The present time and near future of Mobile Radio Networks and Services[1]

Introduction to the EPMCC '97 Proceedings

Bernhard Walke
Communication Networks, Aachen University of Technology
Kopernikusstr. 16
52074 Aachen
Germany
email: walke@comnets.rwth-aachen.de
WWW: http://www.comnets.rwth-aachen.de/~walke

1.1 GSM 900 / DCS 1800

With a spectacular growth in GSM 900 based networks in Europe at the current time with approx. 10 million subscribers and the rapid expansion of DCS 1800 based networks, this gives the impression that the essential steps in development have been achieved. One forgets that these networks are designed as an extension of ISDN to the mobile domain, only restrictedly solving this task.
With the pressure of competition of other concepts for cellular networks (UMTS, IMT 2000, wideband spread spectrum CDMA) and in order to be able to give better support to mobile image and data services, the GSM 900/DCS 1800 systems have to be developed further in various aspects. The expected demand for ISDN-compatible mobile data services (64 kbit/s) requires a rapid development of radio interfaces. Appropriate works run on ETSI GSM/2+ or are considered there.
Examples are:

- GPRS (General Packet Radio Service) for Multiplex-Data transmission of many virtual connections over one or several parallel-used traffic channels.
- Point-to-Multipoint speech and data services like those usual with trunked mobile radio systems.
- High bit rate speech and services for images and data over parallel used traffic channels (HSCSD, High Speed Circuit Switched Data) and/or release of the TDMA frame structure to be able to use the 200 kHz wideband carrier in total (or even many of them in parallel) to support one or more services together.
- Software radios able to download the software to configure the radio according to the services available at a given location or able to switch in between several standard air interfaces.

As a result, with a further developed radio interface and corresponding options implemented in the mobile terminal, new services and applications will be offered. This in addition will require fixed network enhancements to be able to offer the new services and applications, e.g. Mobile Computing.
This development of cellular networks is not to be seen as isolated, but instead must be seen in consideration to the further development of other mobile radio systems, which will be introduced partly parallel or delayed and will appear in subareas as a competitor cf. Chapters 1.2 to 1.7. The organization of intelligent mobile radio networks concerning signaling, database organization and distribution, the offer of (network predominant) value-added services, network administration etc. is still in its initial phase.
Similar new demands as mentioned for GSM 900/1800 systems are also expected for TETRA based trunked mobile radio networks. TETRA systems in addition need the development of algorithms and protocols for a direct communication between mobile stations (Direct Mode).

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[1] The following text is taken from my book "Mobile Radio Networks and their Protocols" to appear in German in Nov. 1997 by Teubner Verlag, Stuttgart and in English by Wiley & Sons, Chichester, UK in Spring 1998.

1.2 DECT

Digital wireless systems according to the ETSI/DECT Standard find themselves (as 'small' systems) already widely in use and at the moment enter the market as 'large' systems for partial coverage of application areas of larger private branch exchanges. Systems like that are well suited for movable mobile applications inside of buildings and in the immediate surroundings of the particular fixed station (up to 300m distance outdoors).
Since only a fraction of the future mobile subscribers will use communication services outside of the conurbation, DECT systems as personal communication systems in densely built-up surroundings can reach a high percentage of all mobile radio subscribers with sufficient coverage and would, with the implementation of the function mobility management, compete considerably with cellular networks. An appropriate example is the Personal Handyphone System (PHS) in Japan.
Its inherent strength is its suitability for the internal building supply which easily bleeds off the public supply outside of buildings. From the actual standardisation activities for DECT outdoor systems, the expected corresponding pressure of the European Union and the fact that cellular network providers experiment with DECT systems as a radio subsystem in the GSM/DCS 1800-network (and to think about two-modi devices GSM+DECT and/or DCS 1800+DECT), one can conclude that here considerable developments will be observed.
DECT systems are flexible compared with GSM concerning the specified radio interface of possible services and therefore allows more freedom, e.g. for the use as a Local Area Network (LAN) or as a wireless radio access technique to the fixed telecommunication networks (Radio Local Loop, RLL).

1.3 Radio in the Local Loop, RLL

The deregulation of the voice service monopoly in Europe will lead to an expansion of up until now, a company internal used corporate network for serving customers of larger firms and (later) all conveniently situated companies and private customers in competition with former national monopoly network operators. This will be accompanied by the development and arrangement of local cellular radio networks on the basis of Point-to-Multipoint radio relay and/or local fixed radio subscriber connection, which ISDN basis and primary multiplex interfaces offer and will act as an access network to fixed networks.
GSM is only slightly suited for this, as the available transmission rate is distinctly smaller than with ISDN. DECT can offer ISDN interfaces in a multichannel operation, corresponding Standards have been specified by ETSI/RES 03 in 1996. Local cellular networks are closely related to the systems described in Chapters 1.1.and 1.2, however require further development work in order to be able to fulfil their tasks economically and cost effectively.
Apart from cellular networks with a sector or radial supplied area in the field of the base station, tandem links from the base station (like with DECT-Relays) and tree-type arrangements of radio relay tracks towards the end of the fixed network access for the local loop area are expected in the field, in order to bridge 'the last mile' between fixed networks and customers. This is why the same cellular used frequency range or public radio relay ranges (e.g. 2.5, 3.4, 10, 17, 23, 27, 38 GHz) come into question.

1.4 Wireless LANs

For the usual Internet applications, which today, in many cases are achieved via a Local Area Network (LAN), there is a considerable need for the cordless connection of movable personal computers to achieve flexibility regarding space and place of installation. The standardisation has just worked out solutions, which means a first quick step in this direction (IEEE 802.11, ETSI/HIPERLAN). Up to now, so-called one-hop solutions have been made possible (with the ability to support partly meshed stations), which tend to require a base station to connect movable stations to a fixed network (e.g. LAN), at one of the frequency bands of 2.4, 5.3, 40, 60 GHz. Here further developments for cable saving are possible and necessary.
Since these wideband networks enable comparable data transmission rates such as LANs (typically up to 20 Mbit/s), they are suitable as replacements for LANs and less so for the support of new Multimedia services. Such new services place real-time demands on the

transmission system (not easily available from the Internet) that can only be supported after considerable further development. Apart from movable stations, mobile terminal equipment can also be supported. For cordless LANs, media such as infra red or light is also being discussed, alongside radio. Mobility of terminal equipment places new demands on the Internet protocol stack.

1.5 Universal Mobile Telecommunications System UMTS

From the view point of the MoU UMTS group (Memorandum of Understanding for the Introduction of UMTS), the evolutionary beginnings for existing systems and their integration in existing systems and networks appears desirable even though the technical realisation is expensive. The narrow pass of existing mobile communication systems is the available bit rate which does not suffice for new futuristic applications and should be flexibly divided according to need. UMTS will be seen from some, as a complete new system and from others, as a further development of the GSM. UMTS compatibility to GSM will be seen as an urgent objective, which can probably be reached through so-called Multimode Terminals (Software radio).

1.6 Wireless Broadband Systems

The enlarged introduction and the increasing acceptance of broadband services via the ATM-transmission technique of existing glass fibre networks (B-ISDN) with 34 (E3), 155, 600 and 2400 Mbit/s transmission rate, requires the broadband connection possibility of movable and/or mobile terminal equipment over a mobile broadband system comparable to GSM900/1800 regarding the narrow-band ISDN. The technological position allows radio supported, cellular, mobile broadband systems with a 34 Mbit/s user data rate to be realised. Appropriate development work is under way in the EU's ACTS[2] Programme. In contrast to those systems mentioned in Chapter 1.4, real-time oriented Wireless-ATM systems are based on an ATM-cell transmission at the radio interface. These types of systems are logically closely comparable to the DECT system (in relation to ISDN). As soon as ATM networks connect real-time terminals directly, which have been developed for heterogeneous, faulty, no real-time capable networks and/or services, the application of many Internet protocols has to be revisited.

1.7 Mobile Satellite Radio

Geostationary satellites are preferably suited for the provision of fixed or slow moving stations (ship) as the receiving antennas have to be very big in order to be conditioned to absorption. Various companies plan to realise world-wide mobile radio networks on the basis of low (700-1700 km high, LEO, Low Earth Orbit) and/or intermediate flying (10-16 Tkm, ICO, Intermediate Circular Orbit) satellites. A radio illumination with 1.6 GHz for portable satellite receivers (400 g) is aspired to be guaranteed. Even though such systems are suited primarily for the provision of countryside and suburbia, the plans suggest that a blanket coverage is also aimed at areas served well by cellular networks.

Apart from switching functions in the satellites to connect mobile stations with the next fixed station, the switching between movable and fixed (geostationary) satellites and the control of the radio link between non-geostationary satellites is to be dealt with. Satellite networks will then also aspire to take over the traffic as near to the source as possible and to transfer as near to the goal as possible without and/or with minimal use of fixed networks.

1.8 Universal Personal Mobility

Apart from radio and transmission-specific functions, mobile communication requires special services in the fixed network. Mobile radio systems usually have a radio- and a fixed network

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[2] Advanced Communication Technologies and Services Projects SAMBA, WAND, MEDIAN, AMUSE etc.

part. The mobility management of subscribers will be essentially realised through functions in the fixed network, which are based on the Signalling System Number 7 (SS.7).
Recently, the architecture of the Intelligent Network, IN and for the Universal Personal Telecommunication, UPT for fixed networks has been developed world-wide and standardized at ITU-T. As a consequence of this, one will be able to be reached world-wide on one personal telephone number with all services, on fixed and mobile radio networks, independent of the network service provider. The concepts for a network-domain all-embracing mobility support with operator transparent service provisioning are still to be developed.
In order to benefit and to avoid possible disadvantages, it is planned that each subscriber controls the specific situation, for which calling subscribers and with what services he/she would like to be reached at the current time and what happens with the remaining incoming calls.
All services not connected to the subscriber will be dealt with according to its guideline e.g. changed into the service form, directed to storage or referred to a third. The development of such services will firstly be primarily realised for the use, through subscribers, of mobile radio networks because only they can gain universal access to the network. Accordingly these services will be realised and introduced in the context of mobile communication.

1.9 Systems with Intelligent Antennas

In a short while, the possibility of spectrum efficiency increase [(bit/s/(MHz*km²)] through the introduction of so-called intelligent antennas based on smart antenna arrays of all types of mobile radio systems will be examined. For obvious reasons (dimensions, complexities, unchanged reusable existing mobile devices), this technology will be firstly fully discussed for the introduction of a cellular system in the fixed stations. With an array-gain, the transmission range (and the cell radius) can be enlarged or the transmit power (and the interference) reduced, through a suitable (adaptive) design of the antenna diagram. A dynamic, radio relay-like Point-to-Multipoint mobile communication is then made possible.
A real spatial multi-user system (Space Division Multiple Access, SDMA) for drastic intensification of the spectrum efficiency and network capacity [Erl./(MHz*km²)] can be implemented via this efficiency intensification through the transmit power reduction and/or increase in the transmission range. This access protocol has not been seen to be different from the established Time-/Frequency Division Multiple Access, T/FDMA and CDMA protocols but instead as a compatible enlargement. From the idea one assumes that an antenna array receives the signals of several subscribers using the same Time/Frequency/Code Channel (SDMA-gain) and from that, the spatial route destinations of the received signals (Directions of Arrival, DoA) will be determined. With the help of this route destination information, the data detection in the uplink and beam design in the downlink can now be carried out, which one can imagine as a simulative adaptive design of the directional antenna diagram for each subscriber with only one antenna group.
Before the introduction of such antenna groups, considerable research and development work in connection with the total concept as well as all system parts is necessary. The group antenna encircles itself, the frontends and most importantly the algorithms for the processing of signals (parameter estimation, data estimation, beam design) and an intelligent (dynamic) channel allocation. It is obvious, that a direction-based subscriber separation (of a spacious multiuser system) can only be managed with spaciously well separated subscribers in the same channel. The production of such spacious well separated subscriber trunking arrangements is an important task for the channel allocation.
It is also obvious, that the radio interface protocols of existing mobile radio systems will have to be adapted to these new concepts. The radio resource management in the network would gain considerable advantages from the dynamic channel allocation process which would benefit from the use of antenna beams and result in a guaranteed minimum interference level.
Higher complexities in exchange for a measurable capacity gain of the total system is a trend in the development of large systems in Europe which is seen as an important possibility to securing or even to building upon existing market positions of products. This means that systems with intelligent antennas are to be seen as a contribution to secure the world-wide accepted position with cellular mobile radio systems and to test the foundations of new technology, which in future generations of the GSM900/1800 and/or UMTS will come into operation.

1.10 Mobile Radio Systems with Dynamic Channel Allocation and Multiple Access of the Frequency Spectrum

Dynamic channel allocation is an intelligent method in order to allocate tight radio resources tailor-made for the wireless communication between communicating terminals. Only through these measures can e.g. the capacity of the ETSI/DECT systems which uses dynamic channel allocation be enlarged by several orders of magnitude inexpensively indoors compared with the GSM900/1800 system which uses fixed channel allocation. The first publications indicate that a comparable or somewhat smaller capacity increase also in outdoor mobile radio systems appears to be possible. Affected are all those systems mentioned in Chapter 1.1 to 1.8, so that the development and research work for each of the named systems appears attractive.
A higher capacity on the basis of a dynamic channel allocation allows more simultaneous communication relationships in existing frequency bands to be realised. This will be possible in the current GSM900/1800 systems when new channel allocation processes will be developed and tested on a trial basis.
The scarcity of the frequency spectrum for mobile radio applications has led to the FCC[3] (USA) and the BMPT/BAPT[4] (D) first allocations being carried out for the joint use of the same spectrum for public mobile radio services relying on different radio interface protocols.
Up until now very little is known quantitatively about the compatibility of neighbouring mobile radio systems in the frequency spectrum and about the compatibility of operational systems in the same frequency band. It also obviously deals here with the improvement of the spectrum efficiency through measures of competitive use of the same frequency band.

1.11 Further Aspects

Self-organising wireless systems

For applications with a higher local density from wireless communicating systems, which will be operated in the frequency bands above 5 GHz and which is why line-of-sight link is required between the systems communicating among themselves, decentralised organisation forms (doing without centralised base stations) appear to be advantageous. One talks of so-called Adhoc networks which have fully decentralized self-organisation as the most essential characteristic. Further features of such systems are:

- Application of some or all stations as a relay (forwarder node) on a multi-hop Route between communicating stations.
- Support of both, synchronous and asynchronous transmission services as is usual with ISDN and with local area networks.
- Independent self routing of calls and acceptance/log-off of stations to/from the networks.
- Provision of relay stations for connection with the fixed network.
- Decentralized network management.
- Local limitation on areas with e.g. a few km diameter.
- Dynamic re-use of the radio resource according to the cellular principle.

Such systems require several radio hops, typical for every communication relationship therefore heavily burdening the spectrum more than the conventional (mobile) radio system which only needs one radio hop per communication relationship. This means Multi-hop systems have to rely on capacity increasing measures like adaptive antennas and the application of the SDMA process, in order to be comparable in spectrum efficiency.

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[3] Federal Communications Commission

[4] Bundesminister für Post und Telekommunikation/Bundesamt für Post und Telekommunikation

Electromagnetic Environment Compatibility

Conventional mobile radio systems use circular antennas through which the environment is accordingly burdened with electromagnetic waves ('Electrosmog'). Intelligent antennas guide the transmit power directly at the receiver whereby the transmit power can be considerably reduced compared to circular radiating antennas with the same transmission range.
The influence of biological systems through electromagnetic waves is at the moment being examined scientifically and should be considered with the development of new technology for mobile radio systems.

1.12 Relations to the EPMCC '97 papers

The EPMCC '97 papers contained in this Proceeding, address most of the systems, concepts and problems introduced above. And it is a pleasure to see how much progress seems possible based on some of the single papers in the respective fields.
I would like to congratulate the authors of accepted papers to take part in a symphony of other excellent scientific contributions towards the continuous progress and further development of mobile and/or wireless systems!
I would also like to thank all of the members of the Scientific Programme Committee for their time and efforts spent selecting those papers best suited for a presentation to EPMCC '97. The names of the reviewers are listed below.
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