Zeitschrift: Technische Mitteilungen / Schweizerische Post-, Telefon- und Telegrafenbetriebe = Bulletin technique / Entreprise des postes, téléphones et télégraphes suisses = Bollettino tecnico / Azienda delle poste, dei telefoni e dei telegrafi svizzeri

Herausgeber: Schweizerische Post-, Telefon- und Telegrafenbetriebe

Band: 73 (1995)

Heft: 6

Artikel: Towards a universal mobile communication plaform

Autor: Bajenesco, Titu I.

DOI: https://doi.org/10.5169/seals-875943

Towards a Universal Mobile Communication Platform

Titu I. BAJENESCO, La Conversion

Zusammenfassung

Der Weg zur universellen mobilen Kommunikationsplattform

Die Idee eines paneuropäischen zellularen Mobilfunksystems wurde 1982 von einem Komitee der Europäischen Konferenz der Post- und Telekommunikationsadministrationen (CEPT) ausgearbeitet. Das daraus entstandene System ist heute allgemein unter dem Namen GSM bekannt. Volldigitale Systeme, wie sie sich heute im Versuchsstadium befinden, werden eine noch bessere Spektrumausnützung und tiefere Systemkosten erlauben. Digitale Systeme werden die doppelte Kapazität von vergleichbaren Analogen Systemen aufweisen und hochqualitative Datenübertragung ermöglichen. Für GSM wird eine besondere Form der Frequenzsprungmodulation (Frequency Shift Keying, FSK) verwendet, bei der die Frequenz des HF-Trägers mit den zu übermittelnden Daten moduliert wird. Die genauere Bezeichnung dieser Modulation lautet «0.3 GMSK» (Gaussian Filtered Minimum Shift Keying). Die Zellenstandorte eines Zellularsystems sind mit einem zentralen Prozessor verbunden, der das Mobilnetz mit dem ortsfesten Telefonnetz verbindet, und werden von ihm gesteuert. Zwei Typen von Architektur sind möglich: zentralisiert und dezentralisiert. Es ist nicht abzustreiten, dass GSM ein sehr komplexes System ist, aber dies wird allgemein als der

Résumé

Vers une plate-forme de communication mobile universelle

L'idée d'un système de radiocommunication cellulaire paneuropéen a été conçue en 1982 par un comité de la conférence européenne des administrations des postes et télécommunications (CEPT). Le système qui en est résulté est aujourd'hui connu sous le nom de GSM. Les systèmes entièrement numérisés, tels qu'ils font encore aujourd'hui l'objet d'essais pilotes, permettront une meilleure utilisation du spectre et une réduction des coûts. Grâce à la numérisation, les installations auront une capacité deux fois plus importante que des systèmes analogiques comparables et assureront une transmission de données de haute qualité. Dans le système GSM, on utilise une forme particulière de modulation par saut de fréquence (Frequency Shift Keying, FSK), dans laquelle la fréquence de la porteuse HF est modulée par les données à transmettre. La désignation précise de cette modulation est «0.3 GMSK» (Gaussian Filtered Minimum Shift Keying). Les emplacements des cellules d'un système cellulaire sont connectés à un processeur central qui relie le réseau mobile au réseau téléphonique fixe et qui en assure la gestion. Deux types d'architectures sont envisageables: une architecture centralisée ou décentralisée. Il est indéniable que le système GSM

Riassunto

Verso la piattaforma di comunicazione mobile universale

Il progetto di un sistema di radiocomunicazione mobile cellulare paneuropeo è stato elaborato nel 1982 da un comitato della conferenza europea delle amministrazioni postali e delle telecomunicazioni (CEPT). Il sistema che ne è risultato è generalmente conosciuto con il nome di GSM. I sistemi completamente digitali che si trovano attualmente in fase di sperimentazione consentiranno uno sfruttamento dello spettro ancora migliore e saranno meno costosi. I sistemi digitali avranno una capacità raddoppiata rispetto a quella di sistemi analogici paragonabili e assicureranno una trasmissione dei dati di alta qualità. Per il GSM viene utilizzata una forma speciale della modulazione a spostamento di frequenza (Frequency Shift Keying, FSK) nella quale la frequenza della portante HF viene modulata con i dati da trasmettere. Questa modulazione è chiamata più precisamente «0,3 GMSK» (Gaussian Filtered Minimum Shift Keying). Le posizioni delle celle di un sistema cellulare sono collegate con un processore centrale che le guida. Questo processore collega la rete mobile con la rete telefonica fissa. Sono possibili due tipi di architetture: l'architettura centralizzata e l'architettura decentralizzata. Non si può negare che il sistema GSM sia un sistema molto complesso

Summary

Towards a Universal Mobile Communication Platform

The idea of pan-European Cellular Mobile Radio System was conceived in 1982 by a committee of the Conference of European Posts and Telecommunications Administrations (CEPT). The system that has emerged from this process has become widely known as the GSM system. Currently in the experimental stage, digital cellular systems will allow even greater spectrum efficiency and lower system costs. Digital systems will be able to carry double the capacity of comparable analogue systems and provide high quality mobile data communications. GSM uses a modulation that is a special form of Frequency Shift Keying (FSK), meaning that the data to be transmitted modulates the frequency of the RF carrier. This modulation is more accurately called 0.3 GMSK (Gaussian Filtered Minimum Shift Keying). The cell sites in a cellular system are interconnected to and controlled by a central processor, which also connects the mobile network to the landline telephone network. Two types of architecture are possible: centralized and decentralized. There is no disputing the fact that GSM is a very complex system, but it is generally considered that this is the price that has to be paid to achieve a performance level nearing that of the fixed net-

Preis angesehen, der zum Erreichen einer dem Festnetz angenäherten Leistungsfähigkeit und einer der vorausgesagten Nachfrage entsprechenden Teilnehmerkapazität bezahlt werden muss. Es wird jedenfalls erwartet, dass das zum Betrieb einer Teilnehmerbasis von 10 Millionen im Jahre 1999 nötige Ausrüstungsvolumen Preise ermöglicht, die zu heutigen Analogsystemen konkurrenzfähig sind.

est fort complexe, mais tel est le prix des performances pratiquement comparables à celles du réseau fixe, un prix qui devra être payé par les usagers que l'on peut aujourd'hui déjà estimer fort nombreux. En effet, on s'attend qu'à la mise en service d'un ensemble permettant la connexion de 10 millions d'usagers, en 1999, le volume des équipements nécessaires permettra d'offrir des prix concurrentiels par rapport aux systèmes analogiques actuels.

ma ciò viene considerato il normale prezzo da pagare per raggiungere un'efficienza che si avvicina a quella della rete fissa e una capacità di utenti corrispondente alla richiesta prevista. In ogni caso ci si attende che il volume degli equipaggiamenti necessari nel 1999 per l'esercizio di una base di utenti di 10 milioni consenta di fissare prezzi competitivi rispetto ai sistemi analogici attuali.

work and to achieve a subscriber capacity able to meet the predicted demand. It is expected however that the total volume of equipment needed to support a subscriber base of 10 million by 1999 will allow prices to remain competitive with current analogue systems.

The basic user needs

Although desirable, mobility creates problems: more road traffic means more traffic jams, more money needed to build roads, and greater deterioration of the environment through pollution. The basic user needs can be reduced to three things only [1]:

- *small-size equipment*
- *low costs,* both to begin using the service and to continue using it
- *high-quality radio coverage, so* that the user can rely on his phone wherever he wants to use it

These requirements are met by different technologies, but the cellular has a unique advantage in its wide-area coverage.

Cellular telephone radio

Cellular telephone radio can provide a suitable answer to the basic communication needs by injecting hundreds of thousands of lines in each metropolitan area in a short span of time. An economically feasible network can be installed in a large city *(Fig. 1* and *2)* to provide service not only to mobile units, but also to fixed lines needed in houses, offices, factories, etc. Such a network can be *superimposed on the existing wire-line network;* it represents an attractive alternative to the slow expansion of land-line services.

This explains why the radio-based cellular communication was the biggest growth area in telecommunications in the 1980s[1] and why it will also be the biggest growth area in the 1990s.

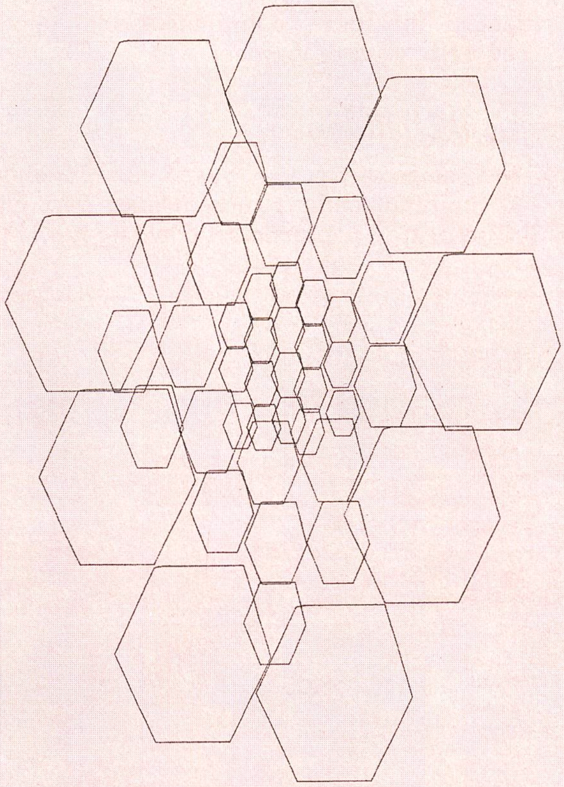

Fig. 1 A typical city radio cell plan; the cells are smaller, where the most users are expected

UPIs and PGS

Fueled by growing network intelligence, cost-efficient wireless access, and increased transmission and switching speeds, the nineties will integrate and evolve these network capabilities towards *Universal Personal Telecommunications (UPT).* The relationship between person and network will take on an entirely different shape, providing an increased level of service and mobility for the user. The availability of unique personal numbers, physical and automatic registration mechanisms, fixed and mobile access, and advanced communicating devices and interfaces will allow network users to receive calls and provide

[1] In 1980 only a very few, very rich people could do this; today, more than 14 million people worldwide have cellular telephones.

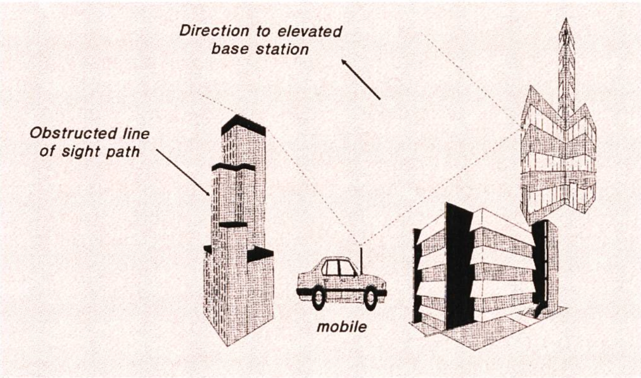

Fig. 2 The mechanism of radio propagation in urban areas

access to advanced services from anywhere in the network. Although the provision of such capability in the network is technologically possible today, there are many standards, operational, interworking, and regulatory issues, that need to be resolved before cost-effective personal communications services (PCS) can be offered to the user.

Technical challenges

All of the major technology-based components to personal communications are falling into place *(Fig. 3)*. The next set of technical challenges will center around the base technology streams, system architectures, standards and multivendor agreements.

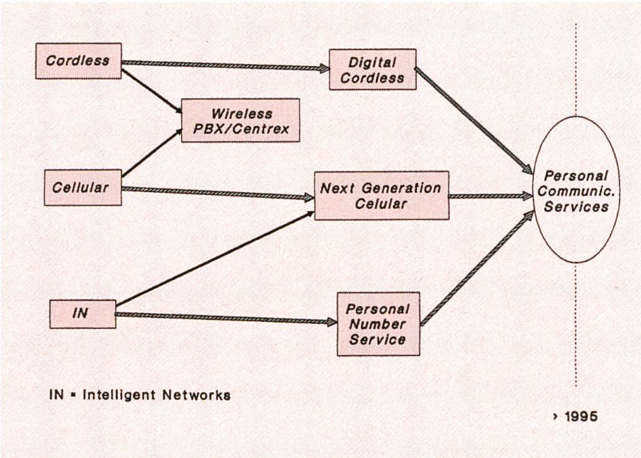

Fig. 3 Personal communications evolution

The base technology streams that are required for personal communications are:
- intelligent network (IN) data bases and services (needed to store personal profile data, accessible across network boundaries and to provide users with access to all IN-based services)
- ISDN
- celluar, microcellular and picocellular access technology[2] (to meet terminal mobility needs)
- high-capacity digital switching (to meet the switching needs of high concentrations of wireless users in metropolitan areas)
- smart-card technology (to facilitate for users the roaming from network to network and from terminal to terminal)

Personal communications architecture will integrate wireless and wire-line networks and provide an equivalent level of network service to both types of users. The layered architecture model [2] for personal communications is presented in *Figure 4*. *Figure 5* [2] shows how such a network provides the necessary wireless and wire-line capabilities.

Service Modelling	*Graphics Tools Simulation Tools Testing Tools*			
Service Creation	*Graphics Tools Modular Service Elements Testing Environments*		*Adminis-tration Interfaces*	*Service Subscr. Interfaces*
Service Management	*Service Management System (SMS)*			
Network Services	*Intelligent Networks Service Control Points Intelligent Peripherals Home Location Registers Authentication Centers*			
Switch Services	*Service Switching Point*	*ISDN Services Operator Services Centrex Voice Messaging Emergency Calling*		
Switching	*Local, Toll, Gateway Exchanges Mobile-Services Switching Centre Packet Switching Store & Forward*			
Network Access	*Wireline Fibre Optic Cable Twisted Pair Coax Cable*	*Wireless Base Station System*		
Person/ Machine Interactions	*Voice Phones, Feature Buttons, Data Phones, Graphics Terminals, Speech Recognition*			

Fig. 4 Personal Communications Layered Architecture

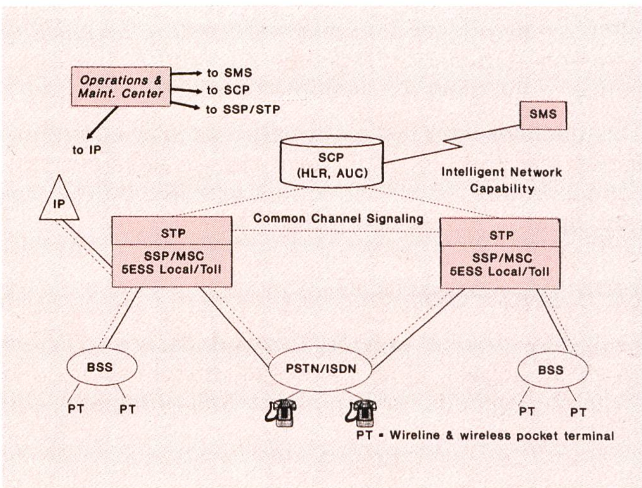

Fig. 5 Typical network architecture for personal communication

[2] With digital TDMA (Time Division Multiple Access), frequency planning can be avoided by use of self-tuning networks based on adaptive channel allocation.

Technical hurdles for the implementation of UPT

In essence, also the key technological hurdles for the implementation of UPT or personal communications services have been overcome. The remaining challenges for UPT are largely standards, politics and regulations. These include

- international numbering plan
- OA&M capabilities (including billing for various subnetworks)
- national and international standardization of network standards
- multivendor agreement of network interfaces
- national regulations governing wireless and wire-line network integration
- price (for administration and user) of personal communications (cost of IN and PCN implementations, standardization of interfaces; lack of wires between the network and the user means lower start-up costs and deployment time scales)

Short history of GSM

The idea of a Pan-European Cellular Mobile Radio System was conceived in 1982 by a committee of the Conference of European Posts and Telecommunications Administrations (CEPT). GSM was originally designed and optimized for use in fast-moving vehicles; nevertheless, hand-portable terminals are appearing on the market. The system that has emerged from this process has become widely known as the GSM[3]. The provision of communication services to mobile customers is a natural extension of the fixed wire-line services in developed countries. In most developing countries, however, such services may be considered a luxury with little importance, since the basic fixed wire-line services are still in great demand and short supply. The major reason for slow expansion is the high costs involved in wiring and rewiring the service area, in addition to some difficulties associated with long-term planning. The GSM service will allow users to make a call or be contacted on their mobile phones anywhere from the South of Italy to the North of Norway or from Moscow to Lisbon. GSM will not replace the existing TACS (Total Access Communication System) or NMT (Nordic Mobile Telephone) systems, but will operate in parallel with them[4] (ACA) [3, 4].

Principles of cellular telephone radio

Currently in the experimental stage, digital cellular systems will allow even greater spectrum efficiency and lower system costs. Digital systems will be able to carry double the capacity of comparable analogue systems and provide high-quality mobile data communication. The first digital systems were installed in Western Europe during 1991/1992.

[3] GSM: Global System for Mobile communications.

[4] A TACS or NMT telephone set will not work on the GSM, nor vice versa, but subscribers on these systems can obviously make telephone calls to GSM subscribers just as easily as they can to Public Switched Telephone Network (PSTN) subscribers.

The concept is very simple: a large geographical area is partitioned into smaller local areas called 'cells'. The block of radio spectrum (hundreds of channels) is also partitioned into smaller subblocks or 'sets'. Channel sets are then assigned to each cell. Two distant cells can use the same channel sets without excessive interference from each other. Allowing the repeated reuse of the same channel sets throughout a service area results in a drastic increase in system capacity. When telephone traffic in a service area increases, the system capacity can be increased accordingly by 'cellsplitting'[5]. Although, in principle, cells can have any shape, the spectrum management and channel assignment coordination process can be simplified considerably by using regular polygons as cells. Among the three regular polygons (square, triangle and hexagon) that cover a two-dimensional space with no holes and no overlaps, a regular hexagon has the largest area for a given cell radius; therefore, it requires fewer cells to cover a given area. Using hexagonal cells, each stage of cell splitting reduces the cell radius by a half and the cell area by a quarter. If carried out uniformly throughout the service area, this process would quadruple the number of cells and therefore the frequency reuse factor and system capacity. Variation in the cell size throughout the same service area will provide the flexibility needed to match the available spectrum with the nonuniform traffic requirements of that area.

GSM uses a modulation that is a special form of Frequency Shift Keying (FSK), meaning that the data to be transmitted modulates the frequency of the RF carrier. This modulation is more accurately called 0.3 GMSK[6] (Gaussian Filtered Minimum Shift Keying). The words 'minimum shift' denote that the phase of the carrier does not contain discontinuities when plotted against time.

System features

The GSM features – which will ensure success in the market place – are those which offer tangible benefits to users and include:

- integration of voice and data
- economies of scale for equipment manufacture
- improved system performance in parameters such as voice quality and handover
- 'smart-card' access, permitting multiple users of the same cellphone, but with individual billing
- low terminal cost
- low service cost
- ISDN compatibility
- automatic international roaming, so that the user

[5] New fixed antennas or 'cell sites' are placed halfway between existing antennas, splitting large cells into smaller cells. This process increases frequency reuse and therefore the system capacity. The cell-splitting process is gradual and nonuniform to reflect the nonuniformity of telephone traffic and differences in growth rates throughout a service area.

[6] 0.3 GMSK means that the modulating waveform is filtered using a Gaussian filter, where the product of the 3-dB bandwidth times the duration of one bit period equals 0.3. All digital cellular systems must use some sort of filtering to prevent interference from 'splintering' into adjacent frequency bands.

- can make calls on his phone in any country as readily as in his own
- 'sleep mode' – longer battery life in standby mode
- ability to support hand-held portables
- a range of new services and facilities

Supplementary services and various nonspeech services can be listed among the new services and facilities (ISDN capability, full ISDN numbering, data at rates up to and including 9.6 kbit/s, two messaging services – Short Message Service Point to Point [SMSPP] and Short Message Service Cell Broadcast [SMSCB], facsimile service, etc.).

To achieve these significant benefits, the GSM system is radically different from other systems. The major differences are: the signal is transmitted in bursts (Time Division Multiplex, TDM), the speech is digitally encoded to a low data rate and transmitted in a very efficient modulation format; by frequency hopping, transmitting only when someone is speaking and controlling the power of the transmissions.

Cellular mobile telephone systems usually start with center-excited cells with omnidirectional cell sites[7]. The cochannel interference is reduced by employing 60°- or 120°-directional antennas, with each antenna primarily serving vehicles located in the range of its front lobe. The cell-splitting process can be repeated several times until physical and practical considerations limit further cell division.

GSM architecture

The cell sites in a cellular system are interconnected to and controlled by a central processor which also connects the mobile network to the land-line telephone network. Two types of architecture are possible: centralized and decentralized. In centralized architecture, operation of the whole cellular network is controlled by a single sophisticated Mobile Telecommunication Switching Office (MTSO). This is connected to the Public Switched Telephone Network (PSTN) and to the individual cell sites, normally via wire lines. It performs the rerouting operation needed when a handoff takes place, in addition to carrying out many other cellular call-processing operations.

In densely populated areas, where the distance between the MTSO and the cell sites is not large, the centralized approach can be used effectively and economically. For sparsely populated areas, where traffic density is low, or for isolated communities the decentralized architecture is economically more feasible[8].

[7] Cell radius is usually large for start-up systems; when traffic growth requires it, cell splitting takes place, increasing the number of cells and thus the capacity.

[8] Although various degrees of decentralization are possible, the basic principle is the same: several cells serving an isolated community are interconnected by a Switching Mobile Center (SMC) which supervises the operation of those few cells. The SMCs are connected to the closest PSTN and act as the primary interface to the telephone network. Handoff supervision, paging operations, and call processing for a connection of cell sites are peformed by their SMC. The SMCs are connected to each other and to a Master Mobile Center (MMC) which serves as primary man-machine interface and master data base. Keeping customer records, billing, analysing telephone traffic, and other network management and administrative operations for the entire cellular network are performed by the MMC.

Fixed systems

In a fixed cellular radio system both antennas are stationary. The elevated cell site antenna is located at the center (or corner) of a hexagonal cell, and the customer antenna is also fixed, say at the rooftop of a house. Many standard cellular principles – such as frequency reuse and cell splitting – apply in the same manner.

There are many advantages to the fixed cellular as compared with the mobile cellular:
- logic unit is simpler, resulting in a smaller cost for the radio
- no handoffs needed, resulting in simpler and cheaper switching facilities
- both antennas are high, resulting in line-of-sight links most of the time; therefore, propagation loss is smaller
- lack of motion results in the absence of short-term multipath fading; this results in smaller signal-to-interference ratio requirements
- directional antennas can be implemented at both ends, increasing frequency reuse and thus system capacity

Investment requirements

There is no disputing the fact that GSM is a very complex system but it is generally considered that this is the price that has to be paid to achieve a performance level nearing that of the fixed network and to achieve a subscriber capacity able to meet the predicted demand. It is expected, however, that the total volume of equipment needed to support a subscriber base of 10 million by 1999 will allow prices to remain competitive with current analogue systems.

The investment requirements of a typical cellular network can range from US$ 5 million to 100 million, depending on size, traffic capacity, and topology. In addition, operators generally have to purchase a licence which basically allocates a specific radio frequency. When it comes to providing licences to private operators, they are typically auctioned off to the highest qualified bidder.

The minimum economic scale of a cellular network is much smaller than the conventional network, largely because cellular technology does not require building an extensive outside plant network. Minimum configurations of cellular systems fall in the range of 3000 to 5000 subscribers. Smaller networks of 2000 to 5000 subscribers can cost as much as US$ 4000 to 5000 per subscriber, while larger networks can cost much less, perhaps US$ 1000 per subscriber[9]. It is difficult to generalize about minimum economic scale of a cellular network because of the vastly differing conditions from case to case – licence fees, network configuration, and tariff structure. The fixed costs are a function of the licence fee and the switching and control portion of the network, which includes network

[9] This compares favourably with an average investment requirement of US$ 2000 to 2600 for a standard wire connection in an urban network, although cellular telephones can cost the subscriber US$ 2000 to 3000 (installed).

management, billing, and accounting equipment and can be quite high. There are also certain initial costs associated with adapting the switching system to local signaling standards.

Cellular tariffs are typically higher than standard telephone rates by multiples of two or three, although this again varies widely, depending on the regulatory structure of the country which determines the relative rates for standard and cellular service.

Technical risks

The experts have considered carefully the technical risks of adopting GSM rather than a well-established analogue system (in the case that the respective frequency band is available) and have also sought the views of operators and manufacturers on this point. The risks may be considered to be:
- that GSM will be subject to technical problems early on, which may delay the introduction or result in an unreliable or poor quality service
- that the operator will find the system difficult to operate and maintain due to the high level of system complexity

In fact, the development of GSM specifications has received a very high level of attention from operators and manufacturers who have been able to draw on considerable experience of current analogue cellular systems. Trials have been arranged at various times to test the novel aspects, culminating in system validation trials which have now been successfully completed. Thus, major problems with GSM are unlikely to occur, although new equipment is likely to present some teething problems. There is also some risk to time-scaling, but since some nations plan to install GSM immediately, it would not be alone as the 'guinea pig' for the system. For the same reasons cell planning for GSM should be much simpler[10] than for analogue systems; system expansion to meet increasing demand will also be easier.

GSM will offer users the benefit of using their cellular handsets in whatever European country they are in. Although studies show that the proportion of international roaming is unlikely to be very large, it will be a key service for international travelers and businessmen. It is also worth highlighting that the maritime service is likely to be a significant user of international roaming facilities for shipping in European coastal waters.

Interference with hearing aids and car electronics

Unlike analogue transmission's steady signals, TDMA transmits in bursts[11], so its peaks are much higher. Inevitably, high-power transmitters affect other electronic devices. For example, if the power device for a GSM phone is placed next to circuits that control air bags, there is quite a high risk of interference [5].

Tests in Germany, Australia and the United Kingdom show that the time division multiple access method – a burst signaling mode used for GSM and other digital cellular systems – interferes with hearing aids from as far as 30 meters. At a range of three to five meters, hearing aid wearers experience a humming noise. In some cases, the noise is painful, according to the tests.

Car manufacturers are concerned that GSM handsets may interfere with electronic devices, including those that control air bags and ABS brakes. Since TDMA signaling meets European Commission requirements for electromagnetic compatibility, it is not clear who will have to accept the responsibility and costs associated with fixing interference problems.

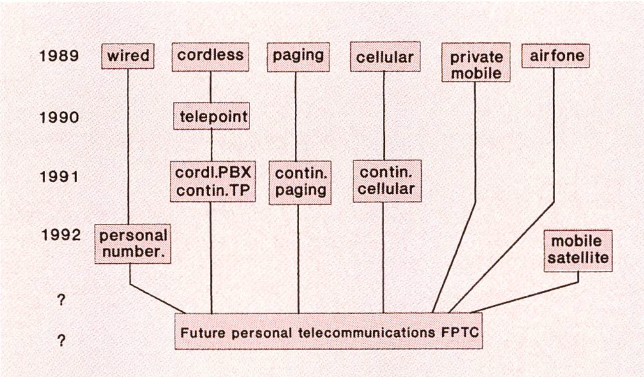

Fig. 6 Evolution towards FPTC (Future Personal Telecommunications)

Future Personal Telecommunications (FPTC) *(Fig. 6* and *Table 1)*

In summary, personal telecommunications offers all communication services anytime and anywhere to anybody by the use of a single-identity and pocketable communication terminal (for simplicity, we include a smart card in the expression 'terminal'). Local Area Networks (LAN) go one step further: the identity resides in the terminal (or modem). Telepoints will extend some applications of cordless telephones,

Table 1.
Capabilities of GSM, DECT and FPTC systems

Capabilities	GSM	DECT	FPTC
Voice services	*	*	*
Non-voice services	*	*	*
Message services	*	*	*
Complete local coverage	O	*	*
National networks	*	*	*
International networks	*	*	*
International roaming	*	*	*
Personal numbering	O	O	*
Pocketable terminal	O	*	*

[10] GSM will ultimately be able to achieve much smaller cell sizes and consequently higher traffic densities than analogue systems. Further developments – such as the half-rate speech codex – will provide up to twice the capacity for little extra outlay.

[11] Code division multiple access – a competing signaling method to TDMA – has not been found to cause interference.

give access to national networks, and provide a kind of limited personal numbering[12], since the terminal with the ID usually travels with the person.

The prime aim of digital European cordless telecommunications (DECT) is to cover the typically short-range applications *(Fig. 7)* of cordless private networks (PBX and LAN) as well as Telepoint and Wireless Local Loop. The design of the DECT standard is led by the need for pocketable terminals and in-house operation.

The European Radio Messaging Network (ERMES) is still a paging system, i.e., it will still offer only limited service capabilities. The main advantage over DECT or GSM will be the very small size of the terminals (which are only receivers) and the expected low prices compared to the speech transceivers used in DECT or GSM. Figure 4 shows the different application areas accessing the radio medium which we finally expect to be covered (perhaps with the exception of mobile satellite) by personal telecommunications[13].

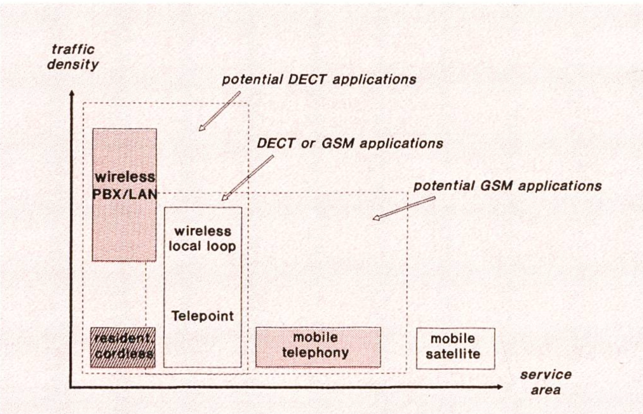

Fig. 7 Application areas of radio access

The GSM, DECT and FPTC systems capabilities are compared in Table 1.

In RACE (Research into Advanced Communications for Europe) project 1043, research is done towards a third generation mobile intercommunication system and focuses on two mobile services:

- MBS (Mobile Broadband System), aiming at providing broadband services (from 1 Mbit/s to more than 70 Mbit/s user information rate) in a mobile environment to professional users
- UMTS (Universal Mobile Telecommunication System), aiming at the provision of mobile services (narrow band) to a large number of users

[12] Rather than numbering subscriber loops, as in the wired telephone networks, we speak here of personal numbering or identity number (ID). Such a communication ID may be located in a communication terminal carried by the user; however, the ID may be contained in a module separate from the terminal, i.e. in a smart card.

[13] Areas are shown in terms of service area (per base station) versus traffic density. Note that the Telepoint and Wireless Local Loop applications could potentially be covered by both DECT and GSM, while for the other areas only one of the technologies is applicable

This UTMS third-generation system aims to meet the following requirements:

- the functional integration of mobile cellular, paging, cordless and PMR (Private Mobile Radio) systems into a new universal mobile system
- the necessary standardized environment for the provision of mobile services to a large number of subscribers
- the universality – to start with Europe – provided in the public, business and domestic environment
- the possibility to support a wide variety of terminals (ranging from light-weight cheap hand-held communicators supporting only voice services or paging for the mass market to more sophisticated car-based terminals supporting a larger scale of services for specific applications)

Conclusions

- Radio frequency spectrum is not (or will not be) a problem.
- Mass production will contribute to drastically reduced prices.
- Cellular radio contributes to the expansion of communication services in both dense metropolitan areas and remote rural locations.
- GSM systems at 900 MHz are expected to have 14 million users by the year 2000. We believe that there is a much larger market for mobile communications if consumer requirements are met.
- MTS will be implemented according to the IN concept. The separation of call and connection provides more flexibility and efficiency with respect to the use of network resources.
- With the growth of the demand for mobile telecommunications and the growth of users of such services, there should be an increased interest in the security of the system, both out of privacy and operating considerations.
- A mobile office is a realizable concept; GSM provides an impressive set of data features facilitating innovative mobile office concepts.
- Uncommitted radio systems utilizing dynamic adaptivity are a powerful vehicle for extending service integration, universal connectivity and efficient cost-effective use of available network resources to the bandwidth- and performance-limited mobile communications environment.

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Titu I. Bajenesco, M. Sc., MBA, MQRA, Prof. Eng. – Member of the New York Academy of Sciences, Senior Member IEEE, International Expert and Consultant – was involved in the management of international and national telecommunications projects, in the feasibility studies, development and design of advanced telematic systems, systems integration with LANs, MANs and WANs, in joint ventures, liberalization and privatization, master plan for the future development of national telecoms, etc. His previous experience includes reliability and quality engineering of microelectronic components and complex telematic systems, especially in the field of advanced telecommunications systems. He holds two patents, is author of many technical books and papers written in six different languages, and has received international managerial citations for his work.