

# GSM/EDGE Radio Access Network (GERAN) - Evolution of GSM/EDGE towards 3G Mobile Services

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## ABSTRACT

The GSM/EDGE standard is taking steps to define a fully capable 3G mobile radio access network. The 3GPP Release 5 will specify a GSM/EDGE radio access network (GERAN) which can connect to 3G mobile core network through Iu interface and is capable of offering the same set of services – conversational, streaming, interactive and background - as the UMTS terrestrial radio access network (UTRAN). At the same time, the 3G core network develops towards "All IP network" which provides benefits for the mobile network operators in terms of IP transport and efficient support of IP based services.

## I. INTRODUCTION

The GSM standard has evolved from a basic voice service to a wide variety of speech and data services over a decade. One of the latest completed steps, the Release 1999, introduced the 8PSK modulation providing a threefold increase of the peak data rates. The addition of the 8PSK modulation was made without modifications to the established GSM/GPRS architecture. Two new data features, Enhanced GPRS (EGPRS) [1][2][3][4] and Enhanced Circuit Switched Data (ECSD) [5] were introduced as well as the Compact mode for the narrowband deployment (1 MHz bandwidth at the minimum) [1][2]. EGPRS is an enhancement to the GPRS and uses Gb interface in communication to the packet switched core network, and ECSD is an enhancement to the HSCSD (High Speed Circuit Switched Data) and uses A interface towards the circuit switched core network.

After the Release 1999 the next major step in the GSM/EDGE evolution path is the Release 5 of the 3GPP. In this step the functional split between the GSM/EDGE Radio Access Network (GERAN) and the core network (CN) will be harmonized with UTRAN, enabling GERAN to connect to the same 3G core network and provide the same set of services as UTRAN. The new architecture implies significant modifications to the GERAN radio protocols. Also the efficient support of IP based services requires new functionalities in the radio protocols.

While only the data services were enhanced with the 8PSK modulation in the release 1999 of GSM/EDGE,

the Release 5 of GERAN applies the 8PSK modulation to speech services as well. The addition of 8PSK modulated speech channels not only increases the data rate available to speech services, but can also enhance the spectral efficiency of the same services. In the Release 1998 of GSM, the addition of the Adaptive Multi Rate (AMR) brought a significant speech quality improvement. With AMR Wide Band (AMR-WB), the speech quality in GERAN is improved even further to reach a level that exceeds wireline quality.

The paper is organized as follows: The 3G traffic classes are described in Chapter II (3G Mobile Services) and the new GERAN architecture in Chapter III (GERAN Architecture). Chapter IV describes the GERAN radio protocols. The GERAN physical layer is described in detail in Chapter V (Physical Layer). Chapter VI presents the conclusions.

## II. 3G MOBILE SERVICES

As a part of the radio access network harmonization, services provided by GERAN are aligned with the UMTS traffic classes. There are four different classes of traffic:

- conversational,
- streaming,
- interactive, and
- background.

In *conversational class* speech or video is carried between end-users. The QoS requirements are mainly set by human perception. Failure in meeting the requirement causes degradation of the user-perceived quality of service (QoS), often to a level that is unacceptable.

*Streaming traffic* is one-way user data transfer (control data is transferred also in the other direction, typically uplink) having no absolute delay requirement. However, there is a strict requirement to preserve time relation between information entities. The stream can be time aligned in the receiving end by buffering data. During the transmission phase relatively large delay variations can be accepted.

*Interactive traffic* consists of sessions where human or machine is requesting data from a remote computer. In this traffic type it is characteristic that there exists a re-

quest-response pattern of data transfer. Another characteristic feature is that it is usually important to guarantee correct delivery of requested data. As an example: web browsing, data base enquiry, polling of measurement data can be mentioned.

*Background traffic* has the most relaxed delay requirement of the four traffic classes. It is assumed that the end user does not expect the data for some time. Therefore, the data transfer can be made on background when there is no delay critical data to be transferred. Typical traffic belonging to this category is SMS (short message service), e-mail and file transfer.

IP-based multimedia is a new service category in the Release 5 of GERAN. This means both conversational speech and video. On circuit switched domain these services exist already in the Release 1999. However, GERAN Release 5 makes it possible to provide all services (both real time and non-real time) in packet domain, which is attractive for operators, as only one (packet) core network needs to be operated [6]. A major step towards an "All-IP network" is made at the same time by adopting SIP (session initiation protocol) based call control. With SIP it is possible to provide basic call control functions that exist today. What is equally important is that SIP provides a flexible and future proof mechanism for applications combining voice, video and multimedia. Consequently, GERAN will offer the user the freedom to have multiple traffic flows in parallel, e.g. speech call, e-mail transfer and web browsing at the same time.

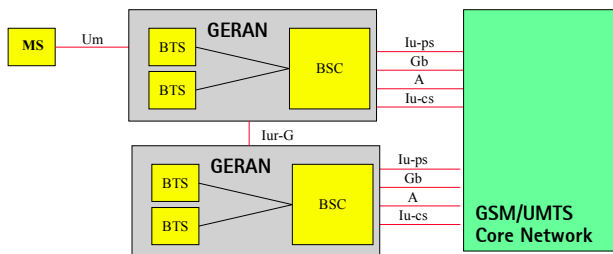


Figure 1. The proposed new GSM/EDGE radio access network architecture.

### III. GERAN ARCHITECTURE

The basic principles that are used for the design of GERAN architecture are:

- Separation of the radio related and not radio related functionalities between the core network and the radio access network. This would enable development of the platform that would allow for provisioning of services independent of the access type.
- Support of services for pre-Release 5 terminals must be ensured.
- Maximize commonalities between GERAN and UTRAN but maintain the backward compatibility for GERAN. The key alignment point between the GERAN and UTRAN is the common interface towards the 3G core network (Iu interface). Consequently, GERAN should provide the same set of

services as UTRAN, e.g. support the same radio access bearers and QoS mechanisms as in UTRAN.

- Standardization of the GERAN should support a true multivendor environment.

The GERAN architecture is shown in Figure 1.

#### III.1 Legacy interfaces

The protocol model for *legacy interfaces* is based on the Release 1999 of GSM/EDGE and consequently the functionality split between the radio access and the core network is unchanged.

**Gb interface.** The Gb interface is used in GSM/GPRS to connect Serving GPRS Support Node (SGSN) and Base Station Subsystem (BSS). This interface is needed in GERAN for supporting pre-Release 5 terminals.

**A interface.** Traditional interface in GSM that is used to connect BSS and MSC (mobile switching center) will be supported by GERAN. This interface is needed to support pre-Release 5 terminals, as well as to provide new enhanced services like e.g. wideband telephony (with WideBand Adaptive Multi Rate – AMR-WB - speech codec) and support for 8-PSK modulated speech channels.

#### III.2 New interfaces

The general protocol model for new interfaces is based on the protocol model used in UMTS and is shown in Figure 2. The layers and planes are logically independent of each other, which offers additional flexibility. For example, if needed, transport network protocol layers, may be changed in the future with virtually no impact on the radio network layer.

**Iu interface.** This interface is common between UTRAN and GERAN. The Iu interface is specified at the boundary between the core network (CN) and the radio access network (RAN). The Iu interface towards the PS domain of the core network is called Iu-ps, and the Iu interface towards the CS domain is called Iu-cs. The Release 5 of GERAN will support both interfaces. The protocol model for Iu-ps interface is shown in Figure 3. Note that the transport network layer may change in Release 4, in particular due to allowing other than AAL5/ATM transport technologies.

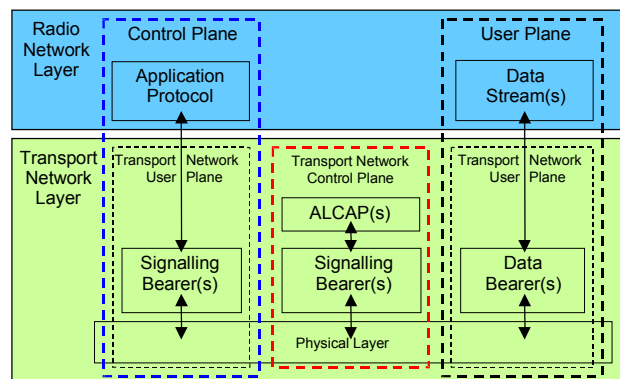


Figure 2. General UMTS protocol model.

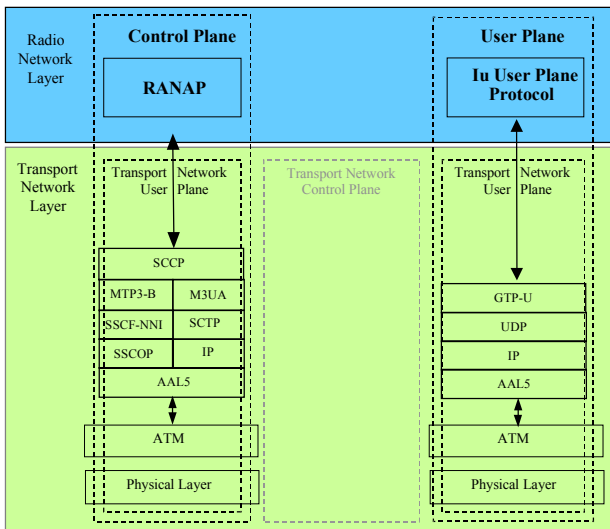


Figure 3. Protocol model for Iu-ps interface.

**Iur-g interface.** This is an interface that provides a logical connection between any two GERANs and supports the exchange of signaling information between two GERANs. The Iur-g interface is based on UTRAN Iur interface [7]. However, only a subset of the functionalities is needed for the GERAN, mainly related to the cell-level mobility management. Therefore it is proposed that only Radio Network Subsystem Application Part (RNSAP) Basic Mobility Procedures and RNSAP Global Procedures be adopted from UTRAN and modified as necessary. These procedures do not require the user plane, as illustrated in the protocol model in Figure 4 (again the Transport Network Layer may change in the Release 5 of GERAN).

The functionality split across these interfaces is aligned with UTRAN-CN split. For GERAN this means that the functionalities like ciphering and header adaptation are moved from the CN and are part of the radio access network. In addition the cell level mobility management tasks are solely part of the radio access network.

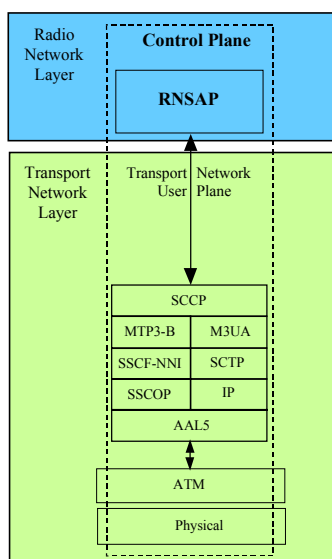


Figure 4. Protocol model for Iur-g interface (subset of UTRAN Iur).

The main benefit of the harmonization is that an operator deploying both radio access technologies (GERAN and UTRAN) may operate one single core network, and both access technologies can provide the same set of services. This includes provision of all the UMTS traffic classes also through GERAN. For the network and terminal manufacturers, the harmonization gives benefit in form of synergies in protocol and interface implementation.

The harmonization of the GERAN and UTRAN architectures simplifies the future development of these radio access technologies, e.g., towards an All-IP system. The IP transport is expected to give benefit for the operators by bringing down the transmission costs.

#### IV. GERAN RADIO PROTOCOLS: PDCP, RRC, RLC AND MAC

Figures 5 and 6 show the user plane and the control plane protocol stacks in packet-switched domain (up-to layer 2 only), when connected through Iu-ps to the 3G CN. Protocol stacks when connecting to the circuit switched core network (CN) domain with Iu-cs are not shown. Neither are shown the protocol stacks when connected to the CN through legacy interfaces, A and Gb.

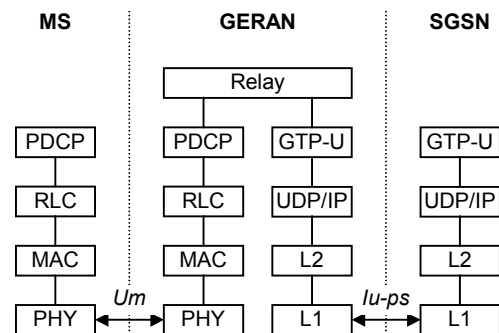
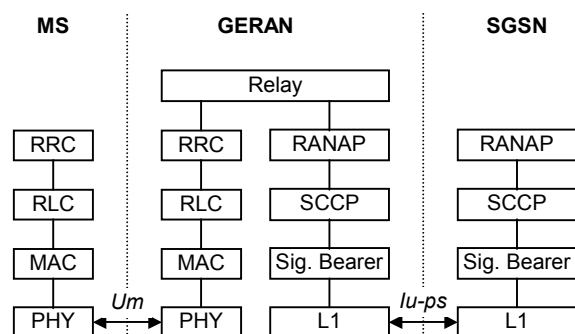


Figure 5. User plane protocol stack towards PS CN domain through Iu-ps.



Sig. Bearer: Signaling Bearer

Figure 6. Control plane protocol stack towards PS CN domain through Iu-ps.

#### IV.1 Packet Data Convergence Protocol – PDCP

The PDCP<sup>1</sup> allows for the transfer of user data using services provided by the RLC, and header adaptation of the redundant network PDU control information (IP headers) in order to make the transport over the radio interface spectrum efficient. Two different header adaptation mechanisms will be used by the PDCP, for GERAN, header compression and header removal.

*Header Compression* consists of compressing transport and network level headers (e.g. RTP/UDP/IP) so that decompressed headers are semantically identical to the original uncompressed headers. Header compression is suited for generic Internet applications (i.e., not specific to GERAN), especially multimedia applications.

*Header Removal* consists in removing completely transport and network level headers (e.g. RTP/UDP/IP). The receiving entity can, however, regenerate the headers based on information submitted at the call set-up and from the link and physical layers. Semantically, original and regenerated headers may be different. Header removal targets optimized speech bearer for which the transmission over the radio interface is circuit-switched like.

#### IV.2 Radio Resource Control – RRC

The RRC protocol is based on both GSM RR [8] and UTRAN RRC [9] specifications. Many new RR concepts introduced to UTRAN (compared to GSM Release 99), have been adopted from UTRAN RRC to GERAN RRC, e.g. the Radio Bearer (RB), the RRC connection and the RRC connection mobility management concepts. Other RRC functions are e.g., broadcast of information related to the non-access stratum (core network) and the access stratum, paging/notification, routing of higher layer PDUs, control of requested QoS, initial cell selection and re-selection in idle mode, support for location services, control of security functions and MS measurement reporting and control of the reporting.

RRC realizes the QoS requirements of the RAB by establishing a RB between MS and GERAN. For each RB RRC allocates either a dedicated or a shared channel. In case of dedicated channels, RRC also takes care of radio resources allocations. In case of shared channels, MAC takes care of radio resource allocations. The RRC state model is shown in figure 7.

RRC connection mobility means that in RRC connected mode, the GERAN tracks the location of MS without CN involvement. When there is no RRC connection, i.e. in idle mode, the MS is identified by non-access stratum identities (e.g. IMSI, TMSI and P-TMSI) and the GERAN has no own information about the individual MS. The RRC connected mode has two levels of accuracy for RRC connection mobility: Cell and GERAN Registration Area (GRA). In the cell level of accuracy, the MS makes cell updates after each GERAN cell re-

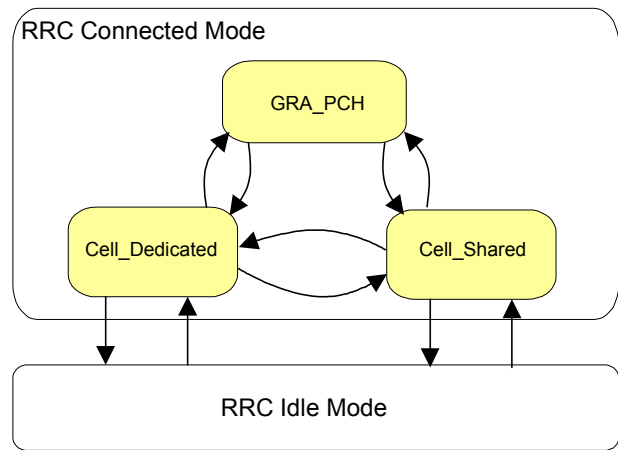


Figure 7. RRC states and state transitions.

lection and respectively the network tracks the MSs location on cell level. For inactive users the MS may fall back to the GRA level of accuracy. In this state the MS location is known only with the GRA accuracy.

#### IV.3 Radio Link Control – RLC

The RLC protocol allows for the data transfer in *transparent*, *acknowledged* or *unacknowledged* modes, and in addition notifies unrecoverable errors to upper layer.

When in *transparent mode*, RLC has no functionality and does not alter the data units of the upper layer.

In *non-transparent mode*, the RLC is responsible for ciphering RLC PDUs in order to prevent any unauthorized acquisition of data. RLC non-transparent mode is built based on the (E)GPRS if the Radio Access Bearer (RAB) is mapped onto a Packet Data Traffic Channel (PDTCH). Alternatively, the RAB may be mapped onto a data TCH for which new data blocks are defined. Signaling is performed on a Packet Associated Control Channel (PACCH) when PDTCH is used, and on Fast Associated Control Channel (FACCH) and Slow Associated Control Channel (SACCH) when data TCH is used. The mapping of a RAB onto the proper traffic channel is dependent on the MAC mode in use and the targeted traffic class, as described in the next chapter. In *acknowledged mode*, Backward Error Correction (BEC) procedures are provided that allow error-free transmission of RLC PDUs through two possible selective ARQ (Automatic Repeat reQuest) mechanisms: Type I ARQ and *Hybrid Type II ARQ* (Incremental Redundancy). In *unacknowledged mode*, no BEC procedure is available.

#### IV.4 Medium Access Control – MAC

The MAC sublayer allows the transmission over the physical layer of upper layer PDUs in dedicated or shared mode. A MAC mode is associated with a physical subchannel for use by one or more mobile stations (dedicated or shared mode respectively). The MAC layer handles the access to and multiplexing onto the physical subchannels of mobile stations and traffic flows.

<sup>1</sup> PDCP replaces LLC and SMDCP of the GPRS Release 1997/98/99.

## V. GERAN PHYSICAL LAYER

The physical layer of GERAN interfaces the MAC and the RRC protocols. It offers logical channels and the associated transmission services. Logical channels are divided in two categories:

- traffic channels, and
- control channels.

Traffic channels are intended to carry either encoded speech or user data while control channels carry signaling or synchronization data. Logical channels are multiplexed either in a fixed predefined manner, or dynamically by the MAC on physical subchannels. Physical SubChannels (PSCH) are the units of the radio medium. Some are reserved by the network for common use, others are assigned to dedicated connections with MSs (Dedicated Physical SubChannel - DPSCH), or are assigned to a shared usage between several MSs (Shared Physical SubChannel - SPSCH). The types of logical channels that are allowed on a PSCH depend on the mode of the PSCH. In the following emphasis is laid on the traffic channels.

Traffic channels of type TCH are intended to carry either encoded speech or user data on physical subchannel in the dedicated MAC mode only i.e. for one MS only. The TCH uses circuit-like connection over the radio interface. The TCH can either be GMSK or 8PSK modulated. One main characteristic of the channel coding for the TCH is the use of diagonal interleaving. There are two categories of TCHs that are Speech TCH and Data TCH.

The channel coding of the Speech TCH is optimized to maximize the perceived speech quality. Output bits from the speech codec are divided into different classes based on their subjective importance and the bits of the different classes are protected unequally in channel coding. Earlier releases of the GSM standard already introduced a Full Rate (FR) and Half Rate (HR) speech on GMSK channels, an Enhanced Full Rate (EFR) speech on GMSK channels, and finally the AMR codec on both full rate and half rate GMSK channels.

The GERAN release 5 will introduce the wideband AMR codec (AMR-WB) for high quality speech services, and will introduce the narrowband AMR on half rate 8PSK channels to increase the speech capacity. Note that a quarter rate 8PSK channel is under consideration as well [10].

Table 1 lists the average code rates for the different AMR codec modes and code rates. A diagonal interleaving over eight bursts is used on the full rate channel, over four bursts on the half rate and over two bursts on the quarter rate channel. Figure 8 shows the link level performance of the 7.4 kbps AMR codec in full, half and quarter rate channels. The decrease in the link level performance in the quarter rate mode is due to the higher code rate and smaller interleaving depth.

Table 1. Speech frame sizes and code rates for different AMR codec rates (both in GMSK and 8-PSK channels). *x* means that the codec mode does not fit the channel.

Codec Mode	Bits per Speech Frame	Average Code Rate			
		GMSK		8PSK	
		FR	HR	HR	QR
12.2	244	0.54	x	0.36	0.72
10.2	204	0.45	x	0.30	0.60
7.95	159	0.35	0.70	0.24	0.47
7.4	148	0.33	0.65	0.22	0.44
6.7	134	0.30	0.59	0.20	0.40
5.9	118	0.26	0.52	0.18	0.35
5.15	103	0.23	0.46	0.15	0.31
4.75	95	0.21	0.42	0.14	0.28

Unlike Speech TCH, the channel coding of Data TCH includes equal error protection of the payload bits. Furthermore, due to the more relaxed delay requirements, the channel coding is enhanced with longer interleaving.

A wide range of data TCHs already exist in GSM/EDGE standard, using both GMSK and 8-PSK modulation, and offering data rates from 9.6 kbps to 43.2 kbps in a single slot configuration (see Table 2). In multislot configuration (HSCSD/ECSD), the maximum bit rate increases to 345.6 kbps. The GERAN physical layer will reuse these Data TCHs. Typically GERAN will use Data TCHs for services with relaxed delay requirements (e.g. streaming services) in a dedicated MAC mode.

Table 2. Data TCH modulation and coding schemes.

TCH	Modulation	Code rate	Data rate (kbps)
TCH/F9.6	GMSK	0.53	9.6
TCH/F14.4		0.64	14.4
E-TCH/F28.8	8PSK	0.42	28.8
E-TCH/F32.0		0.47	32.0
E-TCH/F43.2		0.64	43.2

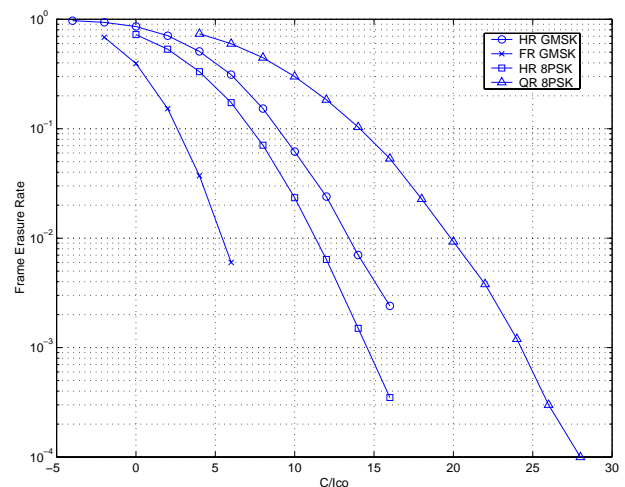


Figure 8. Link level performance of FR, HR and QR channels with AMR 7.4 kbps in typical urban channel with 3 km/h (TU3) and ideal frequency hopping.

Table 3. EGPRS modulation and coding schemes

MCS	Modulation	Code rate	Data rate (kbps)
MCS9	8PSK	1.0	59.2
MCS8		0.92	54.4
MCS7		0.76	44.8
MCS6		0.49	29.6
MCS5		0.37	22.4
MCS4	GMSK	1.0	17.6
MCS3		0.80	14.8
MCS2		0.66	11.2
MCS1		0.53	8.8

Packet Data Traffic CHannels (PDTCH) are intended to carry user data on physical subchannels in either dedicated or shared MAC mode. PDTCH is temporarily dedicated to one MS but one MS may use multiple PDTCHs in parallel for individual packet transfer (multislot configuration). PDTCH allows several MSs to be multiplexed on the same SPSCH. PDTCH also allows several traffic classes from the same MS to be multiplexed on the same PSCH (shared or dedicated).

The channel coding of PDTCH uses short rectangular interleaving in order to ensure efficient multiplexing. In GPRS, four different coding schemes based on GMSK modulation were standardized. In EGPRS an additional set of 9 coding schemes, using both GMSK and 8PSK modulation were introduced (see Table 3 for the modulation and coding schemes and Figure 9 for the throughput performance). The available data rates run from 8.8 kbps to 59.2 kbps in a single slot configuration. In multislot configuration the maximum data rate can be brought to 473.6kbps. PDTCH can be used by GERAN for any traffic class.

Power control for speech is available in GSM/EDGE through the SACCH, which enables a power control interval of 480ms. The release 1999 of GSM/EDGE introduced the Fast Power Control (FPC) for ECSD. The FPC signaling is made in-band, allowing a control interval of 20ms (24 times faster than through the SACCH).

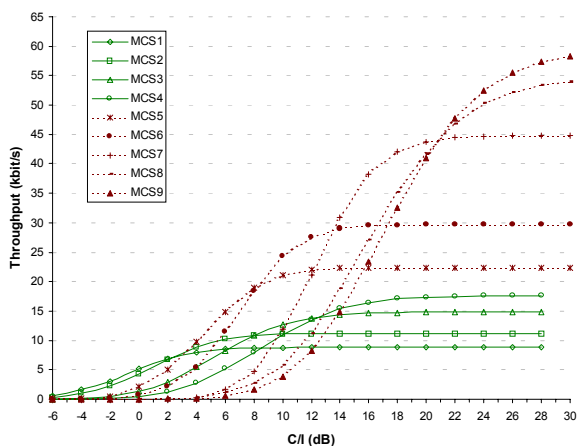


Figure 9. EGPRS throughput on typical urban channel with 3 km/h (TU3) and ideal frequency hopping (without incremental redundancy).

The release 5 of GERAN will introduce Fast Power Control (FPC) for speech services on dedicated physical subchannels. The FPC signaling is mapped onto every SACCH burst, allowing a control interval of 120ms (four times faster than through the SACCH). Unlike in-band signaling, it can be used on any speech traffic channel (both 8PSK and GMSK modulated) as well as on any other channel where the SACCH is allocated, and does not impact the speech channel coding. The advantages of FPC are twofold. Not only the signal quality is enhanced, but the level of interference to other users is also reduced. FPC enhances the overall spectral efficiency [5].

## VI.CONCLUSION

The alignment of the GSM/EDGE radio access network (GERAN) architecture with the UTRAN architecture

- allows GERAN to connect to the 3G core network through Iu interface, and
- allows GERAN to provide the same set of 3G services as UTRAN.

Further, the alignment makes the future development of both radio access technologies (GSM/EDGE and WCDMA) towards All IP network smoother.

Other significant developments in the Release 5 of GERAN include the efficient support for IP-based services, the provision of high quality speech services with AMR-WB, and spectral efficiency enhancements of speech services with 8PSK speech channels and fast power control.

## REFERENCES

- [1] R. Pirhonen, T. Rautava, J. Penttinen, TDMA Convergence for Packet Data Services, *IEEE Personal Communications*, 1999.
- [2] A. Furuskär et al, EDGE: Enhanced Data Rates for GSM and TDMA/136 Evolution, *IEEE Pers. Commun.*, Vol. 6, No. 3, June 1999, pp. 56-66.
- [3] Y. Zhao, G. Sébire, E. Nikula, Advanced Measurements for EGPRS Link Quality Control, to appear in *the proceedings of APCC 2000*, November 2000.
- [4] K. Balachandran et al, A Proposal for EGPRS Link Control Using Link Adaptation and Incremental Redundancy, *Bell Labs Technical Journal*, July-September 1999.
- [5] S. Hamiti, M. Hakaste, M. Moision, N. Nefedov, E. Nikula, H. Vilpponen, Enhanced Circuit Switched Data for Real Time Services over GSM, *VTC'99 fall*, Sep. 1999, pp. 578-582.
- [6] X. Qiu, K. Chawla, L.F. Chang, J. Chuang, N. Sollenberger, J. Whitehead, RLC/MAC Design Alternatives for Supporting Integrated Services over EGPRS, *IEEE Pers. Commun.*, Vol. 7, No. 2, April 2000, pp. 20-33.
- [7] 3GPP TS 25.420, UTRAN Iur Interface General Aspects and Principles, Release 1999.
- [8] ETSI GSM 04.18, Radio Resource Control Protocol, Release 1999.
- [9] 3GPP TS 25.331, RRC Protocol Specification, Release 1999.
- [10] T. Bellier, M. Moision, E. Nikula, R. Pirhonen, H. Rantala, Quarter Rate AMR Channels – A Speech Capacity Booster in GSM/EDGE, *Proceedings of WPMC'00*, November 2000.