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A Packet Radio Protocol for Group Communication Suitable for the GSM Mobile Radio Network

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Abstract: **GSM is in use in many European countries mainly to provide point-to-point telephone conversation and mobile data services.**

GSM only offers circuit switched services on the air interface (GSM phase 2). Future digital mobile radio systems based on TDMA (TETRA, UMTS, ...) will use a packet access mechanism, which is known to give a better utilisation of the transmission medium in case of bursty traffic.

A packet access mechanism within GSM could provide several new services as medium, high and variable bit rate services which are required in fields as railway and road transport informatics and mobile data communication.

Some different proposals for a packet radio service suitable for GSM are discussed in this paper. A packet access protocol suitable for GSM was developed and analysed by simulation. Radio wave propagation and the resulting bit errors are taken into account by modelling the channel according to a Rayleigh fading channel.

I. The need of packet access in GSM

Small trunks of circuit switched channels as those used in mobile telephone networks yield to a low achievable channel utilisation (Table 1). If some services could use the remaining capacity without changing the quality of service this would be of great interest for all network operators.

The transmission of packetised data promises to make use of this remaining capacity.

Furthermore, packet radio permits the integration of different low and medium bit rate services and also variable and bursty bit rate services without wasting transmission capacity.

Packet Radio within GSM can be used in data applications as the connection of many DTEs (Data Terminal Equipment) via dedicated traffic channels (TCHs).

This allows mobile transactions and interactive applications as in:

- personal data communication (electronic mail, file transfer, remote login, ...)
- applications in fields of rail and road transport informatics such as fleet management, dynamic route guidance and advance traffic control
- mobile packet video applications

Packet Radio within GSM can also be used in voice applications as trunked radio like group communication in half duplex mode and voice mail services. Duplex telephony based on packet radio can only be used if the additional delay of approximately 90 ms is acceptable for each direction.

II. Characteristics of Voice and Data Applications

In the following section different voice and data applications will be characterised and the integration within GSM will be outlined.

A. Transmission of FAX coded data (Group 3)

The transmission of FAX-group-3 (T.30,T.4) coded data can be characterized by a half-duplex

Number of TCH	Maximum Channel Utilisation $P_{loss} = 0.02$	$P_{loss} = 0.01$
7	0.4279	0.3609
14	0.5977	0.5304
28	0.7343	0.6724
42	0.7978	0.7400

Table 1: Channel Utilisation of a Loss System

data transmission with different bit rates in different phases. During the signalling phases (T.30 phases B and D) the data rate is only 300 bit/s. During the message phase (T.30 phase C) the data rate is up to 9600 bit/s but only in one direction.

Within GSM the FAX services requires a dedicated duplex traffic channel with a constant user rate. This leads to an inefficient utilisation of the reverse channel.

B. Personal data communication

Personal computers are evolving into portable computers and are increasingly present in business and home environment. The penetration of personal computers, local and wide area computer networks will spark the urge to new infrastructures for a mobile environment. The most important applications in personal data communication are messaging services as electronic mail, store-and-forward fax transmission, document interchange via file transfer and remote access to a foreign host or data base.

The exchange of electronic mail yields to short transactions of textual messages with a mean length of 1000 bytes. This messages are normally insensitive to transmission delay.

File transfer requires the use of mainly one direction and can be compared to the transmission of a FAX.

Login to a remote host will not require a high mean bit rate but in case of a transmission request users will desire short delays.

Within GSM a datagram service is provided called Short Message Service (SMS) which allows the transmission of datagrams with a length up to 160 byte. The total data rate of this service is about 300 bit/sec. For higher rates the allocation of a dedicated traffic channel is necessary, with a data rate of approximately 9600 bit/s. In this case the subscriber has to pay for the total communication phase or he has to accept high establishing delays for each transmission of approximately 5 seconds.

A packet radio service could provide a short setup delay.

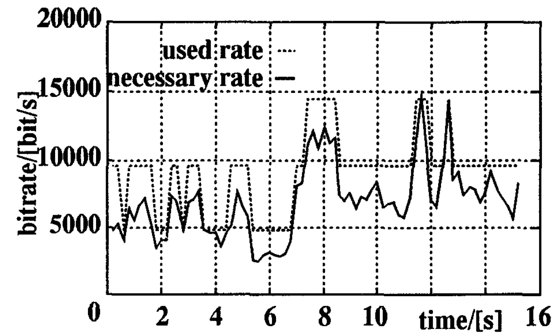

Figure 1: Bit rate of a video telephony sequence

C. Group communication (half duplex)

Group communication which is currently provided by trunked private mobile radio systems could also be provided within GSM. Group communication can be characterized by short voice messages which occur 4 to 20 times per hour and per mobile station. The voice activity within this voice messages can be assumed less than 100% but higher than in telephony. The delay requirements are weaker than in telephony and a total delay of 500 ms is acceptable.

D. Road Transport Informatic Applications

The only Road Transport Informatic Applications which are currently provided within GSM is the possible distribution of traffic related data within broadcast channels.

In trunked private mobile radio applications a message which was received from a mobile station should be distributed to a distinguished group, possibly in a different cell. The repetition of uplink messages to downlink channels is done in trunked control centers connected to the mobile services switching center.

E. Mobile Video Communication

Advanced very low bit rate image coding schemes (H.26X/MPEG2/MPEG4) are able to encode moving images to low but variable bit rates usable in mobile environment 3..15 kbit/s (Fig. 1)[5]. Additionally a duplex voice channel will be needed. These variable bit rates can be provided using a packet access mechanism. The delay requirements are comparable to voice telephony.

III. Fast Channel Assignment

Most of the mentioned problems can be solved by providing fast call setup procedures within GSM signalling channels (RACH/ DCCH) which can provide setup times down to 1 second (Fig. 2).

After this fast channel assignment the data transmission could be realised in two ways:

- The use of the Radio Link Protocol would provide a high throughput (up to 9600 bit/s). To avoid the exchange of RLP-XID-parameter the RLP should be suspended after transmitting a packet and resumed after the fast channel assignment of the next packet.
- A second possibility could be a new SAPI (e.g. SAPI 2 see Fig.3) of the LAPDm which allows the use of FACCH and SDCCH for user data. Throughput of LAPDm is lower (7680 bit/s), but the use of LAPDm allows to change the channel (FACCH/SDCCH) within the transmission of a channel. With this possibility a starting or handovered voice call may shift a packet data transmission to a SDCCH. This would allow the integration of packet data without an increasing loss probability of voice calls.

A fast channel assignment procedure would allow packet data services with only a small number of modifications in the GSM call setup, but the packet transition delay of these fast channel assignment procedure is not acceptable for some delay sensitive voice and data applications.

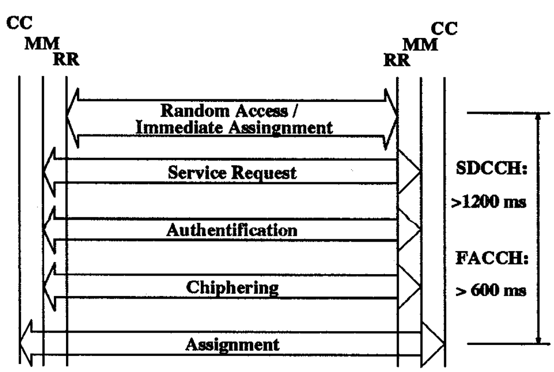

Figure 2: Minimum Call Setup Time

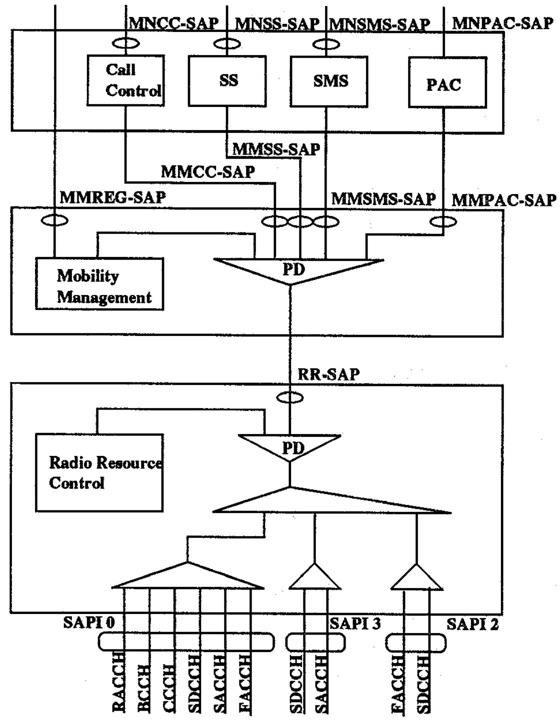

Figure 3: Packet Data using LAPDm (SAPI 2)

Furthermore some applications require new methods to allow broadcast and multi cast without renouncing confidentiality aspects.

IV. CELLPAC-V&D: A Voice-and-Data Packet-Access-Protocol

To allow a lower delay and to allow the accommodation of a high number of packet users, a new stochastically multiplexed logical channel structure have to be defined.

The following section describes a packet access mechanism which has been developed for packet-dedicated traffic channels. The number of these packet-dedicated traffic channels may vary in time depending on the voice and packet data load.

The CELLPAC-V&D protocol is based on reservation Aloha[6] and can be integrated into GSM without changing the burst and frame structure.

A. Packet Control Channel

To support random access on the uplink a packet control channel is needed on the downlink. This

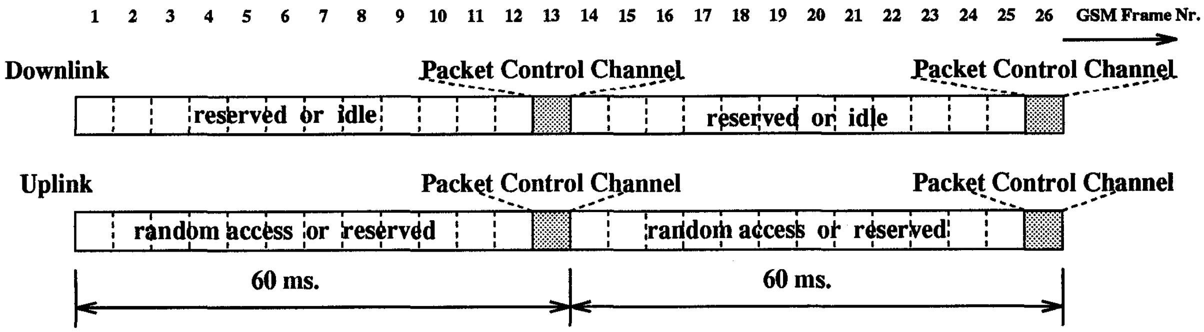

Figure 4: CELLPAC-V&D Channel Structure

packet control channel is necessary to report the actual state of the uplink and to transmit acknowledgements to successfully received access bursts. Additionally it can be used to indicate a starting downlink transmission.

For a first access a virtual call setup is necessary using random access channel (RACH) and dedicated control channels (DCCH). This virtual setup should include the ciphering initialisation.

Up- and downlink are organized as usual for traffic channels in a multi-frame structure of 26 frames (Fig. 4). Downlink slots which are normally used for slow associated control channel (SACCH) are dedicated to carry the packet control channel. This yields to a periodic structure of 60 ms. The uplink channel slots are reserved or used for random access.

The contents of the normal burst, which is transmitted on the packet control channel exists in three different formats: One format is used to acknowledge successfully transmitted access bursts, one is used for paging of mobile terminated packets and in all other slots of this channel an idle format is transmitted, containing state information of all channels used for the packet service.

All the packet control information is protected using a Frame Check Sequence. One normal burst contains control information of two half-rate channels using a convolutional coder as forward error correction.

B. Random Access

In case of a random access phase mobile stations try to access to the uplink using an access burst. This access burst contains a random number similar to RACH and a priority number.

Successfully received access bursts are acknowledged on the packet control channel, the corresponding downlink or if more than one access bursts was received on another dedicated traffic channel. Packet Control Channel Information can also be carried on idle half rate downlink channels.

V. Simulation of Packet Radio in GSM

For the simulation of the protocol a simulation tool (written in C++) was developed containing basic simulation modules (random number generation, statistical evaluation, ...), GSM modules for source and channel coding and propagation and channel modules for indoor and outdoor environment

To protect packet data communication information against channel errors, forward error correcting codes were analyses on non-interleaved normal and access bursts. A Rayleigh fading channel and ideal frequency hopping was assumed. The results of different codes for different carrier to interference ratio are shown in the following table:

FEC	Burst Error Rates (Normal Burst) C/I		
	10dB	7dB	4dB
no FEC	25.18%	39.70%	56.48%
RSC GF(2^6)	19.15%	31.59%	47.89%
GSM 1/2 K=4	15.63%	26.75%	41.64%

FEC	Burst Error Rates (Access Burst)		
	C/I		
	10dB	7dB	4dB
no FEC	21.70%	35.15%	51.35%
RSC GF(2^6)	17.22%	28.84%	44.35%
GSM 1/2 K=4	17.13%	29.40%	44.95%

PCCH coding	Mean Access Delay (due to channel errors)		
	C/I		
	10dB	7dB	4dB
no FEC	40ms	70ms	170ms
GSM 1/2 K=4	35ms	50ms	120ms
+ repetition	22ms	30ms	85ms

For the simulation of group communication no silence descriptors are necessary. No front end clipping was chosen and the mean access delay was limited to 500 ms. The voice activity within a call was assumed to be 100%. Two different station activities with 10mErl and 50mErl were assumed with a negative exponential distributed call interarrival time and a Erlang distributed call duration (mean = 10s, variance = 10 s^2).

So the protocol can carry up to 1300 half rate mobile stations (10mErl) on one GSM carrier (Table 2).

VI. Conclusion

CELLPAC-V&D allows the integration of packet voice and packet data services without changing the GSM burst and channel structure. The protocol is adaptive to packet load by changing the number of assigned channels depending to packet traffic and circuit switched voice traffic using fast channel assignment. Different speech coding and data rates (HR, FR and high speed data) are allowed simultaneously. A discontinuous reception on the downlink channel is possible, controlled by paging bit.

This can only be reached by additional transmission delay of approximately 90 ms. In the actual version of the protocol packet dedicated TCHs must use the same frequency (up to 16 half rate channels).

Number of Channels (HR-TCH)	Number of Mobile Stations (HR coding) A=50 mErl	A=10 mErl
2	10	50
4	35	190
8	105	520
16	240	1300

Table 2: Group Communication within GSM using CELLPAC-V&D

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