in some systems.
- Voiceband transmission. A lot of PLMN based systems have limited voice frequency bandwidth, because of the modulation limitaions in the radio system. This results in poorer voice quality (this RLL connections produce approximately 4 qdu), makes the transmission of 12/16 kHz tariff pulses rather difficult and allows lower bit rates compared to the wired lines in case of data transmission. The typical maximum bit rate in case of FM modulation is 4.8 kbit/s.
- Delay. The call setup times are 1-3 seconds longer than in wired networks, because of the time needed for the signalling at the radio interface. In case of some digital radio systems additional speech coding and channel coding delays have to be considered as well.
- Grade of Service (GoS). In PLMN systems the permitted loss is generally 2 to 5 percent. This value cannot be accepted in telephone systems, the allowable maximum is 1 percent. However, a slight increase in the GoS can result less expensive networks.
- Security, confidentiality. As radio transmission can be detected by anybody, encryption have to be applied in the RLL systems to prevent eavesdropping.

5.1.1. PLMN based RLL with mobile switching centre (MSC)

In the first RLL systems complete PLMN systems were used and the RLL system was connected to the local telephone exchange via inter-exchange trunk lines (Fig. 1). This solution is rather expensive and is proposed in special cases only. It is not a real RLL solution, because the system is not connected to the subscriber stage of the telephone exchange.

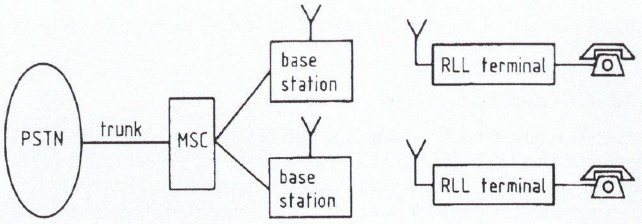


Fig. 1. PLMN based RLL with MSC

5.1.2. PLMN based RLL without MSC

This is the most often applied RLL solution. In this case the RLL system provides interfaces between the local exchange and the telephone terminals. A typical configuration is shown in Fig. 2. The MDF (main distribution frame) or DDF (digital distirbution frame) of the local exchange is connected to a control and concentrator unit via 2-wire or PCM lines. The control and concentrator unit, which can be located in the exchange, controls the radio system and concentrates the telecommunications traffic between the exchage and the base station.

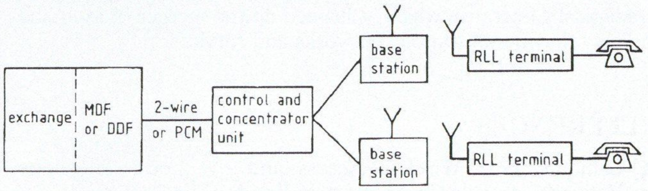


Fig. 2. PLMN based RLL without MSC

There are several products on the market: Ericsson's RAS 1000, Motorola's WiLL and Nokia's DAXnode 2000 are the most important ones in Europe [6]. These products are continously developing and the limitations listed above are gradually disappearing from them.

5.2. RLL systems based on cordless telephone (CT) systems

The cordless telephone is a replacement of the cord between the telephone terminal and its handset. The CT equipment consists of two parts. The fixed part (FP) is connected to the subscriber end of the local loop and provides radio connection to the portable part (PP) which can be at a distance of maximum 200 metres from the FP. By using the new digital CT systems, the CT2/CAI (common air interface) [7] and DECT (Digital European Cordless Communications) [8], CT can be now applied in the local loop. Both CT2/CAI and DECT have 32 kbit/s ADPCM speech coding which provides excellent speech quality and data transmission capabilities. The digital CT systems can be used in public applications outside the home and office environments.

5.2.1. Telepoint

The telepoint system is similar to the public payphone service. The subscribers can originate calls with their PPs via FPs located in public places. The FPs are connected to the local exchange. Identification, billing and other administrative tasks are performed by a remote operation and maintenance system which can be connected on-line or off-line to the FPs. Telepoint is a public service which is offered at public places (e.g. railway stations, airports, shopping centres, etc.) and are generally not capable of receiveng calls.

5.2.2. Neighbourhood telepoint

The neighbourhood telepoint (NT) is an enhanced version of the Telepoint which can be considered as an RLL system. In this case the FPs are located near the homes and the users can have access to the telephone system via their PPs. In case of NT the users can be connected only to specific FPs, thus their mobility is limited compared to the Telepoint, but they can receive calls as well.

5.2.3. CT based RLL

The CT based RLL is similar to the NT but instead of PPs RLL terminals are used (Fig. 3.) The advantage of this solution is its excellent quailty, the low costs and high capacity. However, the coverage area of the FPs are rather small and therefore a number of FPs are required for continuous coverage. Another drawback is that each FP requires wired connection, so this solution cannot be used in areas where there is no telecommunications infrastructure.

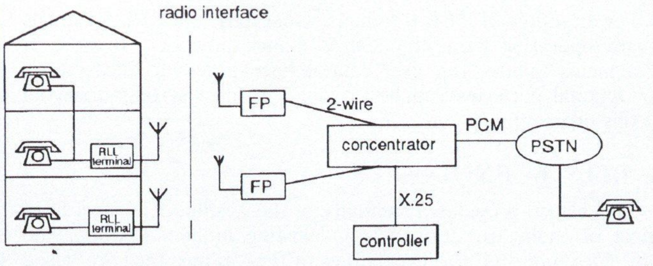


Fig. 3. CT based RLL system

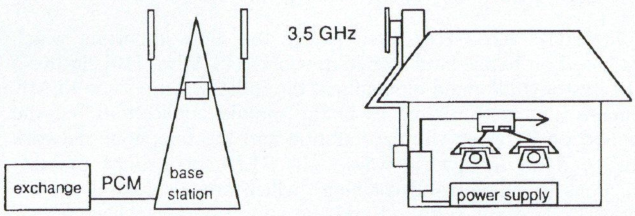


Fig. 4. Functional diagram of the FRA system

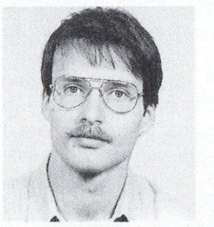
The CT based RLL systems are rather new and therefore there are no proven products on the market.

6. THE FUTURE OF RLL

In the next few years new RLL systems will be developed which will provide ISDN compatibility and will be capable of transmitting at Nx32 or 64 kbit/s. The capacity of the systems will be enhanced by advanced radio techniques (such as improved TDMA, CDMA, etc.) and by applying sophisticated cellular technology. The need for larger capacity will require the use of higher frequency bands which will necessitate the reconsideration of existing frequency allocation. The costs of connecting subscribers by RLL will dramatically decrease which will speed up the merger of fixed and mobile telecommunications networks and services.

REFERENCES

[1] Calhoun, G.: Wireless Access and the Local Telephone Network. Artech House, Boston, London, 1992.
[2] Radio in the Local Loop. ETSI RES3 munkadokumentum.
[3] H. Posti, R. Uola, P. Patronen and H. Jokinen: WLL Extension of GSM. GSM Workshop, Helsinki, October 12-13, 1993.
[4] ETS 300 324-1 és ETS 300 347-1.
[5] T.-né Ökrös, Á. Dárdai: Ultrarövidhullámú rádiótelefon berendezések és rendszerek. MPK, Budapest, 1990.
[6] T.-né Ökrös, A. Bausz, G. Döbrőssy and B. Kiácz: Rádiós megoldások alkalmazása az előfizetői hurokban. PKI tanulmány, 1994.
[7] I-ETS 300 131: "Radio Equipment and Services (RES); Common air interface specification to be used for the interworking between cordless telephone apparatus in the frequency band 864,1 MHz to 868,1 MHz, including public access services".
[8] ETS 300 175: "Radio Equipment and Services (RES); Digital European Cordless Telecommunications (DECT) Common Interface".



Balázs Kiácz received his M.Sc.E.E. degree from the Technical University of Budapest in 1988. He joined PKI in September 1988 as researcher assistant and was appointed researcher (1991) and project manager (1994). He started as computer aided antenna designer but since 1990 he has been working on the radio and network aspects of mobile communication systems and Radio in the Local Loop (RLL) networks. Currently he is the co-ordinator of PKI's activities in MATÁV's RLL project. He has presented papers at national and international conferences, gave lectures at post-graduate courses of the Technical University of Budapest and has publications in several periodicals.

DIGITAL MOBILE TELECOMMUNICATION ON THE RAILWAYS

I. TARI A. KARÁDI and SZ. SÜLLE

MÁV HUNGARIAN STATE RAILWAYS
GENERAL DIRECTORATE
H-1062 BUDAPEST
ANDRÁSSY ÚT 73-75.

1. INTRODUCTION

The railways apply radio equipment for many purpose (traffic controlling, dispatching, shunting, etc.) to provide communication between the mobile vehicles or workers beside the railway line and the sedentary occupation. The construction of the various allotted railway radio networks are different and so they construct independent systems which are not connected with each other.

In the next section a brief overview is given on the existing radio networks of the MÁV (Hungarian State Railways), similarly to the other European railways.

2. OVERVIEW OF THE EXISTING RADIO NETWORKS

Because of serving the control and safety of the railway traffic, the most important railway radio application are the ground-train radio network and the shunting radio network.

The task of *the ground-train radio network* is to provide the possibility of communication between the controller, who controls the railway line and the staff of the mobile vehicle running on the line. MÁV use for this purpose two versions (considering the base of the technical realization and the provided service) of the ground-train radio network.

- The earlier and more up-to-date realization was constructed before the issue of the UIC (Union of Railways) 751-3 code. This is an open network, the calls are made orally, so it is not selective and there is no caller identification and emergency call. The radio network works in the 160 MHz band, the base stations in duplex and the mobile radios in semi-duplex mode, so the central controller does not need the push-to-talk button while the drivers need that, but therefore the construction of the mobile equipment is simpler (for example there is no duplex filter) and cheaper. The centre controls the trackside base stations through four-wire links. MÁV use synchronous and quasi-synchronous networks. In the quasi-synchronous network high stability crystal oscillator provides the necessary frequency accuracy. In the synchronous network the synchrony of the oscillator frequencies of the base stations is assured by a synchronous signal taken from the master base station. MÁV has almost 2000 km line of this radio network, and uses 12 duplex channels for this purpose. This channels are allocated for the railway lines not causing interference. When a mobile arrives to a new railway line, the driver has to switch manually the channel to be able to make contact with the competent controller. On the 2000 km railway line about 500 mobile radios are in use at MÁV. The construction of the radio network working in the 160 MHz band is shown in Fig. 1.

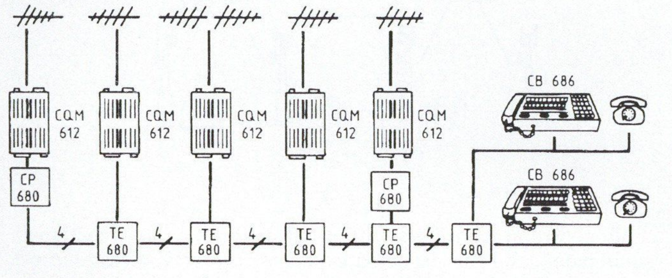


Fig. 1.

- In the last two years we began installing ground-train radio networks which meet the specifications of the UIC 751-3 code and so in the main services are compatible with the radio network of the European railways. It provides higher safety for the railway traffic: there are emergency and broadcast call, selective call and caller identification. This identifier is the train running number which can be set individually. This radio network is working in duplex mode, so the driver does not have to handle the push-to-talk button, and the base stations transmit continuously. Very important service of this network, beside oral commands and reports, coded information can be transmitted, for example predefined texts or pictograms. In the 450 MHz band we use the so called UIC channels for this purpose, with a margin of 25 kHz between radio channels. These frequencies are allocated by the Radio Administrations of the European countries and are agreed by the neighbouring railways. Four frequencies are combined in a standard chart to form a "quadrifrequency group", it is necessary to have three frequencies for the lineside transmitters which are in rotation, and the fourth frequency is for the mobile transmitter. For the satisfactory coverage of an entire line with radio waves, the minimum reception voltage must be attained or exceeded over 95 % of distance and for 95the best signal of the lineside transmitters working in three different frequencies. There is possibility to communicate with the shunting radio network (local "C" mode). There are also possibilities to connect into the private railway telephone network or to transmit information from the central control or the driver to the train staff or the passengers via loudspeakers if there is train announcement equipment according to the UIC 568 leaflet. MÁV have about 500 km line applied with this network and have about 60 mobile radios. The UIC ground-train radio network is shown in Fig. 2.

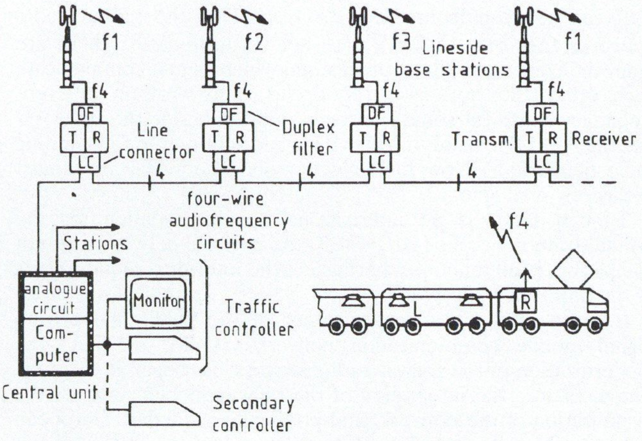


Fig. 2.

- A special application of the ground-train radio network is *the secondary line radio traffic control*. This is almost identical with the UIC ground-train network from technical point of view. It is appropriate for labour-saving purposes on the low traffic secondary lines on the stations (station inspectors) so that the traffic control is made from a dedicated station of the line. (The controller gives his commands and permissions to go on to the driver through the radio.)

The aim of *the shunting radio network* to provide communication between the foreman shunter (handportable radio) and the locomotive driver (mobile radio) and the station inspector (fix radio). This network is simplex, one network uses one frequency, at MÁV in the 160 MHz or in the 450 MHz band. The shunting radio network is shown in Fig. 3.

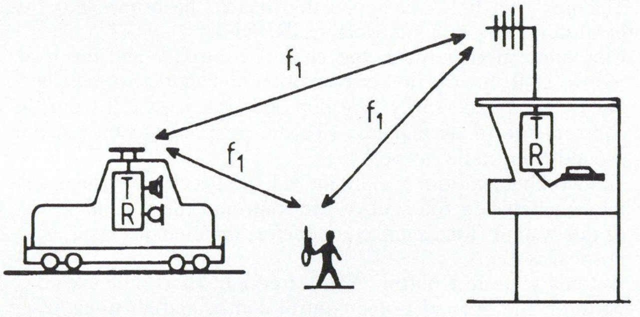


Fig. 3.

In bigger railway stations radio network is available for different railway services if their technology needs the radio (for example for *rolling stock inspection, stationary break test, ordering of departure, marking off coaches*). These networks are identical with the shunting radio network (use one frequency in simplex mode).

The *dispatcher network* covers the whole country, works in a simplex channel, in different channels in the area of the different railway headquarters. The fix base stations are connected with wire links. The network is open, the speeches are not secret. It is used for dispatching and accident protection, providing mobile communication between the vehicles carrying out their certain duty and the fixed dispatcher or other workers beside the railway lines.

3. THE MODERNIZATION OF THE RAILWAY MOBILE RADIO NETWORK

Now we examine the applicability of the *trunked radios* at the railways, but we have not got yet working trunked network. At the railways we could use the advantages of the trunked radio system in the bigger stations (or more stations) where all mobile participants of an area could be combined into one network. The centre controls the radio channels and allocate them to the participants, so we can save radio channels.

It can be seen from the section 2. That the railway radio networks (not only at MÁV) are not so up-to-date. There are many different networks in application which cannot communicate each other, do not save frequencies, and work in different frequency bands (at some European railways beside the 160 MHz and the 450 MHz band, the 80 MHz band is also used for shunting radio networks). Now the railway mobile networks are almost exclusively analogue.

Though there is an international recommendation for the ground-train networks (UIC 751-3) the national networks are not compatible in all functions, because of the individual requirements of the different railways.

Because of the vast improvement of the public and private digital mobile communication networks (GSM, TETRA) the modernization of the railway radio network has begun in this way. The aims are: the integration of the railway mobile services, the digitalization of the network, and producing a standard European railway radio network. The 7B9 workgroup of the UIC works in this field, and this workgroup has analyzed the existing standards from the point of view of the railway requirements. Two standard systems were chosen for further examination: GSM (Global System for Mobile Communication) and TETRA (Trans European Trunked Radio). A project was originated to carry out these aims, and called EIRENE (European Integrated Railway Radio Enhanced Network).

In the first step the main requirements of the system and the services to be integrated into the system were specified. The main requirements of the system are:

- be a digital system;
- work in the 900 MHz band;
- possible to operate up to 500 km/h velocity;
- put into operation in 1997;
- be an open standard making possible the competition of the manufacturers of the system elements;
- wider area of use because of economical reasons.

The next ten fields of application has to be drawn into this integrated railway radio network (EIRENE):

1. Communication between the central controller and the locomotive staff: mainly oral conversation and short text messages, but there is necessarity of group and broadcast call from the controller to many mobiles. (This corresponds to the existing ground-train radio network).
2. Traincommunication: mainly individual speech and data transmission between the staff of the train and the ground service of the system (for example conductor, maintenance staff, diagnostical system).
3. Automatic Train Control (ATC): frequent short data exchange between the ground traffic control centre and all trains using ATC system.
4. Remote control: mainly short data reports to shunting locomotives, cranes, points, barriers, break testers, on-train air conditioning, etc. In this field in many cases safety regulations must be satisfied, that is why there is a need of fail safe mechanism to stop the train when the radiolink fails because of any reason.
5. Emergency call in an area: short data messages (alarm) or oral warning from the controller or a locomotive driver or trackside workers to all trains and other trackside workers staying in that area (typical 10 – 15 km). Emergency calls demand short call set-up time (less then 1s).
6. Shunting: need of group and individual communication, this application also has strict safety requirements.
7. Dispatching system: provides mobile communication for the trackside workers (building or maintenance workers).
8. Local communication in stations or marshalling yards: provides communication for the local station staff (individual or group call).
9. Railway mobile network covering the whole country: provides communication for the cars or vans on roads, mainly individual call is required.
10. Communication service for passengers: public telephone, fax, computer service on trains.

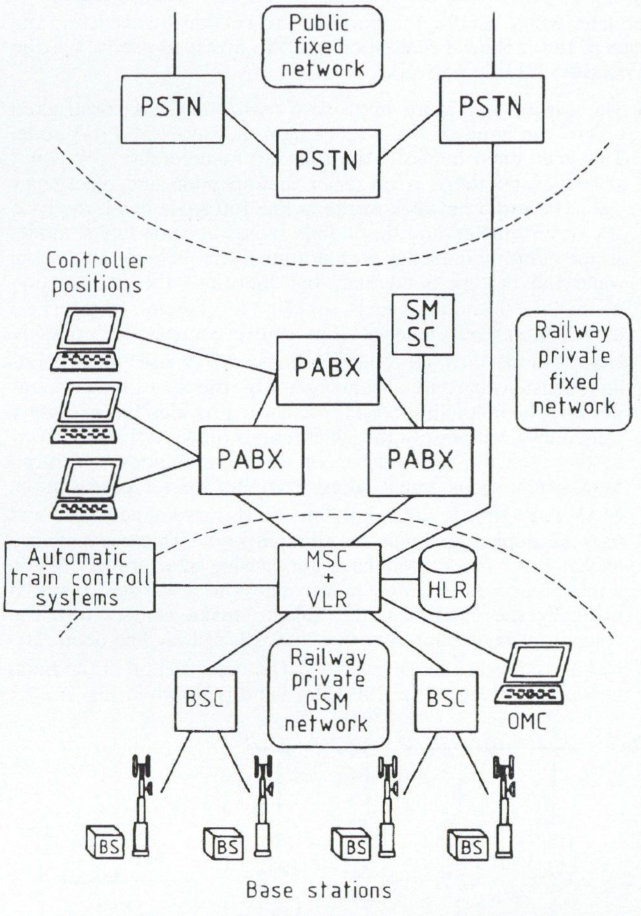


Fig. 4.

After careful consideration of all technical and functional requirements and the expected expenses, the 7B9 workgroup of the UIC in 1993 decided that a standard, based on GSM standard and taking the additional railway requirements into account has to be worked out. The ETSI (European Telecommunications Standards Institute) SMG (Special Mobile Group) and the UIC 7B9 workgroup are working on this standard (GSM-R). The structure of the GSM-R and the connected networks are shown in Fig. 4. The GSM-R network consists of the following units:

- Base Station System (BSS), which contains the Base Station Controller (BSC) and the base station radio transceivers.
- Network Subsystem which is connected to the BSS through interface. This subsystem contains the Mobile Switching Centres (MSC), which are responsible for call direction and management. In the databases of the MSC are stored the data of the participants of the network. The HLR (Home Location Register) stores the data of the participants registered into this GSM-R network and VLR (Visitor Location Register) stores the data of the participants registered into an other GSM-R network, but operating in this network.
- Operational and Maintenance Centre (OMC) which supervises the network.
- Mobile Station (MS), the transceiver of the mobile equipment is in connection with the BSS through the air interface, the Subscriber Identity Module (SIM) contains the specific data of the MS.

In the railway application (GSM-R) the base GSM infrastructure is to be completed with:

- Group Call Register (GCR) which is making possible the group an broadcast calls.
- Units for the railway specific addressing (for example with train running numbers which can change), and unit for transmission of predefined short messages.
- Interfaces to the private railway telephone network, to public networks, to the traffic control centre and to special railway systems as ATC.

Special requirements of the mobile stations are:

- Be able to communicate to an other MS without the GSM infrastructure in direct mode.
- Special Man-Machine Interface (MMI) for the cab radios of the railway vehicles.

The present state of the EIRENE project:

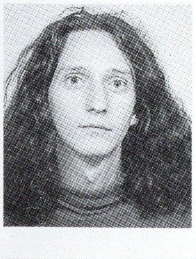
- The full specification of the system is ready.
- The standardization is in progress.
- The UIC workgroup has assigned the trial sites (in Germany and France) representing all railway conditions.
- A tender was announced, which was obtained by the MORANE consortium.
- Some of the manufacturers have already drawn into the project.
- The manufacture of the prototype and the building of the trial site began in this year.
- From 1997 the system will be ready to be installed and to work.
- In the international and high speed lines this system must be put into operation as soon as possible.

We hope that MÁV can start this kind of modernization before the turn of the millennium.

4. SUMMARY

The aim of this article is the introduction of the mobile radio networks at the railways, their characteristic, importance, role in the railway technology. On the other hand outlines the future of the international railway mobile telecommunication. This integrated and digitalized system, called GSM-R, is based on the public GSM system and is developed according to the railway requirements.

István Tari graduated in communications engineering from the Technical University of Budapest in 1967. He received specialized engineer degree in transmission technics in 1971. He works at MÁV in different fields of the telecommunication service from 1967. Now he works in General Directorate of the MÁV as head deputy of the Department of Telecommunication, Signalling, and Power supply. His main duty is the establishment of the up-to-date digital technics in the railway telecommunication. He is member of the HTE.



Szabolcs Sülle was graduated in communications engineering from the Technical University of Budapest in 1994. From 1994 he works at MÁV in the Centre of Telecommunication, Signalling, and Power supply in the Radio Development group.

Amália Karádi was graduated in communications engineering from the Technical University of Budapest in 1970. She received specialized engineer degree in transport automatization in 1980. From 1970 she works at MÁV in different fields of the telecommunication and signalling service. From 1987 she works in General Directorate of the MÁV in Department of Telecommunication, Signalling, and Power supply where she was leader of group in the Department of Operation, and now works in the Department of Telecommunication. Her main field is development and operation of the railway radio networks, and establishment of the digital technics in this field. She is a member of the UIC 7B9 workgroup and takes part in the GSM-R standardization work. She is member of the HTE.

TARIFFING OF CELLULAR SERVICES IN NORWAY

P. BLIKSRUD

TELENOR MOBIL AS
NORWAY

1. HISTORICAL BACKGROUND

The NMT (Nordic Mobile Telephone) systems were designed and specified jointly by the Nordic Telecom Operators, i.e. the Nordic fixed network monopolies. The work started in the early 1970's and NMT 450 was opened in 1981.

The market demand turned out to be far higher than originally expected; resulting in a burdening of the allocated frequencies. NMT 900, which is basically the same system as NMT 450, but with a somewhat improved transmission quality, was introduced in December 1986.

Both NMT systems offered roaming capabilities from the start within the Nordic countries (and later also with some other countries).

Norwegian Telecom, as well as the other Nordic operators, participated extensively in the common European effort of developing the GSM specifications, and started operating the new digital system in May 1993.

The operator was now no longer enjoying monopoly in the mobile communications market. A new player, Netcom GSM AS, opened his GSM system later in 1993. Because of this, the "Mobile" department of Norwegian Telecom had to become a separate company and was given the name Tele-mobil, which again later was changed to Telenor Mobil.

The population of Norway is some 4.3 millions, and the cellular penetration has evolved as follows:

1981:	0.04 %
1982:	0.3 %
1983:	0.5 %
1984:	0.9 %
1985:	1.5 %
1986:	2.0 %
1987:	2.8 %
1988:	3.5 %
1989:	4.0 %
1990:	4.7 %
1991:	5.5 %
1992:	6.6 %
1993:	8.5 %
1994:	13.3 %
1995:	~21 %

2. WHAT DID THE SUBSCRIBERS REQUIRE?

In the early days of the NMT 450 system, the subscribers' tolerance was fairly high. The fact that you communicate automatically while on the move, and could be reached without the caller knowing your location, was quite overwhelming and the main demand from customers was coverage. Only car mounted or rather heavy portable mobiles were available, and then at a high price level (some 25 000 NOK, which corresponds to 450 000 HUF). Not everybody could afford that, and even bad communications quality was accepted since it revealed the posession of a highly prestigeous instrument.

The question of tariffs in the first years had a simple answer: A quarterly fixed fee (200 NOK) and a communication charge of 2.90 NOK (VAT inclusive) for any call destination within the Nordic countries. Since the mobile operator was part of the fixed network operator, there was complete reciprocity between mobile originated and mobile terminated calls, and international calls to destinations outside the Nordic region were charged at the same rate as were fixed telephone originated communications.

The inflation rate in Norway during the 1980's was relatively high, which meant that the cellular tariffs were adapted fairly often. Such changes had very little impact on the average amount of communcation time actually initiated by the mobile subscribers. It is obvious that the market segment reached found an essential need covered by cellular systems, and that the entrance fee to the system (i.e. the terminal price) was so high that only people and companies with few economical worries entered the arena.

Therefore the concept of tariffing was not very prominent as a means of evolving the market.

This situation was also enhanced by the operator's organizational incubance with the fixed network operator, which again was quite tightly govermental run. An overall political cornerstone at that time was that access to communications means should equally distributed in the society with as little dependence as possible on geographical and other differences. Such principles do not leave much room for thinking of tariff flexibility.

3. TOUCHING THE CONSUMER MARKET

Passing 5 % penetration level in the beginning of the 1990's focused the operators mind on the fact that most of the professional market was reached, and that further development had to consider mobile users with one foot in the consumer, or private, behaviour pattern.

Terminal prices were on their way down the cost ladder with quite some speed, thus lowering the barrier to the system, and tempting users who did not necessarily regard mobile communications as a must, but rather as something nice to have and something to rely upon in extraordinay situations. This implied that they would not be willing to pay too much for having access to the system, but would be willing to pay, rather substantially, if a real need should occur.

At the same time the initial establishing of the two analog systems, the NMTs, was over, and basic use of it was catered for on such a scale, that there would be possibilities of expoiting the system better, as additional usage not necessarily would been too high requirements on additional capacity. It was evident that the professinal users accessed the systems strongly during working hours, leaving spare capacity for the rest of the day.

A new subscriber category was introduced in 1992 with a low fixed annual fee and with differentiated tariffs between peak- and off-peak hours. The peak-hour tariff was set a level prohibiting high for ordinary use.

	Entrance fee	Annual fee	Peak min. charge	Off-peak min.charge
Ordinary tariff	100	1800	3.50	3.50
Private tariff	100	500	10.50	3.50

This proved to be very successful. The fact that the tariffs started to be adopted to what different people deemed the services worth, opened up for new segments in the market. The fact that the average consumer subscriber brings less revenue than the professional, is compensated by the increased subcriber number.

Later was introduced another subscriber category with tariffs adopted more to the heavy users, it is called "Professional", and the tariffs for this category are set at zero entrance fee a high annual fee, but low communication charges.To exemplify, the following table shows an extract from the present situation on NMT:

	Entrance fee	Annual fee	Peak min. charge	Off-peak min.charge
Professional	0	3500	2.42	2.42
Primary	150	1850	3.03	2.62
Private	500	500	9.07	2.62

4. SIMPLICITY AND FLEXIBILITY

While the average consumer customer is much concerned about keeping his/her telecommunications expences as low as possible; it is also a concern to get value for money, i.e. to have a close feeling that he/she gets something back for what is paid. In this respect the annual fee is an expense for him that is psychologically felt a bit wasted. And there are smaller companies which are concerned about economical control and about the prediction of the expenses.

Based on such viewpoints, a particular subscription category has been introduced, the so-called Private 200 or just P200. The essence of this tariff category is that the subscriber has to pay 200 NOK each month (or 2400 NOK a year) but each month the subscriber can make calls for the same amount without additional charges, and unused airtime in one month may be transferred to the next. Likewise, too much airtime consumed in one month may be, at least within a certain limit, transferred to be covered within next month's payment. The peak-hour tariff in this case is 7,00 and the off-peak is 2.62.

Another tariffing offer to subscribers is the "+" – subscription which is overlaid all the subscription categories (with the exception of NMT Private). A fixed monthly fee of 150 NOK gives access to free calls to national fixed telephone numbers and Telenor Mobil mobiles during the weekends. This has of course increased the traffic on non-working days, but within, although close to, acceptable limits.

5. IMPACT FROM COMPETITION

The importance of network competition is often quoted as a must for cellular success.

However, none of the Nordic countries have enjoyed this during the deployment and operation of the NMT systems. The success in this case must stem from the fact that there is a benefit of monopoly in thereduction of the initial costs to embrace only one set of infrastructure, and this enables the operator to keep prices at an acceptable level for an emerging market while still gaining revenue.

To illustrate the view that monopoly prices would not necessarily lag too much behind duopoly tariffs, a simplified overview is given below of the situation in the Nordic countries and the UK some years ago, before the competition in the former had really taken off:

	Connection	Subscription/month	Minute charge
Denmark	700	80	2.80
Finland	160	80	3.90
Norway	100	150	3.50
Sweden	410	160	4.30
UK	700/600	300	3.90

After the roll-out of the GSM systems in Norway had brought the coverage areas up to a level where they could really be offered as an alternative to the NMT systems, the competition from the new player on the market has reduced the overall tariff level 10–15 %.

However, the two GSM systems available to the customers are quite alike; some differences in the instant coverage, but the eventual plans are the same; the supplementary services offered are more or less the same, for the most determined by the production schemes of the infrastructure manufacturers.

In this situation the products are the same, and accordingly the price for the services must be on the same level, or else the cheapest operator would grab all the customers. The tariff differentiation would essentially be reflected in different ways of applying the tariffs, e.g. setting different off-peak hours, free calls in the week-end, lower tariffs for calling a few, pre-selected numbers etc.

The way tariffing is applied should also reflect the fact that some customers are interested in very detailed schemes, only to pay for service when he is actually using it. Others would be inclided to appreciate simple principles so that the amount he is expected to pay each month can be well predicted.

The tariffing of access to supplementary services, or value added services by Telenor Mobil is in general kept on a low level, as these are belived to incur added communications and by that gain the necessary revenue to cover the operational costs.

6. DISTRIBUTION CHANNELS AND SUBSCRIBER BONUS

While the UK market, and later also the French and German, have relied on the function of so called Service Providers offering the terminals and subscription to the customers, the Nordic operators initially started out with completely independant suppliers of mobile hardware. In addition to airtime commissions, the Service Providers are usually given a bonus for connecting subscribers to the network, and such bonuses are used to subsidize the terminal prices to lower the entrance barrier for new customers. The concept of Service Providers has not been introduced in the Norwegian market, but there is now closer connections between the network operators and the distribution chains. The hardware supply is at the moment based on particular agreements with the operator, in some cases only one, in some cases both, which infer that a bonus is offered for each to connection to the network. The competetion has been quite fierce in this respect, yielding extensive bonuses to the suppliers. The resulting subsidy to the customer's terminal procurement entails price levels of 1 NOK for the cheapest equipment types. In one case was reported as a special offer from a supplier: 50 NOK in addition to the handset.

Although such bonus offering in principle lies outside the concept of tariffing, it has nevertheless a clear conncetion to it, as seen from the customer's standpoint, and also from the operator's, as the actual tariffing must cater for revenue to cover the expenses incurred by bonuses.

7. CONCLUSIONS

In the evolution of the cellular business in Norway, the philosophy of tariffing could possibly be categorized into different phases:

- The first phase refers to the monopoly regime, where tariffs were simple, rigid and influenced by political thinking, i.e. principle related.
- The second phase refers to the duopoly regime, where tariffing is influenced by the market focus introduced by competition and the awareness of adaption to what the market segments are willing to pay, i.e. market related.
- The third phase, yet to come, where the full liberalisation opens the possibility of multi actor competition in several links in communication value chain, where tariffing will be influenced by the real cost of each link and possible choices in quality offered, i.e. cost related.

But both for the present and future situation it is of utmost importance that the tariffing principles are flexible.

Petter Bliksrud graduated from the Technical University of Norway in 1968, and has since worked with the Norwegian Telecommunications Administration, later Telenor, on both maritime, aeronautical and land mobile systems. He has participated in several international bodies on terrestrial and satellite mobile communications, and in particular within the environment evolving the GSM standard and operational procedures. He was the seventh chairman of the GSM MoU (1990). He now has the position of R&D manager with Telenor Mobil AS, Norway.

PANNON GSM'S APPROACH TO NETWORK QUALITY ASSESSMENT

T. RAKÓ and Ø. MIKKELSEN

PANNON GSM TELECOMMUNICATIONS COMPANY
H-1134 BUDAPEST
VÁCI ÚT 37.

1. INTRODUCTION

Today mobile telephony is a highly competitive market. In 1994 two GSM operators opened their commercial services which resulted in a great challenge to quickly cover an important part of the land and population, provide intelligent value added services and maintain high-level service quality. In this competitive environment Pannon GSM focused on providing a great variety of high quality services. Quality became a strategic issue and early arose the need to establish a quality policy including goals, the framework for assessment, and countermeasures. This approach was the driving force behind a recently started project aiming to redefine quality objectives, work out a new measurement concept, detect major problems in the planning, implementation, operation and maintenance, and propose organisational changes if necessary to improve network quality.

2. NETWORK QUALITY CYCLE

In our approach network quality undergoes a continuous cyclic evolution. As a first step the company's quality objectives are established. Then planning and implementation are done with the specified network quality in view. Quality is regularly assessed during operation which provides a feedback for planners, contractors, and the operation and maintenance staff to improve internal processes. Such a cycle should lead to an improved level of service quality.

Quality assessment is a four-step procedure. First data are collected from the network. Then the information is presented that enables the analysis of network performance. Based on the results of the analyses, proposals are prepared to improve network quality by means of modifying internal processes or to alter the quality objectives.

The main inputs of network planning from quality assessment are network performance and coverage data. Quality measurements also provide information in connection with network capacity such as the average traffic per subscriber or traffic growth. The fulfilment of the roll-out plan and the faults in newly constructed sites are the relevant feedback for the implementation process whilst operation and maintenance relies on a great variety of network performance data.

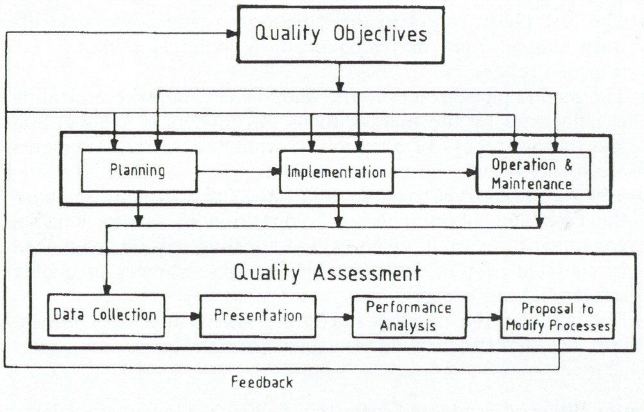


Fig. 1. Network Quality Cycle

The fulfilment of the quality objectives is assessed with the help of quality parameters which are designed to be customer-oriented, decision-promoting, and objectively determinable. Quality parameters comprise Pannon GSM's whole range of activities. However, in this paper we restrict ourselves to discussing network quality related aspects.

3. DATA SOURCES

In order to be able to assess network performance, quality parameters are collected from several sources. The main information sources are summarized in Fig. 2.

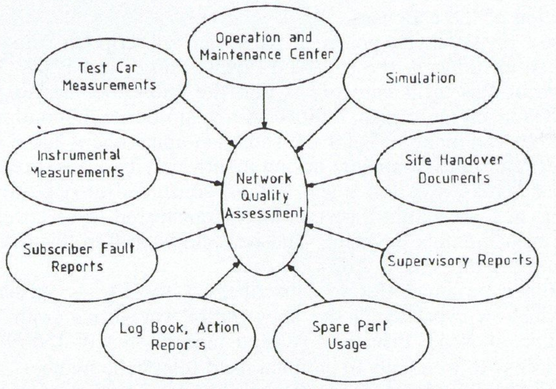


Fig. 2. Main information sources for network quality assessment

The Operation & Maintenance Centre (OMC) is one of the most important sources of quality measurements. It is linked to major network elements such as MSC, BSC, HLR and others. It enables, hereby, on the one hand to continuously detect, locate and correct faults and breakdowns in the system by means of alarms and commands given through a man-machine interface, on the other hand to perform a wide range of measurements by making use of the OMC database which stores the counters of measurements and observations started in various network elements.

Whilst OMC is a powerful tool for assessing network quality from the operator's point of view, test car measurements intend to show how subscribers see the network. A Geographical Information System being part of the measuring system, one can easily link network performance to geographical location. Test car and test phone measurements are widely used to check radio planning.

Subscribers fault reports represent subjective information on network quality. However, when these reports are evaluated according to failure type, geographical distribution, etc. they have an important contribution to network quality assessment.

The log book kept in the Network Control Centre, the action reports on repairs, and the reports on used spare parts also provide important information on typical faults in the network. These sources are inevitable when identifying the reasons for faults or insufficient performance detected with the help of the OMC or test car measurements.

Instrumental measurements such as e.g. interface or protocol analyses, BER or interference measurements are first of all tools for fault finding, but they also provide data on network quality (e.g. transmission quality on the air interface and the microwave links).

The quality of the building and construction work as well as that of the GSM and transmission equipment installation, which has an effect on future network quality, is assessed by supervisory inspections during and after the implementation process. The result of these inspections is included in the site handover documents.

Finally, simulation is a method to foresee network performance in the planning phase. Currently we use the Nokia Planning System to planning cellular coverage; this software includes a GSM simulator as well.

4. MEASUREMENTS AND REPORTS ON QUALITY

OMC provides the bulk of the electronically measurable data. The OMC counter measurements are classified according to the network element they refer to. This corresponds to the structure of the OMC measurement database which consists of a BSC, an MSC, and an HLR database. The most important measurements are as follows:

BSC-BTS measurements:
- cell outage time;
- busy hour traffic and congestion on traffic and signalling channels;
- dropped call rate, reasons for dropped calls;
- handover success rate between cell pairs;
- average signal strength and signal quality at the BTS and the mobile stations, radio link balance;
- uplink interference.

MSC measurements:
- traffic, congestion, ratio of successful calls in traffic categories and destinations;
- subscriber facilities usage time;
- announcement channel measurements;
- cell traffic measurements;
- inter BSC and MSC handover measurements;
- successfully arriving visitors.

HLR measurements:
- number of subscribers;
- number of home visitors to other PLMNs;
- number of activated services.

SMSC measurements:
- submitted and delivered short messages;
- success rate for submission and delivery.

Voice Mail System measurements:
- disk space and line usage;
- connection time.

Test car measurements are performed partly within the scope of regular quality surveys, partly to assess network performance in problematic regions or in the service area of new sites. They provide information on the signal level and signal quality of the serving cell, signal level of the neighbouring cells, system response time, mobile station output power level, handovers, dropped calls, etc.

The information we gain from supervisory reports comprises the minor and major faults found during the inspection in site construction, equipment cabinet manufacturing, GSM and transmission equipment installation, cabling, etc. Supervisory reports enable to determine typical faults in the implementation phase as well as to evaluate the subcontractors' work.

The log book and the action reports on repairs contain the exact reason for a certain fault (e.g. air-conditioner, transmission or GSM equipment, cabling etc.). These fault reasons, together with spare part usage are linked to network performance degradations such as cell outage or high dropped call rate what helps evaluate the importance of fault types.

Reports on quality are produced at various levels and for various time intervals. Detailed reports are made for the technical staff whilst summary reports are produced for the management. Daily, weekly, and monthly reports are regularly prepared as well as trends for longer periods.

Measured data are analyzed in detail and, therefore, reports include th e explanation of unsatisfactory network performance and the proposed actions as well. The latter information represents the feedback in the network quality cycle.

5. QUALITY PROJECT

The commitment to high quality service provision induced Pannon GSM to start a quality project. The purpose of the project is to detect major problems leading to degradation in network quality and suggest solutions to improve network performance and thus customer satisfaction.

As a first step we worked out a new structured measurement system which is more suitable for failure detection than our old system. We provided a new definition sheet for each measurement comprising — among others — hints on what fault can be detected with the measurement, what other measurements can be done to investigate problem cases more in detail, and which organizational unit is responsible for deviations from the quality objectives.

The new measurement system provided valuable assistance in detecting major causes of unsatisfactory quality in the network. We followed a most simple method when revealing problems. The philosophy behind our approach is that in many cases decreased network quality is a result of some trivial error or malfunction in planning, implementation or operation which is easy to eliminate. The remedy is less obvious for the rest of the problems; in such cases thorough investigations are needed and improved quality can often be attained only by more sophisticated means such as e.g. network fine tuning.

First we concentrated on "trivial" errors as their detection is simple and quick and, therefore, we expected a rapid improvement in network quality after their elimination. Other problems were tackled in the second phase.

In the first phase of the project we concentrated only on a couple of important quality parameters such as cell outage time, busy hour congestion, dropped call rate, etc. We ranked the network elements in the order of decreasing performance, selected the worst cases and tried to find an explanation for their bad performance. We made efforts to standardize explanations so that we can later tackle similar problems in a similar manner. Then statistics on the reasons for bad quality helped us to assess the importance of each failure cause.

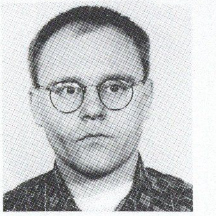
This simple method enabled to find some important bottlenecks in the network. Furthermore, it proved to be most useful in preparing decisions as it helped the management to rank problems and tackle the important malfunctions. Having revealed major problems in the operation, effective countermeasures were taken by the organizational unit(s) responsible for the failure. This included the exchange of faulty parts or appliances, as well as the modification of internal processes or planning.

In the second phase, the circle of the examined quality parameters was extended. The emphasis moved towards deeper analyses and the project provided more assistance for network tuning.

6. CONCLUSIONS

Quality assessment is a complex issue — part theory, part judgement. This paper explains what framework for network quality assessment Pannon GSM has worked out, based on own practice and the experiences of Nordic PLMN operators. The discussion also focused on the company's efforts to improve internal processes in order to attain better network performance.

Tibor Rakó received his M.Sc. degree in electrical engineering from the Technical University of Budapest in 1990. From 1990 to 1994 he pursued postgraduate studies at the Technical University of Budapest and the Ecole Nationale Supérieure des Télécommunications de Bretagne in Brest, France. In March 1994 he joined Pannon GSM Telecommunications Company. He provided assistance on special tasks related to radio and transmission systems. Since June 1995 he is the project manager of Pannon GSM's quality project. He participated in the standardization work of ETSI Sub Technical Committee SMG4. He is the author of several articles and conference papers.



Østein Mikkelsen received his M.Sc. degree in electrical engineering from the University of Chalmers (Gothenburg, Sweden) in 1989. From 1989 to 1990 he was a radio planner at Telenor in Oslo. In 1990 he became the project manager responsible for the radio part of the first GSM network. From 1992 to 1993 he was the planning manager of the Oslo network. In 1993 he became the GSM-manager of the south-eastern part of Norway. In mid 1995 he joined Pannon GSM Telecommunications Company as system planning manager.

WESTEL 900 GSM SERVICES AND TARIFF POLICY

CH. MATTHEISEN

WESTEL 900 GSM MOBILE TELECOMMUNICATION LTD.
H-1117 BUDAPEST
KAPOSVÁR U. 5-7.

1. BASIC PHILOSOPHY

WESTEL 900 GSM's basic service and tariff policy is to provide an affordable, high-quality mobile telephone service that customers can easily use. All of these points are equally important in bringing the service to the market. In general, WESTEL has taken the following principles as guides in developing its policy:

- Segmentation. The market for mobile telecommunications consists of a number of different types of users; in order to capture as many customers as possible, it is important to offer services and tariffs which appeal to as many of these types as possible.
- Consumer orientation. We see GSM mobile telephone service not just as a business tool, as mobile phones have traditionally been marketed, but as a private consumer-oriented communications benefit. Services and tariffs should always keep this in mind.
- Keep it simple. Basic mobile telecommunications alone, not to mention the array of enhanced services available today, is itself an extremely complicated and potentially confusing product. It is therefore important to keep any offerings put to the market as simple as possible. The easier our service is to use, the more benefit both we and the customer derive from it.
- Add value. WESTEL 900's basic brand positioning objective is to be the GSM market leader in Hungary. This positioning has to be maintained through a high level of quality in all aspects of the business, from network coverage to handset servicing and customer service. In order to justify this investment, it is vital that the customer perceive that we are adding real value to the service in everything we offer.

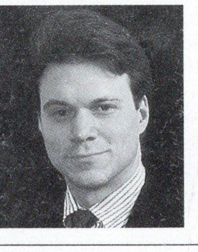
2. TARIFFING POLICY

A fundamental tenet of WESTEL 900's tariffing policy is that the the company is at the same time a network operator and a service provider; WESTEL 900 maintains the relationship with the end-user. This is in contrast to the experience in other GSM countries, such as Germany and Great Britain, where network operators (such as D1 in Germany and Vodafone in the UK) are distinct from service providers, who actually "own" the customer. Direct connection with customer gives more control over consumer price point and distributors. Airtime wholesaling surrenders pricing policy to service providers; pricing loses consistency and ceases to be a source of differentiation or a source of supporting the brand positioning.

Tariffs and prices in the GSM field consist of a number of disparate elements: handset price, connection fee, monthly access and airtime (per minute) charges.

3. SERVICES POLICY

- Adding value. Services offered by WESTEL 900 should demonstrably add value for which the customer has a real demand.
- Enhancing, not distracting from mobility benefits. It is very easy to be tempted by technology into diverging from the core business of providing mobile communications for customers. Many of our enhanced services therefore focus on consumer benefits that are directly relevant to mobility: voice mail, text messaging, fax mail, fax and data transmission (and the related access to e-mail). Basic mobile telephony is itself a complicated business, without becoming distracted by a number of other things we could offer that are not closely related to the core business.



Chris Mattheisen economist, MA, 34 years old. BA from Indiana University, Bloomington. MA in economics from Columbia University. Co-founded own consulting firm, KM Associates in Budapest in 1990. Joined WESTEL 900 in 1993. Director of Marketing and Sales since 1994. Speaks English, Hungarian, German and Czech.

DEVELOPMENT IN GSM SPEECH CODING

K. NIUTANEN

NOKIA TELECOMMUNICATIONS
H-1126 BUDAPEST
KIRÁLYHÁGÓ TÉR 8-9.

1. INTRODUCTION

GSM networks have been build and expanded throughout the continent at a remarkable pace. Until now the network operators have been busy in building the basic network. The more mature networks are beginning to reach the status where more attention is paid to the quality and capacity enhancements of the networks.

The market forecasts in mobile telephony have been always below the actual development. Now penetration levels close to 50 % are not regarded crazy, actually rather reasonable. Two technological development needs arise if and when this happens. First, the capacity of the networks need to match the usage of the mass market. This pushes for techniques saving radio spectrum. This means packing information into smaller and smaller space. Secondly, such penetration require that cellular phones really replace the PSTN phones. This would require that the speech quality in cellular phones matches that of land line. Enhancing the quality of speech would actually mean transmitting more information. These two requirements are clearly conflicting.

Capacity and quality enhancements are incorporated in the GSM standard. Half rate coding enhances capacity, enhanced full rate coding speech quality. In the following these two coding schemes, their status and consequences are discussed.

2. HALF RATE CAN INCREASE THE SERVED SUBSCRIBERS BY OVER 200 PER CENT

The half rate specification was frozen in the beginning of 1995. When will half rate be available? Currently the most probable time seems to be in the latter half of 1996.

Half rate seems to promise the capacity increase in the networks, that would be required by the mass market. For example, if a TRX is upgraded to a half rate version, the amount of traffic channels increases from 7 to 15. Assuming a 2 % blocking in the air interface, this amount of channels can handle a traffic of 9 Erlangs, opposed to the 2.9 Erlangs of the full rate TRX. Assuming that the subscribers cause a traffic of 25 mErlang each, the amount of subscribers one TRX can serve increases from 116 to 360; that is 210 %.

The capacity increase of half rate is lucrative, because it does not affect the radio network planning or the locations of the base stations at all. It only implements a means of utilizing the existing radio frequencies available in a more effective way.

The drawback or challenge of capacity increase is not in the infrastructure side, but on the terminal side. This kind of capacity increase can only be achieved if all the terminals in the TRX area can support half rate. In other words, to maximize the capacity increase of half rate, all the full rate terminals in the market would need to be replaced by half rate terminals. How is this then achieved? Unfortunately new terminals need to be sold to the subscribers. An operator could encourage subscribers to buy a new terminal by giving lower call tariff for the half rate terminals, because they use only half of the resources compared to the full rate phone.

3. GSM SPEECH QUALITY IS EVEN, BUT "METALLIC"

The other side of the capacity problem is that of speech quality. Many have commented the sound of GSM to be "metallic" or "unnatural", even "unrecognizable". After the first ten calls or so, the frequent GSM users' talking partners get used to the "new voice" of the GSM user. As soon as this stage is reached, the GSM speech quality is generally regarded better than that of the analog systems, as it is more even. The signal strength variations are not noticed as clearly as in analog systems. In good signal conditions the speech quality of analog cellular systems is taken as "more natural and normal" compared to GSM.

Such speech quality discussions have risen discussions and development of a more advanced speech coding technique. It is most likely that the high penetrations like 50 % predicted will not be achieved with the current level of quality. The consumer market is much more demanding than the current user s, mostly business people, are. Nowadays users can be regarded as the early adopters, who understand the technology quite well, and appreciate the value that mobility brings to them. Additionally they are willing to pay for the service. Understanding the technology would mean that these users would not expect the telephone to work in basements or in elevators. Consumers, on the other hand might have seen mobile telephones in movies, used anywhere, and would expect this to be the case in reality. On the quality side, the consumers are used to land line speech quality. They would not appreciate the fine coding techniques that are used for compressing the data to save the frequencies in the air interface. They would only notice, that the quality of the service is bad, and would stop using the phone. This would clearly be the case with the higher tariffs of mobile services.

4. AN ENHANCED FULL RATE CODEC FOR PCS MARKET OFFERS SUPERIOR QUALITY

To address the quality needs of the market place Nokia has been active in developing an enhanced full rate coder, EFR. The joint development together with the University of Sherbrooke has now been approved for the PCS market in the US.

Before approving the EFR for the PCS market, an independent research laboratory, the COMSAT Laboratories, run a quite comprehensive test set to verify the quality of the codec. These test compared the EFR to the current full rate coder, the 32 kbit/s ADPCM, used in landlines, and the available version of the coder to be used in CDMA. The subjective tests showed that the new coded was equivalent to the ADPCM coder in most of the tests being better in some of them. It outperformed by far the current full rate coder and that used in CDMA.

This coder was after the testing selected as the codec for the PCS market in the USA. In ETSI no enhanced full rate coder has been approved at the time of writing this article (September 1995). The major GSM equipment suppliers are working to get the same codec approved for ETSI, too. One codec throughout the world would result in considerable economies of scale. Additionally much resources would be saved during the specification phase. This would make the manufacturing of the codec more economical in the long run. End users would benefit eventually, as the equipment costs would be reduced.

When could the enhanced full rate codec be available in Europe? Naturally, as there is no proven standard at the moment, the implementation will happen only after the implementation of half rate.

Let us assume that EFR is standardized by ETSI. How will this affect the GSM market. Will operators implement this into the network and begin offering Hi-Fi quality mobile service? Specially the quality difference between the EFR and the current coder is noticed when non-voice signals are transmitted over GSM. The new coder can cope with DTMF signals as well as music. How will this affect the market place? Will end users be willing to accept poorer quality service when this Hi-Fi quality service is also available? Is it possible to compensate the poorer quality with lower tariffs?

5. SPEECH CODING CAN BE USED AS A MARKETING TOOL

Let us look at a scenario, what could happen, if both coders, the half rate and the enhanced full rate, were available. Let us assume that one operator, named EveryOne, and another, named Hi-Fi, were competitors in the market.

The business idea of EveryOne could be to "Offer Mobile Telephone Service of EveryOne to EveryOne". They could introduce a tariffing scheme: "Pay only for usage", without any monthly fee, so that the entry barrier for the masses would be very low. Additionally the terminals could be sold with the option of buying it back at a 90 %n price, should the consumer find the service unsatisfactory. This would further reduce the entry barrier into the network.

The pricing of the service of EveryOne would bring a wave of new users into the network, benefiting of the "try with low cost" scheme made possible. During the trial period the network should be capable of serving a huge amount of people, who would most probably be interested in making normal calls, nothing more fancy. To ensure that normal service is available for the masses, EveryOne would implement half rate into the network. The new service would be sold to the consumer users in connection with half rate telephones.

The rival, Hi-Fi, could introduce a business idea "It's like (Hi-Fi) Music to Your Ears". The high quality service would be offered with a higher tariff scheme. The higher tariff would be justified by a higher speech quality in the network. Hi-Fi would target the business users by emphasizing the image of the company in connection to the superior quality. A company using such high quality service would also get the image of being a high quality company. To be able to offer the service, Hi-Fi would need to implement the EFR into her network. The premium service would be sold to the subscribers together with new EFR telephones.

6. CAPACITY OR QUALITY, IS EITHER THE ONLY SOLUTION FOR THE MARKET?

Which of the operators will do better? The assumptions given would drive the consumers to be served by EveryOne and business users by Hi-Fi. However, there are some obstacles, which might change the clear segmentation.

First, will EveryOne really have sufficient capacity in the network? To utilize the capacity from implementing half rate fully requires that all subscribers in the network use half rate telephones, not only the users of the inexpensive service. The normal full rate users will naturally be served by the network, but they will always occupy twice the amount of network resources compared to the half rate users. Thus, from the resource usage point of view, these users should be charged twice the amount of half rate users. However, form the subscriber point of view, what justifies this price difference? Till now we have not been able to verify the final speech quality of half rate, but according to preliminary information, the quality difference between normal full rate and half rate is not that substantial that it could justify a remarkable tariff difference. Even if it could, how should this be done? If the mass service would be offered at half the price of the normal service, would there be a business case? On the other hand, raising the price of the existing customers using full rate mobiles most probably result in churn to the rival operator.

Another issue is the speech quality. Is it so that the lower quality will be tolerated, even at a lower price. If we take an analogy from the audio business, low quality service will not survive. Practically all records sold today are CD records, the time of LPs is gone.

Is the conclusion then, that Hi-Fi will be the winner? How will his business do? Is it sufficient to make business with only premium service? If the service takes off well, will there be enough capacity in the network. If there is a shortage of capacity, it equals poor service, even though the speech quality in good signal conditions would be superior. How will Hi-Fi build the required capacity? Will she stick to full rate technology only and use microcellular structures and advanced radio techniques to build the capacity? Another option could be to introduce half rate into the network and start selling a lower priced service, too.

7. SPEECH CODING IS NOT ONLY A TECHNICAL ISSUE, IT IS A MIXTURE OF BUSINESS AND TECHNIQUES

There is no simple solution to the contradicting requirements of enhancing capacity and coverage.

Most probably a clear cut either-or solution is out of the question. A combination of capacity and high quality service is needed. The question is, how to introduce this and implement it in the network. To get the best out of it, operators will benefit of a good understanding of the market place and close so-operation with vendors mastering the technology.

Kenny Niutanen has a Licetiate of Technology degree from Helsinki University of Technology. He joined Nokia in 1992. He has been working from the very beginning in GSM system marketing. He has been involved in the marketing activities in Central and Eastern Europe. System marketing in Nokia is a function between technology and sales. In this position he has gained a good insight of the technological capabilities and market opportunities of GSM.

THE ERICSSON GSM SWTICHING SYSTEM, FEATURES AND CAPABILITIES

M. BLOMQVIST

ERICSSON RADIO SYSTEMS AB
STOCKHOLM
SWEDEN

1. INTRODUCTION

This paper gives an overview of the Ericsson GSM Switching System (CME 20 SS), features and capabilities. The paper also looks upon the evolution of GSM 900/DCS 1800 to better cater for the needs of different categories of users, operators and service providers.

2. CME 20 SS – A SUCCESS STORY

The CME 20 Switching System has been successful from the very first day of the implementation of GSM/DCS networks, starting in July 1991. From that day, more than 40 operating companies around the world have chosen the CME 20 Switching System (SS). A continuously strong effort in research and development has put the CME 20 SS in a very strong position on the market: An effort that will continue to fulfill the operators' and the end-users' demands in the future.

Ericsson has a leading role as a total system supplier thanks to broad experience from various telecom areas such as fixed networks, all mobile standards, Intelligent Networks, transmission, DECT, business communication, CCITT#7 signalling, etc. This broad experience is a guarantee for high switching system functionality, in-service-performance, and for a future proof switching system based upon AXE10. CME 20 SS is known worldwide for its high feature availability and feature productivity.

In the era of GSM, Ericsson has played an important role in the work of specifying the GSM standard and will also play an important role in the future.

2.1. CME 20 Structure

The CME 20 Switching System (SS) consists of logical nodes like the Home Location Register (HLR), Mobile Switching Center (MSC), Visitor Location Register (VLR), Gateway Mobile Switching Center (GMSC), Authentication Center (AUC) and Equipment Identity Register (EIR).

The MSC/VLR also include the functionality for a national transit exchange, International Gateway, Signaling Transfer Point (STP), SMS-GMSC, SMS-IWMSC. The MSC/VLR is now being developed also to cater for the Service Switching Function (SSF).

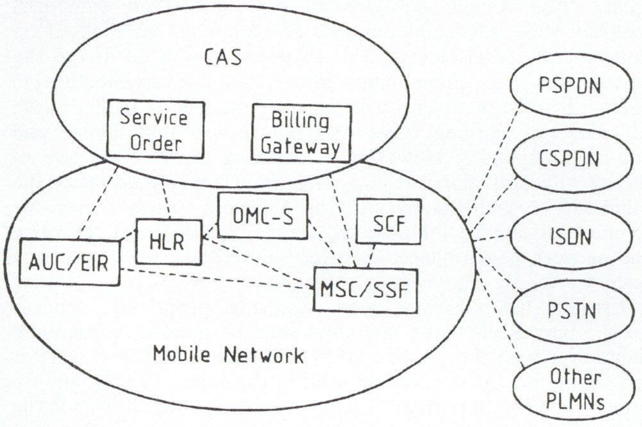


Fig. 1. CME 20 SS structure

3. RAPID GROWTH – CAPACITY IS THE CRUCIAL ISSUE!

The growth rate for mobile subscribers is accelerating on all markets, as mobile telephony becomes more widely accepted and affordable. The growth has been greater than anyone could have imagined and it is still difficult to imagine the predictions being made for the future.

In the early GSM days the services attracted mainly business users with a typical traffic of 25 mErl per subscriber and a mobility pattern similar to older analogue systems.

Due to the substantial fall in GSM/DCS handset prices, decreasing size, better battery economy, etc, we see cellular based solutions also for office and other indoor environments with completely different user patterns – traffic up to 150–200 mErl per subscriber and a low degree of mobility.

The same goes for the consumer market segment where digital cellular is now becoming an affordable service for very large groups of users. The tendency seems to be that the market for the handhelds is now following the penetration curve for other consumer electronic equipment.

The switching system is the heart of a cellular radio network, and the powerful Ericsson Switching System based on a well established reliable platform gives a competitive edge. New features and services demand high capacity as regards processors and memory.

The main objective with CME 20 services and switching is to give the operator the tool for decreasing costs and increasing revenue. In the CME 20 switching system, this is achieved by meeting the following three main objectives:

- To be able to provide the types of services that allow the operator/service provider to competitively position or differentiate end-user products and services towards desired target markets, thus making the operator/service provider more attractive and increasing revenues.
- To equip the network operators with market-segmenting tools to enable them to provide a wide variety of services.
- To reduce costs by increasing the capacity of switching subsystems or constituent parts of the system without compromisizing the service quality.

We see the need for processing capacity doubling every second year. The subscriber stream, new services and applications — such as mobile Intelligent Networks — are developed and the usage of existing services increases.

Ericsson recently launched a new interface compatible and high-performance central processor which offers quadrupled processing power compared to its predecessor. In the hard-nosed competition between operators, a four fold increase in traffic capacity could be a real revenue-generator with a minimum of system impact.

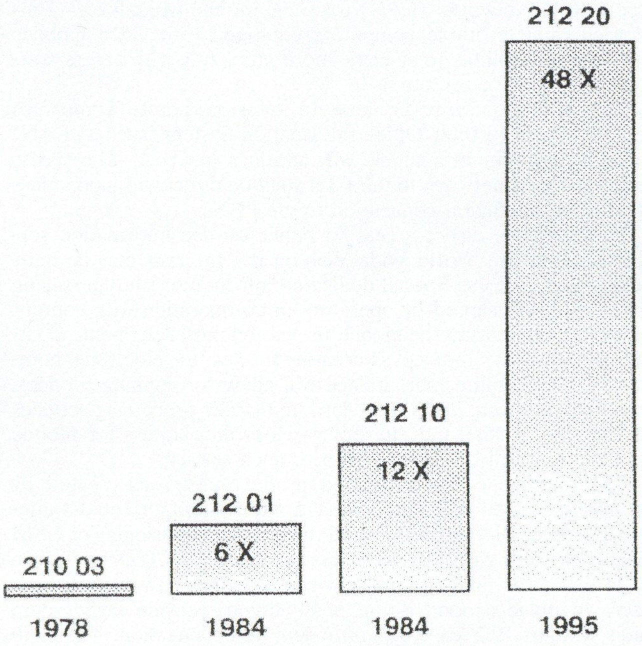


Fig. 2. CP performance boost, CP performance compared to previous generations

The new central processor also allows mobile operators to deploy new services and applications quickly at the same time as they boost their network management and implement still larger nodes.

At the same time, the development is ongoing for the next generations of processors to assure the provisioning of high-capacity switches and HLRs in 1997/98 and onwards.

4. ENTERING NEW MARKET SEGMENTS ON A COMPETITIVE MARKET – THE IMPORTANCE OF NEW SERVICES AND APPLICATIONS

Competing on the highly competitive mobile telecommunication market there is a definite need to differentiate the offering to the subscribers. One important factor is the service offering.

The CME 20 Switching System supports all basic services defined by ETSI, and it also supports a comprehensive set of supplementary services which can complement and modify tele services and bearer services.

Ericsson also provides innovative features, such as Single Personal Number, Dual Numbering, and Immediate Call Itemisation, Geographically Differentiated Charging, Local/Regional Subscription, etc.

4.1. *Fax and Data Communication*

Fax and data has been launched in most markets and will be used as a differentiator. Today the use of fax and data services is quite low and it will probably stay low for some time to come. The key for success lies in user-friendly services with high capabilities.

Present GSM systems provide circuit switched data capabilities, and such bearer services are suitable for data transfers using analogue modem interworking with PSTN, unrestricted digital ISDN access for interworking with ISDN terminal adapters, basic PAD or dedicated PAD access to public packet data (X.25) networks.

The wireless data market is set to become highly competitive. Several countries already have more than one dedicated wireless data operator and the competition will intensify as GSM data roll out continues. By the end of the decade a significant portion of the total number of mobile subscribers around the world will use and work with wireless datacom applications integrated with their normal voice services. GSM and PCS networks will transport a large amount of the data traffic through to external connectionless oriented packet data networks.

Corporate customers may want a dedicated access for office Local Area Networks (LAN) for their mobile work force. Employees using portable computers equipped with GSM mobiles with data capabilities may work more efficiently with access software products for remote use.

The operator must be able to offer corporate companies remote access to their Office Information System (such as LAN) or host computer in a simple way and at a low cost. The access from the GSM network to the PTN shall be direct and modemless (that is, with a digital connection to the PBX).

Furthermore, direct access to public on-line information services such as the World Wide Web on the Internet may be marketed by operators. Special dedicated information and messaging services may designed by operators in co-operation with content providers, addressing the mobile professional user segment. CommerceNet on the Internet is creating models for electronic commerce. The on-line marketplace will allow for banking services, merchant services, and credit card and order processing services to emerge. A fast and efficient wireless data access for mobile professionals will be vital for utilizing such services.

The purpose of such bundled product proposals created by an operator is to offer more image and market oriented value-added data services in addition to the normal provisioning of GSM Bearer services with dial-up access through PSTN/ISDN.

To make the fax and data services more attractive to the end-user, an obvious need is the possibility to provide higher data rates, at least 19.2 kbps with a modem less connection. The High Speed Circuit Switched Data work item in GSM phase 2+ plays an important role.

5. VALUE ADDED SERVICES

Today the need to introduce services that differentiate between competing networks has acquired a sense of urgency. To differentiate while adhering to a standard like GSM is however, a dilemma.

Intelligent Network techniques provide a solution to this dilemma. A technique the Ericsson SS had adopted early in development. This has been seen as one of the main roads forward to provide new services rapidly and reliably rather than wait until the standardization is ready. The IN technique also provides a toolkit for introducing enhancements beyond the basic functionality of the standard.

The next step to take is to be able to provide these services also for subscribers roaming outside the Home PLMN. Therefore Ericsson takes a leading role in the standardization of the CAMEL mechanism in GSM phase 2+.

The Ericsson Intelligent Network (IN) service access provides access to IN services. Services which can be reached with this access are:

- Virtual Private Number;
- Private Numbering Plan;
- Location Based Services;
- Common Directory Number;
- Flexible Call Screening Services;
- Universal Access Number;
- Freephone Service;
- Pre-Paid SIM Service.

The Ericsson Mobile IN is implemented in many operating networks today. This is a sign of Ericsson's long and broad experience in different telecommunication areas and the ability to combine applications for the success of the operator.

In addition to the existing functionality, some network optimization will be achieved in the near future, such as integrating the SSF into the MSC/VLR, so that network resources can be used more effectively. The SSF will support ETSI Core INAP.

By allowing subscriber data exchange between the HLR and the Mobile SCP, much more sophisticated mobile intelligent network services can be implemented. In this context the HLR can be modelled to a Service Data Point (SDP) containing a Service Data Function (SDF). This allows the Mobile SCP to obtain data related to the mobile subscriber such as current location and the subscriber status (idle, busy, not reachable).

The Unstructured SS Data (USSD) mechanism is foreseen as a means for communication between the end-user and the Mobile SCP. The mechanism can be used for service control and for other information transfer between the end-user and the network.

In the standards, the cellular and the intelligent network architectures have been developed side by side with a different focus. The cellular development has focused on wide area mobility while intelligent network development has focused on rapid service provisioning. The challenge now is to merge the best of the two communities into a suitable architecture in deployed networks. This will naturally start in a limited scale to enter the learning curve of rapid service provisioning and end-user response. However, in the long term perspective of this architecural marriage it is important to consider that the rapid service provisioning must be balanced with a reasonable solution for service interactions, service management, charging and network performance when the services are used at a large scale.

Ericsson has also developed numerous proprietary services for the purpose that the operators shall be able to differentiate themselves with the existing GSM infratructure. These services can in the most cases only be used in the home PLMN and are usually the most important. The most severe competition is in the home market!

The following examples can be mentioned:

- This feature provides the possibility to divide the MSC/VLR service area into different tariff areas. A tariff area is an area within the MSC/VLR service area with a certain region dependent tariff origin value. Tariff areas can overlap each other which means that different subscriber groups can have different tariffs in the same area. It also enables Tariff Origins to be prioritised, so that in the case of a particular subscriber with overlapping areas, each assigned a different tariff origin, the highest priority Tariff Origin will be selected. That is, if a subscriber is located within a micro cell which is overlaid by a macro cell, then the tariff origin for the micro cell could have the higher priority.
  This concept gives the operator the possibility to create different zones within the PLMN where different tariffs can be applied. For example a subscriber may have a low tariff for call originated in his home town, a high tariff in city areas, and a normal tariff for calls originated in the rest of the PLMN. The different tariff areas can be applied differently for different subscribers or groups of subscribers (end-user segments). The tariff applies for originating calls made from within a certain area independently of the distance of the call.
- Immediate Call Itemisation (also called 'Hot Billing') is used when call records are required to be output as soon as possible

after the call in order that the data may be used to bill third parties for the use/rental of a mobile telephone.
The function in the MSC provides the interface only to the 'Hot Billing' computer system. In order that a complete 'Hot Billing' feature be implemented, the necessary computer system is required to receive the data and then either process this centrally for access by terminals located at the rental offices or transfer it for processing by each rental company itself with their own computer systems.

- The feature service segmentation based on subscriber priority level gives the network operator means to offer certain mobile subscribers preferential grades of service at channel allocation. The feature, used in conjuction with the BSS feature Differential Channel Allocation, can be used for creation of subscriptions where for example low paying subscribers (such as the private segment) gets lower grade of service in areas where business subscribers shall have precedence at peak-hours. The low paying segment behavior will then be to move their traffic to off-peak hours of the day/week.
The business segment and other important subscriber segments, like rescue forces and police, will have a higher grade of service.
The priority level will only be used at call set up so a held call will not be lost during handover due to a low priority level.
The priority level is subscription based: that is an indication (priority category) is set in the HLR per subscriber.

6. CME 20 SS – DECT

DECT, developed as a radio access technology for connection to the ISDN or to PTNs (Private Telecommunications Network) offers yet another possibility to combine the strong mobility concept in the GSM switching system with an alternative radio access where emphasis has been laid on optimizing for high capacity and accepting restrictions related to local terminal mobility at low speeds.

By extending GSM/DCS networks with DECT products for business indoor radio coverage applications, Ericsson can offer additional possibilities for cellular operators:

- to capture new end-user segments and
- to increase the penetration of mobile users in indoor environments.

The CME 20 SS regards DECT as an additional access product for GSM/DCS networks:

- Offering cost-efficient solutions for indoor high capacity coverage to business applications.
- Offering roaming capabilities between different DECT areas by using the mobility management in the GSM/DECT networks.
- Offering new distinct possibilities to deploy differentiated tariff structures for indoor and outdoor coverage, respectively.
- Offering speech quality comparable to the quality of the fixed network or the enhanced GSM speech codec.

Ericsson, being a well advanced supplier of both GSM 900/DCS 1800 and DECT, is pioneering also this application.

7. IN SERVICE PERFORMANCE – A KEY TO END-USER ACCEPTANCE

The success of GSM with a never ending stream of new subscribers puts high demands on the in service performance of the network equipment as well as the speech quality. These aspects of operation are fuels in the competition between operators.

When the subscriber base is growing and going from business users to private users we are entering a segment that is not used to mobile telephone to the same extent as the business users. Therefore, availability of the network and high speech quality is a prerequisite for optimal revenue.

The Ericsson Echo Canceller (EC) in pool is one step forward for speech quality. It allows the operator to:

- Dimension some redundancy into the echo canceller, and thus pro-actively avoid inferior service quality for the end-user.
- Exercise the echo cancellers during low traffic periods in order to isolate faulty ECs.
- Allow the most economical EC dimensioning in cases where many small routes emanate from the MSC.

Recent comparisons show that this solution gives better performance than Echo Cancellers placed in trunks.

The development of the enhanced full rate codec will further enhance the speech quality as perceived by the end-user.

Ericsson is investing a lot of effort in constantly improving the Switching System availability to the highest as possible in the telecommunication area.

The CME 20 stand-alone HLR is renowned for its good reliability and high capacity. As the network grows, many operators are implementing stand-alone HLRs. The Ericsson HLR, which can cater to up to 1,000,000 subscribers, will therefore have geographical redundancy capabilities. That is, if the HLR is destroyed, for example in an earthquake or fire, another HLR will take over the operation with all information up to date.

8. COMBINED MSC/BSC – THE PORTABLE CELLULAR SYSTEM

Ericsson recently launched the combined MSC/BSC, a portable cellular system housed in a 20 foot shelter delivered as a pre-installed system with all needed equipment except radio base stations. The system is dimensioned for 15,000 subscribers and is aimed for the following applications:

- For local switching in rural and scarcely populated areas (deserts, forests, islands). (No call loops for local calls are needed, so transmission costs are reduced.)
- In cities with low penetration.
- When coverage is essential and there is low penetration.
- At big temporary events, such as exhibitions, sporting events, and emergency situations (fires, floods, etc), or at seasonal holiday resorts, and to relieve pressure on severely loaded existing MSC/VLRs or BSCs.
- In fast-growing networks.
- For small and new networks that are not necessarily fast growing. For instance in underdeveloped countries.

The system is fast to install and mobile to mobile calls could be up and running within a couple of days, with a few days more needed for full inter-operability, depending on the preparations made. Since the system is portable, using for example a truck, it can easily be moved to a new site when needed.

Magnus Blomquist graduated from the Linköping Institute of Technology, Linköping, Sweden, holding a Master of Science degree in Industrial and Management Engineering, in 1985. He joined Ericsson the same year and has held various technical and marketing positions in different product areas within the Ericsson Group since then and holds today a position as Product Manager for MSC/VLR within Ericsson GSM 900 and DCS 1800 product line.

AN OVERVIEW OF WESTEL NMT SYSTEM OPERATION

T. NAGY

WESTEL RADIOTELEPHONE LTD.
H-1033 BUDAPEST
HUSZTI U. 32.

1. HISTORICAL BACKGROUND

It is well known that improved communication facilities are needed in the Eastern European countries. The level of installed fixed phones is far below the averages of Western European countries. Digital services, common in Western Europe, are only available in a few cities in this region. This environment surrounded the formation of a brand new communications company in Hungary, the WESTEL Radiotelephone Ltd. WESTEL 450 is a joint venture of Hungarian Telecommunication Company (HTC, 51 %), and US West International (USW, 49 %).The company was founded in 1989 for the purpose of planning, installing and operating NMT 450 public landmobile service throughout Hungary.

The start-up of this new company was complicated by unknowns. Will the available frequencies be enough? How many subscribers could afford to buy the expectedly expensive mobile sets? Could the company run alone without the financial aid of the owners in long term? How much mobile experience would the employees in the new company have? The answers of the above questions are available today. A lot of positive answers. WESTEL 450 became one of the most successful communications company of Hungary and Middle Europe.

Before the formation of WESTEL, HTC had decided to establish a small PLMN network in Budapest. The market estimate forecasted that around 2000 subscribers would use the service. HTC submitted an international tender for mobile network suppliers, and selected ERICSSON as the primary supplier. HTC ordered a small network based on the NMT 450 standard, consisting of 3 base stations with 48 channels and 1 exchange. The network was installed by ERICSSON, with financing help from the International Monetary Found. These 3 base stations covered 80 percent of Budapest.

The negotiations to establish a joint venture between HTC and USW had already begun, and this small mobile network became a part of WESTEL as HTC's initial contribution. The first mobile call ever done in Hungary and Eastern Europe was made on 15th October, 1990.

The Owners of the company invested more than 100 million USDs by the end of 1995. The license provided by the Ministry of Telecommunication required WESTEL to cover 90 percent of the population until 1993 December 31. The owners are reinvesting the generated profit into the network until 1998.

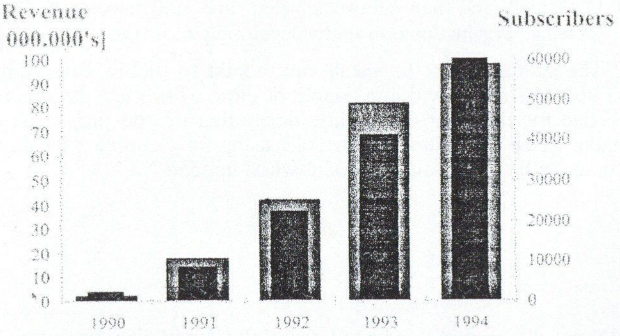


Fig. 1. Growth of the revenue and subscribers

In Hungary, due to the Russian influence in the past, frequencies weren't available for extensive public mobile communications networks. The government assigned the band 455.21-459.99 MHz (base station transmitter frequencies) for the first PLMN network. Even these frequencies were not totally free. The International Railway Networks used a small portion of this band for internal dispatcher communication, and these channels were not allowed to be used by WESTEL. This restriction took away 72 channels from the mobile network, which meant that 180 channels were available for the original purpose. The network uses a channel separation of 20 kHz, duplex distance of 10 MHz, and the network includes a compander circuit for noise reduction. No channel interleaving technique is used. The maximum output power on the sites is 50 Watts ERP/per channel unit.

The customers were very sensitive to the new service so the company had to develop the network very rapidly. We increased the number of base stations within Budapest, and during 1991 company begun to open the service in the countryside. First target was the national resort area around lake Balaton, the North-West route towards the western gateway to Wienna, and the North-East route towards Miskolc. At the very beginning the company decided to plan and install 140 Mbit high capacity microwave backbone system on the above mentioned 3 main routes, because of transporting the planned high traffic from all places of the country. Experience soon showed that the desire for mobile communication was enormous and the forecast of 2000 as a maximum number of mobile subscribers became obsolete. A final target of around 40-.50.000 subscribers was soon establised. In addition, national coverage became a primary objective for WESTEL. A small team of enthusiastic engineers and marketing people started to grow the company and its network. There were 15.000 subscribers and 70 base stations at the end of 1991. In 1992 WESTEL 450 followed to build network in the country towns, two new AXE switches went into operation in Székesfehérvár and in Szolnok. The numbers of base stations grow rapidly, till the end of 1993 we satisfied the Ministry of telecommunications' requirements.

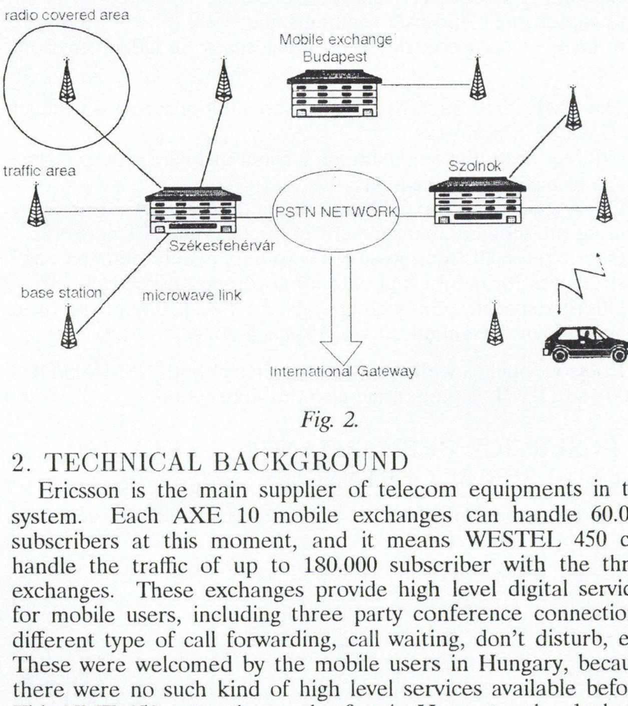


Fig. 2.

2. TECHNICAL BACKGROUND

Ericsson is the main supplier of telecom equipments in the system. Each AXE 10 mobile exchanges can handle 60.000 subscribers at this moment, and it means WESTEL 450 can handle the traffic of up to 180.000 subscriber with the three exchanges. These exchanges provide high level digital services for mobile users, including three party conference connections, different type of call forwarding, call waiting, don't disturb, etc. These were welcomed by the mobile users in Hungary, because there were no such kind of high level services available before. This NMT 450 network was the first in Hungary, who deployed the voice announcements for subscriber related services. The fast network expansion made it possible, that subscribers on the rural area got a European standard telephone network without going through the evolution steps.

More than 5000 radio transceiver channels in three different kinds are working, Ericsson RS 450, RS 4000, and Nokia. At Ericsson's RS 4000 remote configuration is available, it means that we can tune the combiners automatically by a remote command. During the operation work it became very important and comfortable for example in case of introducing new frequency plan. You can send a command from the local swtich to the base station to tune the combiners to a new frequency. Unfortunately the other two equipments doesn't have this feature.

The small capacity 2, 2x4, 2x8 Mbit/s microwave terminals were sold by Ericsson Radar, mainly Minilink 15 family, nowadays we are introducing Minilink 23, 15C and 23C family also. To collect and transport the traffic from the individual base stations to the switch middle and high capacity backbone systems are required. 34Mbit/s data goes through DMC TELECOMs protected and non-protected microwave equipments, and the earlier mentioned 140 Mbit backbone system was sold by NEC. Increasing the efficiency of the network, for consolidation and segregation purpose on the bigger microwave sites we are using digital crossconnectors and Tcoders from Tellabs. Digital crossconnector collects the 2 Mbit trunks come from the base stations with 17 or 25 used 64kbit, and fills 2Mbit trunks with 30 traffic timeslots towards the exchanges. In some cases there is no enough room in a small capacity Minilink, and it is no worth to change to a higher capacity DMC, in this case we installed Tcoders to allow 60 VF channel on one single 2Mbit trunk.

3. TERMINAL AT CUSTOMERS PREMISES

In 1990 Ericsson and Motorola was the only supplier of the telephone terminals. They were very heavy and large equipments, mainly for car installation, not really for portable usage. Soon arrived the phone family of Benefon OY Finland, which contains the Benefon Class terminal. It is a car mounted equipment with CT-2 handset allows to the customer approx. 5-600 meters free distance moving from the car with a lightweight handset. Recognizing the customers' and service providers' expectations, mobile terminal manufacturers developed new and more update, smaller, lighter telephones.

The first big issue was Benefon City, the first ever handheld NMT 450 mobile phone. It was introduced in October 1992. The Benefon remained the leading company developing handhelds in NMT. The most recent phones right now are the Benefon Delta, which was introduced in September 1994 and Nokia 350 introduced in August 1995.

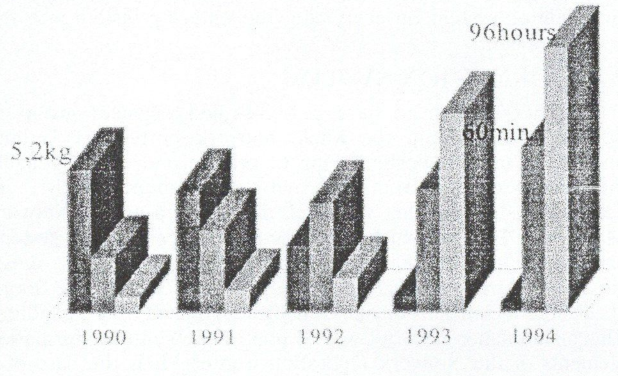


Fig. 3. Evolution of the mobile phones

4. THE BIG CHALLENGE: OPERATION AND MAINTENANCE

At the beginning the company grew very rapidly. The first and most important job was the network developing and expanding. We had to increase the capacity and coverage, because the customers had to have service all over the country. After installing the first base stations and microwave hops the claim to the operation of the working network raised. In addition to the installation works the engineering staff was responsible for the working equipments as well. Because of the huge work at installation side the requirements of the separate operation staff appeared. A small staff began the work at three different places, Budapest, Győr, Debrecen. At the countryside there was only 1 engineer per site. As I mentioned earlier we built the high capacity backbone system in the beginning of 1991, so the network broke out from Budapest at the very beginning, it is involved to place some engineering staff outside from Budapest, because of the significant traveling times. At the end of 1992 eight countryside maintenance centers were established all over the country.

Together with the existing Győr and Debrecen office we joint to the growing sales office network. The earlier mentioned two countryside exchanges Szolnok and Székesfehérvár became the regional operational and maintenance centers of Hungary.

Today the network contains three AXE 10 MTX exchanges, more than 300 base stations and microwave relay stations, 75000 voice frequency channels (64 kbps) and approx. 600.000 km-s long 64 kbps PCM "channels". This hardware can serve 65.000 subscribers at this moment.

5. THE STAFF AND THE DUTY

The operations staff divided into three main parts, the Network Operations staff is responsible for the whole microwave radio and power backup background, the switching staff is responsible for the switching, voicemail, some part of billing information and data network. We have more than 300 sites that means a big duty to the building maintenance staff.

A countrywide service requires non centralized operation. The new exchange had a lot of advantages for the network operators, too. It gives full picture about the state of the system, makes traffic reports, helps to make immediate actions on system failures or traffic problems. After one and a half year of operation WESTEL has installed 2 more exchanges to share the traffic load around the country and to make faster access to the PSTN. The connections between the three exchanges are based on CCITT N7 signalling system, which was unique in Hungary: WESTEL was the first to use so high level signalling in Hungary. This signalling system carries information for interexhange hand-offs and roaming. This feature enables the WESTEL exchanges to be connected to any high level digital network, like WESTEL did during TELECOM 92'. One of the three exchanges was connected to a pilot WESTEL GSM network serving the area of Budapest, making it possible to connect different network's subscribers to each other. The experience of using CCITT N7 signalling system helps to evaluate future connections to ISDN or national GSM networks. In 1993 we introduced the NMT 450i, which allows us to use handheld mobile equipments in the system, and a lot of other features are supported a new, improved software version in the switches (Phase 52).

Three AXE 10 switches have their own staff. Two operator engineers work at the Szolnok and two other at Székesfehérvár switch, they are responsible for the daily operation in daytime, and in nighttime and holidays they have an emergency case all-night service. If some problem occurs in the switch, they can dial-in from home to the AXE 10, they can do everything remotely. If some hardware repair needed, they have to enter the switch 24 hours a day and e.g. replace the faulty module. They are responsible for the software maintenance of the switch, right now Ericsson's Phase 61 running on them. They always keep attention on the traffic, and can do some urgent reconfiguration of the system also.

At Budapest switch premises the operation staff of the AXE 10 is bigger. In the beginning of 1995 we introduced the Voice Mail system in NMT 450, sold by Comverse Ltd. Israel with the capacity of 20.000 subscribers. The Voice Mail is well known in the GSM system, but in NMT 450 is not an average solution. Both Comverse and WESTEL did a big development work to implement the data and billing system connected to the Voice Mail. In GSM because of the continuous two way traffic between the mobile and BSC there is no problem to remind the customer of the new message, but in NMT we have to solve the call-back function. The Comverse Voice Mail system allows to the customer not only the usage of the Mail box, but for example the Fax-box is also available, which is extremely useful for small companies to receive faxes, and it could be very cost effective service (Because of the reduced night-time tariffs).

Another big challenge was introducing the six digit subscriber number. It was necessary because of the capacity of the network and the unified numbering plan of HTC. We had to solve this problem without calling back the subscribers, and reprogramming the mobile phones.

6. OPERATING AND MAINTAINING THE MICROWAVE AND RADIO NETWORK

As I mentioned before, during the last five years eight regional maintenance centers established in addition to Budapest central office. They are: Székesfehérvár, Győr, Nagykanizsa and Pécs in Western-Hungary, Szolnok, Miskolc, Debrecen, Szeged in Eastern-Hungary. Each countryside office has two radio engineers, at Szolnok and Székesfehérvár there are additional two independent power engineers and the regional manager, who is responsible for the half-country operation, and reports to the Network Operations Manager. The whole country is divided into nine almost equal territories, so each pair of radio engineer has approx. 30–40 different sites to operate and maintain. They are working also in nighttime and weekend 24 hours' emergency case service. If some problem occurs in the network, emergency call or paging arrives to the regional engineer from the Network Operation Center.

Each engineer has service car or 4 wheel-drive to reach the site anywhere in the country. Each regional office has its own warehouse, which contains the most necessary repairing kits, for example radio transceiver channel units, combiners, DC-DC units, multiplexers and all variety of microwave spare parts, RF-boxes, indoor cards. This spare part kit allows them to solve all the problems in a very short time of period after alarm receiving. They can reach all of the sites within 90-120 minutes, and they can detect and solve the problem within approx. 3 hours. It is very important, because we have very strict rules coming from the Concession Law. This was the most important reason why we expanded the structure to the countryside. Everybody could imagine what happened if there would be maintenance and operation staff only in Budapest. The travelling time to the farthest site can be 4-.5 hours.

Two power engineers are working at Székesfehérvár and two other at Szolnok. They are responsible for the whole power, rectifier and backup battery system placed in the exchange and in the base stations. Each site has its own rectifier and battery backup system to prepare 48 V/DC to the radio equipments. At Budapest there are three more power engineers, they work with the sites, office buildings, microwave relay stations, AXE switch in Budapest region.

Beyond the unexpected fault events the radio staff has an another very important duty. They have to maintain all the radio and microwave equipments year by year. It means that a year divided into two periods, one in Spring and second in Autumn, when the staff works in a predestined shift. Every night they are measuring the technical quality of one base station's antennas, radio transceivers, combiners, filters by a predefined measuring method. It is very important to keep the radio network in good condition. We can do remote controlled measurement on the channel units via the Cosilom system (which system was developed and installed by Creative Engineering AS, Norway). These measurements unfortunately test only the voice frequency parameters of the channel (distortion harmonic, group delay, psophometric noise, gain absolute, gain VS frequency, absolute delay, phase jitter, transients, distortion intermodulation) but the primary informations coming from this test system are very useful to detect the fault before customers do. If a channel unit has bad gain VS frequency for example, the technician can go to the site, tune the channel unit or replace it.

So we have to measure the radio frequency path also. Cosilom can test one channel unit at one time, it doesn't affect traffic, but we have to stop the transmission if we measure the antennas or the channel units, so it is only possible to do at nighttime, because of the restrictions of Concession.

Microwave hops' revision could be done also in nighttime, if the traffic interruption is necessary. The radio operations group divided into two parts in Budapest premises. One group is responsible for the radio equipments and the low capacity MW equipments (Minilinks), and the other staff responsible only for the digital high capacity transmission network. It means that the maintenance work solved by two different groups, so the load of the engineers are almost equal. Radio operations group does only the base station measurements, the transmission operation group is responsible for the 2, 8, 34, 140 Mbit hops' maintenance.

Additional staff helps the work of the radio and microwave engineers. As earlier I mentioned more than 5.000 radio transceivers, 600 microwave terminals are working in the network. They are very reliable equipments, but some of them sometimes get fault. If the equipment is under warranty, we send back directly to the factory to repair. If the unit is out of warranty, we have a service department, where we can exactly identify the fault, some case we can replace or repair the faulty module, or with an exact fault report we send back to the manufacturer. The existence of service shop proved true during the last one and a half year, because a lot of money were saved on repair cost. We have installed a lot of instruments also in the service shop, so every problem arises in the field can be solved, every measurement can be done here.

7. TRAINING

There are some very important stipulations to organize and support a good maintenance and operation organization. One of the most important condition is the well-skilled engineer team. To reach this term we employ engineers with university or college degree on transmission faculty, and we try to improve our colleagues' knowledge with organizing different training courses. In the company policy it is very important to send the engineers to the manufacturing premises. Over there they can collect information directly from the developing engineers, and from the staff working in the manufacturing. They have big knowledge and experience from other operators as well.

Other very important thing to have training courses within the house. It is important to have the staff wide knowledge of the operating equipments in the network, but also important to have specialized knowledge on one significant equipment. In this case the specialist becomes a teacher or instructor for the other colleagues to deepen their knowledge. We systematically organize inside training courses, in the service department every condition is available.

The third and also very important field of the operation is the maintaining of the sites itself. The over 300 sites mean very big challenge for the building maintenance staff. They are responsible for the maintaining and revising contracts, checking incoming bills, keep in good condition the towers, containers, buildings, the air-condition system on every site, the entering system into the containers etc.

8. INFORMATION SYSTEM

It is not enough to have a well-skilled engineer group to operate and maintain the whole network perfectly. I think one of the most important thing to receive and collect reliable information coming from each network element rapidly. To keep the system running WESTEL developed a unique Network Monitoring System, which monitors all vital part of the system: air temperature on the sites, battery power, starts the diesel generator during power failures, opens and closes the doors, checks the technicians on sites, enables high level MWE handling. This maintenance network will be one of the central information elements of the Network Operation Center. It is the base of a perfect operation that we need correct and true information for quick decisions. A lot of clever equipment and software help us to get there information. In 1995 WESTEL 900 company opened their Network Operation Center, where every alarm and state changing coming from every network element is collected. We hiring service from WESTEL 900, so the Network Operation Center is one of the first and most important information source. They are working in a 24 hours' service, so information is available at all time. Our radio engineers are also watching the status of the network element during daytime, and they can make the decision of the intervention. During nighttime or weekends NOC operators receive the alarm and they can solve the problem or call the closest engineer in the field.

Because of the large variety of the equipments a lot of different monitoring systems are working side by side. One of the most important task of the NOC to collect the information in one big database, to create relations and connections between the different alarms. This requirement solved by the BOS based data collecting and maintaining system developed by Mercury oneone. The different parts of this system are under installation in the Network Operation Center to feed with update and correct information to both WESTEL 900 and WESTEL 450. The different user interfaces are extremely useful to watch the changing of the traffic, and help us to catch sight of the problems before customers do.

9. NEW SERVICES IN THE NMT 450

In 1st April 1994 two GSM operators started their service in Hungary. They are growing very quickly, so three companies has to share the Hungarian market. It means a new and big challenge for the WESTEL 450, to stay in the business and preserve its share. We have to develop our network to increase the handheld coverage, and we have to introduce new services.

It is available to use our NMT network not only for speech but fax and data. As I mentioned in the beginning a big effort was the introducing of the Voice Mail system. It allows us to offer some value added services to the customers. The summarized name of this service is 0660 Voice Journal. It is a up-to-date information service with touch tone operation. 24 hours/7 days availability not only for NMT but landline and GSM subscribers as well on normal tariffs, some free of charge service. A lot of different service is available (General info, Traffic info, Gardening, Travel agencies, WESTEL news, Stock and Commodity Exchange).

Our most important task is serving our customers with their total satisfaction. The engineering staff does everything to keep the network in good condition, and we try to find out new solutions to help the customers in their business and personal life. We hope (and western experiences back up this) NMT 450 is a long life and developing system and this service can stay the competition with the GSM and other newborn facilities.

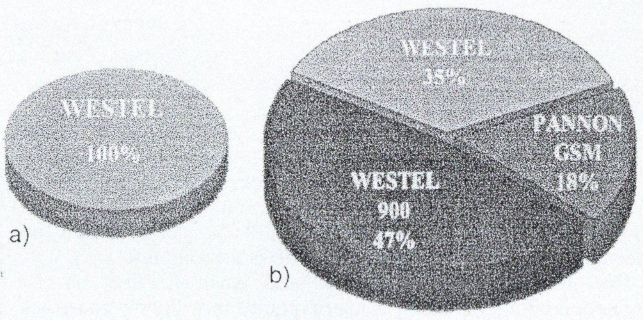


Fig. 4. Market share
a) 1994; b) 1995 June

Tibor Nagy graduated from the Technical University of Budapest (BME), the faculty of Electrical Engineering in 1990. He studied microwave radio and telecommunications technology. He started his work as a radio installation and maintenance engineer at WESTEL Radiotelephone Ltd. in 1990. In 1993 he became responsible for the radio operations and maintenance work at the countryside network outside Budapest area. At the beginning of 1995 Budapest radio operations staff joined to his duty. From September 1995 he is responsibole for the radio and microwave operations of WESTEL 450.

MOBILE COMMUNICATION ANTENNA TECHNOLOGY

P. SCHOLZ

KATHREIN-WERKE KG
ROSENHEIM, GERMANY

The spectacular growth of cellular mobile communication networks with approx. 50 million subscribers world-wide has only been possible through the development of a wide variety of new technologies, such as the increase of frequency spectrum efficiency, data compression, signal processing and also mobile communication network planning. As far as mobile communication network planning is concerned, in addition to the use of the most modern computer technology combined with comprehensive terrain data, base-station antennas play a very important role.

Modern mobile communication antennas must meet the demands of a wide variety of new challenges. Compared to the earlier mobile communication networks, the far higher frequency ranges of the new GSM and PCN networks have a decisive influence on modern antenna design.

In view of the huge quantities involved, new solutions are also necessary in the field of mechanical design. For example, directional antennas are now fully integrated into a self-supporting fibre-glass structure. Also, since many frequency channels are now switched together onto one antenna, low intermodulation performance has become an important aspect.

The optimum coverage of individual cells as well as the avoidance of interference with neighbouring cells calls for antennas with defined radiation diagramme shapes. Antennas with horizontal half-wave bandwidths of 33°, 65°, 90°, 105°, 120° and 160° are standard and many customers have even more specialized requirements. In vertical radiation diagrammes null filling below the main lobe and side-lobe suppression above the main lobe is frequently specified. Many different gain values complete the catalogue of requirements. Simple diagramme synthesis produced by the installation of several individual antennas — as happened with the NMT 450 network — is now no longer acceptable. Fully optimized antennas are required for each individual application. In order to subsequently optimize the coverage, antennas with variable mechanical or electrical downtilts are used.

In view of the growing environmental concern, the antennas also have to be so unobtrusive that a critical observer will not notice them. Customers demand slim, unobtrusive antennas, partially painted in the colours of the surrounding buildings.

In order to reduce the number of antennas required, there is a also growing trend towards dual-polarized antennas. So there is polarization diversity instead of space diversity, above all in connection with the ever growing popularity of mobile phones. Mobile phones are usually held at an angle, so that a mixture of horizontal and vertical radiation components is to be expected.

Furthermore, the strong pressure on prices means that new solutions have to be worked out to meet all the diverse requirements. The folding out of dipole structures from reflector walls has proven to be advantageous, not only technically but also from a price point of view. For the same reasons printed circuit board technology is being increasingly used in antenna design, too.

Outlook: Intelligent antennas for intelligent networks!

The author's biography and photograph not available at time of publication.

MOBILE DATA

DATA COMMUNICATIONS IN WESTEL NMT SYSTEM

M. GYÖMÖRE and J. BÍRÓ

WESTEL RADIOTELEPHONE LTD.
H-1033 BUDAPEST
HUSZTI U. 32.

1. INTRODUCTION

The demand for transmitting non-voice information has been increasing rapidly. Based on international experiences data transmission already accounts for a 10 % share within the telecommunication sector and this ratio is growing fast.

The afore-said tendency would also have an effect on the mobile telephone business, as users require mobility for non-voice applications, too. It is obvious that mobile operators have to response to this challenge.

In order to understand the essence of the mobile data communications the following very simple question has to be answered:

What kind of users have a demand for mobile data transmission?

The answer for the above question is very simple:

Everybody, who wants to use their computer or to send/receive data at any place and any time, requires mobile data transmission.

The above carriage of thought is a good approach but some technical limitations should also be taken into account:

- structure of data network;
- call set-up time;
- rate of data to be transmitted.

The structure of data network mentioned first is a point-to-point one, which is characteristic to all kinds of data transmissions via telephone networks. It seems obvious but some limitations in system development and operation should be considered.

Call set-up time is also well known in wireline telephone networks but the fact that synchronization time falls in the range of 0.5 sec to 30 sec depending on speed and type of modems applied should be taken into account.

As the third technical parameter is concerned, the data speed can be adjusted in a relatively wide range, but the close relationship between synchronization time and data speed should be taken into consideration, i.e. the increase of synchronization time is 2 times more than the increase of data speed. Therefore high speed data transmission could be disadvantageous when only short messages are to be transmitted.

On the basis of the above features we can state that mobile data transmission systems can be used for high data speed and/or computer network applications only with some limitations, but mobile data transmission systems are very advantageous in case of short messages or low speed interactive applications. Taking into account that mobile radio networks are independent of the wireline networks, they may also be considered as backup applications.

The very fast development in the field of computer hardware and software technologies will attract and force new applications, widening the possibilities of the mobile data network users. The latest lap-top and palm-top computers are offering real mobility, but this advantage can only be utilized if mobile data transmission is available enabling the users to be independent of wireline networks. This way owners of the new mobile computers will have real freedom of carrying and using their computers anywhere and anytime as desired long. The computer hardware and software companies are offering a wide range of different solutions for partial or nearly full mobility. Host-client type solutions came into the focus reducing the data transmission requirements and resulting in optimum performance even at lower bandwidth, therefore they represent ideal solutions for data transmission via modems.

It should be noted, that mobile operators are also interested in secondary utilization of their networks, therefore they do all the effort to promote these utilizations.

The mergers of companies involved partly in the telecommunications partly in the computer business have recently been witnessed could also have an effect on the mobile data transmission market. This phenomenon can be recognized behind the lately introduced data transmission networks and services. Although these services have required mainly high speed transmission lines so far, the real mobile applications allowing to apply low speed transmission medias (e.g. mobile data networks) will appear on the market very soon.

Based on the previous survey, below we summarize the driving factors of the mobile data transmission:

- miniaturization and portability of computers;
- mobile operators offering not only voice but data transmission, too;
- merger of computer and telecom industries;
- increased mobility of company's staff;
- growing demand for integrated network services.

2. DATA COMMUNICATIONS IN WESTEL NMT 450 SYSTEM

2.1. *General considerations*

First step: mobile fax

In 1990 WESTEL launched the mobile fax service together with the basic NMT 450 telephone service. Nowadays a considerable portion of NMT 450 terminals have been used not only for voice but fax transmission, too. Based on our operational experiences it can be stated that high quality G3 mode fax machines show excellent performance in fixed applications if handover of radio channel is prohibited. The ECM error correction procedure — applied in more and more fax machines — improves the reliability of the transmission further.

Second step: mobile data

From customer's point of view NMT 450 network is equivalent to a 2-wired switched telephone network with a capability to transmit voice-type information in a bandwidth of 300–3400 Hz. If digital signals are to be transmitted in this bandwidth modems meeting Recommendation CCITT V.32bis should be applied. According to the Recommendation the symbol speed of the afore-said modems is 2400 baud. Therefore to produce 7200, 9600, 12000 or 14400 bps transmission rate 3, 4, 5 or 6 bits should be transmitted within 1 symbol, respectively.

First generation modems consisted still of purely analogue elements. Nowadays new generation of modems became very sophisticated devices, different tasks (e.g. digital filtering, adaptive equalization, symbol synchronization, carrier recovery etc.) are performed by processors.

2.2. *Modem operation principle*

The main task of the modem transmitter part is to convert the incoming serial data stream into an analogue signal appropriate for the band limited, analogue telephone channel (CCITT G.712). The receiver part can be considered as the inverse of the transmitter part. In addition both parts contain also scrambler and descrambler circuits, as for the optimum operation of the modulator and demodulator units statistically random signal stream is required. From this aspect the scrambler's task is to convert any incoming message segments into a pseudo-random signal stream. The scrambler operation is unambiguously determined by the Recommendation. Doing so, a 7200, 9600, 12000 or 14400 bps signal stream corresponding to the required transmission speed will appear at the output of the scrambler. As all the modems meeting V.32.bis Recommendation use uniformly 2400 baud symbol speed a framing function should also be performed converting the consecutive 3, 4, 5 or 6 data bits into one source symbol. Based on the previous procedure, we can speak of 8, 16, 32 or 64 source code word. According to the Recommendation, a complex signal is ordered to each code word and the complex signal will modulate a modulator. Two modulation methods are applied: non-redundant type **Q**adrature **A**mplitude **M**odulation (QAM) and redundant type **T**rellis **C**ode **M**odulation (TCM). In the first case the number of source code set elements exactly equals with the number of signal elements at the coder output so only a simple memory-free correspondence takes place among the elements of the input source code and of the complex signal set. In case of trellis coding the number of complex signal elements is double of the possible source code elements. This redundancy will result in a more effective data transmission characterized by lower bit error rate, if signal-to-noise ratio is better than 14 dB.

2.3. Particularities of the analogue cellular radio-telephone networks

The basic question to be answered: why standard modems can not be used on analogue cellular radiotelephone networks with satisfactory results? To give answer to this question, first we should examine what are the main particularities of radiotelephone networks compared to wireline telephone networks.

Handover

This function is the basic feature of radiotelephone networks and it is used in order to handover mobile terminals from a disturbed or noisy channel to an other traffic channel thus improving speech quality. During handover not only a short break of connection but readjustment of basic technical parameters takes also place. One of the problems caused by this procedure is the carrier interruption. It takes about 0.5 – 1.5 sec which is a relatively short time in case low data speeds, but at higher data rates it may cause serious problems. Even more problems may be caused by the change of the channel parameters mainly in cases when inter-cell handover occurs. The latter case means that all the parameters (e.g. overall line delay, group delay time etc.) of the transmission path change. As the standard modems are concerned they tolerate the carrier interruption quite well, but the change of the channel parameters would result in an increase of BER or in the drop out of synchronization. The cellular modems can solve the problem by a resynchronization process which starts when the carrier interruption time is longer than a pre-adjusted threshold level. The resynchronization process repeats the initial process applying the same protocol. During the resynchronization process the DTE unit is blocked by the <CTS> - <RTS> hardware control signal of the modem. An important feature of this process is the possibility to re-adjust the channel transmission speed, which is required if the new channel is worse in quality than the old one and it is favorable if the new channel is better in quality than the old one. Sometimes the change of the channel transmission speed is surprising for the users but it does not cause any problem, if the DTE unit's transmission speed is higher than the line speed (e.g. double of it) and the data speed conversion is switched on. Switching off the handover (as it is frequently done in case of fax transmission over radio) seems to be a solution. It is true, but only in case of fixed applications and interference free environment, because real mobile applications and inevitable interferences require the handover of radio channels.

Modulation

Modulation methods applied by ordinary modems are appropriate in wireline telephone networks but — according to our experiences — they are often inadequate in radiotelephone networks. For this reason cellular modems apply special modulation methods taking into considerations the characteristics of the radio channel.

Power level variation

Modems applied in wireline telephone networks should provide output level high enough to drive long cables. Moreover, output level of ordinary modems can not be adjusted in case of the mostly used asynchronous mode and can only be slightly adjusted in case of synchronous mode. In radio applications these output levels are too high and cause overdrive. The special cellular modems solve the problem on the following way: during the basic synchronization process, one side of the modem pairs decreases its output level gradually and — at the same time — sends a special pattern to the counter-side which sends an acknowledgment back. Having the proper output level adjusted this way, the whole procedure is repeated vice versa.

Multi-path fading

In mobile radio systems multi-path fading frequently occurs due to reflections and diffractions on the propagation path. Forward Error Correction (FEC) methods applied in cellular modems minimize the effect of multi-path fading and establish a highly reliable transmission characterized by very low **B**it **E**rror **R**ate (BER) even under unfavorable environmental conditions.

2.4. Cellular modems applicable for data transmission on NMT 450 network

Nowadays demand for data transmission is continuously increasing even in case of mobile applications. NMT system offers a good solution to meet the above demand applying special cellular modems. We have carried out detailed and very thorough examinations on cellular modems available on the Hungarian market under extreme operational circumstances and have found some models operating with special cellular protocol and showing reliable operation on the NMT network. It is very important to note that cellular modems offer their special features only if they are applied in pairs. The range of their transmission speed is 4.8 – 12 kbps in asynchronous mode without data compression. Applying the V.24bis data compression procedure the transmission speed can be doubled in general. In synchronous mode (e.g. X.25) the transmission speed falls in the range of 2.4 – 9.6 kbps.

Main characteristics of cellular modems:

- compatibility with Hayes AT and V.25bis command set;
- special modulation and forward error correction;
- automatic transmit level and line speed control;
- adaptive line equalization;
- fast compensation of carrier interruptions, due to intra-cell or inter-cell RF channel handover;
- 12 V DC operation (in car application);
- G3 fax operation mode.

Another way to solve the problems of mobile data transmission in the NMT 450 system is the solution worked out by BENEFON applying the same method for data transmission as in the signallization channel (i.e. the internal FFSK modem is applied). The BENEFON's DMS adapter works at 1200 bps in asynchronous mode. Very useful features of the DMS adapter are the built in ciphering algorithm and the extremely short set-up time of data connection (1 sec app. following call set-up).

Main characteristics of DMS modems:

- compatibility with Hayes AT command set;
- fast synchronization (1 sec app.);
- 1200 bps FFSK modulation;
- built in 64 bit ciphering algorithm;
- small size direct interface to radiotelephone sets produced by BENEFON;
- cost effective solution;
- presently available in mobile radiotelephone version, wireline version will soon be available.

It should be mentioned that the "ordinary" telephone modems (widely used in the wireline networks) can also be used in the NMT 450 network but reliable operation can only be maintained at lower transmission speeds and with prohibition of RF channel handovers.

3. OUTLINES OF THE FUTURE: MOBILE DATA GATEWAY (MDG) SYSTEM

WESTEL Radiotelephone Ltd. is continuously widening its service offerings in order to response to the expectations and requirements of the users. WESTEL's **M**obile **D**ata **G**ateway (MDG) project is one important step on this way. The basic aim of the MDG project is to provide access via the NMT system to a domestic or international data network. As these networks do not have interfaces handling cellular protocols mobile users have been cut off them.

MDG system receives the incoming calls coming from the mobile terminals across the NMT switch where it is connected to. The system consists of a terminal server and a UNIX computer. The terminal server receives the incoming calls via different modems connected to it, while the UNIX computer performs management tasks, on the basis of parameters forwarded to it. If the user requires selection from several possibilities, it can be made from a menu. The registration procedure and the users' authorizations determine the mode and character of accessible sources. Having the user registered, the system initiates an automatic procedure determining the routing functions required by the user in other words a connection is established between the user and the service required (e.g. IP, X25, leased line). The connection points required by the users can be both on private and on public networks. The switching method applied provides possibility for further applications and extensions (e.g. connection to future data networks: ISDN, Frame Relay etc.), too. The MDG system supports the simple terminal sessions as well as SLIP and PPP protocols inside the system and towards external systems on a transparent way, too.

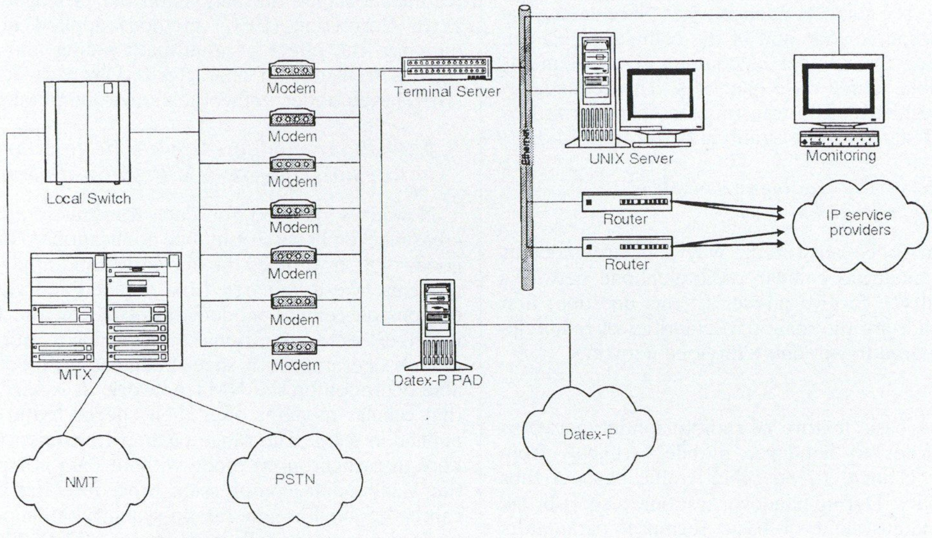


Fig. 1. Mobile Data Gateway Project

4. ABBREVIATIONS

BER:	Bit Error Rate
CTS:	Clear To Send
DMS:	Data Mobile Station
DTE:	Data Terminal Equipment
ECM:	Error Correction Mode
FEC:	Forward Error Correction
FFSK:	Fast Frequency Shift Keying
G.712:	CCITT Recommendation for performance characteristics of PCM channels between 4-wire interfaces at voice frequencies
G3:	CCITT Recommendation for fax protocol
Hayes AT:	Industrial standard modem command set
IP:	Internet Protocol
ISDN:	Integrated Service Digital Network
NMT:	Nordic Mobile Telephone
PCMCIA:	Personal Computer Memory Card International Association
PPP:	Point to Point Protocol
QAM:	Quadrature Amplitude Modulation
RTS:	Request To Send
SLIP:	Serial Link Internet Protocol
TCM:	Trellis Code Modulation
V.25bis:	CCITT Recommendation for modem command set
V.32bis:	CCITT Recommendation for 2-wire, duplex modems operating at data signalling rates of up to 14400 bps for use on the general switched telephone network and on leased telephone-type circuits
V.42bis:	CCITT Recommendation for compression and error correction protocol for async. data transmission
X.25:	CCITT Recommendation for interface specification between DTE and packet-switched data network

Mihály Gyömöre graduated in wireless telecommunication engineering in 1967 and received a second degree in microwave telecommunication technology in 1970 at the Electrical Engineering Faculty of Technical University, Budapest. From 1967 to 1990 he worked at the Precision Engineering Company (FMV) in different positions, last of all as head of the long-term development department. The scope of his activities were high capacity microwave systems, video & voice switching matrixes, and spread spectrum radio systems. In 1992-1993 he worked at the SAT-NET Ltd. From 1994 he is the business development director of WESTEL Radiotelephone Ltd.

Jenő Bíró worked at the Hungarian PTT from 1978 to 1982, he was responsible for the installation and maintenance of crossbar and digital PABXs. From 1982 to 1984 he developed optical pressure sensors. He worked at the Computer and Automation Research Institute of the Hungarian Academy of Sciences where he assembled, installed and maintained GD80 and other mini computers. From 1987 to 1990 he worked at Számszöv installed and maintained LANs and Unix computers. He dealt with assembling and installation of PCs and LANs. He has been working at WESTEL since 1993, he is responsible for the mobile data projects.

DATA COMMUNICATIONS IN PANNON GSM

G. M. LÉDERER

PANNON GSM TELECOMMUNICATIONS COMPANY
H-1134 BUDAPEST
VÁCI ÚT 37.

1. INTRODUCTION

Today, after five years of cellular history in Hungary, more than 200,000 mobile subscribers are able to talk and move around at the same time in Hungary. This huge number expresses the needs of mobility not only for the professionals, but also for the entrepeuners and other areas of the society. At the same time, the demand for mobile data communications has grown and every one of the cellular operators is trying to fulfill these needs. In the following pages, you will find the strategy that Pannon GSM is following in this area.

2. THE TECHNICAL BACKGROUND

We will give only a very brief and not very detailed description of the GSM data services, as the whole subject could take several hours and details can be found elsewhere also. The GSM system is a digital, time division cellular radio system, which basically samples the speech and transmits it in digital chunks. This means also good quality, as the errors can be corrected during the transmission time. Due to the digital nature of the GSM system, data transfer has to be done in a different way than in analogue cellular systems. The GSM system transmits the digital speech information in small packets, and the data communication has to fit somehow in this packet communication also. This means that during a data communication call, pure digital information is sent over the air. Of course the bit rate of the data to be transmitted is different from the bit rate of the GSM traffic channels, meaning additional transformations are needed. It is very important to state here that in this part of the presentation we consider fax as a specialized way of data communications (we will see later the differences between fax and data transfer also).

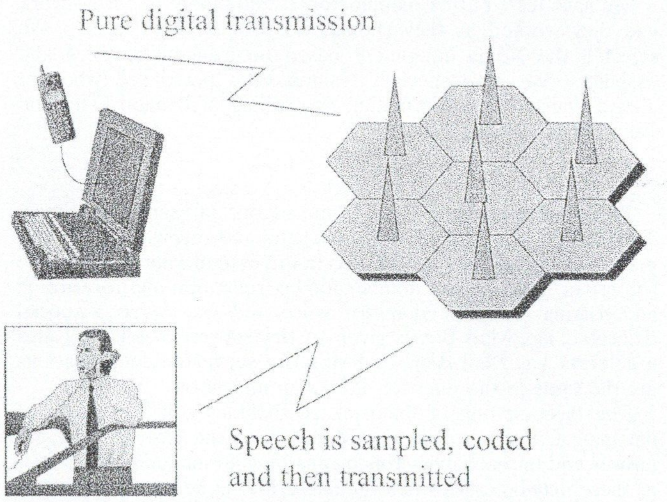


Fig. 1. Speech and Data transmission in GSM

The above mentioned digital nature of the GSM system means extra equipment at both the Mobile Switch and also at the mobile endpoint. On the following slide the different equipment needed an its functions can be seen.

As the slide shows, one of the digital legs has been opened, meaning that one of the modems has been sliced into two pieces, one piece being at the mobile end, while the other at the MSC end. In this way the data travels on the air in digital form, meaning also greater possibility to correct most errors during the radio transmission. As the error correction could be also included in the communication software used for the data call, the GSM standard offers two ways of data transmission, transparent and non-transparent. In transparent mode no retransmission is made for error correction, while in non-transparent mode a more sofisticated error correction is included in the radio link. In transparent mode, the error correction has to be done by the software of the modem or by the communication package.

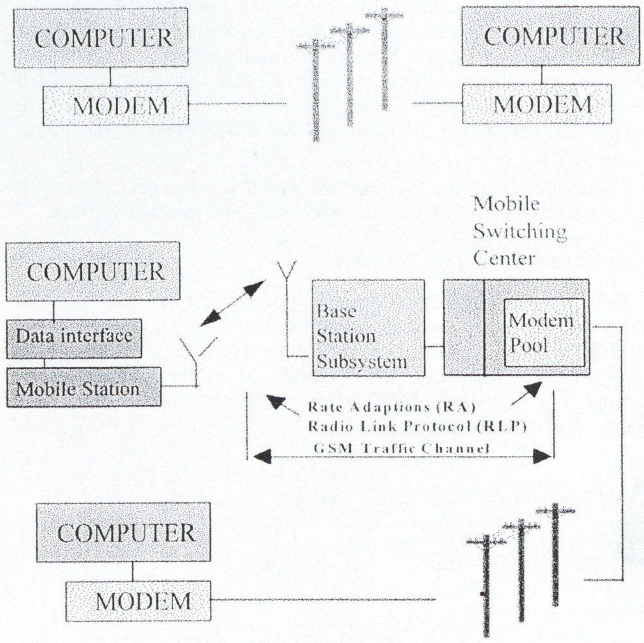


Fig. 2. PSTN and GSM Data communication

Due to compatibility reasons, mobile to mobile data calls are also routed through the modem-pool (two modems are used in mobile to mobile calls).

As we said in GSM we have pure digital data transmission with additional equipment at both the switch and the mobile end. This digital nature means advantages and some disadvantages also.

2.1. Advantages

- pure digital transfer and error correction means more reliability;
- digital encryption means data security;
- due to digital transfer, cell handover is not noticeable at the endpoints, meaning that the user gets *real mobility*;
- GSM means a wide ability to roam in foreign countries;
- GSM terminals and additional equipment are very small in dimensions and the hand-sets have longer battery life.

2.2. Disadvantages

- additional equipment is needed at the switch and also at the mobile end;
- as additional equipment is used in the switch, the mobile terminated data call has to be initiated in a different way. This means a separate number for each data subscriber (in case of transparent data calls this means also separate number for each baud rate because the switch is not able to detect the communication speed);
- currently only very few suppliers offer the possibility to switch between speech and data during the call, so if a call is initiated as data call, it will behave like that until hang-up (alternative speech and data during the same call is a GSM Phase 2 and

Phase 2+ service);
- the fact of having separate data numbers and special interface at the mobile end, makes the product more complicated to sale.

As we mentioned, there are differences between fax and data calls also. Following are the main aspects of fax transmission:

2.3. Differences of Fax and Data Transmission

- Fax transmission is standardized, baud rates, error correction, resolution and page layout are common all over the world.
- Fax transfer protocol is also standardized and includes error correction, meaning that data transfer can be done transparently.
- The modem pool at the switch has to simulate a standard fax machine, so the modems used for fax are different from those used for data.

As the fax reception — like mobile terminated data calls — needs also a special call set-up procedure, a different fax number is given to the subscriber. We have to mention that at the moment not many suppliers or operators are offering the ability to switch between speech and fax during a call (like for data, alternative speech and fax during the same call is a GSM Phase 2 and Phase 2+ service).

GSM offers also another service which is often not considered as data transmission and that is SMS or short message service.

2.4. Short Message Service

SMS is a very convenient point-to-point communication service, which for some applications is often better as a data transfer tool than GSM Data. Its function is to deliver messages of maximum 160 characters from one GSM mobile to another GSM mobile, through the so called SMSC (short message center), which is a GSM network element.

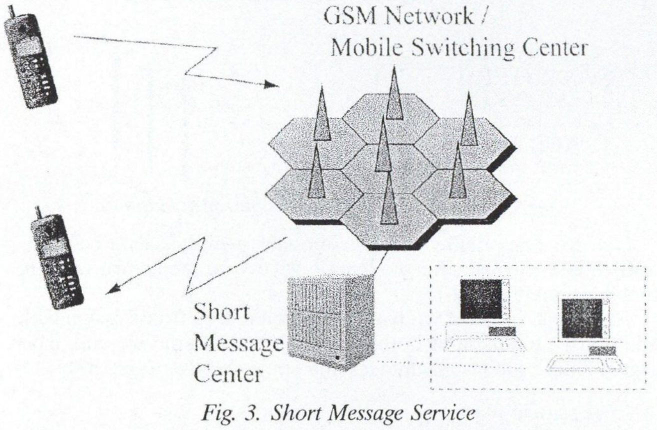


Fig. 3. Short Message Service

The SMSC works in a store and forward principle, delivering the messages received only when the destination subscriber is reachable in the network. If for any reason (like the mobile SMS memory is full or reception conditions are bad) the message is not delivered, it is put into a queue and tried to be delivered later, according to a retry table.

The main features of SMS are:
- mobile to mobile transmission;
- uses the signalling channels of the GSM network, no traffic channel is used;
- fast delivery time (within seconds), no call set-up time is required;
- the SMSC can also send and receive SMS messages;
- 100 % error correction as every bit is sent again until correctly received;
- as information is sent in packages and every message generates a billing record, billing can be based on the amount of information exchanged;
- works on roaming also (if allowed in the visited network).

After the short technical introduction, on the following pages we will present the other side of the coin: how are we doing the "packaging" of the data services at Pannon GSM.

3. WHAT IS OFFERED BY PANNON GSM TODAY?

- Pannon Data
- Pannon Fax
- Pannon FaxTár
- Pannon Hívó

3.1. Pannon Data

Pannon Data is the product name of our GSM Data Communication Packet. It is an additional packet over the normal voice subscription. The additional services like call forwarding and call barring can be set also differently on voice and data. This means that the user can forward data calls while not forwarding voice calls, or can inhibit international voice calls, but leave the possibility to make international data calls.

We offer both transparent and auto-bauding non-transparent services to our subscribers. We also offer the equipment needed to use the data services. This is the Nokia DTP-2 PCMCIA Data Interface Card, which is able to send and receive faxes and to make data connections with auto-bauding in non-transparent mode. The configurations which we recommend can be seen in the following slide:

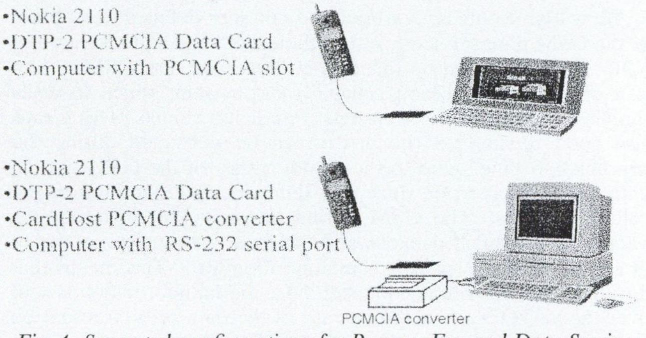


Fig. 4. Suggested configurations for Pannon Fax and Data Services

For those Subscribers, who wish to use a normal PC for data communications we offer a device which is able to hold a PCMCIA card and transform it into a normal RS-232 serial port modem.

We have tested other manufacturers equipment in our network and they worked as they should, no problem was faced. We selected the Nokia equipment based on availability, price and usability. We have specially trained sales personnel, who are always available for information and selling of Pannon Data and Pannon Fax services.

3.2. Pannon Fax

Pannon Fax is the product name of our fax service package. The package contains the GSM fax send and receive services, fax mail and fax mail alert by SMS. As in the case of Pannon Data, the subscriber gets another number for fax reception and forwarding and barring is independent for voice and fax. Also a special dedicated Fax Mail Box is given to the subscribers, having also a different Fax Mail Alert by SMS. The suggested configurations are the same as the ones for data communication.

The basic setting of the package includes call forwarding of incoming fax calls to the Fax Mail Box in the case of busy, no answer and unreachable. This means that no incoming fax is lost, as there may be cases when the subscriber is not available or has no equipment to connect to the mobile. If a fax is received by the Fax Mail Box, an SMS message is sent to the Subscriber.
The faxes in the Fax Mail Box can be handled in four ways:
1. Calling the voice mail and instruct it to forward the fax to the mobile with interface and computer connected.
2. Calling the voice mail and instruct it to forward the fax to another Fax Mail Box.
3. Calling the voice mail and instruct it to forward the fax to a normal PSTN fax.
4. Calling the voice mail from a PSTN fax and download immediately the fax.

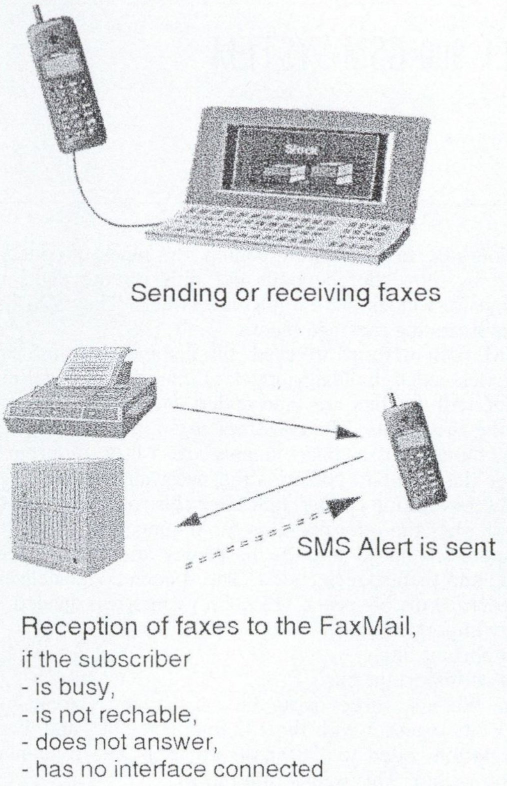


Fig. 5. Fax management possibilities — #1

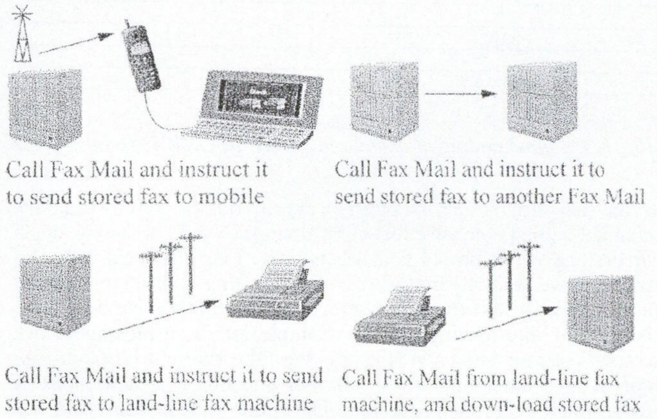


Fig. 6. Fax management possibilities — #2

Up to 50 faxes can be stored in the Fax Mail Box for a length of 14 days. Fax messages in the Fax Mail Box are classified as Printed and Non Printed Faxes, depending whether a fax was printed successfully in any of the ways above mentioned.

The Pannon Fax service works also on roaming, of course depending on the availability of the service in the visited network.

3.3. Pannon FaxTár

After introduction of the PannonFAX service, we realized that many customers just need the Fax Mail Box and do not use the GSM Fax services. We decided to introduce a service which gives a totally independent fax number to the Subscriber, which essentially is routed to a Fax Mail Box. The fax messages can only be downloaded from a PSTN fax, as the Subscriber has no mobile fax. Of course the Subscriber gets an SMS Fax Mail Alert message when receiving a new fax.

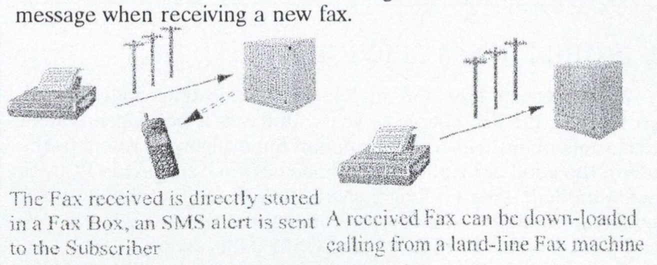


Fig. 7. Pannon FaxTár Service

3.4. Pannon Hívó

Pannon Hívó is the product name of our SMS services. Yes, we are talking about many services which are related somehow to our SMSC. Today this includes:

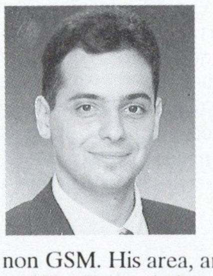
- Mobile to Mobile Short Message sending.
- Voice Mail Alert by Mobile Terminated Short Message.
- Special applications for SMS, like Pannon Exchange Service, Pannon Internal Phone Book.
- Broadcast messaging to our Subscriber Base: new services, remainder of payments, etc.

Mobile Terminated messaging (or more plainly receiving of SMS) is free of charge to all our Subscribers, while Mobile Originated messaging (sending of SMS) is free of charge for our Voice Mail Subscribers and other Subscribers can order it for a very small amount. Above 100 messages sent by month a charge per message applies, in order to prevent commercial message sending (we do not want to bother our Subscribers with "Junk Mail" in the form of SMS).

Mobile Originated messaging was introduced March of 1995, being a very high success. The only problem we faced was the wide range of hand-sets in our network. At that time only Nokia hand-sets supported the Sending of SMS, while at the time of writing this article Siemens and Sony came out with a hand-set able to send SMS. Today we still have hand-sets from rare origin in our network, which do not even receive SMS, making Voice Mail Alert by SMS useless.

4. CONCLUSION

As it can be seen Pannon GSM has many services which are able to make data transfer in its network. At the time being more and more Subscribers use these services. Due to the more complicated nature of Pannon DATA and Pannon FAX, we have special trained people in both Customer Care and Sales handling questions and problems from the Subscribers. We are also working in special applications and projects (like Internet Access) to give more and more to our Customers. If you have any questions please do not hesitate and call our 24 hour customer care, who will be ready to answer.



Gábor Mario Léderer graduated at the Technical University of Budapest, in 1991. He has been working in advertising for a couple of years, later joining Pannon GSM in 1994. He started as Distribution Co-ordination Manager, being responsible for the outlook of the Showrooms and Delaer Network. Since 1995 he is the responsible for Network Product Development in the Technical Department of Pannon GSM. His area, among others, is the Voice Mail System, Data and Fax Transmission and other Special Value Added Services. He also holds a degree in Foreign Trade Economics.

DATA COMMUNICATIONS IN WESTEL 900 GSM SYSTEM

N. VANNAI

WESTEL 900 GSM MOBILE TELECOMMUNICATION LTD.
H-1117 BUDAPEST
KAPOSVÁR U. 5-7.

1. MOBILE DATA SERVICES

It is amazing how the mobile communications industry has grown over the last couple of years. Today it is no longer evident that a talk about trips on Information Superhighways refers to the use of the good old landline telephone network, a desktop PC with audio modem. We no longer need to look for the phone socket under the table to connect our computer to these highways. We can do it wireless from now using GSM data services.

Among the cellular mobile telephone systems GSM took the first steps towards the realization of wireless information services and the real mobility.

Data and fax services are becoming available over the GSM networks in more and more countries. The international roaming possibility enables the GSM user to hang on a database or to access to information-related services. To send or receive data files or fax messages the user needs only a small GSM handset, a credit card size GSM data interface and a laptop computer with suitable communications software.

2. DIGITAL TRANSMISSION OF ANALOGUE SIGNALS IN GSM SYSTEMS

Since GSM is an all-digital system, the processing of speech or other signals will be performed digitally, mainly by software. Therefore, the first step is to convert analogue speech into digital signals. The most common sample rate in telecommunication systems is 8 kHz using a 256 levels (8 bit) quantization. The method results 64 kbit/s data rate and is called PCM, Pulse Code Modulation.

One of the benefits of using digital transmission is the increased capability of traffic density, it can handle more subscribers. In GSM the specified channel separation is 200 kHz. Eight "simultaneous" call can use the same frequency band using TDMA. The PCM-coded speech channel delivers 64 kbit/s. Eight such channels would give a bit rate of 512 kbit/s, so we must somehow lower the bit rate significantly for each speech channel to be able to keep within the allowed frequency band. This is accomplished by speech coding. There are generally two principles:

- Vocoder;
- Waveform coder.

GSM uses a hybrid one which is the mixture of the vocoder and waveform coder, it is called Linear Predictive Coding-Long Term Prediction-Regular Pulse Excitation coder (LPC-LTP-RPE). The speech is sliced into 20 ms pieces and each piece is coded separately. Hybrid coders give channel speed from 5 kbit/s and quality increasing with bit rate. GSM uses 13 kbit/s full rate channel, but in the near future 6.5 kbit/s half rate channel will be introduced also.

With digital transmission, the quality of transmitted signal is often expressed with BER (Bit Error Rate). Obviously we want this rate to be as small as possible. We are, however, not able to reduce it to zero, due to the constantly changing transmission path. This means that we have to allow a certain amount of errors, and yet be able to restore the transmitted information, or at least be able to detect errors so that we do not use the information as if it were true. GSM uses channel coding to detect and correct errors in the received bit stream. This means, that we have to send more bits than required for the information but we have a better chance to restore the data. Error control codes can be divided into two categories:

- Block coding;
- Convolution coding.

In block codes we have a number of information bits to which we add some check bits which have a relationship only with the information bits. In convolution coding, the block of coded digits generated by the coder depends not only on the digits in the current message block shifted into the coder. They also depend on bits in preceding message blocks.

In GSM, both methods are used. First, some of the information bits are block coded, building a block of information together with check bits. All the bits are than coded with a convolution code forming the coded bits. The two steps are applied to both speech and data, though the coding schemes are a little different. The reason for this "double" coding is that we want to correct errors if we can (convolution coding) and after this we can detect (block coding) whether the information is too damaged to use.

The speech is sliced into 20 ms pieces and these pieces are digitalized and then speech coded. The speech coder delivers 260 bits for each 20 ms of speech (13 kbit/s) which are divided into:

- 50 very important bits;
- 132 important bits;
- 78 not so important bits.

To the 50 bits, three parity bits are added (block coding). These 53 bits together with the 132 important bits and 4 tail bits are convolution coded to 378 bits (rate 1:2). The remaining bits are not protected. This is illustrated in Fig. 1.

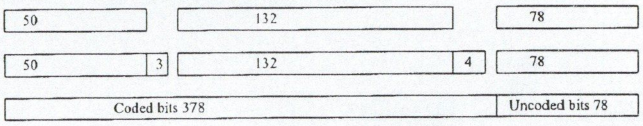


Fig. 1. Channel coding of digitalized speech in GSM (456 bits in one block)

In real life bit errors often occur in bursts. Unfortunately, channel coding is most effective in detecting and correcting single errors and error bursts that are not too long. To deal with this problem we want to find a way of separating consecutive bits of a message, so that these are sent in a non-consecutive way. This is done by interleaving. As an example let say a message block consists of four bits each (Fig. 2). We take the first bit from four consecutive blocks put these number-one bits in a new block of four, which we can call a frame. The same thing is done with bits 2 to 4 from the four message block. Then we transmit the frames of number-one bits, number-two bits etc.

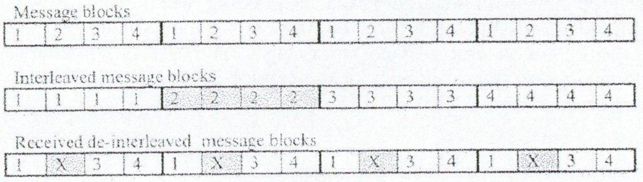


Fig. 2. Interleaved message blocks

During the transmission, frame 2 gets lost. Without interleaving, a whole message block would be lost, but in this case the interleaving has the result that only the second bit in each message block is faulty. With channel coding, the information in all blocks can then be restored.

In GSM, the channel coder provides 456 bits for every 20 ms of speech.These are interleaved, forming eight blocks of 57 bits each, see Fig. 3. A second level of interleaving is applied according to Fig. 4.

1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
449	450	451	452	453	454	455	456

Fig. 3. Interleaving of 20 ms of encoded speech, 8 frames 57 bits long

Fig. 4 a shows a normal GSM burst. It begins with 3 trail bits, then 57 encrypted information bits, 1 stealing bit, 26 bits long training sequence, 1 stealing bit, again 57 encrypted information bits and 3 bits trail at the end. If we take 2x57 bits from the same speech frame and insert them into the same burst, then the loss of this burst (e.g. due to fading) would result in a total loss of 25 % missing bits, which is too much for the channel coding to cope with. So we have to add another level of interleaving in between two speech frames. This will increase the delay in the system, but now we can afford to lose one whole burst since the loss only effects 12.5 % of the bits from each speech frame, and with channel coding we can correct it.

3	57	1	26	1	57	3

a. Normal burst

A	B	C	D
20 ms speech 456 bits = 8x57	20 ms speech 456 bits = 8x57	20 ms speech 456 bits = 8x57	20 ms speech 456 bits = 8x57

b. Four speech segments

3	A	1	26	1		3
3	A	1	26	1		3
3	A	1	26	1		3
3	A	1	26	1		3
3	B	1	26	1	A	3
3	B	1	26	1	A	3
3	B	1	26	1	A	3
3	B	1	26	1	A	3
3	C	1	26	1	B	3
3	C	1	26	1	B	3
3	C	1	26	1	B	3
3	C	1	26	1	B	3
3	D	1	26	1	C	3
3	D	1	26	1	C	3
3	D	1	26	1	C	3
3	D	1	26	1	C	3

c. Consecutive speech bursts after second level interleaving

Fig. 4. Second level interleaving

A block diagram of a GSM phone (Fig. 5) shows the different signal processing steps involved in the speech transmission.

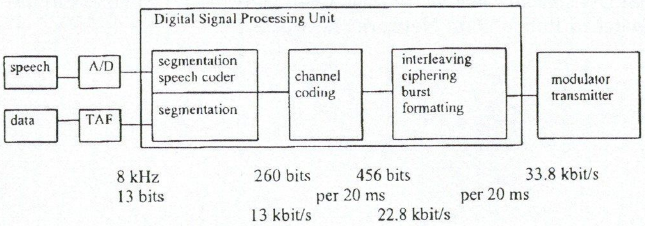


Fig. 5. Block diagram of a GSM mobile transmitter

3. DATA TRANSMISSION OVER GSM

From Fig. 5 we can see, that the analogue signal is sampled with 8 kHz speed and 13 bits quantization and is processed into a 13 kbit/s bit stream. The speech processing takes into account the human speech organs. That means, that this channel is not transparent for those analogue signals, which differs from the human speech. So if we want to transmit data or analogue fax signals over a GSM phone, we have to implement a Terminal Adaptation Functionality (TAF) between the data source and mobile terminal. On the network level we need an InterWorking Unit (IWU) to translate the GSM formatted data stream to a modulated analogue signal and vice versa.

Telecommunication services within GSM are basically divided into teleservices (TS) and bearer services (BS), which are described by attributes. These attributes characterize the capability and configurations of the terminal equipment's and the originating and terminating network. The bearer service to be accessed is indicated in the bearer capability information element (BCIE) carried in the SETUP message from the mobile station, or from a translated ISDN-BC if it is a data call from ISDN.

The BCIE is analyzed in the MSC in order to find out if routing to IWU is necessary. If so, IWU reads some of the information in the BCIE in order to connect the right functionality.

4. INTERWORKING WITH PSTN NETWORK

The main function of the interworking unit is to support the data services in GSM, such as data and telefax transmission. The necessary interworking functions will supply the following:

- To supply modems and faxmodems to the mobile user.
- To perform necessary protocol conversion.
- To perform necessary rate adaptations.

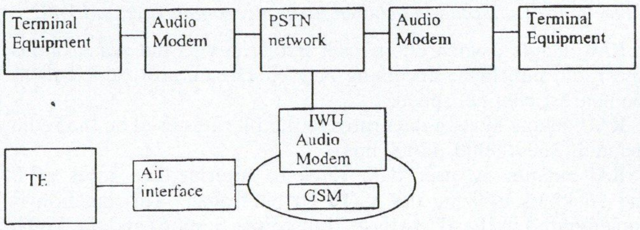


Fig. 6. Interworking with PSTN network

5. QUALITY OF SERVICE

One of the General attributes is Quality of service. Two Quality of service attribute values for bearer services are defined:

- transparent;
- non transparent.

The Transparent service (Fig. 7) will transmit data transparently across a radio interface. This ensures a constant and known transmission speed, but the error rate may be high. This does not have to be a problem, if there is an overlaying application that uses a protocol with fault detection and retransmission between the terminals end to end.

With a nontransparent service (Fig. 8), a layer 2 protocol is added over the radiopath. It is based on X.25 layer 2 adapted to the cellular environment. The GSM defined Radio Link Protocol (RLP) ensures an error free transmission. The actual user transmission speed will then be unknown, due to the retransmission capabilities. The RLP is terminated in the IWU.

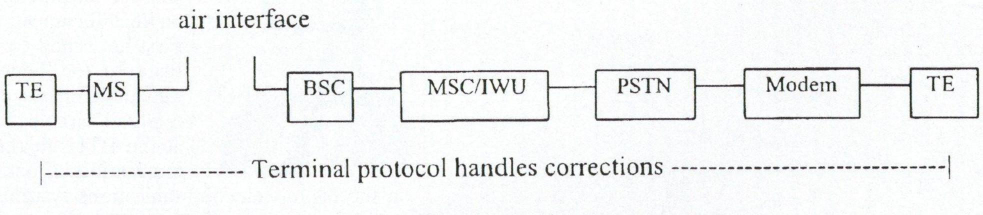


Fig. 7. Transparent transmission. Known capacity, unknown quality.

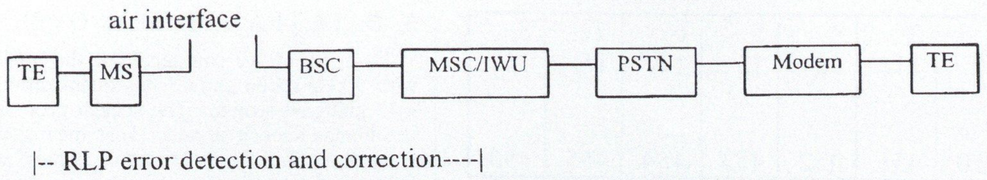


Fig. 8. Nontransparent transmission. Known quality, unknown capacity.

6. SETUP OF A MODEM CONNECTION

If the user is connected to a GSM, the terminal interface will be unchanged (V.24), but a lot of conversions are done in the data stream.

1. The mobile station (MS) has to adapt the speed to the radio interface.
2. The Base Station Controller (BSC) has to convert the signals to V.110 frames and insert them into the 2 Mbit/s PCM stream.
3. In the MSC/IWU there will be functions to remove the adaptations that the MS and BSC made, to get back the terminal interface (V.24) against the modem. For nontransparent services, The RLP entities in MS and IWU must also be connected.

Fig. 9 shows the rate adaptation elements between an asynchronous (ASy) user and IWU, the elements are symmetric, they work on the MS side and the network side also.

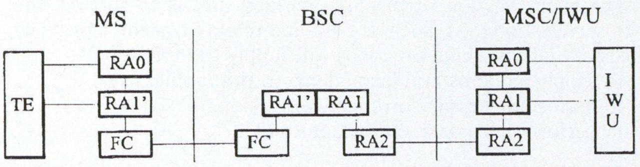


Fig. 9. Rate adaptation between an asynchronous user and IWU

RA0 adapts asynchronous user data rates to the synchronous (Sy) radio interface. Incoming ASy bitsrtream are padded to fit the nearest channel speed.

RA1' adapts Sy user data rates to the bit rates used on the radio channel (3600, 6000, 12000 bps).

RA1 adapts Sy user data rates to intermediate rates of 8 and 16 kbit/s utilizing the V.110 80 bit frame. This function is implemented in the BTS (Base Transceiver Station) and the IWU.

RA2 adapts the intermediate rate 8 and 16 kbit/s to the standard rate of 64 kbit/s.

The interleaving during data transmission is much more complicated than during speech transmission. The data stream is sliced into 456 bit long frames. One frame is divided into 22 pieces (2*6+2*12+2*18+16*24 bits). Slices from four consecutive frames are packed into one burst (2*57 bits) in such a way, that one frame is transmitted in 22 bursts. The first 6 bits of the frame in the first burst, 12 in the second, 18 in the third, then 24 bits in 16 bursts, following 18, 12 and six bits again. And it works!

7. AUTOMATIC FACSIMILE (FAX)

The facsimile teleservice is supported between a facsimile Gr.3 terminal in GSM and another Gr.3 terminal in PSTN or ISDN. Only automatic facsimile group 3, transparent is supported. The speed can be 9600, 7200, 4800 or 2400 bps. The alternate speech/facsimile will be supported in a phase 2 release.

Because of the nontransparency of the speech channel, transmitting fax messages needs also Terminal Adaptation Functionality and IterWorking Unit between GSM and PSTN or another network.

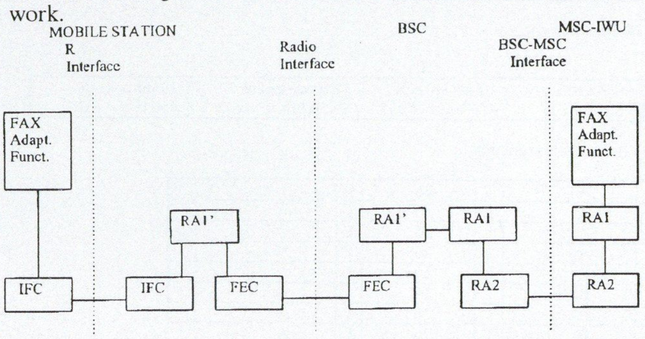
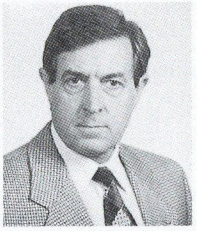


Fig. 10. Fax information transfer protocol model
IFC – Interface Circuit; FEC – Forward Error Correction

Fig. 10 shows the protocol model for the automatic fax teleservice. All the protocol entities specific to this teleservice are confined in fax adaptors (FA) both at the mobile station and the IWU ends. The protocol between group 3 terminals is T.30. Due to the high bit error rates and long delays on the radio interface, and also the inability to support some features of the T.30, a modified T.30 protocol is used. This protocol is denoted T.30'.

In this article we mentioned only the interworking between GSM and PSTN networks. In the near future as all the necessary interfaces will be available GSM will interwork with ISDN , PSPDN (Packet Switched Public Data Network), CSPDN (Circuit Switched Public Data Network) networks.



Nándor Vannai finished his study in 1967 on the Technical University of Budapest. First he joined to the Industrial Research Institute for Telecommunications, he designed automatic test equipment's for integrated circuits. From 1971 he worked at the BTU, in the Institute for Telecommunications Electronics. He is interested in the digital telecommunications systems, especially in different type of spread spectrum systems. For two years he has worked at WESTEL 900 GSM Co. as an engineering manager.

FUTURE SYSTEMS

FUTURE WIRELESS SYSTEMS

J. S. CSAPO

MOTOROLA
1475 W SHURE DR
ARLINGTON HEIGHTS
USA

1. DRIVING FORCES

Large number of companies, organizations and interested individuals are continuously asking where the wireless technology is going and what the future holds for it. What new needs and new technologies will emerge, and what impact will they have? Prediction is always difficult and extremely risky, of course, but we at Motorola believe that many current trends can be extrapolated with some certainty. Our view is that the future is being driven by the relentless improvements in the enabling technologies on one side, and the marketplace's needs on the other side. Most significant among these drivers are developments in digital and software technologies, increases in system capacity, increases in quality of service along with decreases in operational cost, and the desire for greater ease of use.

2. ENABLING TECHNOLOGIES

2.1. Digital Technology

The microprocessors and the Digital Signal Processor (DSP) are doubling of their processing power in every 18 to 24 months, the memory devices are quadrupling of their storage capabilities, and new digital transmission and switching capabilities are being introduced all the time.

These new developments will make possible very intelligent algorithm implementations in the frame of revolutionary new architectures. Complex algorithms with very large computational and memory requirements will be implemented in order to raise the overall performance of the systems to levels deemed impossible a few years ago because of the unavailability of supporting devices or their cost implications.

2.2. Software

To achieve maximum performance, future systems will be highly algorithm driven, and will allow for continues improvement because of their software upgradeability. Object Oriented Programming is already being used today in some products, and we can see wide penetration of this technology in the future. This technology provides good pre-implementation simulation capability, wide reuse of known modules, and fast implementation. The very real-time intensive DSP programs are being implemented by DSP oriented higher level descriptive languages. These technologies are going to take out of the art of software writing, and going to put it into the sphere of repeatable rule based engineering.

Because of ever increasing software development cost, the reuse of software during continuous hardware evolution will be a major competitive advantage for those companies able to implement it. This will be accomplished by the emergence of the "Firewalls" within the subsystem, and sub-modules in order to allow the software independent update of hardware.

3. THE NEEDS OF THE MARKET PLACE

In the following we are commenting on each of the key market drivers and their expected future directions.

3.1. Capacity

The primary need of the operators now and in the foreseeable future is system capacity. System capacity is defined here as relative capacity to the AMPS system using a seven cell reuse pattern. Fig. 1 shows the evolution of relative capacity in the last 12 years through refinements of the analog technologies, and the introduction of digital technologies. Based on the chart we can realistically assume that by the year 2000 the new and improved systems are going to be digital, and their capacity will be 20+ times higher than the original AMPS.

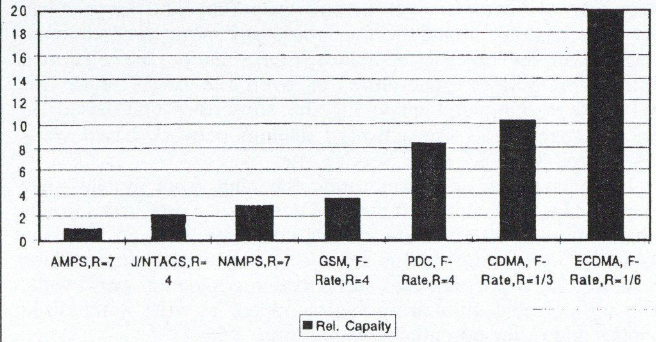


Fig. 1. Cellular Systems Relative Capacity Increas

3.2. Cost

Although equipment cost is a major consideration for the infrastructure providers, it is just a small fraction of the total. A more important measure is the cost of owning and operating the system. This includes actual hardware and software cost, the cost of the cell site, the electric utility cost (including the cost of cooling), interconnect cost, and the cost of the maintaining the site. Because these contribute so much to the total cost, the more expensive hardware is sometimes the less expensive solution for the long run.

The cost problem can be solved item-by-item or it can be addressed strategically, selecting a single attribute and using it to drive all the other attributes closer to optimum. In case of Motorola, the primary driver is the physical size. The increased use of integrated circuits has brought down the size and power consumption, and has reduced the number of field visits by maintenance personnel because of the improved reliability of our Base Stations. The application of integrated circuits also allowed multiple traffic channels in a single DS-O 64 Kbps time slot, resulting in greatly extended traffic carrying capability on the digital link.

This is where we are today. Although we still have far to go in exploiting other possibilities, we can already see the limits of this approach. To maintain our momentum, fundamental functional re-partitioning will occur in new architecture based systems.

3.3. Ease of Operations

Easy operation of the infrastructure means that the system needs minimum care and attention. It also means that when problem develops, it is automatically identified, and the faulty equipment is automatically removed and replaced, without disruption to the service. After the service recovery actions are executed the system is capable of self diagnosing the faulty unit, and providing sufficient information to the maintenance organization to allow timely repair.

Today's Wireless Network and Operation and Maintenance systems are getting close to these capabilities. Substantial advancements are going to be introduced in the area of Man Machine

Interface (MMI) in the form of Graphic User Interfaces (GUI), which allow much faster and easier communication between the operator and the system. The future will bring the introduction of the "Expert Systems" based solutions which will assist the operator to identify complex problems by analyzing trends, based on collections of historical data. Trend analysis will be able to identify performance degradation trends, and will provide advance notice of impending problems exceeding the pre-set threshold limits.

3.4. Ease of use

Ease of use refers to the ability of the subscriber unit to implement desired functions without forcing the user to memorize complex operational sequences. It also includes the subscriber unit being available anywhere at almost any time.

All these factors are driven by the enabling technologies based on high performance processors and integrated circuits. High performance processors will make possible a vast improvement on the nearly 100 years old MMI interface—the keypad—replacing key strokes with voice activated commands.

We consider a technology to be ultimately successful when the elements of the technology become completely invisible. The voice activated interface will be so transparent that the user will not have to think about the mechanics any more than someone plugging in an electric appliance thinks about the electrical distribution grid or generators, or even the cost. With this will come locking and unlocking the subscriber unit based on voice recognition, voice activated dialing, network based voice synthesized Short Message Service, etc.

These enablers are accelerating the shift from mobile units to portables and sub-portables. There are a few cities today where the portable units are making up greater than 85 % of the subscribers population. This trend is going to continue reaching close to 100 % portable and sub-portable population world wide. The sub-portable units are going to appear as wrist watch sized phones and other potential jewelry items.

Serving the subscriber's needs will require not only the convenience of the small size and long operation, but also the availability of the communication channels on demand and under any circumstances. This requirement is partially addressed by the radio channel spectral efficiency, as we mentioned under the Capacity section.

The other aspect of the radio channel availability is the adequacy of high quality radio coverage. This will be provided by extremely complex transmit power control algorithm, which will take into account the needs of each user and the needs of the surrounding users for interference free communications. The future systems will be able to adopt to the continuously changing RF environment after system deployment.

Desire for smaller and smaller units along with advances in circuit, receiver, and battery technologies will extend the subscriber unit's active time from a very few to nearly a hundred hours, making possible weeks of operation without concern for condition of the battery. This is another example of how disappearance of an element of the technology (in this case of the spare battery) is indication of that technology's success.

3.5. Quality of service

Service quality can be defined in many ways. Our definition is restricted to the key subscriber-visible items, such as the clarity of voice, reliability of the communication channel, and availability of service.

The latest advancement in voice-coding technology allows low bit rate coders to approach the performance of high bit rate wireline coders. Fig. 2 shows a comparison of recent voice-coder test results. It is impressive that the Enhance Voice Coder (EVRC) technology although rather new, is already proving to be competitive with the best of the low bit-rate wireline coder. Future improvements are highly likely, and could bring the performance of this coder in parity with the 32 or 64 Kbps PCM coders. The new systems and subscriber units are being produced with sufficient flexibility to make them upgradable to the latest voice coder technology.

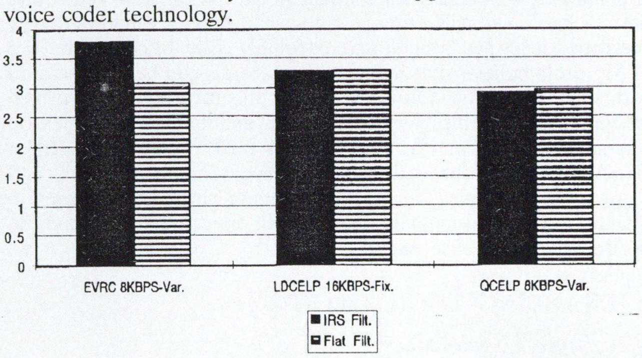


Fig. 2. Voice Coder Frequency Response Test by MOS Score

The quality of the communication channel — frame or bit error rates — is being maintained by highly adaptive controls, such as fast power control and extensive use of error correction algorithms. Future systems will not exhibit audible degradation of voice quality under 3 % to 5 % Frame Error rate conditions.

The availability of service of wireless systems must approach the availability of wired systems. That implies that new systems must provide continuous operation even if major elements of the system fails, and the total system outage must not exceed 3 minutes per year. This level of system availability will be achieved in spite of the multiple new software loads being added each year to the system to bring new feature capabilities to the market.

I have tried to give you a quick glance of the future, based on the technological and market forces which are forming our industry. As I said, predictions are risky and I would not be surprised if those I have just been making turn out to be wrong. But even if they are, I don't think we will be disappointed, because life always outperforms everyone's wildest dreams.

John S. Csapo received his M.S.E.E. and Post Graduate degree in Digital Control Theory from the Technical University of Budapest, Hungary in 1965 and 1969, respectively. From 1965 to 1977 he was with the Hungarian Oil Company as a member of Technical Staff supporting computer operations. Since 1978 he has worked for International Telephone and Telegraph (ITT) and GTE Corporations on Integrated PABX developments as a Senior Systems Engineer and later as Director of Engineering. In the last 10 years he has been with Motorola and his main interest and responsibilities are wireless systems and system specifications. He and his team have been instrumental in the Motorola SuperCell product definition. He is a member of the CDMA Steering Committee responsible for the accelerated introduction of the CDMA technology into the wireless marketplace.

GMS/PCN BASE-STATION TESTERS FOR PRODUCTION, INSTALLATION AND SERVICE

A well-thought-out, user-friendly operating concept, compact size and low weight as well as rugged construction make the new testers an ideal choice for production, service and heavy-duty installation work: CMD 54 handles digital mobil-radio base stations to GSM standard and CMD 57 base stations to GSM and PCN (DCS 1800) standards.

Digital Radiocommunication Testers CMD 54 and CMD 57 join the successful CMD family, which can now provide testers for GSM and DCS 1800 base stations (Fig. 1). The highly flexible GSM/DCS 1800 testers of the first generation were designed for use in development and quality management. CMD 54/57, the testers of the second generation, are tailor-made to meet the requrements of production, installation and servicing of GSM/DCS 1800 base stations. The new testers of course have all the well-known advantages of the CMD family [1]–[3].

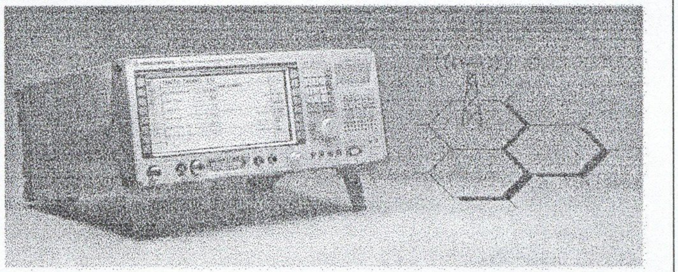


Fig. 1. Digital Radiocommunication Tester CMD 54/57 — specialist for GSM and PCN base-station measurements

1. EASY OPERATION

With the user interface of Digital Radiocommunication Tester CMD 52 for GSM mobiles — the first member of the CMD family — Rohde & Schwarz set a standard for the operation of compact testers. CMD 54/57, too, has separate *test menus* and *configuration menus*. The test menus include only those functions that are needed for measurements. General parameters, e.g. for tolerance masks, are defined in configuration menus. This separation provides for an extremely clear-cup operating concept. CMD 54/57 checks results for compliance with user-definable tolerance limits. *Pass/fail indicators* make it easy to interpret results correctly, even if the operator has little experience with test of this type (Fig. 2.).

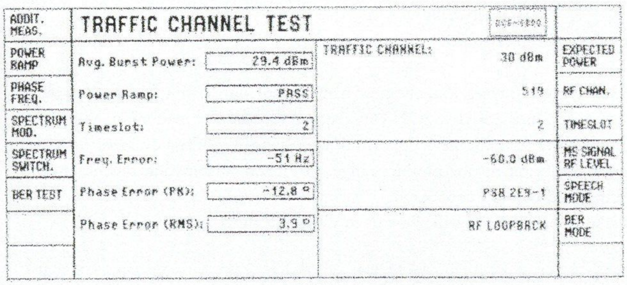


Fig. 2. Main measurement menu presents all results in short, clear-cut form. Specific menus can be called via softkeys for more extensive, in-depth measurements.

In addition to *manual control*, which is the main operating mode in servicing, CMD 54/57 features remote control via the optional *IEC/IEEE – bus interface*. This mode of operation will be mainly used in production environments. As far as installation is concerned, the serial *RS-232-C remote-control interface* is the most interesting feature, as all laptops or notebooks commonly used in installation are fitted with this type of interface.

2. COMPREHENSIVE MEASUREMENTS

The signalling requirements that have to be met by base-station testers are different from those to be fulfilled by mobile testers. In the case of mobiles the tester acts as a master and controls the mobile, while in the case of base stations the DUT (base station) is the master. Here it is not possible for the tester to set the base station to a particular RF channel via the air interface. Base-station measurements therefore require the use of special interfaces of control units.

However, the DUT not only acts as a master in terms of control, it also supplies the timing and frequency reference signals. A base-station tester therefore needs to synchronize to the base station, CMD 54/57 can use either the C0 carrier from the base station or an external trigger for synchrinization. With the option Reference Frequency Inputs/Outputs CMD-B3, CMD can be synchronized to virtually any external reference frequency.

The *basic version* of CMD 54/57 can carry out all essential base-station *measurements*:

- Tx power level including power ramping with a large dynamic range (> 72 dB),
- phase and frequency error,
- spectrum due to modulation,
- spectrum due to switching,
- bit error rate.

Thanks to a tailor-made concept providing a selectable average rate, extremely fast spectrum measurements (Fig. 3) are possible: GSM modulation spectra averaged over 500 frames are available in less than 60 s.

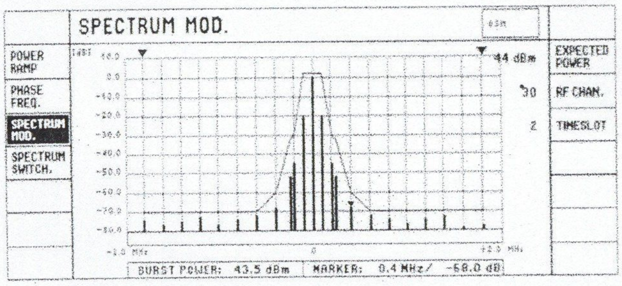


Fig. 3. In spectrum measurement menu, spectral lines are shown as bargraphs. Detailed analysis is facilitated by markers and tolerance masks.

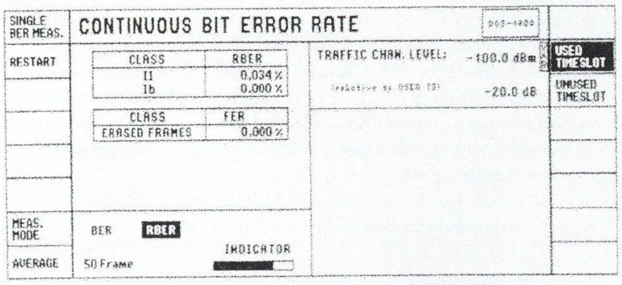


Fig. 4. Menu for continuous bit-error-rate measurement provides fast overview of base-station receiver characteristics

Bit-error-rate measurements (Fig. 4) on base stations involve some difficulty because, unlike mobile tests, there is no uniform test procedure specified by GSM/PCN standards. CMD 54/57 therefore provides various ways of determining the bit error rate of a base station:

- *Via loopback on base station*

CMD 54/57 transmits a pseudo-random bit sequence in the speech frames. The base station returns this bit sequence to CMD 54/57 via a switchable loop. CMD 54/57 compares the pattern received with the pattern sent, and so determines bit error rate.

- *Via loopback on CMD*

CMD 54/57 receives the speech frames sent by the base station and loops them back to the base station. Bit error rate is determined by the base station.

- *Via CMD remote-control interface*

CMD 54/57 again injects a pseudo-random bit sequence in the speech frames. A number of the speech frames received by the base station is recorded by an external unit (e.g. a PC). The bit sequence is sent back to CMD 54/57 via the IEC/IEEE – bus or the RS-232-C interface, and CMD calculates bit error rate.

- *Via optional A_{bis} interface*

CMD 54/57 sends a psuedo-random bit sequence to the base station, monitors the bit sequence at the A_{bis} interface between the base-station controller and the base station and calculates bit error rate.

In addition to the GSM-specific measurements described above, CMD 54/57 features a *DC ammeter and voltmeter*, especially designed for pulsed signals to test power supplies. The ammeter measures maximum, minimum and average current.

A wide variety of *options* ensures that CMD 54/57 can adapt to any measurement environment easily. Beside the options referred to above, AF Measurement Unit CMD-B41 with frequency counter is particularly worth mentioning, as this adds an *AF voltmeter*, a *distortion meter* and a *frequency counter* that operates up to 60 MHz to the facilities already provided by CMD 54/57. Rohde & Schwarz is constantly developing new options in line with the latest standards and recommendations, thus providing an instrument that can handle tomorrow's requrements too.

REFERENCES

[1] Mauckschs, T.: Digital Radiocommunication Tester CMD – Test system for production testing and servicing of mobile GSM telephones. *News from Rohde & Schwarz* (1993), No. 142, pp. 4-6.

[2] Maucksch, T.: Measurements on GSM mobiles using Radiocommunication Tester CMD. *News from Rohde & Schwarz* (1994), No. 144, pp. 31-32.

[3] Mittermaier, W. and Holzmann, G.: Digital Radiocommunication Tester CMD 55 – GSM and PCN tester in one compact unit. *News from Rohde & Schwarz* (1994), No. 145, pp. 18-20.

RUDOLF SCHINDLMEIER
Rohde & Schwarz

(reprint from R & S News *146*)

SIMPLE DISCRETE TIME MODELS FOR MULTIPLEXER WITH HOMOGENEOUS ON-OFF SOURCES*

K. BEGAIN

DEPT. OF COMPUTER SCIENCE
MU'TAH UNIVERSITY
61710 MU'TAH, JORDAN

L. JEREB, M. TELEK and T. V. DO

DEPT. OF TELECOMMUNICATIONS
TECHNICAL UNIVERSITY OF BUDAPEST
1521 BUDAPEST, HUNGARY

1. INTRODUCTION

Broadband ISDN (B-ISDN) is the network planned to carry different types of information including voice, video, and data. The CCITT has adopted the Asynchronous Transfer Mode (ATM) as the switching technique for the future high speed network due to its flexible and effective utilization of network resources. Since then ATM has become an intensive research area and the main interest has been devoted to the development of methods in order to ensure Quality of Service requirements (throughput, cell loss, delay, etc.) for each data type.

ATM is a packet-like switching and multiplexing technique in which messages are split into short fixed-length (53 Bytes) packets called cells. Cells may be lost or may suffer delay for different reasons, while they are transmitted from the source to the destination. The buffer overflow in an intermediate switching or multiplexing node can be one of the reasons of the loss or delay. The tolerance for cell loss or delay varies with the type of traffic carried. For example, packetized voice traffic allows relatively high cell loss probability but it has little tolerance to the delay while data can tolerate some delay but is very sensitive to the cell loss.

In this paper, the problem of multiplexing is addressed. Namely, the special case of N identical ON-OFF sources with one high speed output is considered.

This problem has been studied in many papers providing both analytical and simulation results, however, most of them assume a continuous time or fluid flow model of the system which is only an approximation of the real situation.

Anick et al. [1] considered the general data handling problem assuming continuous time model with exponential distributions for both the ON and the OFF intervals. The time unit was taken as the average of the ON intervals. The information unit was taken as the incoming information per time unit. In their model the server capacity was a given (not integer) value and the buffer size was infinite. The equilibrium buffer content distribution and its moments were derived for the model. Numerical results for the overflow probability of a predefined buffer backlog were presented as well.

Kosten [6] studied a similar model assuming a finite number of different groups of ON-OFF sources, but the time unit was not defined. Similar achievements were presented (eigenvalues-eigenvectors, buffer content distribution, ...) and numerical results for two groups of sources were given.

Daigle and Landford [2] used the same model of [1] to study the problem of packet voice communication system. While Halfin [3] modified the previous model and allowed finite and infinite number of ON-OFF sources and a state-dependent Poisson message arrival with general packet length distribution. The results were provided with Laplace—Stieljes transforms for the equilibrium buffer content distribution, from which the moments and the delay characteristics were also derived. Some computational experiences and comparisons in case of Poisson input processes were summarized as well.

Mitra [9] used a similar model for production machines with service and failed states. In addition to the traditional results implemented on these kinds of problems, he gave a detailed study on stable and unstable systems. Tucker [11] also used a model similar to [1], but the server capacity was defined as an integer number of information units and the buffer size was finite. Results on buffer content distribution, cell loss, and delay were given with simulation comparisons.

Li [8] assumed a finite number of ON-OFF sources, with exponential distributions for both the ON and the OFF intervals, a finite buffer size and a non-integer channel (server) capacity. He defined the group of states where packets are blocked and derived the mean holding time and the initial distribution for this group. He also gave results concerning the mean duration of the overloaded periods. An embedded Markov chain at the end of the overloaded periods was introduced which describes the worst case for the arriving packet concerning the delay. The paper presented many simulation results and approximations for integrated voice and data examples.

The common feature of the above mentioned models is that all of them have assumed a continuous time distribution for the ON and OFF intervals. On the other hand, Li [7] introduced a discrete time model assuming finite number of ON-OFF sources and geometrical distributions for the ON and OFF intervals. He fixed that in one time unit only one ON and/or OFF source can change state. The channel capacity was assumed to be an integer number of sources and the buffer size could be either zero (burst switching-clipping case) or infinite (packet switching case). Similarly, he defined overloaded and underloaded intervals and derived the mean cumulative time spent by a given (underloaded or overloaded) process in a given state. For the case of burst switching, he determined the bit clipping rate (BCR) and the mean length of the overloaded (clipping) periods with numerical results. Meanwhile for the packet switching case, he defined an embedded Markov chain such as that in [8] that was described before.

Finally, Hübner and Tran-Gia [5] used similar model, but in their model the server capacity was given as a non-integer number of information units and the buffer size was finite. They defined three cases:

- fixed number of ON sources (Quasi-stationary analysis) for which steady-state probabilities and cell blocking probabilities were given,
- fixed number of ON-OFF sources for which approximations based on the quasi-stationary results were given,
- model for call admission control (CAC) where blocking probabilities were calculated.

In this paper, a discrete time model based on a finite number of sources and a finite size buffer is introduced from which results on cell loss, average buffer length, and delay are given.

In Section 2, the main assumptions for this model are given, and the mathematical model is derived in a step-by-step manner. Section 3 defines three different model alternatives. Section 4 gives the steady-state solution from which the most important expressions on performance parameters are obtained. Section 5 shows the numerical example and, finally, some conclusions complete the paper.

2. MODEL ASSUMPTIONS

2.1. *Physical model*

Consider a multiplexing node with the following features :

- N identical sources with two states (ON, OFF).
- Sources in the ON state generate cells with rate v_s, where the time unit is taken so that $v_s = 1$ [cell/time unit] holds.
- Sources in the OFF state do not generate any cells.
- There is one output transmission link with the transmission rate $v_l = C$ [cells/time unit].

* This work was performed with the support of the European Community through the contract COPERNICUS-1463.

- If more cells arrive than the link capacity, the extra cells are stored in a buffer of length L.
- Cells arriving when the buffer is full are lost.

The system is studied in order to find analytical results on the expected cell loss, the cell delay, and the average buffer content.

2.2. Source process

Assume that the behaviour of a source can be described by a discrete-time Markov chain (DTMC) with two states (ON-OFF). The distribution of the length of the ON periods is assumed to be of geometrical with parameter β, while the OFF periods are also geometrical with parameter α. The transition probabilities of the DTMC are:

$$Pr[OFF \to ON] = \alpha$$
$$Pr[ON \to OFF] = \beta \qquad (1)$$

Let us define now ξ_n denoting the number of sources in ON state at time n. It is obvious that this process is also a DTMC with state space $\Omega = \{0, 1, ..., N\}$ and the state transition probabilities can be written as:

$$p_{ij} = \qquad (2)$$
$$\sum_{k=\max(i+j-N,0)}^{\min(i,j)} \binom{i}{k}(1-\beta)^k \beta^{i-k} \binom{N-i}{j-k} \alpha^{j-k}(1-\alpha)^{N-i-j+k}.$$

This expression of the transition probabilities takes into account that the transition from state i to state j may occur if k out of the i ON sources ($0 \le k \le i$) stay in the ON state and $(j-k)$ other sources turn from the OFF to the ON state.

Let $\mathbf{P}^{(n)} = \{P_i^{(n)}\}$ ($P_i^{(n)} = Pr\{\xi_n = i\}$) denotes the state probability vector of process ξ_n at time n and $\mathbf{p} = \{p_i, i = 1, \ldots, N\}$ denotes the steady state probability vector of ξ_n.

2.3. Buffer content

The process describing the number of cells in the buffer plays an essential role in evaluating the performance parameters mentioned before. Let η_n denote this process with state space $\Phi = \{0, 1, \ldots, L\}$, where L is the size of the buffer. The state transition probabilities of η_n are dependent on the state of process ξ_n, therefore one should study the two processes together.

2.4. Global model

By these assumptions, we define the compound process (ξ_n, η_n) with the states (i, j), where $i = 0, 1, \ldots, N$ and $j = 0, 1, \ldots, L$ and the state transition probabilities as follows: $p_{i,j,u,v} = Pr[u$ ON source, v cells in buffer at time $(n+1)|i, j$ at time $n]$, and the state probability matrix can be written as $\Pi^{(n)} = \{\Pi^{(n)}(i, j)\} = Pr\{\xi_n = i, \eta_n = j\}$ and the steady-state probability matrix is denoted by $\pi(i, j)$.

In order to determine these probabilities, it is necessary to state that since the channel rate (capacity) is assumed to be an integer number of cells per unit time, a micro slot can be also defined as the time necessary to transmit one cell on the output channel. Although, one can suppose more reasonable to choose the micro slot as the time unit, the time unit was chosen the macro slot to ensure the Markov (memoryless) property for processes ξ_n and (ξ_n, η_n).

This fact and the fact that i cells are generated during a time unit when i sources are in the ON state imply that the state transition probabilities of the compound process (ξ_n, η_n) vary depending on the arrival process.

3. CELL ARRIVAL MODELS

The accurate analysis of the introduced physical model requires a detailed knowledge of the distribution of the incoming cells in the macro slots and it is very hard to evaluate numerically even for small models. In the paper, we study three different special situations of the arrival process for which the performance parameters are easy to evaluate and provide information on the range of the performance measures.

Model 1: Arrivals occur at the beginning of the time slot

In this case we assume that one cell arrives from every ON source at the beginning of any time slot, so that the buffer content will be $\min(i + j, L)$ cells, where i is the number of ON sources and j is the number of cells in the buffer at the end of the previous time slot. Thus, the number of cells that will be found in the buffer at the end of the time slot can be written as:

$$\eta_{n+1} = \max(\min(j + i, L) - C, 0). \qquad (3)$$

Using the above approach, the number of cells $c_{i,j}$ and the total delay of cells $d_{i,j}$ in state (i, j) can be expressed in the following form:

$$c_{i,j} = \max(i + j - L, 0) \qquad (4)$$

$$d_{i,j} = \sum_{l=j}^{\min(i+j,L)-1} l, \qquad (5)$$

where the delay is measured in the micro slot units.

Model 2: Cells arrive one-by-one in the micro slot starting when the buffer becomes empty, and the remaining cells (if any) arrive at the end of time slot

For state (i, j)

$$\eta_{n+1} = \min(\max(j + i - C, 0), L), \qquad (6)$$

$$c_{i,j} = \max(i + j - C - L, 0), \qquad (7)$$

and

$$d_{i,j} = \sum_{l=0}^{\min(i-\max(C-j,0),L-\max(j-C,0))-1} \max(j - C, 0) + l \qquad (8)$$

hold, where $\max(C - j, 0)$ is the number of empty micro slots after all the cells being served when $C > j$ and $\max(j - C, 0)$ gives the number of cell remaining at the end of the slot. It is obvious, that only one of the above quantities can take positive value at the same time.

Model 3: Cells arrive in batch in the micro slot after the buffer becomes empty or at the end of macro time slot

In this case we assume that cells arrive in batch either immediately after the buffer becomes empty or at the end of macro time slot if the buffer is not empty in the macro time slot.

For state (i, j)

$$\eta_{n+1} = \max(\min(\max(j-C, 0)+i, L)-\max(C-j, 0), 0) \qquad (9)$$

$$c_{i,j} = \max(\max(j - C, 0) + i - L, 0), \qquad (10)$$

and

$$d_{i,j} = \sum_{l=0}^{\min(\max(j-C,0)+i,L)-1} (\max(j - C, 0) + l). \qquad (11)$$

4. PERFORMANCE PARAMETERS

Taking into account the model alternatives used to describe the arrival procedure for process (ξ_n, η_n), it can be seen that, for any time instant n, (ξ_{n+1}, η_{n+1}) depends only on (ξ_n, η_n), which means it is a DTMC with transition probabilities $p_{i,j,u,v}$ can be defined as follows:

$$p_{i,j,u,v} = \begin{cases} p_{i,u} & \text{if } \eta_n = j \text{ and } \eta_{n+1} = v \\ 0 & \text{otherwise,} \end{cases} \qquad (12)$$

where $p_{i,u}$ is the transition probability of process ξ_n and v is calculated based on the above model alternatives.

With these transition probabilities, the steady-state probabilities $\pi = \{\pi(i, j)\}$ of the compound process (ξ_n, η_n) can be obtained from the well-known DTMC Eq. (5). Then, the main performance parameters for the system can be given as follows:

- **The average cell loss**

$$Cl = \frac{\sum_{i=0}^{N} \sum_{j=0}^{L} \pi(i, j) \cdot c_{i,j}}{\sum_{i=0}^{N} i \cdot p_i}, \qquad (13)$$

where p_i denotes the steady state probability of state i of process ξ_n, and the denominator gives the average number of the arrived cells.

- **The average cell delay**

$$D = \frac{\sum_{i=0}^{N} \sum_{j=0}^{L} \pi(i,j) \cdot d_{i,j}}{\sum_{i=0}^{N} \sum_{j=0}^{L} (i - c_{i,j}) \cdot \pi(i,j)}, \tag{14}$$

where the denominator gives the average number of transmitted cells.

- **The average buffer content**

$$B = \sum_{j=0}^{L} j \cdot \left(\sum_{i=0}^{N} \pi(i,j) \right). \tag{15}$$

In the next section, we give a numerical example on the model presented in the paper for all models and provide diagrams on the performance parameters.

5. NUMERICAL EXAMPLES

The models are demonstrated on an ATM multiplexer with ON-OFF type voice input channels with mean talkspurt duration $\beta^{-1} = 352$ ms and mean silence duration $\alpha^{-1} = 650$ ms [10]. The output channel is assumed to be T1 line with a rate of 1.536 Mbps. Taking into account that each ON source generates data with rate 64 kbps and each 47 Byte should be encapsulated into 53 Byte cell by AAL1, the source speed will be 72,17 kbps and thus $C = 21$. With these values the time unit is 5.875 ms and the micro time slot is 279.76 μs.

Figs. 1–4 show the calculated results for the expected cell loss and average cell delay versus buffer size with $N = 30$ (Figs. 1, 2) and with $N = 40$ (Figs. 3, 4) respectively, while Figs. 5, 6 show the same parameters versus the number of sources.

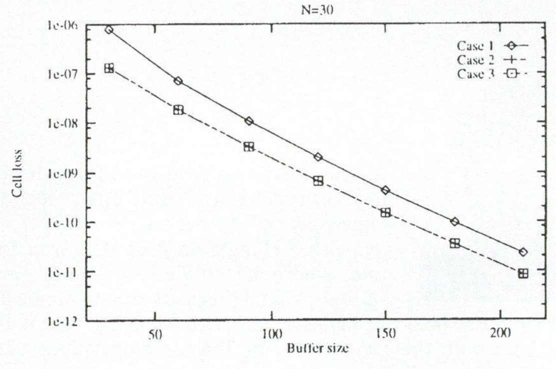


Fig. 1. Cell loss probability

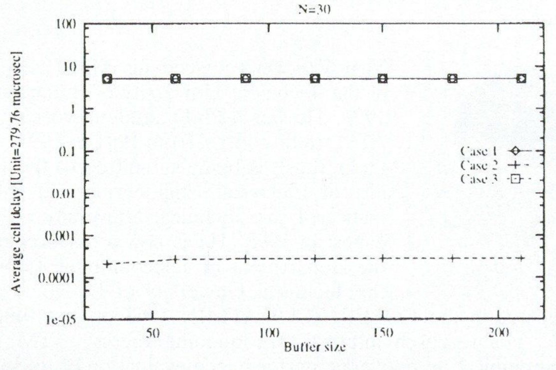


Fig. 2. Average cell delay

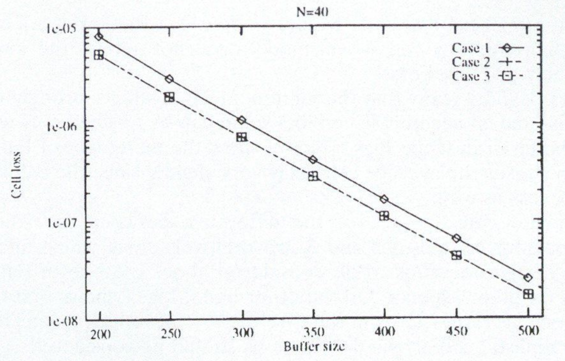


Fig. 3. Cell loss probability

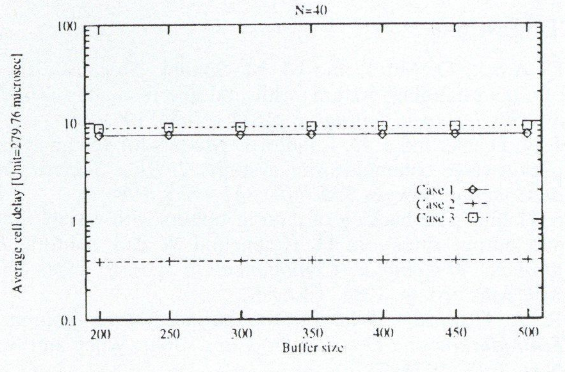


Fig. 4. Average cell delay

It can be seen (Figs. 5, 6) that the difference between Model 1, 2 and Model 3 becomes less as the number of sources increases. This is due to the fact that all cell arrival models behave similarly in the heavy load situations.

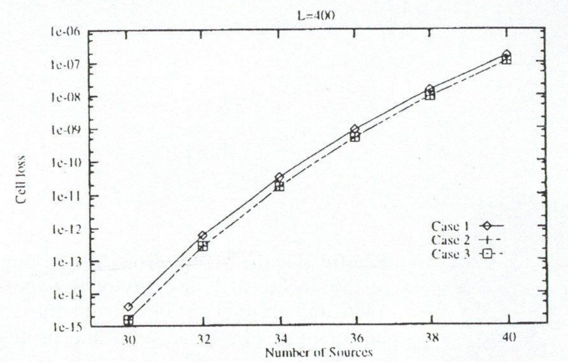


Fig. 5. Cell loss probability

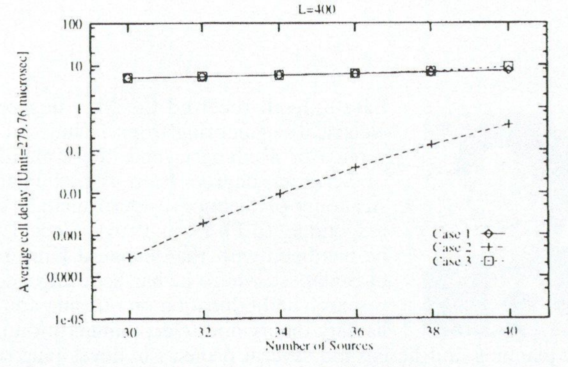


Fig. 6. Average cell delay

The numerical results of Model 3 show that the lower cell loss probability for any cell arrival model does not implies the lower cell delay and vice versa.

Figs. 1 and 2 show that the increment of N affects strongly the cell loss and an acceptable cell loss value can be reached only with high buffer size, while Figs. 1 and 2 show the increment of buffer size increases the average cell delay very slightly since the cell loss will be less as well.

For the case $N = 40$, the difference between the values obtained for Models 1,2 and 3 are relatively small which allows some design decisions to be considered about the size of buffer based on other aspects. On the other hand, Fig. 1 shows that this difference is rather large in the case of $N = 30$, which means that more realistic cell arrival distributions should be considered.

6. CONCLUSIONS

The paper presents performance models of an ATM multiplexing node for which explicit expressions are given for the most important performance parameters; cell loss, cell delay and buffer content.

The models are based on the two-dimensional DTMC with the number of ON sources and the number of cells in the buffer.

The models are implemented on an IBM RISC-6000 Model-570 machine and they provide relatively short execution time even for higher N and L values (e.g., for $N = 40$ and $L = 500$ the execution time was 258 seconds).

In addition, the numerical example showed some interesting results on the three different arrival model alternatives introduced in the paper giving some indications on the upper and lower limits for all the performance parameters mentioned before.

REFERENCES

[1] D. Anick, D. Mitra, and M. M. Sondhi: Stochastic theory of a data handling systems with multiple resources. *The Bell Systems Technical Journal*, 61:1871–1894, 1981.

[2] J. N. Diagle and J. D. Landford: Models for the analysis of packet voice communication systems. *IEEE J. Selected Areas on Communications*, SAC-4(6):847–855, 1986.

[3] S. Halfin: The backlog of data in buffers with variable input and output rates. In H. Rudin and W. Bux, editors, *Performance of Computer-Communication Systems*, pages 307–319, Amsterdam, 1984. Elsevier.

[4] R. A. Howard: *Dynamic Probabilistic Systems, Volume II: Semi-Markov and Decision Processes*. John Wiley and Sons, New York, 1971.

[5] F. Hubner and P. Tran-Gia: Performance of the finite capacity asynchronous multiplexer with modulated input. *Telecommunication Systems*, 1:263–278, 1993.

[6] L. Kosten: Theory of data-handling with groups of multiple resourses. In H. Rudin and W. Bux, editors, *Performance of Computer-Communication Systems*, pages 321–331, Amsterdam, 1984. Elsevier.

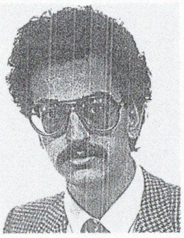
[7] S. Q. Li: A new performance measurement for voice transmission in burst and packet switching. *IEEE Transactions on Communications*, COM-35:1083–1094, Nov. 1987.

[8] S. Q. Li: Study on information loss in packet voice systems. *IEEE Transactions on Communications*, COM-37:1193–1202, Nov 1989.

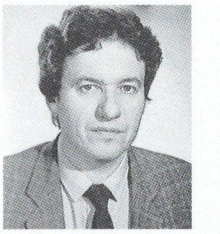
[9] D. Mitra: Theory of a fluid model of producers and consumers coupled by a buffer. *Advanced Applied Probability*, 20:646–676, 1988.

[10] K. Sriram and W. Whitt: Characterizing superposition arrival processes in packet multiplexers for voice and data. *IEEE J. Selected Areas on Communications*, SAC-4(6):833–846, 1986.

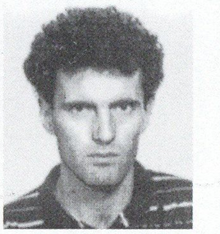
[11] R. C. Tucker: Accurate method for analysis of packet speech multiplexer with limited delay. *IEEE Transactions on Communications*, COM-36:479–483, April 1988.



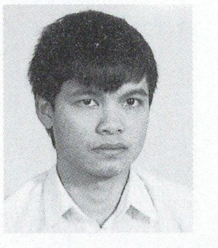
Khalid Begain received his MSEE degree at the Technical University of Budapest in 1986 and dr.univ in 1988 from the same university. He is an assistant professor in M'utah University in Jordan. He is mainly concerned in the field of reliability of electronic systems and queuing theory.



László Jereb received the M.S. degree in electrical engineering from Technical University of Budapest, and the Candidate of Sciences degree from the Hungarian Academy of Sciences (approximately corresponding to Ph.D. in 1986). Since 1971, he has been with the Technical University of Budapest, where he has been engaged in research and education on queuing and reliability theory and telecommunication network planning and he has led several projects in developing software tools aiming at the reliability analysis of complex electronic systems and the planning and analysis of telecommunication networks. He is a member of IEEE Communication Society and of the Scientific Society for Telecommunications of Hungary.



Miklós Telek was graduated from the Faculty of Electrical Engineering, Technical University of Budapest, in 1987. He joined the Hungarian Post Research Institute, where he studied modelling, analysis and planning aspects of communication networks in the field of reliability and performability. Since 1990 he has been with the Department of Telecommunications, Technical University of Budapest. His current research interests are reliability theory, network performance analysis and simulation. He is a member of the Scientific Society for Telecommunications of Hungary.



Tien Van Do received his MSEE degree at the Technical University of Budapest in 1991. He was a Ph.D. student working on ATM traffic control from 1991 to 1994. His Ph.D. thesis is being submitted to the Faculty of Electrical Engineering and Informatics of the Technical University of Budapest in 1995. He is now a researcher in the Department of Telecommunications of the Technical University of Budapest and participates in the COPERNICUS-ATMIN 1463 project funded by EC. His research interests are queuing theory, ATM and telecommunication networks, performance evaluation of telecommunication networks.

Digitális telefonközpontok
Mikrohullámú és optikai átviteltechnika
Digitális mobil telefonos rendszerek
Zárt láncú rádiótelefonos rendszerek
Hálózatépítő elemek
Kulcsrakész vállalkozások
Távközlési szoftverek
Távközlési klímaberendezések
Távközlési rendszerek áramellátása
Ericsson Kft.
Budapest XIV., Hungária krt. 162.
levélcím: 1475 Budapest, Pf. 154
telefon: 265 7100
telefax: 262 7861
ERICSSON

Welcome to our GSM system!

Select 216-01

Bring your GSM network with you while roaming in Hungary. By selecting the Pannon GSM network, you connect yourself to a premier GSM service provider. Relax and enjoy your stay knowing our Customer Service representatives are there to assist you 24 hours a day in both English and Hungarian, telephone: (36-1) 270-4120 or from your GSM handset 030.

PANNON GSM
Az élvonal.