EDGE Phase 2 Evolution of EGPRS for Supporting 3G Real-time Services

Krishna Balachandran, Cristian Demetrescu, Richard Ejzak, Sanjiv Nanda, Hong Xie

Lucent Technologies

1 Introduction and Scope

General Packet Radio Service (GPRS) was introduced by ETSI to meet the ever-increasing demand for wireless data over GSM radio interface. The Enhanced GPRS (EGPRS Phase 1) was later introduced to increase the spectrum efficiency and data throughput by using higher modulation scheme and link adaptation techniques. While (E)GPRS uses packet-switched technology to efficiently transmit best-effort data, the real-time services (e.g. voice) are still supported via the circuit-switched systems. This service separation reduces the potential spectrum efficiency gain resulting from multiplexing different services on the same radio channel.

This paper describes the key new concepts needed to introduce statistical multiplexing of all bearer classes on the GERAN air interface for delivery over the packet-switched network in R2001. It focuses only on the support of overall UMTS service requirements as described in [1], and does not address network architecture issues or circuit-switched services.

The central new service requirement for GERAN (compared to EGPRS Phase 1) is the support of real-time speech service using the packet-switched backbone network. The focus of the document is the definition of new traffic and control channels to support statistical multiplexing of speech, real-time data, and non-real-time data, and the corresponding new MAC procedures that are needed to guarantee QoS.

2 List of Acronyms

AMR	Adaptive Multi-Rate
ARI	Access Request Identifier
BCCH	Broadcast Control Channel
BEP	Bit Error Probability
BFACCH	Burst-based FACCH
CCCH	Common Control Channel
CID	Carrier Identifier
CTS	Carrier Time Slot
DBMCH	Downlink Block Message Channel
DFACCH	Dim-and-Burst FACCH
DMT	Downlink (Burst) Message Type
DPRCH	Downlink Periodic Reservation Channel
DTCH/FS	Downlink Traffic Channel for Full Rate Speec
DTCH/HS	Downlink Traffic Channel for Half Rate Spee
DTCH/FD	Downlink Traffic Channel for Full Rate Data
DTCH/HD	Downlink Traffic Channel for Half Rate Data
EDT	End Downlink Traffic
EEP	Equal Error Protection
EGPRS	Enhanced General Packet Radio Service
EUT	End Uplink Traffic
FACCH	Fast Associated Control Channel
FACKCH	Fast Acknowledgment Channel
FASSCH	Fast Assignment Channel
FFS	For Further Study
FR	Full-Rate
FRACH	Fast Random Access Channel
GERAN	GSM/EDGE Radio Access Network
HR	Half-Rate
IP	Internet Protocol
L1	Layer 1 (Physical Layer)
MAC	Medium Access Control
MCS	Modulation and Coding Scheme
MR	Measurement Report
MS	Mobile Station
MSACCH	Modified Slow Associated Control Channel
NRT	Non-Real Time
OFF	Offset in Frames
PBCCH	Packet Broadcast Control Channel
PCCCH	Packet Common Control Channel
PDCP	Packet Data Convergence Protocol
PH	Phase
QoS	Quality of Service
RAB	Radio Access Bearer
RAN	Radio Access Network
RDC	Reassign Downlink Control
RDT	Reassign Downlink Traffic
RLC	Radio Link Control
RR	Radio Resource Management
RRBP	Relative Reserved Burst Period
RT	Real Time
RTP	Real Time Protocol
RUC	Reassign Uplink Control
RUT	Reassign Uplink Traffic
SACCH	Slow Associated Control Channel
SD	Start Delay
SDT	Start Downlink Traffic
SID	Silence Descriptor
SUT	Start Uplink Traffic
TBF	Temporary Block Flow
TBFI	Temporary Block Flow Identifier
TCP	Transport Control Protocol
TFI	Temporary Flow Identifier
TS	Time Slot
UDP	User Datagram Protocol
UEP	Unequal Error Protection
UBMCH	Uplink Block Message Channel
UPRCH	Uplink Periodic Reservation Channel
UMT	Uplink (Burst) Message Type
UMTS	Universal Mobile Telecommunications Sys
USF	Uplink State Flag
UTCH/FS	Uplink Traffic Channel for Full Rate Speech
UTCH/HS	Uplink Traffic Channel for Half Rate Speec
UTCH/FD	Uplink Traffic Channel for Full Rate Data
UTCH/HD	Uplink Traffic Channel for Half Rate Data
UTRAN	UMTS Terrestrial Radio Access Network
VAD	Voice Activity Detection

3 Service Requirements

Service requirements for GERAN are based on those of UMTS, with the addition of an optimized speech service based on GSM/AMR. These requirements describe the radio bearer classes, the need for parallel bearer flows, handover, and alignment with UMTS core network. Specific error, throughput, and delay requirements for each bearer class are FFS, but

range of capabilities is clear from current UMTS requirements.

3.1 Support of Radio Bearer Classes in Alignment with UMTS

The UMTS radio bearer classes for conversational, streaming, interactive, and background services cover a range of real-time and non-real-time data services with a wide range of error, throughput, and delay requirements. The GERAN requirements for these services will be aligned with UMTS with adjustments as necessary to capture unique characteristics of the GERAN.

Voice service requirements are based on those of GSM/AMR. A GERAN radio bearer class will be specifically optimized for voice service.

3.2 Support for Parallel Bearer Flows with Different QoS

The GERAN shall support up to three parallel bi-directional bearer flows with different QoS requirements. This capability will enable support of simultaneous voice and data service as well as multimedia service.

3.3 Handover Requirement for RT Services

Voice and real-time data services have QoS characteristics not supported by existing EGPRS reselection procedures. The GERAN shall include procedures to support maintenance of acceptable (TBD) QoS during network-assisted handover procedures for voice and real-time data services. The details of these handover procedures are outside the scope of this document.

3.4 Alignment with UMTS Core Network

The GERAN shall conform to the core network interface requirements established for UMTS with only those changes necessary to adapt to unique characteristics of the GERAN. In particular, this requires that the GERAN provide the Iu-ps interface to the UMTS core network.

4 Targeted Configuration

4.1 Blocking Limited Deployment

This concept proposal is optimized for blocking limited deployment, where the greatest capacity is achieved by utilizing available traffic-carrying channels to the fullest degree. In a blocking limited deployment, traditional circuit channels for delivery of voice and real-time data services are inefficient due to significant periods of "dead time" during a typical flow. For voice service with a voice activity factor approximately 40%, there is considerable potential to increase overall capacity with statistical multiplexing of traffic channel resources [4].

4.2 Interference Limited Deployment

Since an interference-limited system must operate at some fraction of its channel capacity to achieve acceptable aggregate performance, statistical multiplexing typically offers little or no capacity advantage. However, interference-limited deployment (e.g. 1/3 reuse) becomes blocking limited with techniques like beam forming and power control. See [5] and [5]. It is more appropriate to optimize the GERAN for deployment configurations that take advantage of the application of the latest interference management techniques, which make them more blocking limited. This approach assures that the greatest capacity benefits are available in all configurations.

4.3 Less Aggressive Reuse (e.g. 4/12) Preferred when Spectrum Available

Blocking limited deployment is and will be common for the foreseeable future. Blocking limited deployment is preferred in areas not limited by availability of spectrum. It is also preferred in areas where uniform quality of service is a requirement, since coverage “holes” become more common when operating in interference limited conditions.

4.4 All New Traffic and Control Channels

This paper introduces new traffic and control channels that are completely compatible with beam forming and power control techniques, enabling their use for all new traffic and control channels. This is achieved by designing all communication on these channels to be point-to-point. There are no multicast or broadcast control messages or control fields in any downlink transmissions. In particular, no USF is required in any downlink burst.

5 Multiplexing Principles

The benefits of statistical multiplexing are achieved through the application of the following principles.

5.1 Unidirectional Traffic and Control Channels

All new control and traffic channels are unidirectional, with independent frequency and slot allocation in the uplink and downlink directions. Available resources can be dynamically allocated as necessary to traffic and control channel functions. This allows for maximum flexibility in allocation of available resources. Breaking the historical association between uplink and downlink channels is necessary for statistical multiplexing of speech, in particular, since the uplink and downlink resource demands occur independently. Breaking the association between uplink and downlink maximizes the resource pool available for assignment when new data or speech becomes available for transmission.

A primary consideration for any new GERAN concepts must be the impact on half-duplex mobiles, given their cost advantages. The new control and traffic channels are specifically designed to support half-duplex mobiles in a manner that maximizes the pool of traffic and control channel resources available for assignment to these mobiles.

Another consideration for further study is the impact of variable uplink/downlink carrier separation on mobiles.

5.2 EGPRS Phase 1 and Phase 2 Traffic on Different Time Slots

Because of the need to allocate uplink and downlink channels independently, it is not possible to multiplex EGPRS Phase 1 and Phase 2 (GERAN) traffic on the same time slot. This traffic must be segregated onto separate time slots at any one time. However, time slots can be dynamically switched between supporting one type of traffic or the other, thus allowing the maximum possible capacity with traffic segregation.

There is no limitation on the ability of EGPRS Phase 1 and Phase 2 traffic to share the same broadcast and common control channels.

5.3 Multiplexing Different QoS Classes

This proposal supports the multiplexing of all QoS classes onto the same channels. The same uplink an downlink resource pools are shared among all flows, regardless of their QoS class, maximizing the advantages of statistical multiplexing.

5.4 Operation of TBF Establishment

The concept of a Temporary Block Flow (TBF) of GPRS/EGPRS is enhanced in the GERAN to have a unique profile with direction, QoS, and protocol attributes.

5.4.1 Negotiation of TBF Profile

Before establishment of any TBF between a mobile and the network, it camps on the CCCH or PCCCH in the current cell, and is governed by procedures currently defined in EGPRS. When the first TBF is established, its attributes are defined as follows:

- The TBF is either unidirectional (uplink or downlink) or bi-directional. A voice TBF would typically be bi-directional. A data TBF could be either unidirectional or bi-directional. Data traffic requiring any significant exchange, such as upper layer acknowledgments, could be bi-directional, thus saving the overhead of repeated TBF establishment for periodic traffic.
- The TBF is assigned QoS attributes consistent with the desired service quality and bearer class. Given the assigned QoS attributes, the TBF may also be eligible for network-directed handover procedures to minimize service disruption while switching between two cells.
- The TBF is assigned protocol attributes. For example, for voice service the TBF uses physical layer channel coding optimized for voice, and eliminates headers associated with other protocol layers. Data services will typically require physical layer channel coding optimized for data and the presence of the headers for all protocol layers to control more complex protocol functions.

5.4.2 MAC Procedures for Established TBF

Once the first TBF is established, the mobile remains on the new RT traffic and control channels, regardless of the presence or absence of data to send, until all TBFs for the mobile are released. Each TBF remains valid regardless of activity until it either times out or is explicitly released by the network.

5.4.3 Channels for Fast Resource Assignment

When there is no data transfer in the downlink direction (no downlink traffic channel is assigned to the TBF), a mobile with a RT TBF must monitor a common downlink control channel for fast resource assignment directives.

These assignment directives assign traffic channel resources to the TBF as needed to support data transfer with the agreed-to QoS attributes.

When the TBF has an active downlink traffic channel assignment, it typically monitors the same physical channel for fast associated control channel messages with alternative assignment directives. As an alternative for mobiles with adequate multi-slot capability, the mobile may be required to monitor both the downlink traffic channel for user data and a common downlink control channel for fast assignment directives.

When a mobile has more than one TBF active in the downlink direction, it may be required to monitor either a common downlink control channel and/or one (or more) of the downlink traffic channels for fast assignment directives.

5.4.4 Traffic Channel Assignment

When the TBF requires a downlink traffic channel for data transfer, the network sends a fast assignment directive to the mobile to allocate a downlink traffic channel for the data transfer.

When the TBF requires an uplink traffic channel for data transfer, the mobile sends a fast access request on an uplink fast access control channel. The network responds with a fast assignment directive to allocate the necessary uplink resource.

In all cases, since QoS and protocol attributes have been negotiated during establishment of the TBF, there is no ambiguity as to the parameters of the resource request or assignment. These attributes do not change from one resource request or assignment to the next during a TBF.

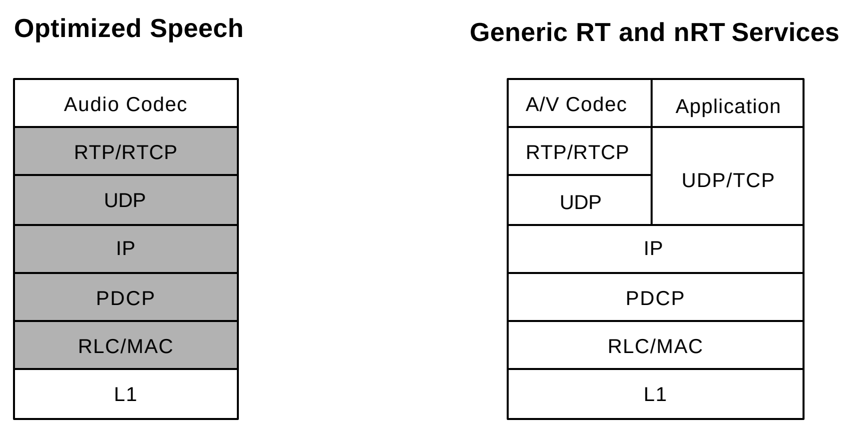
5.4.5 Timing Alignment and Power Control

For as long as a mobile has at least one TBF established, it remains in timing alignment and under power control. This allows for all access bursts to be of normal length, since abbreviated bursts are not needed to allow for misalignment. This also avoids the extra overhead of performing these functions at the beginning of each traffic channel assignment.

6 Protocol and Architecture

6.1 Protocol Architecture

To support optimized speech, RT and NRT users over packet bearer, two different protocol stacks are proposed to meet the requirements of optimized speech and data bearers, as shown in **Figure 1.**



Note: Headers associated with shaded protocols are stripped before transmitted over the RF link

Figure 1 User Plane Protocol Stack

The protocol stack used for a particular TBF is negotiated at the TBF setup along with the QoS attributes. For optimized speech bearer, a dedicated unidirectional traffic channel is allocated to a speech TBF during a talk spurt. Hence no RLC/MAC header is used. The IP/UDP/RTP header information is exchanged at speech TBF setup and is, therefore, eliminated from the speech frame transmission over the RF interface. Any call control signaling (e.g. H.323 or SIP call setup) associated with a speech TBF (e.g. VoIP) will be carried on a data TBF separate from the speech TBF.

For RT and NRT data users, the EGPRS Phase 2 protocol stack is kept. Some form of lossless header compression is highly desirable for all data TBFs (including streaming multimedia) and is FFS.

6.2 RLC/MAC

The GERAN will reuse the EGPRS Phase 1 RLC with only those extensions needed to adapt RLC procedures to the new RT traffic and control channels.

The RT MAC is new for the GERAN, based on the fast access and assignment procedures of this paper.

6.3 Radio Interface Aspects

The GERAN Layer 1 is an enhanced version of the EGPRS Phase 1 Layer 1. Enhancements are related to the introduction of new types of traffic and control channels, as described in sections 7 and 8.

7 Traffic Channel Design

All traffic channels in GERAN are considered to be *unidirectional* channels. Chain interleaving is done on speech traffic channels and block interleaving for data. Half-rate traffic channels use alternate bursts (either all even-numbered or all odd-numbered bursts) on a time slot. This has a significant multiplexing advantage for half-duplex mobiles. In the case of NRT data, it permits ease of multiplexing with RT data and voice. All traffic channel resources are allocated in units of half-rate traffic channels. A full-rate speech channel is comprised of two half-rate speech channels. Multi-rate data channels are comprised of separate data streams on independent half-rate data traffic channels

Speech, RT and NRT users may share a time slot by being assigned to two different half-rate channels on the same slot. One or more half-rate traffic channels are allocated to a specific speech or data user for the duration of a talk spurt or “data spurt”. *No* headers or stealing bits are required for the receiver to distinguish between these traffic channels. For data channels, stealing bits and header formats are used as in EGPRS Phase I, but the USF is eliminated on the downlink

All traffic channel assignments are through messaging on the new control channels (including TCH associated control channels).

7.1 Speech Traffic Channel Design Principles

Speech traffic channels are based on supporting the GSM/AMR modes on full-rate and half-rate channels. The full-rate channel coding for the GSM/AMR modes is the same as in current GSM/AMR. The channel coding for half-rate AMR modes will be based on 8PSK modulation.

7.1.1 Interleaving

Interleaving in all cases will be chain interleaving over 40 msec, as in GSM/AMR. For a full-rate traffic channel the interleaving is over 8 radio bursts in 40 msec, with a chaining overlap of 4 radio bursts in 20 msec. While the two half-rate channels comprising the full-rate channel may be on a different carrier, time slot, and/or phase, the interleaving is performed across the allocated bursts in strict temporal order. For a half-rate traffic channel, the interleaving is over 4 radio bursts spaced over 40 msec, with a chaining overlap of 2 radio bursts in 20 msec. This half-rate interleaving mode is sometimes described as 0246/1357, to describe the use of alternate bursts for each of two half-rate channels over the 8 bursts in a 40 msec interval. The alternative of block interleaving of 2 speech frames over 4 consecutive bursts in 20 msec intervals alternating between two half-rate channels is sometimes called 0123/4567 interleaving. Study has shown 0246/1357 interleaving is preferable for statistically multiplexed half-rate traffic channels for speech, see Ref. [2].

7.1.2 Compatibility with Half-Duplex Mobiles

Half-duplex mobiles typically have severe constraints on the combination of uplink and downlink channels that they can support. This is an important consideration since statistical multiplexing works more efficiently with a larger pool of resources available for allocation. Ref. [2] shows that the best statistical multiplexing efficiency is achieved for half-duplex mobiles by defining all half-rate traffic and control channels to use no more than every other burst on any one time slot. Section 7.4 shows this burst allocation for half-rate speech channels.

7.1.3 Headers

Since the entire channel (either full-rate or half-rate) is dedicated to a TBF for the length of a talk spurt, there is no need for additional header beyond what is in existing GSM/AMR.

7.1.4 Half Speech Block

With chain interleaving, half of the information transmitted in the first and last 20 msec intervals of a talk spurt is typically unusable. Since AMR has multiple compatible modes of operation with different sizes of speech, it is possible to define new channel coding for these currently unused bits to transmit special speech frames. For example, with the 7.4 kbps mode of operation, it is possible to specify alternative channel coding on the first block of unused bits to encode a single 4.75 kbps speech frame. The performance of this *half speech block* is somewhat worse than the performance of the remaining speech frames, but the overall impact on the quality of a typical talk spurt is small.

Use of the half speech block reduces the delay to the beginning of a talk spurt by 20 msec. By starting a talk spurt with a half speech block, the overall time on the traffic channel is also reduced by 20 msec (corresponding to the first 20 msec interval typically needed to start up a chain interleaving sequence).

By using a half speech block for the last speech frame of a talk spurt, which is relatively unimportant to the intelligibility of the talk spurt, the overall time on the traffic channel is reduced by an additional 20 msec (for a total of 40 msec). This is accomplished by eliminating the need to transmit the last 20 msec portion of the last valid speech frame.

The half speech block could also be used in the middle of a talk spurt to free up room to transmit a frame of control information. This is called “dim-and-burst” signaling as opposed to “blank-and-burst” signaling, which replaces an entire speech frame with a frame of control information. This “dim-and-burst” concept is under investigation as a potential alternative method of encoding FACCH.

7.1.5 Initial Burst of a Talk Spurt

In GSM, interleaving must begin on a radio block boundary, which occurs every 20 msec. Since every talk spurt is specifically assigned to a traffic channel, it is not necessary to maintain this 20 msec granularity. Allowing a talk spurt to begin on any burst improves the average delay to the beginning of a talk spurt by approximately 5 msec for half-rate channels, since the assignment granularity is reduced from 20 msec to 10 msec. The average improvement for full-rate channels is approximately 7.5 msec, since the assignment granularity is reduced from 20 msec to 5 msec.

7.1.6 AMR VAD and Hangover

The current AMR VAD and hangover interval are not designed to provide optimal performance in a system with statistical multiplexing of speech. They are both candidates for further study to reduce the average length of talk spurts without significantly increasing the rate of occurrence of talk spurts (which would cause an increase in load on the RT control channels). For example, it should be possible to reduce the hangover interval from 7 frames to a lower number such as 2 or 3. It is not yet known how this would impact control channel load or the occurrence of speech clipping.

7.2 Data Traffic Channel Design Principles

The data traffic channels are designed for full compatibility with the speech traffic channels, while reusing the MCS1 through MCS9 channel coding schemes defined for EGPRS.

7.2.1 Interleaving

For half-rate data channels, the interleaving is 0246/1357 block interleaving, where each data block is interleaved over 4 consecutive odd or even bursts (alternate bursts).

7.2.2 Compatibility with Half-Duplex Mobiles

As in section 7.1.2, half-rate data traffic channels have the same advantages in statistical multiplexing efficiency as half-rate speech traffic channels.

7.2.3 Headers

Since each half-rate channel is dedicated to a TBF for the length of a data spurt, there is no need for additional header beyond what is in existing EGPRS. The USF is unused and could be redefined for other purposes. The TFI is similarly unused in this approach as defined, but has potential value for additional data multiplexing options if replaced with the ARI and/or TBFI.

7.2.4 Initial Burst of a Data Spurt

As in section 7.1.5, data channels may begin a data spurt on any assigned burst, offering the same improvement in delay to the beginning of the data spurt as for a talk spurt.

7.3 Traffic Channel Definition

The following traffic channels are defined.

- Downlink Traffic Channel for Half Rate Speech (DTCH/HS). This channel comprises one half of a time slot on alternate bursts with four burst chain interleaving. This channel uses 8PSK modulation and unequal error protection.
- Downlink Traffic Channel for Full Rate Speech (DTCH/FS). Two half-rate channels with independently allocated carrier, slot, and phase comprise a single full-rate speech channel. Eight burst chain interleaving is performed across the allocated bursts in temporal order. This channel uses GMSK modulation.

- Downlink Traffic Channel for Half Rate Data (DTCH/HD). This channel comprises one half of a time slot on alternate bursts with four burst block-interleaving. EGPRS Phase I modulation and coding schemes (MCS1-MCS9) are used for the blocks (four alternate bursts). The USF is freed up.
- Uplink Traffic Channel for Half Rate Speech (UTCH/HS). This channel comprises one half of a time slot on alternate bursts with four burst chain interleaving. This channel uses 8PSK modulation.
- Uplink Traffic Channel for Full Rate Speech (UTCH/FS). Two half-rate channels with independently allocated carrier, slot, and phase comprise a single full-rate speech channel. Eight burst chain interleaving is performed across the allocated bursts in temporal order. This channel uses GMSK modulation and unequal error protection.
- Uplink Traffic Channel for Half Rate Data (UTCH/HD). This channel comprises one half of a time slot on alternate bursts with four burst block interleaving. EGPRS Phase I modulation and coding schemes (MCS1-MCS9) are used for the blocks (four alternate bursts).

7.4 Half-rate Traffic Channel Structure

Half-rate traffic channels comprise either even-numbered bursts (channel 1) or odd-numbered bursts (channel 2) of a time slot. This even or odd burst allocation of a half-rate traffic channel is not changed in a multiframe. It is worth noting that for current GSM traffic channels, the burst allocation alternates every 13 frames within a multiframe between odd bursts and even bursts. This change in burst allocation is necessary for maximum compatibility with half-duplex mobiles. Figure 2 shows an example of the proposed half-rate traffic channel structure for speech.

For data traffic channels, there is no MSACCH, and all allocated bursts in the time slot are available for traffic.

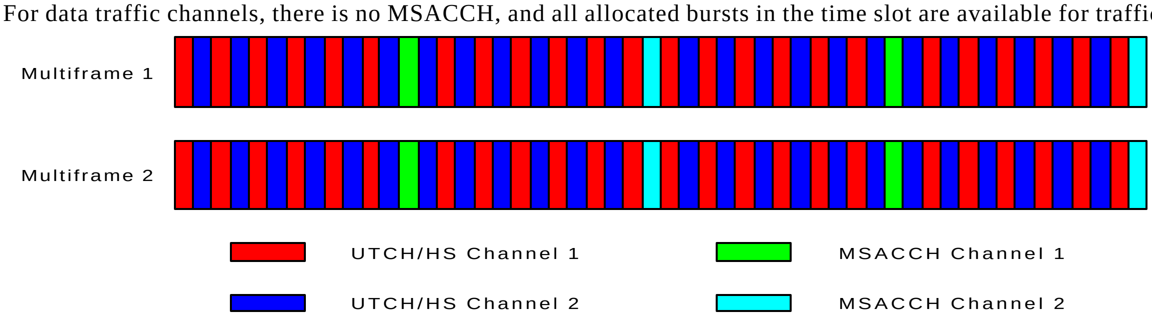


Figure 2 Half-rate traffic channel structure for speech.

7.5 Multiplexing of Speech and Data Traffic

Two different half-rate traffic channels (speech or data) may be assigned to the two different phases, i.e. odd-numbered bursts or even-numbered bursts, of a time slot. The speech traffic channels (half-rate or full-rate) are allocated to a speech user for the duration of a talk spurt. A simplified fixed allocation procedure allocates one or more half-rate data traffic channel (s) continuously to a TBF for the duration of a data spurt.

Multiplexing with full-rate speech traffic is performed independently on the two half-rate channels that comprise the full-rate speech channel

8 Real Time Control Channel Design

8.1 Control Channel Functions

The existing BCCH or PBCCH provides the broadcast information needed for the mobile to access the GERAN. The existing CCCH or PCCCH provide the capability to negotiate the attributes of the initial TBF and to communicate the parameters needed for access to the RT control channels. Once in a voice, RT data or NRT data TBF, the following functions are needed (unless an exception is listed).

- **Access Request:** The mobile must have the ability to request uplink resources on behalf of a TBF.
- **Traffic and Control Channel Assignment**: The network must have the ability to make traffic and control channel assignments (for both uplink and downlink resources) to the mobile.
- **End-of-TBF Control**: The mobile must have the ability to request the network to end a particular TBF. The network must have the ability to direct a mobile to immediately terminate a TBF.
- **Acknowledgment of Network Directives**: The mobile must have the ability to acknowledge traffic and control channel assignments and end-of-TBF directives to trigger any necessary retry procedures to assure rapid resource allocation.

- **Timing Advance and Power Control**: The network must be able to signal to the mobile any necessary adjustments in timing advance and power control.
- **Handover Signaling**: If a mobile has an established TBF for voice or RT data, it is eligible for handover procedures. In this case, the mobile is required to provide periodic neighbor cell measurement reports to the network. The network will send the necessary handover directives to the mobile as appropriate to maintain the mobile under control of the RT control channels during and after handover to minimize service disruption.
- **Negotiation of Additional TBFs**: It must be possible for either the mobile or network to begin negotiation of additional TBFs while under control of the RT control channels, subject to the multi-slot capabilities of the mobile. In particular, it must be possible to establish a default data TBF for control signaling while under control of the RT control channels.
- **AMR Signaling**: AMR signaling include, e.g., AMR mode request, AMR mode command, and periodic SID update.

  During a voice TBF, it must be possible for the network to send periodic AMR mode commands to the mobile. During a voice TBF outside of a downlink talk spurt, it must be possible for the network to send periodic SID information to the mobile.

  During a voice TBF, it must be possible for the mobile to send periodic AMR mode requests to the network. During a voice TBF outside of an uplink talk spurt, it must be possible for the mobile to send periodic SID information to the network.
- **RLC Signaling**: RLC signaling may include, for example, ack/nack messages, and BEP measurements.

  During a data TBF in the process of communicating in the downlink direction, it must be possible for the mobile to send periodic RLC control messages to the network.

  During a data TBF in the process of communicating in the uplink direction, it must be possible for the network to send periodic RLC control messages to the mobile.

  If a data traffic channel has already been allocated to a TBF in a direction requiring transmission of an RLC control message, existing RLC procedures already allow RLC control messages to be freely multiplexed with RLC data frames.

8.2 Control Channel Design Principles

The key functions of the RT control channels that enable statistical multiplexing are fast access, assignment, and acknowledgment. The following principles assure the rapid performance of these functions.

8.2.1 Burst-Based Channels

All fast access, assignment, and acknowledgment channels use single burst messages. This assures high capacity, point-to-point transmissions for compatibility with beam steering and power control procedures, and fine temporal granularity, with a transmission opportunity every 5 or 10 msec.

8.2.2 Access Request Identifier

Each mobile is assigned an ARI as a unique identifier during access and assignment procedures on the RT control channels. By including the ARI in the access burst, the network performs contention resolution immediately rather than waiting for contention resolution procedures on a traffic channel, as in GPRS and EGPRS. The network may respond immediately with a single burst assignment message including the ARI.

8.2.3 Half-Rate Channels

The fast access, assignment, and acknowledgment channels are all half-rate channels, being allocated all the odd- or even-numbered bursts in a given slot. If needed for fast control channel capacity, multiple half-rate channels may be allocated to each channel type as needed to provide the equivalent capacity of a full-rate channel or more.

Note in particular that a fast access channel is completely allocated for contention access. The network does not broadcast USF to signal contention opportunities. Since there is no need to monitor USF, this saves up to 40 msec in waiting to perform an access attempt in certain situations.

8.2.4 Fast Retry

Since all half-rate access, assignment, and acknowledgment channels have 10 msec retry granularity, this allows for rapid retry of these procedures up to once every 10 msec. When multiple half-rate channels are allocated for a particular channel type, the retry granularity may be reduced to 5 msec. This performance assumes rapid processing of individual bursts at the mobile and network. Even with a high error rate on these channels, access and assignment procedures can be performed quickly and efficiently [3]. Note that frequency hopping is desirable on these channels to reduce or eliminate burst-to-burst fading correlation.

8.2.5 Fast Control Channel Assignment

The fast access, assignment, and acknowledgment channels are allocated at the establishment of a TBF, and continue to be used throughout the TBF unless they are reassigned.

8.3 Associated Control Channel Definition

Several new associated control channels are defined to support the necessary control channel functions while the mobile is active on a traffic channel in the direction that control signaling is required. All the new associated control channels defined herein are associated with traffic channel defined in 7.3.

8.3.1 Fast Associated Control Channel (FACCH)

A FACCH is associated with each speech traffic channel. Standard FACCH coding as in GSM AMR bearer is used. Alternative coding for the FACCH on half-rate speech channels is under investigation using the half speech block concept described in section 7.1.4.

Blocked-based signaling messages that require minimal delay and reliability, e.g. handover directives, are transmitted over FACCH.

8.3.2 Burst-Based FACCH (BFACCH)

A BFACCH is associated with each traffic channel defined in 7.3.

Burst based control messages are transmitted over BFACCH replacing a single burst of speech or data for fast access, assignment and acknowledgment while on a traffic channel.

BFACCH is distinguished from speech or data traffic using a new training sequence or stealing bits. Decoding is attempted on the data from the remaining bursts. BFACCH channel coding is for further study.

8.3.3 Modified Slow Associated Control Channel (MSACCH)

A MSACCH is associated with each speech traffic channels. A MSACCH is a set of bursts on a periodical basis and has the same structure as SACCH defined for GSM speech traffic channels. An example of MSACCH associated with half-rate traffic channel is shown in Figure 2.

Some block based signaling messages, e.g. Neighbor Measurement Report, are transmitted over MSACCH.

8.4 Common Control Channel Definitions

8.4.1 Fast Random Access Channel (FRACH) – uplink only

A FRACH is designed to transmit single burst fast contention access messages. The traffic on the FRACH is isolated from the RACH and PRACH. Since the mobiles accessing on the FRACH are assumed to be time-aligned, the guard period on the FRACH burst is shorter and the message size can be larger. The maximum message length on the FRACH is TBD.

A half-rate FRACH comprises either all odd-numbered or all even-numbered bursts in the uplink portion of a time slot. A cell may assign more than one FRACH for capacity and/or faster retry granularity.

8.4.2 Fast Acknowledgment Channel (FACKCH) – uplink only

A FACKCH is designed to transmit single burst messages to acknowledge assignments and termination directives from the network. FACKCH transmissions occur in reserved bursts. The mobile uses the FACKCH when either no uplink traffic channel is available for burst signaling (BFACCH), or the network requires the mobile to use a separate channel for this signaling (e.g. to avoid excessive uplink BFACCH use during an uplink talk spurt).

Single burst acknowledgment message is transmitted on FACKCH on a polled basis using a RRBP scheme (identifying the placement of the reserved burst). This permits multiple burst-based assignment/acknowledgment sequences to be completed within a 20-msec block period and improves the speed and reliability of real-time statistical multiplexing.

A half-rate FACKCH comprises either all odd-numbered or all even-numbered bursts in the uplink portion of a time slot. A cell may assign more than one FACKCH for capacity and/or faster retry granularity.

8.4.3 Fast Assignment Channel (FASSCH) – downlink only

A FASSCH is designed to transmit single burst assignment and termination messages to the MS. Different messages are used to assign downlink traffic channels, downlink control channels, uplink traffic channels, and uplink control channels. The network may use the FASSCH either when there is no downlink traffic channel allocated to the MS (to allow BFACCH signaling), or to avoid excess BFACCH signaling on a downlink traffic channel.

A half-rate FASSCH comprises either all odd-numbered or all even-numbered bursts in the downlink portion of a time slot. A cell may assign more than one FASSCH for capacity and/or faster retry granularity.

8.4.4 Uplink Periodic Reservation Channel (UPRCH)

An UPRCH is used to transmit signaling messages that need to be updated on a periodic basis, e.g. SID_Update and Neighbor Measurement Report. An UPRCH is designed for MSACCH signaling continuity when an uplink traffic channel is released.

An UPRCH is released at the assignment of an uplink traffic channel, and a new periodic reservation on an UPRCH is assigned to a mobile in a speech TBF at the release of an uplink traffic channel.

A half-rate UPRCH comprises either all odd-numbered or all even-numbered bursts in the uplink portion of a time slot. A cell may assign more than one UPRCH for capacity. The network reserves one of every 13 bursts on a half-rate UPRCH for each voice TBF not in an uplink talk spurt. 13 voice TBFs can simultaneously share a half-rate UPRCH.

8.4.5 Downlink Periodic Reservation Channel (DPRCH)

A DPRCH is used to transmit signaling messages that need to be updated on a periodic basis, e.g. SID_Update, timing advance, and power control. A DPRCH is designed for MSACCH signaling continuity when a downlink traffic channel is released.

A DPRCH is released when the downlink traffic channel is assigned, and a new periodic reservation is assigned to a mobile in a speech TBF at the release of the downlink traffic channel.

A half-rate DPRCH comprises either all odd-numbered or all even-numbered bursts in the downlink portion of a time slot. A cell may assign more than one DPRCH for capacity. The network reserves one of every 13 bursts on a half-rate DPRCH for each voice TBF not in a downlink talk spurt. 13 voice TBFs can simultaneously share a half-rate DPRCH.

8.4.6 Uplink Block Message Channel (UBMCH)

A UBMCH is designed to multiplex block (4 bursts) messages, e.g. RLC signaling, from multiple mobiles, using polled reservation bursts in a RRBP-like scheme. The mobile uses the UBMCH when either no uplink traffic channel is available for block signaling (e.g. FACCH), or the network requires the mobile to use a separate channel for this signaling (e.g. to prevent FACCH use for ack/nack signaling on the uplink during a downlink data spurt simultaneous with an uplink talk spurt).

A half-rate UBMCH comprises either all odd-numbered or all even-numbered bursts in the uplink portion of a time slot. A cell may assign more than one UBMCH for capacity.

8.4.7 Downlink Block Message Channel (DBMCH)

A DBMCH is designed to multiplex block (4 bursts) messages, e.g. RLC signaling, handover directives, etc., to multiple mobiles. The network may use the DBMCH either when there is no downlink traffic channel available for block signaling (e.g. FACCH), or to avoid excess control signaling on a downlink traffic channel.

A half-rate DBMCH comprises either all odd-numbered or all even-numbered bursts in the downlink portion of a time slot. A cell may assign more than one DBMCH for capacity.

While not on a downlink traffic channel, a mobile may be configured to monitor either a FASSCH, a DBMCH, or both a FASSCH and a DBMCH. A mobile with only non-real-time TBFs may only monitor a DBMCH and not need to monitor a FASSCH. For a mobile configured to monitor only a FASSCH (perhaps due to multislot restrictions), any necessary signaling on the DBMCH may be performed by using the FASSCH to temporarily assign a mobile to a DBMCH only for the duration of the necessary transmission.

8.5 Multiplexing of Common Control Channel

The FRACH, FACKCH, UPRCH, FASSCH, DPRCH, UBMCH and DBMCH may each be configured as a group of one or more half-rate control channels. A half-rate control channels uses either every odd or every even burst on a timeslot in each multiframe.

These channels are *never* multiplexed together. The control messages on the FRACH, FACKCH, UPRCH, FASSCH, DPRCH, UBMCH and DBMCH are always carried on different half-rate channels.

Two different half-rate control or traffic channels may be assigned to the two different phases (all odd or all even) of a slot. Note that the burst allocation for half-rate control channels is compatible with and identical to the burst allocation for half-rate traffic channels.

Half-rate control channels of any type may be clustered in two ways so as to maximize traffic channel allocation possibilities when statistically multiplexing traffic for half duplex mobiles. When mobiles do not need to access a group of channels simultaneously, channels operating in the same direction of transmission may be optimally assigned to the same phase of the same timeslot on different carriers. This situation applies to multiple copies of the same control channel type. It also applies to all other control channel types unless they are specifically configured for simultaneous access, which might be needed for the FASSCH and DBMCH channels. For simultaneous access, they might be optimally assigned to the same phase of neighbor timeslots on the same carrier.

9 Overview of Real Time TBF Operation

The definition of TBF (GPRS Phase 1) is enhanced to support RT services. A RT TBF may be bi-directional (e.g. speech) or unidirectional (e.g. best effort data). The initial establishment of a RT TBF is carried on a PCCCH or CCCH. Each RT TBF has an associated TBF profile. The negotiation of a RT TBF profile during TBF setup includes the QoS requirements and the protocol stack supported by the RAB.

Additional information that is exchanged during initial TBF setup includes the following:

- A temporary MS Access Request Identifier, ARI, is allocated by the network and is sent to the MS.
- Carrier information (including frequency-hopping sequence) is communicated to the MS, either by broadcast message over PBCCH/BCCH or explicit signaling. The details are FFS.
- TBF identifier (TBFI) is assigned to the MS per requested TBF.
- TBF Inactivity Timer is negotiated for RT and NRT data TBFs. It is optional for RT speech TBF (FFS).

Once a RT TBF is established, the MS is assigned a set of RT control channels, namely FRACH, FACKCH, UBMCH and UPRCH (for speech TBF only) for uplink signaling, and FASSCH, DBMCH and DPRCH (for speech TBF only) for downlink signaling and control. An UPRCH (or a DPRCH) may be reassigned each time a UTCH (or a DTCH) is released. The rest of the control channels, i.e. FRACH, FACKCH and UBMCH for uplink, and FASSCH and DBMCH for downlink, do not need to be reassigned for the duration of the TBF.

The uplink and/or downlink traffic associated with the RT TBF is activated independently using fast access and fast assignment procedures. Additional RT and NRT TBF(s) can be negotiated and established on the RT control channel(s).

An established bi-directional TBF has the following 4 states: TBF Inactive, DL Active, UL Active, and DL and UL Active. The state transition diagram for a single bi-directional RT TBF is shown in Figure 3. The state transitions for a unidirectional RT TBF and NRT TBF (as defined in EGPRS Phase 1) are a subset of the states and allowable transitions associated with bi-directional RT TBF.

9.1 RT TBF State Definition

9.1.1 RT TBF State: TBF Inactive

In this state, there is no uplink or downlink traffic channel assigned to the MS for the TBF. The MS and the network may independently initiate uplink and downlink traffic, set up a new TBF, end a current TBF, or end all TBFs associated with the MS. The network may also reassign common control channels to the MS.

A timer may be associated with this state per RT TBF, which allows the MS to be in TBF established state for a configurable time after the downlink and uplink traffic end. This avoids re-negotiation of the RT TBF profile, should downlink or uplink traffic flow resume within a short period of time.

9.1.2 RT TBF State: DL Active

In this state, the MS is assigned a downlink traffic channel associated with the RT TBF.

Downlink single burst messages are transmitted using BFACCH. Other downlink signaling and control messages are transmitted using FACCH and/or MSACCH during a speech TBF, or using the PACCH associated with the data traffic channel. Alternately, the network may establish that block signaling messages are to be transmitted on a DBMCH, if the mobile has an acceptable multislot class.

Uplink signaling and control messages are carried on uplink common channels assigned to the MS, which are shared among parallel TBFs the MS may have established.

New TBFs may be initiated on the RT control channels.

9.1.3 RT TBF State: UL Active

In this state, the MS is assigned an uplink traffic channel associated with the RT TBF.

Uplink single burst messages are transmitted using BFACCH. Other uplink signaling and control messages are transmitted using FACCH and/or MSACCH during a speech TBF, or using the PACCH associated with the data traffic channel. Alternately, the network may establish that block signaling messages are to be transmitted on a UBMCH, if the mobile has an acceptable multislot class.

Downlink signaling and control messages are carried on downlink common control channels assigned to the MS, which are shared among parallel TBFs the MS may have established.

New TBFs may be initiated on the RT control channels.

9.1.4 RT TBF State: DL and UL Active

In this state, the MS is assigned an uplink traffic channel and a downlink traffic channel associated with the RT TBF.

Both downlink and uplink single burst messages are transmitted using BFACCH. Other signaling and control messages are transmitted using FACCH and/or MSACCH during a speech TBF, or using the PACCH associated with one of the data traffic channels. Alternately, the network may establish that block signaling messages are to be transmitted on a DBMCH and/or UBMCH, if the mobile has an acceptable multislot class.

New TBFs may be initiated on the RT control channels.

9.2 Support for Multiple TBFs

The MS or the network may initiate an additional TBF from any of the four TBF states (see Section 9.1) of the established TBFs. Assuming that there are N TBFs being established, where N > 0, and each established TBFs may be in any of the four states, **Figure 4** illustrates the establishment/release of the (N+1)th TBF and corresponding TBF state transition. Each of the established TBFs maintains independently its own TBF state. The signaling for establishing additional TBF may be carried over RT block message control channels, or the PCCCH/CCCH. This is FFS.

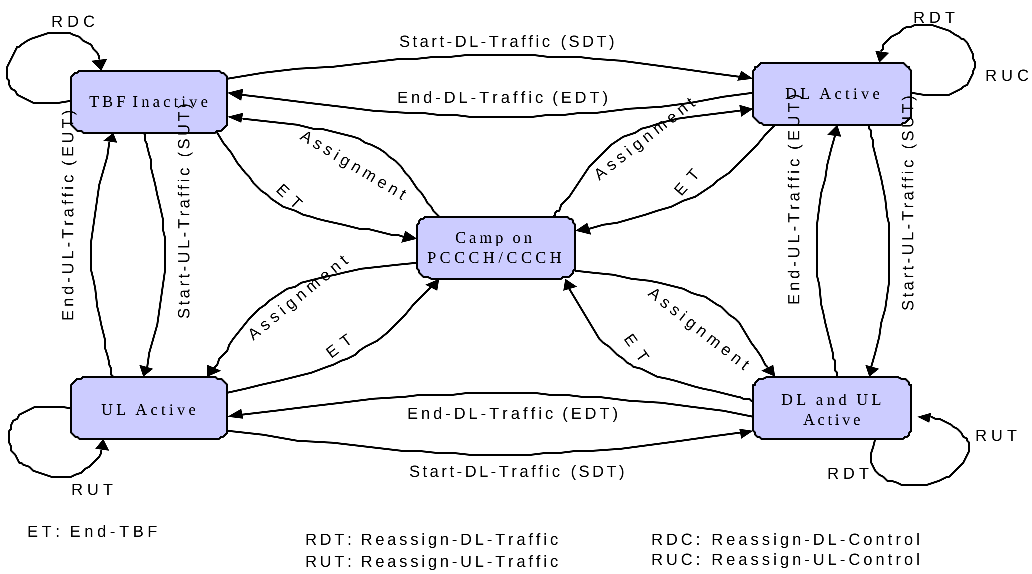


Figure 3 State Transition Diagram for an Initial Single Bi-directional RT TBF.

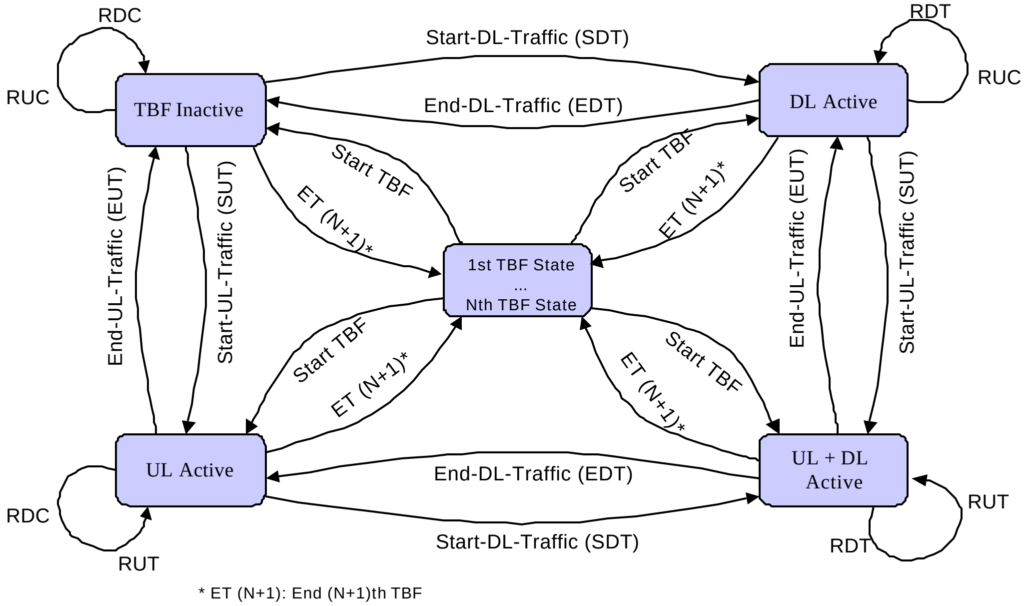


Figure 4 State Transition Diagram for the (N+1)th bi-directional TBF

10 References

[1] ETSI SMG2 EDGE Tdoc 2e99-555, “Draft GSM/EDGE RAN Concept Document, v0.1,” workshop drafting group.

[2] ETSI SMG2 Tdoc 2-00-199, “Interleaving for Half Rate Channels in EGPRS Phase II,” Lucent Technologies.

[3] ETSI SMG2 doc 2-00-201, “Performance of burst-based access and assignment for EGPRS Phase II,” Lucent Technologies.

[4] ETSI SMG2 Tdoc 2-00-202, “Capacity and Control Channel Overhead for Statistical Multiplexing of Voice in EGPRS Phase II,” Lucent Technologies.

[5] ETSI SMG2 EDGE Tdoc 2e99-574, “Capacity in Blocking and Interference Limited Scenarios”, AT&T and Lucent Technologies.

[6] UWCC Global Summit 2000, “Capacity benefits of switched beams and power control for data and voice over EGPRS”, K. Balachandran, K. Chang, N. Sanjiv,