Presentation of Specification to TSG RAN

Presentation to:	**TSG RAN Meeting # 23**
Document for presentation:	**TR25.896, Version 2.0.0**
Presented for:	**Approval**

Abstract of document:

This document is a technical report titled 'Feasibility Study for Enhanced Uplink for UTRA FDD' for the Release 6 study item “Uplink Enhancements for Dedicated Transport Channels"

Changes since last presentation to TSG RAN:

TR25.896 version 1.0.0 was presented for information for TSG RAN meeting #21. Since then the TR has grown from 63 pages to 180 pages long. Among very many other things the conclusions and recommendations chapter has been completed. More detailed descripton in [1].

Outstanding Issues:

No Outstanding Issues.

Contentious Issues:

No Contentious Issues.

References:

[1] RP-040021, Status Report for SI on Uplink Enhancements for Dedicated Transport Channels

3GPP TR 25.896 V2.0.0 (2004-03)

Technical Report

3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
Feasibility Study for Enhanced Uplink for UTRA FDD;
(Release 6)

Keywords

UMTS, radio, packet mode, layer 1

3GPP

Postal address

3GPP support office address

650 Route des Lucioles - Sophia Antipolis
Valbonne - FRANCE
Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Internet

http://www.3gpp.org

Copyright Notification

Contents

Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

3 or greater indicates TSG approved document under change control.

y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

1 Scope

This present document is the technical report for the Release 6 study item "Uplink Enhancements for Dedicated Transport Channels"(see [1]).

The purpose of this TR is to help TSG RAN WG1 to define and describe the potential enhancements under consideration and compare the benefits of each enhancement with earlier releases for improving the performance of the dedicated transport channels in UTRA FDD uplink, along with the complexity evaluation of each technique. The scope is to either enhance uplink performance in general or to enhance the uplink performance for background, interactive and streaming based traffic.

This activity involves the Radio Access work area of the 3GPP studies and has impacts both on the Mobile Equipment and Access Network of the 3GPP systems.

This document is intended to gather all information in order to compare the solutions and gains vs. complexity, and draw a conclusion on way forward.

This document is a 'living' document, i.e. it is permanently updated and presented to TSG-RAN meetings.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TD RP-020658: "Study Item Description for Uplink Enhancements for Dedicated Transport Channels ".

[2] 3GPP RAN WG1 TDOC R1-00-0909, "Evaluation Methods for High Speed Downlink Packet Access (HSDPA)", July 4 2000

[3] Hämäläinen S., P. Slanina, M. Hartman, A. Lappeteläinen, H. Holma, O. Salonaho, "A Novel Interface between Link and System Level Simulations", Proceedings of ACTS summit 1997, Aalborg, Denmark, Oct. 1997, pp. 509-604.

[4] 3GPP RAN WG1#29 TDOC R1-02-1326, "Link Prediction methodology for System Level Simulations", Shanghai China, November 5 2002.

[5] Ratasuk, Ghosh, Classon, "Quasi-Static Method for Predicting Link-Level Performance" IEEE VTC 2002.

[6] 3GPP TR 25.942 V3.3.0 (2002-06), RF System Scenarios, June 2002.

[7] 3GPP TR 25.853 V4.0.0 (2001-03), "Delay Budget within the Access Stratum", March 2001.

[8] 3GPP TS 25.133 V3.11.0 (2002-09), "Requirements for support of radio resource management (FDD) (Release 99)", September 2002.

[9] Hytönen, T.; "Optimal Wrap-around Network Simulation", Helsinki University of Technology Institute of Mathematics Research Reports, 2001, www.math.hut.fi/reports/, Report number A432

[10] “Source Models of Network Game Traffic", M. S. Borella, Proceedings, Networld+Interop '99 Engineer's Conference, May 1999.

[11] 3GPP RAN WG1#30 TDOC R1-03-0083, “Link Prediction Methodology for System Level Simlations,” Lucent Technologies, San Diego, USA, January 7-10, 2003.

[12] 3GPP2, 1xEV-DV Evaluation Methodology.

[13] ETSI TR 101 12, Universal Mobile Telecommunications System (UMTS); Selection procedures for the choice of radio transmission technologies of the UMTS (UMTS 30.03 v3.2.0)

[14] TS 25.214, v5.3.0, “Physical layer procedures (FDD)”, December 2002

[15] TS 25.331, v5.4.0, "Radio Resource Control (RRC); Protocol Specification", March 2003

[16] TS 25.321 v.5.5.0: ”Medium Access Control (MAC) Protocol Specification", June 2003

3 Definitions, symbols and abbreviations

E-DCH	Enhanced DCH, a new dedicated transport channel type or enhancements to an existing dedicated transport channel type (if required by a particular proposal)
E-DPCCH	Enhanced DPCCH, a physical control channel associated with the E-DPDCH (if required by a particular proposal)
E-DPDCH	Enhanced DPDCH, a new physical data channel or enhancements to the current DPDCH (if required by a particular proposal)

4 Introduction

At the 3GPP TSG RAN #17 meeting, SI description on “Uplink Enhancements for Dedicated Transport Channels” was approved [1].

The justification of the study item was, that since the use of IP based services becomes more important there is an increasing demand to improve the coverage and throughput as well as reduce the delay of the uplink. Applications that could benefit from an enhanced uplink may include services like video-clips, multimedia, e-mail, telematics, gaming, video-streaming etc. This study item investigates enhancements that can be applied to UTRA in order to improve the performance on uplink dedicated transport channels.

The study includes, but is not restricted to, the following topics related to enhanced uplink for UTRA FDD to enhance uplink performance in general or to enhance the uplink performance for background, interactive and streaming based traffic:

- Adaptive modulation and coding schemes
- Hybrid ARQ protocols
- Node B controlled scheduling
- Physical layer or higher layer signalling mechanisms to support the enhancements
- Fast DCH setup
- Shorter frame size and improved QoS

5 Requirements

- The overall goal is to improve the coverage and throughput as well as to reduce the delay of the uplink dedicated transport channels.

- The focus shall be on urban, sub-urban and rural deployment scenarios. Full mobility shall be supported, i.e., mobility should be supported for high-speed cases also, but optimisation should be for low-speed to medium-speed scenarios.
- The study shall investigate the possibilities to enhance the uplink performance on the dedicated transport channels in general, with priority to streaming, interactive and background services.
- Features or group of features should demonstrate significant incremental gain, with reasonable complexity. The value added per feature should be considered in the evaluation.
- The UE and network complexity shall be minimised for a given level of system performance.
- The impact on current releases in terms of both protocol and hardware perspectives shall be taken into account.
- It shall be possible to introduce the new features in the network which has terminals from Release’99, Release 4 or Release 5.

6 Reference Techniques in Earlier 3GPP Releases

6.1 DCH Setup Mechanisms

A fundamental concept in WCDMA is the connection state model, illustrated in Figure 6.1.1. The connection state model enables optimization of radio and hardware resources depending on the activity level of each UE.

- Users with high transmission activity (in either uplink, downlink or both) should be in CELL_DCH state, where power-controlled dedicated channels are established to/from the UE. In CELL_DCH state, the UE is assigned dedicated radio and hardware resources, which minimizes processing delay and allows for high capacity.
- Users with low transmission activity should be in CELL_FACH state, where only common channels are used. The major advantages with CELL_FACH state are the possibility for low UE power consumption and that no dedicated hardware resources in the Node B are needed.
- Users with no transmission activity are in CELL_PCH or URA_PCH states, which enable very low UE power consumption but do not allow any data transmission. These states are not discussed further in this section.

Switching between CELL_DCH and CELL_FACH are controlled by the RRC based on requests from either the network or the UE. Entering CELL_DCH implies the establishment of a DCH, which involves a physical layer random access procedure, NBAP and RRC signaling, and uplink and downlink physical channel synchronization.

Clearly, it is desirable to switch a UE to CELL_FACH state when there is little transmission activity in order to save network resources and to reduce the UE power consumption. Switching between CELL_DCH and CELL_FACH is especially useful in scenarios with a large number of bursty packet data users, where there is a risk that the system becomes code limited if users temporarily not receiving/transmitting any packets are not switched to CELL_FACH. When the activity increases, the UE should rapidly be switched back to CELL_DCH and a dedicated channel be established.

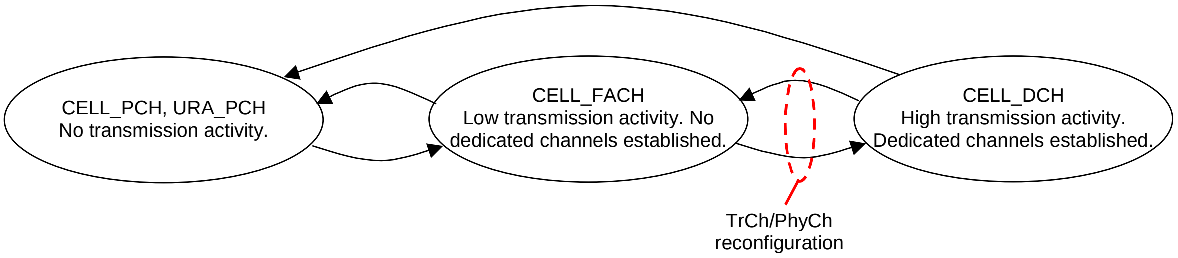

Figure 6.1.1: Connection states.

6.1.1 Uplink/Downlink Synchronization

The DCH setup procedure in Rel99/4/5 is illustrated in Figure 6.1.2. At time t_1, downlink data arrives to the RNC and a decision to establish a DCH is taken at time t_2. The decision is sent to the UE via the S-CCPCH, which starts to establish synchronization to the downlink DPCCH at time t_4, using the standardized procedure described in [14].

The downlink synchronization procedure is divided into two phases: The first phase starts when higher layers in the UE initiate physical dedicated channel establishment and lasts until 160 ms after the downlink dedicated channel is considered established by higher layers. During this time, out-of-sync shall not be reported and in-sync shall be reported using the CPHY-Sync-IND primitive if the downlink DPCCH quality exceeds a threshold for at least 40 ms. The second phase starts 160 ms after the downlink dedicated channel is considered established by higher layers. During this phase, both out-of-sync and in-sync are reported, depending on the situation in the UE. As the UE is not allowed to report in-sync until at least 40 ms after the start of the first synchronization phase, the interval T_4 equals at least 40 ms.

Once the UE has detected the in-sync condition for the downlink DPCCH, the UE starts transmitting the uplink power control preamble at time t_5. The length of the power control preamble, T_5, is set by higher layer signaling. During this period, the Node B establishes synchronization with the UE on the uplink. Once the power control preamble is finished, at t_6, the UE uplink/downlink DPCH is established and data transmission may begin.

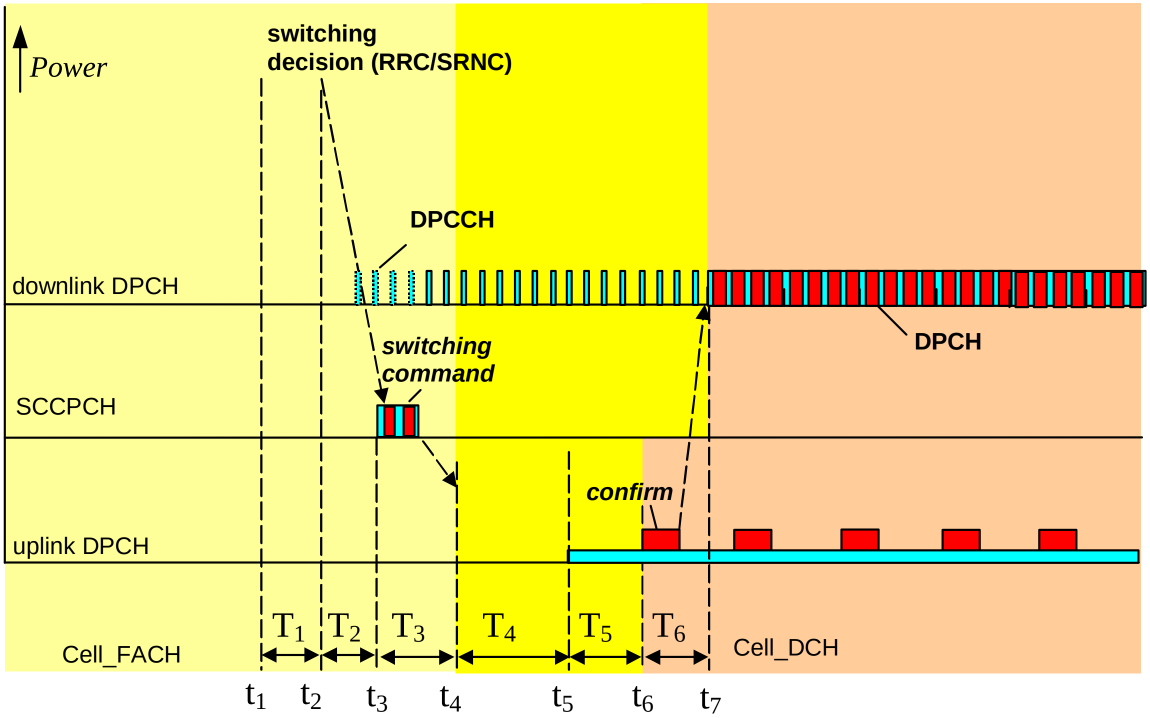

Figure 6.1.2: Rel99/4/5 procedure for DCH establishment. Note that T_6 is optional and data transmission may start already at t_6.

6.2 Uplink TFCS Management with RRC Signalling

There are following TFCS reconfiguration messages available in current specifications [15]:

- Complete reconfiguration, in which case UE shall remove a previously stored TFCS set, if it exists
- Addition, in which case UE shall insert the new additional TFC(s) into the first available position(s) in ascending order in the TFCS.
- Removal, in which case UE shall remove the TFC indicated by “IE” TFCI from the current TFCS, and regard this position (TFCI) as vacant.
- Replace, in which case UE shall replace the TFCs indicated by “IE” TFCI and replace them with the defined new TFCs.

In addition to those, there is also Transport format combination control message defined in [15], with which the network can define certain restrictions in the earlier defined TFCS set, as described below.

- Transport Format Combination Subset in the TFC control message can be defined in the format of TFCS restriction; for downgrading the original TFCS set. There are several different formats possible. The message can define the minimum allowed TFC index in the original TFCS set. Or it can define that a certain TFC subset from the original TFCS set is either allowed or not. One possible way to define the message is to list what Transport channels have restrictions, and then list the allowed TFIs for the restricted Transport channels.
- Transport Format Combination Subset in the TFC control message message can be defined in the format of canceling the earlier TFCS restriction; i.e. defining that the original TFCS set is valid again.

Transport format combination control message includes activation time. The activation time defines the frame number /time at which the changes caused by the related message shall take effect. The activation time can be defined as a function of CFN, ranging between 0…255, the default being “now”.

Transport format combination control message can also include an optional parameter of TFC control duration, which defines the period in multiples of 10 ms frames for which the defined restriction, i.e. TFC subset , is to be applied. The possible values for this are (1,2,4,8,16,24,32,48,64,128,192,256,512).

In [15], in chapter 13.5, it is defined separately for each RRC procedure, what kind of delay requirements there are for UE. For TFCS control messages there are following delay requirements:

- TRANSPORT FORMAT COMBINATION CONTROL : N1 = 5 . This defines the upper limit on the time required to execute modifications in UE after the reception of the RRC message has been completed. This means that after receiving the TFCS control message, the UE shall adopt the changes in the beginning of the next TTI starting after N1*10ms .
- TRANSPORT FORMAT COMBINATION CONTROL FAILURE: N2=8. This defines the number of 10 ms radio frames from end of reception of UTRAN -> UE message on UE physical layer before the transmission of the UE -> UTRAN response message must be ready to start on a transport channel with no access delay other than the TTI alignment. The UE response message transmission from the physical layer shall begin at the latest (N2*10)+TTI ms after completion of the reception of the last TTI carrying the triggering UTRAN -> UE message. When Target State is CELL_DCH, the UE response message transmission from the physical layer may be additionally delayed by the value of IE "SRB delay".

6.3 Transport Format Combination Selection in the UE

6.3.1 Description of TFC selection method

The TFC selection is a MAC function that the UE uses to select a TFC from its current TFCS whenever it has something to transmit. The TFC is selected based on the need for data rate (i.e. UE buffer contents), the currently available transmission power, the available TFCS and the UE’s capabilities. The details of the TFC selection function are covered in [8] and [16].

The most important parameters governing the behavior of the TFC selection function are called X,Y and Z, and their values have been agreed to be static in the current specifications. Table 6.3.1 below shows the values of these parameters.

Table 6.3.1: X, Y, Z parameters for TFC selection

X	Y	Z
15	30	30

Based on these parameters, the UE shall continuously evaluate based on the *Elimination*, *Recovery* and *Blocking* criteria defined below, how TFCs on an uplink DPDCH can be used for the purpose of TFC selection. The following diagram illustrates the state transitions for the state of a given TFC.

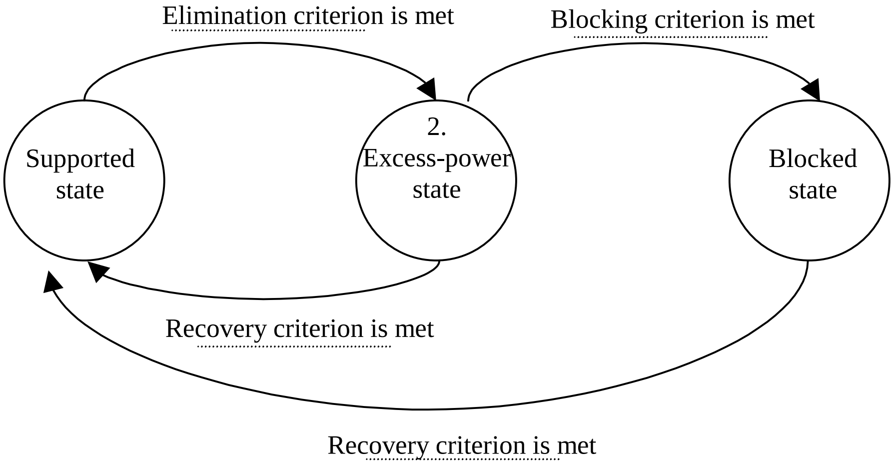

Figure 6.3.1: State transitions for the state of a given TFC

The evaluation shall be performed for every TFC in the TFCS using the estimated UE transmit power. The UE transmit power estimation for a given TFC shall be made using the UE transmitted power measured over the measurement period, defined in section 9.1.6.1 of [8] as one slot, and the gain factors of the corresponding TFC. Table 6.3.2 below, extracted from [8], shows the specified accuracy requirements for measuring UE transmit power over the one slot measurement period, as a function of the current transmit power level relative to maximum output power.

Table 6.3.2: UE transmitted power absolute accuracy

Parameter	Unit	Accuracy [dB]	
		PUEMAX 24dBm	PUEMAX 21dBm
UE transmitted power=PUEMAX	dBm	+1/-3	±2
UE transmitted power=PUEMAX-1	dBm	+1.5/-3.5	±2.5
UE transmitted power=PUEMAX-2	dBm	+2/-4	±3
UE transmitted power=PUEMAX-3	dBm	+2.5/-4.5	±3.5
PUEMAX-10≤UE transmitted power<PUEMAX-3	dBm	+3/-5	±4

NOTE 1: User equipment maximum output power, PUEMAX, is the maximum output power level without tolerance defined for the power class of the UE in TS 25.101, section 6.2.1.

The UE shall consider the *Elimination* criterion for a given TFC to be detected if the estimated UE transmit power needed for this TFC is greater than the Maximum UE transmitter power for at least X out of the last Y successive measurement periods immediately preceding evaluation. The MAC in the UE shall consider that the TFC is in Excess-Power state for the purpose of TFC selection.

MAC in the UE shall indicate the available bitrate for each logical channel to upper layers within T_{notify} from the moment the *Elimination* criterion was detected.

The UE shall consider the *Recovery* criterion for a given TFC to be detected if the estimated UE transmit power needed for this TFC has not been greater than the Maximum UE transmitter power for the last Z successive measurement periods immediately preceding evaluation. The MAC in the UE shall consider that the TFC is in Supported state for the purpose of TFC selection.

MAC in the UE shall indicate the available bitrate for each logical channel to upper layers within T_{notify} from the moment the *Recovery* criterion was detected.

The evaluation of the *Elimination* criterion and the *Recovery* criterion shall be performed at least once per radio frame.

The UE shall consider the *Blocking* criterion for a given TFC to be fulfilled at the latest at the start of the longest uplink TTI after the moment at which the TFC will have been in Excess-Power state for a duration of:

$(T_{notify} + T_{modify} + T_{L1\_proc})$

where:

T_{notify} equals 15 ms

T_{modify} equals $MAX(T_{adapt\_max}, T_{TTI})$

$T_{L1\ proc}$ equals 15 ms

T_{adapt_max} equals $MAX(T_{adapt\_1}, T_{adapt\_2}, ..., T_{adapt\_N})$

N equals the number of logical channels that need to change rate

T_{adapt_n} equals the time it takes for higher layers to provide data to MAC in a new supported bitrate,

for logical channel n. Table 6.3.3 defines T_{adapt} times for different services. For services where no codec is used T_{adapt} shall be considered to be equal to 0 ms.

Table 6.3.3: T_{adapt}

Service	T_{adapt} [ms]
UMTS AMR	60
UMTS AMR2	60

T_{TTI} equals the longest uplink TTI of the selected TFC (ms).

Before selecting a TFC, i.e. at every boundary of the shortest TTI, the set of valid TFCs shall be established. All TFCs in the set of valid TFCs shall:

1. belong to the TFCS.
2. not be in the Blocked state.
3. be compatible with the RLC configuration.
4. not require RLC to produce padding PDUs
5. not carry more bits than can be transmitted in a TTI (e.g. when compressed mode by higher layer scheduling is used and the presence of compressed frames reduces the number of bits that can be transmitted in a TTI using the Minimum SF configured).

The UE may remove from the set of valid TFCs, TFCs in Excess-power state in order to maintain the quality of service for sensitive applications (e.g. speech). Additionally, if compressed frames are present within the longest configured TTI to which the next transmission belongs, the UE may remove TFCs from the set of valid TFCs in order to account for the higher power requirements.

The chosen TFC shall be selected from within the set of valid TFCs and shall satisfy the following criteria in the order in which they are listed below:

1. No other TFC shall allow the transmission of more highest priority data than the chosen TFC.
2. No other TFC shall allow the transmission of more data from the next lower priority logical channels. Apply this criterion recursively for the remaining priority levels.
3. No other TFC shall have a lower bit rate than the chosen TFC.

The above rules for TFC selection in the UE shall apply to DCH, and the same rules shall apply for TF selection on RACH and CPCH.

UE shall consider that the Blocking criterion is never met for TFCs included in the minimum set of TFCs (see [15]).

6.3.2 TFC selection method as a reference case for Enhanced Uplink DCH

The important parameters to be included to the simulation assumptions for TFC selection method in the reference case are:

a) Accuracy of the UE transmit power estimate. See table 6.3.2 in the previous section as a reference. This will have an effect how fast UE moves a certain TFC to excess power state. Since the accuracy depends on the currently used transmit power level, it is noted for the purpose of general understanding, that the accuracy is thus in average worse with a bursty traffic model, in which quite often only DPCCH is transmitted, than with more real-time type of application in which transmission of DPDCH is more continuous. Also the location in the cell will effect to the accuracy due to the same reason. It is however seen that for the sake of simplicity, it would be appropriate to define only one value for this parameter used in all simulations.

   It is thus proposed that the accuracy defined for the maximum Ptx power level, ±2 dB, is used in all cases, for the sake of simplicity of the simulations. This is to be modelled so that the error is lognormally distributed with zero mean and std=1.2159 dB, which has the effect of causing 90% of the errors to occur within ±2 dB of the zero mean. It is noted that the accuracy requirements in [8] are also defined for 90% probability.

b) Delay between the moment when elimination criterion is met in L1 and when the TFC is moved into blocked state. See the previous section as a reference, together with the Annex A.6.4.2.1 from [8], defining the maximum delay to be $T_{notify} + T_{modify} + T_{L1\_proc} + T_{align\_TTI}$. In addition to this , if criterion is met with a maximum misalignment between the frame boundary, an extra 14 slots (9.33 ms) will need to be added to this delay. It is proposed that in the simulation assumptions the assumption is that there is no codec (e.g. AMR) involved, the rate of which should be adjusted and that the longest TTI in the selected TFC is T_{TTI} =10 ms= T_{modify}. This will result in a maximum delay of (9.33 ms + $T_{notify} + T_{modify} + T_{L1\_proc} + T_{align\_TTI}$) = (9.33 + 15 + 10 + 15 + 10) ms= 59.33 ms.

c) Delay between the moment recovery criterion is met and when TFC is moved back to supported state. See the previous section as a reference, together with the Annex A.6.4.2.1 from [8], defining the maximum delay to be $T_{notify} + T_{modify} + T_{L1\_proc} + T_{align\_TTI.}$ In addition to this , if criterion is met with a maximum misalignment between the frame boundary, an extra 14 slots (9.33 ms) will need to be added to this delay. It is proposed that in the simulation assumptions the assumption is that there is no codec (e.g. AMR) involved, the rate of which should be adjusted and that the longest TTI in the selected TFC is T_{TTI} =10 ms= T_{modify}. This will result in a maximum delay of (9.33 ms + $T_{notify} + T_{modify} + T_{L1\_proc} + T_{align\_TTI}$) = (9.33 + 15 + 10 + 15 + 10) ms= 59.33 ms.

d) TFCS ; i.e. the set of allowed user bit rates allocated to the UE. These are the bit rates that UE can use in the TFC selection algorithm. There should be enough steps in the TFCS to allow the UE to decrease the used data rate in a flexible fashion at the cell edge. It is proposed that there are two TFCS sets used in the reference case: [8, 16, 32, 64, 128, 256, 384] kbit/s and [8, 16, 32, 64, 128, 256, 384, 768, 1000] kbit/s . The idea why to have 2 sets is to allow to study different peak data rate in the proposed schemes with a sensible TFCS set in the reference case to be compared with.

The parameters and parameter values explained above are inserted to the Annex A.3, System simulation assumptions, Table A - 8 - System Level Simulation parameters used in the reference rel99/rel4/rel5 case.

It is noted that TFC selection method should be modelled also in the new schemes proposed for Enhanced Uplink DCH, if there is no clear reason why it can not/should not be included into the proposed scheme. The parameters used should be the same, or at least similar (e.g. TFCS set), as defined in the reference case.

6.4 RNC controlled scheduling: DRAC and TFCS Restriction

In R99/R4/R5, the uplink scheduling and rate control resides in the RNC. UE transmission can be controlled using DRAC and TFCS Restriction.

The **DRAC** (Dynamic Resource Allocation Control) procedure is used by the network to dynamically control the allocation of resources on an uplink DCH. The method is based on statistical scheduling. In each TTI, the UE determines whether it can transmit or not based on the DRAC static parameters which have been determined by the RNC ("Transmission Time Validity" and "Time duration before retry").

DRAC parameters are broadcasted in SIB 10. The UE determines the most stringent DRAC parameters from the last received values from each cell of its active set. It also determines the allowed subset of TFCS according to the selected maximum bit rate value.

Rules have been defined so that the UE always know which DRAC static parameters to use: in case several SIB10 messages from different cells are scheduled at the same time, the UE shall only listen to the SIB10 broadcast in the cell of its Active Set having the best CPICH measurements.

7 Overview of Techniques considered to support Enhanced Uplink

7.1 Scheduling <NodeB controlled scheduling, AMC>

The term “Node B scheduling” denotes the possibility for the Node B to control, within the limits set by the RNC, the set of TFCs from which the UE may choose a suitable TFC. In Rel5, the uplink scheduling and rate control resides in the RNC. By providing the Node B with similar tools, tighter control of the uplink interference is possible which in turn, may result in increased capacity and improved coverage. Two fundamental approaches to scheduling exist:

- Rate scheduling, where all uplink transmission occur in parallel but at a low enough rate such that the desired noise rise at the Node B is not exceeded.
- Time scheduling, where theoretically only a subset of the UEs that have traffic to send are allowed to transmit at a given time, again such that the desired total noise rise at the Node B is not exceeded.

The usage of either rate or time scheduling is of course restricted by available power as the E-DCH will have to co-exist with a mix of other transmissions by that UE and other UEs in the uplink. A hybrid of these two approaches is also possible, where different proposals will tend to favor one or other of the fundamental approaches.

The scheduling schemes can all be viewed as management of the TFC selection in the UE and mainly differs in how the Node B can influence this process and the associated signaling requirements. Hence, this section aims at describing the commonalities among the scheduling schemes. Whether one or multiple methods for the Node B to influence the UE TFC selection process is to be supported is FFS.

The set of TFCs from which the UE may choose a suitable TFC is denoted “Node B controlled TFC subset” in the following. The UE selects a suitable TFC from the “Node B controlled TFC subset” employing the Rel5 TFC selection algorithm (or modifications thereof if applicable). Any TFC in the Node B controlled TFC subset might be selected by the UE, provided there is (1) sufficient power margin, (2) sufficient data available, (3) TFC is not in the blocked state. The Node B controlled TFC subset relates to the TFCS and minimum set defined in Rel5 as

- “TFCS”. This is identical to the TFCS in Rel5 and is the set of all possible TFCs as configured by the RNC.
- “Node B controlled TFC subset”. The TFC selection algorithm in the UE selects a TFC from the “Node B controlled TFC subset”. Note that the “Node B controlled TFC subset” is equal to or a subset of the TFCS and, at the same time, equal to or a superset of the minimum set, i.e.. “Minimum set” $\subseteq$ “Node B controlled TFC subset” $\subseteq$ “TFCS”.

- “Minimum set”. This is identical to the minimum set in Rel5 as specified in [15]. The UE can always select a TFC from the minimum set as TFCs in the minimum set never can be in blocked state.

In Figure 7.1, the different (sub)sets are illustrated. Setting the “Node B controlled TFC subset” equal to the TFCS would result in behavior identical to Rel5. Furthermore, note that the smallest possible “Node B controlled TFC subset” may be larger than the minimum set, i.e., “Node B controlled TFC subset” ⊃ “minimum set”.

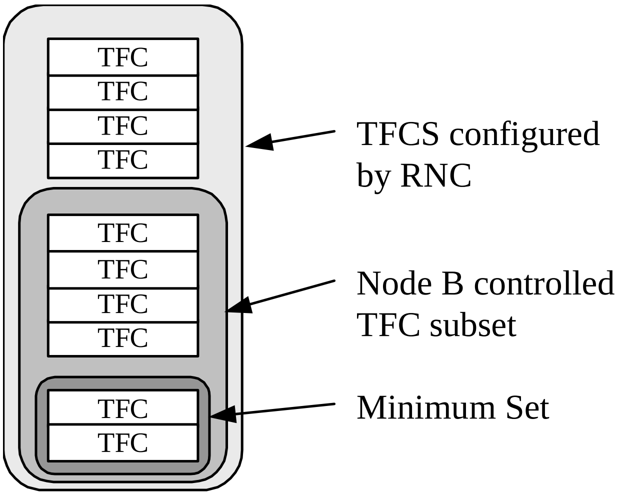

Figure 7.1 : Illustration of different sets of TFCs.

The ideas behind the ”Node B controlled TFC subset” are similar to the use of *transport format combination control* specified in [15]. This signaling is typically used to allow the RNC to control the allowed uplink transport formats by specifying a "TFC subset" along with an optional duration under which the “TFC subset” is valid. Node B scheduling can be viewed as providing the Node B with similar tools, but allowing for faster adaptation to interference variations. The interaction between RNC TFC control and Node B TFC control is FFS, although a preferable solution is to require the UE not to choose a TFC outside any of these restrictions.

The main difference between scheduling strategies is how updates to the “Node B controlled TFC subset” are controlled. In principle, an update needs to specify

- The new “Node B controlled TFC subset”
- The start time and the duration for which the update is valid
- The “Node B controlled TFC subset” to use when the scheduling period has expired.

This information can either be signaled, deduced from rules mandated in the specifications, or combinations thereof. The main difference between different scheduling approaches therefore lies in the signaling and the rules associated with the signaling. For example, simplistic implementations of rate scheduling and time scheduling could be as follows:

- Rate scheduling results if the “Node B controlled TFC subset” of different UEs are updated such that data transmission from different UEs may overlap in time, regardless of the data rates used. The new “Node B controlled TFC subset” is valid until the next time it is updated.
- Time scheduling results if the “Node B controlled TFC subset” of different UEs are updated such that only a small set of the UEs have the possibility to transmit using TFCs outside the minimum set. The updated “Node B controlled TFC subset” have a relatively short validity, typically in the order of milliseconds, where after the “Node B controlled TFC subset” reverts to the situation prior to the scheduling interval or to the minimum set.

Depending on the scheduling scheme, the signaling may take different forms. Typically, both downlink and uplink signaling is required.

Downlink signaling is required to command the UE to update the “Node B controlled TFC subset”. The start time and the duration for which the update is valid may either be signaled explicitly or deduced from rules mandated in the specifications. The signaling can either be dedicated for a certain UE, or common for several UEs. Furthermore, the signaling can either be absolute, i.e., directly specify the “Node B controlled TFC subset”, or relative, i.e., specify the new “Node B controlled TFC subset” as an update of the previous subset. The former typically allows for more rapid changes to the “Node B controlled TFC subset”, while the latter may imply less signaling overhead in the downlink direction.

In the uplink, signaling is typically required to indicate to the Node B that the UE has data to transmit. Additional information may be provided to the Node B, e.g., the amount of data, an indication of the power availability in the UE, channel quality etc.

If E-DCH utilizes the HARQ, the possible operations for scheduling considering retransmission are as follows.

- Autonomous retransmission by UE: UE sends the retransmission at subsequent retransmission timing without allowance of Node-B if UE receives no ACK. In this case, UE does not need to monitor the scheduling related channel for retransmission. But UE could cause unexpected interference in the cell if Node B does not reserve the noise rise of this UE for retransmission.
- Scheduled by Node B for retransmission: UE sends the retransmission if UE receives no ACK and Node B allows retransmission at retransmission timing. In this option, one possibility is that UE may be allowed to retransmit only if the TFC of initial transmission is within the allowed TFC subset assigned by Node B. In this case, retransmission could be delayed if Node B assigns the lower TFC subset than TFC of initial transmission. Another possibility is that even if the assigned TFC subset doesn’t include the TFC of initial transmission, UE is allowed to retransmit with the same TFC of initial transmission at a transmit power derived appropriately from the assigned TFC subset.

Considering above relationship, the design of scheduling scheme needs to take into account HARQ operation.

7.1.1 Node B Controlled Rate Scheduling by Fast TFCS Restriction Control

7.1.1.1 Purpose and General Assumptions

The purpose of the studied technique is to enable more efficient use of the uplink power resource of the cell in order to provide a higher cell throughput in the uplink and a larger coverage area for higher uplink data rates for streaming, interactive and background class services. These goals are to be reached by fast Node B controlled uplink scheduling which provides a better control to uplink noise rise and enables better control to noise rise variance.

In the existing Rel'99/Rel'4/Rel'5 system the uplink scheduling and data rate control resides in the RNC, which is not able to respond to the changes in the uplink load as fast as a control residing in Node B could. Thus the Node B control is seen to be requiring less UL noise rise headroom for combatting overload conditions. Node B control is also seen capable of smoothing the noise rise variance by allocating higher data rates quickly when the uplink load decreases and respectively by restricting the uplink data rates when the uplink load increases.

This enhancement technique is a method which itself does not require changes to the uplink DCH structure but rather introduces new L1 signalling to facilitate fast UL scheduling by means of transport format combination control. Hence the method does not require a new transport channel to be defined, but does not forbid it either. The method can be applied with or without other enhancements such as for example HARQ and Fast DCH Setup.

7.1.1.2 General Principle

The basic principle of the technique is to allow Node B set and control a new restriction to the TFC selection mechanism of the UE by fast L1 signalling. From the UE point of view the scheduling principle is the same than in existing Rel'99/Rel'4/Rel'5 system with the modification that there would be additional L1 control over a new restriction to its TFC selection mechanism. In the UTRAN side, a new scheduling by the means of fast TFCS restriction control is introduced in Node B.

All the same functions considered for the enhancement technique can be achieved with already existing RRC procedures for TFCS configuration and transport format combination control. However, by allowing the Node B to have control over TFCS restrictions (i.e. provide a mechanims for transport format combination contorol in L1) enhances the speed of which the UTRA can adapt to the changes in the UL load. In Rel'99/Rel'4/Rel'5, restricting the set of alowed TFCs in a TFCS is done using an RRC signalling procedure called transport format combination control.

7.1.1.3 Restricting the Allowed Uplink TFCs in a TFCS by L1 Signalling

In the subsequent chapters, a new mechanism and related L1 signalling are introduced. The purpose is to enable the Node B to have a fast control over the TFC subset allowed to be used by the TFC selection algorithm of the UE. This is to be achieved by defining two TFC subsets of the TFCS (A "Node B allowed TFC subset" and a "UE allowed TFC subset"), and control signalling for adjusting these subsets.

Node B provides UE with an allowed TFC subset" from which the UE's TFC selection algorithm selects a TFC to be used by employing the TFC selection method defined in Rel'99/Rel'4/Rel'5 specifications. This TFC subset provided by the Node B is is named the “UE allowed TFC subset”.

In order to give RNC efficient control over the "UE allowed TFC subset" primarily controlled by the Node B, the RNC provides the Node B with a second TFC subset named “Node B allowed TFC subset”. Node B defines and freely reconfigures the "UE allowed TFC subset" as a subset of the "Node B allowed TFC subset". It is expected that with the “Node B allowed TFC subset” RNC is able to do similar TFC restrictions as done in Rel'99/Rel'4/Rel'5 by using Transport Format Combination Control procedure defined in RRC signalling. Both subsets are defined individually for each UE.

The “UE allowed TFC subset” and the “Node B allowed TFC subset” may be signalled in the form of TFC pointers pointing to the TFCS of the UE, if the TFCs can be arranged in an order that corresponds to the TFC restriction rule (or scheduling strategy) that the Node B would be willing to apply. The ordering rule may be explicit or implicit.

In a example illustrated in the Figure7.1.1 below the Node B may want to restrict the TFCs is the order of Tx power for the CCTrCH. In Figure 7.1.1, the TFCs in a TFCS are shown ordered in descending order (with respect to the power required) starting from zero. Both TFC pointers are initialised to both the Node B and to the UE by the RNC in the beginning of the connection. After initialisation the Node B can command the UE pointer up/down with the restriction that UE pointer may not exceed Node B pointer. The TFC selection algorithm in the UE may select any TFC up to the TFC indicated by the UE pointer. The purpose here is to control the UE's power usage by restricting it's TFC (i.e. data rate) selection.

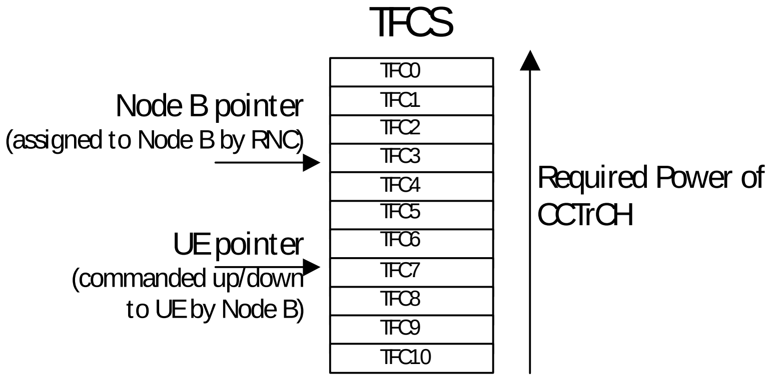

Figure 7.1.1: Depiction of the TFC pointers

The UE and Node B allowed TFC subsets should not restrict the use of the TFCs in the minimum TFC set guaranteed to be available for UE's TFC selection at all times unless the minimum TFC set definition in the already existing specifications is changed. (Minimum TFC set is defined in Rel'99/Rel'4/Rel'5 specifications)

7.1.1.4 Issues Requiring Further Studying

It is FFS, how a DCH controlled with this method could be multiplexed with DCHs controlled with Rel'99/Rel'4/Rel'5 methods, especially keeping in mind that simultaneous conversational traffic should be possible. Methods for using separate code channel and TFCS, as well as multiplexing the Node B controlled DCH with e.g. a DCH carrying voice in the same CCTrCH are to be studied. Naturally, if a DCH carrying e.g. conversational traffic is multiplexed with a DCH carrying streaming, interactive or background traffic, the first DCH carrying conversational traffic still represents the non-controllable load and only the second DCH could be controlled by the proposed method.

It is FFS how the method should work in different reconfiguration cases, such as physical channel and transport channel reconfigurations, TFCS reconfiguration for the UE, Node B allowed TFC subset reconfiguration for the Node B. E.g. in TFCS reconfiguration it should be defined whether UE continues the transmission with the new “UE allowed TFC subset”, or continues with the old one. To allow flexible update of “Node B allowed TFC subset" to the Node B, and simultaneously minimise the amount of RRC signaling, one possibility is that "Node B allowed TFC subset" is not informed to the UE at all.

It is also FFS how the method should work in soft handover. One possibility in the event the use of two pointers is applicable is to use the same kind of method as defined for TPC commands. I.e. each cell in the active set receives L1 signalling from the UE and transmits L1 signalling to the UE independently from the other cells. Only if all the cells in the active set command the UE pointer increment, the UE increases the UE pointer with one step. Respectively, if at least one Node B in the active set commands the UE pointer decrement, the UE decreases the UE pointer (and therefore the maximum power that can be transmitted) with one step. Also other possibilities exist and should be investigated.

The impacts of L1 signalling errors (including possible error accumulation) is FFS. This includes possible mitigation techniques. Both the non-SHO and the SHO cases need to be considered.

7.1.1.5 Signalling to Support Fast TFCS Restriction Control

7.1.1.5.1 L1 signaling

Two new L1 messages are introduced in order to enable the transport format combination control by L1 signalling between the Node B and the UE.

- Rate Request (RR), sent in the uplink by the UE to the Node B. With the RR the UE can ask the Node B to change the set of the allowed uplink transport format combinations within the transport format combination set.
- Rate Grant (RG), sent in the downlink by the Node B to the UE. With RG, the Node B can change the allowed uplink transport format combinations within the transport format combination set.

7.1.1.5.2 RRC signalling

7.1.1.5.3 Iub/Iur signalling

7.1.2 Method for Node B Controlled Time and Rate Scheduling

7.1.2.1 Purpose and General Assumptions

Current UMTS R99/R4/R5 DCH specifications support autonomous UE transmission and UE TFCS control using Radio Resource Control (RRC) messaging to establish and manage a per UE Transport Format Combination Set (TFCS). TFCS reconfiguration latency and update rate is restricted by the communication delay between the RNC and Node-B since the TFCS reconfiguration function is centralized in the RNC. Besides using more frequent and lower latency TFCS updates to better manage uplink interference, additional advantages are possible by controlling the time at which UEs transmit compared to allowing autonomous UE transmissions. If TFCS control is to be shared between the RNC and Node B to enable fast TFCS control and higher UE uplink data rates are to be supported, then controlling time of UE transmissions may also be necessary to most efficiently and correctly control uplink intereference levels for maximizing throughput.

7.1.2.2 General Principle

The basic principle of the technique is to allow Node B control of UE TFCS and UE transmission time by fast L1 signalling. The difference to existing R99/R4/R5 systems is that the UE would receive additional L1 control over its TFC selection and L1 control of its transmission time. From the UTRAN's perspective, scheduling by means of TFCS indicator and transmission time control is introduced at the Node B. A UE is sent a scheduling assignment by a scheduling Node B. The UE transmits during the time interval specified by the downlink scheduling assignment using a restricted TFCS, which is determined from a TFCS indicator in the scheduling assignment. It is possible to make use of existing RRC procedures for TFCS configuration and transport format combination control and utilize them at the Node B for determining a TFC. RNC and Node B control of UE TFCS and transmission time allows the UTRAN to control the changes in the UL load.

In order to achieve a better QoS and fairer scheduling decisions, Node B may also create relative Comparative Metric (CM) for UE using, for example, a combination of the following:

- It employs buffer status information received from UEs to create another comparative metric. This metric explains how much congestion is faced by each UE at uplink. Each UE is aware of buffer filling status of other UEs.
- It may also employ information for each UE such as the achieved QoS or latency to the destination and use such information to create a comparative metric for each UE. This comparative metric reveals how well each UE is doing the term of QoS provisioning comparing to other UEs.

Node B sends CM along side the TFCS to each UE for determining the UL scheduling events. In addition, it is also useful to utilise historical information and trend for each UE to determine the CM and control scheduling events for a better QoS and UL load balance.

7.1.2.3 Controlling UE TFCS and transmission time

In the subsequent chapters, a new mechanism for scheduling and related L1 signalling is introduced. The purpose is to enable the Node-B to explicitly determine when and which UE's should transmit data on the uplink and to control the TFCS at each scheduled UE to control the uplink interference level and variation.

Instead of a Node-B continously controlling each UE's TFCS by sending up/down adjustments to a pointer, the Node-B sends a TFCS indicator (which could be a pointer e.g.) in the signaled scheduling assignment. The scheduling assignment also indicates the scheduling time interval over which the UE must transmit given it has non-zero buffer occupancy. The TFCS indicator specifies the TFC(s) corresponding to the highest rate/power level the UE is allowed to transmit at during the specified time interval. After the scheduled time interval has elapsed, the TFCS reverts back to the set that existed prior to the scheduled time interval. A scheduled UE is allowed to choose among the TFCs in the restricted TFCS in terms of rate and power as determined by the TFCS indicator and based upon its own status e.g. actual available power and latest buffer status. In addition, UE may also choose rate, power and transport format based on CM. CM gives UEs information about their standing among other UEs in terms of relative congestion of buffer data and relative QoS or latency to the destination. The rates used by the UE could be signaled on the associated uplink signalling channel e.g. E-DPCCH at the time of transmission. Uplink power control information received by each UE may be used to effectively adjust the TFCS indicator over the scheduling interval.

The Node B may decide which UE(s) are allowed to transmit and the corresponding TFCS indicators on a per TTI basis based on, for example, some knowledge of the following:

- Buffer status of each UE
- Power status of each UE[1]
- Local Node B measured channel quality estimate for each UE[2] or maximum UE power capability at Node B.
- Available interference Rise Over Thermal (RoT) margin (or threshold level) at the Node B
- Comparative Metric (CM) for each UE

The RoT margin may be computed by taking into account the thermal noise, other cell interference (Ioc), the Eb/No requirements for power controlled (e.g. voice) channels (see Figure 7.1.2) and information provided by the RNC.

Node B Controlled Time and Rate scheduling may have several advantages. Reduced latencies in rate control, exploitation of fast channel quality variations, more precise RoT control (i.e., better interference management), and consequently, better efficiency for a given RoT constraint are enabled through such Node B controlled scheduling. Downlink signaling overhead is only required for a small number of scheduled UEs, rather than for all UEs in the case of a continuously updated TFCS. Furthermore, the scheduled mode can more precisely control how many UEs transmit data on their respective enhanced uplink channel in a given time interval. In the uplink of CDMA systems, simultaneous transmissions always interfere with each other and therefore, the scheduled mode can even ensure that always, for example, only one UE transmits data on its enhanced uplink channel at a time. Under certain conditions, this is likely to enhance throughput.

---

[1] Note that power status is also effectively updated at the serving Node B(s) by each uplink data transmission from the accompanying TFCI or TFRI information. It also may be advantageous to include buffer occupancy updates at the time of each uplink transmission in addition to periodic or triggered updates.

[2] Note that UE maximum power capability along with knowledge of the UE DPCCH power can be used for determining the TFCS indicator. Equivalently, Ec/Nt for the DPCCH measured at the Node B along with UE power margin to DPCCH power ratio can be used for determining the TFCS indicator.

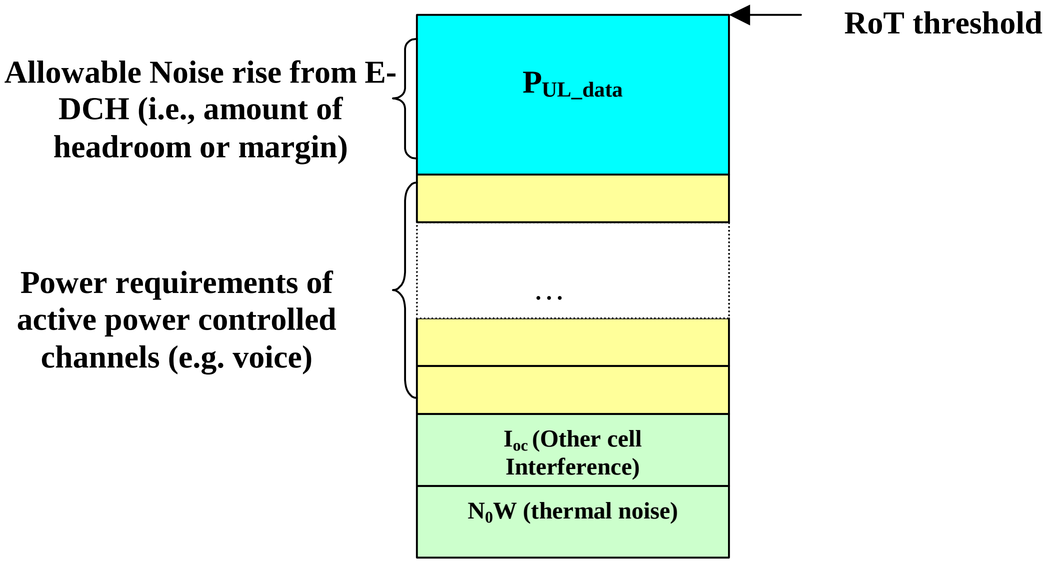

Figure 7.1.2: Noise Rise Bin for Node B controlled scheduling.

7.1.2.4 Issues Requiring Further Study

It is FFS how the method should work in soft handover. One problem is that scheduling UEs in soft handoff without any coordination between Node Bs in the active set could lead to RoT violations that significantly impact power controlled channels. However, one possibility is to simply send TFCS indicators that restrict UEs power level in soft handoff to control their interference impact on adjacent non-scheduling cells. The Node B would need to be made aware of a UEs soft handoff state in this case. Alternatively or additionally, TFC determination by the UE can include using soft handoff state information. Another limitation of scheduling a UE in soft handoff is that if the UE simply follows the scheduling command of either Node B, then the active set Node B(s) for the UE that do not schedule the user, may not attempt to decode its data. Therefore, the UE transmission will not derive any macro-diversity benefit. Yet another possiblility FFS is to use only TFCS control for UEs during soft handoff and allow autonomous transmissions. This alternative may avoid the complexity that could result in the operation of the Time and Rate scheduling in SHO. Finally, it is possible that each active set serving cell uses its knowledge of link imbalance (e.g. based on uplink DPCCH SNR consistently below the RNC defined outer loop power control threshold) to help limit scheduling activities for a given UE in soft handoff.

It is also FFS to minimize the number of scheduling information status update messages that are sent or alternatively how often scheduling information requests are made. Similarly, it needs to be determined whether UEs should autonomously report scheduling information (periodically and/or triggered on events) or whether they should only be requested by the Node B.

Finally, it is also for FFS on how to support both TFCS controlled autonomous transmissions and TFCS controlled and transmission time controlled scheduling for both the enhanced uplink DCH and along with the Rel’99/Rel’4/Rel’5 DCHs. The co-existence of the different modes may provide flexibility in serving the different traffic types. For example, traffic with small amount of data and/or higher priority such as TCP ACK may be sent using only a rate control mode with autonomous transmissions compared to using time and rate-control scheduling as the former would involve lower latency and lower signaling overhead. It also may be desirable to confine autonomous transmissions to specific time intervals different than when scheduled transmissions occur.

7.1.2.5 Signalling to Support Fast Node-B Time and Rate Control

7.1.2.5.1 L1 Signalling

Two new L1 messages are introduced in order to enable fast time and rate-control between the Node B and the UE.

- Scheduling Information Update (SI), sent in the uplink by the UE to the Node B. With the SI the UE can provide the Node B buffer occupancy and rate or power information so its scheduler(s) can maintain fairness and determine the UEs TFCS indicator and appropriate transmission time interval.

- Scheduling Assignment or Grant (SA), sent in the downlink by the Node B to the UE. With SA, the Node B can set the TFCS indicator and subsequent transmission start time(s) and time interval(s) to be used by the UE.

7.1.2.5.1.1 Uplink Signalling of Scheduling Information Update

7.1.2.5.1.1.1 Explicit scheduling information update signaling

With the explicit scheduling information update, the UE can provide the Node B with either the amount of data in its buffer or the supportable data rate as well as the transmit power status.

Since Node B cannot predict data occurrence in the UE buffer, a possible method to save uplink RoT resource would be that the UE autonomously starts transmitting the scheduling information update when the amount of data in the UE buffer exceeds a predefined threshold. The threshold can be defined by taking into account the amount of data, which can be autonomously transmitted within the delay requirement without acquiring the scheduling grant. Attaching CRC to the scheduling information update could help the Node B to detect it.

If signalling of the supportable data rate is employed, the UE could get the scheduling grant only after sending the supportable data rate to the Node B, since the Node B cannot estimate the data rate that can be accommodated by the UE.

If the data amount reporting is employed, the Node B can estimate the amount of data remaining in the UE buffer from its knowledge of amount of data received after the previous report. This provides a possibility to reduce the signalling overhead. However, it should be noted that the Node B cannot take into account new data, which has occurred after the previous report.

Possible options for data amount reporting are listed as follows:

- Periodic reporting: Amount of data in the UE buffer is reported periodically after the initial reporting. It would be worthwhile noting that the data amount reporting may be useless if no new data has occurred after the previous report. It is also noted that each UE could have different timing offset for the data amount reporting to spread out the uplink interference as done in CQI reporting in HSDPA.

- Event-triggered reporting: After the initial reporting, amount of data in the UE buffer can be reported at any time if new data occurs at the UE buffer after the previous report. How frequently it will be reported would depend on realistic traffic situation.

- Event-triggered reporting at periodic timings: After the initial reporting, amount of data in the UE buffer can be reported at the predefined periodic timings only if there is new data occurred after the previous report. The maximum reporting frequency is limited by the predefined reporting period.

Exact definition of the data amount report is FFS.

Regarding the report timing of the transmit power status, a possible option could be to send the transmit power status at the same time as the supportable data rate or the data amount report. However, another possible option could be to allow different report timing due to the following reasons:

- For efficient scheduling operation between multiple UEs, the Node B may need periodic reporting of the transmit power status from each UE.

- The data amount report timing may depend on the traffic situation as discussed above.

Exact definition of the transmit power status report is FFS. It could be a short-term measurement if instantaneous information about the transmit power status is needed. On the other hand, considering that the short-term variation in uplink channel condition can be overcome by the power control to a certain extent, it could be a long-term measurement. It is noted that it may be possible for the Node B to calculate the long-term measurement by taking average of the short-term measurements.

7.1.2.5.1.1.2 Other ways of conveying scheduling information update to Node B

7.1.2.5.2 RRC Signalling (TBD)

7.1.2.5.3 Iub/Iur Signalling (TBD)

7.1.3 Scheduling in Soft Handover

When more than one Node B control the cells present in the UE active set, there are several alternatives as to the location of the scheduling entity which controls the UE. Possible solutions are:

- The Node B controlling the best downlink cell (as defined by RRC for DSCH/HS-DSCH operation) is identified as the sole scheduling entity.
- The Node B controlling the best uplink cell (the meaning of best uplink cell would have to be defined precisely) is identified as the sole scheduling entity for the UE.
- All Node Bs controlling one or more cells in the UE active set are identified as valid scheduling entities. This approach requires an additional decision procedure in the UE when the UE receives the scheduling assignments from multiple Node Bs.

It is noted that the E-DCH transmission of the UEs in soft handover may have an effect on the RoT variation of the multiple cells in the active set. If one Node B is identified as a sole scheduling entity, scheduling of a UE in SHO without consideration of non-scheduling cells in the active set could lead to an unexpected variation of the RoT in those cells. To control the RoT variation, it is possible that a Node B uses information from the network, for example, a scheduling weight for each UE in soft handover.

If multiple Node Bs are identified as valid scheduling entities, a UE in a SHO region may receive different scheduling assignments from multiple Node Bs and hence UE operation upon receiving the scheduling assignments should be defined. Possible UE operations are as follows:

- UE chooses the scheduling assignment from the ones indicated by the controlling Node Bs. For example, either the best scheduling assignment or the worst one can be chosen.
- UE combines the scheduling assignments from the controlling Node Bs based on a certain algorithm. For example, UE generates a single scheduling assignment by applying weighting factor (determined by the network) to each scheduling assignment.

Various options have to be considered in terms of system performance in particular in presence of link imbalance and in terms of overall system complexity. Reliability of downlink signalling in soft handover, e.g., the scheduling assignment(s) from the controlling Node B(s), should be taken into account in further evaluation.

If the Node B controlled scheduling in soft handover is not seen as feasible, then one possibility would be to turn off the Node B controlled E-DCH scheduling in soft handover.

7.1.4 Node B Controlled Rate Scheduling by Persistence Control

The basic principle of the technique is to allow fast control of the number of UEs that can transmit while fast control of their TFCS restriction is still taking place. Fast control of the number of UEs is enabled by use of a persistence parameter which works in a similar way to that used for RACH or DRAC in R99/4/5. In each TTI the UEs may transmit data with a probability given by the persistence parameter. The persistence (p) is controlled and periodically updated by the Node B within constraints determined by the RNC (unlike the case of DRAC where only the RNC determined the persistence parameter).

The method is beneficial in rate control mode because one can control the interference in a system by using a single persistence value since the UE's are transmiting asynchronously. The persistence represents the available interference the system can tolerate and thus prevent's UE's in rate control mode to introduce additional interference. This in turn improves uplink capacity.

7.1.4.1 Issues Requiring Further Studying

It is FFS to determine how rate scheduling with persistence control would work in soft handoff. One possibility is to send persistence information from all Active Set cells. Another possibility to avoid uplink interference management problems from soft handoff is for a UE in soft handoff to further restrict its TFCS based on its soft handoff state. Alternatively, the persistence parameter could be modified by UEs when in soft handoff. The persistence information would apply to the rate controllable load [composed of non signaling and non-conversational data] of a CCTrCH. It is for further study on how persistence would be used in the case of multiple CCTrCHs.

7.1.4.2 Signalling to Support Fast Rate Scheduling by Persistence Control

7.1.4.2.1 L1 signaling

The persistence parameter *p* needs to be signaled on the DL to the UE from the Node-B. The persistence parameter can be different for different users.

7.1.5 Brief Overview of Different Scheduling Strategies

The purpose of this subsection is to provide a brief overview of the different scheduling strategies currently listed in the TR to simplify the understanding and highlight similarities between different proposals.

7.1.5.1 Node B Controlled Rate Scheduling by Fast TFCS Restriction Control

The basic mechanism used in this approach allows the Node B to expand/reduce the “Node B controlled TFC subset” e.g. one step at a time by differential up/down commands sent on the downlink from the Node B. The update is valid until the next update received from the Node B. Transmissions from different UEs may overlap in time.

7.1.5.2 Node B Controlled Time and Rate Scheduling

The basic mechanism used in this approach allows the Node B to update the “Node B controlled TFC subset” to any allowed value through explicit signaling specifying the new “Node B controlled TFC subset”, the start time and the validity period. The validity period is short, in the order of milliseconds, where after the “Node B controlled TFC subset” reverts to the value prior to the scheduling period. Updates of the “Node B controlled TFC subsets” for different UEs are coordinated by the Node B in order to avoid transmissions from multiple UEs overlapping in time to the extent possible.

For UEs with low delay tolerance services, a deterministic cooperative approach for time and rate scheduling may be possible for example utilising congestion-based Comparative Metric (CM) described in Section 7.1.2 to decide which UE should transmit ,when and at what data rate.

7.2 Hybrid ARQ

7.2.1 General

Node B controlled hybrid ARQ allows for rapid retransmissions of erroneously received data units, thus reducing the number of RLC retransmissions and the associated delays. This can improve the quality of service experienced by the end user. As a Node B controlled retransmission is less costly from a delay perspective, the physical channel can be operated with somewhat higher error probability than in Rel 5, which may result in improved system capacity. The retransmission probability for the initial transmission is preferably in the order of 10-20% when evaluating hybrid ARQ as closed loop power control is used for the uplink, maintaining a given quality level. Significantly higher retransmission probabilities may lead to considerably reduced end user throughput, while at very small retransmission probabilities the Node B controlled hybrid ARQ will not provide any additional gains compared to R99/4/5. Soft combining can further improve the performance of a Node B controlled hybrid ARQ mechanism.

Not all services may allow for retransmissions, e.g., conversational services with strict delay requirements. Hybrid ARQ is thus mainly applicable to interactive and background services and, to some extent, to streaming services.

Thus, the major targets from a performance point of view with hybrid ARQ to consider in the evaluation of uplink hybrid ARQ are

- reduced delay
- increased user and system throughput

The design of an uplink hybrid ARQ scheme should take the following aspects into account:

- Memory requirements, both in the UE and the Node B. Rapid retransmissions reduce the amount of buffer memory required in the Node B for buffering of soft bits when a retransmission has been requested.
- Low overhead. The overhead in terms of power and number of bits required for the operation of the hybrid ARQ protocol should be low, both in uplink and downlink. Note that, unlike the HS-DSCH, the number of simultaneous users employing hybrid ARQ for transmitting data in the uplink may be significant, stressing the fact that the overhead for each user needs to be kept at a minimum.
- In-sequence delivery. The RLC requires in sequence delivery of MAC-d PDUs. Note that the in sequence delivery mechanism can be located either in the Node B or the RNC, depending on the scheme considered.
- Operation in soft handover. In soft handover, data is received by multiple Node Bs and alignment of a user's protocol state among different Node Bs needs to be considered. This problem is not present for the HS-DSCH, were reception occurs at a single node, the UE. Therefore, the feasibility of different modes of hybrid ARQ in conjunction with soft handover needs to be studied and, if found feasible, the cost of the required signaling investigated.
- Multiplexing of multiple transport channels. Hybrid ARQ cannot be used by all transport channels and multiplexing of transport channels using hybrid ARQ and those not using hybrid ARQ needs to be considered. In the downlink, there is a separate CCTrCh carrying the HS-DSCH, while the assumption of a separate CCTrCh is not necessarily true in the uplink scenario. In R99/4/5, only a single uplink CCTrCh is allowed.
- UE power limitations. The operation of the UE controlled TFC selection for R99/4/5 channels need to be taken into account in the design. In particular, UE power limitations in conjunction with activity on other transport channels with higher priority should be considered.
- Complexity. The hybrid ARQ schemes studied should minimize as much as possible the additional implementation complexity at all involved entities.

7.2.2 Transport Channel Processing

A protocol structure with multiple stop-and-wait hybrid ARQ processes can be used, similar to the scheme employed for the downlink HS-DSCH, but with appropriate modifications motivated by the differences between uplink and downlink. The use of hybrid ARQ affects multiple layers: the coding and soft combining/decoding is handled by the physical layer, while the retransmission protocol is handled by a new MAC entity located in the Node B and a corresponding entity located in the UE.

ACK/NAK signaling and retransmissions are done per uplink TTI basis. Whether multiple transport channels using hybrid ARQ are supported and whether there may be multiple transport blocks per TTI or not are to be studied further. The decision involves e.g. further discussion whether the current definition of handling logical channel priorities by the UE in the TFC selection algorithm remains as in R99/4/5 or if it is altered. It also involves a discussion on whether different priorities are allowed in the same TTI or not. The R99/4/5 specifications require a UE to maximize the transmission of highest priority logical channel in each TTI. If this rule is maintained, the delay for different logical channel priorities could be different, depending on whether the TFCS contains one or several transport channels.

Channel coding can be done in a similar way as in the R99/4/5 uplink. Transport blocks are coded and rate matching is used to match the number of coded bits to the number of channel bits. If multiple transport channels are multiplexed, rate matching will also be used to balance the quality requirements between the different transport channels. Note that multiplexing of several transport channels implies that the number of bits may vary between retransmissions depending on the activity, i.e., the retransmission may not necessarily consist of the same set of coded bits as the original transmission.

Unlike the downlink, the uplink is not code limited and initial transmissions typically use a lower code rate than is the case for HS-DSCH. Incremental redundancy with multiple redundancy versions is mainly beneficial at a relatively high initial code rate. Thus, the need for support of multiple redundancy versions may be smaller in the uplink than for the HS-DSCH. Explicit support for multiple redundancy versions, if desired, can be incorporated in the rate matching process as was done for HS-DSCH.

7.2.3 Associated Signaling

Associated control signaling required for the operation a particular scheme consists of downlink and uplink signaling. Different proposals may have different requirements on the necessary signaling. Furthermore, the signaling structure may depend on other uplink enhancements considered.

The overhead required should be kept small in order not to waste power and code resources in the downlink and not to create unnecessary interference in the uplink.

Downlink signaling consists of a single ACK/NAK per (uplink) TTI from the Node B. Similar to the HS-DSCH, a well-defined processing time from the reception of a transport block at the Node B to the transmission of the ACK/NAK in the downlink can be used in order to avoid explicit signaling of the hybrid ARQ process number along with the ACK/NAK. The details on how to transmit the ACK/NAK are to be studied further.

The necessary information needed by the Node B to operate the hybrid ARQ mechanism can be grouped into two different categories: information required prior to soft combining/decoding (outband signaling), and information required after successful decoding (inband signaling). Depending on the scheme considered, parts of the information might either be explicitly signaled or implicitly deduced, e.g., from CFN or SFN.

The information required prior to soft combining consists of:

- Hybrid ARQ process number.
- New data indicator. The new data indicator is used to control when the soft combining buffer should be cleared in the same way as for the HS-DSCH.
- Redundancy version. If multiple redundancy versions are supported, the redundancy version needs to be known to the Node B. The potential gains with explicit support of multiple redundancy versions should be carefully weighted against the increase in overhead due to the required signaling. Note that, unlike the HS-DSCH, the number of users simultaneously transmitting data in the uplink using hybrid ARQ may be significant.
- Rate matching parameters (number of physical channel bits, transport block size). This information is required for successful decoding. In R99/4/5, there is a one-to-one mapping between the number of physical channel bits and the transport block size, given by the TFCI and attributes set by higher layer signaling. This assumption does not hold for hybrid ARQ schemes if the number of available channel bits varies between (re)transmissions, e.g., due to multiplexing with other transport channels. Hence, individual knowledge of these two quantities is required in the Node B.

The information required after successful decoding can be sent as a MAC header. The content is similar to the MAC-hs header, e.g., information for reordering, de-multiplexing of MAC-d PDUs, etc.

The information needed by UE necessary to operate the hybrid ARQ mechanism is either explicitly signaled by Node B, or decided by the UE itself, depending on the scheme. It is noted that whether the UE will decide the parameter values or the Node B will signal them, could affect the round trip time for HARQ retransmissions.

7.2.4 Operation in Soft Handover

The support of hybrid ARQ in different forms in soft handover requires careful consideration. In one possible scheme, all Node Bs serving the UE process the received data and transmit ACK or NAK to signal the result. If the UE does not receive an ACK from any of the involved Node Bs, it will schedule a retransmission. Otherwise, the transport block(s) will be considered as successfully transmitted and the UE will increment the new data indicator to signal to all involved Node Bs that the new data should not be soft combined with previous transmissions. To ensure that all involved Node Bs have the possibility to decode the transmission, regardless of the result from earlier transmissions, self-decodable transmissions are preferable.

A major problem with Node B controlled hybrid ARQ in soft handover is the link imbalance. Since the associated up- and downlink signaling does not benefit from the soft handover gain, it might be error-prone and/or require significant power offsets. Therefore, the feasibility of hybrid ARQ in soft handover situations should be investigated, taking the power required for control signaling into account. Protocol robustness in presence of signaling errors needs to be considered and additional protection of the control signaling may be required.

In the downlink direction, the UE may not be able to receive the ACK/NAK signals from all involved Node Bs. The consequences of downlink ACK/NAK errors are similar to the uplink ACK/NAK errors studied for HS-DSCH and it should be studied whether solutions similar to those used for HS-DSCH are applicable.

In the uplink direction, not all involved Node Bs may be able to receive the associated control signaling from the UE, which may lead to unsynchronised soft buffers between different Node Bs. This could result in erroneous combining of new packets with previously stored packets that have not been flushed. One possibility to reduce the occurrence of erroneous combining could be to increase the reliability of the uplink HARQ control signaling. This could be for example done by power offsets or by increasing the number of bits for the New Data Indicator thus making a wrap around of the NDI less likely. An alternative could be to operate without soft combining in soft handover situations, removing the need for reliable outband signaling of the new data indicator and the hybrid ARQ process number. More robust inband signaling can be used for these quantities instead. Node B controlled ARQ without soft combining could be considered in non-soft-handover as well, if clear gains are seen only from the ARQ mechanism and not from the soft combining itself. Another possibility, preserving support for hybrid ARQ with soft combining in soft handover, could be to synchronize the NodeB's soft buffer content via additional network signalling or to locate the soft buffer in the Node B and the final ACK/NAK decision in the RNC. This technique allows the RNC to align the soft buffer status in each Node B and may benefit from the soft handover gain for the related hybrid ARQ control signaling, but the delays will be larger than for a pure Node B controlled scheme.

7.3 Fast DCH Setup Mechanisms

7.3.1 Background

Possible enhancements include, but are not limited to, the physical layer random access procedures, NBAP/RRC signaling, and uplink/downlink synchronization procedures. Any enhancement, or combination of enhancements, to the procedures for fast DCH establishments should fulfill the following requirements:

- Allow for significant reduction in switching delays.
- Fit into the connection state model and, to the extent possible, reuse existing procedures and techniques.
- Allow for unaffected operation of existing UEs and Node Bs

7.3.2 Reducing Uplink/Downlink Synchronization Time

Establishing a DCH requires the UE and Node B to synchronize the physical up- and downlink channels as briefly described in Section 6.1.1. Techniques to reduce the downlink and/or uplink synchronization time should be studied as a part of the overall goal of reducing the delays associated with DCH establishment.

The overall delay from t_1 to t_7 in Figure 6.1.2 depends both on the implementation, the performance requirements on the UE, and the procedures in the 3GPP specifications. T_1 and T_2 mainly depend on network implementation. T_3 depends on the TTI used for FACH, which could be shortened at the cost of a reduced interleaving gain, and the UE processing delays. In this section, a technique for reducing T_4, accounting for 40+(N312-1)*10 ms delay, where N312=(1, 2, 4, 20, 50, 100, 200, 400, 600, 800, 1000) and T_5, accounting for 10-70 ms delay, by using an improved synchronization scheme is proposed.

The proposed enhancement is illustrated in Figure 7.3.1. The basic idea is to replace the presently defined DPCCH uplink and downlink synchronization scheme requiring a time interval T_4+T_5 (specified in [14]) with an enhanced scheme reducing this time to 10 ms. A power ramping procedure is used, where the power of the uplink DPCCH is ramped up from a calculated initial power level by sending power up commands from the Node B until the Node B has obtained synchronization to the uplink signal. Acquisition of the uplink signal is indicated to the UE on the downlink DPCCH simply by sending power down commands. In the radio frame following the power control preamble, data transmission on both uplink and downlink DPDCH can start.

InFigure 7.3.2, the power ramping phase is illustrated in more detail. Downlink and uplink DPCH transmission shall start at the same frame number, which shall be indicated in the switching message to the UE. Note that the UE already has received data on the S-CCPCH and thus is synchronized to the network, and the relative timing between downlink DPCH and S-CCPCH is known from L3 signaling, In Figure 7.3.2, downlink transmission starts at time instant t_1 (which corresponds to $t_4 = t_5$ in Figure 7.3.1), with some offset relative to the frame timing of the CPICH. The offset is indicated to the UE in the switching command. Uplink transmission shall start with a timing offset relative to the downlink DPCH, i.e., at $t_1+T_0+\tau$, where τ is the delay of the first detected path measured on CPICH and T_0 = 1024 chip intervals, as specified in [14]

For uplink ramping, a predefined setting of all DPCCH bits is preferably used to make it possible to collect all transmitted energy for initial synchronization in the Node B receiver without caring on modulation. Uplink DPCCH power is ramped up with one step per slot. In the ramping phase, downlink TPC bits from the Node B should be set to "up". As soon as the Node B receiver has been reliably synchronized to the uplink, the Node B shall enter power control operation, i.e., transmit up/down power control commands and evaluate the TPC information received on the uplink DPCCH (time instant t_2 in Figure 7.3.2). In-sync detection is tested in Node B similarly as for PRACH preambles based on thresholds. The UE is informed when Node B obtains in-sync through the TPC pattern received on the downlink.

Note that the Node B uplink receiver can collect the energy for the entire ramping phase, not only the energy of the last slot. Furthermore, as there is no modulation present on the DPCCH, it is possible to achieve a very large processing gain at the receiver, equal to all 2560 chips (34 dB). This allows for very power efficient, highly secure detection of the DPCCH transmission in the Node B. One possibility is to use peak detection in long-term delay power spectrum estimations, which for instance can be calculated with a matched filter.

The initial downlink DPCCH power level is determined in the same fashion as in the present procedure, i.e., by using the initial downlink DPCH power level IE present in the "Radio Link Setup/Addition Request" messages. Setting of the initial power is implementation dependent. If prior information on the distance between UE and Node B or a path loss measurement is available in the RNC, this can be used for more tight setting of the initial downlink DPCCH power level. If no distance or path loss information is available, a "broadcast power level" needs to be employed. To secure reception of the downlink DPCCH, its initial power should in any case be chosen somewhat higher than needed according to pre-calculations. This means that as soon as the inner power control loop starts operation (time instant t_2 in Figure 7.3.2), it is very likely that downlink power is ramped down first. In the proposed fast synchronization scheme, setting of initial downlink power is much less critical than in the Rel99/4/5 scheme as a somewhat too high power would be employed only for a very short time interval.

DPCH setup failure in the Node B is identified when no uplink synchronization is obtained within the preamble period. In the case, the downlink DPCCH transmission should be stopped at the end of the preamble interval. Stop of downlink transmissions shall be identified in the UE by means of a fast DL DPCCH synchronization status detection scheme and stop further uplink transmissions. Further handling of DPCH setup failure could be done in several ways. For instance, a new attempt could be made a predefined time after the first try. Alternatively, the physical channel reconfiguration failure procedure as defined in [15]. could apply also for this new scheme.

Introducing enhancements such as those described above can be done by defining "Synchronization Procedure C" in addition to procedures A and B already specified in [14]. The impact on higher layers, the interaction with power control, and in which scenarios a new synchronization procedure may be applied are for further study.

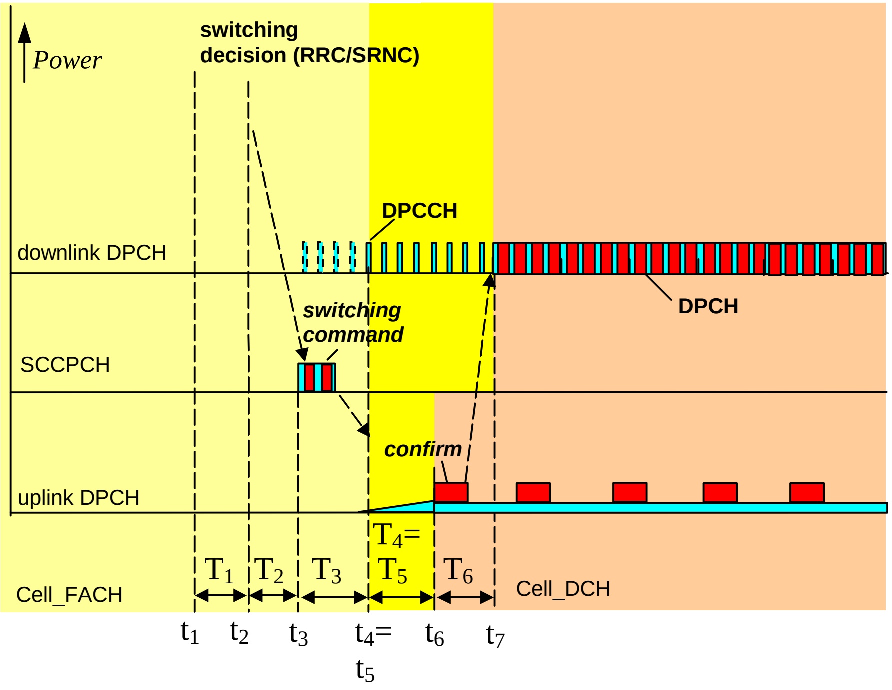

Figure 7.3.1: Enhanced procedure for DCH establishment.

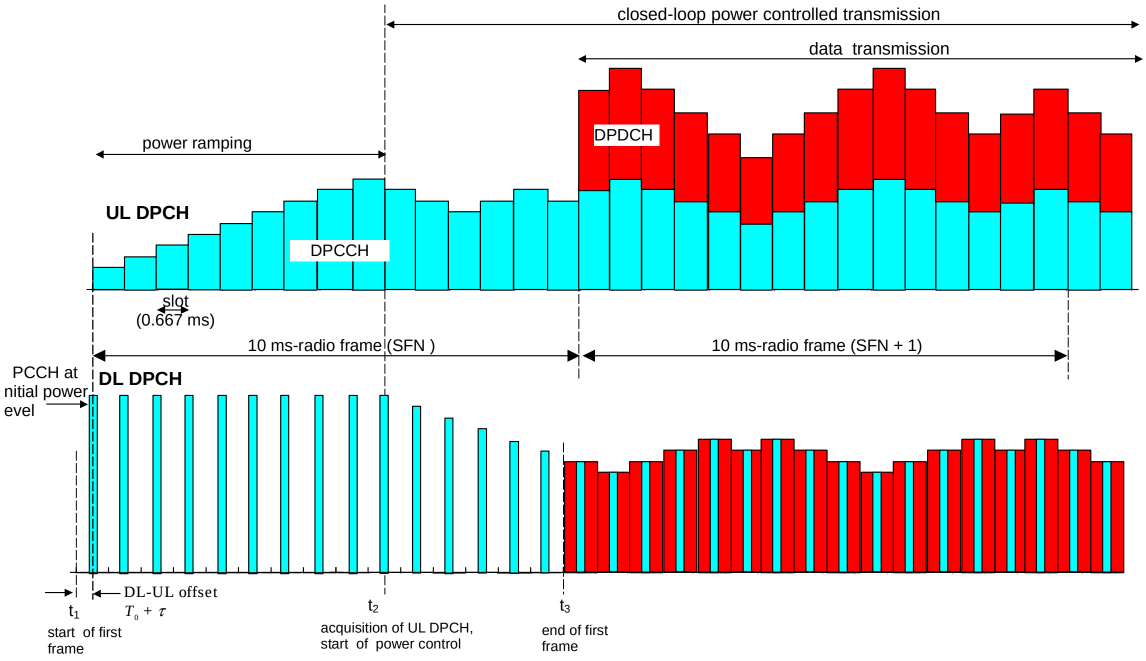

Figure 7.3.2: Illustration of the enhanced uplink/downlink synchronization scheme.

7.4 Shorter Frame Size for Improved QoS

Reducing the minimum TTI supported from the 10 ms in Rel5 to a lower value may reduce the transfer delay through a reduced Uu transfer delay and reduced delays due to TTI alignment (incoming data to be transmitted has to wait until the start of the next TTI). A reduced TTI may also allow for reduced processing time as the payload sizes are reduced compared to a larger TTI, a shortened roundtrip time in Node B controlled hybrid ARQ protocols and reduced latencies in some scheduling schemes. Reduced delays may also result in a higher system throughput and better resource utilization.

Thus, the major targets from a performance point of view with a reduced uplink TTI are:

- improved end-user quality
- increased user and system throughput
- significant delay reduction

The introduction of a reduced TTI should take the following aspects into account:

- End-user delay. Any reduced TTI considered should result in the possibility for a significant reduction in uplink delay while still support reasonable payloads.
- Choice of shorter TTI. It is preferable if the Rel5 minimum TTI of 10 ms is a multiple of the reduced TTI considered. The obvious choice is a 2 ms TTI, which also is an alignment to the short TTI adopted for HS-DSCH.
- Link performance. The influence of a short TTI on link performance need to be considered.
- Channel structure. Support of services and applications using Rel5 channels should be considered. The operation of UE controlled TFC selection need to be taken into account. Any increase in UE peak-to-average ratio should be analyzed and kept low.
- Complexity. Any complexity increase due to a reduced TTI should be clearly motivated by a corresponding performance gain.

7.5 Signalling to support the enhancements

7.5.1 Downlink signalling

7.5.1.1 Basic considerations

It can be assumed that the operation of enhanced uplink DCH requires some new signalling in downlink direction. Whether this would be (hybrid) ARQ related, scheduling related, or something else is for further discussion.

There are some requirements for the physical channel structure for L1 signalling in downlink:

- The L1 signalling in downlink should be independent from HS-DSCH operation: UE should not be required to support HS-DSCH operation at the same time with E-DCH in uplink, but it should be possible to have E-DCH in uplink and HS-DSCH in downlink at the same time.
- Delays should be kept low.
- Signalling should be possible also when the UE's DCH is in SHO. The support of E-DCH in SHO is FFS.
- Signalling reliability and overhead should be considered.
- Signalling peak power and average power requirements in the downlink should be considered.

7.5.1.2 Downlink signalling multiplexed on existing channel

Embedding the enhanced uplink signaling bits into an existing downlink code channel could be done e.g. by:

- Puncturing DPDCH bits
- Introducing a new downlink DPCH slot format (e.g. by creating a separate DPCCH field)
- Other means introducing space for the signalling bits in the DPCH

Multiplexing the signalling on the existing channel does not consume additional downlink codes or require the UE to receive any additional code channels. However, additional DPDCH power is required in order to compensate the lost energy of the DPDCH bits stolen for signaling which may result in additional downlink interference. Further, all the designs typically face a tradeoff between the required power for the signalling bits and number of DPCH bits used for signalling.

7.5.1.3 Downlink signalling on a new code channel

The enhanced uplink signaling bits could be sent on a new downlink code channel e.g. by:

- Introducing a new dedicated code channel for each UE for the signalling
- Introducing a new shared code channel(s) for the signalling

Introducing a new dedicated or shared code channel(s) does not require modification of the existing channel structure. However, it consumes additional downlink code(s) as well as requires the UE to receive additional code channel(s). On a shared code channel, signalling for multiple UEs could be multiplexed on a same shared code channel. One method of the multiplexing is to allocate mutually orthogonal symbol patterns to identify and carry signaling for each UE (i.e. code multiplexing). The other method is to allocate different time periods to identify and carry signaling for each UE (i.e. time multiplexing). Combination of both time and code multiplexing is also possible. Transmission of the signaling in new code channel(s) also requires additional downlink transmit power and hence may result in additional downlink interference.

7.5.2 Uplink signalling

7.5.2.1 Basic considerations

Operation of enhanced uplink DCH may also require signalling in the uplink direction. Whether this would be (hybrid) ARQ related, scheduling related, or something else is for further discussion.

There are some requirements for the physical channel structure for L1 signalling on uplink:

- The L1 signalling in uplink should be independent from HS-DSCH operation: UE should not be required to support HS-DSCH operation at the same time with E-DCH in uplink, but it should be possible to have E-DCH in uplink and HS-DSCH in downlink at the same time.
- Delays should be kept low.
- Signalling should be possible also when the UE's DCH is in SHO. The support of E-DCH in SHO is FFS.
- The effect of PAR needs to be taken into consideration when designing signalling channel for the uplink.
- The relative power offsets between various uplink channels needs to be set appropriately so as to achieve reliable signalling while at the same time optimising peak and average power requirements at the UE.
- Signalling reliability should be balanced with minimizing overhead.
- Signalling channel can be sent time aligned or not time-aligned with the enhanced uplink DCH. The effect of time aligned or not time aligned control channel on Node-B decoding time, sector throughputs etc. should be considered.

7.5.2.2 Coding, multiplexing and mapping options

Table 7.5.2 provides a list of parameters and possible options related to coding, multiplexing and mapping of the UL signalling. All of these options can be combined and the value of each combination could be evaluated. Some of the resulting combinations are described and evaluated in section 9.2.4

Table 7.5.2: UL signalling coding, multiplexing and mapping options

Parameter	Options	Comments
TTI	10 ms / 2 ms	2 ms is to illustrate a shorter TTI value
Timing relative to E-DCH transmission	Aligned / prior	Transmission prior to E-DCH transmission provides possibility for early decoding procedure, but implies longer HARQ delays or reduced processing time in the UE
CRC	Yes / no	
Coding	CC / Block / Repetition / Hybrid	Repetition coding allows for early UL signalling decoding and may reduce buffering requirement in the Node B
Mapping	(E-)DPDCH / DPCCH / E-DPCCH	(E-)DPDCH and DPCCH mapping are described in section 7.5.2.2.1 and 7.5.2.2.2 respectively. Mapping the control bits on a new code channel is described in section 7.5.2.2.3; using SF=256 allows mapping of UL signalling bits with either 2 ms or 10 ms TTI.

7.5.2.2.1 Mapping on (E-)DPDCH

The UL signalling bits could be mapped on the DPDCH or E-DPDCH using one of the approaches described in table 7.5.3.

Table 7.5.3: UL signalling mapping options on DPDCH

Mapping option	Applicable TTI	Backward compatible	Payload	Comments
DPDCH as a TrCH	10	Yes	Large	Described in section 7.5.2.2.1.1. Implies that the UL signalling transmission is frame aligned with the DPCH.
(E-)DPDCH with TDM	2/10	(Yes)	Large	This approach is described in section 8.4.1.1.2.2.

7.5.2.2.1.1 Mapping on DPDCH using a TrCH

Assuming 10 ms TTI, the UL signalling bits can be mapped on the DPDCH using an in-band signalling approach. UL signalling is therefore considered as a regular transport channel and is multiplexed with other transport channels and mapped on the DPDCH. The UL signalling error rate can be controlled by adjusting the rate matching parameter and adding a CRC.

The Node-B procedure for E-DCH decoding is hierarchical in the sense that the Node B first has to decode the DPDCH to have access to the UL signalling bits and subsequently decode the E-DPCH. From a layering point of view this approach implies that a transport channel would be terminated at the Node-B. The only new requirement on the Iub is a mean to signal that a particular TrCH contains the UL signalling bits.

One significant benefit with this approach is the backward compatibility with earlier releases. Indeed the UL signalling bits are received as any other TrCH by the legacy Node B and the RNC can simply discard the data or even use it for resource management.

7.5.2.2.2 Mapping on DPCCH

The UL signalling bits could be mapped on the DPCCH using one of the approaches described in table 7.5.4.

Table 7.5.4: UL signalling mapping options on DPCCH

Mapping option	Applicable TTI	Backward compatible	Payload	Comments
Rel-5 TFCI approach	10	(Yes)	<8 bits	Straightforward approach. Implies that the UL signalling transmission is frame aligned with the DPCH.
Split mode TFCI	10	No	<8 bits	Replication of downlink approach in the uplink. May not need frame alignment with DPCH (FFS)
Bit stealing (e.g. FBI)	10	(Yes)	Small	Impacts performance of DPCH and may prevent use of existing features (e.g. closed loop diversity or SSDT)
New slot format(s)	2/10	No	Unlimited	Offers the most flexibility at the price of backward compatibility.

7.5.2.2.3 Mapping on a new code channel

This approach consist in mapping the UL signalling bits on a new physical code channel. Table 7.5.5 provides a summary of the key aspects of such approach.

Table 7.5.5: UL signalling mapping options on new code channel

Mapping option	Applicable TTI	Backward compatible	Payload	Comments
New code channel	2/10	Yes	Unlimited	Straightforward approach which offers a maximum of flexibility and is fully backward compatible. Potential PAR issues.

7.6 Miscellaneous enhancements

7.6.1 Support for enhanced channel estimation

Degraded performance of channel estimation leads to an increased SNR requirement for the same BLER target. For the higher data rates conceived for E-DCH, any reduction in the high SNR requirement could lead to higher system capacity. One possible technique to reduce the required SNR is to allow for better channel estimation techniques at the receiver. L1 techniques to facilitate better channel estimation at the receiver should be considered. These include:

- Transmission of additional pilot energy
- Data aided channel estimation
- Modified power control procedure

To justify the use of any L1 based enhanced channel estimation techniques, the following studies must be conducted.

- Incremental benefit of any enhanced L1 scheme over existing mechanisms
  - Impact on link performance
  - Impact on system capacity
- Impact on PAR and associated cell coverage
- Impact on receiver complexity
- Backward compatibility

8 Physical Layer Structure Alternatives for Enhanced Uplink DCH

8.1 Relationship to existing transport channels

It remains to be determined whether there will be a new transport channel added to RAN specification. Uplink enhancements may

- consist of methods limited on improving the utilization of existing transport channels or
- introduce methods that require new transport and physical channels

In order to encompass both possibilities, the transport channel is referred here as E-DCH.

8.1.1 Transport Channel Structure

To support some of the enhancements currently under consideration, a new transport channel type, the E-DCH, is introduced. Depending on future decisions on which enhancements to support and how to support them, the E-DCH may or may not be identical to the DCH.

In order to find a suitable structure for supporting the E-DCH, there are some issues that need to be addressed:

- The number of E-DCHs supporting simultaneous transmission
- Static or semi-static TTI.
- One or multiple CCTrCHs. Either one or multiple uplink CCTrCHs are required, depending on the physical channel structure adopted.

In Figure 8.1.1, a generic structure is illustrated, not making any particular assumption on the number of CCTrCHs, E-DCHs or the TTIs supported. For E-DCHs using (hybrid) ARQ, a new MAC-e entity is introduced to handle the retransmission protocol in a similar way as for HS-DSCH. In any scheme with more than one MAC-e, there will be a dependency between the MAC-e entities as, according to section 7.2.3, a single ACK/NAK per uplink TTI is used. Thus, if multiple E-DCHs are supported, a retransmission request is valid for all E-DCHs using hybrid ARQ in the corresponding interval.

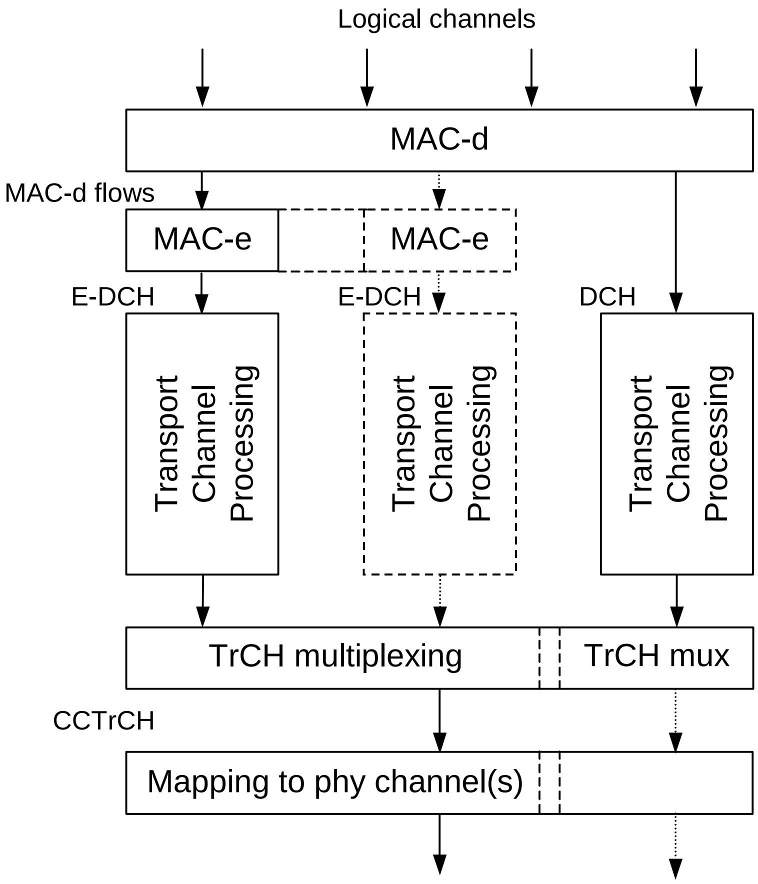

Figure 8.1.1: Simplified illustration of possible transport channel structures.

8.1.1.1 Number of E-DCHs

Supporting only one E-DCH may simplify transport channel multiplexing and reduce the amount of additional outband signaling. MAC layer multiplexing may be used to support (simultaneous) transmission of multiple MAC-d flows (possibly with different priorities) into a single transport channel. Inband signaling may be used for separating the received data into different MAC-d flows instead of relying on the TFCI.

Supporting multiple E-DCHs may allow for greater flexibility but may require more outband signaling compared to a single E-DCH. One E-DCH can be set up for each MAC-d flow. Outband TFCI signaling is used to demultiplex the received data into multiple transport channels/MAC-d flows.

The interaction with TFC selection needs to be considered. According to Rel5, logical channels in the uplink have absolute priority, i.e., the UE shall maximize transmission of high priority data in each TTI. Whether this rule is to be maintained for the E-DCH or not is FFS, although the TFC selection needs to take both DCHs and E-DCHs into account. If the Rel5 principle is retained, TFC selection and MAC-e (if applicable) multiplexing must be jointly designed in order not to “starve” low-priority MAC-d flows.

8.1.1.2 TTI

A static TTI, i.e., the specifications mandates a single TTI value to be supported by the E-DCH, may simplify the processing. Obviously a static TTI will prohibit the use of (hybrid) ARQ in conjunction with TTIs other than the one specified for E-DCH.

A semi-static TTI, i.e., the network configures the TTI to use when configuring the E-DCH, is in line with other Rel5 transport channels and may be useful in some situations.

8.2 TTI length vs. HARQ physical channel structure

Two different TTIs have been mentioned in conjunction with uplink enhancements: either reusing the existing R99 10 ms TTI or introducing a shorter (e.g., 2 ms) TTI:

- Using a 10 ms TTI allows for reusing the R99 DPDCH structure, including baseband processing and TFCI signaling. The drawback is the, compared to a shorter TTI, larger delays. Using QPSK in the uplink can lead to an increase in PAR, although the value of the PAR increase remains to be investigated.

- Using a 2 ms TTI allows for reduced delays. The drawback is the need for a new physical layer frame structure and TFCI-like signaling. The most straightforward way of supporting a short (2 ms) TTI seems to be the introduction of a new code multiplexed physical channel in the uplink. Using additional codes in the uplink can lead to an increase in PAR, although the value of the PAR increase remains to be investigated.

These TTI lengths of 10 ms and 2 ms are considered here as examples.

If E-DCH utilizes physical layer HARQ, there is a need to transmit ACK/NACK signaling in a downlink physical channel. N defines the minimum number of HARQ processes required to provide continuous transmission. However, increasing the number of HARQ channels also adds to round trip time and thus N cannot be arbitrarily large. A compromise between round trip time and processing time is of main importance when considering the selection of N.

If the available time for downlink signaling and UE/Node B processing is made long enough through suitable selection of N, ACK/NACK could be embedded in existing Rel’99 downlink channel structure, i.e. within a 10 ms TTI. Another option is to reserve a specific field shorter than 10 ms time period, in a downlink physical channel for ACK/NACK as is done in HS-DPCCH for uplink in Rel’5 HSDPA. The downlink ACK/NACK field length is naturally independent of TTI length in uplink.

Figure 8.2.1 depicts the general concept of timing for E-DCH HARQ process. After having received transport block(s) on E-DCH the Node B has T_{NBP} for processing and sending acknowledgement to the UE. In here no assumption is made on which downlink physical channel the ACK/NACK in DL would be sent. Based on the acknowledgement and possible other information provided by the UTRAN, the UE decides whether it resends the transport block(s) or transmits new transport block(s). The processing time available for the UE between receiving the acknowledgement and transmitting the next TTI in the same HARQ process is T_{UEP}.

The length of the acknowledgement field in DL directly affects the available processing time in Node B and UE. The length of the acknowledgement field might also affect the required power offset for transmitting it, relative to DL DPCCH, depending on the scheme. With 10 ms TTI and high enough N, acknowledgement could e,g, be embedded in existing multiplexing structure within a 10 ms TTI. This might allow more space for coding and smaller power offset for transmitting ACK/NACK than in the case where ACK/NACK is inserted into downlink physical channel within a shorter time period than 10ms.

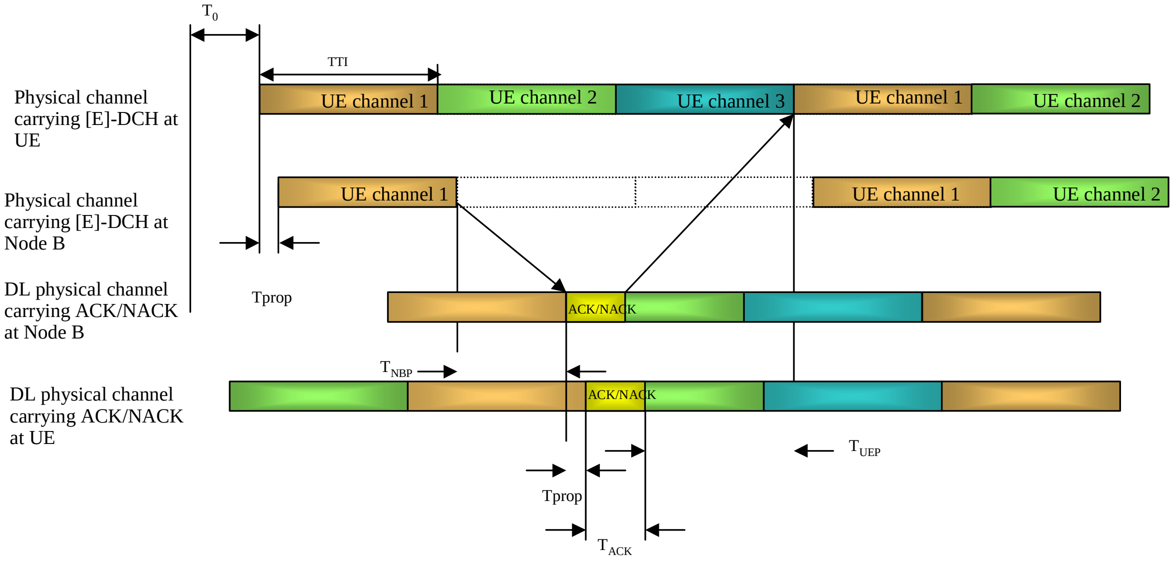

Figure 8.2.1. HARQ timing schematic for N=3, TTI=10 ms, as an example.

Table 8.2.1 presents some estimations for available processing time TTI lengths 10 ms and 2 ms, with N=2,3,4,5. The timing calculations assume a roundtrip delay of 0.1 ms. The acknowledgement signal from the Node B may be spread over one of more slots. However, the longer T_{ACK} becomes, the less processing time there is available for UE and RNS. For TTI=10 ms case, a T_{ACK} = 10 ms is possible if N=3 or larger. With TTI=2 ms, T_{ACK} necessarily has to be shorter.

Table 8.2.1. Examples of UE and Node B processing times with E-DCH

TTI length (ms)	**N**	**T_{ack} (ms)**	**$T_{NBP}+T_{UEP}$ (ms)**
10	2	2	7.9 (0.8xTTI)
10	3	2	17.9 (1.8xTTI)
10	3	10	9.9 (1.0xTTI)
10	4	2	27.9 (2.8xTTI)
10	4	10	19.9 (2.0xTTI)
2	4	2 (3 slots)	3.9 (1.95 x TTI)
2	5	2/3 (1 slot)	7.23 (3.6xTTI)
2	5	4/3 (2 slots)	6.56 (3.3xTTI)
2	6	4/3 (2 slots)	8.56 (4.3xTTI)
2	6	2 (3 slots)	7.90 (4.0xTTI)
2	7	2 (3 slots)	9.90 (5.0xTTI)

The table shows examples of the total time available for UE and Node B processing in the case of implicit scheduling. Thus, the figures in Table 8.2.1 represent minimum round trip time. Other methods with e.g. additional control channels would increase the round trip time or reduce available processing time. These methods are investigated separately. Note that the length of the E-DCH TTI also has an impact on the processing time needed. Since a shorter TTI contains fewer bits than a longer one, the processing load for baseband processing such as interleaving and turbo decoding is smaller and less time is consumed. On the other hand, interleaving gain is impacted when short TTI length is employed.

The choice of TTI and N should be done in conjunction with selecting the structure of the downlink ACK/NAK transmission. Furthermore, the maximum data rate supported will affect the required processing times. Herein, the assumption that maximum data rate would be around 1-2Mbit/s was used.

More detailed analysis of the required processing times are needed in the future, but this gives some rough estimate how the TTI length affects the HARQ physical layer structure. In addition to processing times, important issues to consider are the physical layer structure for sending the L1 signaling in uplink and downlink, and the performance and complexity related to that.

8.3 Multiplexing alternatives in general

This chapter is describing the different alternatives of how E-DCH can be multiplexed with the existing Rel'99 channel structures. (E-DCH is used as a general term referring to both a possible new type of transport channel and to possible enhancements to an existing transport channel)

There are basically two different alternatives to introduce the E-DCH: it can either be time multiplexed with other DCHs in the same way as different DCHs are multiplexed in Rel'99 or it can be code multiplexed, i.e., sent using a dedicated code channel. These alternatives are described and discussed in the following subsections.

Issues that need to be studied when considering each multiplexing alternative are:

- Possible introduction of TTI lengths shorter than 10ms
- Possible Slot or frame synchronism for E-DCH users
- Flexibility of H-ARQ operation for both soft-handoff and non soft-handoff case.

- Variable gain factors and modulation for E-DCH
- Peak to Average Power Ratio (PAR)
- Interoperability with Rel’99/Rel’4/Rel’5 base stations and support of existing R99/4/5 channels
- Impact of possible introduction of shorter TTI lengths to TFC selection algorithm
- Impact of possible introduction of multiple uplink CCTrCHs to higher layers

8.3.1 Reuse of current physical layer structure

In this alternative the E-DCH is time multiplexed into the same coded composite transport channel (CCTrCH) as the other DCHs if present. The TFCI indirectly informs where and how many bits of each DCH within the CCTrCH are, regardless of the DCH being a Rel99 DCH or an E-DCH.

Time multiplexing is easiest to implement if the TTI length is 10/20/40/80 ms, since then the Rel'99 transport channel multiplexing chain can be used. There may naturally be some enhancements, e.g., to rate matching, to support the potential new enhanced uplink features, e.g., hybrid ARQ.

The advantage of time multiplexing of the E-DCH with Rel99 DCHs is that no new code channels are unnecessarily introduced. The multicode transmission would only be used for high data rates in a similar way as specified in Rel99. This approach minimises the required peak to average power ratio (PAR) in the UE transmitter provided only one DPDCH is used. The code channel structure of this alternative is the same than is already used in Rel'99.

It may be difficult to use higher order modulation and variable gain factors with this approach. Further, the number of available channel bits on a DPDCH for E-DCH depends on the presence of higher priority DCH’s (e.g voice) and may impact the flexibility of HARQ operation.

With the similar coding chain for E-DCH with Rel’99 DCH and time multiplexing scheme to a single CCTrCH, the possibilities of decoding E-DCH in Rel’99/Rel’4/Rel’5 Node Bs could be considered even though no soft combining is performed in those Node Bs. This kind of backward compatibility can increases the macro diversity gain in SHO, especially when previous release Node Bs are included in the active set.

8.3.2 Allocating a separate code channel for Enhanced uplink DCH

In this alternative the E-DCH is code multiplexed with other DCHs, i.e., sent using a dedicated code channel, thus introducing a new CCTrCH in the uplink. (Note, that Rel'99 only allows one CCTrCH in the uplink per UE.)

The advantages of code-multiplexing include, among others, simpler introduction of new/shorter TTI lengths, increased flexibility of HARQ operation , and support of adaptive modulation.

Introducing a new code channel may increase PAR in some cases which should be studied. Further, the available resources, such as power, for the code channel carrying E-DCH depends on the presence of higher priority DCHs being carried on the other code channels.

8.4 Multiplexing alternatives in detail

Currently there are physical channel structures under study both with 10 ms TTI and with 2 ms TTI. Here all the possible structures are explained shortly, and also the main difference compared to other structures.

The main assumptions are:

- The maximum possible data rate allocated to DCH simultaneously with E-DCH can be anything, up to 2Mbit/s, as long as UE capability supports the combination of DCH and E-DCH with the simultaneously allocated bit rates. Thus no restrictions for the simultaneous data rates of E-DCH and DCH have yet been agreed.

These assumptions should be taken into account in the channel structure descriptions in the below subsections.

Issues to be considered when any channel structures are studied and benefits and drawbacks of them are compared further are listed below:

- What is the maximum data rate that UE is able to utilise for E-DCH simultaneously with DCH. And what is the maximum data rate that UE is able to utilise for DCH simultaneously with E-DCH. This type of analysis should be made for different UE capability categories.
- What is the PAR for a certain UE capability with different structures. When PAR is analysed and compared for different structures, it should be compared so that the total data rate for E-DCH and DCH that UE supports is the same with both structures.
- Is it possible to utilise 8PSK in these structures, i.e. what does time multiplexing and code multiplexing of EDCH and DCH mean in relation to 8PSK.

What is the desired structure when thinking about how the network side can allocate TFCS in an accurate way to the UE so that UE is able to utilise maximum allocation most of the time during the allocation period.

8.4.1 Physical layer structures in time domain (TS25.212)

8.4.1.1 General structures describing only how to multiplex DCH and E-DCH

8.4.1.1.1 Physical Layer Structure Supporting minimum TTI of 10ms

8.4.1.1.1.1 Code multiplexing between DCH and E-DCH

This could be considered, if there is a desire to have totally separate processing , i.e. rate matching etc., for E-DCH and DCH. There are two possibilities for defining code multiplexing between E-DCH and DCH, explained below.

a) Code multiplexing between DCH and E-DCH, with separate UE capabilities for DCH and E-DCH data rate, with the assumption that UE is able to support the combination of these data rates simultaneously. Here it is assumed that UE capability is defined so that DCH with certain data rate is assumed to be possible to send code multiplexed simultaneously with E-DCH, when E-DCH is transmitted at maximum data rate that UE supports for E-DCH. Figure 8.4.1 depicts this case with an example.

   This scheme assumes that there are two CCTrCHs, one carrying DCHs , the other carrying EDCHs.

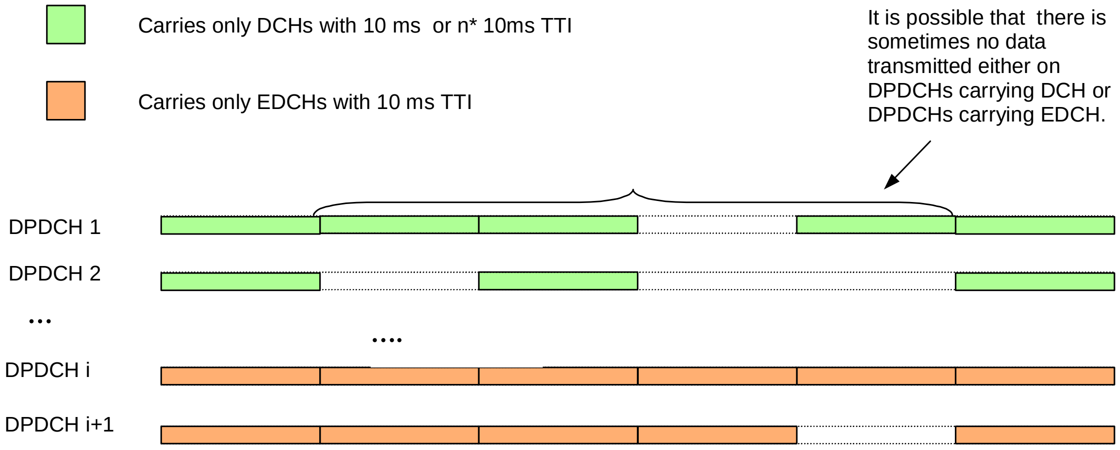

Figure 8.4.1. An example showing code multiplexing with separate UE capabilities for DCH and E-DCH , with minimum TTI=10 ms for E-DCH. Here the transmission of DCH does not decrease the data rate of E-DCH.

b) Code multiplexing between DCH and E-DCH assuming there are following UE capability parameters defined:
    - UE capability for the total data rate of DCH and E-DCH
    - UE capability for the total number of codes that UE supports being common for DCH and E-DCH.

This scheme assumes that there are two CCTrCHs, one carrying DCHs, the other carrying EDCHs.

This means that there are certain limitations how DCH and E-DCH can occur simultaneously. If e.g. DCH would have higher priority than E-DCH, it would mean that DCH can occur any time, but data rate for E-DCH needs to be clearly reduced in the frames when DCH is transmitted.

Figure 8.4.2 depicts this case with an example, where it is assumed that DCH is assumed to fit to one DPDCH code channel, while in a generic case the maximum data rate of DCH could be anything depending on UE capability and TFCS. Another assumption as an example in this figure is that DCH would have higher priority than EDCH. In this example the transmission of DCH means that data rate is decreased for E-DCH in the same TTI.

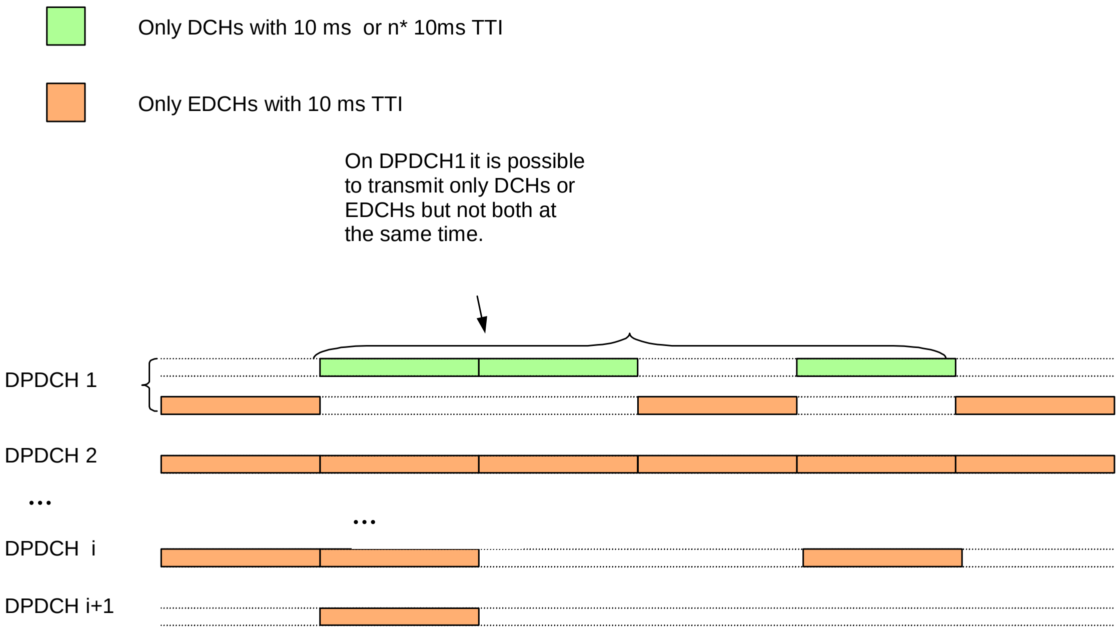

Figure 8.4.2. An example showing code multiplexing with UE capabilities defined in a combined fashion for E-DCH and DCH, with minimum TTI=10 ms for E-DCH.

8.4.1.1.1.2 Time multiplexing between DCH and E-DCH

This could be considered if it is seen acceptable to have processing of E-DCH and DCH done together, in rate matching etc. This means that there is no need to change the Rel5 physical layer structure and no need to change the Rel5 TFC selection algorithm. Thus one CCTrCH carries both DCH and E-DCH. Figure 8.4.3 depicts this with an example.

It is to be noted that in this structure, similar to rel99/rel4/rel5, if data for both DCH and E-DCH exist in the frame it depends on the number of bits and which TrCH number is selected for DCH on which and how many DPDCHs there are DCH bits and on which and how many DPDCHs there are E-DCH bits. This is if the current uplink TrCH multiplexing structure is assumed.

As an example, if DCH is carried on the first TrCH, TrCH1, and if the maximum number of channel bits for DCH in the TFCS is such that it always fits to one DPDCH with SF=4, then in the figure 8.4.3, only DPDCH1 carries both E-DCH and DCH bits, and DPDCH2 – DPDCHi carry only E-DCH bits.

As another example, if DCH is carried still on the first TrCH, TrCH1, and if the maximum number of channel bits for DCH in the TFCS is such that it always fits to two DPDCHs, then in the figure 8.4.3, it will vary from TTI to TTI, depending on what is the transport format of DCH used in that TTI, which DPDCHs will carry DCH bits and which DPDCHs will carry EDCH bits. In this example, in the TTIs in which DCH has the transport format referring to maximum data rate of DCH, both DPDCH1 and DPDCH2 will carry DCH bits. If the transport format of DCH does not totally fill DPDCH2, then DPDCH2 also carries some of E-DCH bits, and the rest of the E-DCH bits are carried on DPDCH3-DPDCHx. In TTIs where DCH has zero data rate, all DPDCHs may carry E-DCH bits.

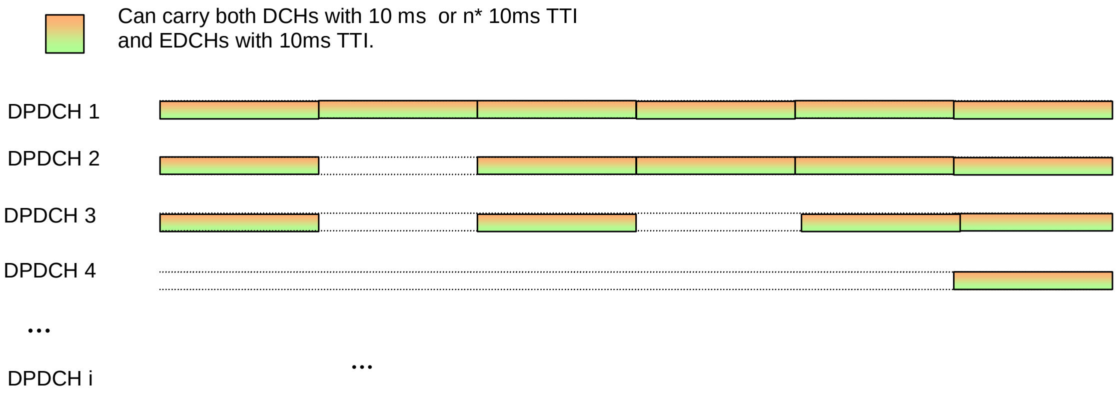

Figure 8.4.3. Time multiplexing with minimum TTI=10 ms for E-DCH.

8.4.1.1.2 Physical Layer Structure Supporting minimum TTI of 2ms

8.4.1.1.2.1 Code multiplexing between DCH and E-DCH

This could be considered, if there is a desire to have totally separate processing , i.e. rate matching etc. , for E-DCH and DCH and allow 2 ms TTI for E-DCH. There are two possibilities for defining code multiplexing between E-DCH and DCH, explained below.

a) Code multiplexing between DCH and E-DCH, with separate UE capabilities for DCH and E-DCH data rate, with the assumption that UE is able to support the combination of these data rates simultaneously. Here it is assumed that UE capability is defined so that DCH with certain data rate is assumed to be possible to send code multiplexed simultaneously with E-DCH, when E-DCH is transmitted at maximum data rate that UE supports for E-DCH. Figure 8.4.4 depicts this case with an example.

   This scheme assumes that there are two CCTrCHs, one carrying DCHs, the other carrying EDCHs.

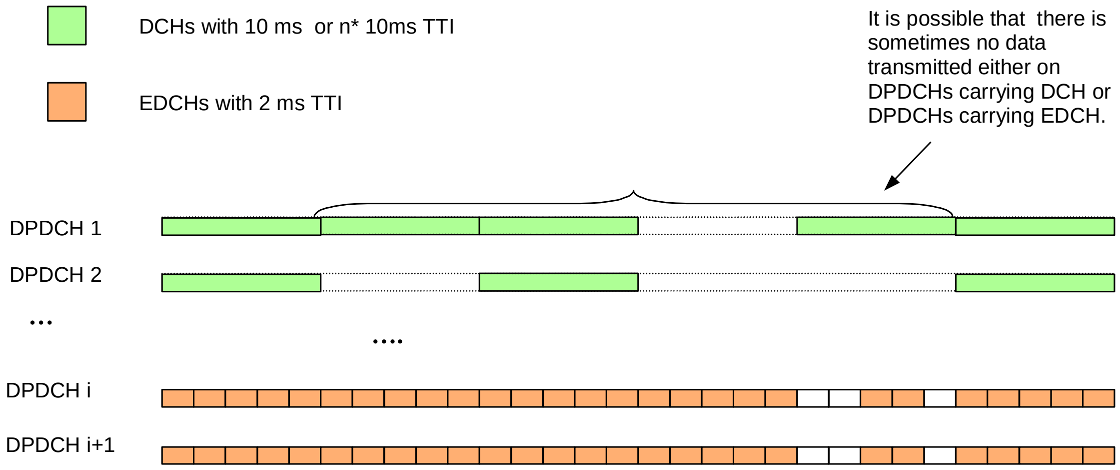

Figure 8.4.4. Code multiplexing with separate UE capabilities for DCH and E-DCH , with minimum TTI=2 ms for E-DCH. Here the transmission of DCH does not decrease the data rate of E-DCH.

b) Code multiplexing between DCH and E-DCH assuming there are following UE capability parameters defined:

   - UE capability for the total data rate of DCH and E-DCH
   - UE capability for the total number of codes that UE supports being common for DCH and E-DCH.

This scheme assumes that there are two CCTrCHs, one carrying DCHs, the other carrying EDCHs.

This means that there are certain limitations how DCH and E-DCH can occur simultaneously. Assuming as an example that DCH would have higher priority than E-DCH, it would mean that DCH could occur any time, but data rate for E-DCH needs to be clearly reduced in the frames when DCH is transmitted.

Figure 8.4.5 depicts this case with an example, where it is assumed that DCH is assumed to fit to one DPDCH code channel, while in a generic case the maximum data rate of DCH could be anything depending on UE capability and TFCS. Another assumption as an example in this figure is that DCH would have higher priority than EDCH. In this example the transmission of DCH means that data rate is decreased for E-DCH in the same TTI.

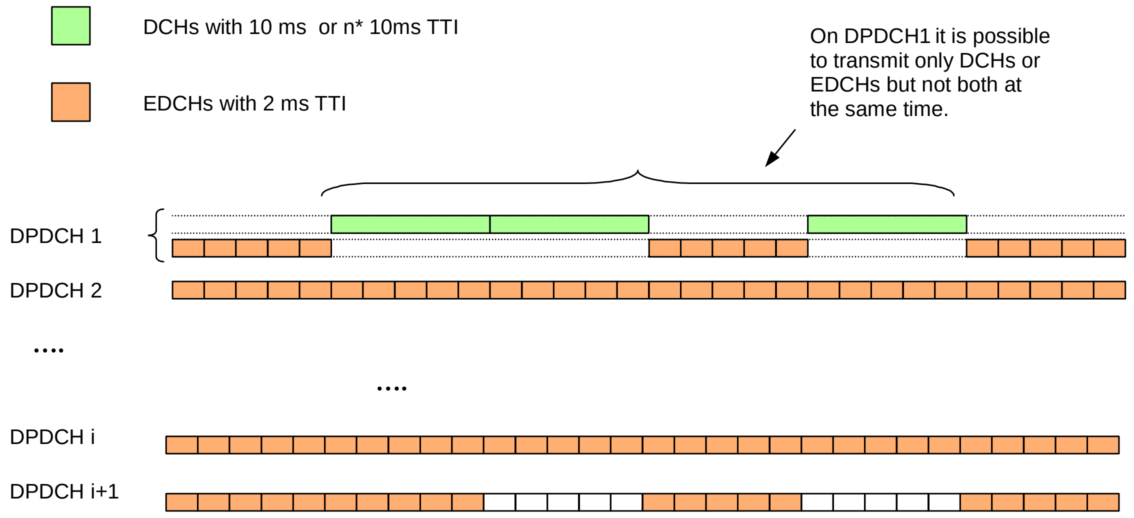

Figure 8.4.5. An example showing code multiplexing with UE capability defined in a combined fashion for E-DCH and DCH, with minimum TTI=2ms for E-DCH.

8.4.1.1.2.2 Time multiplexing between DCH and E-DCH

Figure 8.4.3 is valid also here, in the context when it is analysed what code channels can be used in different frames for carrying DCH and E-DCH. So it is copy pasted here and renamed as figure 8.4.6. Also the same assumptions as were explained for figure 8.4.3 are valid here.Figure 8.4.6 depicts this with an example.

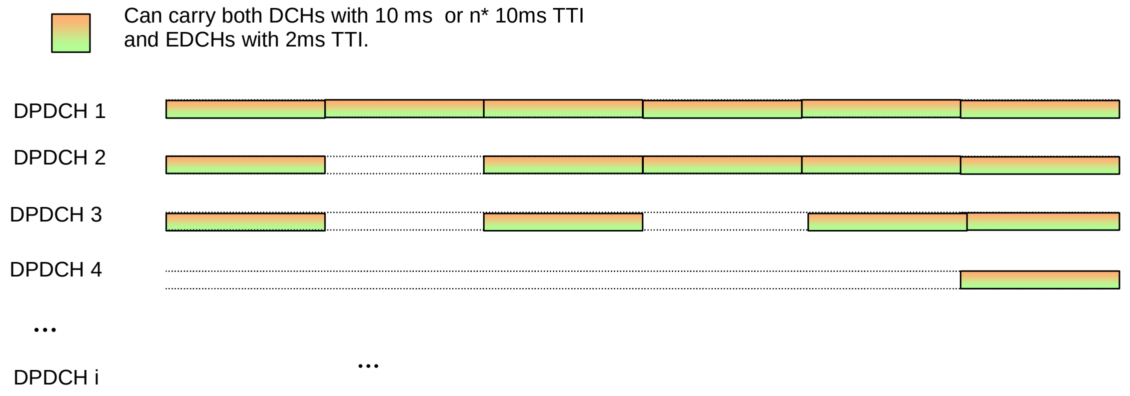

Figure 8.4.6. Time multiplexing between 2 ms TTI E-DCH with 10ms TTI E-DCH.

The difference here compared to time multiplexing with minimum TTI of 10ms is that here there can be different possibilities in terms whether there is only one CCTrCH carrying both DCH and E-DCH, or whether there is a separate CCTrCH carrying DCH and a separate CCTrCH carrying E-DCH. Also there are different possibilities how to do the time multiplexing. The proposals currently available for describing the actual multiplexing of DCH and E-DCH and issues related to number of CCTrCHs are explained below:

a) Utilising place holder bits in the transport channel multiplexing. This is described with the figure 8.4.7 below. The idea in this is that if the EDCH(s) are the first transport channel(s) in the TFCS, the bits in the frame after 2nd interleaving will be in known positions. Thus it is proposed here that so called E-DCH 'place holder bits ' will be run through TrCH multiplexing, to reserve place in these known positions. After the 2nd interleaving the bits from EDCH(s) replace the 'place holder bits'. This method assumes a fixed TFC during 10 ms radio frame. It is for ffs, whether fixed TFC during 10ms radio frame will be feasible.

   This scheme assumes that one CCTrCH carries both DCH and E-DCH.

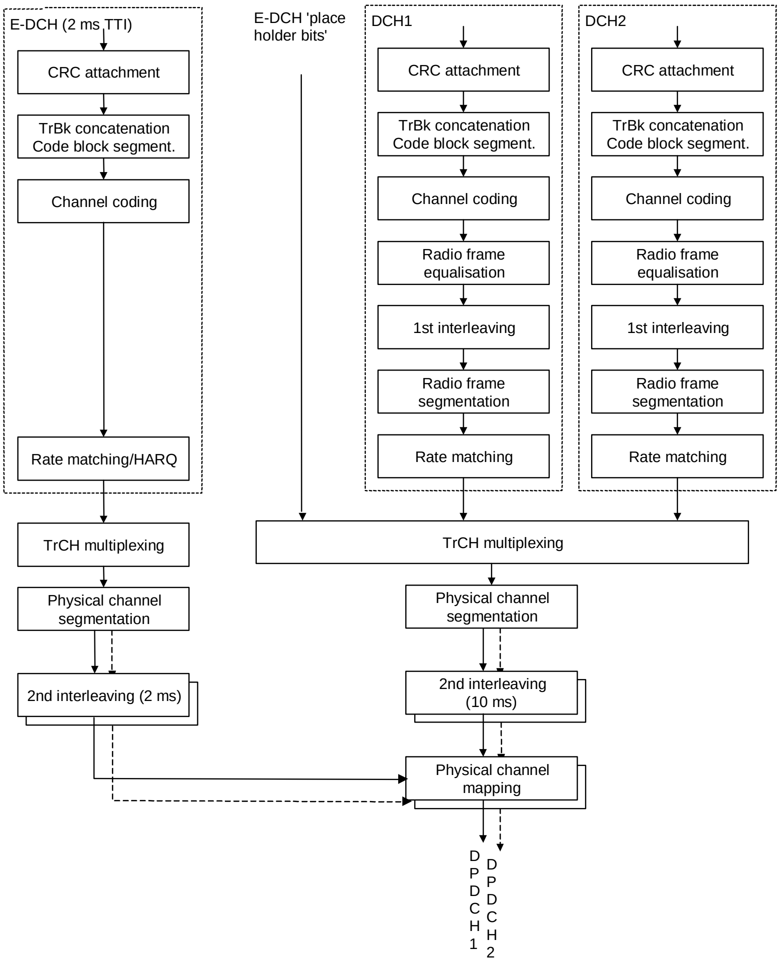

Figure 8.4.7. Time multiplexing of E-DCH (2ms TTI) and DCH (10ms TTI) with place holder bits.

b) Utilising SF reduction. This is described in the figure 8.4.8 below. The idea here is to utilise SF reduction to create gaps in the 2ms TTI(s) in which EDCH is desired to be transmitted . This could be defined either with two separate CCTrCHs or with one CCTrCH carrying both DCH and EDCH.

   This method could be defined either with fixed TFC during radio frame, or fixed TFC during 2 ms. It is ffs whether TFC should be fixed during radio frame or during 2 ms .

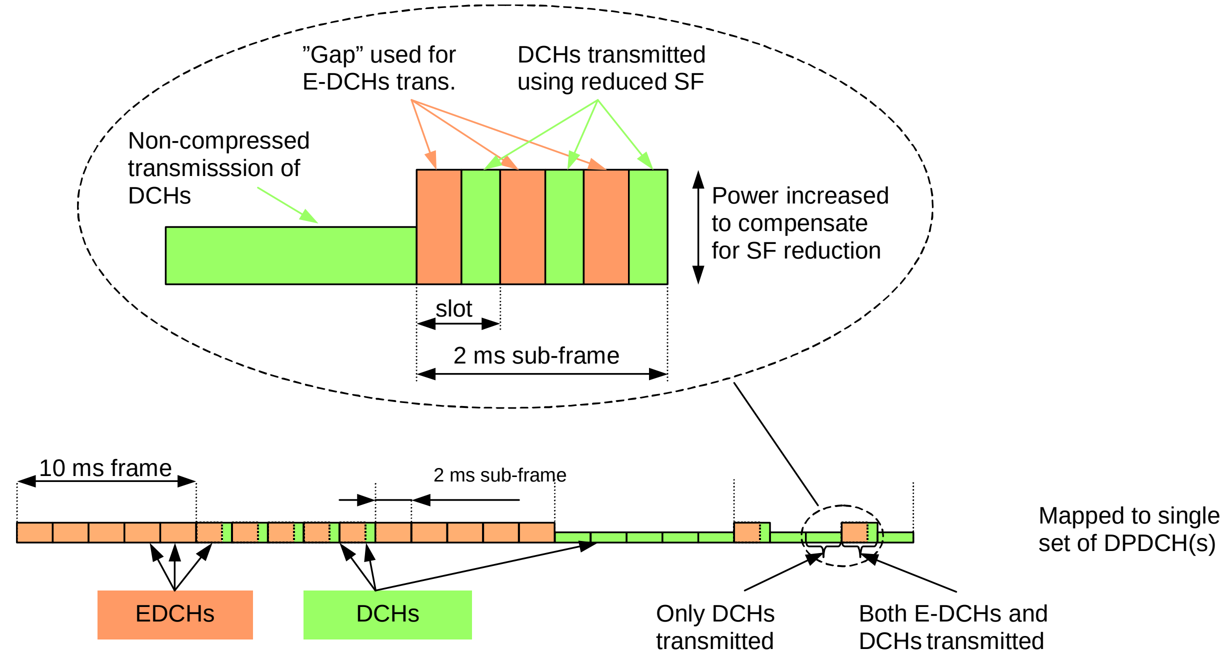

Figure 8.4.8. Time multiplexing of E-DCH (2ms TTI) and DCH (10ms TTI) with SF reduction. Whether TFC is fixed per 10 ms or per 2 ms is ffs.

8.4.1.2 More detailed structures defining how to multiplex L1 signaling (HSDPCCH, DPCCH, EDPCCH) with DCH and E-DCH

There are following possibilities:

- Time multiplexing at least some of the L1 signaling code channels with DCH and/or E-DCH
- Code multiplexing between L1 signaling channels and E-DCH/DCH

More detailed structures under study will be added here later on. These should be defined here so that the both possibilities, code multiplexing or time multiplexing between E-DCH and DCH are considered.

8.4.2 Physical layer structures in code domain

In this section the cases under study for enhanced uplink DCH are described in line with TS 25.213 titled “Spreading and modulation”. Further complexity issues, as well as backwards compatibility, need to be studied.

Cases utilizing only BPSK (Note: QPSK = 2 BPSK code channels)

Cases	**Description of the case**	**Needed physical code channels**
Case 1	All channels, E-DCH, DCH, HSDPCCH, DPCCH and EDPCCH are code multiplexed	DPCCH, DPDCH, E-DPDCH, HS-DPCCH, E-DPCCH
Case 2	E-DCH, DCH, EDPCCH on the same code channel (DPDCH). Only DPCCH and HS-DPCCH on a separate code channel. Thus EDPDCH does not exist.	DPCCH, DPDCH, HS-DPCCH
Case 3	E-DCH, DCH, EDPCCH, and HS-DPCCH on the same code channel (DPDCH). Only DPCCH on a separate code channel. Thus EDPDCH does not exist.	DPCCH, DPDCH
Case 4	E-DCH, EDPCCH, HS-DPCCH on the same code channel (E-DPDCH). DPCCH and DCH on separate code channels	DPCCH, DPDCH, E-DPDCH
Case 8	All channels, E-DCH, DCH, HS-DPCCH, DPCCH, E-DPCCH1, E-DPCCH2 and E-DPCCH3 are code multiplexed	DPCCH, DPDCH, E-DPDCH, HS-DPCCH, E-DPCCH1, E-DPCCH2, E-DPCCH3

Cases utilizing also 8PSK (Note: the performance of 8PSK has to be first evaluated before it can be adopted).

Cases	**Description of the case**	**Needed physical code channels**
Case 5	Case 2, except that it utilizes 8PSK for transmitting DPDCH if the total number of physical channel bits from both E-DCH and DCH would need to be accomodated on either three, six or nine code channels of SF=4 (or SF=2).	DPCCH, DPDCH, HS-DPCCH
Case 6	Case 3, except that it utilizes 8PSK for transmitting DPDCH if the total number of physical channel bits from both E-DCH and DCH would need to be accomodated on either three, six or nine code channels of SF=4 (or SF=2).	DPCCH, DPDCH
Case 7	Case 4, except that it utilizes 8PSK for transmitting E-DPDCH if the total number of physical channel bits from E-DCH would need to be accomodated either three, six or nine code channels of SF=4 (or SF=2).	DPCCH, DPDCH, E-DPDCH

The additional assumptions are:

- If time multiplexing is used between DCH and E-DCH, then multicode transmission for carrying both of them is used only in conjunction with the lowest possible spreading factor (SF=4 or SF=2).
- If code multiplexing is used between DCH and E-DCH, the SF's used for DPDCH and for EDPDCH are independent of each other. Multicodes for E-DPDCH, carrying E-DCH, are utilized only with the lowest possible spreading factor (SF=4 or with SF=2. Correspondingly for DPDCH, carrying DCH, the multicodes are utilized only with the lowest possible spreading factor SF=4. Mapping the E-DCH on one SF=2 and one SF=4 DPCH is possible.
- Any SF can be used for code channels carrying EDCH and/or DCH, if the transport format combination is such that it does not require multicodes.
- The figures below are generalized in the sense that the term "DPDCH" is used for denoting the physical channels carrying both DCH and E-DCH. Furthermore, the mapping of channels not present in Rel5 to I or Q in the figures is solely for illustrational purposes.

8.4.2.1 Case 1: Structure when using code multiplexing for all channels

The enhanced uplink consists of a new channel called Enhanced DCH (E-DCH). . The L1 signaling are sent on the E-DPCCH. The overall structure of the enhanced uplink when all channels are code multiplexed, is shown in Figure 8.4.9. The figure is drawn so that the physical code channels are all called DPDCHs for the purpose of generalizing the figure. Each DPDCH can carry either DCH(s) or E-DCH(s) but not both at the same time.

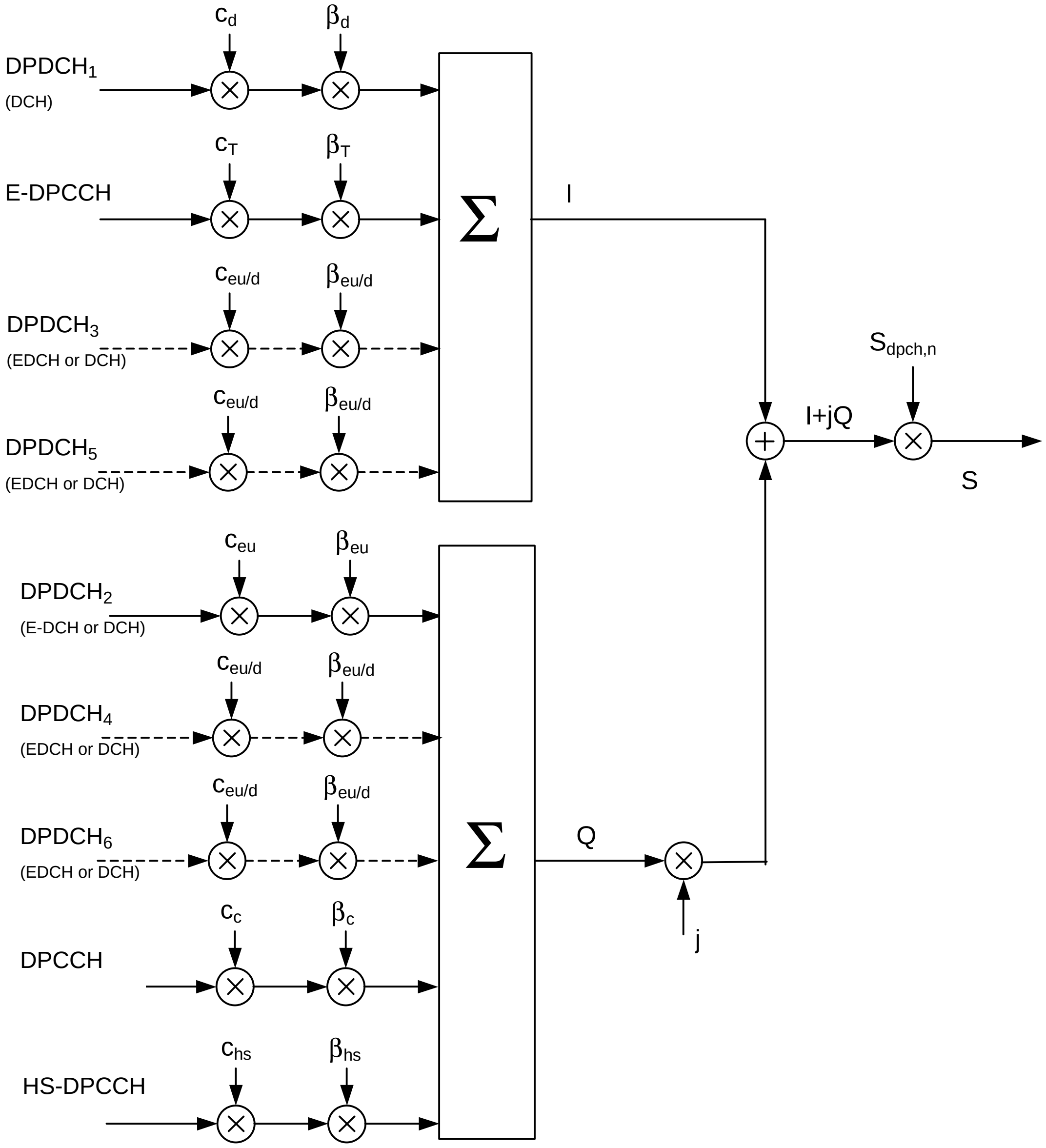

Figure 8.4.9. Case 1: Structure for Enhanced Uplink

8.4.2.2 Case 2: Structure when E-DCH, DCH and EDPCCH are time Multiplexed

In this structure the E-DCH, DCH, EDPCCH are time-multiplexed on the same code channel (DPDCH). Here again all the code channels can be called DPDCHs, since E-DPDCH does not exist. Only DPCCH and HS-DPCCH are on a separate code channel. This uplink structure is shown in Figure 8.4.10.

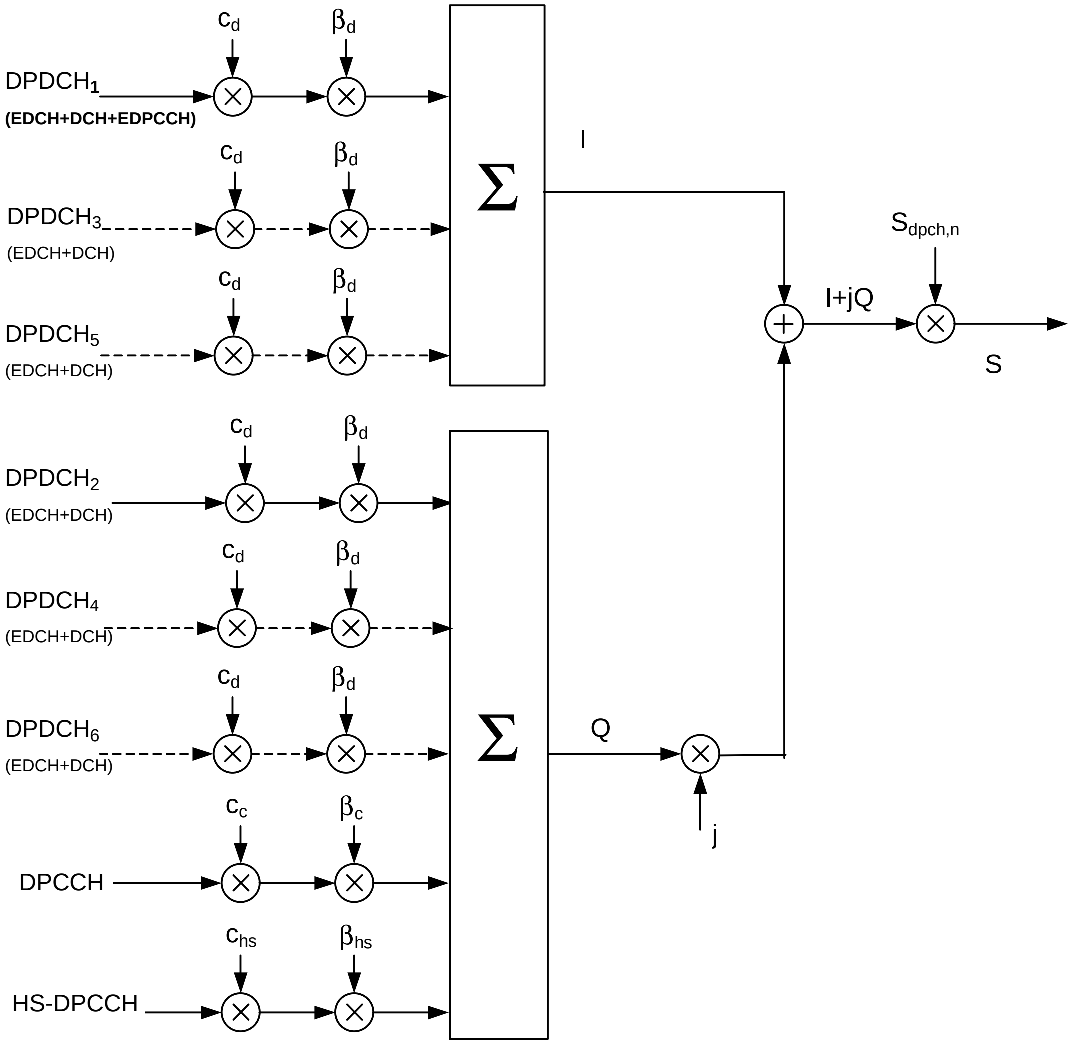

Figure 8.4.10. Case 2: Structure for Enhanced Uplink

8.4.2.3 Case 3: Structure when E-DCH , DCH and EDPCCH and HS-DPCCH are time multiplexed

In this structure the E-DCH, DCH, EDPCCH and HS-DPCCH are time-multiplexed on the same code channel (DPDCH). Here again all the code channels can be called DPDCHs, since E-DPDCH does not exist. Only DPCCH is on a separate code channel. This uplink structure is shown in Figure 8.4.11.

Note, that any PAR results for this case can also be utilized for analyzing a PAR for a UE that does not support HSDSCH, but does support EDCH, since then HSDPCCH does not exist.

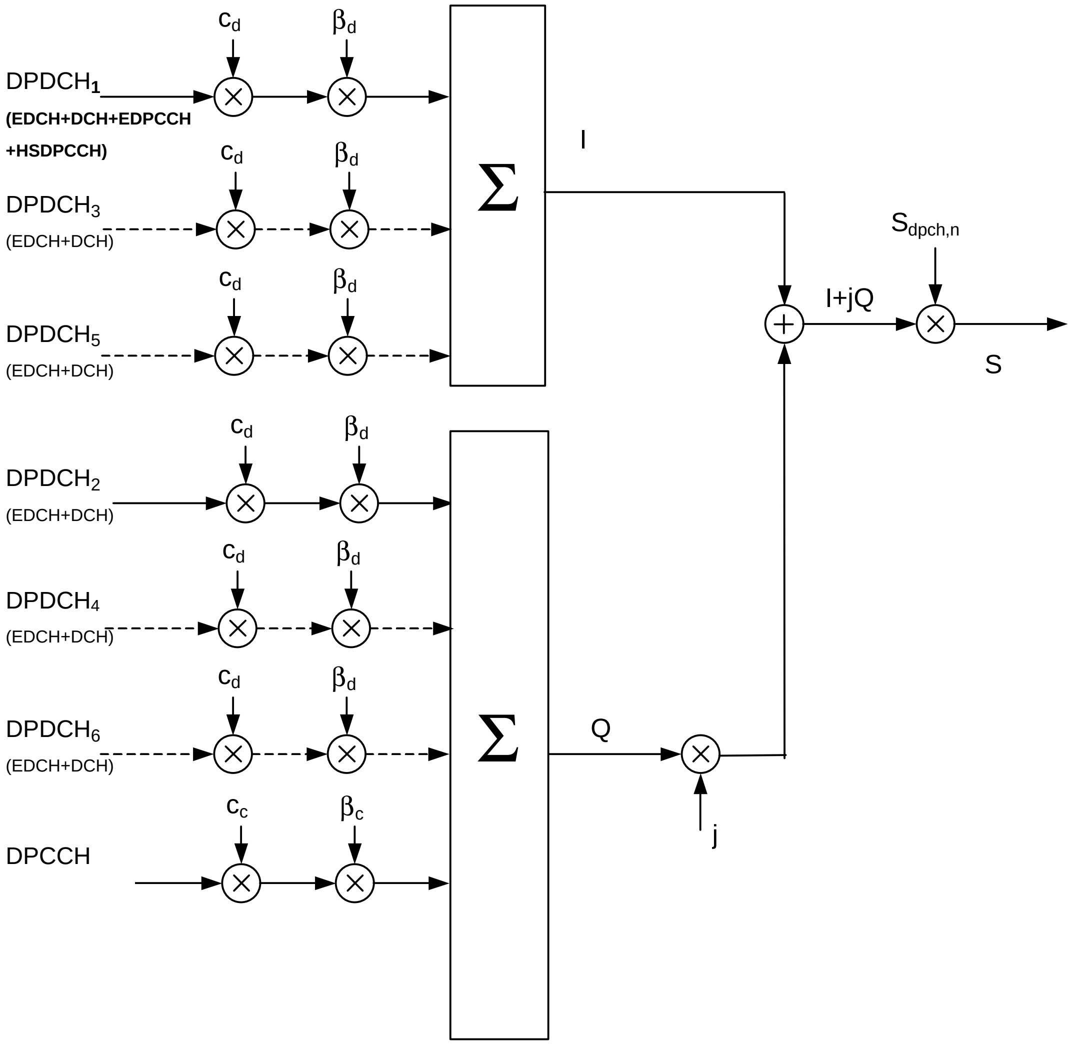

Figure8.4.11. Case 3: Structure for Enhanced Uplink

8.4.2.4 Case 4: Structure when E-DCH, EDPCCH and HSDPCCH are time multiplexed

In this structure the E-DCH, EDPCCH and HS-DPCCH are time-multiplexed on the same code channel (DPDCH). Only DPCCH and DCH are on a separate code channel. This uplink structure is shown in Figure 8.4.12.

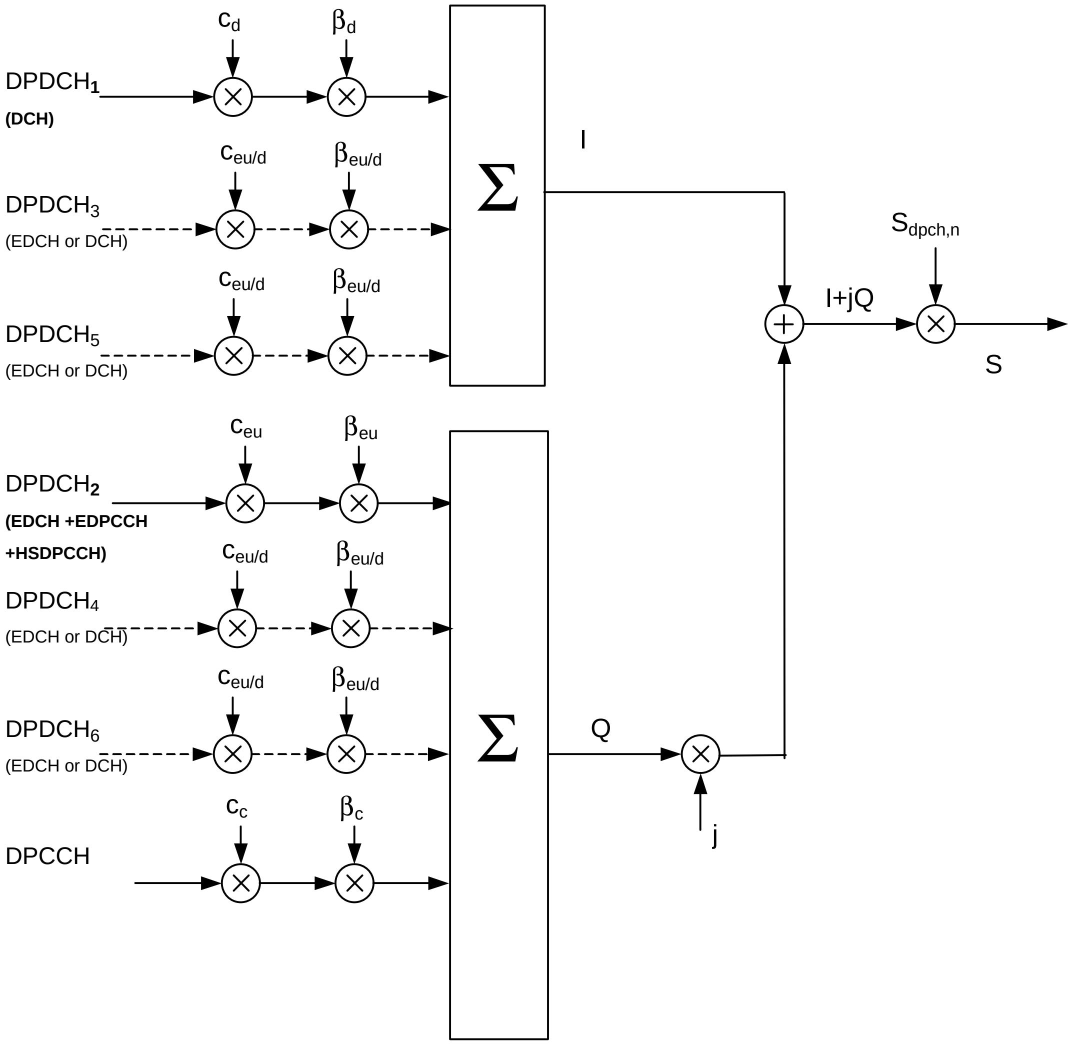

Figure 8.4.12. Case 4: Structure for Enhanced Uplink

8.4.2.5 Case 5: Structure similar to case 2, but with 8PSK included

It is similar to Case-2 except that it utilizes 8PSK for transmitting DPDCH if the total number of physical channel bits from both E-DCH and DCH would need to be accomodated on either three, six or nine code channels of SF=4 (or SF=2).

8.4.2.6 Case 6: Structure similar to case 3, but with 8PSK included

It is similar to Case-3 except that it utilizes 8PSK for transmitting DPDCH if the total number of physical channel bits from both E-DCH and DCH would need to be accomodated on either three, six or nine code channels of SF=4 (or SF=2).

8.4.2.7 Case 7: Structure similar to case 4, but with 8PSK included

It is similar to Case-4 except that it utilizes 8PSK for transmitting E-DPDCH if the total number of physical channel bits from E-DCH would need to be accomodated on either three, six or nine code channels of SF=4 (or SF=2).

8.4.2.8 Case 8: Structure when using code multiplexing for all channels

The enhanced uplink consists of a new channel called Enhanced DCH (E-DCH) which is mapped on a new physical channel called E-DPDCH. The associated L1 transmission format and request signalling are mapped respectively on a new E-DPCCH1 and E-DPCCH2 channels. Finally this structure supports a secondary pilot channel E-DPCCH3 which enables the Node B to improve the receive performance of the uplink channels. The overall structure of the enhanced uplink when all channels are code multiplexed, is shown in Figure 8.4.13 The figure is drawn so that the physical code channels are all called DPDCHs for the purpose of generalizing the figure. Each DPDCH can carry either DCH(s) or E-DCH(s) but not both at the same time.

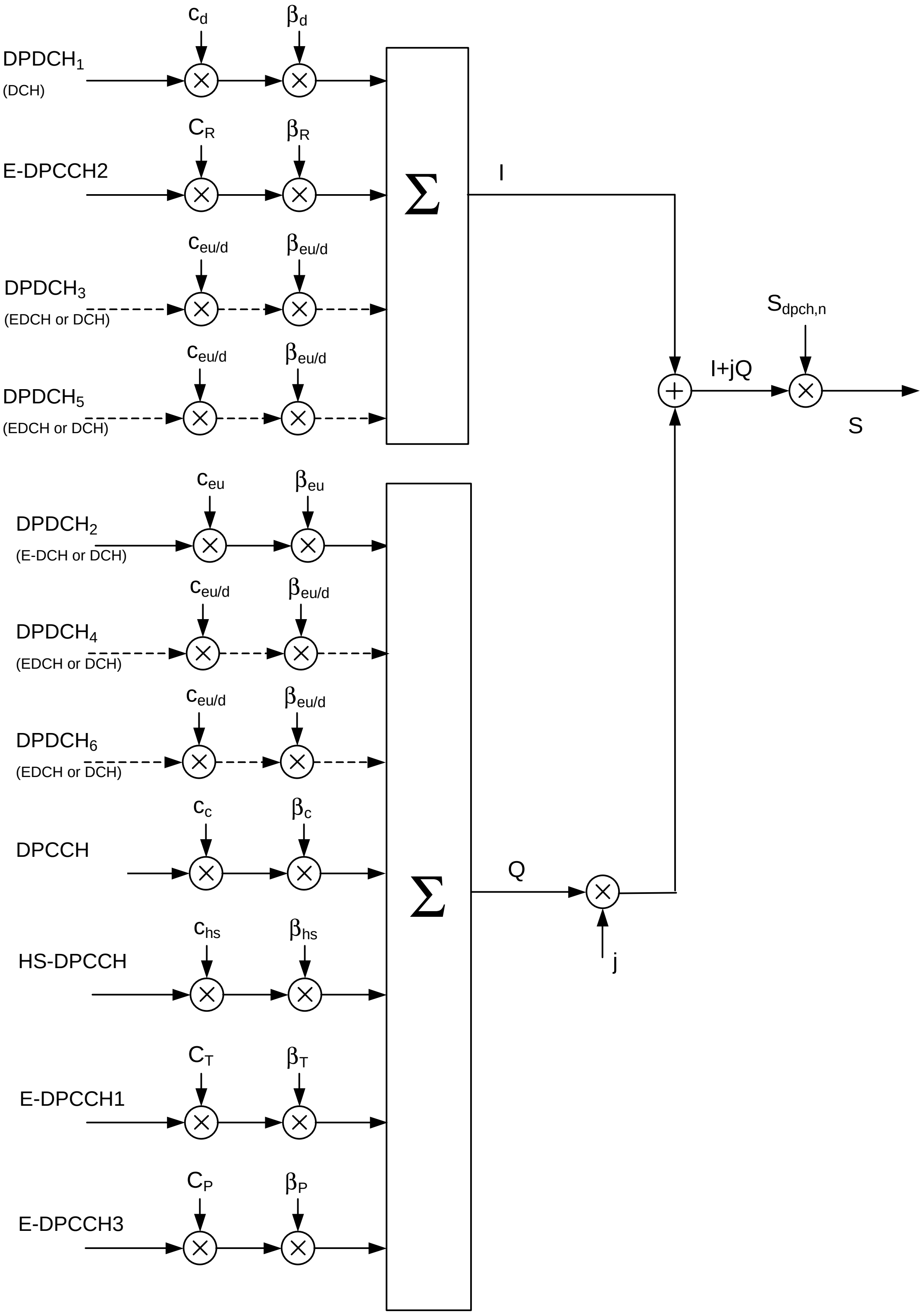

Figure 8.4.13 Case 8: Structure for Enhanced Uplink

8.5 E-DCH timing

E-DCH timing should be investigated taking into account the following aspects:

- Impact on system level performance, e.g., due to the noise rise peaks caused by the partial overlap between E-DCH transmissions from different UEs
- Relationship and impact to the Node B controlled scheduling and the hybrid ARQ

- UE and Node B complexity for handling E-DCH transmission/reception in relation with the existing uplink channels such as DPCCH, DPDCH, and HS-DPCCH
- Impact on UE transmit power management

It is FFS how to arrange E-DCH transmission timing. A simple approach to define E-DCH timing could be to have a fixed timing offset with respect to the downlink DPCH timing in a similar way to Rel-99/4/5. Another alternative could be to define E-DCH timing for all UEs with respect to a common downlink code channel, e.g., P-CCPCH so that E-DCH TTI timing at Node B can be aligned to a certain extent.

9 Evaluation of Techniques for Enhanced Uplink

9.1 Scheduling <NodeB controlled scheduling, AMC>

9.1.1 Performance Evaluation

9.1.1.1 Comparison of Centralized and Decentralized Scheduler

In centralized scheduling, the scheduler is located in RNC, and is responsible for simultaneous scheduling of UEs across multiple cells. Thus, it is possible to take into account the impact of each scheduled UE in all cells of its active set. However, the drawback of such scheme is the significant scheduling delay. To reduce the scheduling delays and take advantage of the possible fast scheduling gains, Node-B scheduling is needed. There, the scheduling is decentralized, since the knowledge of the received signal level is available only at the scheduling Node-B, and each Node-B schedules the UEs without considering their contribution to the other cells. Hence, there is an advantage of the decentralized scheduling over the centralized scheduling due to the shorter delays incurred in the scheduling process and the possibility of exploiting the fast scheduling gain, but the lack of knowledge of the impact a UE may have on the other cells’ rise-over-thermal noise (RoT) is a disadvantage.

The following results reflect the performance comparison of the Rel-99 uplink structure and procedures with decentralized and centralized scheduler. The results are therefore derived with 10 ms TTI, long scheduling period of 200 ms with the uplink request delay and the downlink grant delay uniformly distributed between 60 ms and 100 ms; HARQ is not used for either of the scheduling approaches. The objective is to determine the loss due to the partial information availability in the decentralized scheduler, without exploiting any possible fast scheduling gains, and form a benchmark for the gains needed to be provided by faster scheduling.

The system performance is obtained for the channel mix of PA3 30%, PB3 30%, VA30 20% and VA120 20%. Considered scheduler algorithm is Proportional Fair (PF). Scheduler related assumptions are given in Tdoc R1-031004 for centralized scheduling and in Tdoc R1-031246 for decentralized scheduler.

9.1.1.1.1 Results with Full Buffer

10 UEs with always full buffers are dropped in each cell, in a 19 Node-B, 3-cell wrap-around system layout.

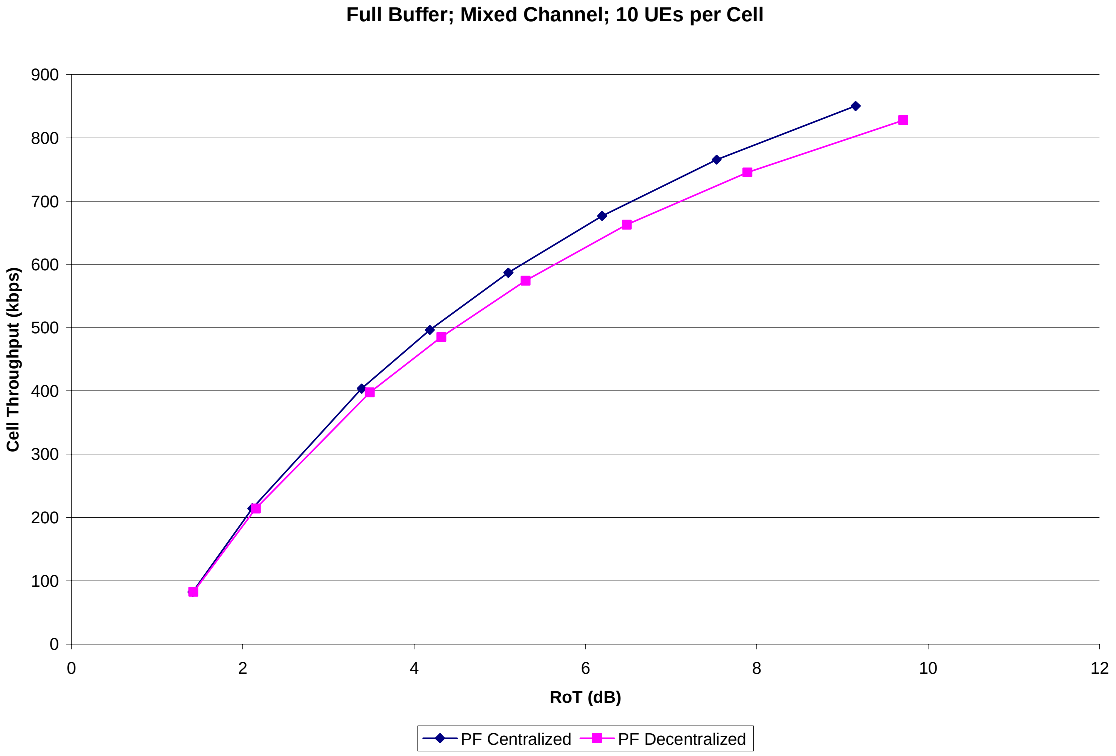

Figure 9.1.1.1: Average cell throughput as a function of average RoT – Full Buffer

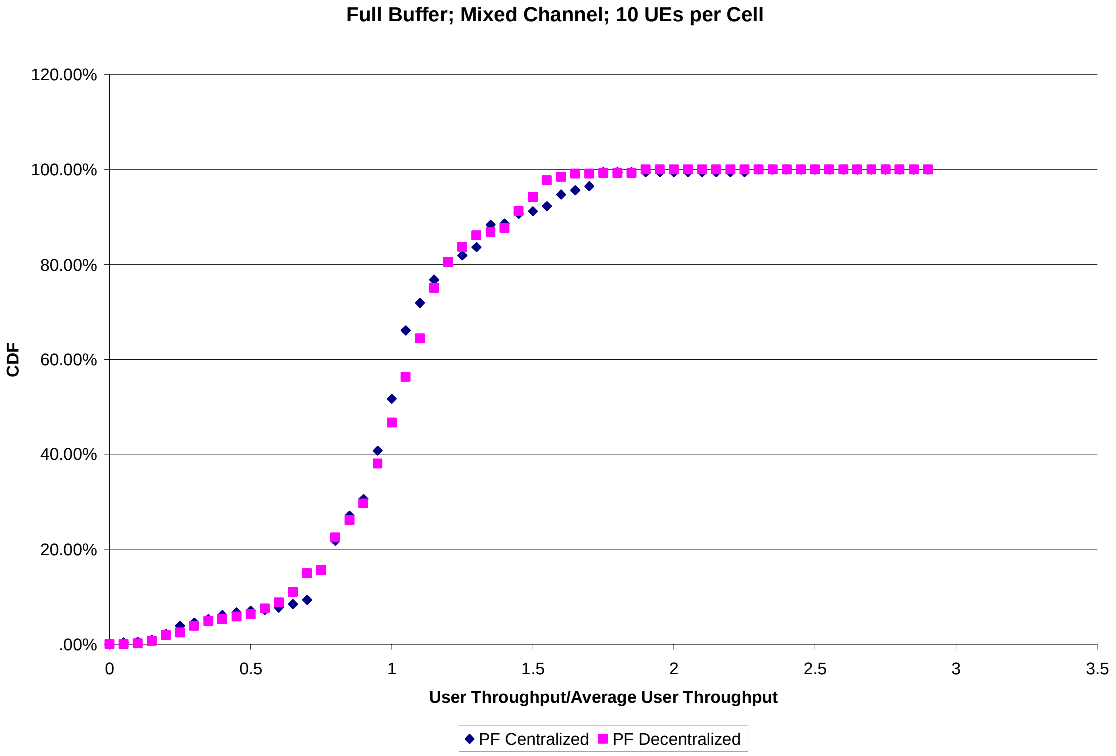

Figure 9.1.1.2: Fairness curve - CDF of the normalized throughput per user – Full Buffer

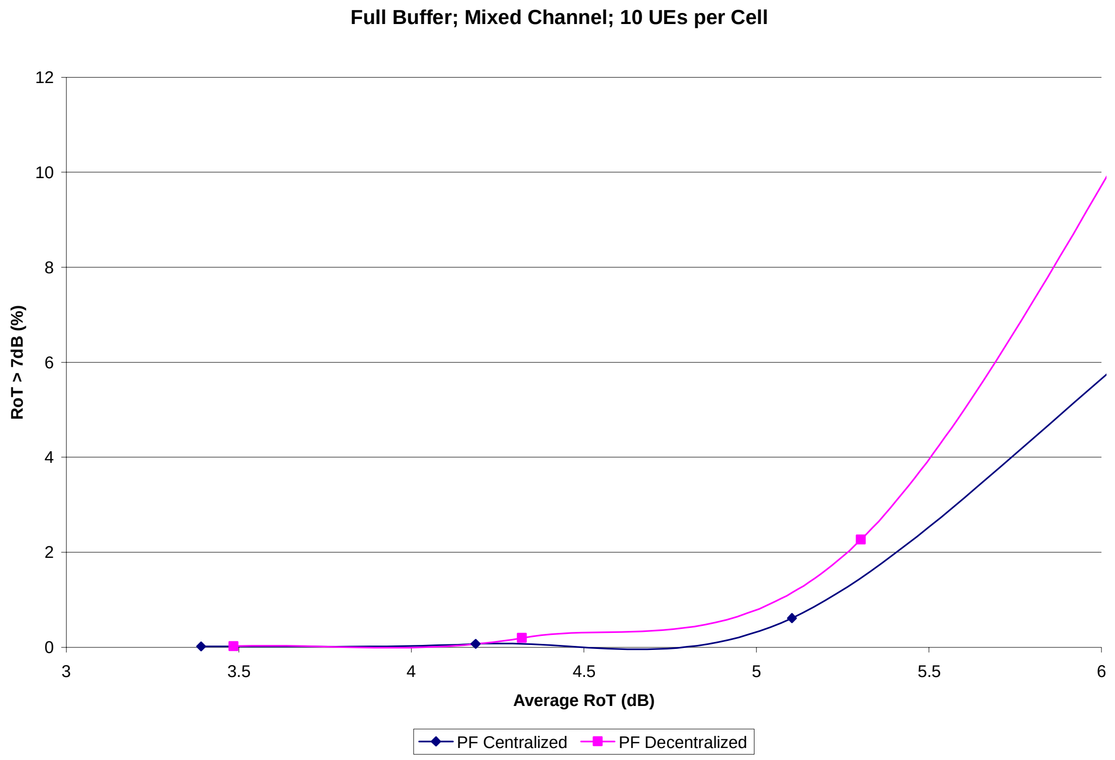

Figure 9.1.1.3: Percentage of time the RoT is greater than 7 dB – Full Buffer

9.1.1.1.2 Results with Mixed Traffic Model

The traffic model is a mix of FTP, Near Real Time Video and Gaming users, with 12 users per cell (4 FTP, 4 Video, 4 Gaming users).

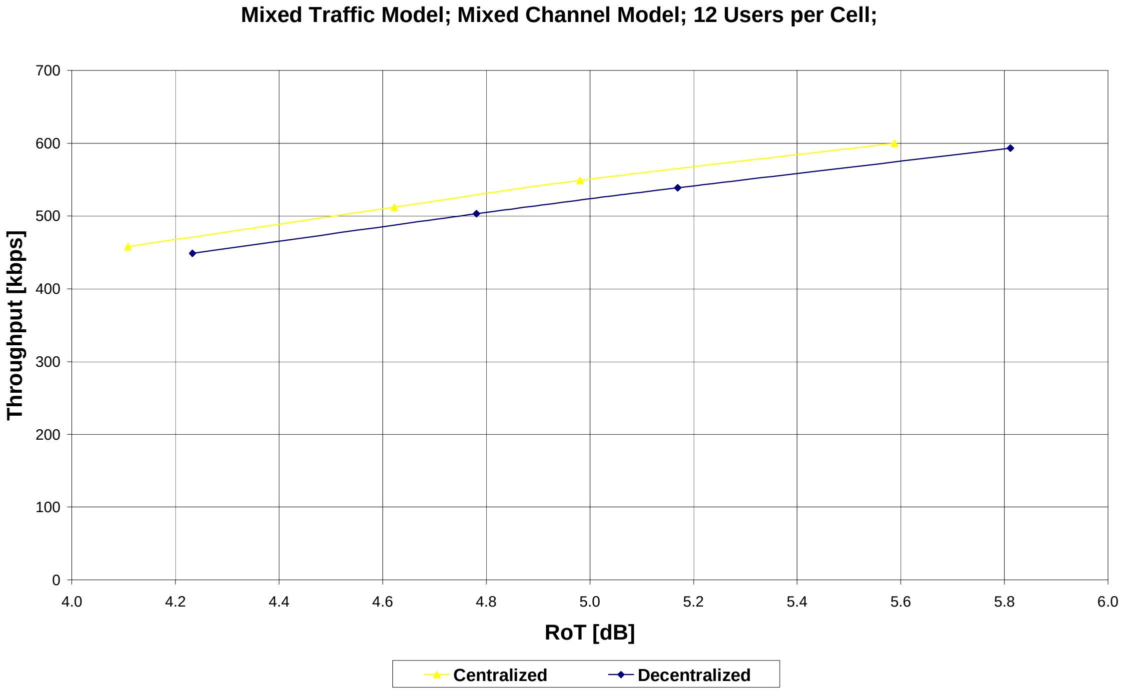

Figure 9.1.1.4: Average cell throughput as a function of average RoT – Mixed Traffic Model

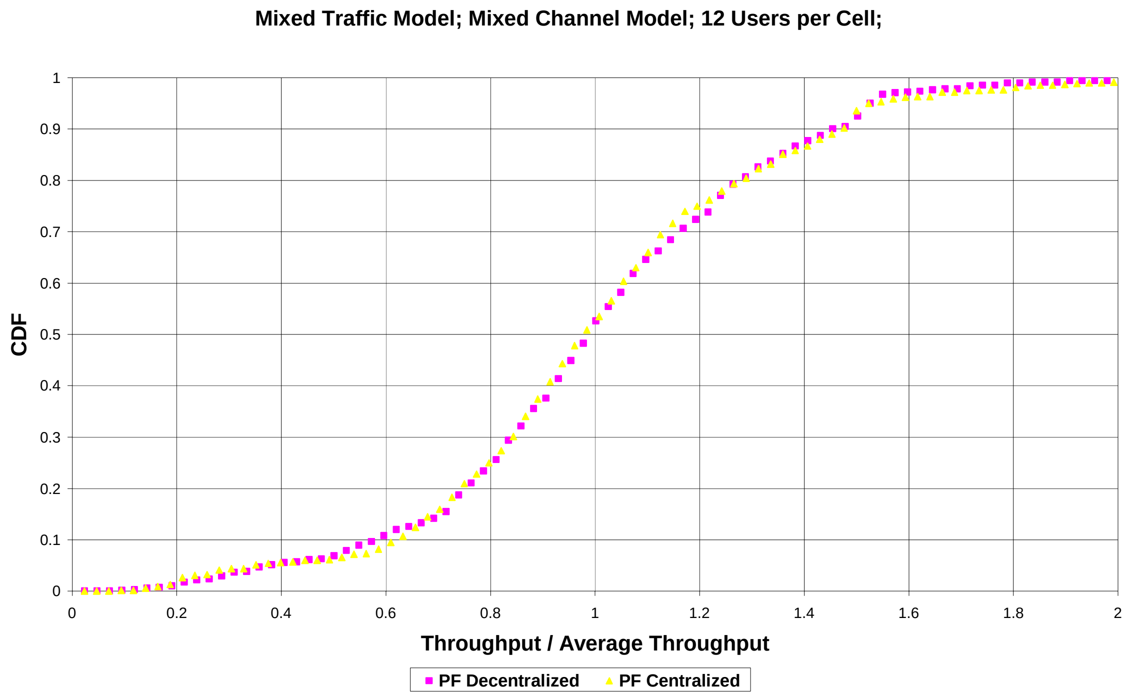

Figure 9.1.1.5: Fairness curve - CDF of the normalized throughput per user – Mixed Traffic Model

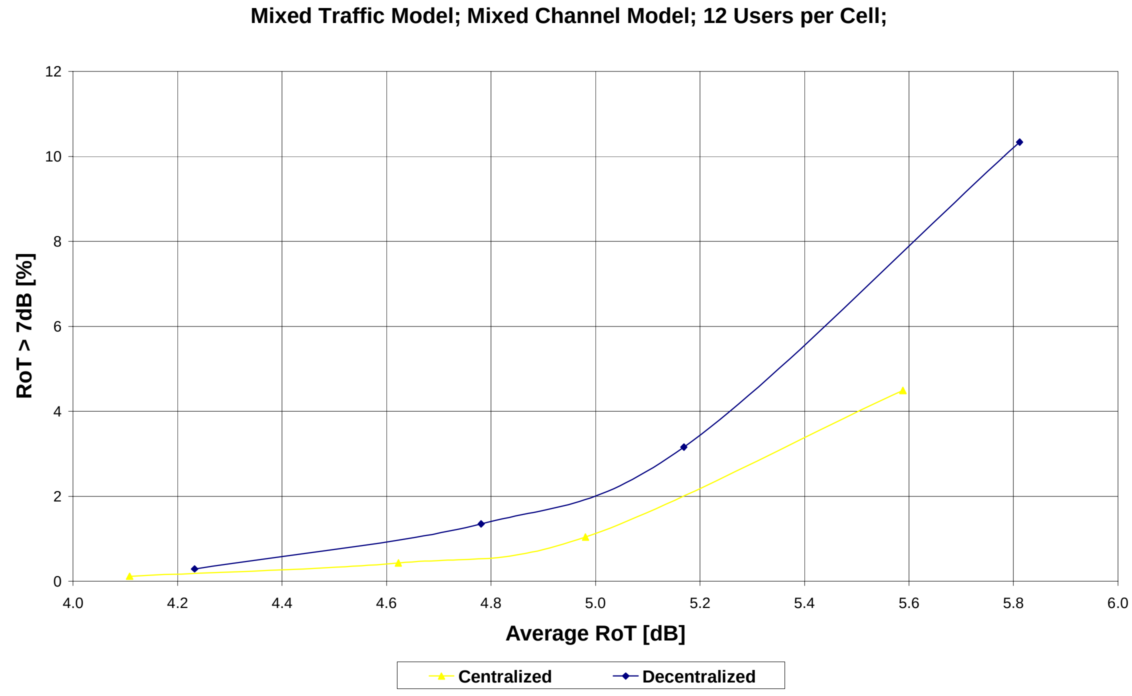

Figure 9.1.1.6: Percentage of time the RoT is greater than 7 dB – Mixed Traffic Model

9.1.1.1.3 Discussion

Based on the results presented in sections 9.1.1.1.1 and 9.1.1.1.2 it can be seen that for the same average RoT, the centralized scheduler yields a throughput gain over the decentralized scheduler. Also, while the fairness remains the same, the RoT overshoot (Probability {RoT > 7dB}) is higher in the case of decentralized scheduling. This happens due to the lack of information about the interference a UE causes to the neighbouring cells. This degradation represents the minimum benchmark for the gains to be provided by faster scheduling and other techniques that rely on faster scheduling.

9.1.2 Complexity Evaluation <UE and RNS impacts>

9.1.3 Downlink Signalling

9.1.4 Uplink Signalling

9.1.5 8PSK link performance

Note: Simulation assumptions behind the results in the tables below differ. Please refer to R1-040074 and R1-040049 for complete set of simulation assumptions.

Table 9.1.5.1: 8PSK to 3xBPSK link level performance comparison – Single Transmission

Channel model	TTI	SF	Data rate	Coding rate	8PSK performance loss		
					BLER = 10%	BLER = 20%	BLER = 50%
AWGN	2 ms	4	2304 kbps	0.80	2.4 dB	2.4 dB	2.4 dB
AWGN	2 ms	4	1536 kbps	0.53	1.7 dB	1.7 dB	1.6 dB
AWGN	2 ms	4	960 kbps	0.33	1.0 dB	1.0 dB	0.8 dB
PedA 3km/h	10 ms	4	960 kbps	0.33	1.2 dB	1.4 dB	1.5 dB
VehA 30km/h	10 ms	4	960 kbps	0.33	1.1 dB	1.3 dB	1.4 dB
PedA 3km/h	10 ms	4	1024 kbps	0.36	1.5 dB	1.5 dB	1.5 dB
PedA 3km/h	10 ms	4	1280 kbps	0.44	1.7 dB	1.6 dB	1.6 dB
PedA 3km/h	10 ms	4	1536 kbps	0.53	2.2 dB	1.9 dB	2.0 dB

Source: R1-040074, R1-040049

Table 9.1.5.2: 8PSK to QPSK link level performance comparison – Single Transmission BLER = 1%

Channel model	TTI	SF	Data rate	QPSK Coding rate	8PSK Coding rate	E-DPDCH/ DPCCH ratio	8PSK perf. Loss
AWGN	2 ms	4	1440 kbps	0.75	0.5	6 dB	0.7 dB
AWGN	2 ms	4	1440 kbps	0.75	0.5	8 dB	0.6 dB
AWGN	2 ms	4	1440 kbps	0.75	0.5	10 dB	0.6 dB
AWGN	2 ms	4	1440 kbps	0.75	0.5	12 dB	0.6 dB
AWGN	2 ms	4	1440 kbps	0.75	0.5	14 dB	0.5 dB

Source: R1-040074

Table 9.1.5.3: 8PSK to 2xBPSK link level performance comparison – Single Transmission

Channel model	TTI	SF	Data rate	Coding rate		8PSK performance loss (gain)		
				2xBPSK	8PSK	BLER = 10%	BLER = 20%	BLER = 50%
PedA 3km/h	10 ms	4	960 kbps	0.50	0.33	0.7 dB	0.7 dB	0.7 dB
PedA 3km/h	10 ms	4	1024 kbps	0.53	0.36	0.9 dB	0.8 dB	0.8 dB
PedA 3km/h	10 ms	4	1280 kbps	0.67	0.44	0.5 dB	0.5 dB	0.5 dB
PedA 3km/h	10 ms	4	1536 kbps	0.80	0.53	(0.2) dB	(0.1) dB	(0.1) dB

Source: R1-040049

Table 9.1.5.4: 8PSK to 2x/3xBPSK link level performance comparison – Residual BLER = 1% after 2 Tx

Channel model	TTI	SF	Data rate after 1 Tx	Initial Coding rate			8PSK performance loss (gain)	
				2xBPSK	3xBPSK	8PSK	2xBPSK	3xBPSK
PedA 3km/h	10 ms	4	960 kbps	0.50	0.33	0.33	0.9 dB	1.5 dB
PedA 3km/h	10 ms	4	1024 kbps	0.53	0.36	0.36	1.0 dB	1.2 dB
PedA 3km/h	10 ms	4	1280 kbps	0.67	0.44	0.44	1.0 dB	1.2 dB
PedA 3km/h	10 ms	4	1536 kbps	0.80	0.53	0.53	0.8 dB	1.3 dB

Source: R1-040049

9.2 Hybrid ARQ

9.2.1 Performance Evaluation

9.2.1.1 Hybrid ARQ performance with and without soft combining

In this section, link level performance results of the hybrid ARQ with and without chase combining are presented for 144 kbps and 480 kbps with the Rel-99 turbo code of 1/3 coding rate and the Rel-99 rate matching. The results are provided on ITU Pedestrian A channel at 3kmph and 30kmph.

Simulation assumptions are listed in the Table 9.2.1 below.

Table 9.2.1. Simulation assumptions

Chip Rate	3.840 Mcps
Carrier Frequency	2 GHz
Propagation Channel	Pedestrian A 3km/h, 30km/h
Channel Estimation (CE)	real CE (DPCCH 6 pilot bits)
Inner-loop transmit power control (TPC)	On
Outer-loop power control	Off
TPC step size	1dB
TPC delay and error rate	1 slot, 4%
Receiver	Rake
Antenna configuration	2 antenna space diversity
Channel oversampling	1 sample/chip
Turbo code information	R=1/3, K=4, 8 iteration, Decoder : Max Log MAP
Information bit rate	144kbps / 480kbps
SF	8 (144kbps) / 4 (480kbps)
Modulation	Dual BPSK
E-DCH TTI	10ms
Hybrid ARQ	Chase Combining(CC) / No Combining(NC)
Maximum number of transmission	3
ACK/NACK signaling error	No error
Rate matching	Rel'99 Rate matching
Gain factor	β_c =5, $\beta_{E-DPDCH}$ =15
Cell configuration	Single omni-cell and single user

The throughput is calculated as

$$Throughput = \frac{R_{\inf}}{N_{av}}$$

where $R_{\inf}$ is the information bit rate and N_{av} is average number of transmissions.

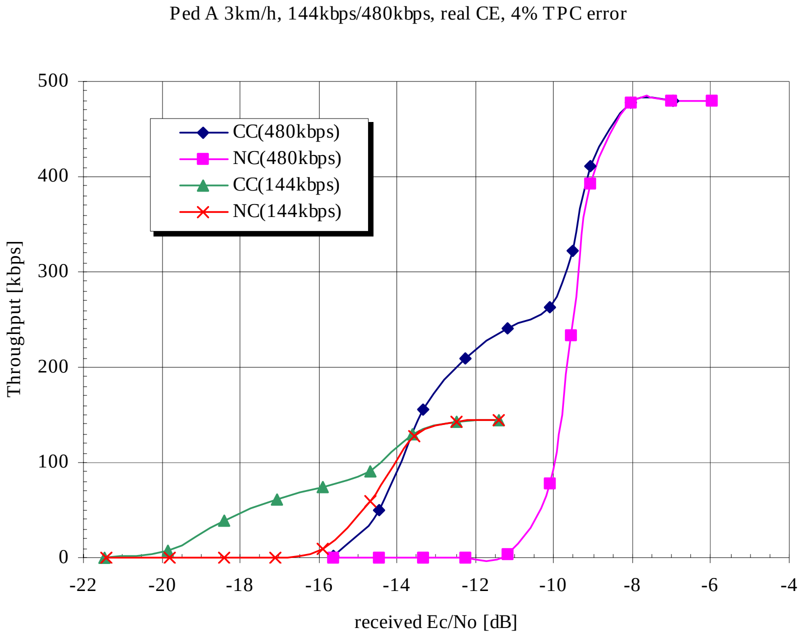

Figure 9.2.1. Throughput in Pedestrian A 3 km/h with power control

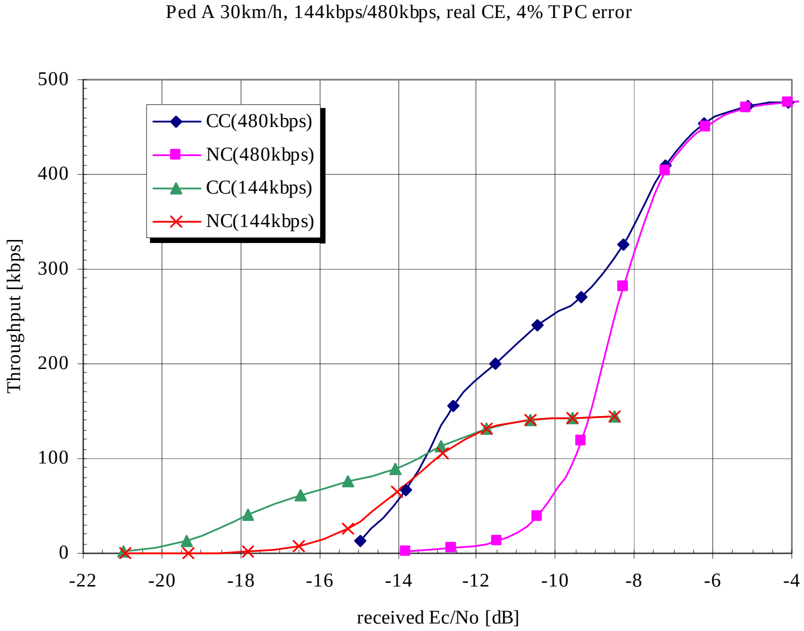

Figure 9.2.2. Throughput in Pedestrian A 30 km/h with power control

Figure 9.2.1 and Figure 9.2.2 show the throughput performance in Pedestrian A with 3 km/h and 30km/h, respectively. It can be seen that the chase combining provides throughput gain when the UE available power is limited so that the hybrid ARQ without chase combining suffers from throughput loss. It is noted that the gain from the soft combining in a realistic scenario should be studied further, since more than two data rates could be typically available to choose depending on, e.g., the UE available power and the scheduling command received from the scheduling Node B(s).

Figure 9.2.3 and Figure 9.2.4 show the average number of transmissions in Pedestrian A 3 km/h and 30km/h, respectively. It can be seen that the chase combining can reduce the number of transmissions significantly.

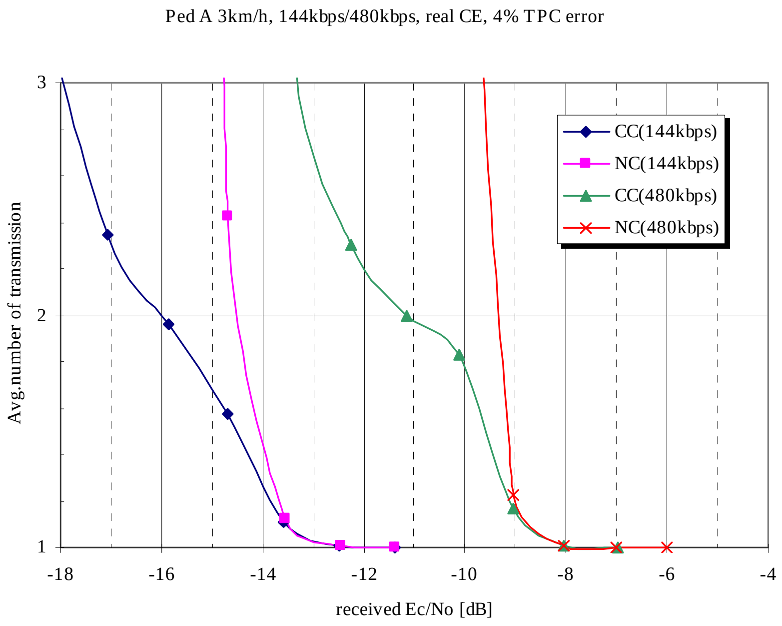

Figure 9.2.3. Average number of transmissions in Pedestrian A 3km/h with power control

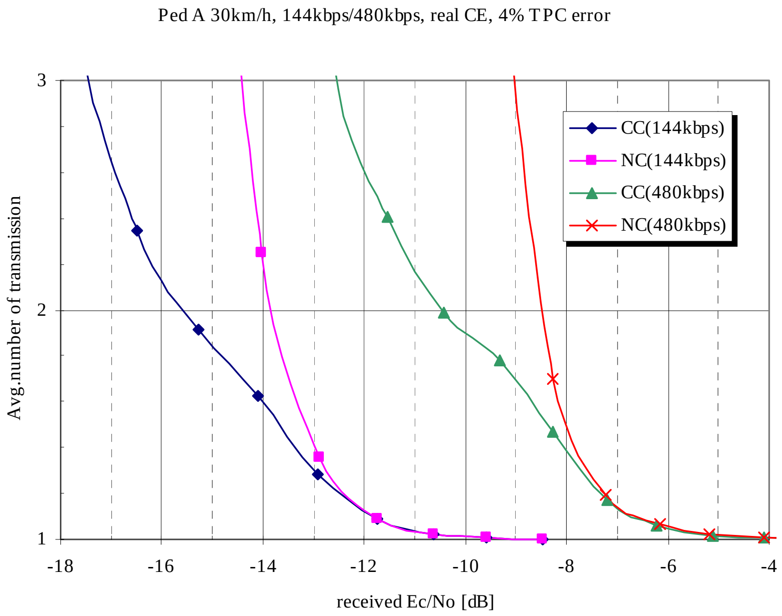

Figure 9.2.4. Average number of transmissions in Pedestrian A 30km/h with power control

Figure 9.2.5 shows the BLER curve of 480 kbps in Pedestrian A 3km/h for each transmission with the chase combining.

Figure 9.2.6 and Figure 9.2.7 show the delay distributions with the first transmission BLER = 17% and 49%, respectively. It can be seen that the chase combining can cut down the number of transmissions to two transmissions even with the first transmission BLER = 49%. The gain of the chase combining in delay distribution is more emphasized with the higher first transmission BLER. This could be beneficial especially for delay sensitive applications.

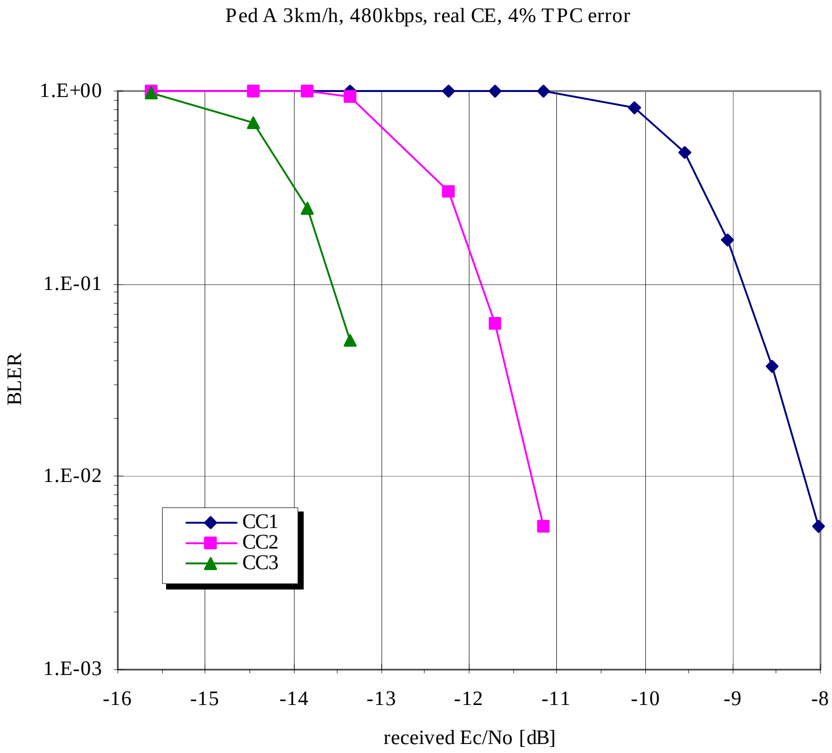

Figure 9.2.5. BLER for 480 kbps in Pedestrian A 3km/h

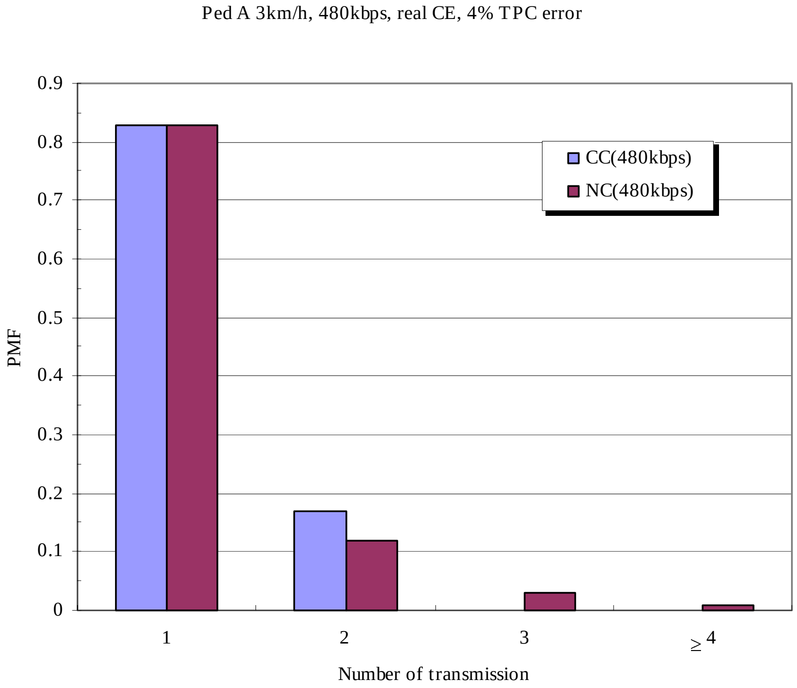

Figure 9.2.6. Delay distribution with the first transmission BLER = 17% for 480 kbps in Pedestrian A 3km/h

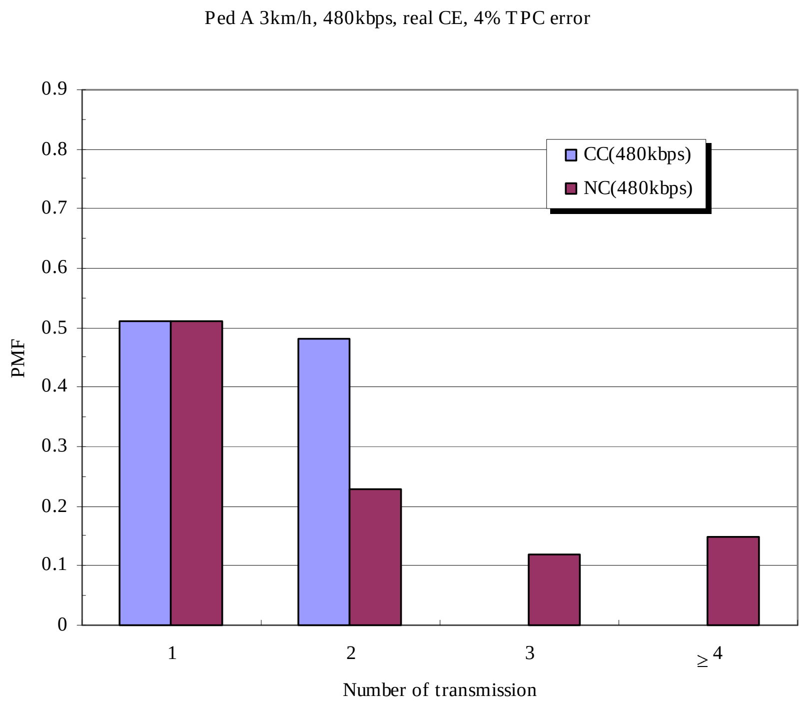

Figure 9.2.7. Delay distribution with the first transmission BLER = 49% for 480 kbps in Pedestrian A 3km/h

9.2.1.2 Hybrid ARQ performance in soft handover

In this section, the link level performance of the hybrid ARQ in soft handover with and without the macro diversity is evaluated. In the simulation, uplink transmit power is controlled by applying the “or of down” rule to the power control commands sent from the active set Node Bs. The UE and Node B operation when the macro diversity is enabled or not is as follows:

- Macro diversity “ON”: All active set Node Bs decode the E-DCH packet and generate ACK/NACK. The UE performs the retransmission only if there is no ACK.
- Macro diversity “OFF”: Only a single active set Node B decodes the E-DCH packet and generates ACK/NACK. The UE performs the retransmission in case of NACK.

The simulation results of the hybrid ARQ with the chase combining are presented for 144 kbps with the Rel-99 turbo code of 1/3 coding rate and the Rel-99 rate matching. The results are provided on ITU Pedestrian A channel at 3kmph. In the simulation, two active set Node Bs are assumed and different link imbalance conditions in uplink are taken into account. Other detailed simulation assumptions are set as described in Table 9.2.1. It is noted that in this section, the total received Ec/No in the active set corresponds to the sum of the Ec/No experienced by both Node Bs within the active set.

Figure 9.2.8 and Figure 9.2.9 show the throughput and the average number of transmissions, respectively, versus the total received Ec/No in the active set with 0dB link imbalance. It can be seen that the macro diversity provides noticeable performance gain. It is noted that the macro diversity gain increases as the received energy is increased.

Figure 9.2.10 and Figure 9.2.11 show the simulation results with 3dB link imbalance. The macro diversity gain is more emphasized compared to the case that only the weaker cell decodes the E-DCH packet. The macro diversity gain can still be seen with respect to E-DCH decoding at the stronger cell, although the gain is reduced.

It is noted that the results in this section show the ideal performance of the macro diversity operation, assuming no hybrid ARQ control signalling errors.

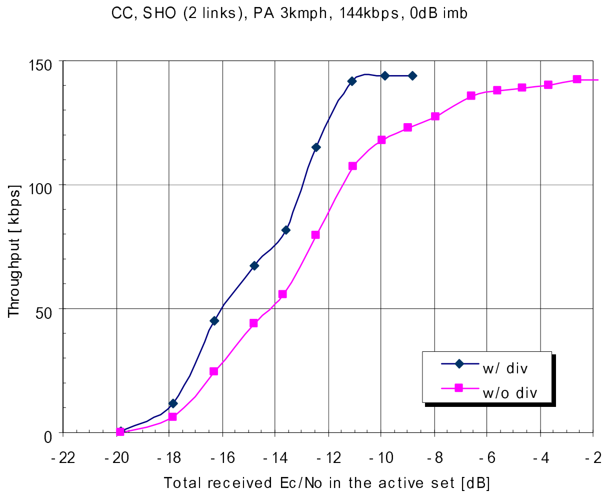

Figure 9.2.8. Throughput in soft handover with 0dB link imbalance in PA 3kmph

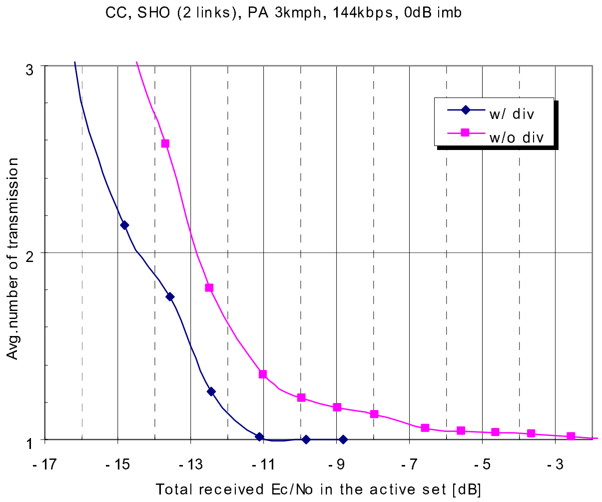

Figure 9.2.9. Average number of transmissions in soft handover with 0dB link imbalance in PA 3kmph

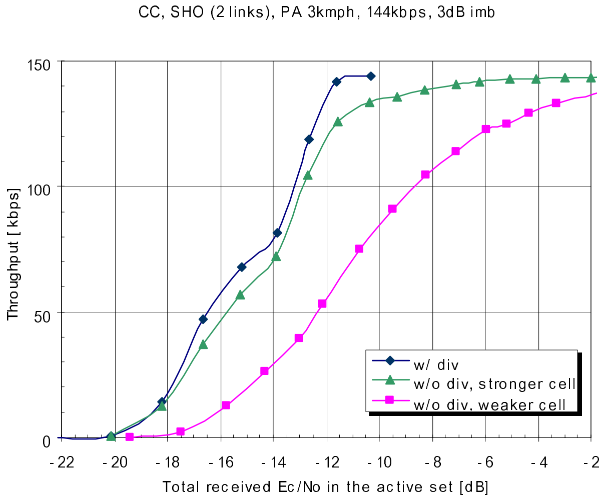

Figure 9.2.10. Throughput in soft handover with 3dB link imbalance in PA 3kmph

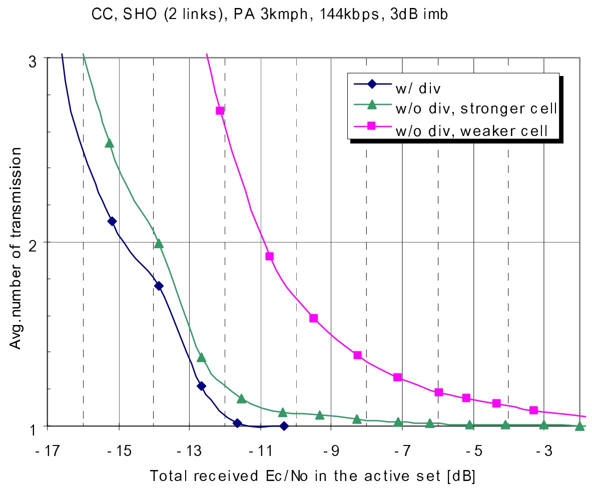

Figure 9.2.11. Average number of transmissions in soft handover with 3dB link imbalance in PA 3kmph

9.2.1.3 HARQ Efficiency

In this section, the benefits of link level retransmissions, and issues of HARQ efficiency and the maximum number of retransmissions needed to support on E-DPDCH are addressed. Here, E-DPDCH denotes the physical set of channelization codes used to carry E-DCH content.

A reference MCS for a sample 2ms TTI is shown in Table 9.2.2.

Index	**Transport Block Size**	**Mod**	**Code Rate**	**Rate (kbps)**		
				1 Tx	**2 Tx**	**4 Tx**
4	1280	QPSK	0.333	640	320	160
7	2048	QPSK	0.533	1024	512	256
9	2560	QPSK	0.333	1280	640	320
15	4096	QPSK	0.533	2048	1024	512
19	5120	QPSK	0.444	2560	1280	640
31	8192	QPSK	0.711	4096	2048	1024

Table 9.2.2 Reference MCS – 2ms TTI

From Table 9.2.2, the same target rate can be achieved using different transport formats and number of transmissions. The performance of E-DPDCH is now evaluated with 1 or 2 or 4 target transmissions for the *same* target data rate, as shown in Table 9.2.3

Target Data Rate (kbps)	**MCS**		
	1 Tx	**2 Tx**	**4 Tx**
640	4	9	19

1024	7	15	31

Table 9.2.3 Simulation Set – 2ms TTI

The simulation assumptions and results are shown in Annex A.2.1.1.

For a 2ms sample TTI and associated link level performance shown in Figures A.2.1.1.1 to A.2.1.1.4 and Tables A.2.1.1.1 and A.2.1.1.2, it is seen that:

1. For the same *target* data rate, as the *target* number of transmissions increases, the link efficiency improves.
    a. The efficiency improvement reduces as the base number of transmissions increases.
    b. The link efficiency gain from 1 to 2 transmissions is more than the gain from 2 to 4 transmissions.
2. The optimal DPCCH SNR typically decreases and E-DPDCH/DPCCH power ratio increases as the number of transmissions increases.
3. For the same *target* data rate, as the maximum number of transmissions increases, the E-DPDCH can be terminated relatively earlier ➔ effective data rate is higher.
    a. For a target *maximum* of 2 transmissions, the average number of *required* transmissions is 1.7 ➔ early termination factor is 1.7/2 = 0.85
    b. For a target *maximum* of 4 transmissions, the average number of required transmissions is 3.0 ➔ early termination factor is 3.0/4 = 0.75
4. For the same *effective* data rate, as the maximum number of transmissions increases, the link efficiency increases.
5. The first transmission BLER can be very high for the most efficient link operation
    a. This does not necessarily maximize throughput.
6. For the same number of target transmissions, throughput can be maximized or delay can be reduced, at the cost of link efficiency.
7. For the same effective data rate and same base TTI, as the maximum number of transmissions increases, the average delay increases.

9.2.2 Complexity Evaluation <UE and RNS impacts>

9.2.2.1 Buffering complexity

9.2.2.1.1 Soft buffer at Node B

The principle of hybrid ARQ is to buffer E-DCH TTIs that were not received correctly and consequently combine the buffered data with retransmissions. The actual method of doing soft combining depends on the HARQ combining scheme selected. In Chase combining scheme the receiver always combines the full retransmission of the failed TTI, i.e. the amount of data in the receiver buffer remains the same. In the incremental redundancy schemes the receiver buffers coded symbols, which introduce new information to the E-DCH TTI transmitted first, i.e. the amount of data to be buffered increases with consecutive retransmissions. However, in practice the buffer in the receiver needs to be dimensioned considering the maximum number of coded bits of the E-DCH TTI after all the incremental redundancy has been introduced. Regardless of the HARQ combining scheme soft combining is done on L1 of Node B before the decoding stage of FEC. Prior to decoding these symbols are soft-valued, i.e. each symbol is represented by two or more bits. Here we call them soft symbols.

For N-process SAW HARQ, the number of soft symbols to be buffered in L1 receiver can be estimated generally as follows, since no new PDUs are transmitted on a subchannel before the previous packet is acknowledged. The receiver has to buffer one E-DCH TTI for each HARQ process and for each UE. The next transmission is either a new packet or a retransmission of an erroneous packet. In either case, the maximum buffering need is N E-DCH TTIs. The actual size of the buffer needed for each E-DCH TTI depends on the HARQ combining scheme as described above. Thus, for N-process stop-and-wait ARQ the L1 buffering at Node B for one UE can be expressed as:

$$buffer = (softsymbols_{TTI} \times N)$$

Table 9.2.4 shows some examples for the soft buffer size required at Node B per UE. It should be noted that soft buffer is needed for all UEs waiting for retransmission at a given time. Thus these values have to be multiplied by the number of active UEs using E-DCH. Depending on particular implementations, the buffer may be shared between UEs and thus the total size of soft buffer can be reduced given that not all active UEs transmit simulteanously using the most demanding format. Also, it may be possible to re-use some existing buffers.

Table 9.2.4 Node B soft buffer size (kilo soft symbols) per UE, for some example values of N (number of HARQ processes) and TTI lengths

	N=4, TTI=10 ms	N=3, TTI=10 ms	N=8, TTI=2 ms	N=6, TTI=2 ms
BPSK, SF=4	38.4	28.8	15.36	11.52
QPSK or 2*BPSK, SF=4	76.8	57.6	30.72	23.04
8PSK or 3*BPSK, SF=4	115.2	86.4	46.08	34.56
2*QPSK or 4*BPSK, SF=4; or QPSK, SF=2	153.6	115.2	61.44	46.08

It should be noted that soft buffer in the Node B is not needed if soft combining is not used, e.g., with physical/MAC layer ARQ without soft combining.

9.2.2.1.2 Reordering buffer in radio network

Due to physical/MAC layer (H)ARQ, the MAC-e PDUs may be received in wrong order. Therefore, reordering of the MAC-e PDUs is required either in the Node B or in the RNC. Here the required reordering buffer size per UE is estimated. In the estimation it is assumed that only one high bit rate reordering queue is active for a UE at a time. Furthermore, maximum of 3 retransmissions per MAC-e PDU is assumed and the buffer size is calculated for the worst case where one ARQ process requires retransmissions while the others get blocks through and forward them to reordering queue. The worst case buffer size is then calculated as

$$reorderingbuffer = [3(N-1)+1] \times (bits/TTI)$$

These values have to be multiplied by the number of E-DCH UEs served by the Node B or by the RNC, depending on the location of the reordering buffer. Depedending on implementation and location of the re-ordering buffer, it may be possible to re-use some existing buffers.

Table 9.2.5 Reordering buffer size (kB) per UE, for some example values of N (number of HARQ processes) and TTI lengths

User data rate	N=4, TTI=10 ms	N=3, TTI=10 ms	N=8, TTI=2 ms	N=6, TTI=2 ms
384 kbit/s	4.8	3.36	2.1	1.5
768 kbit/s	9.6	6.72	4.2	3.1
1 Mbit/s	12.5	8.8	5.5	4.0
1.5 Mbit/s	18.8	13.1	8.3	6.0

9.2.2.1.3 Retransmission buffer in UE

In addition to buffers in the receiver side, also some buffer at UE side is needed. The retransmission buffer can be either at MAC layer as info bits or at physical layer as coded bits. The total number of coded bits is typically 3 times the number of info bits. Table 9.2.4 shows also the required retransmission buffer size in kbits (assuming that coded bits are buffered). Depending on implementation it may be possible to re-use existing buffers.

9.2.2.2 Encoding/decoding and rate matching complexity

Rate 1/3 turbo code specified in Rel99 as well as the two stage rate matching specified for HSDPA are supposed to be possible to reuse for E-DCH with some modifications. These are not considered to bring much more complexity for uplink processing than already is in Rel99/4/5.

9.2.2.3 UE and RNS processing time considerations

One of the major complexity issues for fast HARQ is the tight processing time requirement that it sets to the Node B and the UE. Section 8.2 already discusses the processing times as well as other delay components related to fast HARQ.

9.2.2.4 HARQ BLER operation point and complexity

Section 9.2.1.3 states that HARQ efficiency is increased when the maximum number of transmissions is increased. That also implies that the first transmission BLER is increased. From complexity point of view, the increase of BLER operation point (to 50% or even higher) also means complexity increase. If the first transmission BLER is high and the single user throughput is kept the same, then the peak data rate has to be increased, which means that more hardware and/or software resources have to be allocated for each user both at UE and radio network side. On the other hand, if single user throughput is allowed to decrease and the system throughput is increased by allowing more users in the cell, this also requires more hardware and/or software resources in the network side. The higher peak data rate per user or more users both imply that the amount of processing, as well as the amount of the buffering is increased at Node B. Also the amount of Iub traffic and buffering and processing at RNC is increased if the reordering is performed at RNC.

Roughly speaking BLER=50-60% operation point requires that the baseband buffers and amount of processing resources are doubled compared to BLER=10% operation point.

9.2.3 Downlink Signalling

9.2.4 Uplink Signalling

9.2.4.1 E-TFC signalling

This section provides some simulation results for a number of combinations derived from the options described in section 7.5.2.1. The options under consideration are listed in table 9.2.1

Table 9.2.4.1: E-TFC coding, multiplexing and mapping options

Parameter	**Case 1**	**Case 2**	**Case 3**
# of E-TFC bits	10	5	10
TTI	10 ms	10 ms	2 ms
CRC	No	No	No
Coding	Block [30,10] + Repetition [5 times]	Block [30,10]	Block [30,10]
Mapping	E-DPCCH SF=256	DPCCH	E-DPCCH SF=256
Offset relative to DPCCH	Variable	0 dB (can not be changed by design)	Variable
Modulation	BPSK	BPSK	BPSK
Results in section	9.2.4.1.1.1	9.2.4.1.1.2	9.2.4.1.1.3

9.2.4.1.1 Summary of results

Table 9.2.2 provides a summary of the simulation results assuming a target E-TFC error rate of 1%. It is FFS whether this target is appropriate.

Table 9.2.4.2: E-TFC coding, multiplexing and mapping options

Parameter	**Required offset to DPCCH [dB] to achieve 1% error rate on E-TFC**		**Comments**
DPCCH SNR	**-21 dB**	**-24 dB**	
Case 1	-9 dB	-4 dB	No issue
Case 2	@ 0 dB BLER < 1e-3	@ 0 dB BLER < 1e-1	This approach requires a power offset on the TFCI bits (new option) in order to achieve the target error rate in difficult conditions.
Case 3	1 dB	-	Required power offset is similar to one required for HS-DPCCH transmission.

9.2.4.1.1.1 Case 1 results

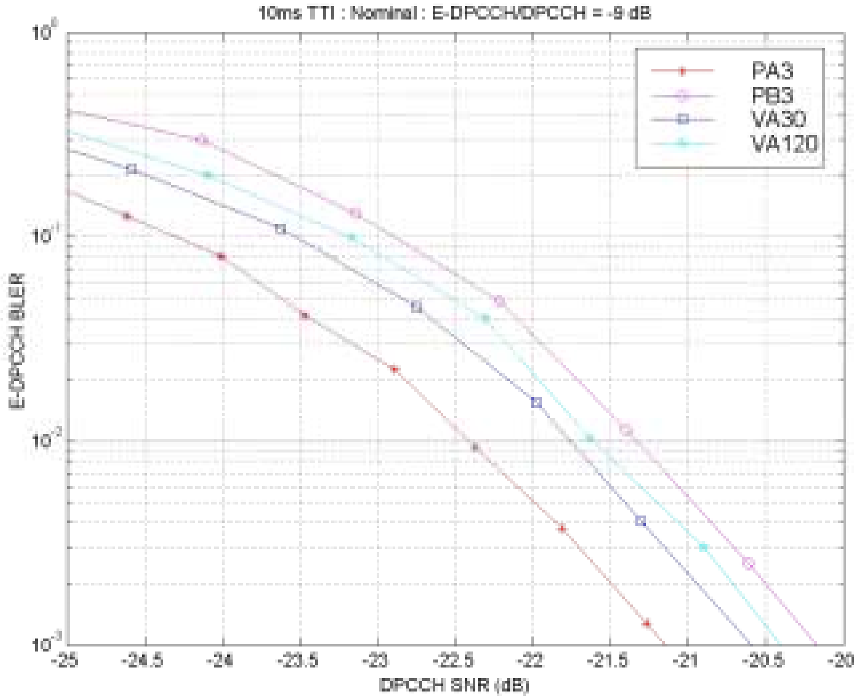

Figure 9.2.4.1 E-DPCCH/DPCCH = -9 dB

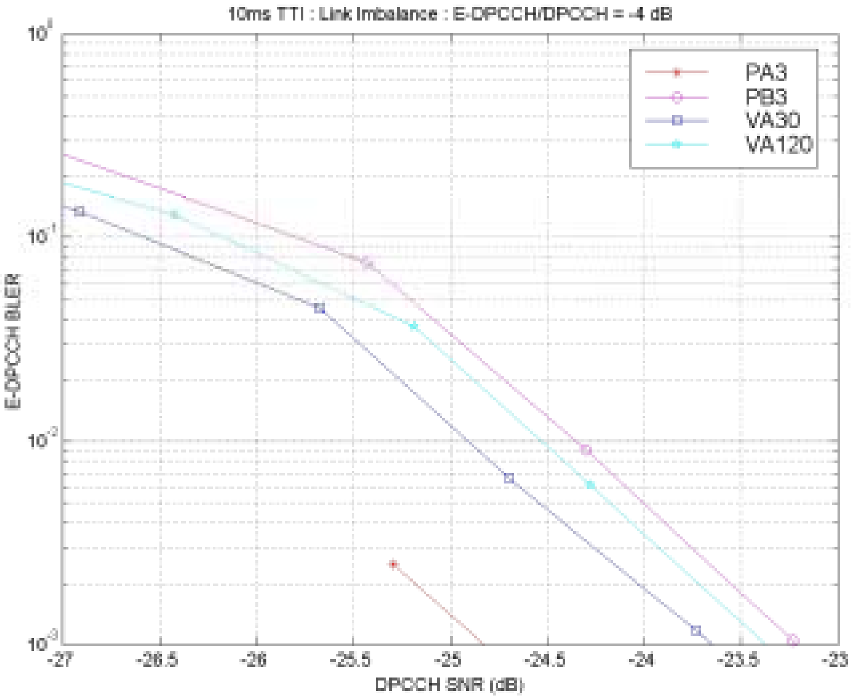

Figure 9.2.4.2: E-DPCCH/DPCCH = -4 dB

9.2.4.1.1.2 Case 2 results

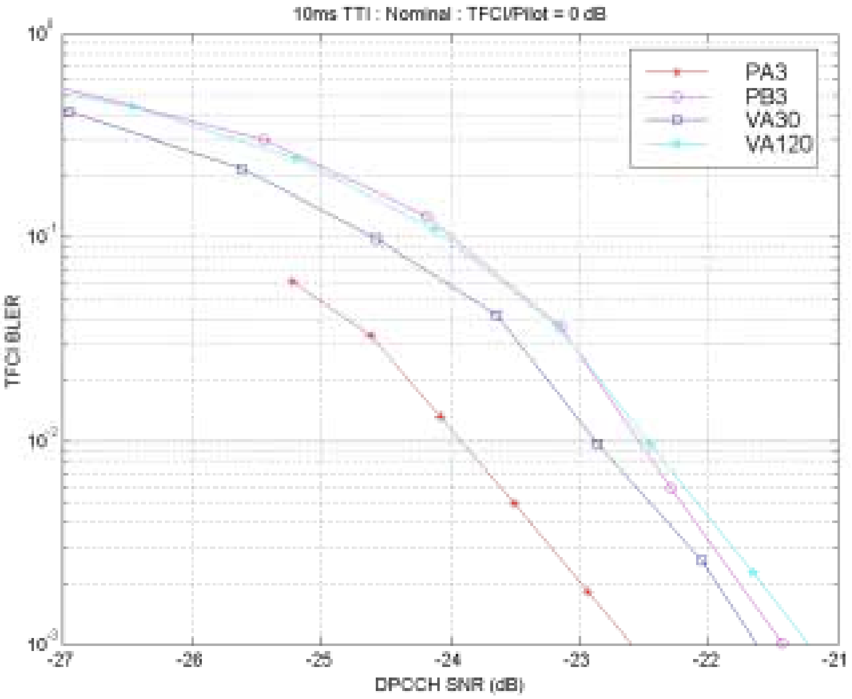

Figure 9.2.4.3: TFCI/DPCCH = 0 dB

9.2.4.1.1.3 Case 3 results

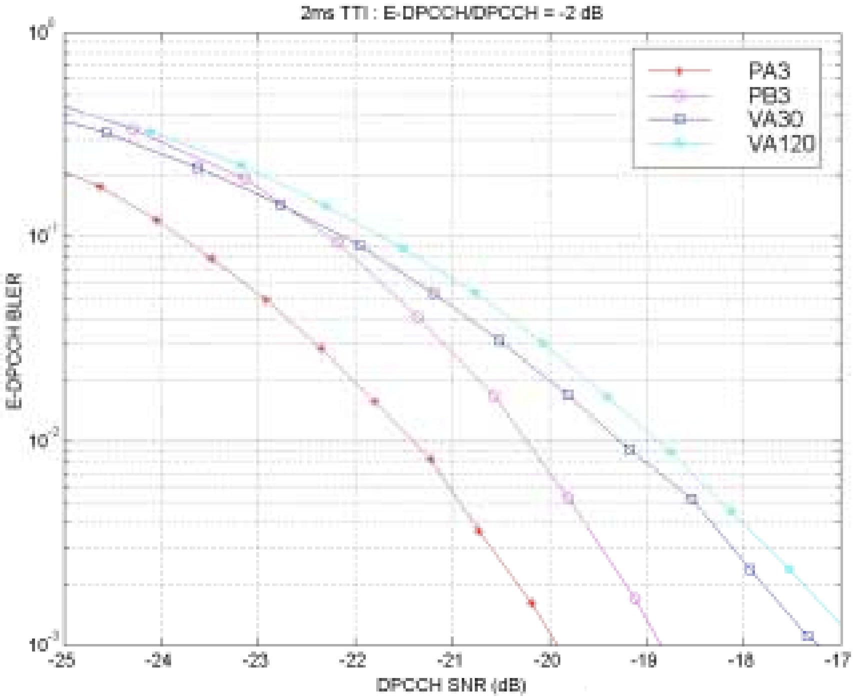

Figure 9.2.4.4: E-DPCCH/DPCCH = -2 dB

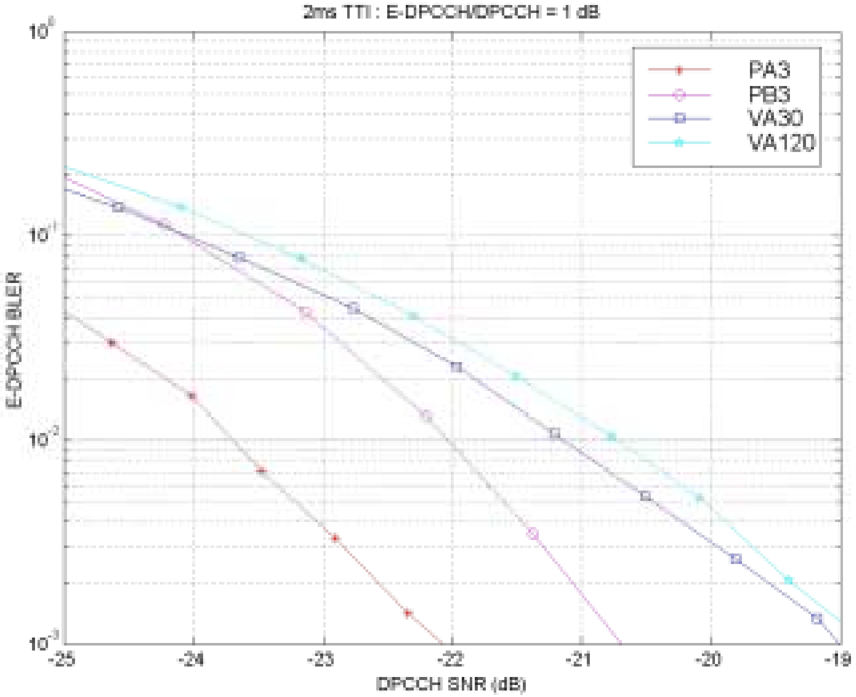

Figure 9.2.4.5: E-DPCCH/DPCCH = 1 dB

9.2.4.1.2 Simulation assumptions

Table 9.2.4.3 summarizes the simulation parameters.

Table 9.2.4.3: Simulation parameters

Parameter	**Value**
Channel Estimation	On
DPCCH slot format	0
Inner Loop Power Control	On
ILPC Step Size	+/- 1 dB
Outer Loop Power Control	Off, DPCCH SNR target varied
PC feedback delay	1-slot
PC command BER	4%
Channels	PA3, PB3, VA30, VA120
Number of Rx antennas	2

9.3 Fast DCH Setup Mechanisms

9.3.1 Performance Evaluation

9.3.2 Complexity Evaluation <UE and RNS impacts>

9.3.3 Downlink Signalling

9.3.4 Uplink Signalling

9.4 Shorter Frame Size for Improved QoS

9.4.1 Performance Evaluation

Two possible candidates for the frame size are 2ms and 10ms. In this section, we present the E-DCH system performance with 2ms TTI vs. 10ms with HARQ and a Node-B scheduler. **The comparison is performed assuming the same maximum physical layer delay equal to 40 ms. Comparison performed using a different criterion (e.g. different max delay value, average delay, …) may yield different relative results.**

9.4.1.1 Data only, Full buffer

The system configuration has been set as shown in Table 9.4.1.1.1. A subset of the MCS used for 2 ms and 10 ms are shown in Annex 2.2.1 and 2.2.2.

Table 9.4.1.1.1: Simulation parameters

<table>
<tr><th>Parameter</th><th colspan="2">Configuration</th></tr>
<tr><td>Layout</td><td colspan="2">19 Node-B, 3-cell wrap-around layout</td></tr>
<tr><td>Channel model</td><td colspan="2">Mixed (PA3 30%, VA30 50% and VA120 20%) and individual</td></tr>
<tr><td>Traffic model</td><td colspan="2">Full buffer</td></tr>
<tr><td>#UE per cell</td><td colspan="2">10</td></tr>
<tr><td>Duration</td><td colspan="2">200 s + 10 s warm-up</td></tr>
<tr><td rowspan="2">HARQ</td><td><i>2ms TTI</i></td><td><i>10ms TTI</i></td></tr>
<tr><td>Max # of transmissions = 4
# of HARQ processes = 5
Re-transmission delay = 10 ms
Ack/Nack errors = 0%</td><td>Max # of transmissions = 2
# of HARQ processes = 3
Re-transmission delay = 30 ms
Ack/Nack errors = 0%</td></tr>
<tr><td>Scheduling algorithm</td><td colspan="2">Proportional fair</td></tr>
<tr><td>Scheduling process</td><td colspan="2">As described in R1-031246. Decentralized Node-B scheduler with 1 serving cell per UE = best DL (same as HSDPA serving cell). All cells in UE’s active set send ACK/NAK.</td></tr>
<tr><td>Scheduling delays</td><td colspan="2"><table>
<tr><th></th><th>2ms E-DCH</th><th>10ms E-DCH</th></tr>
<tr><td>Period</td><td>2 ms</td><td>10 ms</td></tr>
<tr><td>Uplink SI delay</td><td>10 slots</td><td>35 slots</td></tr>
<tr><td>DL Grant delay</td><td>1 slot</td><td>1 slot</td></tr>
</table></td></tr>
<tr><td>Power control</td><td colspan="2">Outer loop driven by 1% BLER on DPDCH
Inner loop error rate = 4%</td></tr>
<tr><td>DCH</td><td colspan="2">TFCS = 8 kbps (100% duty cycle)
Minimum set: 8 kbps</td></tr>
<tr><td>E-DCH</td><td colspan="2">TFCS = TFS = MCS as shown in Table 2
Minimum set is empty

E-TFC elimination:
Similar to R99 TFC elimination. UE MAC decides upon the E-DCH TFC in SUPPORTED_STATE and EXCESS_POWER_STATE every radio frame. The parameters {x, y, z} are set to {15, 30, 30} as in Rel-99.</td></tr>
<tr><td rowspan="3">E-DPCCH</td><td><i>2ms TTI</i></td><td><i>10ms TTI</i></td></tr>
<tr><td>β / β_c = 17/15</td><td>β / β_c = 7/15</td></tr>
<tr><td colspan="2">E-DPCCH errors: 0%</td></tr>
<tr><td rowspan="2">SHO</td><td><i>2ms TTI</i></td><td><i>10ms TTI</i></td></tr>
<tr><td>When in SHO E-TFS is restricted up to instantaneous 512kbps</td><td>When in SHO E-TFS is restricted up to instantaneous 256kbps</td></tr>
<tr><td>Decoding</td><td colspan="2">Short term link level curves: [A2.2.1] with implementation-I and [A2.2.2]</td></tr>
</table>

Figure 9.4.1.1.1 and Figure 9.4.1.1.2 compare the E-DCH cell throughput with 2ms and 10ms TTI. It is seen that compared to 10ms TTI, the system performance with 2ms TTI improves by 16% at 4.5 dB RoT. Figure 9.4.1.1.3 shows that 2 ms yield a better fairness. The RoT overshoot curve given in Figure 9.4.1.1.4 indicates that 10ms TTI has a higher RoT overshoot.

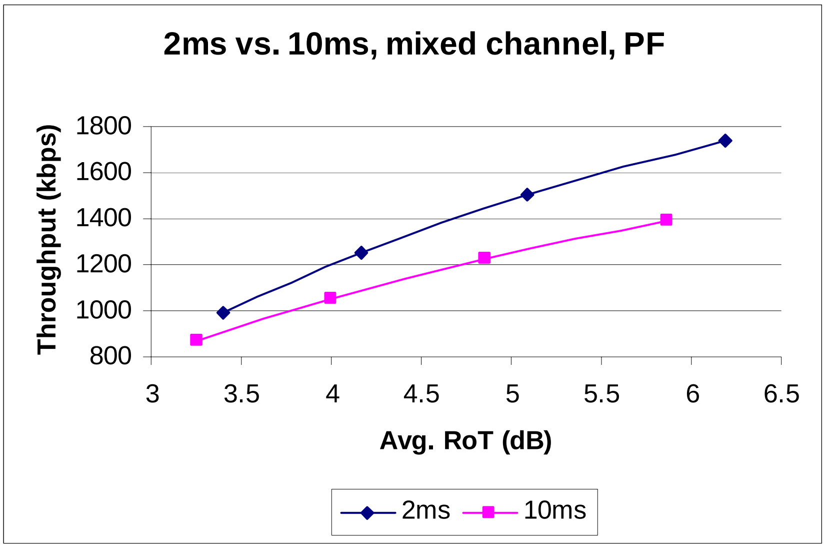

Figure 9.4.1.1.1: Average cell throughput as a function of average RoT – mixed channel

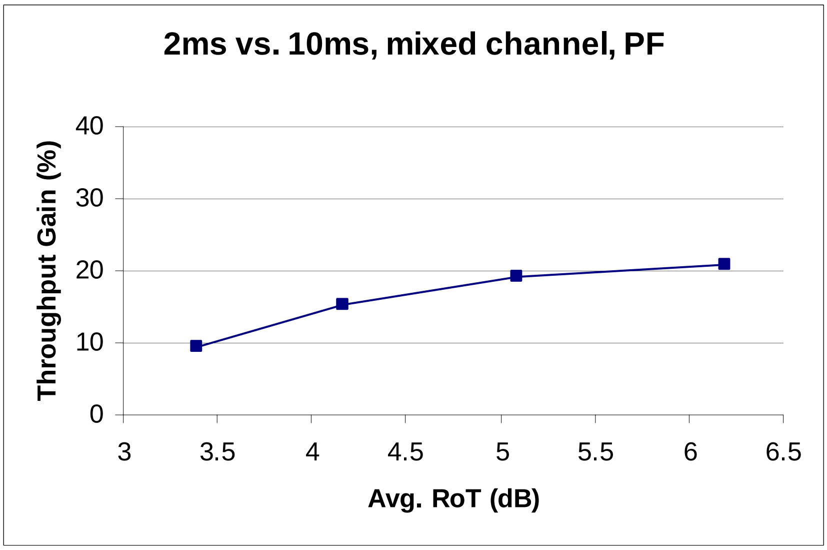

Figure 9.4.1.1.2: Throughput gain between EUL 2ms and EUL 10ms – mixed channel

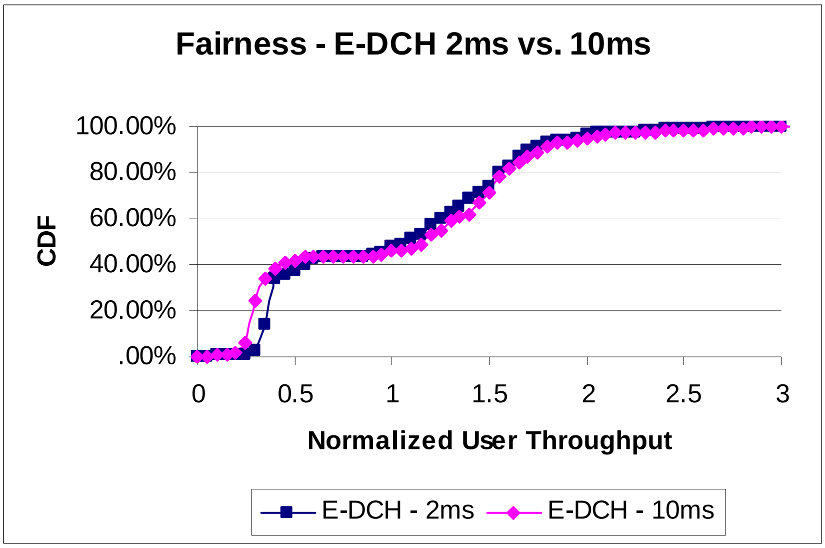

Figure 9.4.1.1.3: Fairness curves - mixed channel

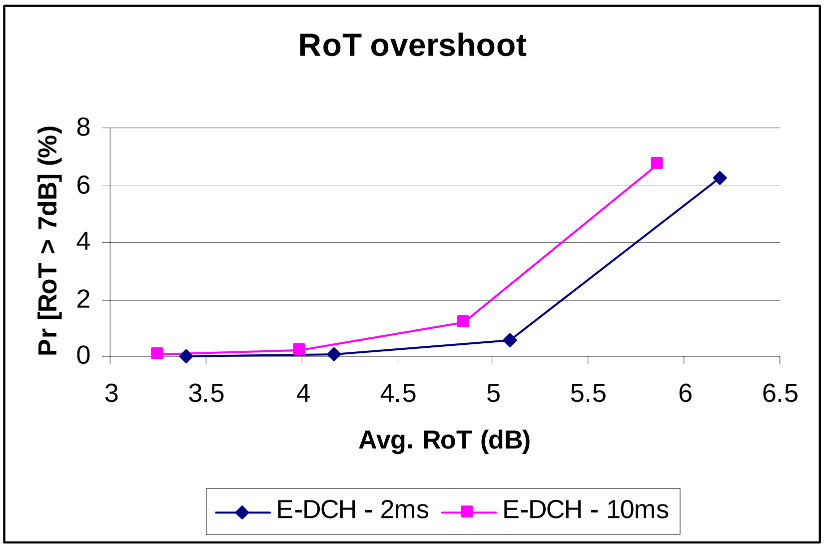

Figure 9.4.1.1.4: Percentage of time the RoT is greater than 7 dB – mixed channel

9.4.1.2 Data only, Traffic models

The system configuration has been set as shown in tables 9.4.1.1.1, except for the number of UE and traffic model part which is as shown in table 9.4.1.2.1. A subset of the MCS used for 2 ms and 10 ms are shown in Annex 2.2.1 and 2.2.2.

Table 9.4.1.2.1: Simulation parameters for mixed traffic model

Parameter	Configuration
#UE per cell	12
Traffic model	Mixed (4 FTP, 4 Video, 4 Gaming)

Table 9.4.1.2.2 shows the values of tau parameters used for FTP users.

Table 9.4.1.2.2: Tau parameters used for FTP

Delay component	Symbol	Value
The uplink transmission time of a TCP data segment from the client to the Node-B	τ_1	Determined by uplink throughput
The sum of the time taken by a TCP data segment to travel from Node-B to the server and the time taken by an ACK packet to travel from the server to Node-B	τ_2	Exponential distribution Mean = 50 ms.
Time taken by the ACK to travel from Node-B to client	τ_3	Lognormal distribution Mean = 50 ms Standard deviation = 50 ms
Increased delay to account for RLC retransmissions from residual uplink physical layer BLER	τ_4	Constant = 0 ms, if packet is not in error after all physical layer retransmissions = 200 ms, else

The following figures present the system performance of E-DCH with different TTI lengths. The comparison of the performances, in terms of cell throughput, fairness, RoT overshoot, and delays are shown.

Figure 9.4.1.2.1 shows the system throughput as a function of the average RoT. The gain of around 10% of the system with 2ms TTI over the 10ms TTI can be observed.

The RoT overshoot is given in Figure 9.4.1.2.2. It can be seen that the RoT overshoot for the region of interest is similar for both, 2 ms TTI and 10 ms TTI.

The cumulative density function (CDF) of user throughputs normalized by the average throughput per user is used to represent the fairness. The fairness curve, given in Figure 9.4.1.2.3, shows that the fairness of the system with 2 ms TTI is slightly degraded compared to 10 ms TTI, primarily due to the higher instantaneous data rates.

Figures 9.4.1.2.4 to 9.4.1.2.7 present the average packet call delays and the average packet delays. Packet call delay is the time between two consecutive reading periods. For Gaming users, packet call delay represents the time of a gaming session that includes the time during which the packets are generated (active period), and the time needed for transmission of the data packets accumulated during the active period. For FTP users, packet call delay is the time needed for an FTP file upload. Packet delay is the time needed for a packet to be received at a Node-B. It can be seen that the delays are decreased for the system with 2 ms TTI when compared to the 10 ms TTI.

Figures 9.4.1.2.8 to 9.4.1.2.11 show the CDF of the packet call delays and packet delays, for both systems, with 2 ms TTI and 10 ms TTI. It can be seen that the delay characteristics of the 2 ms TTI are superior over the 10 ms TTI, for all traffic models.

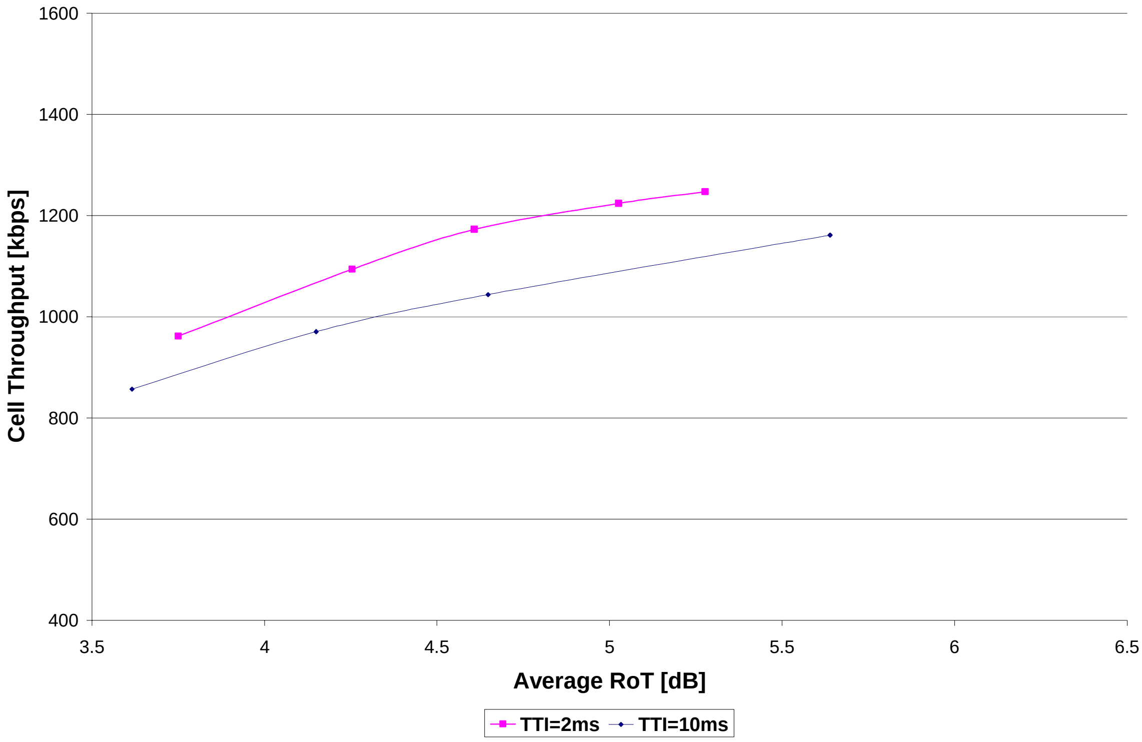

Figure 9.4.1.2.1: Average cell throughput as a function of the average RoT

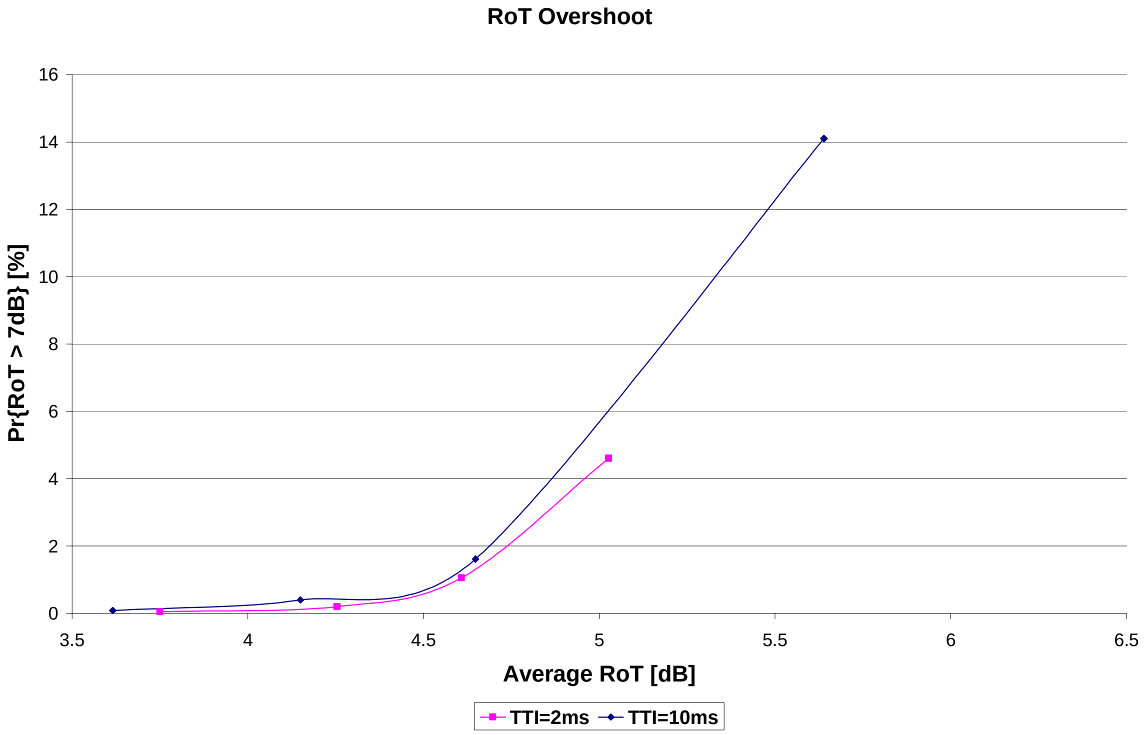

Figure 9.4.1.2.2: Percentage of time the RoT is greater than 7 dB

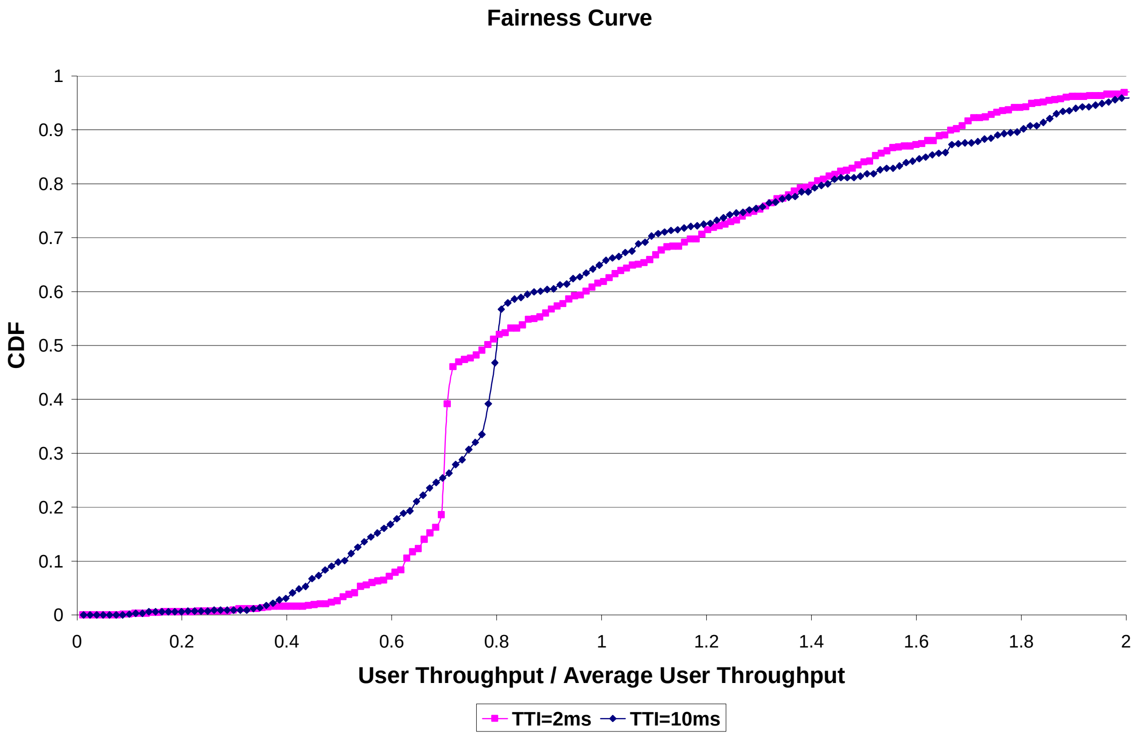

Figure 9.4.1.2.3: Fairness curves

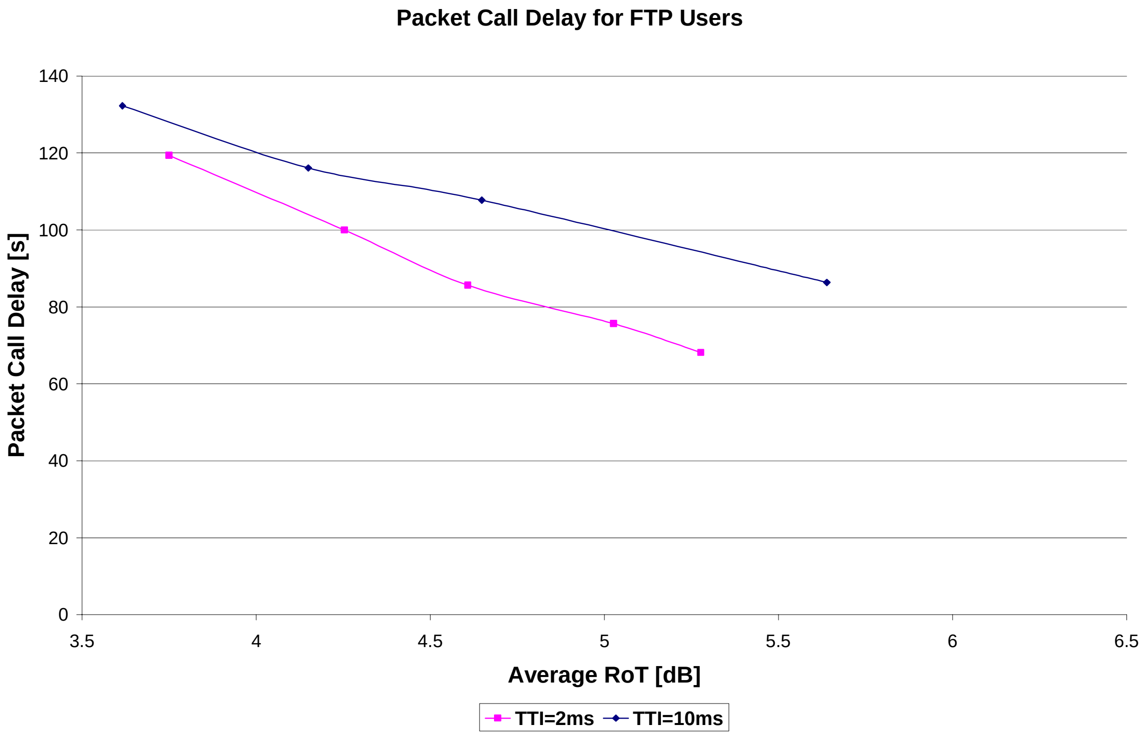

Figure 9.4.1.2.4: Average packet call delay for FTP users

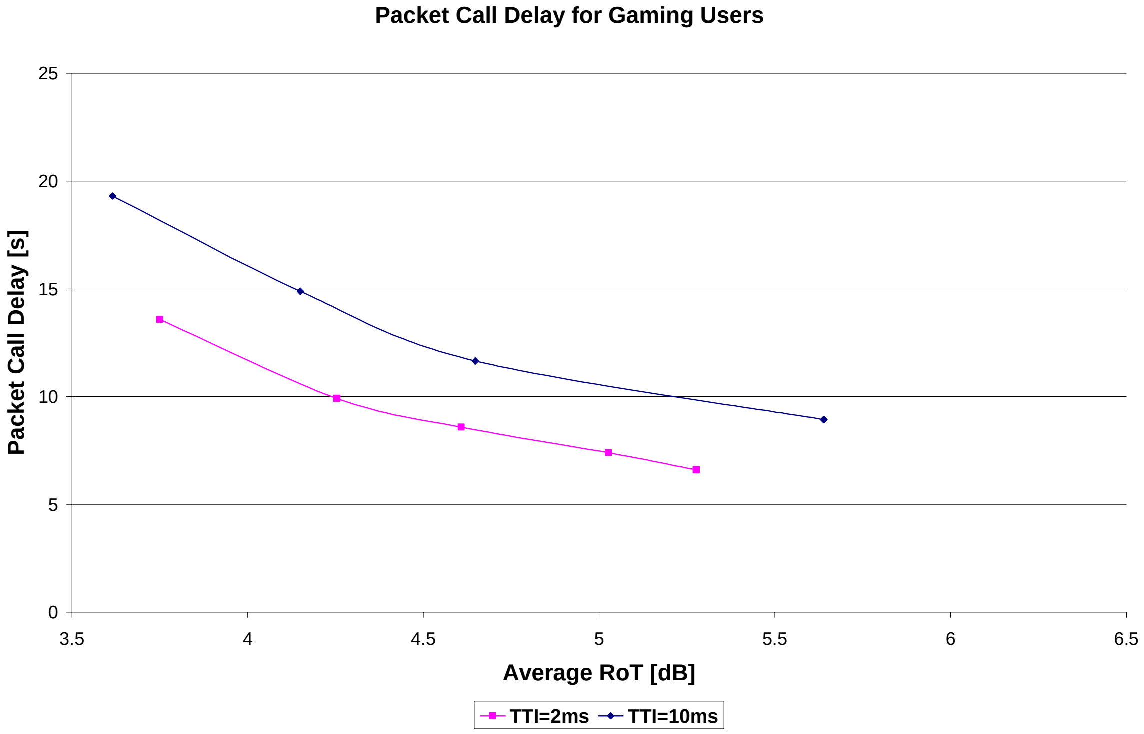

Figure 9.4.1.2.5: Average packet call delay for Gaming users

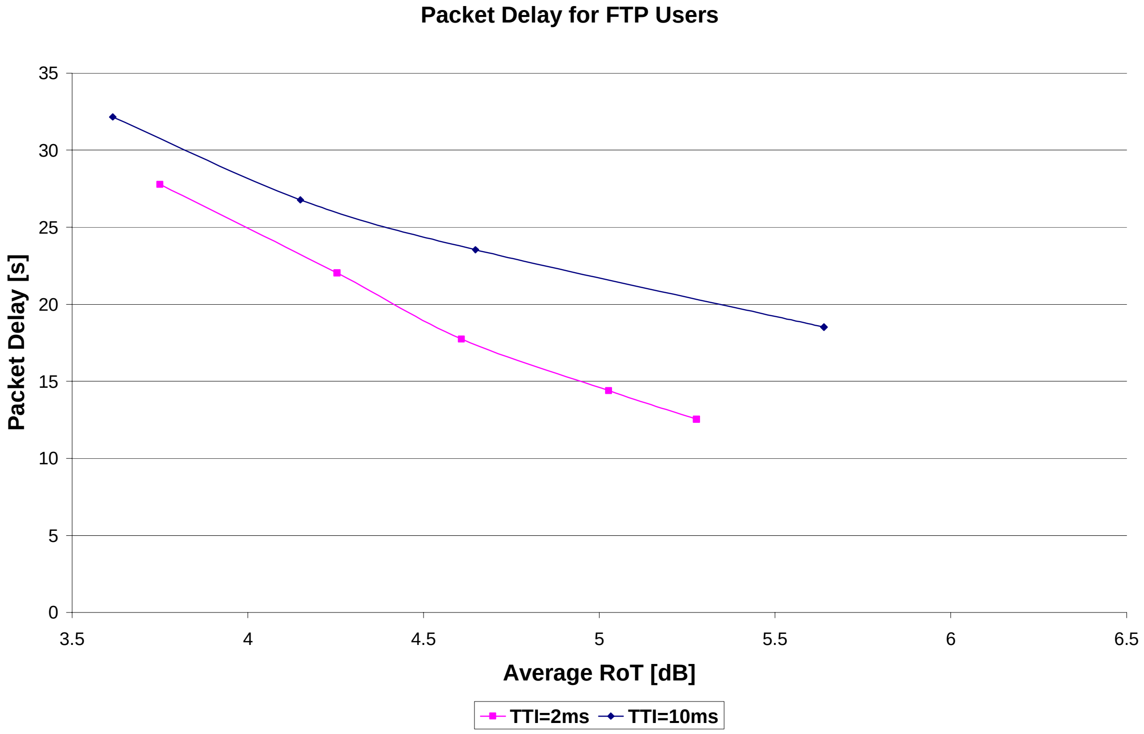

Figure 9.4.1.2.6: Average packet delay for FTP users

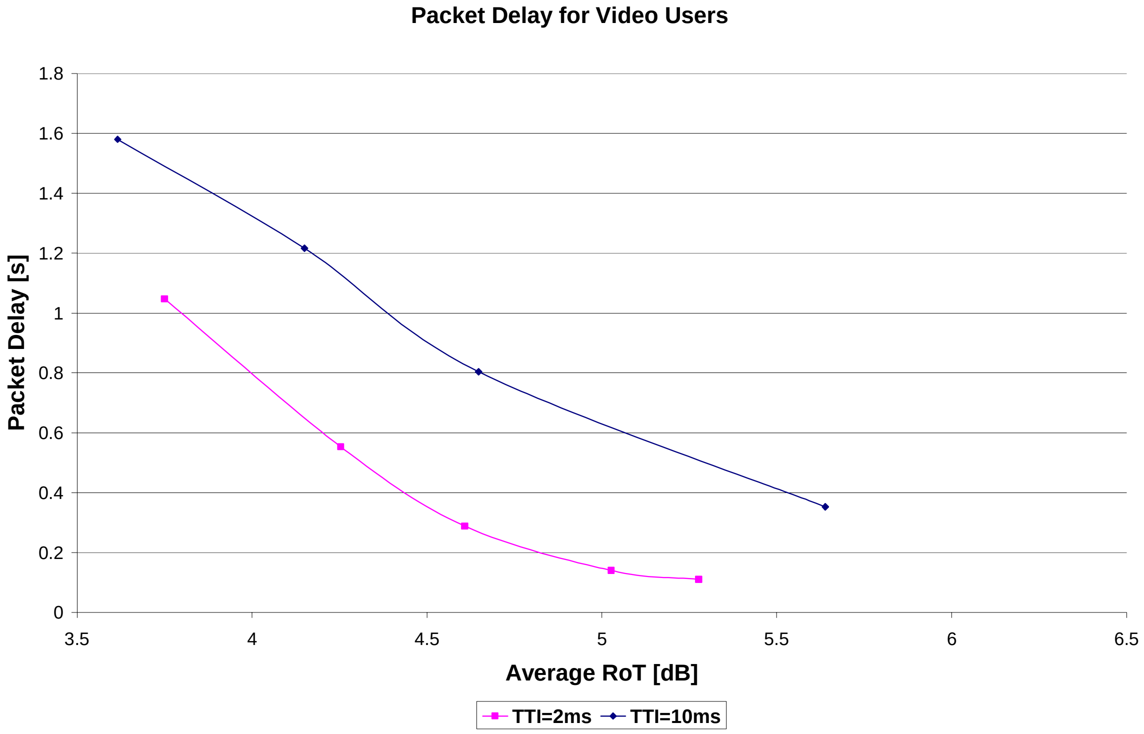

Figure 9.4.1.2.7: Average packet delay for Video users

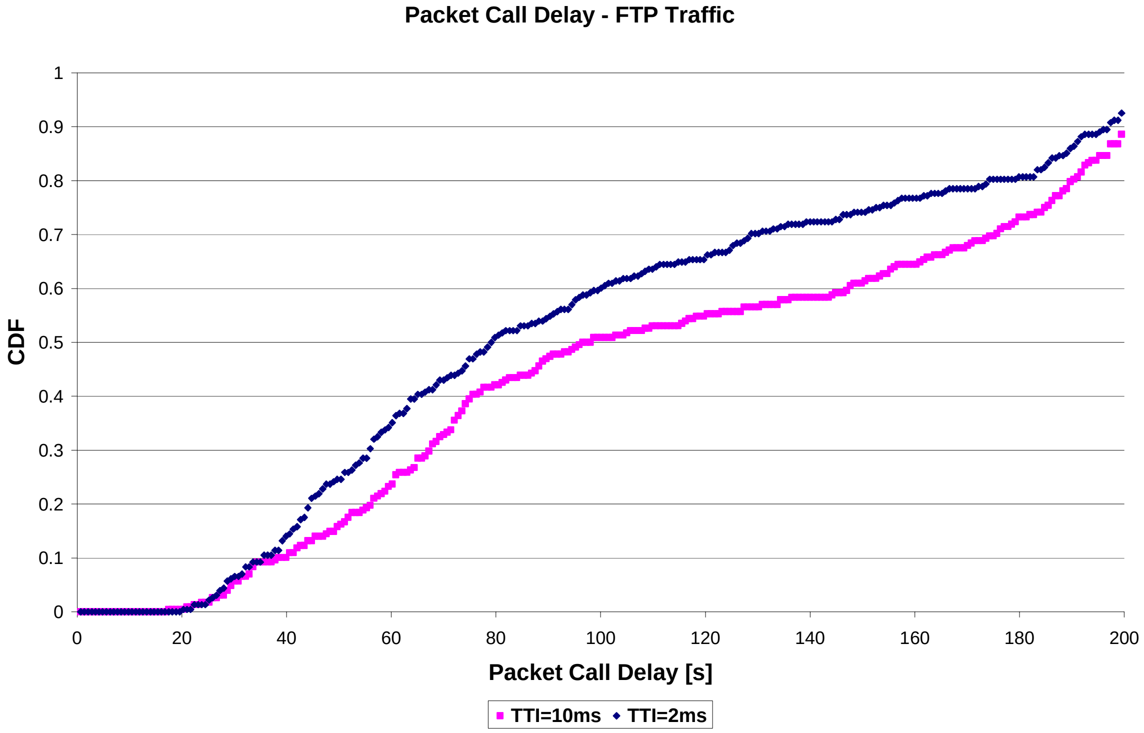

Figure 9.4.1.2.8: CDF of the packet call delays for FTP users

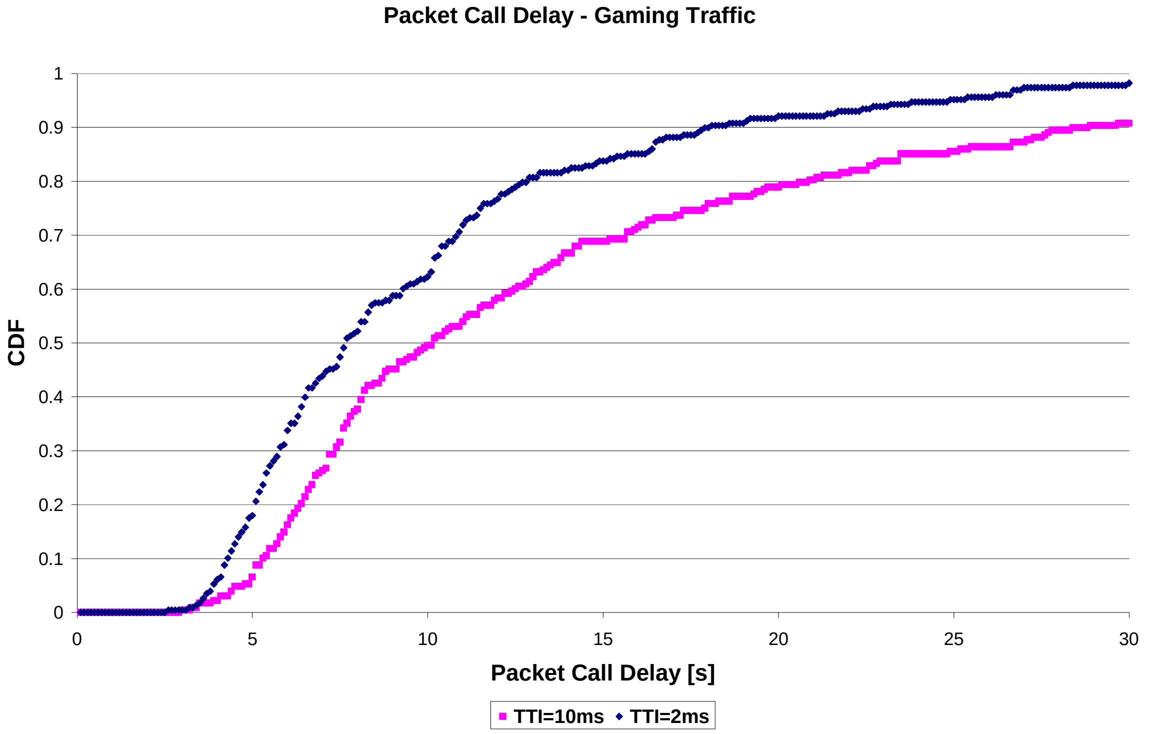

Figure 9.4.1.2.9: CDF of the packet call delays for Gaming users

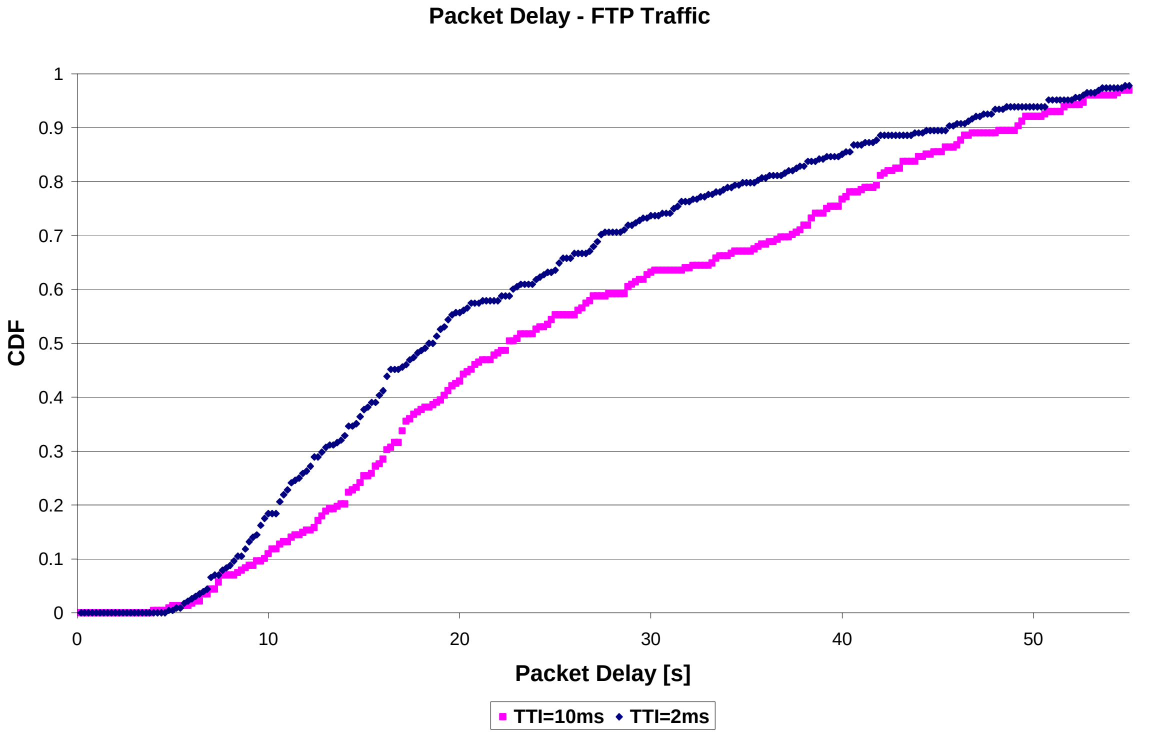

Figure 9.4.1.2.10: CDF of the packet delays for FTP users

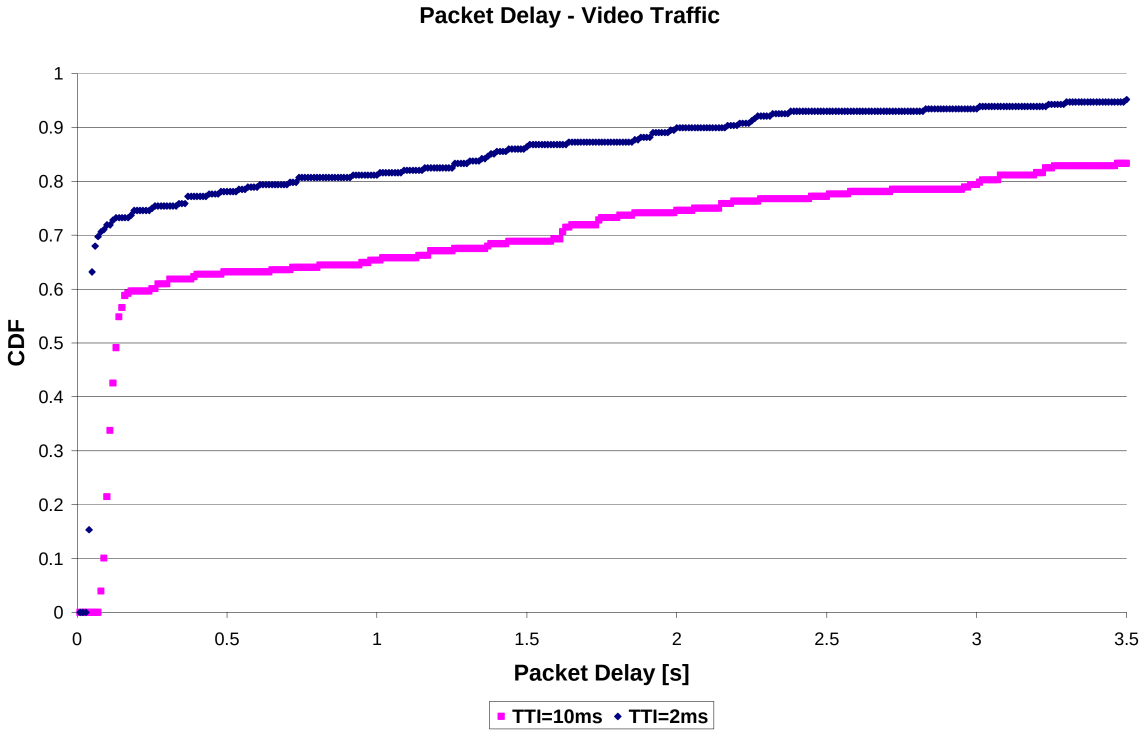

Figure 9.4.1.2.11: CDF of the packet delays for Video users

9.4.1.3 Voice & Data, Full buffer

This section considers the impact on (legacy) voice users. The system configuration has been set as shown in tables 9.4.1.1.1 and 9.4.1.1.2. A subset of the MCS used for 2 ms and 10 ms are shown in Annex 2.2.1 and 2.2.2.

Table 9.4.1.3.1: Simulation parameters for voice users

Parameter	Configuration
DCH	Voice UE: TFCS = {Null, SID and 12.2kbps} = Minimum set; TTI: 20ms, 40% voice activity
Duration	500 s + 10 s warm up

The following figures compare the system performance of E-DCH with 2ms and 10ms TTI in terms of average cell throughput, fairness and RoT overshoot with 20UEs present in the system.

Figure 9.4.1.3.1 and Figure 9.4.1.3.2 compare the E-DCH cell throughput with 2ms and 10ms TTI. It is seen that compared to 10ms TTI, the system performance with 2ms TTI yields higher throughput, similarly as what can be observed in section 9.4.1.1. The throughput is less than in sections 9.4.1.1 as part of the resources are taken by voice UEs and more data UEs are transmitting on DPDCH with 8kbps. Figure 9.4.1.3.3 shows that the voice outage with 2ms is slightly lower than with 10ms, but they are all very small in both cases. 2ms sees a better fairness than 10ms TTI, as demonstrated in Figure 9.4.1.3.4. The RoT overshoot curves given in Figure 9.4.1.3.5 indicate that 10ms TTI has a higher RoT overshoot, but again the overshoot is very small with both 2ms and 10ms TTI.

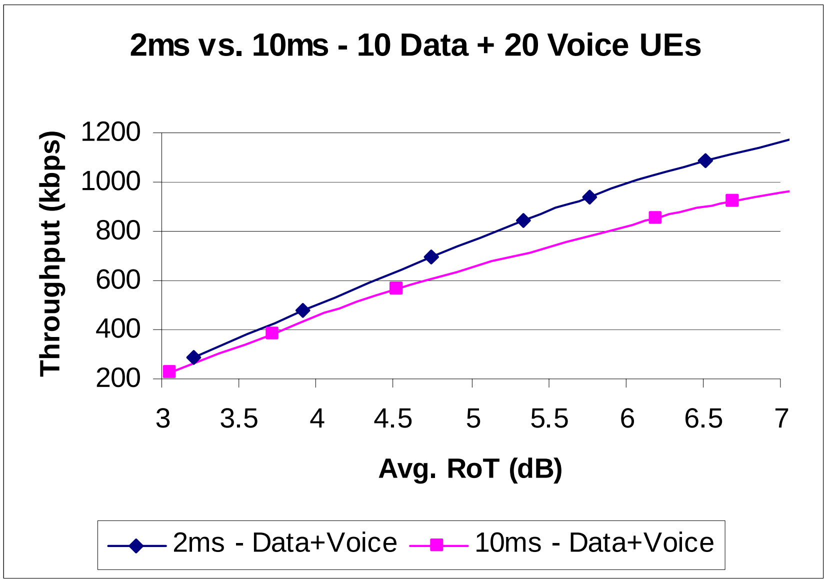

Figure 9.4.1.3.1: Average cell throughput as a function of average RoT – mixed channel

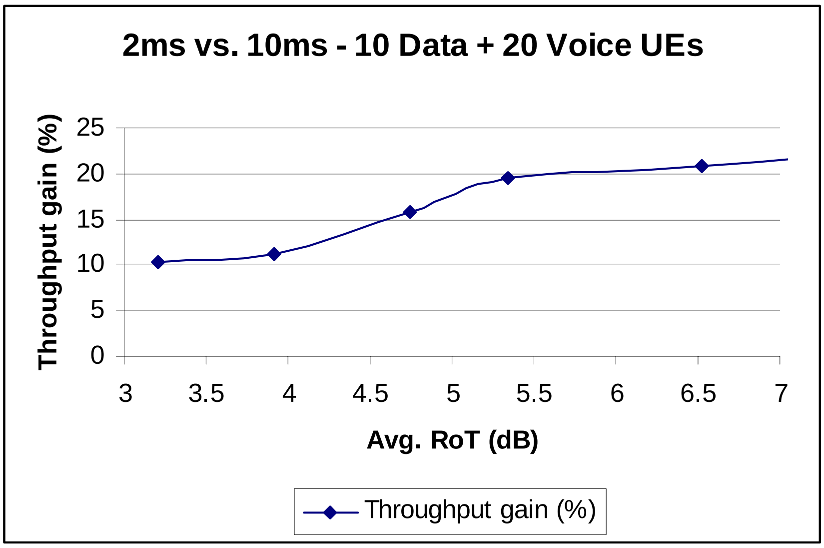

Figure 9.4.1.3.2: Throughput gain between 2ms and 10ms

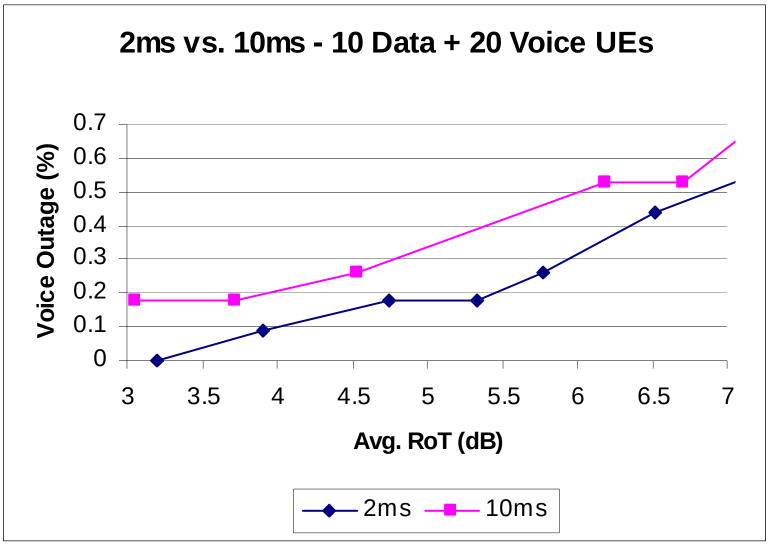

Figure 9.4.1.3.3: Voice Outage with 2ms and 10ms TTI

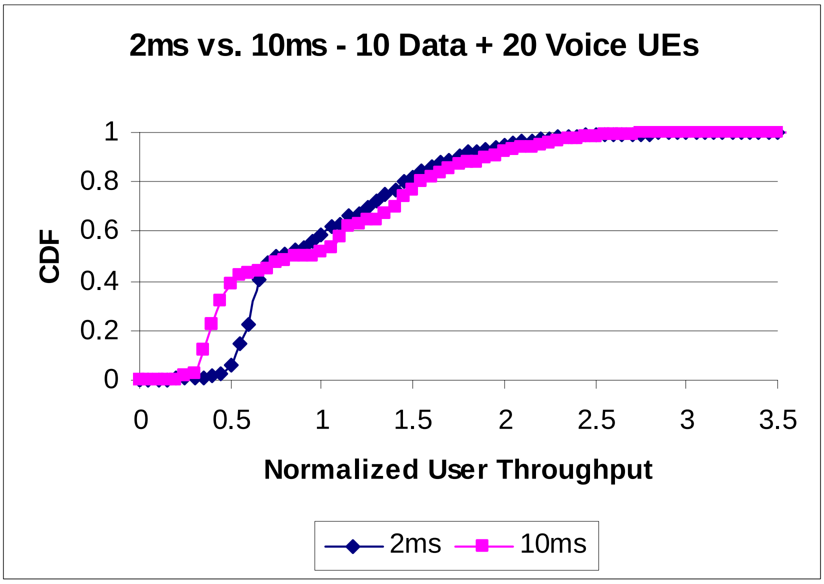

Figure 9.4.1.3.4: Fairness curves - mixed channel

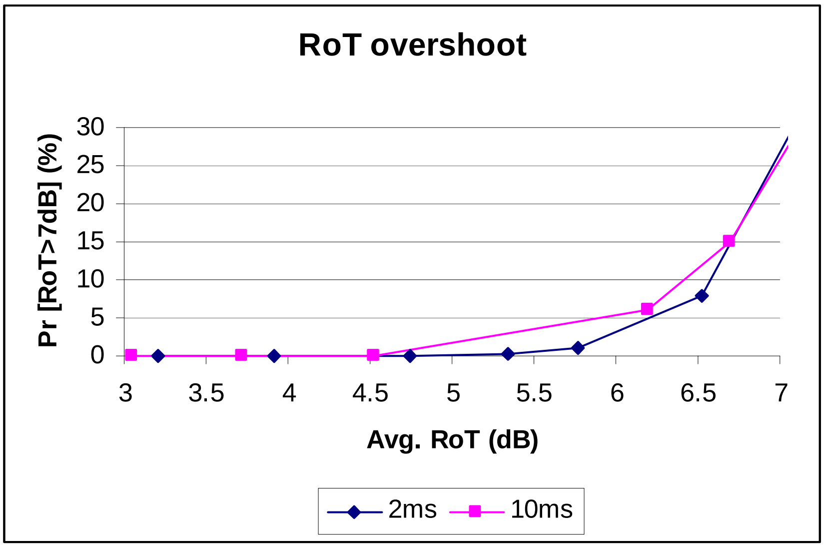

Figure 9.4.1.3.5: Percentage of time the RoT is greater than 7 dB – mixed channel

9.4.2 Complexity Evaluation <UE and RNS impacts>

Introduction of a shorter TTI (than 10 ms) affects the following aspects of the UE and Node B:

a) Timing

  - The timing aspect of both 2 and 10 ms TTI is covered in section 8.5.
  - Use of a shorter TTI may result in tighter delay requirements between DL and UL reception and transmission if used in conjunction with a fast ARQ mechanism.

b) Physical channel structure

  - Physical channel structures compatible with a shorter TTI are described in sections 8.4.2. The associated impact on PAR (relevant for the UE only) is presented in section 9.5.1

c) HARQ (if introduced for E-DCH)

  - Buffering requirements associated with the introduction of HARQ for both 2 and 10 ms TTI are shown in section 9.2.2.
  - In general a lower TTI results in lower buffer requirements compared to 10 ms TTI

In addition, the introduction of a shorter TTI also affects the TFC selection procedure in the UE

- Complexity of TFC selection relates to the number of CCTrCh, their respective timing and TTI. The number of CCTrCh and timing is not specific to the TTI discussion although introduction of a shorter TTI would likely prevent the use of a single time aligned CCTrCH. Consequently the introduction of a shorter TTI will impact the TFC selection procedure.

Depending on whether the Iub/Iur interfaces frame protocol are adapted to 2 ms the impact on the RNS may or may not be significant. The complexity impact of adapting the Iub/Iur frame protocol is FFS.

9.4.3 Downlink Signalling

No specific downlink signalling is associated with a shorter E-DCH TTI value compared to 10 ms TTI. However the channel structure supporting the signalling may be different than the one used for 10 ms TTI. In case the downlink control signalling is also using a shorter TTI, the power requirement to transmit the signalling would be higher than for a 10 ms TTI.

In case the system supports semi-static configuration supporting both 10 ms TTI and a shorter TTI, RRC signalling would be necessary to switch between one TTI and the other.

9.4.4 Uplink Signalling

No specific uplink signalling is associated with a shorter E-DCH TTI value compared to a 10 ms TTI. However the channel structure supporting the control signalling may be different that the one used for 10 ms TTI. In case a shorter TTI value is used for the control structure the power requirement to transmit the signalling would be higher as shown in section 9.2.4.

9.5 Physical layer structures

9.5.1 Complexity evaluation

9.5.1.1 PAR analysis

The parameters and results for the analysed cases are shown below. The idea how the parameters are shown in the tables is that if the E-DCH and DCH are inserted to the same code channel/s, then the parameters are shown in the column of DPDCH (DPDCH meaning a generalized name for code channels carrying both E-DCH and DCH). If E-DCH are DCH are carried on separate code channels, then the parameters are given so that for code channels carrying E-DCH they are in the column of E-DPDCH. And the parameters for code channels carrying DCH are in the column of DPDCH.

The main parameters to be listed for each code channel are :

- Branch (Br) defines whether the code channel is on I or Q branch.
    - DPCCH, HS-DPCCH and E-DPCCH are only assumed to be carried on one physical code channel, so for these the Br defines the branch that they are carried on, either I -branch or Q- branch.
    - For DPDCH and/or E-DPDCH this defines the branch for the first code channel for the physical channel type in question. Thus if Br is defined to be Br = I in the tables below, it means that $DPDCH_1$ is on I branch , $DPDCH_2$ is on Q branch, $DPDCH_3$ is again on I branch etc. Thus the assumption is that every other additional code channel is on I branch , every other is on Q branch.
    - 8PSK is indicated with p8
- Power level of code channel/s relative to other code channels (β factor). In the tables, it is defined in the form of x / 15 as in current specifications, out of which only the value x is included in the tables. The same terminology is assumed to be used as in Rel5, i.e.
    - For DPCCH and DPDCH(s), the β -factor is defined relative to each other. And since the code channel having higher amplitude is defined to have amplitude 1, the β -factor of either DPCCH or DPDCH is equal β =x/15 =15/15 =1.
    - For HS-DPCCH the β -factor is as defined in TS25.214.Some of the PAR results presented here use β -factors that are not constrained to the set of β –factors defined in Release-5.
    - For E-DPCCH the β -factor is as defined for the HS-DPCCH with no constraint on the set of delta values.
    - For E-DPDCH the β -factor is defined relative to amplitude 1, since either DPCCH or DPDCH has the amplitude of 1. This ensures that there is enough dynamic range for defining β factors for DPDCH and DPCCH.
    - In the case of E-DCH transmitted using QPSK, it is assumed that the QPSK signal is constructed from two code channels, and that beta applies to each code channel for data.
    - For E-DCH transmitted using 8PSK, it is assumed that the modulation constellation points have the same energy as for the QPSK case (amplitude of the constellation point equals to √2 beta) , and therefore beta applies to each of the I and Q components for data.

- Spreading factor of each code channel (SF). If this is greater than 4 in the tables, it means that no multicodes are used. If this is equal to 2 or 4, the number of multicodes could be derived from the data rate.
- Channelisation code (C). This defines explicitly what channelisation code was used, with the terminology of current specification.

The analysis is divided to different sections based on how many channel bits there are in total for both E-DCH and DCH. This is defined with the help of the number of channel bits fitting to certain number of BPSK code channels with SF=4. This allows to look at different data rate regions separately.

PAR results are given for a number of parameter sets. The rationale for these sets are described in table 9.5.1, including the assumption of the BLER level in the initial transmission for the data, at least if that is assumed to be differing between DPDCH and EDPDCH. The rationale is provided for the sole purpose of PAR evaluation under various scenarios and does not reflect any decision by RAN WG1 relative to the final channel configuration in support of enhanced uplink.

Table 9.5.1 – Parameter Set Rationale

Parameter Set	Rationale
1	The betas are derived considering the Eb/Nt requirements of each physical channel as described in R1-031349 and R1-031367. This assumes target BLER for E-DCH of 20% and target BLER for DPDCH of 1%, and assumes DPCCH is boosted for improved channel estimation performance for high data rates on E-DCH.
2	The Beta values have been derived assuming non ideal receiver and DPCCH Ec/Nt = -21 dB. These Beta values are selected for the purpose of optimum performance in this scenario. Whether the performance is optimum can still be verified later.In addition, for case 2, the beta values have been selected assuming 10 ms TTI, and 1% BLER in the first transmission. (note that the beta values are different than those used in TS 25.104). In addition for case 8, the beta values have been selected assuming 2 ms TTI, and BLER of x% in the initial transmission. Furthermore a 12.2 kbps DCH is assumed to be mapped on the DPCH. Note that the channelisation codes assigned to the Rel-5 physical channels differ from Rel-5 hence configurations equivalent to Rel-5 ones are listed under case 8. The beta values for E-DPCCH1 and E-DPCCH2 channels are based on results provided in chapter 9. E-DPCCH3 (pilot) is only assumed to be transmitted for the highest E-DCH rates as it does not seem provide any benefit for lower E-DCH rates.
3	The beta values are defined with the help of the WG4 specification TS 25.141, containing uplink measurement channels, i.e. also beta factors for different data rates for NodeB performance tests. In this parameter set the beta factors for case 3 are exactly the same as in TS25.141, since they are assumed to give the best performance for DPCH for the given data rates according to WG4. For other cases than case 3, the beta factors are defined so that the percentage of pilot power from the total transmitted signal is as close as possible to one in case 3, taken the limitation into account that the βc cannot be higher than 1. BLER in the initial transmission is here assumed to be a value within range 1-20 %. For the sake of making PAR comparison of different cases easier, it is assumed here, that the BLER in the initial transmission is the same for DCH and EDCH, which means that the channel bit energy for DCH and EDCH is equal. Thus the beta factor for code channel carrying EDCH is defined to be $\beta e= \beta d * \mathrm{sqrt}(SF_{DCH}/SF_{EDCH})$. Beta factors for L1 signaling channels (E-DPCCH or HS-DPCCH) are assumed to require 6 dB higher power than DPCCH in the low to medium data rates (up to 1 BPSK code channel with SF=4) since that might be in soft handover, and equal power with DPCCH with higher data rates than that.

9.5.1.1.1 Total number of channel bits from both E-DCH and DCH that can be accommodated one BPSK code channel with SF=4

Parameters and results:

Table 9.5.1.1.1: Cases 1-7

Param set	Case	DPCCH				DPDCH				E-DPDCH				HS-DPCCH				E-DPCCH				99.9% PAR [dB]
		Br	β_c	SF	C	Br	β_d	SF	C	Br	β_{eu}	SF	C	Br	β_{hs}	SF	C	Br	β_T	SF	C	
1	1	Q	11	256	0	Q	15	64	16	I	24	32	8	Q	15	256	32	I	15	128	1	4.75
1	1	Q	15	256	0	Q	10	64	16	I	42	4	1	Q	7	256	32	I	7	128	1	3.64
1	2	Q	11	256	0	I	33	16	4					Q	15	256	64					3.06
2	2	Q	15	256	0	I	15	64	16													3.10
2	2	Q	15	256	0	I	15	64	16					Q	15	256	64					3.65
2	2	Q	15	256	0	I	15	64	16					Q	30	256	64					3.65
3	1	Q	15	256	0	I	15	64	16	Q	42	8	2	I	30	256	1	Q	30	256	32	4.92
3	1	Q	15	256	0	I	15	64	16	Q	30	16	4	I	30	256	1	Q	30	256	32	4.95
3	1	Q	15	256	0	I	15	64	16	Q	21	32	8	I	30	256	1	Q	30	256	32	4.85
3	2	Q	5	256	0	I	15	8	2		-	-		Q	10	256	64		-	-		3.11
3	2	Q	8	256	0	I	15	16	4		-	-		Q	16	256	64		-	-		3.30
3	2	Q	10	256	0	I	15	32	8		-	-		Q	20	256	64		-	-		3.43
3	1	Q	15	256	0	I	15	64	16	Q	60	4	1	I	30	256	1	Q	30	256	32	4.69
3	2	Q	5	256	0	I	15	4	1		-	-		Q	9	256	64		-	-		3.10
3	3	Q	5	256	0	I	15	4	1		-	-			-	-			-	-		3.06
3	4	Q	15	256	0	I	15	64	16	Q	60	4	1									4.01

Table 9.5.1.1.1b: Case 8

Case		8	8	8	8
Parameter set		2	2	2	2
99.9% PAR [dB]		4.70	4.70	5.20	4.90
DPCCH	Br	Q	Q	Q	Q
	β_c	15	15	15	15
	SF	256	256	256	256
	C	0	0	0	0
DPDCH	Br	I	I	I	I
	β_d	15	15	15	15
	SF	64	64	64	64
	C	8	8	8	8
HS-DPCCH	Br	Q	Q	Q	Q
	β_{hs}	15	30	15	30
	SF	256	256	256	256
	C	32	32	32	32
E-DPCCH2 (request)	Br			I	I
	β_R			17	30
	SF			64	64
	C			1	1

Table 9.5.1.1.1c: Backward compatible settings

Case		1	1	8	8	8	8
Parameter set		1	1	2	2	2	2
99.9% PAR [dB]		5.36	4.73	3.63	3.64	5.41	5.32
DPCCH	Br	Q	Q	Q	Q	Q	Q
	β_c	11	15	15	15	15	15
	SF	256	256	256	256	256	256
	C	0	0	0	0	0	0
DPDCH	Br	I	I	I	I	I	I
	β_d	15	10	15	15	15	15
	SF	64	64	64	64	64	64
	C	16	16	16	16	16	16
HS-DPCCH	Br	Q	Q	Q	Q	Q	Q
	β_{hs}	15	7	15	30	15	30
	SF	256	256	256	256	256	256
	C	64	64	64	64	64	64

Case		1	1	8	8	8	8
Parameter set		1	1	2	2	2	2
99.9% PAR [dB]		5.36	4.73	3.63	3.64	5.41	5.32
E-DPDCH	Br	Q	Q				
	β_{eu}	24	42				
	SF	32	4				
	C	16	2				
E-DPCCH	Br	I	I				
	β_T	15	7				
	SF	128	128				
	C	1	1				
E-DPCCH2 **(request)**	Br					Q	Q
	β_R					17	30
	SF					64	64
	C					1	1

9.5.1.1.2 Total number of channel bits from both E-DCH and DCH that can be accommodated in two BPSK code channels with SF=4

Parameters and results:

Table 9.5.1.1.2: Cases 1-7

Param set	**Case**	**DPCCH**				**DPDCH**				**E-DPDCH**				**HS-DPCCH**				**E-DPCCH**				99.9% PAR [dB]
		Br	β_c	SF	C	Br	β_d	SF	C	Br	β_{eu}	SF	C	Br	β_{hs}	SF	C	Br	β_T	SF	C	
1	1	Q	15	256	0	I	6	64	8	I+Q	40	4	1	Q	5	256	32	I	5	128	1	3.97
1	2	Q	15	256	0	I+Q	40	4	1					Q	7	256	32					3.79
2	2	Q	7	256	0	I+Q	15	4	1													4.00
2	2	Q	7	256	0	I+Q	15	4	1					I	7	256	1					4.40
2	2	Q	7	256	0	I+Q	15	4	1					I	14	256	1					4.75
3	1	Q	15	256	0	I	15	64	16	IQ	60	2*4	2	Q	15	256	32	I	15	256	1	4.44
3	1	Q	15	256	0	I	15	64	16	Q	85	2	1	I	15	256	1	Q	15	256	32	4.59
3	2	Q	5	256	0	IQ	15	2*4	1		-	-		I	5	256	1		-	-		4.03
3	3	Q	5	256	0	IQ	15	2*4	1		-	-			-	-			-	-		3.69
3	4	Q	15	256	0	I	15	64	16	IQ	60	2*4	2		-	-			-	-		3.98
3	4	Q	15	256	0	I	15	64	16	Q	85	2	1		-	-			-	-		3.95

Table 9.5.1.1.2b: Case 8

Case		8	8
Parameter set		2	2
99.9% PAR [dB]		5.70	6.05
DPCCH	Br	Q	Q
	β_c	15	15
	SF	256	256
	C	0	0
DPDCH	Br	I	I
	β_d	15	15
	SF	64	64
	C	8	8
HS-DPCCH	Br	Q	Q
	β_{hs}	15	30
	SF	256	256
	C	32	32
E-DPDCH	Br	I+Q	I+Q
	β_{eu}	34	34
	SF	4	4
	C	1	1
E-DPCCH	Br	Q	Q
	β_T	17	30
	SF	64	64
	C	2	2
E-DPCCH2 (request)	Br	I	I
	β_R	17	30
	SF	64	64
	C	1	1

Table 9.5.1.1.2c: Backward compatible settings

Case		1	8	8
Parameter set		1	2	2
99.9% PAR [dB]		4.16	5.85	6.12
DPCCH	Br	Q	Q	Q
	β_c	15	15	15
	SF	256	256	256
	C	0	0	0
DPDCH	Br	I	I	I
	β_d	6	15	15
	SF	64	64	64
	C	16	16	16
HS-DPCCH	Br	Q	Q	Q
	β_{hs}	5	15	30
	SF	256	256	256
	C	64	64	64
E-DPDCH	Br	I+Q	I+Q	I+Q
	β_{eu}	40	34	34
	SF	4	4	4
	C	2	2	2
E-DPCCH	Br	I	I	I
	β_T	5	17	30
	SF	128	64	64
	C	1	1	1
E-DPCCH2 (request)	Br		Q	Q
	β_R		17	30
	SF		64	64
	C		1	1

9.5.1.1.3 Total number of channel bits from both E-DCH and DCH that can be accommodated in three BPSK code channels with SF=4

Parameters and results:

Table 9.5.1.1.3: Cases 1-7

Param set	Case	DPCCH				DPDCH				E-DPDCH				HS-DPCCH				E-DPCCH				99.9% PAR [dB]
		Br	β_c	SF	C	Br	β_d	SF	C	Br	β_{eu}	SF	C	Br	β_{hs}	SF	C	Br	β_T	SF	C	
1	1	Q	15	256	0	I	5	64	8	p8	67	4	1	Q	4	256	32	I	4	128	1	3.44
1	5	Q	15	256	0	p8	47	4	1					I	5	256	1					3.64
1	5	Q	15	256	0	p8	78	4	1					I	4	256	1					3.30
3	1	Q	15	256	0	I	15	64	16	Q	60	3*4	1,3	I	15	256	1	Q	15	256	32	5.5
3	1	Q	15	256	0	I	15	64	16	I Q	85 60	2 + 4	1 1	Q	15	256	32	I	15	256	1	5.2
3	2	Q	5	256	0	I	15	3*4	1,3		-	-		Q	5	256	32		-	-		5.3
3	3	Q	5	256	0	I	15	3*4	1,3		-	-			-	-			-	-		5.1
3	4	Q	15	256	0	I	15	64	16	Q	60	3*4	1,3		-	-			-	-		5.2
3	4	Q	15	256	0	I	15	64	16	I Q	85 60	2 + 4	1 1		-	-			-	-		5.0
3	5	Q	4	256	0	p8	15	4 *	1		-	-		I	4	256	1		-	-		3.77
3	6	Q	4	256	0	p8	15	4 *	1		-	-			-	-			-	-		3.5
3	7	Q	15	256	0	I	15	64	16	p8	73	4 *	2		-	-			-	-		3.80

* Here there is one 8PSK stream .

Table 9.5.1.1.3b: Backward compatible settings

Case		1
Parameter set		1
99.9% PAR [dB]		3.61
DPCCH	Br	Q
	β_c	15
	SF	256
	C	0
DPDCH	Br	I
	β_d	5
	SF	64
	C	16
HS-DPCCH	Br	Q
	β_{hs}	4
	SF	256
	C	64
E-DPDCH	Br	p8
	β_{eu}	67
	SF	4
	C	2
E-DPCCH	Br	I
	β_T	4
	SF	128
	C	1

9.5.1.1.4 Total number of channel bits from both E-DCH and DCH that can be accommodated in four BPSK code channels with SF=4

Parameters and results:

Table 9.5.1.1.4: Cases 1-7

Param set	Case	DPCCH				DPDCH				E-DPDCH				HS-DPCCH				E-DPCCH				99.9% PAR [dB]
		Br	β_c	SF	C	Br	β_d	SF	C	Br	β_{eu}	SF	C	Br	β_{hs}	SF	C	Br	β_T	SF	C	
2	2	Q	7	256	0	I+Q	15	4	1,3													5.40
2	2	Q	7	256	0	I+Q	15	4	1,3					I	7	256	1					5.65
2	2	Q	7	256	0	I+Q	15	4	1,3					I	14	256	1					5.85
3	1	Q	15	256	0	I	15	64	16	IQ	60	4*4	2,3	Q	15	256	32	I	15	256	1	5.6
3	1	Q	15	256	0	I	15	64	16	IQ	85	2*2	1	Q	15	256	32	I	15	256	1	4.1
3	2	Q	5	256	0	IQ	15	4*4	1,3		-	-		I	5	256	1		-	-		5.5
3	2	Q	4	256	0	IQ	15	2*2	1		-	-		I	4	256	1		-	-		4.1
3	3	Q	5	256	0	IQ	15	4*4	1,3		-	-			-	-			-	-		5.25
3	3	Q	4	256	0	IQ	15	2*2	1		-	-			-	-			-	-		3.8
3	4	Q	15	256	0	I	15	64	16	IQ	60	4*4	2,3		-	-			-	-		5.2
3	4	Q	15	256	0	I	15	64	16	IQ	85	2*2	1		-	-			-	-		3.75
3	5	Q	5	256	0	p8+I	26 15	4 *	1,3		-	-		Q	5	256	32		-	-		4.63
3	6	Q	5	256	0	p8+I	26 15	4 *	1,3		-	-			-	-			-	-		4.50
3	7	Q	15	256	0	I	15	64	16	p8Q	127 73	4 *	3,1		-	-			-	-		4.58

* Here there are one 8PSK stream + 1 BPSK stream.

Table 9.5.1.1.4b: Case 8

Case		8	8
Parameter set		2	2
99.9% PAR [dB]		5.60	6.25
DPCCH	Br	Q	Q
	β_c	15	15
	SF	256	256
	C	0	0
DPDCH	Br	I	I
	β_d	15	15
	SF	64	64
	C	8	8
HS-DPCCH	Br	Q	Q
	β_{hs}	15	30
	SF	256	256
	C	32	32
E-DPDCH	Br	I+Q	I+Q
	β_{eu}	47	47
	SF	2	2
	C	1	1
E-DPCCH	Br	Q	Q
	β_T	17	30
	SF	64	64
	C	2	2
E-DPCCH2 (request)	Br	I	I
	β_R	17	30
	SF	64	64
	C	1	1

Table 9.5.1.1.4c: Backward compatible settings

Case		8	8
Parameter set		2	2
99.9% PAR [dB]		5.40	5.91
DPCCH	Br	Q	Q
	β_c	15	15
	SF	256	256
	C	0	0
DPDCH	Br	I	I
	β_d	15	15
	SF	64	64
	C	16	16
HS-DPCCH	Br	Q	Q
	β_{hs}	15	30
	SF	256	256
	C	64	64
E-DPDCH	Br	I+Q	I+Q
	β_{eu}	47	47
	SF	2	2
	C	1	1
E-DPCCH	Br	I	I
	β_T	17	30
	SF	64	64
	C	1	1
E-DPCCH2 (request)	Br	Q	Q
	β_R	17	30
	SF	64	64
	C	1	1

9.5.1.1.5 Total number of channel bits from both E-DCH and DCH that can be accommodated in five BPSK code channels with SF=4

Parameters and results:

Table 9.5.1.1.5: Cases 1-7

Param set	Case	DPCCH				DPDCH				E-DPDCH				HS-DPCCH				E-DPCCH				99.9% PAR [dB]
		Br	β_c	SF	C	Br	β_d	SF	C	Br	β_{eu}	SF	C	Br	β_{hs}	SF	C	Br	β_T	SF	C	
3	1	Q	15	256	0	I	15	64	16	IQIQQ	60	5*4	2,3,1	I	15	256	1	Q	15	256	32	6.23
3	1	Q	15	256	0	I	15	64	16	IQ Q	85 60	2*2,4	1,1	I	15	256	1	Q	15	256	32	5.16
3	2	Q	5	256	0	I	15	5*4	1,3,2		-	-		Q	5	256	32		-	-		6.05
3	3	Q	5	256	0	I	15	5*4	1,3,2		-	-			-	-			-	-		5.86
3	2	Q	5	256	0	IQ I	21 15	2*2 4	1 1		-	-		Q	5	256	32		-	-		4.89
3	3	Q	5	256	0	IQ I	21 15	2*2 4	1 1		-	-			-	-			-	-		4.83
3	4	Q	15	256	0	I	15	64	16	IQIQQ	60	5*4	2,3,1		-	-			-	-		5.99
3	4	Q	15	256	0	I	15	64	16	IQ Q	85 60	2*2,4	1,1		-	-			-	-		4.93
3	5	Q	5	256	0	p8 IQ	26 15	4 *	2 3		-	-		I	5	256	1		-	-		4.85
3	6	Q	5	256	0	p8 IQ	26 15	4 *	2 3		-	-			-	-			-	-		4.70
3	7	Q	15	256	0	I	15	64	16	p8 IQ	127 73	4 *	2,3		-	-			-	-		4.67

* Here there are one 8PSK stream + 2 BPSK streams

9.5.1.1.6 Total number of channel bits from both E-DCH and DCH that can be accommodated in six BPSK code channels with SF=4

Parameters and results:

Table 9.5.1.1.6: Cases 1-7

Param set	Case	DPCCH				DPDCH				E-DPDCH				HS-DPCCH				E-DPCCH				99.9% PAR [dB]
		Br	β_c	SF	C	Br	β_d	SF	C	Br	β_{eu}	SF	C	Br	β_{hs}	SF	C	Br	β_T	SF	C	
2	2	Q	7	256	0	I+Q	15	4	1,3,2													6.25
2	2	Q	7	256	0	I+Q	15	4	1,3,2					I	7	256	1					6.40
2	2	Q	7	256	0	I+Q	15	4	1,3,2					I	14	256	1					6.55
3	1	Q	15	256	0	I	15	64	15	IQ	60	6*4	1,2,3	I	15	256	1	Q	15	256	32	6.39
3	1	Q	15	256	0	I	15	64	15	IQ IQ	85 60	2*2 2*4	1 1	I	15	256	1	Q	15	256	32	5.40
3	2	Q	5	256	0	IQ	15	6*4	1,2,3		-	-		I	5	256	1		-	-		6.33
3	3	Q	5	256	0	IQ	15	6*4	1,2,3		-	-			-	-			-	-		6.15
3	2	Q	5	256	0	IQ IQ	21 15	2*2 2*4	1 1		-	-		I	5	256	1		-	-		5.29
3	3	Q	5	256	0	IQ IQ	21 15	2*2 2*4	1 1		-	-			-	-			-	-		5.15
3	4	Q	15	256	0	I	15	64	15	IQ	60	6*4	1,2,3		-	-			-	-		6.20
3	4	Q	15	256	0	I	15	64	15	IQ IQ	85 60	2*2 2*4	1 1		-	-			-	-		5.17
3	5	Q	4	256	0	p8	15	2*4 *	1,3		-	-		I	4	256	1		-	-		5.31
3	6	Q	4	256	0	p8	15	2*4 *	1,3		-	-			-	-			-	-		5.20
3	7	Q	15	256	0	I	15	64	16	p8	73	2*4 *	2,3		-	-			-	-		5.03

* Here there are two 8PSK streams. Notice that cases 1 and 4 are not backwards compatible since DPDCH channelisation code is not according to Rel5 spec.

Table 9.5.1.1.6b: Case 8

Case		8	8	8	8
Parameter set		2	2	2	2
99.9% PAR [dB]		6.30	6.70	6.55	7.10
DPCCH	Br	Q	Q	Q	Q
	β_c	15	15	15	15
	SF	256	256	256	256
	C	0	0	0	0
DPDCH	Br	I	I	I	I
	β_d	15	15	15	15
	SF	64	64	64	64
	C	8	8	8	8
HS-DPCCH	Br	Q	Q	Q	Q
	β_{hs}	15	30	15	30
	SF	256	256	256	256
	C	32	32	32	32
E-DPDCH	Br	I+Q	I+Q	I+Q	I+Q
	β_{eu}	47 & 34	47 & 34	47 & 34	47 & 34
	SF	2 & 4	2 & 4	2 & 4	2 & 4
	C	1	1	1	1
E-DPCCH	Br	Q	Q	Q	Q
	β_T	17	30	17	30
	SF	64	64	64	64
	C	2	2	2	2
E-DPCCH2 (request)	Br	I	I	I	I
	β_R	17	30	17	30
	SF	64	64	64	64
	C	1	1	1	1
E-DPCCH3 (pilot)	Br			Q	Q
	β_P			26	26
	SF			256	256
	C			1	1

9.5.1.1.7 Total number of channel bits from both E-DCH and DCH that can be accommodated in three 8PSK streams with SF=4

Parameters and results:

Table 9.5.1.1.7: Cases 1-7

Param set	Case	DPCCH				DPDCH				E-DPDCH				HS-DPCCH				E-DPCCH				99.9% PAR [dB]
		Br	β_c	SF	C	Br	β_d	SF	C	Br	β_{eu}	SF	C	Br	β_{hs}	SF	C	Br	β_T	SF	C	
3	5	Q	4	256	0	p8	15	3*4 *	1,2,3		-	-		I	4	256	1		-	-		6.07
3	6	Q	4	256	0	p8	15	3*4 *	1,2,3		-	-			-	-			-	-		5.98
3	7	Q	15	256	0	I	15	64	16	p8	73	3*4 *	1,2,3		-	-			-	-		6.00

* Here there are three 8PSK streams.

9.5.1.2 Considerations on PAR analysis

The following parameters affect the average energy per chip requirement

- Overhead channels
- Transmission rate or block size
- Target residual physical layer error rate
- Target maximum physical layer delay
- TTI

The energy per chip requirement relates to the system efficiency and does not depend on UE implementation aspects. The impact of these parameters on the system performance is taken into account in system level simulations to the extent that the cell layout describe in the TR reflects a real deployment scenario.

The following parameters affect the dynamic of the signal (not the average transmit power):

- Channel configuration
- Respective code channel gains
    - These fully depend on the first set of parameters

The signal dynamic affects either the power amplifier complexity or the link budget if the specification allows for a PA back-off under certain channel configurations. The impact may direct (e.g. 99.9% PAR) or indirect (e.g. impact of signal dynamic on ACLR). At this stage, all system level simulation results assume that the additional signal dynamic is handled by the PA; however contrarily to typical R99 configuration being used so far (typical single code UL) the signal dynamic and associated impact is more sensitive to the operating point.

The following examples illustrate the sensitivity of the PAR increase to the set-point.

9.5.1.2.1 Example based on case 2/5 and parameter set 1

Figure 9.5.1.2.1 illustrates the PAR variation when changing the beta values. The curves are using parameter set a cases described in section . The reference beta values are the ones listed in section 9.5.1.1; the actual beta_dpch values equal the reference beta_dpch values multiplied by the factor f listed on the x axis. One should note that case 2 can be seen as being equivalent to Release-5 situation.

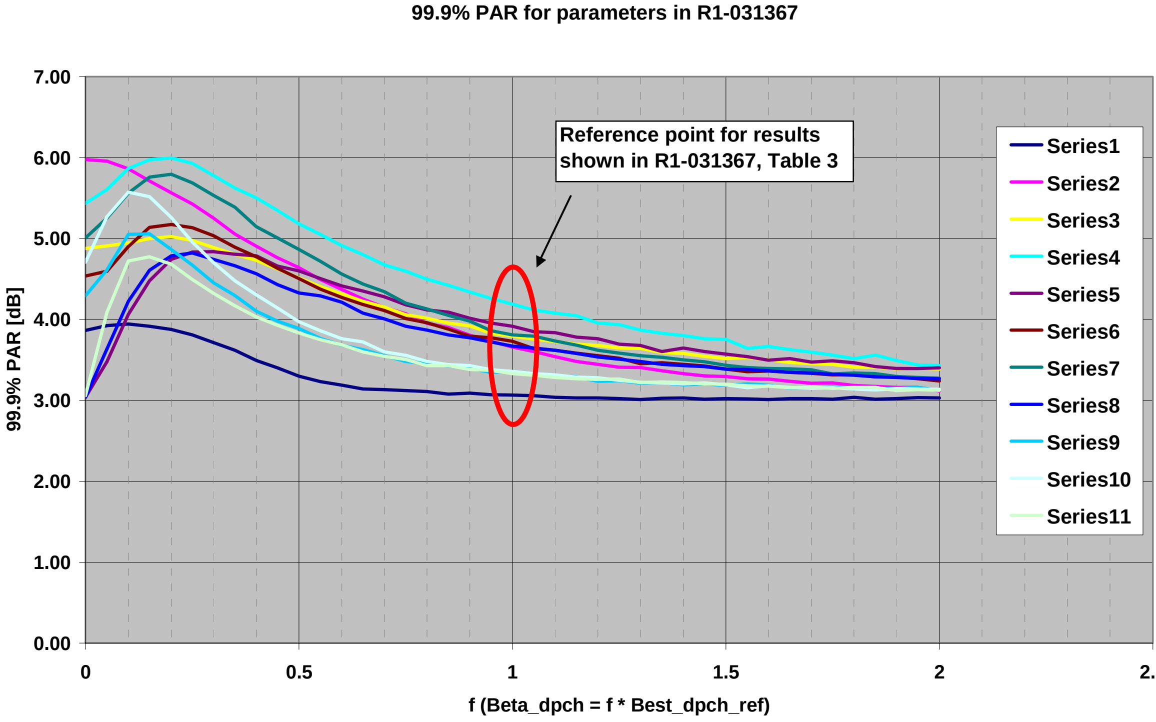

Figure 9.5.1.2.1

9.5.1.2.2 Example based on case 1,2 (BPSK vs 8-PSK)

This example illustrates the relationship between PAR discussion and performance discussion. Looking at the figure 9.5.1.2.2, one could conclude that using 3 BPSK code is a bad idea and that 8-PSK should be used instead. However when considering results presented in R1-04-0049, in turns out that in most cases using 3 BPSK codes saves around 2 dB in Ec/Nt requirement compared to 8-PSK.Taking this into account one then concludes that using 3 BPSK codes is more efficient than using 8-PSK and does not impact the link budget for a particular rate compared to using 8-PSK.

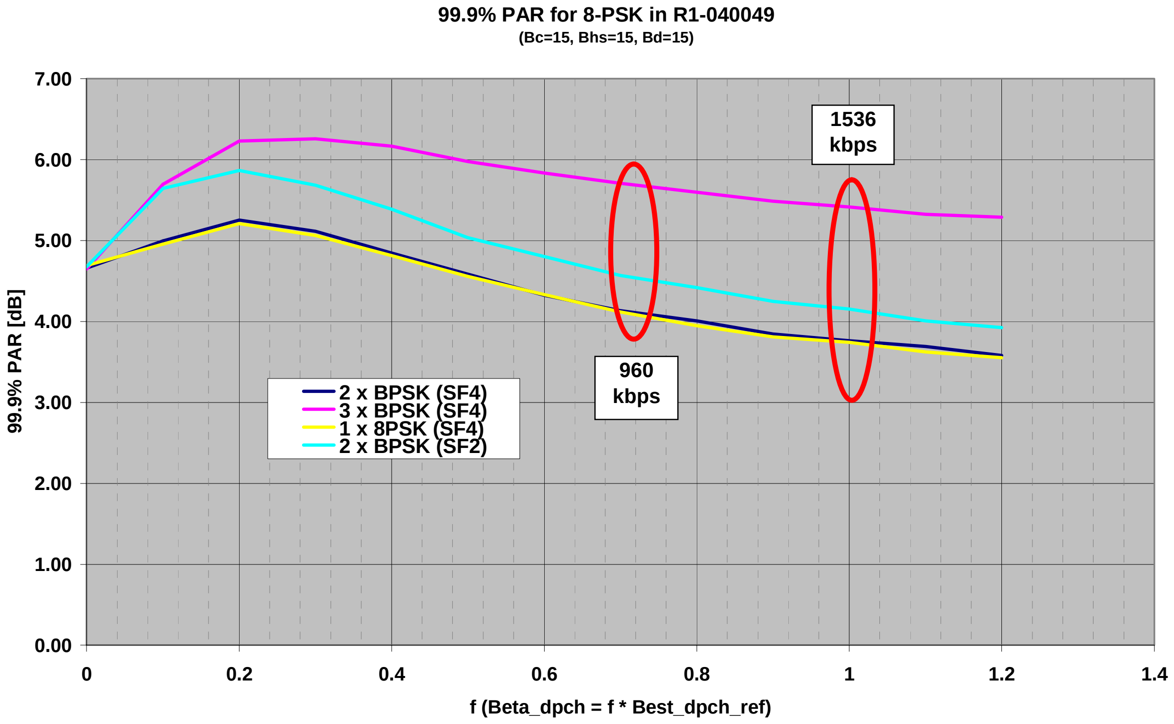

Figure 9.5.1.2.2

9.5.1.2.3 Example for multi-code

Figure 9.5.1.2.3 shows the PAR sensitivity to the number of codes transmitted simultaneously. The reference beta_dpch equals 100 (selected to cover a large range of possible beta_dpch values)

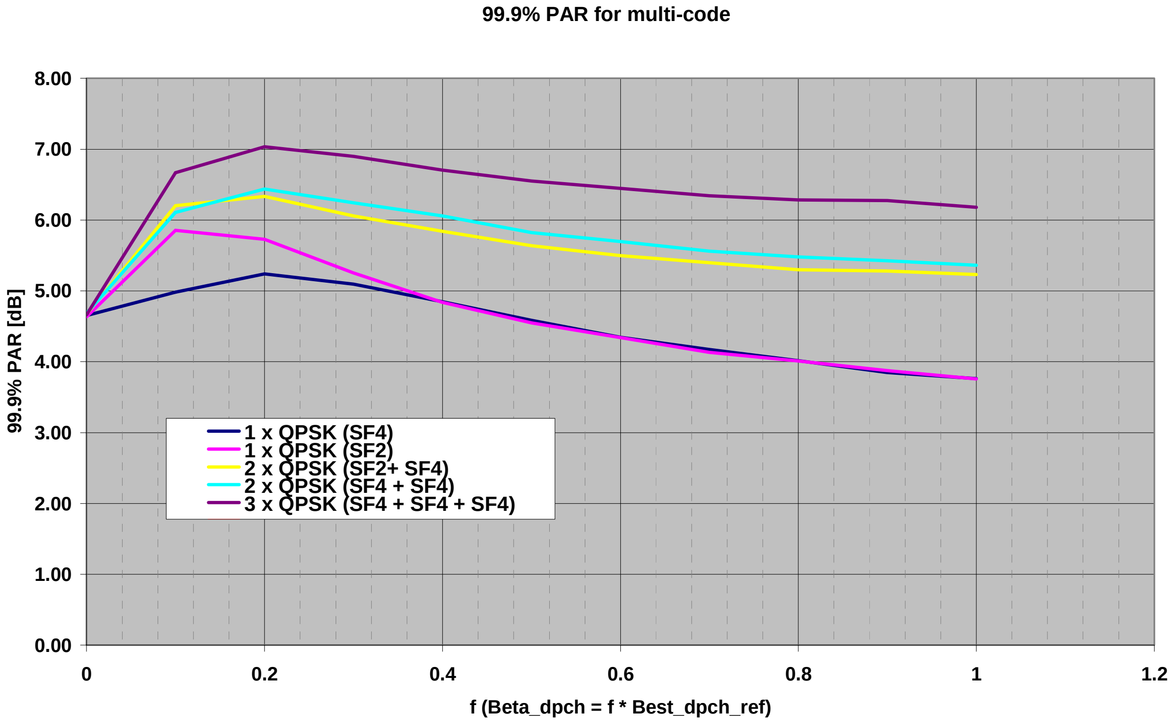

Figure 9.5.1.2.3

9.5.1.2.4 Discussion

Based on figure 9.5.1.2.1 to 9.5.1.2.3 once can derive a few general remarks:

- PAR impact decreases as the signal is dominated by the DCH/E-DCH energy
- PAR impact increase with the number of code channels used for data transmission
- PAR impact peaks when all code channels are transmitted with about the same power
- PAR impact needs to be considered together with the link level performance

The above observations result in a number of possible options to handle PAR aspects in the context of EUL:

- Should the principle that the PA will absorb any PAR increase and related constraints (ACLR) still apply?
- If not, how should the UE derive the allowed PA back-off?
  - Generic PA back-off when using enhanced uplink?
    - May result in reduced efficiency with enhanced uplink
  - As a function of the channel configuration and gains?
    - May become complex to test
    - Could be related to the number of code channels (see figure 3)
  - Forbid certain configurations with certain gain factors
    - For example only allow multi-code E-DPCH when gain factor above a certain beta value
    - May result in a trade-off between efficiency and complexity

These options are FFS in the context of a WI phase. System level simulation used to evaluate the merit of the respective techniques should then consider any solution which would allow the UE to back-off from the nominal maximum transmit power.

9.6 Results including multiple techniques

9.6.1 Results with HARQ, shorter TTI, time & rate scheduling

This section includes results with HARQ, shorter TTI and time & rate Node B scheduling.

9.6.1.1 Full Buffer results

The following results reflect the relative cell throughput gain of E-DCH (EUL), with 2ms TTI, HARQ and a Node-B scheduler, over the system with DCH (Rel-99 assumptions), with 10 ms TTI, long scheduling period and centralized scheduler.

The system configuration is shown in Table 9.4.1.1.1. The TTI is 2ms. Other assumptions are listed in Annex A3.

The MCS for E-DCH is shown in Annex 2.2.1.

The key differences between R99 and E-DCH parameters are summarized in Table 9.6.1.1.1.

Table 9.6.1.1.1

Parameter	R99		E-DCH
TTI	10 ms		2 ms
TFCS	Nomial TFCS: {8, 16, 32, 64, 128, 256, 384} kbps	Enhanced TFCS: {8, 16, 32, 64, 128, 256, 384, 768, 1152, 1536, 1920} kbps	{16, 32, 64, 96,128, 256, 384, 512, 640, 768, 896, 1024} kbps after 4 transmissions.
HARQ	-		5 processes Up to 4 transmissions
Scheduler	RNC (centralized)		Node-B (decentralized)

The following figures present the system performance in terms of average cell throughput, fairness and RoT overshoot, defined as Probability {RoT > 7dB}.

Figure 9.6.1.1.1 and Figure 9.6.1.1.2 compare the cell throughput with E-DCH (2ms TTI, PF scheduler), Rel-99 (nominal TFCS, PF scheduler) and Rel-99 (nominal TFCS, DL Sinr scheduler) with the assumptions shown above. It is seen that compared to Rel-99 with nominal TFCS with PF scheduler, the system performance with E-DCH improves by 70% at 4.5 dB RoT. Higher throughput gain can be observed with higher speed due to the increased time diversity achieved with retransmissions. On the other hand Rel-99 with DL Sinr scheduler can yield relatively high throughput at the cost of extremely bad fairness, shown in Figure 9.6.1.1.3.

The RoT overshoot is given in Figure 9.6.1.1.4. It can be seen that the RoT overshoot is smaller with DL Sinr scheduler with nominal Rel-99 and with EUL with SHO restriction. With DL Sinr, only the best users (in terms of forward link path loss) are scheduled; with EUL the SHO users can only transmit using the instantaneous rate up to 512kbps, therefore, the interference is decreased in both cases. Figure 9.6.1.1.5 to Figure 9.6.1.1.8 present the results with each individual channel models for completeness.

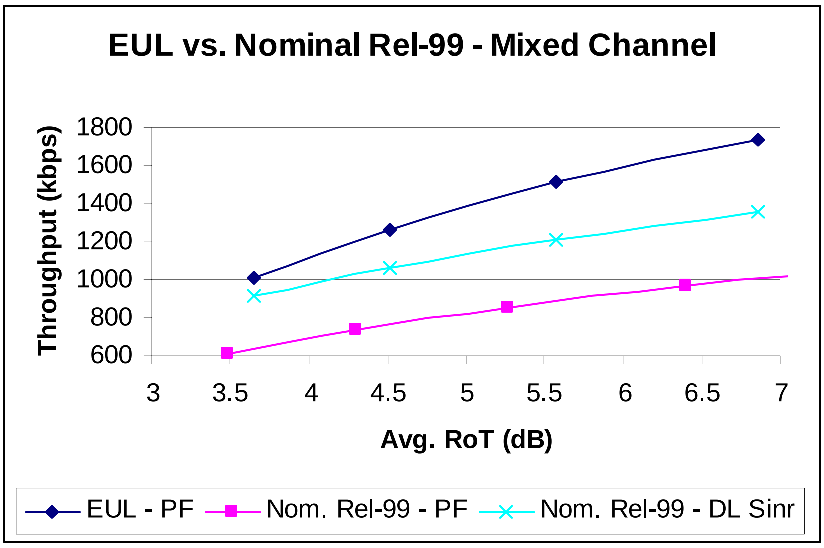

Figure 9.6.1.1.1: Average cell throughput as a function of average RoT – mixed channel

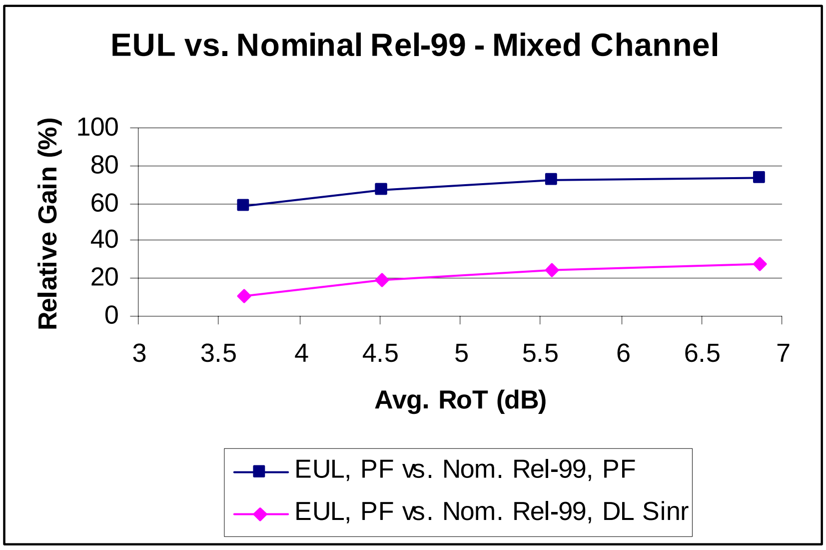

Figure 9.6.1.1.2: Throughput gain between EUL and Nominal Rel-99 – mixed channel

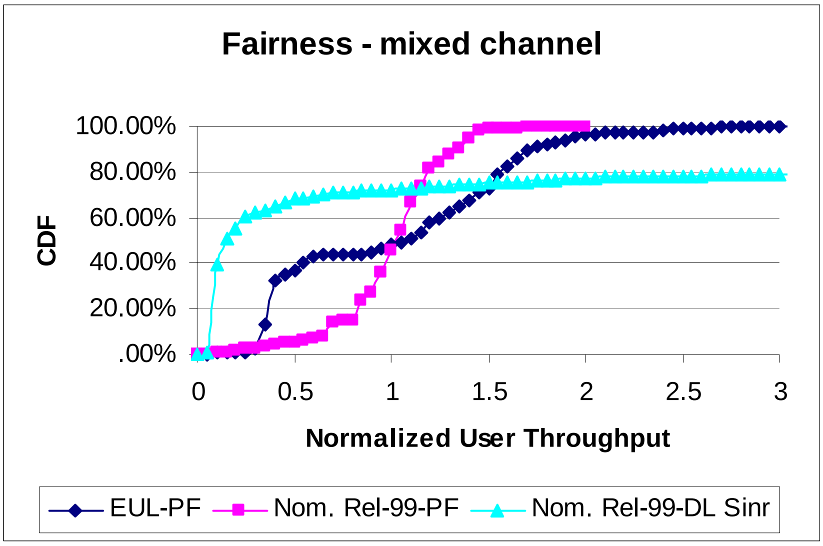

Figure 9.6.1.1.3: Fairness curves - mixed channel

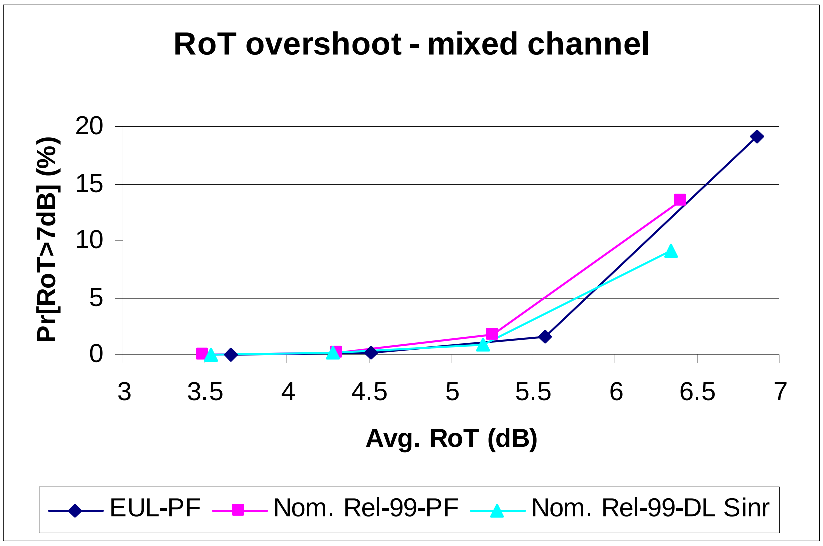

Figure 9.6.1.1.4: Percentage of time the RoT is greater than 7 dB – mixed channel

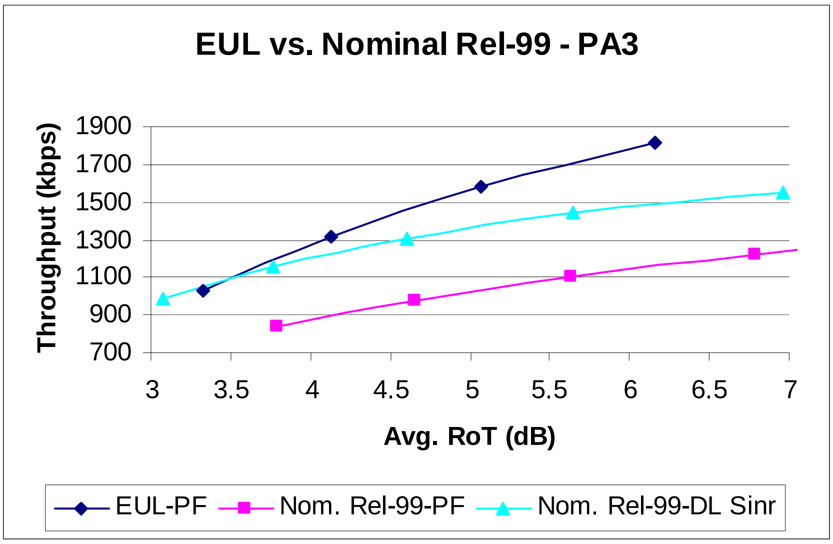

Figure 9.6.1.1.5 Average cell throughput as a function of average RoT – PA3

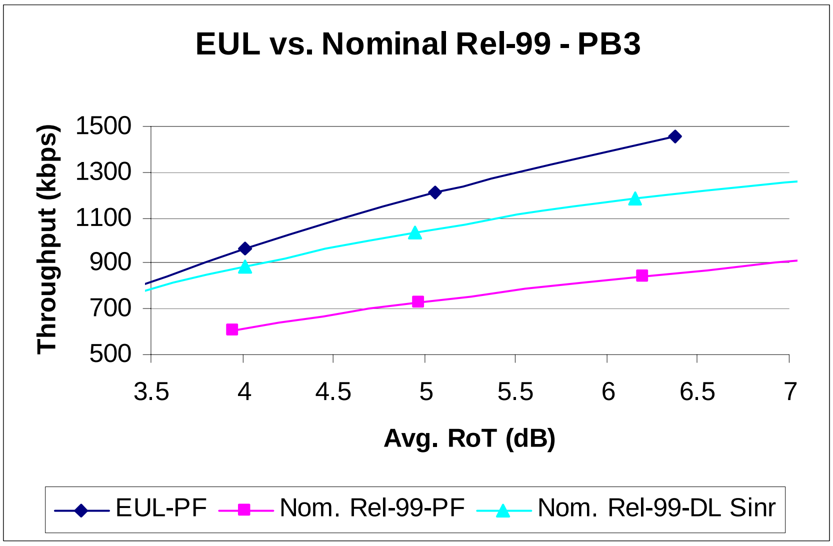

Figure 9.6.1.1.6: Average cell throughput as a function of average RoT - PB3

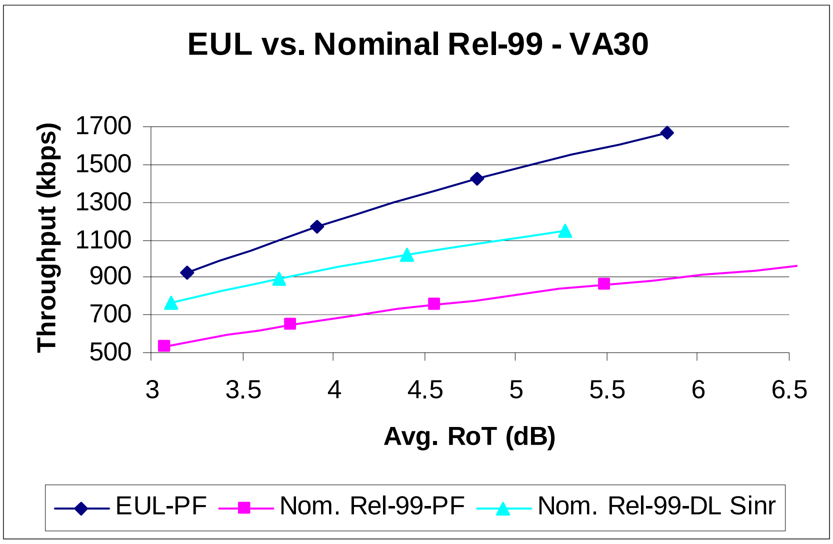

Figure 9.6.1.1.7: Average cell throughput as a function of average RoT -- VA30

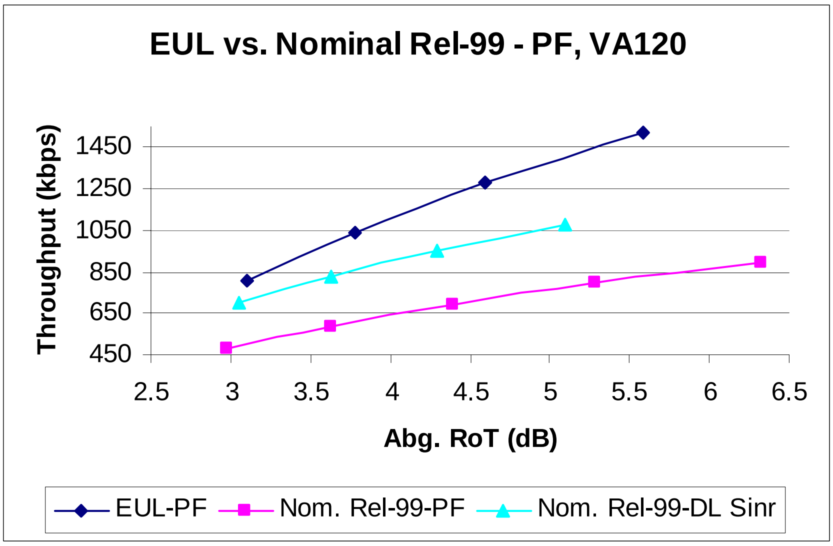

Figure 9.6.1.1.8: Average cell throughput as a function of average RoT - VA120

Recall that the Rel-99 throughput could be increased with higher capability UE class. To illustrate this point the system level results are provided in Figure 9.6.1.1.9 and Figure 9.6.1.1.10 with TF {768, 1152, 1536, 1920} kbps included. These enhanced TFs can be achieved by using up to 5 DPDCHs simultaneously. At 4.5dB average RoT, the gain associated with introducing enhanced TFs with Rel-99 is about 6.7%; while the fairness curve gets a bit worse than that of Rel-99 with nominal TFCS, which is given in Figure 9.6.1.1.11. The RoT overshoot is clearly much larger with enhanced TFCS, shown in Figure 9.6.1.1.12.

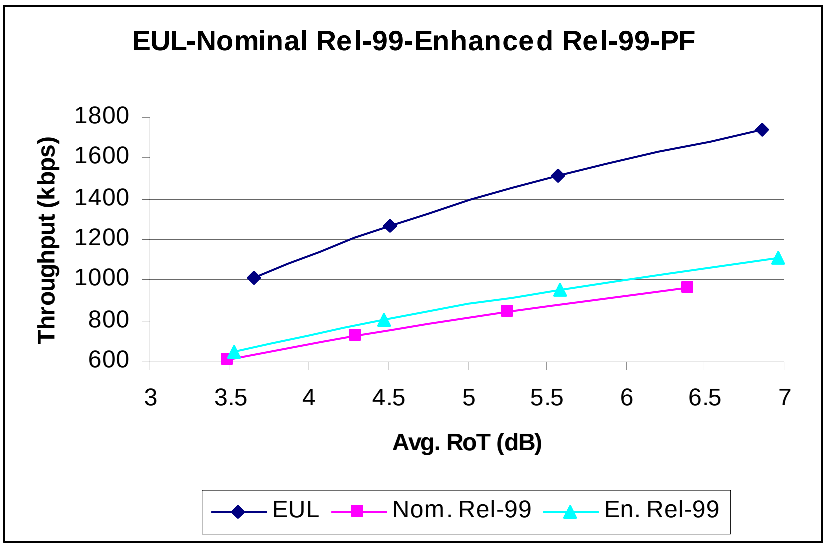

Figure 9.6.1.1.9: Average cell throughput as a function of average RoT

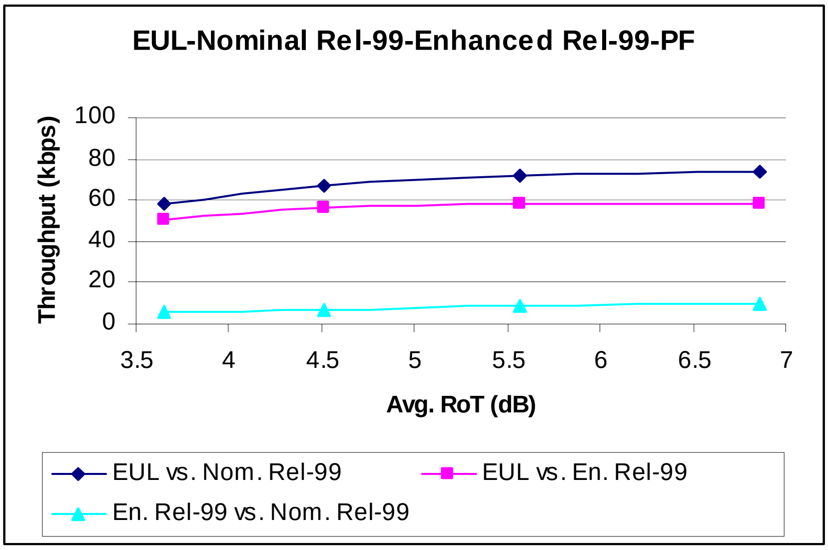

Figure 9.6.1.1.10: Throughput gain between EUL and Rel-99 - PF

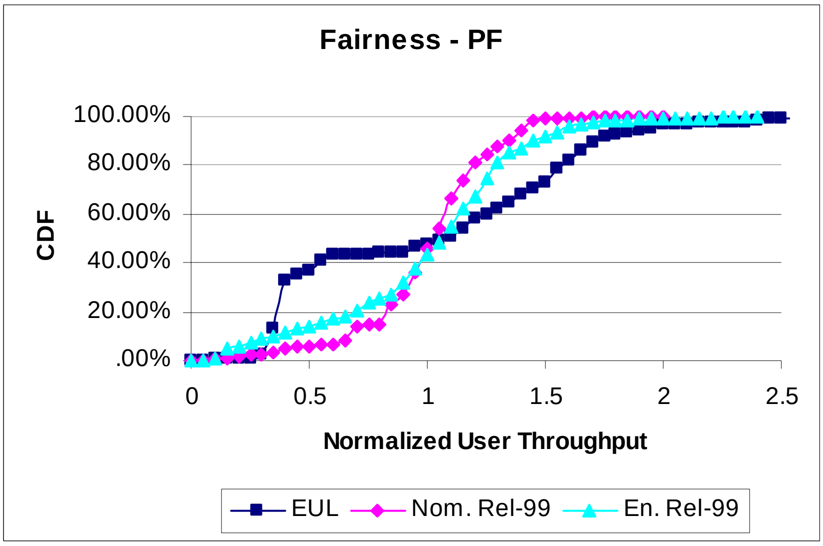

Figure 9.6.1.1.11: Fairness curves with EUL and Rel-99

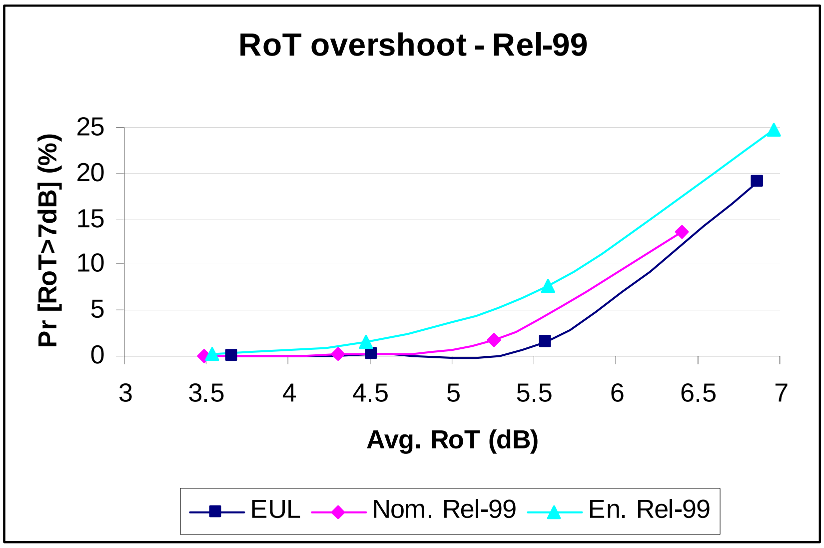

Figure 9.6.1.1.12: Percentage of time the RoT is greater than 7 dB

9.6.1.2 Mixed traffic model results

The following results reflect the relative cell throughput gain of E-DCH (EUL), with 2ms TTI, HARQ and a Node-B scheduler, over the system with DCH (Rel-99 assumptions), with 10 ms TTI, long scheduling period and centralized scheduler.

The system configuration is shown in Table 9.6.3. Other assumptions are as listed in Annex A3.

Table 9.6.3

<table>
<tr><th>Parameter</th><th>Configuration</th></tr>
<tr><td>Layout</td><td>19 Node-B, 3-cell wrap-around layout
Site to site distance = 2800 m</td></tr>
<tr><td>Channel model</td><td>Mixed (PA3 30%, PB3 30%, VA30 20% and VA120 20%)</td></tr>
<tr><td>Traffic model</td><td>Mixed (4 FTP, 4 Video, 4 Gaming)</td></tr>
<tr><td>#UE per cell</td><td>12</td></tr>
<tr><td>UE timing</td><td>UEs are time aligned</td></tr>
<tr><td>Duration</td><td>200 s + 10 s warm-up</td></tr>
<tr><td>HARQ</td><td>Max # of transmissions = 4
# of HARQ processes = 5
Re-transmission delay = 10 ms
Ack/Nack errors = 0%</td></tr>
<tr><td>Scheduling algorithm</td><td>Proportional fair</td></tr>
<tr><td>Scheduling Type</td><td>Rel-99:
RNC scheduler/controller, scheduling period 200 ms

E-DCH:
As described in R1-03-1246. Decentralized Node-B scheduler with 1 serving cell per UE = best DL (same as HSDPA serving cell). All cells in UE’s active set send ACK/NAK.</td></tr>
<tr><td>Scheduling delays</td><td><table>
<tr><th></th><th>DCH</th><th>E-DCH</th></tr>
<tr><td>Period</td><td>200 ms</td><td>2 ms</td></tr>
<tr><td>Uplink SI delay</td><td>Uniform 60-100 ms</td><td>10 slots</td></tr>
<tr><td>DL Grant delay</td><td>Uniform 60-100 ms</td><td>1 slot</td></tr>
</table></td></tr>
<tr><td>Power control</td><td>Outer loop driven by 1% BLER on DPDCH
Inner loop error rate = 4%</td></tr>
<tr><td>DCH</td><td>TFCS = 8 kbps (100% duty cycle)
Minimum set: 8 kbps

Reference link level data as presented in R1-03-1380</td></tr>
<tr><td>E-DCH</td><td>TFCS = TFS = MCS as shown in Table 2
Minimum set is empty

E-TFC elimination:
Similar to R99 TFC elimination. UE MAC decides upon the E-DCH TFC in SUPPORTED_STATE and EXCESS_POWER_STATE every radio frame. The parameters {x, y, z} are set to {15, 30, 30} as in Rel-99.

Reference link level data as presented in Annex 2.2.1</td></tr>
<tr><td>E-DPCCH</td><td>Beta = 17
(based on results in section 9.2.4)</td></tr>
<tr><td>SHO</td><td>E-DCH: When in SHO E-TFS is restricted to MCS-3
(denoted as with SHO restriction)
DCH: No SHO restriction
(denoted as without SHO restriction)</td></tr>
</table>

The MCS for E-DCH is shown in annex A.2.2.1. Table 9.6.1.2.1 shows the values of tau parameters used for FTP users.

Table 9.6.1.2.1: Tau parameters used for FTP

Delay component	Symbol	Value
The uplink transmission time of a TCP data segment from the client to the Node-B	τ_1	Determined by uplink throughput
The sum of the time taken by a TCP data segment to travel from Node-B to the server and the time taken by an ACK packet to travel from the server to Node-B	τ_2	Exponential distribution Mean = 50 ms.
Time taken by the ACK to travel from Node-B to client	τ_3	Lognormal distribution Mean = 50 ms Standard deviation = 50 ms
Increased delay to account for RLC retransmissions from residual uplink physical layer BLER	τ_4	Constant = 0 ms, if packet is not in error after all physical layer retransmissions = 200 ms, else

Figure 9.6.1.2.1 shows the system throughput as a function of the average RoT. The significant gain of the E-DCH over the Rel-99 can be observed, and it is presented in percentages in Figure 9.6.1.2.2.

The RoT overshoot is given in Figure 9.6.1.2.3. It can be seen that the RoT overshoot is smaller for E-DCH results, primarily due to the SHO restriction, since the other cell interference is decreased as compared to the case without it (Rel-99). For the fixed RoT overshoot, the corresponding average RoT is higher for E-DCH, which implies higher throughput.

The cumulative density function (CDF) of user throughputs normalized by the average throughput per user is used to represent the fairness. The fairness curve, given in Figure 9.6.1.2.4, shows that the fairness is degraded for E-DCH compared to Rel-99, primarily due to the SHO restriction and higher data rates.

Figures 9.6.1.2.5 to 9.6.1.2.8 present the average packet call delays and the average packet delays. Packet call delay is the time between two consecutive reading periods. For Gaming users, packet call delay represents the time of a gaming session that includes the time during which the packets are generated (active period), and the time needed for transmission of the data packets accumulated during the active period. For FTP users, packet call delay is the time needed for an FTP file upload. Packet delay is the time needed for a packet to be received at a Node-B. It can be seen that the delays are considerably decreased for E-DCH when compared to the Rel-99.

Figures 9.6.1.2.9 to 9.6.1.2.12 show the CDF of the packet call delays and packet delays, for both E-DCH and Rel-99. It can be seen that the delay characteristics of the E-DCH are superior over the Rel-99, for all traffic models.

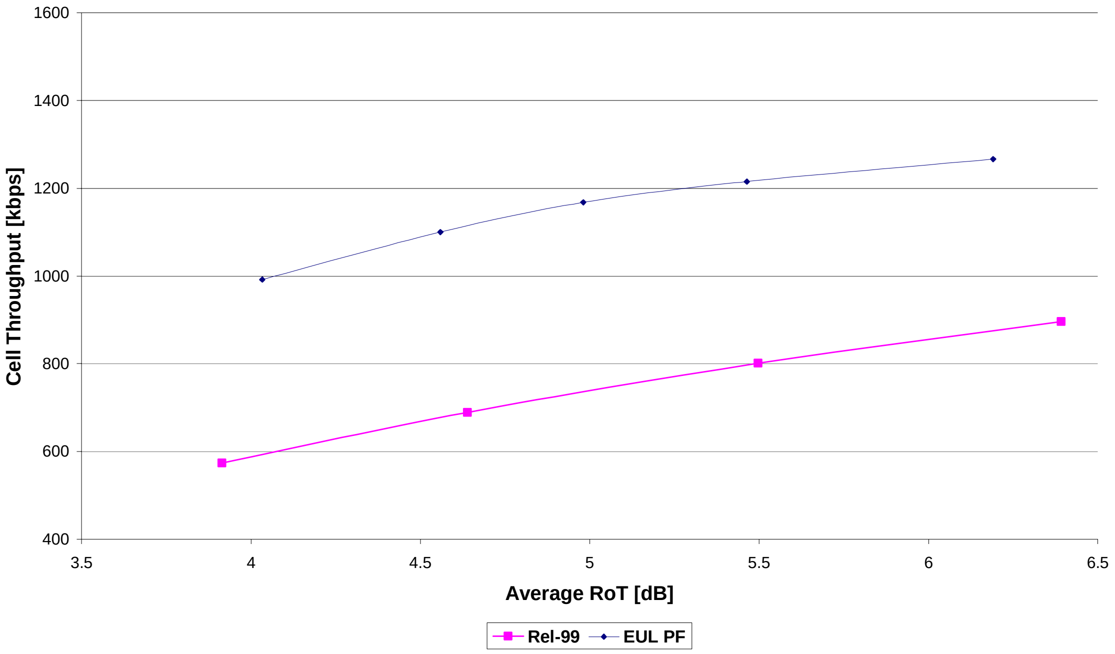

Figure 9.6.1.2.1: Average cell throughput as a function of the average RoT

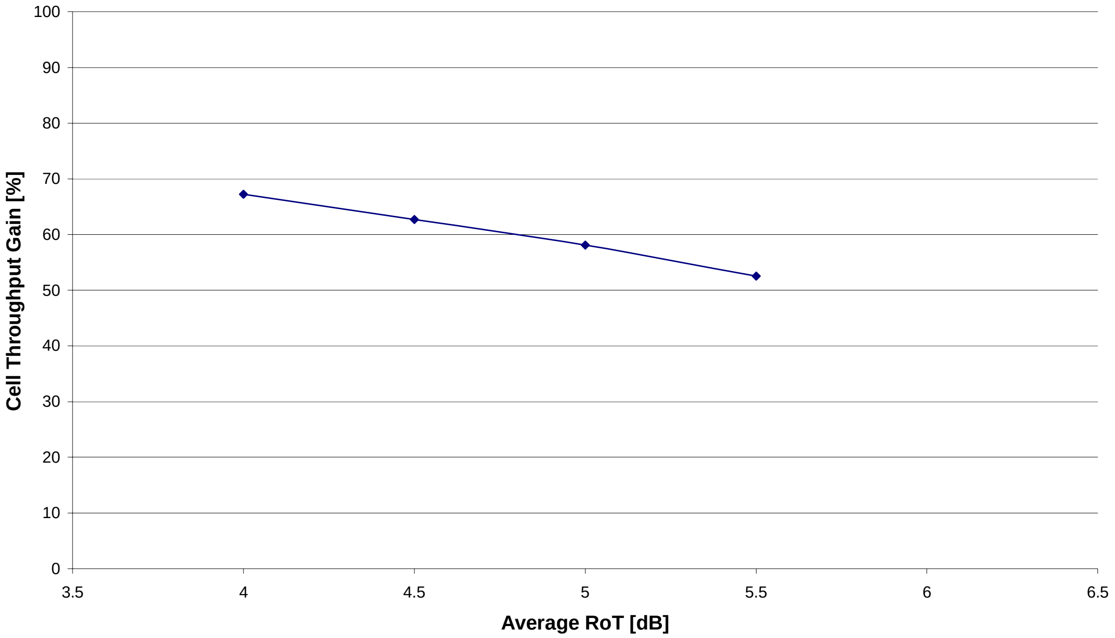

Figure 9.6.1.2.2: Cell throughput gain of EUL over Rel-99 as a function of the average RoT

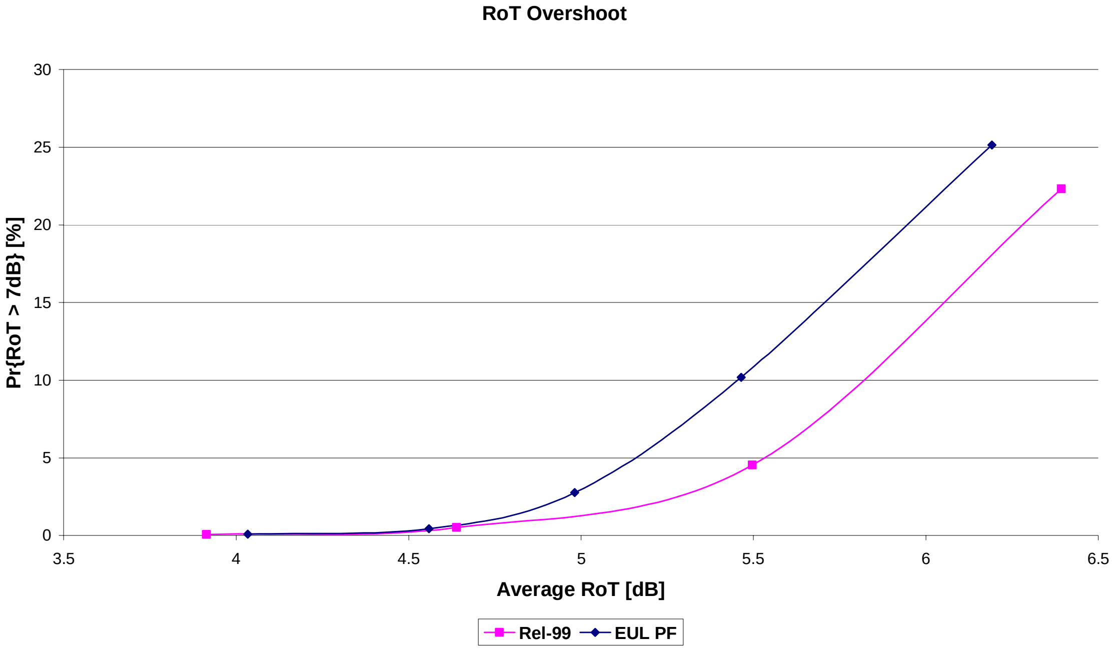

Figure 9.6.1.2.3: Percentage of time the RoT is greater than 7 dB

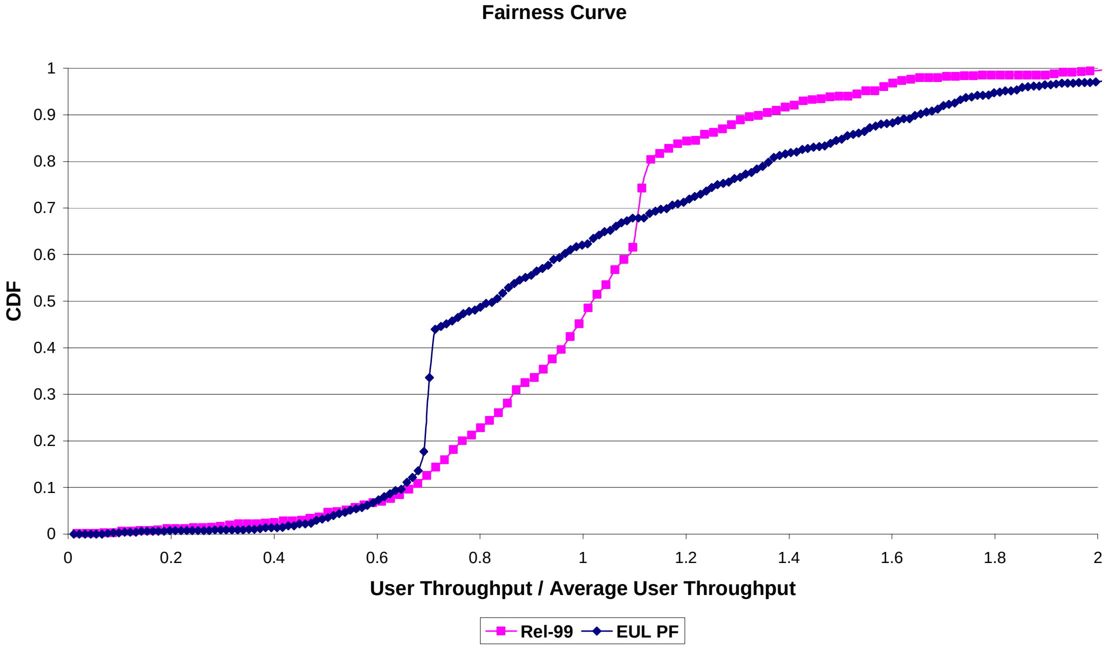

Figure 9.6.1.2.4: Fairness curves for EUL and Rel-99

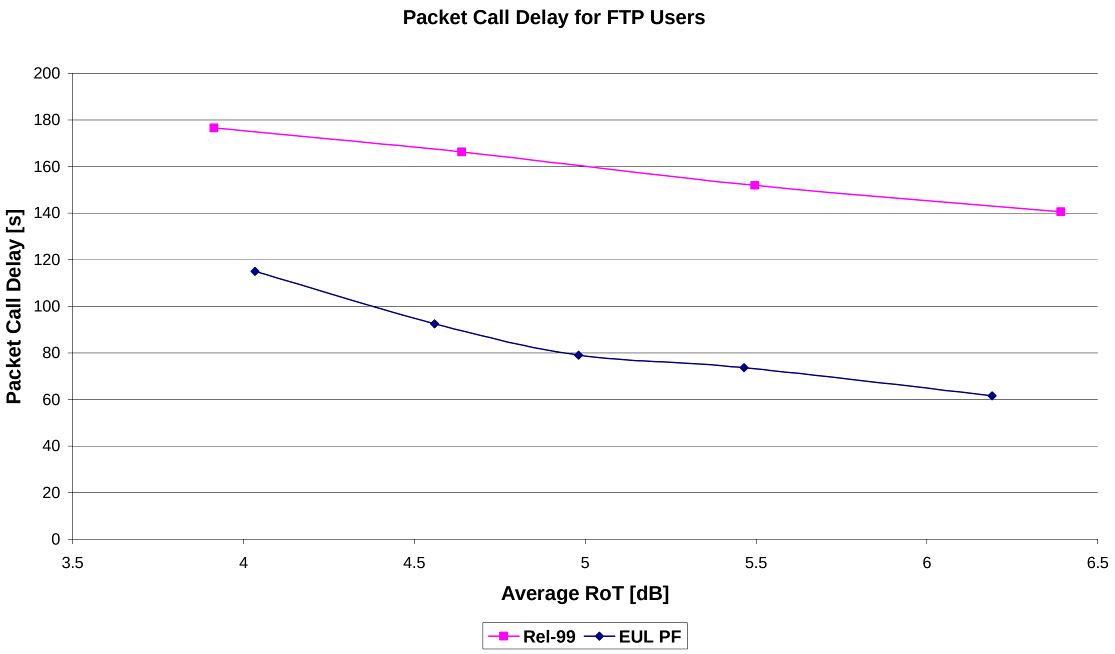

Figure 9.6.1.2.5: Average packet call delay for FTP users, for EUL and Rel-99

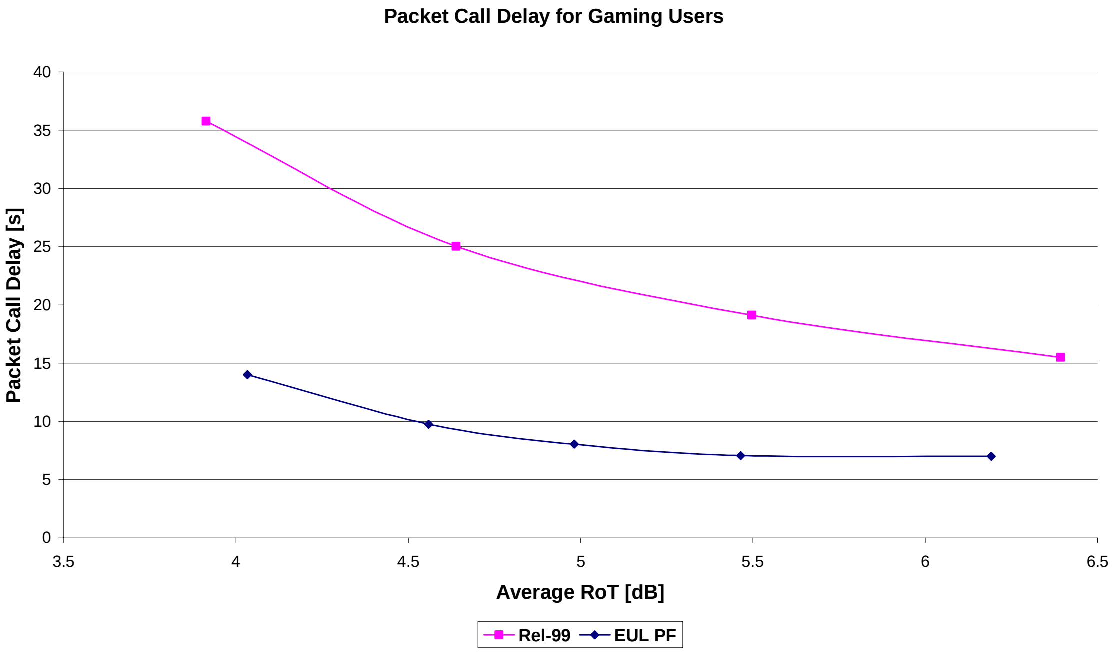

Figure 9.6.1.2.6: Average packet call delay for Gaming users, for EUL and Rel-99

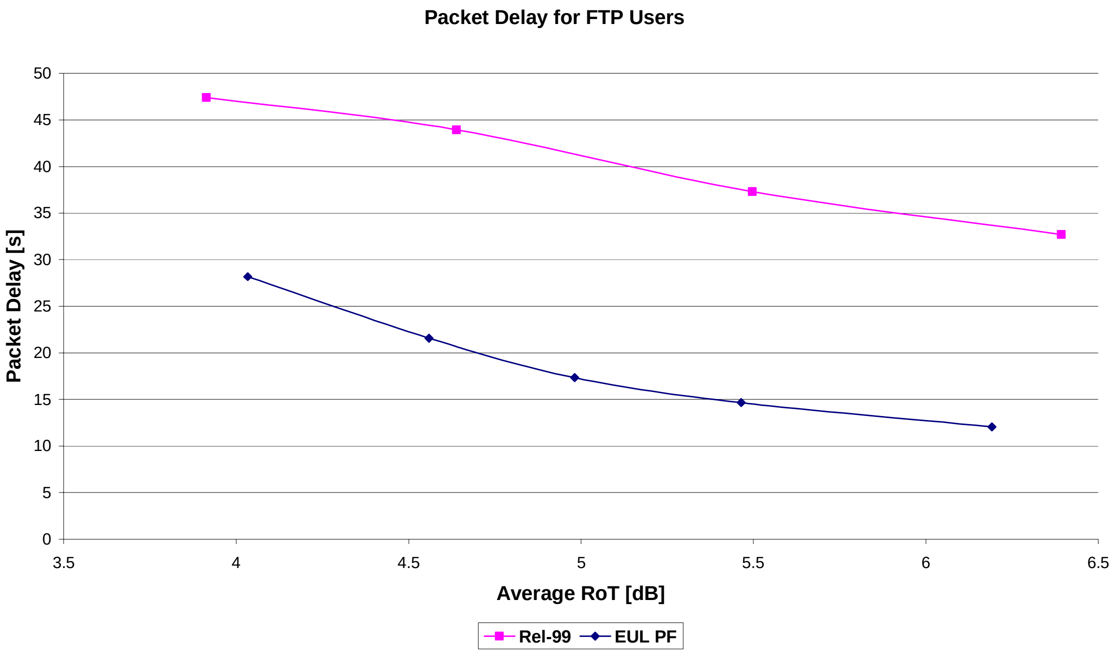

Figure 9.6.1.2.7: Average packet delay for FTP users, for EUL and Rel-99

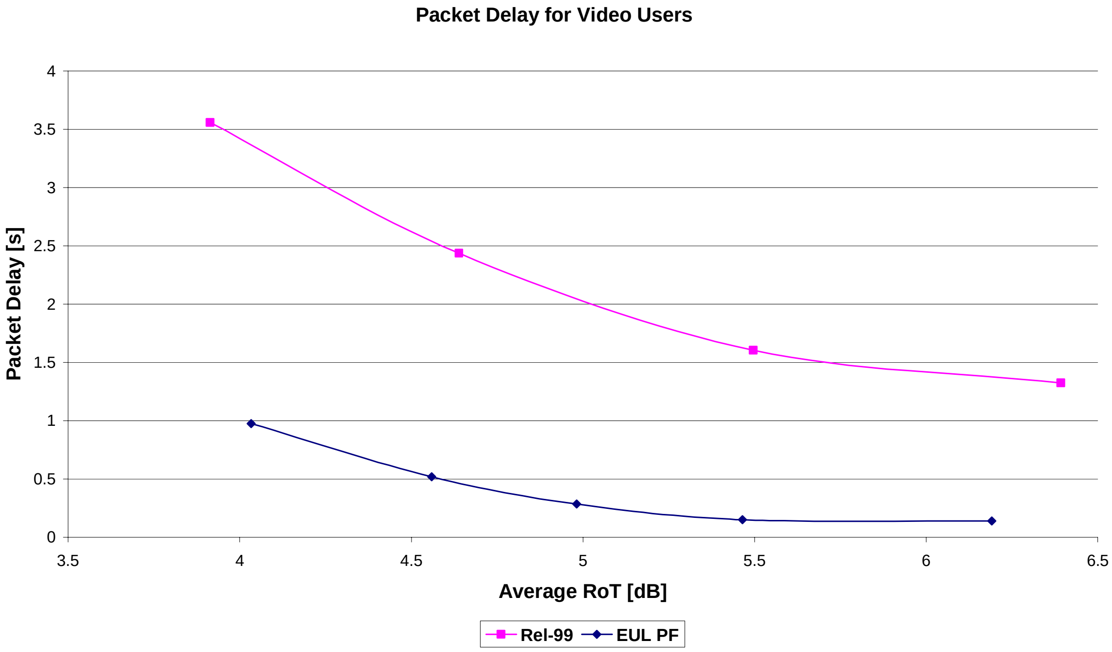

Figure 9.6.1.2.8: Average packet delay for Video users, for EUL and Rel-99

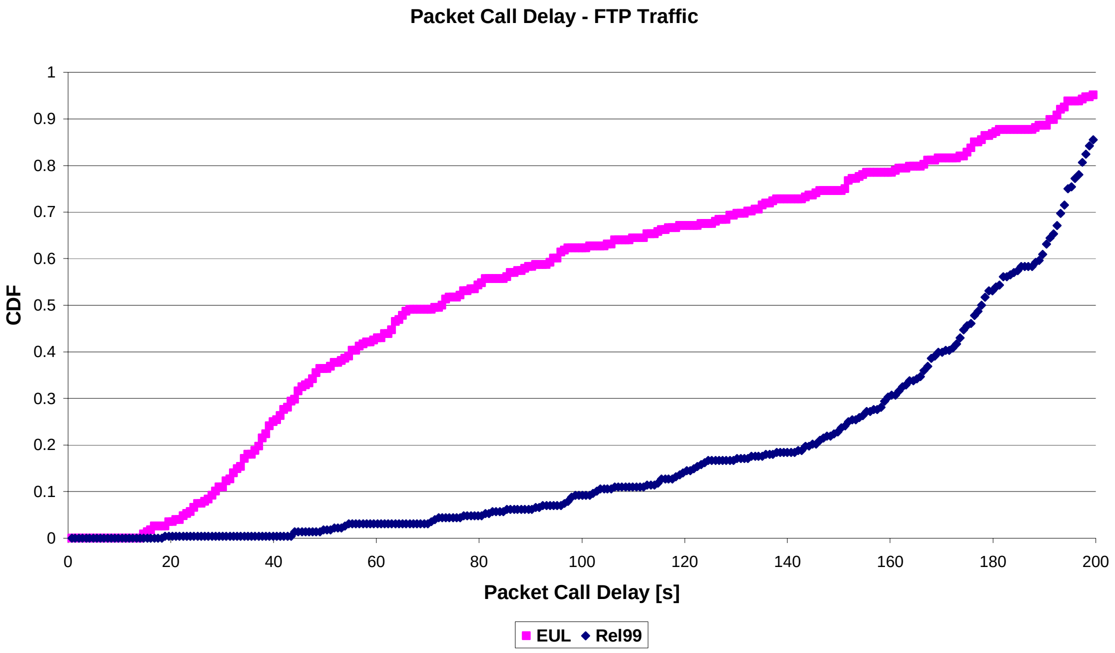

Figure 9.6.1.2.9: CDF of the packet call delays for EUL and Rel-99 for FTP users

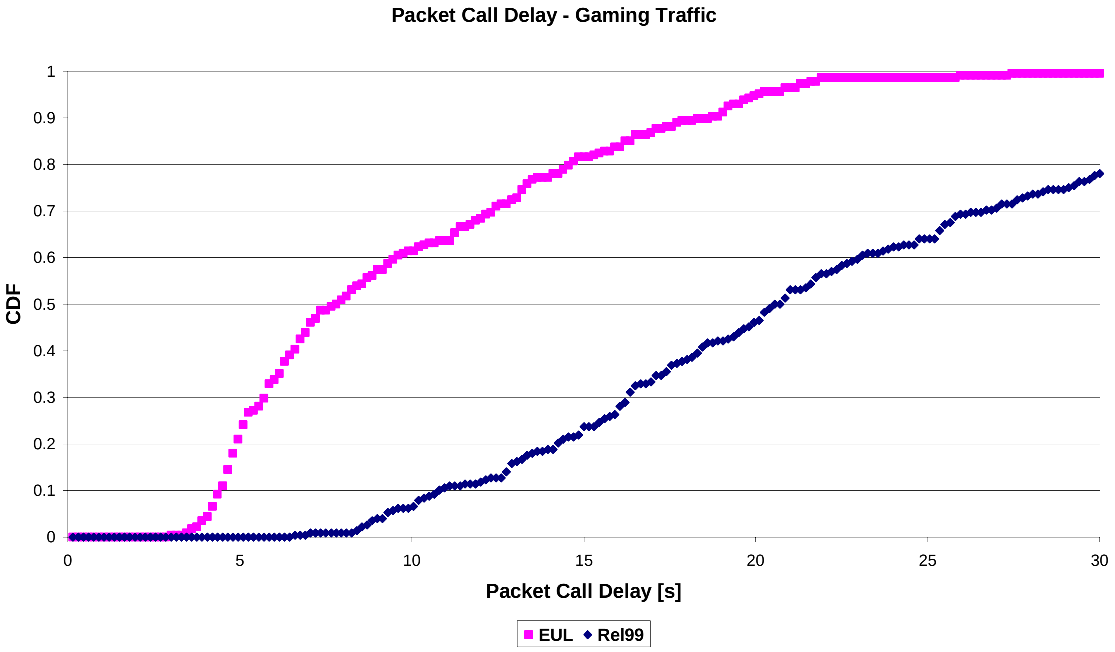

Figure 9.6.1.2.10: CDF of the packet call delays for EUL and Rel-99 for Gaming users

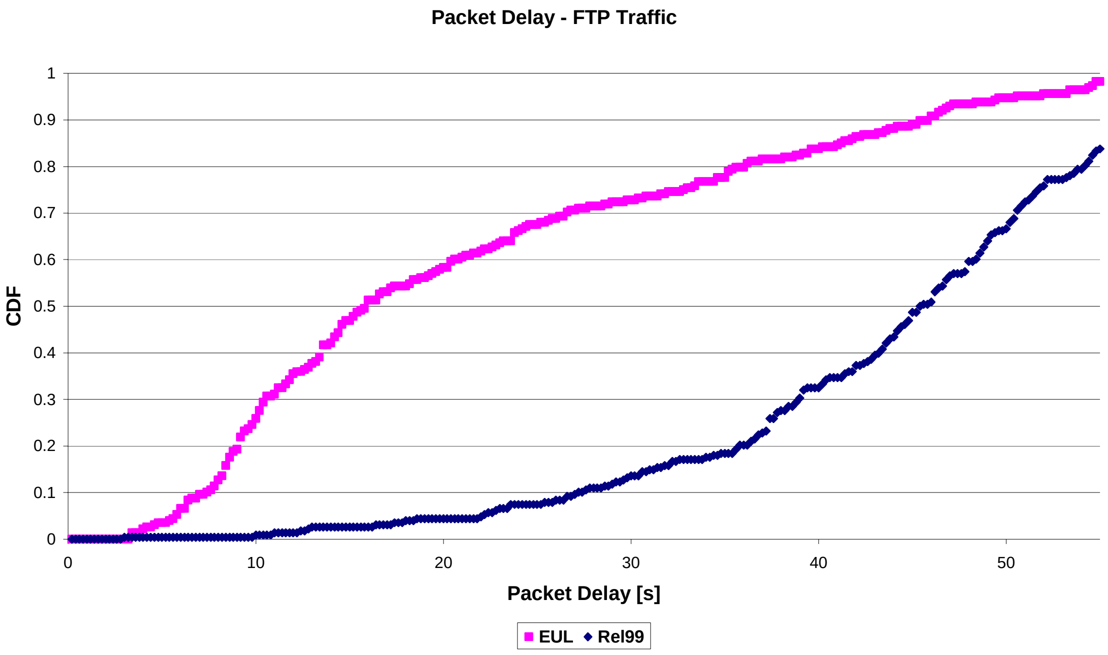

Figure 9.6.1.2.11: CDF of the packet delays for EUL and Rel-99 for FTP users

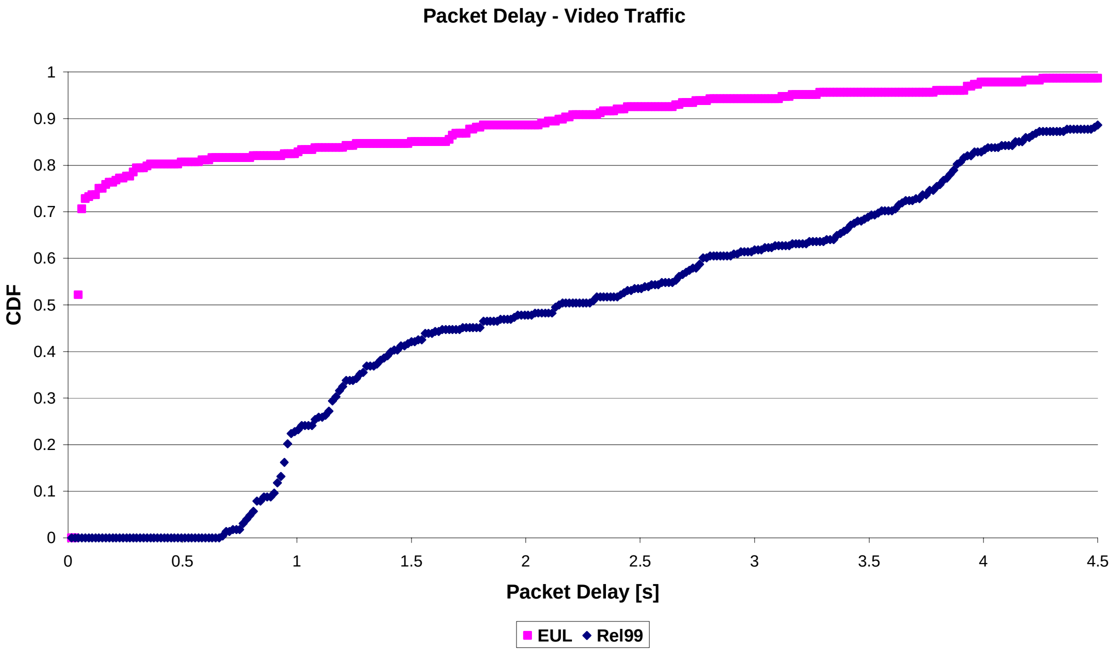

Figure 9.6.1.2.12: CDF of the packet delays for EUL and Rel-99 for Video users

9.6.2 Results with HARQ, 10ms TTI, rate scheduling with persistence

9.6.2.1 Full Buffer results

The following results reflect the relative cell throughput gain of E-DCH, with 10ms TTI, HARQ and with Node-B rate control with persistence, over the system with DCH (Release 99), with 10 ms TTI, 200ms scheduling period and a centralized (RNC based) Round Robin scheduler.

The system configuration is shown in Table 9.6.2.1 Other assumptions are as listed in Annex A3.

From Figure 9.6.2.1 it can be seen that use of the E-DCH with Node-B Rate control with persistence compared to Release 99 uplink with 200ms Time sliced Round Robin yields approximately a 60% improvement in user and cell throughput and 30% reduction in outage (%UEs with user throughput < 16Kbps) for similar RoT statistics as shown in Table 9.6.2.3. For longer RLC round trip time delay and lower R99 dropped frame targets (x% users with >1% dropped frames) the throughput improvement is over 80%.

Figure 9.6.2.2 presents the fairness curve, defined in terms of CDF of the normalized user throughputs. It shows that the fairness remains approximately the same for DCH and E-DCH.

9.6.2.2 Mixed traffic model results

The following results reflect the relative cell throughput gain of E-DCH, with 10ms TTI, HARQ and with Node-B rate control with persistence, over the system with DCH (Release 99), with 10 ms TTI, 200ms scheduling period and a centralized (RNC based) Round Robin scheduler.

The system configuration is shown in Table 9.6.2.1 Other assumptions are as listed in Annex A3.

From Figure 9.6.2.3 it can be seen that use of the E-DCH with Node-B Rate control with persistence compared to Release 99 uplink with 200ms Time sliced Round Robin yields for Gaming traffic approximately a 30% and 45% improvement in cell and user throughput respectively and 10% reduction in outage (%UEs with user throughput < 16Kbps) for similar RoT statistics as shown in Table 9.6.2.5. For NRTV (64Kbps streaming) traffic the outage (% users with more than 2% late (dropped) packets) is reduced by almost 45% while for the Mixture case (1/3 FTP, 1/3 NRTV, 1/3 Gaming) the cell and user throughput is increased by 15% and 50% respectively.

Figure 9.6.2.4 presents the delay curve for Gaming traffic, defined in terms of reduction in average packet call delay. It shows that about a 40% improvement for E-DCH over DCH until the edge of the cell is approached which occurs for a transmission gain of around 125dB.

Figure 9.6.2.5 presents the fairness curve for Gaming traffic, defined in terms of CDF of the normalized user throughputs. It shows that the fairness remains approximately the same for DCH and E-DCH.

Table 9.6.2.1

<table>
<tr><th>Parameter</th><th>Configuration</th></tr>
<tr><td>Layout</td><td>19 Node-B, 3-cell wrap-around layout
Site to site distance = 2800 m</td></tr>
<tr><td>Channel model</td><td>PB3 (Pedestrian B, 3km/h)</td></tr>
<tr><td>Traffic model</td><td>Full buffer or Gaming, FTP, NRTV</td></tr>
<tr><td>Node-B Receiver</td><td>Rake (2 antennas per cell)
8 fingers per UE (finger assignment as in Table A-6)</td></tr>
<tr><td>#UE per cell</td><td>5 or 10 (as indicated)</td></tr>
<tr><td>UE timing</td><td>Time aligned (no offset between users)</td></tr>
<tr><td>Duration</td><td>300 s + 10 s warm-up per Monte Carlo drop (up to 20 drops)</td></tr>
<tr><td>HARQ</td><td>Max # of transmissions = 4 (Chase/IR combining)
N = # of HARQ processes = 3, Re-transmission delay = 30 ms
Ack/Nack errors = 0%</td></tr>
<tr><td>Scheduling Type</td><td>R99: (RNC)
Round Robin scheduler with 200ms scheduling period. Maximum CDM and rate controlled per cell based on Rise over Thermal measurements.

E-DCH: (Node-B) Time + Rate
Node-B Proportional Fair scheduler with
1 serving cell per UE = best DL (same as HSDPA serving cell). All cells in UE’s active set send ACK/NAK.

E-DCH: (Node-B) Rate + Persistence
CDM users transmit autonomously while the maximum data rate and hence the rise over thermal level is controlled by Node-B using a persistence parameter which is signaled by the Node-B.</td></tr>
<tr><td>Scheduling delays</td><td><table>
<tr><th></th><th>DCH</th><th>E-DCH Time+rate</th></tr>
<tr><td>Period</td><td>200 ms</td><td>10 ms</td></tr>
<tr><td>Uplink SI delay</td><td>Uniform 60-100 ms</td><td>10 slots</td></tr>
<tr><td>DL Grant delay</td><td>Uniform 60-100 ms</td><td>1 slot</td></tr>
<tr><td>RLC delay</td><td>100ms or 200ms</td><td>100ms or 200ms</td></tr>
</table></td></tr>
<tr><td>Power control</td><td>Outer loop driven by ZTB 1.6Kbps 10ms TTI and DPDCH services
Inner loop error rate = 4%, delay = 1slot, step size=1dB
PA size: 21dBm,
TFC power measurement error: 2dB std dev.
TFC power measurement delay: 3 slots</td></tr>
<tr><td>DCH</td><td>TFCS = 8,16,32,64,128,256,384 Kbps (see Table 9.6.2.2)

Minimum set: DCCH $(\beta_c,\beta_d)=(15,4)$, ZTB $(\beta_c,\beta_d)=(15,9)$, SID $(\beta_c,\beta_d)=(15,7)$
Reference link level data as presented in R1-040016, R1-040227.</td></tr>
<tr><td>E-DCH</td><td>TFCS = TFS = MCS as shown in Table 9.6.2.2
Minimum set: DCCH, ZTB, SID (if speech+data)

E-TFC elimination:
Similar to R99 TFC elimination. UE MAC decides upon the E-DCH TFC in SUPPORTED_STATE and EXCESS_POWER_STATE every radio frame. The parameters {x, y, z} are set to {15, 30, 30} as in Rel-99.

Reference link level data as presented in R1-040016, R1-040227</td></tr>
<tr><td>E-DPCCH</td><td>TFCI on DPCCH is used to indicate TFC for 10ms TTI
TFC indicated with 20Kbps TFRI channel for 2ms TTI</td></tr>
<tr><td>SHO</td><td>When in SHO E-TFS is restricted via R99 TFC selection</td></tr>
<tr><td>Channel Estimation</td><td>BW=625Hz, non-ideal & modeled in system simulation
(see R1-031276,R1-030313])</td></tr>
<tr><td>Vehicular Penetration/Body Loss</td><td>6 dB (see link budget Annex B R1-040016)</td></tr>
</table>

The TFC for DPDCH and E-DCH are shown in Table 9.6.2.2

Table 9.6.2.2 DCH and E-DCH Per TFC relative power levels

TFC -->	12.2	8	16	32	64	128	256	384	Kbps
beta_d	13	12	15	15	15	15	15	15	
beta_c	15	15	15	11	8	6	4	3	
Ec/Nt total	-17.1	-17.4	-16.5	-14.9	-12.9	-10.9	-7.7	-5.3	dB
DPCCH Ec/Nt	-19.5	-19.5	-19.5	-19.5	-19.5	-19.5	-19.5	-19.5	dB
DPDCH Ec/Nt	-20.7	-21.4	-19.5	-16.8	-14.0	-11.5	-8.0	-5.5	dB
DPDCH Pwr Offset	-1.2	-1.9	0.0	2.7	5.5	8.0	11.5	14.0	dB

TFC -->	640	768	960	1152	1280	1440	Kbps
beta_d	23	26	30	26	29	22	
beta_c	4	4	4	3	3	2	
Ec/Nt total	-4.2	-3.1	-1.9	-0.6	0.2	1.3	dB
DPCCH Ec/Nt	-19.5	-19.5	-19.5	-19.5	-19.5	-19.5	dB
DPDCH Ec/Nt	-4.3	-3.2	-2.0	-0.7	0.2	1.3	dB
DPDCH Pwr Offset	15.2	16.3	17.5	18.8	19.7	20.8	dB

Rates 640Kbps thru 1440Kbps use QPSK modulation

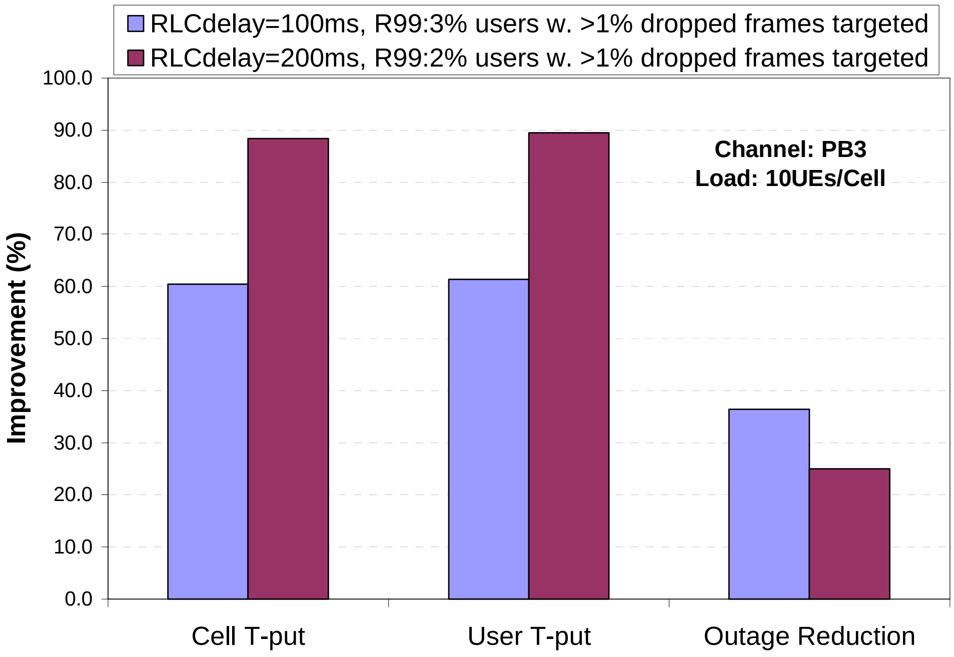

Figure 9.6.2.1: T-put gain of E-DCH over DCH for similar RoT – Full Buffer

Table 9.6.2.3 System/User Performance for Full Buffer traffic, PB3

Scheduling Cases	Avg Cell Load	TTI	Cell T-put	User T-put	%Users>1% dropped Frames	Outage (User T-put <16Kb/s)	Uplink Rise Statistics				
							50%-ile	90%-ile	98%-ile	Avg	Std
	(UEs)		(Kb/s)	(Kb/s)	(%)	(%)	(dB)	(dB)	(dB)	(dB)	(dB)
RLC Delay=100ms											
1) EU: Rate+Persist., N=2	5	10ms	1201	248	0.0	15.2	7.0	8.9	10.7	7.3	1.7
2) EU: Rate+Persist., N=2	10	10ms	1389	142	0.0	15.4	7.1	8.1	8.9	7.2	0.6
RLC Delay=200ms											
3) EU: Rate+Persist., N=3	5	10ms	1244	258	0.0	17.8	6.9	8.7	10.3	7.2	1.8
4) EU: Rate+Persist., N=3	10	10ms	1407	144	0.0	18.3	7.1	8.2	9.1	7.3	0.6
RLC Delay=100ms											
5) R99: Rrobin	5	10ms	870	177	2.5	15.0	6.1	8.2	9.9	6.1	2.4
6) R99: Rrobin	10	10ms	866	88	3.8	24.2	6.7	8.7	10.4	6.8	3.1
RLC Delay=200ms											
7) R99: Rrobin	5	10ms	830	169	1.9	15.7	5.6	7.9	10.4	6.0	3.0
8) R99: Rrobin	10	10ms	747	76	2.7	24.4	6.1	8.7	11.2	6.5	3.5

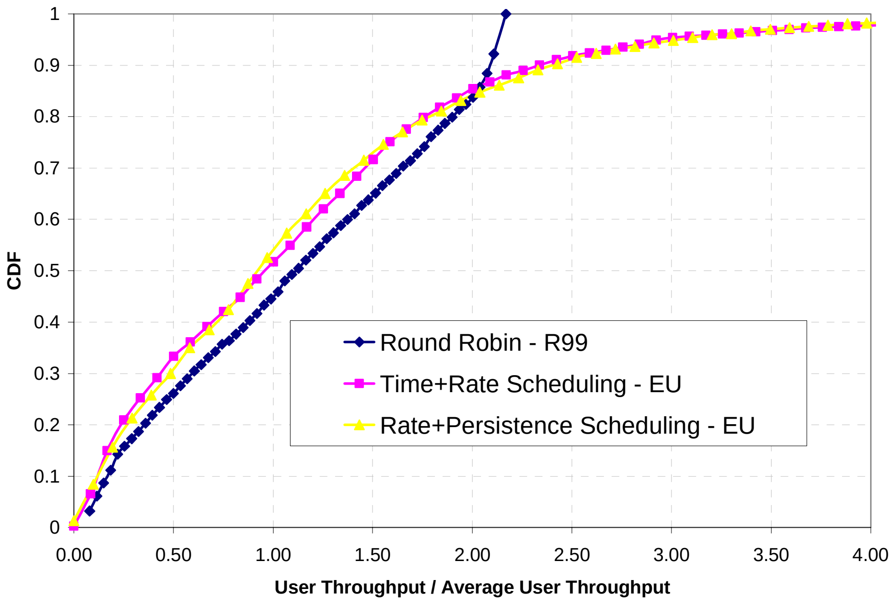

Figure 9.6.2.2: Full Buffer Fairness curve for PB3 (RLC delay=200ms)

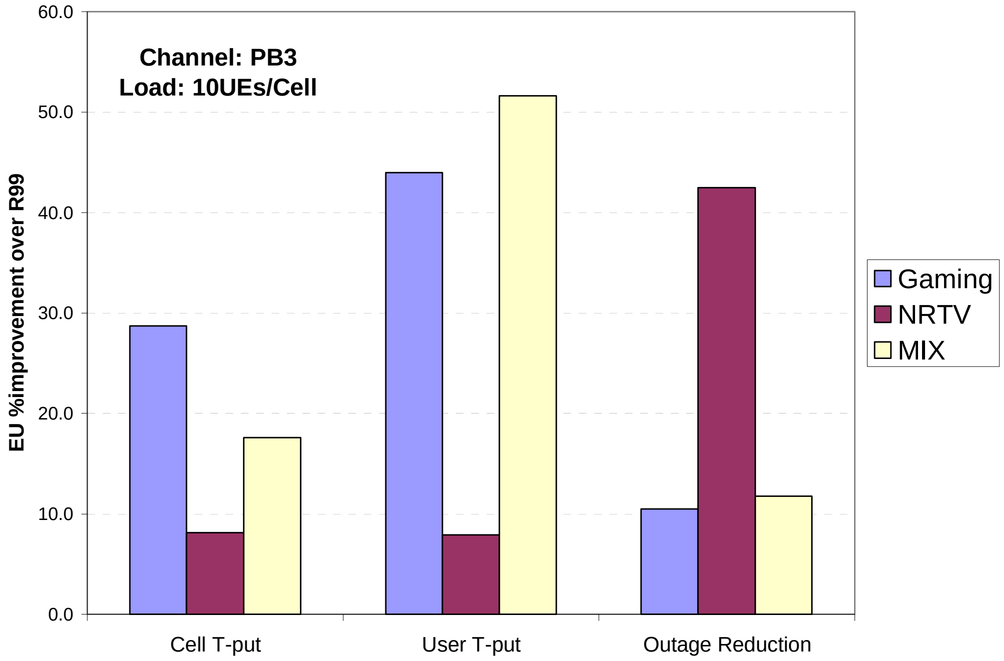

Figure 9.6.2.3: E-DCH improvement over DCH for similar RoT

Table 9.6.2.5 System/User Performance for different traffic

R99 & EU Cases for PB3	Avg Cell Load	TTI	Cell T-put	User T-put	%Users>1% dropped Frames	Outage*	Uplink Rise Statistics				
							50%-ile	90%-ile	98%-ile	Avg	Std
			(Kb/s)	(Kb/s)	(%)	(%)	(dB)	(dB)	(dB)	(dB)	(dB)
Gaming: Rate+Persist.	10	10ms	888	156	0.0	17.9	6.7	9.1	11.8	7.1	3.4
Gaming: R99	10	10ms	690	108	2.1	19.9	5.7	8.3	10.9	6.1	3.6
NRTV: Rate+Persist.	10	10ms	519	52	na	21.8	5.8	8.1	10.2	6.2	2.6
NRTV: R99	10	10ms	480	48	na	37.9	5.2	8.0	10.7	5.6	3.9
MIX: Rate+Persist.	10	10ms	688	141	0.0	20.8	6.6	8.8	11.3	6.8	3.5
MIX: R99	10	10ms	585	93	1.5	23.6	5.7	8.4	10.7	6.0	3.5

* Gaming, FTP outage: User t-put < 16Kbps, NRTV outage: >2% packets late (dropped)

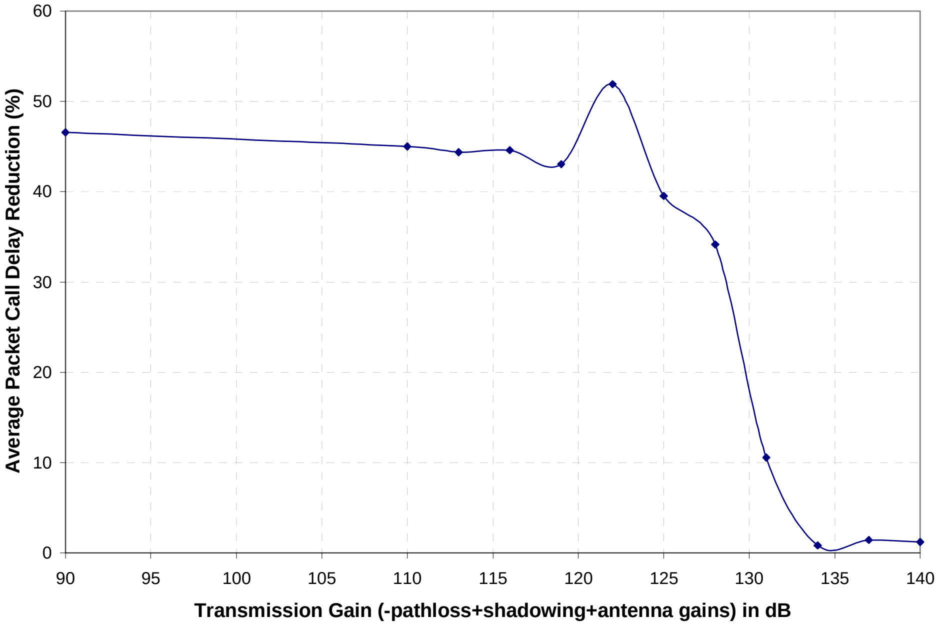

Figure 9.6.2.4 Gaming Traffic: E-DCH Delay Reduction over DCH for PB3

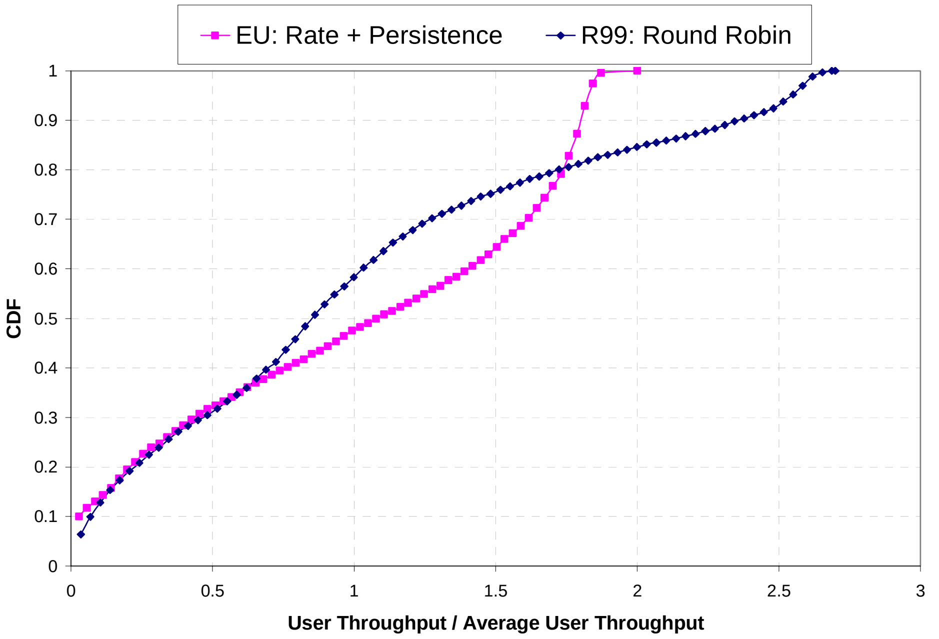

Figure 9.6.2.5 Gaming Traffic Fairness curves for PB3

Table 9.4.1.2.2 shows the values of tau parameters used for FTP users.

Table 9.6.2.6: Tau parameters used for FTP

Delay component	Symbol	Value
The uplink transmission time of a TCP data segment from the client to the Node-B	τ_1	Determined by uplink throughput
The sum of the time taken by a TCP data segment to travel from Node-B to the server and the time taken by an ACK packet to travel from the server to Node-B	τ_2	Exponential distribution Mean = 50 ms.
Time taken by the ACK to travel from Node-B to client	τ_3	Lognormal distribution Mean = 50 ms Standard deviation = 50 ms
Increased delay to account for RLC retransmissions from residual uplink physical layer BLER	τ_4	Constant = 0 ms, if packet is not in error after all physical layer retransmissions else = 100ms or 200 ms

9.7 Compatibility of the enhancements with existing releases

9.7.1 Compatibility at the edge of coverage

It is possible that EUL related functionality will not be deployed across the a whole network from the beginning. This section addresses the compatibility at the edge of enhanced uplink coverage, that is compatibility of the new functionality with Node Bs based on earlier releases.

It should be noted that compatibility issue relates to the uplink transmission; for the downlink transmission using the new functionality, the receiving UE is by definition supporting the new functionality and aware (through signaling mechanisms) of the edge of coverage situation (i.e. radio link sets being received from Node Bs which support and don’t support the new functionality)

In general terms there are two possible situations:

1. The new functionality is not transparent and affects legacy Node B’s covering the area in the first ring around the area covered by Node Bs supporting the new functionality.
2. The new functionality is transparent or hidden to legacy Node B and does not affect their behavior.

9.7.1.1 Non transparent functionality

There are two possible options to address the first situation:

1. Perform a minimum upgrade of the legacy Node Bs such that they can cope with the modified UE behavior without specifically supporting the new functionality.
2. Sacrifice the Node Bs with the new functionality covering the outer ring and use this area as a buffer zone to signal a UE reconfiguration back to the legacy functionality, thus allowing the Node Bs covering the area outside the enhanced cluster to seamlessly handle the particular UE.

These options are always available and do not require particular attention during the design phase of the enhanced functionality as they relate to deployment aspects; however they essentially require upgrades to the Node Bs covering area surrounding the area in which the enhanced functionality should be supported.

9.7.1.2 Transparent functionality

By definition this approach relies on the design of a new functionality or on the use of existing functionality to ensure that legacy Node Bs can handle the new functionality without any modification. The following addresses the Node B based control, HARQ and shorter TTI functionality in that respect.

Node B based control is essentially transparent to a legacy Node B. Whether the UE TFC selection obeys RNC based commands or neighboring Node B based commands does not affect the processing of the actual data by a legacy Node B. As such Node B based control does not create any compatibility issue. However, Node B based control may rely on uplink feedback for UE specific TFC control or TFC assignment. Introduction of this additional uplink signaling channel could be transparent to legacy Node B by using DPCCH puncturing if the number of bits is small or a separate code channel.

Support of HARQ in the uplink involves at least the signaling of some control information in order to allow the Node B to properly combine the various transmissions of different data blocks. Again, this control information can be punctured in what could be seen as a legacy DCH by a legacy Node B (assuming no change to the channel structure) or could be mapped on a separate code channel. With the puncturing option, the legacy Node B may not be able to successfully decode the data (again assuming no change to the channel structure); however, as long as the Node B is configured such that these deterministic errors would not negatively affect the power control behavior, such errors are not an issue. In the same way, if the HARQ scheme relies on incremental redundancy or if a new modulation is introduced this would only result in the legacy Node B not being able to decode the data but would not affect the compatibility for legacy DCH. Alternatively, the E-DCH could be mapped to a separate set of code channels which would not be visible to the legacy Node B.

Introduction of a shorter TTI affects the channel multiplexing structure and procedure. The straightforward option that is transparent to legacy Node Bs is the use of separate code channels for the E-DCH transmission.

In summary one can note that the functionality considered in support of enhanced uplink operation could be introduced in a way that is transparent to legacy node Bs.

9.7.2 Legacy UE

This section addresses the impact of introducing new functionality on legacy UE and associated system performance. Support of higher data rates and possibly shorter TTI in the uplink could potentially result in higher variance in the intra and inter cell interference; this could in turn result in reduced performance of legacy DCH. However, the important metric should be the overall capacity, including voice and data, not just the voice or legacy data capacity. As is suggested by results presented in section [tbd] it seems that the net result is an increase in data throughput when supporting the same number of voice users.

An important special case is the border area between legacy Node B and Node B supporting the new functionality. In this area, the capacity in the area covered by the legacy Node Bs may be affected by the additional interference resulting from UEs operating in the area covered by Node Bs which support the new functionality. However, the new functionality itself enables the system to control the potential interference and interference variance and could be configured in the border area such that the capacity impact in the legacy area is minimum if not null.

9.7.3 Link budget

This section addresses the impact on the uplink link budget. The link budget is potentially affected by increased peak to average and increased peak transmit power requirement to achieve a certain rate.

Introduction of new control fields in the uplink slightly (in relative terms) increases the amount of data (and power) needed to close the link.

Introduction of HARQ seems to result in higher power requirement since it calls for higher peak rate transmission to achieve the same rate as seen by higher layers. However, HARQ actually improves the efficiency of the transmission such that for a certain link budget a UE can transmit with a higher throughput. All the system level results presented in chapter 9 take into account the UE maximum transmit power limit and cell radius; as such the link budget is therefore the same for both legacy uplink and uplink with the new functionality.

Introduction of new code channels affects the peak to average of the resulting signal and results in requirement for additional power amplifier back-off or for more complex power amplifier (larger, better or smarter). Specifically, introduction of new code channels in itself does not affect the link budget but the power amplifier complexity. The link budget would only be affected if one would want to re-use a power amplifier designed for legacy uplink channel structure.

9.7.4 DL capacity

The downlink capacity is affected by the DL control channels to support the new uplink functionality; this includes control data for TFC control or assignment procedure and control data for the HARQ functionality. The impact on average DL capacity is expected to be relatively small. However the variance of the impact expected to be larger (e.g. when handling UE at the edge of the cell) and this may affect the capacity of the cell if the cell resource is only used for streaming services. In contrast there would be minimum impact if part of the cell resource is used for best effort services since the resource could temporarily be preempted to transmit the UL related control information.

9.7.5 Design re-use

Although the goal of the study item was not to decide on the details of each functionality it is apparent that the existing structure, procedures and blocks can be and will be re-used as much as possible. This is strongly driven by the backward and forward compatibility requirement and desire to minimize the increase in complexity.

9.7.6 Conclusion

Based on above considerations one can conclude that it is feasible to introduce new uplink functionality in a way that is fully compatible with systems deployed based on existing releases.

10 Impacts to the Radio Interface Protocol Architecture

10.1 Protocol Model

The proposed new MAC entity (Chapter 8.1.1) is introduced to the Rel99/4/5 MAC sub-layer on UE and network side and covers the E-DCH specific functionality.

Figure 10.1 is an example protocol model for E-DCH. In case that inter-Node B soft handover is supported for E-DCH, the macro diversity selection combining (MDC)[3] and reordering operation may take place in the MAC-es of the serving RNC (MAC-es represents MAC-e functionality of the serving RNC.) Otherwise, the MAC-es functionality is null given that the reordering function would reside in the MAC-e of the Node B.

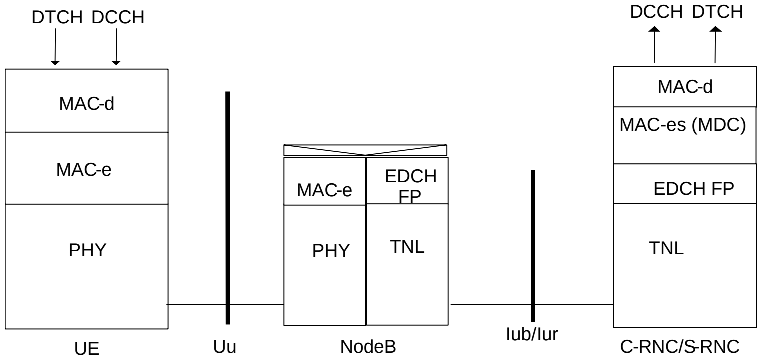

Figure 10.1: Example of protocol model for E-DCH transport channel

10.1 Introduction of new MAC functionality

The new functionalities of Node B controlled Hybrid ARQ and Node B controlled scheduling, considered as enhancements for the uplink dedicated transport channel, require the introduction of new MAC functionalities. These new functionalities could be partly added to the existing MAC-d, e.g. reordering or TFC selection, or included in a new MAC entity, as proposed in chapter 8.1.1. This new MAC entity, which is referred to as MAC-e, is added to the Rel99/4/5 MAC sublayer on UE and on network side and covers HARQ related functionality, e.g. generation of ACK/NACK and retransmissions, as well as the scheduling related functionality. For the definition of the MAC architecture and functionality of the new MAC entity, issues like TFC selection, number of E-DCH transport channels and location of the reordering entity need to be considered, since they have a big impact on the overall architecture. The introduction of a new MAC entity will have an impact on TS25.321.

---

[3] In R’99 the MDC function is considered to be a physical layer functionality of the SRNC.

10.1.1 Introduction of an enhanced uplink dedicated transport channel (E-DCH)

The support of the uplink enhancements, considered in RAN WG1, requires the introduction of an enhanced uplink dedicated transport channel, called E-DCH. It still remains to be decided whether there will be a new transport channel added to RAN specification.

If only one E-DCH transport channel is supported, similar to HSDPA, MAC-e multiplexing may be required to multiplex several MAC-d flows into one E-DCH. In case several E-DCH transport channels are supported, each MAC-d flow is mapped to one transport channel. It needs to be decided whether there are only one or several E-DCH transport channels simultaneously allowed in the same TTI. The simultaneous support of transport channels with different transmission modes, e.g. different TTI lengths or different scheduling approaches, may for example require several E-DCH transport channels per TTI.

10.1.2 HARQ functionality

Node B controlled Hybrid ARQ allows for rapid retransmissions of erroneously received data packets between UE and Node B. A similar retransmission scheme as employed for the HS-DSCH in HSDPA can be used for the E-DCH. It has to be defined whether to adopt a retransmission protocol with asynchronous or synchronous uplink data transmission and with asynchronous or synchronous downlink feedback signalling.

Support of E-DCH HARQ functionality during soft handover is under consideration and link imbalances in soft handover may lead to unsynchronised soft buffers among different Node Bs. Enhancements in HARQ protocol operation, e.g. soft buffer synchronisation, should be discussed in order to provide a reliable HARQ protocol operation during soft handover.

10.1.3 Reordering entity

Since RLC requires in-sequence delivery the location of the reordering entity should be defined. Possible locations for the reordering entity are Node B and RNC. Such decision also depends on whether soft handover is supported or not.

10.1.4 TFC selection

In Rel5 TFC selection in the UE shall be done in accordance with the priorities (logical channel priority) indicated by RRC. In case the same functionality with different logical channel priorities should be maintained in enhanced uplink DCH, the TFC selection in the UE has to take both E-DCH and DCH into account in case of a simultaneous transmission on E-DCH and DCH. TFC Selection for E-DCH can be either done jointly with TFC selection for Rel99/5 DCH channels in MAC-d or in the new MAC-e entity. Some interaction between MAC-e and MAC-d is in both cases required. Furthermore the logical channel priorities for E-DCH need to be discussed.

The impact of multiple CCTrChs and a possible adoption of a shorter TTI on the TFC selection algorithm should be clarified. Furthermore the minimum set of TFCs in the presence of E-DCH should be also discussed.

10.2 RLC

Since the E-DCH is intended to transport dedicated logical channels, layers above the MAC layer should be kept as in Rel99/4/5.

10.3 RRC

To support the uplink enhancements, required new signaling should be added to the RRC specification TS25.331.

11 Impacts to Iub/Iur Protocols

11.1 Impacts on Iub/Iur Application Protocols

Enhancements considered for the uplink dedicated transport channels like Node B scheduling and Node B controlled HARQ will have an impact on the Iub/Iur application protocols, RNSAP and NBAP, TS25.423 and TS25.433 respectively.

To support E-DCH, application protocol procedures for setup, addition, reconfiguration and deletion of related radio links will have to be supported. This will very likely have an impact on Common NBAP procedures (e.g. Radio Link Setup), Dedicated NBAP procedures (e.g. Radio Link Reconfiguration) and corresponding RNSAP DCH procedures. And as in the HSDPA case, CRNC might need to allocate resources to Node B. In addition, the scheduling performed by serving Node B only is decentralized, and only limited information is available. To improve the accuracy of the scheduling, some communication between the RNC and Node Bs and possibly between different RNCs might be necessary. For example, the contribution of UEs scheduled by other serving Node Bs from the Active Set to the uplink interference level (relative to target RoT – rise over thermal) in the serving Node B might be necessary for an efficient scheduling in Node B. For the efficient scheduling, certain changes in NBAP Common Measurement and related RNSAP Global procedures might be required.

Impacts of Fast DCH setup on the application protocols are FFS.

11.2 Impacts on Frame Protocol over Iub/Iur

The introduction of a new Frame Protocol for the E-DCH across Iub/Iur interface needs to be considered. Furthermore since HARQ operation during soft handover is considered to be supported, Iub/Iur signalling might be required in order to provide a reliable protocol operation during soft handover. Alternatively the current DCH FP could be enhanced, e.g. new IEs or Control Frames could be defined. Moreover since shorter TTI for the air interface is under study, possible impact to the frame protocol needs to be considered

12 Conclusions and Recommendations

12.1 Conclusions

In the study of “Uplink Enhancements for Dedicated Transport Channels”, the following techniques have been considered:

- Node B controlled scheduling
- Hybrid ARQ
- Shorter TTI
- Higher order modulation
- Fast DCH setup

Simulation results presented to RAN1 has shown a significant improvement compared to Rel5, in the order of 50%-70% increase in system capacity, 20%-55% reduction in end-user packet call delay and around 50% increase in user packet call throughput, when simultaneously applying Node B scheduling, hybrid ARQ with soft combining, and a shortened TTI. Hence, significant technical benefits have been found for a system using these techniques in conjunction.

Higher order modulation, of which only 8PSK has been studied, has been found to cause a loss in link performance compared to multi-code transmission with BPSK, but may enable peak data rates exceeding 5.76 Mbit/s or may provide implementation benefits in terms of a reduced PAR. The other enhancements studied are not dependent on whether higher order modulation is introduced or not. Thus, from a principal point of view, higher order modulation is independent of the other enhancements studied.

Complexity has been studied in terms of buffering and timing requirements due to hybrid ARQ, PAR impact due to additional physical channels, and power requirements for the associated control signaling. Comments from RAN2 and RAN3 on their respective areas have also been taken into account in the TR. The enhancements can be introduced into the FDD specifications without impacting the backwards compatibility with Rel5 and earlier releases.

All these enhancements, Node B controlled scheduling, hybrid ARQ, shorter TTI, and higher order modulation, have been found to be technically feasible. At least one company has expressed concerns on the benefits of a shorter TTI in comparison with the potential implementation impacts. Some companies have questioned whether the benefit with 8PSK from a PAR perspective outweighs the loss in link performance.

Fast DCH setup has been partially investigated. Methods for reducing the synchronization time when going from CELL_FACH to CELL_DCH have been described but not evaluated in detail in this report. Other aspects of fast DCH setup, e.g., architectural changes and signaling protocols, have not been covered.

12.2 Recommendations

Base on the findings documented in this report, RAN1 recommends to create a work item on uplink enhancements where:

- Node B controlled scheduling, hybrid ARQ, and shorter TTI are parts of the work item;
- Higher order modulation (8PSK and higher) is not part of the work item;
- Fast DCH setup is not part of the work item.

Annex A:
Simulation Assumptions and Results

A.1 Link Simulation Assumptions

A.1.1 Interface between link level and system level

The performance characteristics of individual links used in system simulation are generated a priori from link level simulations. Due to weak uplink pilots, and the resulting poor channel estimates, the link performance predicted by methods that do not account for imperfect channel estimates can yield incorrect results. So, it is very important to account for the effect of channel estimation errors on link performance. Suggested techniques for predicting link error performance in the presence of channel estimation errors are discussed further in the Annex E.

In general, there are two cases of interest:

1. *Comparison of techniques/proposals without H-ARQ*: If the effect of channel estimation errors on link performance is modeled in generating simulations results for a comparison of techniques without H-ARQ, the link error prediction method used should be stated in the simulation assumptions. Otherwise, justification should be provided as to why the comparison is valid. (See Annex E.)

2. *All other cases, i.e., comparison of techniques, one or all of which include H-ARQ combining*: In all these cases, the effect of channel estimation errors on link performance must be accounted for in generating simulation results for the comparison. (See Annex E)

The following table should be included along with the simulation assumptions accompanying all results:

Are any of the techniques being simulated involve H-ARQ combining?	**Is the effect of channel estimation errors on link performance accounted for?**	**Comments**
Yes/No	Yes/No	If the effect of channel estimation errors on link performance is modeled, then state the method. Otherwise, justify why the comparison is valid.

A.1.2 Link level parameters

Table A - 1 below shows the general link level parameters, to be used both in the reference case, and in the new schemes proposed for Enhanced Uplink DCH. Table A - 2 shows the link level parameters to be used in the reference case.

Table A - 1 - General link level parameters

Parameter	Explanation/Assumption	Comments
Channel coder	Turbo 1/3	
Number of iterations for turbo decoder	8	
Turbo decoder	Max Log MAP	
Channel models/ UE speed for channel model	Pedestrian B / 3 km/h, Vehicular A / 30 km/h Pedestrian A / 3 km/h Optional Vehicular A / 120kph	One channel model per simulation

Table A - 2 - Link level parameters for the Rel99/Rel4/Rel5 reference case

Parameter	Explanation/Assumption	Comments
CL power control	ON	
CL power control error rate	4%	
TTI	10 ms	
User data rates in TFCS	8, 16, 32, 64, 128, 256, 384 kbit/s	These data rates are included in the TFC selection modelling in the system level.

A.1.3 Channel models

ITU channel models [2] are used in the link level and system level simulations. Multipath intensity profiles are given below.

The multipath intensity profile of the Pedestrian-A channel is defined as follows:

Relative Delay (ns)	0	110	190	410
Relative Power (dB)	0.0	-9.7	-19.2	-22.8

Table A - 3 - ITU Pedestrian-A channel model.

The multipath intensity profile of the Pedestrian-B channel is defined as follows:

Relative Delay (ns)	0	200	800	1200	2300	3700
Relative Power (dB)	0.0	-0.9	-4.9	-8.0	-7.8	-23.9

Table A - 4 – ITU Pedestrian-B channel model

The multipath intensity profile of the Vehicular-A channel is defined as follows:

Relative Delay (ns)	0	310	710	1090	1730	2510
Relative Power (dB)	0.0	-1.0	-9.0	-10.0	-15.0	-20.0

Table A - 5 – ITU Vehicular-A channel model

The delay intensity profiles are computed from the ITU channel multipath intensity profiles given in the Tables above for a set of transmit and receive filters. The delay intensity profile for 5MHz WCDMA transmit and receive filters (raised cosine with beta=0.22) for a chip rate of 3.84Mcps are given in Table A - 6 The Fractional Recovered Power (FRP) is given in Table A - 6 for each recovered ray. Fraction of un-Recovered Power (FURP) shall contribute to the interference of the finger demodulator outputs as an independent fader.

Table A - 6 - FRP and Delay profile for each ITU channel model for 5MHz bandwidth and 3.84Mcps.

Multi-path	**FRP for each ray (dB)**					**Delay for each ray (Tc)**				
Model	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Pedestrian A	-0.22					0.125				
Pedestrian B	-3.39	-8.45	-8.63	-11.61	-11.74	0.375	1.375	3.250	4.750	9.000
Vehicular A	-3.17	-4.07	-11.19	-13.01		0.125	1.375	2.875	4.250	
Vehicular B	-4.83	-2.39				0.125	1.250			

A.1.4 Description of Short Term FER and ECM Metod

A.1.4.1 Short-term FER method:

The *short-term* Eb/Nt vs. BLER results are generated in the following way:

1. The link simulation is run for a long duration (e.g. 500,000 TTI) with outer-loop set to 1% FER.
2. At the end of each TTI, the following statistics are logged:
    a. TTI averaged Rx traffic Eb/Nt, combined across both antennas
        i. Denoted as *short-term* Eb/Nt
    b. Binary metric denoting whether the frame is in error or not, after decoding
3. At the end of simulation run:
    a. The *short-term* Eb/Nt is placed in bins with a uniform grid, along with the associated binary decoding metric
    b. For each bin, the FER is computed based upon the binary metrics from all values in the bin
    c. This constitutes a *short-term* Eb/Nt vs. FER curve

These curves form a set of look-up tables for the system level simulation. In the system level simulation, the receiver computes the TTI averaged traffic Eb/Nt and looks up the corresponding short-term FER curve. A uniform random variable is then selected based on the FER in the system simulator to determine if the represented frame for that TTI is erased or not.

A.1.4.2 ECM method:

The steps in the ECM method are summarized as follows:

1. Compute the equivalent $(Es/Nt)_m$ per m-th slot.

2. Compute $\sigma^2 = 8 \cdot Q \cdot 10^{(E_s/N_t)/10}$ for BPSK, $\sigma^2 = 4 \cdot Q \cdot 10^{(E_s/N_t)/10}$ for QPSK and $\sigma^2 = 2.6666 \cdot Q \cdot 10^{(E_s/N_t)/10}$ for 8-PSK modulation. Q is a scale factor obtained from running link level simulation.

3. Compute function J(σ) using the following approximation.

$$J(\sigma) \approx \begin{cases} a_1\sigma^3 + b_1\sigma^2 + c_1\sigma, & \text{if } \sigma \le 1.6363 \\ 1 - \exp(a_2\sigma^3 + b_2\sigma^2 + c_2\sigma + d_2) & \text{if } 1.6363 \le \sigma \le \infty \end{cases}$$

where $a_1 = -0.0421061, b_1 = 0.209252$ and $c_1 = -0.00640081$ for the first approximation, and where $a_2 = 0.00181491, b_2 = -0.142675, c_2 = -0.0822054$ and $d_2 = 0.0549608$ for the second approximation.

4. The average C_m is then calculated by averaging over the TTI as per the following

$$C = \frac{k}{M} \cdot \sum_{m=1}^{M} J(\sigma)_m$$ where k = 1,2 and 3 for BPSK, QPSK and 8-PSK modulation respectively

5. The equivalent Eb/Nt is then given by

$$\frac{E_b}{N_t} = \left[J^{-1}\left(\frac{C}{k}\right) \right]^2 \cdot \frac{k}{8Q}$$

where

$$J^{-1}(C) \approx \begin{cases} a_3C^2 + b_3C + c_3\sqrt{C}, & \text{if } \quad 0 \le \mathrm{C} \le 0.3646 \\ a_4\ln(b_4(\mathrm{C}-1)) + c_4\mathrm{C} & \text{if } \quad 0.3646 \le \mathrm{C} \le 1 \end{cases}$$

where $a_3 = 1.09542, b_3 = 0.214217$ and $c_1 = 2.33727$ for the first approximation, and where $a_4 = -0.706692, b_4 = -0.386013$ and $c_4 = 1.75017$ for the second approximation.

The FER is then obtained by applying the Eb/Nt to an AWGN reference curve.

A.1.4.3 Comparison between short term and ECM method

The short term and ECM FER curves was generated as per the parameters shown in TableA1.4.1

Table A.1.4.1. Simulation Parameters

Simulation Parameter	Value
No. of slots/frame	15
No. of chips/second	3.84 Mcps
TTI	2 and 10 ms
Modulation	BPSK
Channels	Ped-A, Ped-B and Veh-A
No. of antennas	2
No. of fingers	1-Ped-A and 5-Ped-B, 4-Veh-A
Lock filter	Yes
Receiver	Rake
Sampling Rate	1X
Inner-Loop PC	ON
Outer-Loop PC	OFF
Power Control Metric	Ideal
PC delay and error	1 slot, 4%
PC step size	1 dB
Pilot/TFCI/FBI/TPC	6/2/0/2
Base Turbo Code	R=1/3, K=4, 8 iterations

Figure A.1.4.1 to figure A.1.4.4 shows the performance comparison of short-term approach to that of the ECM approach for flat, Ped-B and Veh-A channel model at 3, 30 and 120 kmph for 2msec and 10 msec TTI respectively.

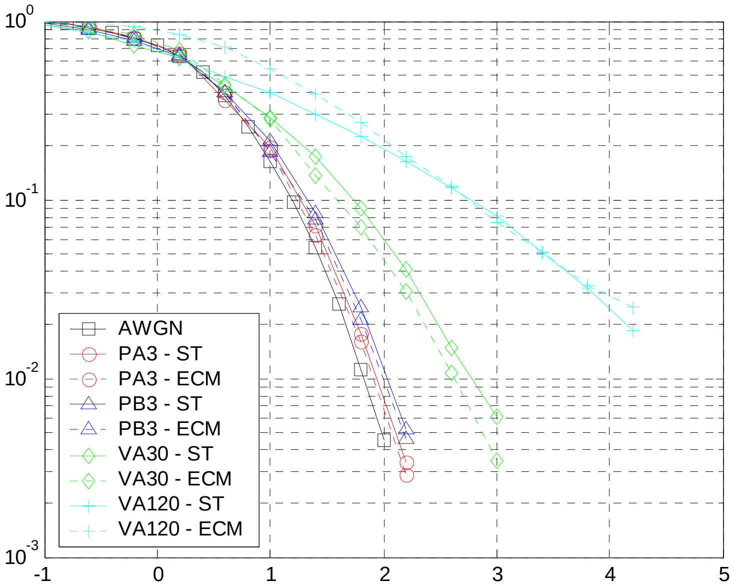

Figure A.1.4.1. Comparison of actual short-term and ECM generated curves – 192 kbps, R=0.4, BPSK, TTI=2ms, SF=8, ideal channel estimation, Q=1.0 for PA3, PB3, Q=2.0 for VA30, VA120.

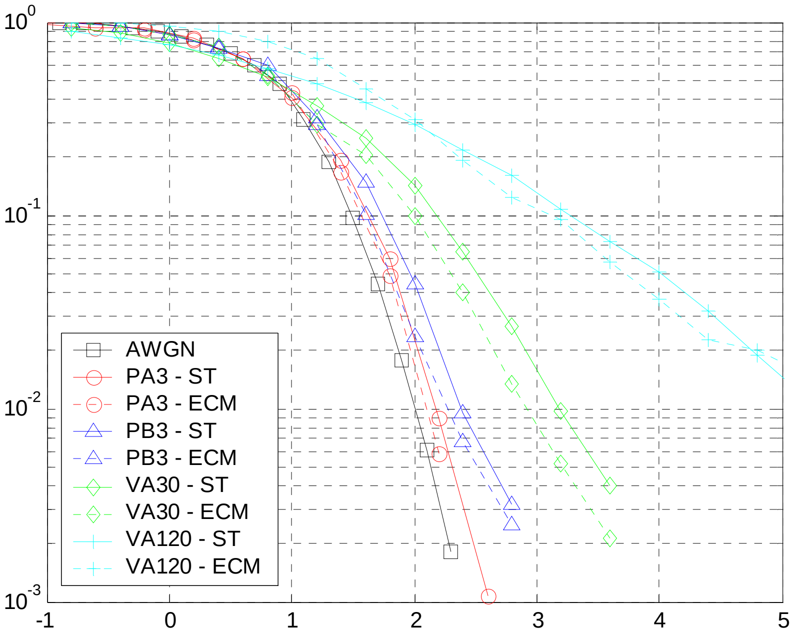

Figure A.1.4.2. Comparison of actual short-term and ECM generated curves – 480 kbps, R=0.5, BPSK, TTI=2ms, SF=4, ideal channel estimation, Q=1.0 for PA3, PB3, Q=2.0 for VA30, VA120.

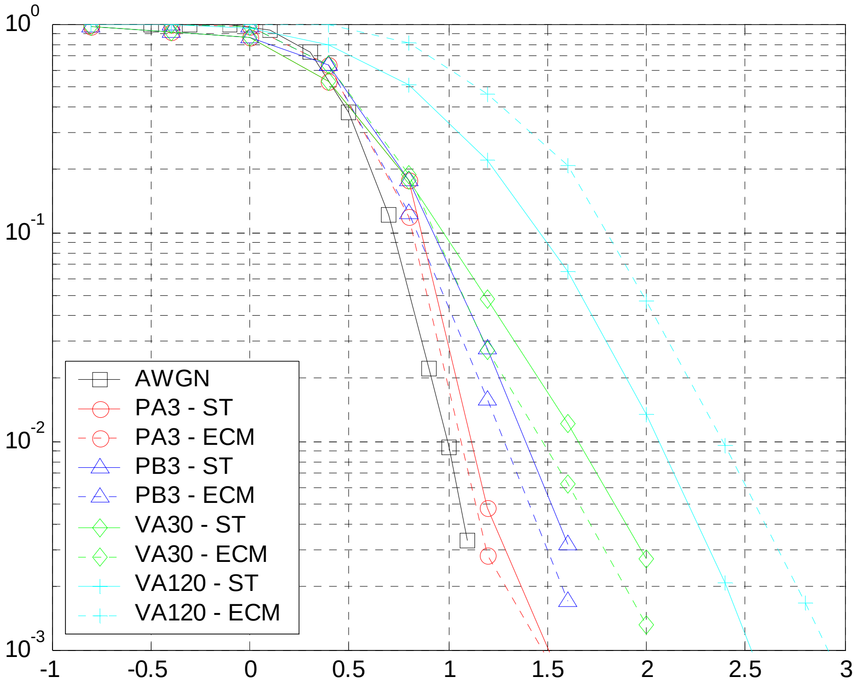

Figure A.1.4.3. Comparison of actual short-term and ECM generated curves – 192 kbps, R=0.4, BPSK, TTI=10ms, SF=8, ideal channel estimation, Q=1.0 for PA3, PB3, Q=2.0 for VA30, VA120.

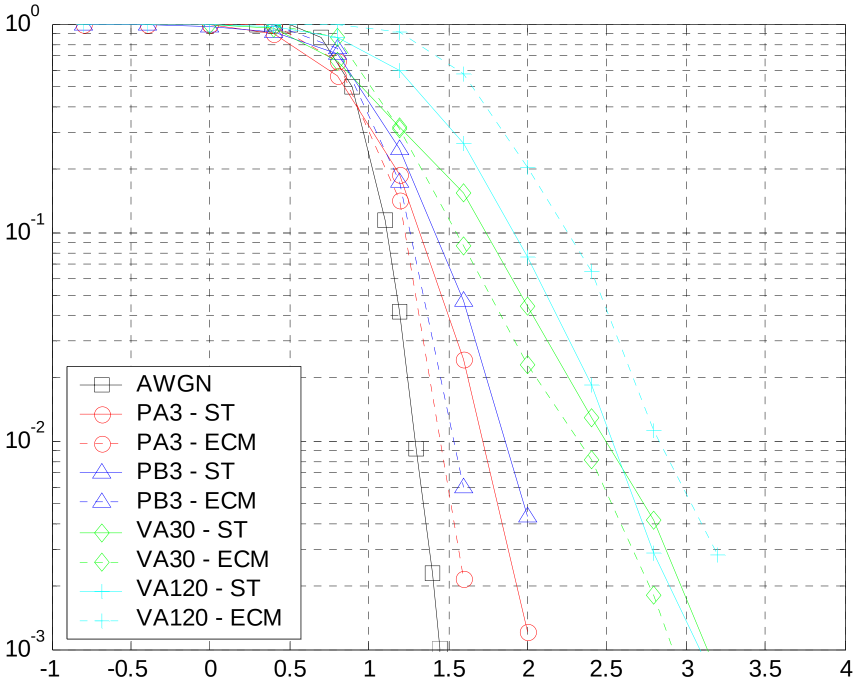

Figure A.1.4.4. Comparison of actual short-term and ECM generated curves – 480 kbps, R=0.5, BPSK, TTI=10ms, SF=4, ideal channel estimation, Q=1.0 for PA3, PB3, Q=2.0 for VA30, VA120.

A.2 Link Simulation Results

A.2.1 HARQ Performance Evaluation

A.2.1.1 HARQ Efficiency and Number of Retransmissions

In this section, the following notation is used:

$$\frac{E_{c,avg}}{N_t} = \frac{E_{c,1}}{N_t}\cdot N_{avg}\cdot\frac{1}{T_{trans}} = \text{Average Ec/Nt}$$

$$\frac{E_{b,comb}}{N_t} = \frac{E_{c,avg}}{N_t}\cdot\frac{W}{R_{t\arg et}} = \text{Average Eb/Nt}$$

$$\frac{E_{c,1}}{N_t} = \frac{E_{c,dpcch}}{N_t}\cdot(1+\frac{E_{c,e-dpdch}}{E_{c,dpcch}}) = \text{Single transmission Ec/Nt including DPCCH overhead}$$

$$N_{avg} = \text{Average number of transmissions needed for successful transmission} \leq T_{trans}$$

$$T_{trans} = \text{Target (maximum) number of transmissions} = 1 \text{ or } 2 \text{ or } 4$$

$$R_{t\arg et} = \text{Target data rate}$$

$$W = \text{Chip rate} = 3.84\text{ Mcps}$$

The simulation assumptions are shown in Table A.2.1.1.1.

Parameter	**Value**
DPCCH Slot format	0
Channel estmation	Realistic
Inner Loop PC	Enabled
Outer Loop PC	Based on Residual BLER
PC BER	4%
PC feedback delay	1-slot
Channel	AWGN
Number of Rx antennas	2
HARQ Xrv	{0}, {0,3}, {0,3,5,7} for 1/2/4 transmissions

Table A.2.1.1.1 Simulation Assumptions

Figures A.2.1.1.1 to A.2.1.1.4 show the simulation results.

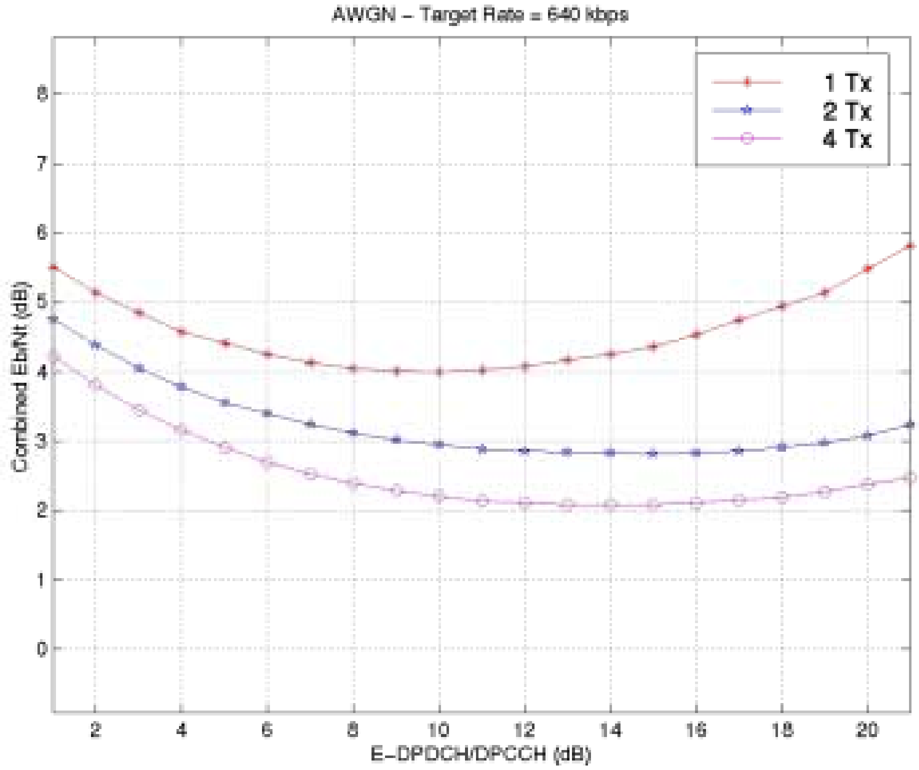

Figure A.2.1.1.1 Eb/Nt vs. E-DPDCH/DPCCH – Target Data Rate = 640 kbps

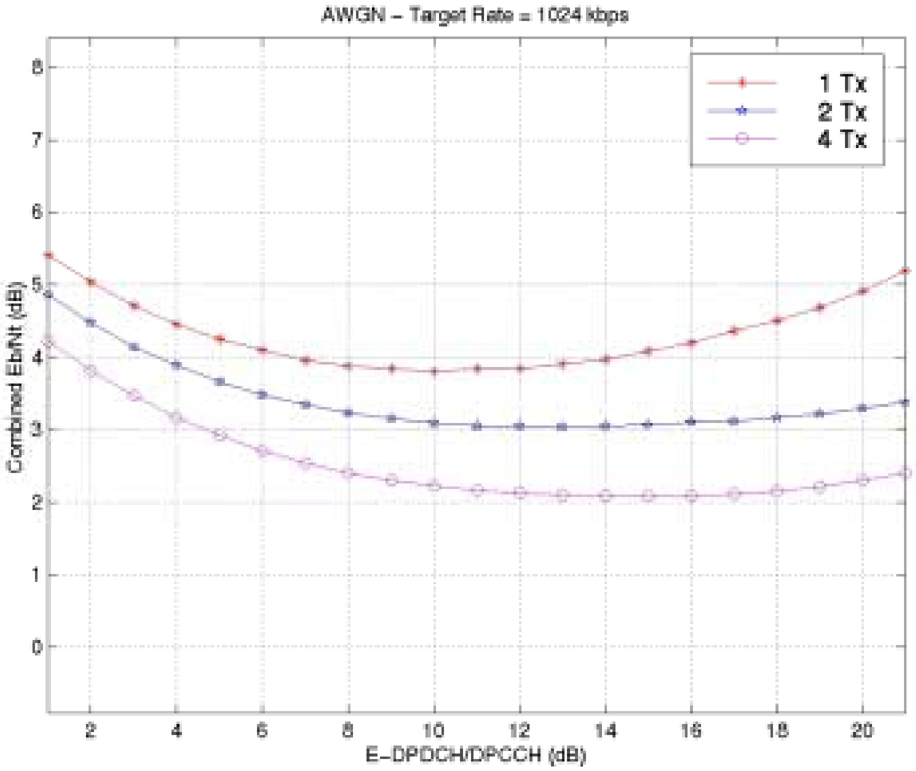

Figure A.2.1.1.2 Eb/Nt vs. E-DPDCH/DPCCH – Target Data Rate = 1024 kbps

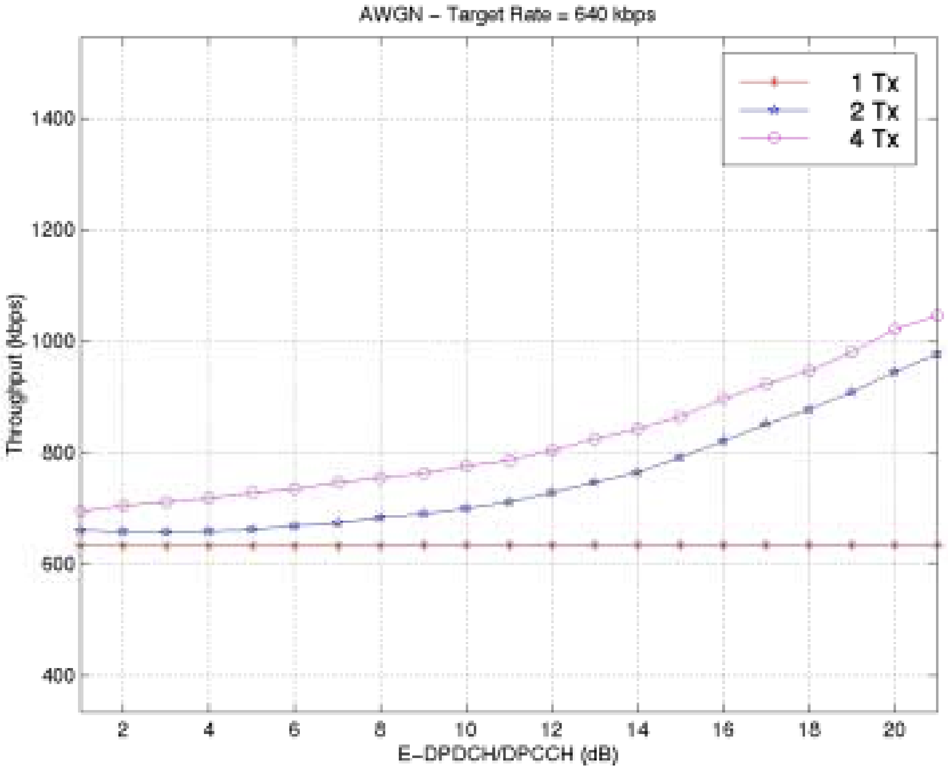

Figure A.2.1.1.3 Throughput vs. E-DPDCH/DPCCH – Target Data Rate = 640 kbps

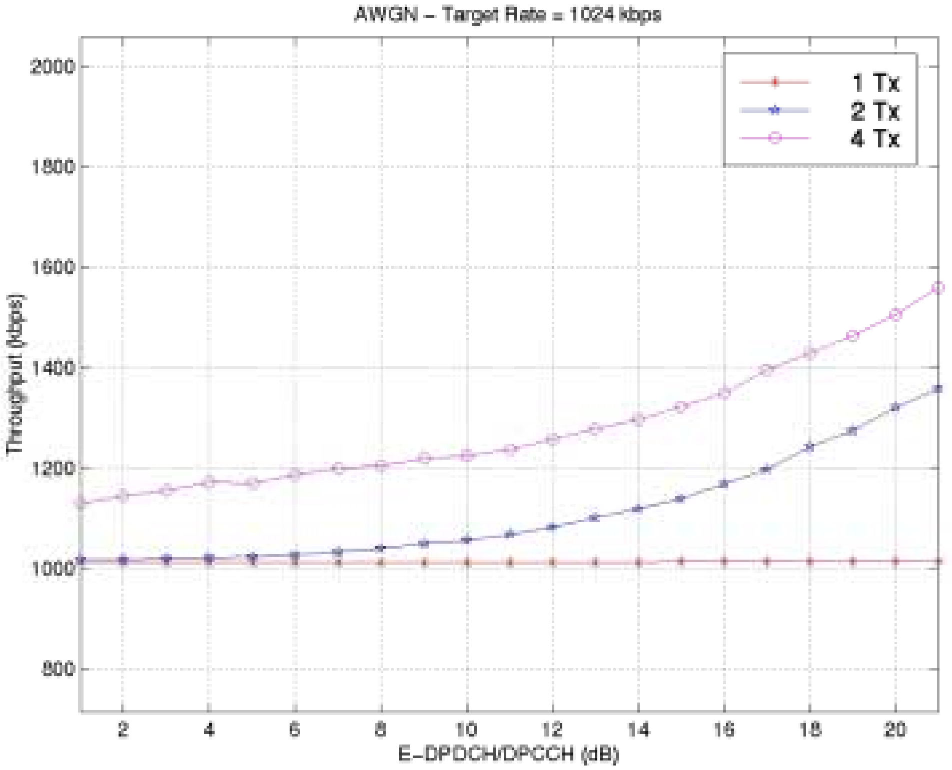

Figure A.2.1.1.4 Throughput vs. E-DPDCH/DPCCH – Target Data Rate = 1024 kbps

The optimal operating points for all cases are shown in Table A.2.1.1.2.

Target Data Rate (kbps)	MCS	Optimal EDPDCH/ DPCCH (dB)	Optimal DPCCH SNR (dB)	Optimal Eb/Nt (dB)	BLER				Average number of transmissions
					1 Tx	2 Tx	3 Tx	4 Tx	
640	4	10	-14.2	4.0	0.01	-	-	-	1.00
640	9	15	-19.1	2.8	0.60	0.01	-	-	1.60
640	19	15	-19.5	2.1	0.99	0.76	0.18	0.01	2.93
1024	7	10	-12.4	3.8	0.01	-	-	-	1.00
1024	15	13	-15.6	3.0	0.84	0.01	-	-	1.84
1024	31	15	-17.6	2.1	0.99	0.84	0.22	0.01	3.07

Table A.2.1.1.2 Optimal Operating Point – 1, 2, 4 transmissions

A.2.2 Link Performance of E-DCH for System Simulations

A.2.2.1 Short-term Link Performance with 2 ms TTI

In this section, the short-term link performance is evaluated for a reference MCS based on 2ms TTI. Without any loss of generality, only 1 TrCH is assumed for E-DCH. Therefore, each TFC translates to a TF. The MCS is shown in Table A.2.2.1.1.

Table A.2.2.1.1 MCS

Transport Block Size	Number of Code Blocks	Modulation	OVSF Code	Code Rate	β_c	β_{eu}	Rate after 4 Tx (kbps)
128(1	1	QPSK	C(4,1)	0.33	15	12	16
256(1	1	QPSK	C(4,1)	0.33	15	17	32
512(1	1	QPSK	C(4,1)	0.33	15	21	64
768(1	1	QPSK	C(4,1)	0.33	15	27	96
1024	1	QPSK	C(4,1)	0.33	15	38	128
2048	1	QPSK	C(4,1)	0.53	15	47	256
3072	1	QPSK	C(2,1)	0.40	15	53	384
4096	1	QPSK	C(2,1)	0.53	15	67	512
5120	2	QPSK	C(2,1) , C(4,1)	0.44	15	61 , 43	640
6144	2	QPSK	C(2,1) , C(4,1)	0.53	15	69 , 49	768
7168	2	QPSK	C(2,1) , C(4,1)	0.62	15	77 , 54	896
8192	2	QPSK	C(2,1) , C(4,1)	0.71	15	86 , 61	1024

1) Repetition has been used to achieve the given data rates

Similar to HS-DPCCH, the E-DPDCH/DPCCH power ratio for each TF are indirectly signalled using beta factors. These power offsets were chosen for optimal link performance with a 1% residual BLER target after 4 transmissions across channel models PA3, PB3, VA30 and VA120.

The rest of the simulation assumptions are shown in Table A.2.2.1.2. For the HARQ operation it is assumed that the 1st and 3rd transmissions are self-decodable, while the 2nd and 4th transmissions are not self-decodable.

Table A.2.2.1.2

Parameter	Value
TTI	2 ms
RV sequence	{0,1,2,5}
Number of HARQ processes	5
IR Inter-TTI	5
Channel Estimation	On
DPCCH Slot Format	0
Power Control	On
Inner Loop PC Step Size	+/- 1 dB
Outer Loop PC Step Size	+ 0.5 dB
PC feedback delay	1-slot
PC BER	4%
Channels	PA3, PB3, VA30, VA120
Rx antennas	2
Number of fingers	1-PA, 5-PB, 4-VA
Channel estimation	Implementation I Implementation II
Residual BLER	1%

The short-term Eb/Nt vs. BLER results are generated in the following way:

1. The link simulation is run for a long duration (500,000 TTI)
2. At the end of each TTI, the following statistics are logged:
    a. TTI averaged Rx Eb/Nt
    b. Transmission number (1st vs. 2nd vs. 3rd vs. 4th)
        i. The inter-TTI duration is maintained at 10ms.
    c. *Accumulated short-term* Rx Eb/Nt

        i. Summation of TTI averaged Rx Eb/Nt from previous transmissions and current transmission, if the transmission number is greater than 1
        ii. This indicates the Eb/Nt associated with soft combining
    d. Binary metric denoting whether the block is in error or not, after soft-combining and decoding

3. At the end of simulation run:
    a. Four different sets of logs are created, each corresponding to either 1, 2, 3 or 4 transmissions
        i. The logged statistics are separated based upon the transmission number
    b. For each log, the *accumulated short-term* Eb/Nt is placed in bins with a uniform grid, along with the associated binary decoding metric
        i. For each bin, the BLER is computed based upon the binary metrics from all values in the bin
4. The four short-term BLER results denote:
    a. BLER after 1st transmission
    b. BLER after 2nd transmission, conditioned on 1st transmission in error
    c. BLER after 3rd transmission, conditioned on 1st and 2nd transmissions in error
    d. BLER after 4th transmission, conditioned on 1st, 2nd and 3rd transmissions in error

In this sense, each BLER curve is conditioned on erroneous previous transmission/s. Note that the TTI averaged Rx Eb/Nt (mentioned in step 2a) is defined as:

$$\text{Rx }\frac{E_b}{N_t} = \text{Rx }\frac{E_{c,pilot}}{N_t} + \frac{E_{c,e-dch}}{E_{c,pilot}} + \frac{\text{\# chips per TTI}}{\text{\# information bits per payload (including overhead)}}$$

Since there are 8 MCS, 4 channel models and 4 possible transmissions resulting in numerous combinations, only a subset of the link simulation results are shown. Figures A.2.2.1.1 to A.2.2.1.12 show a subset of short-term results after {1, 2, 3, 4} transmissions.

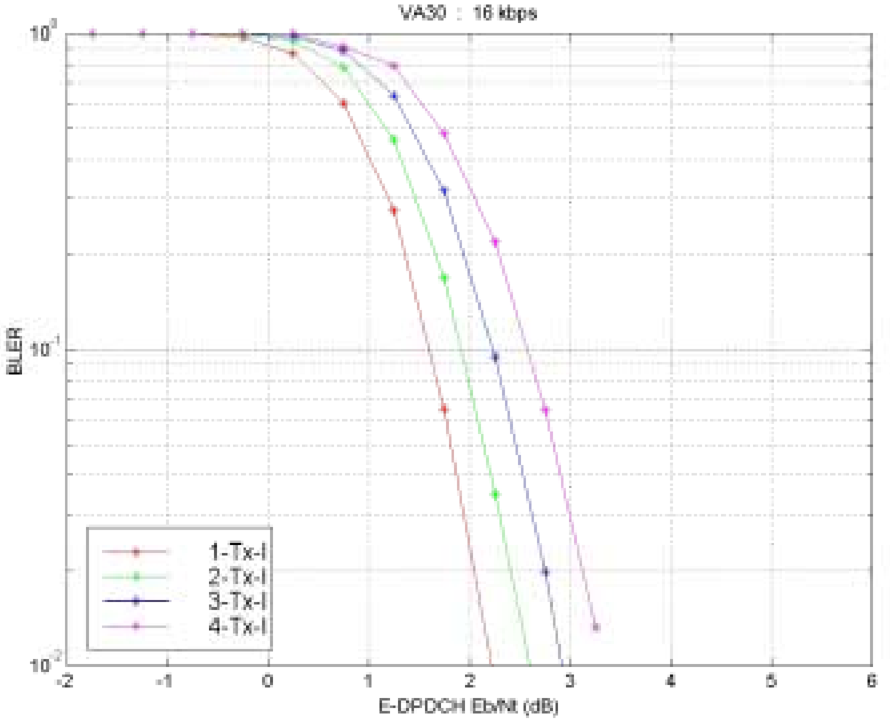

Figure A.2.2.1.1: 16 kbps – VA30

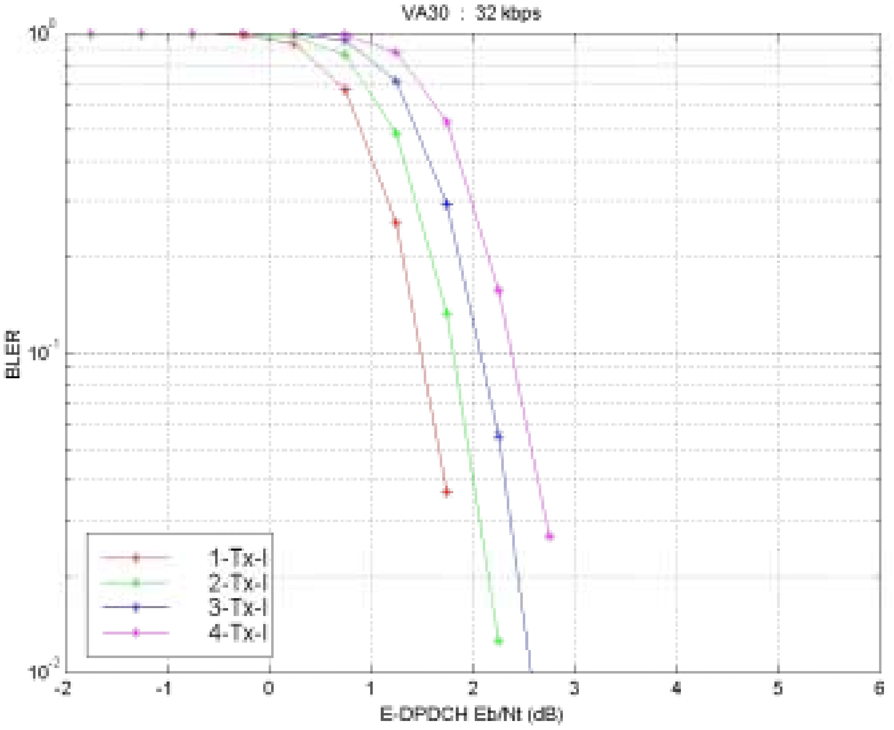

Figure A.2.2.1.2: 32 kbps – VA30

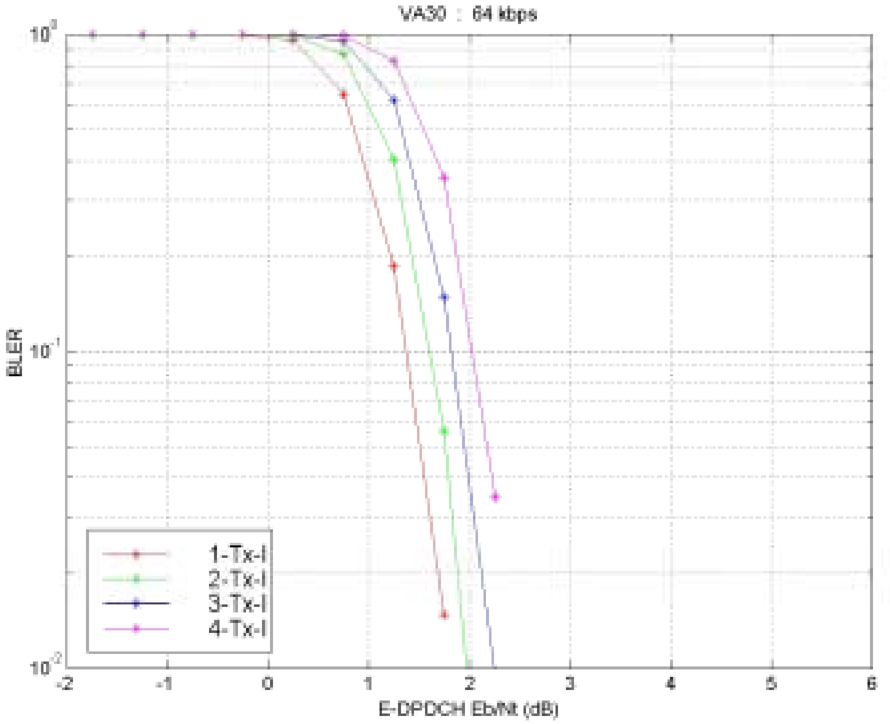

Figure A.2.2.1.3: 64 kbps – VA30

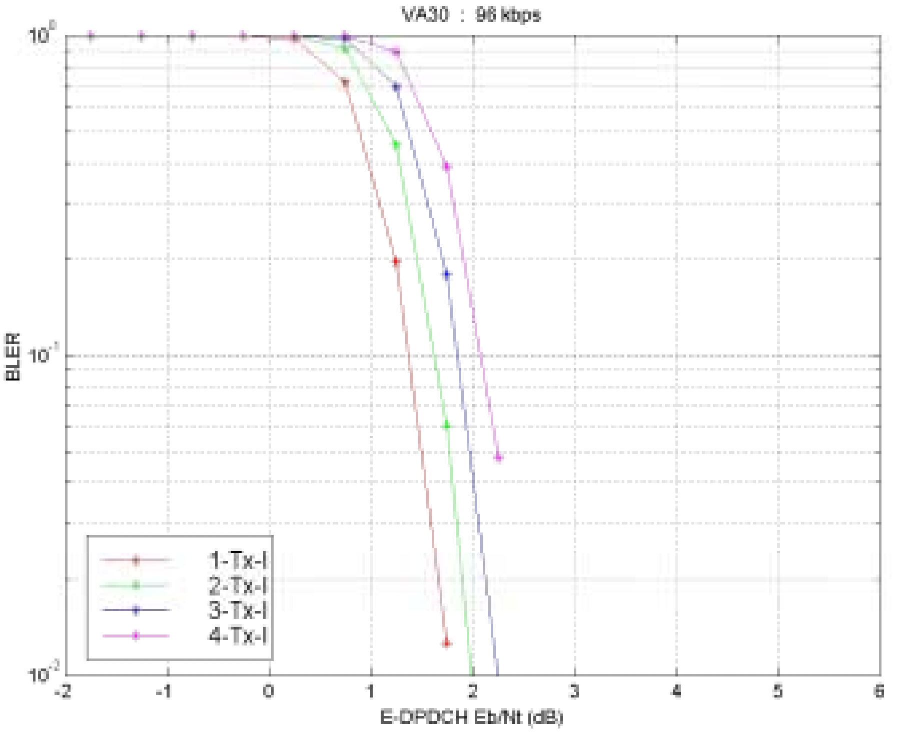

Figure A.2.2.1.4: 96 kbps – VA30

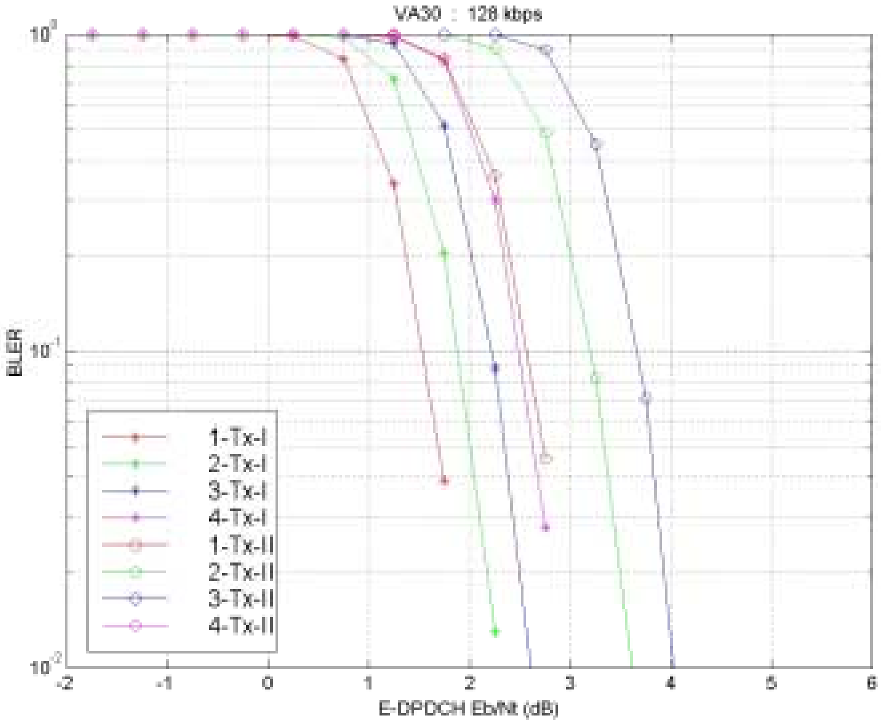

Figure A.2.2.1.5: 128 kbps – VA30

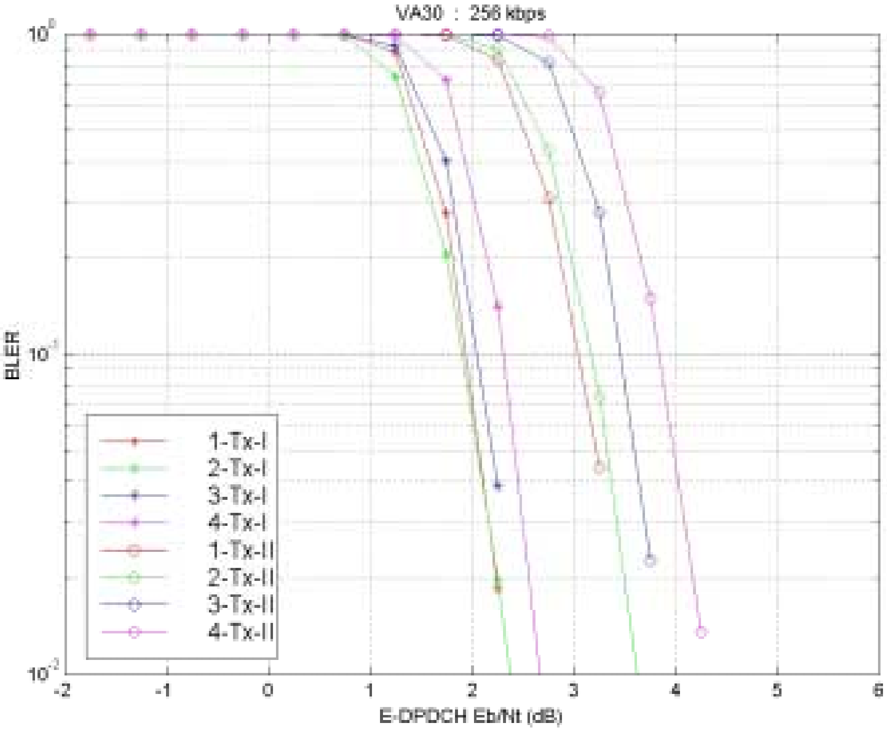

Figure A.2.2.1.6: 256 kbps – VA30

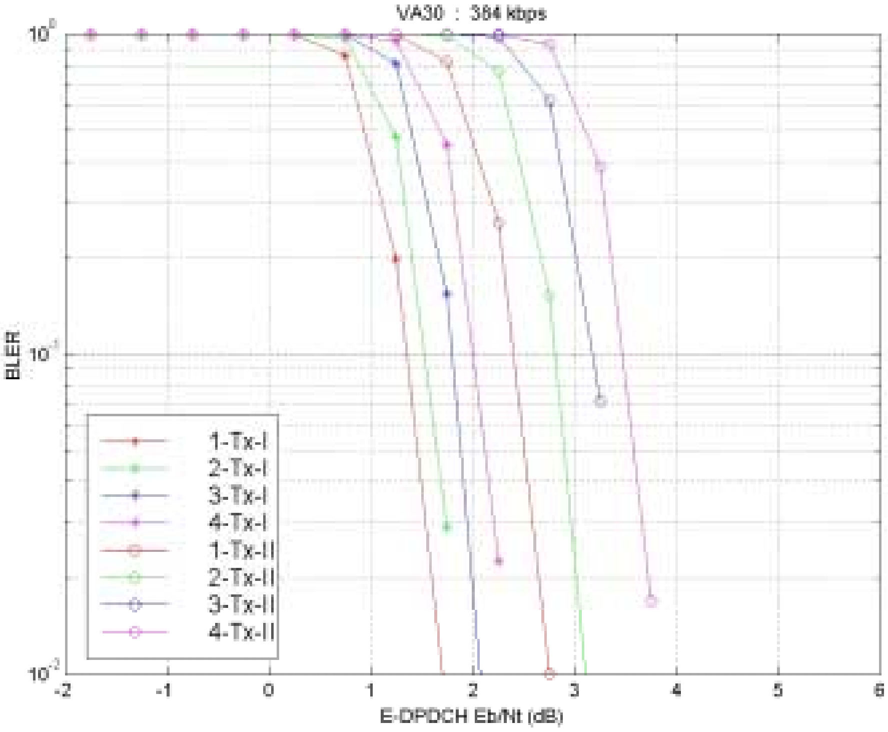

Figure A.2.2.1.7: 384 kbps – VA30

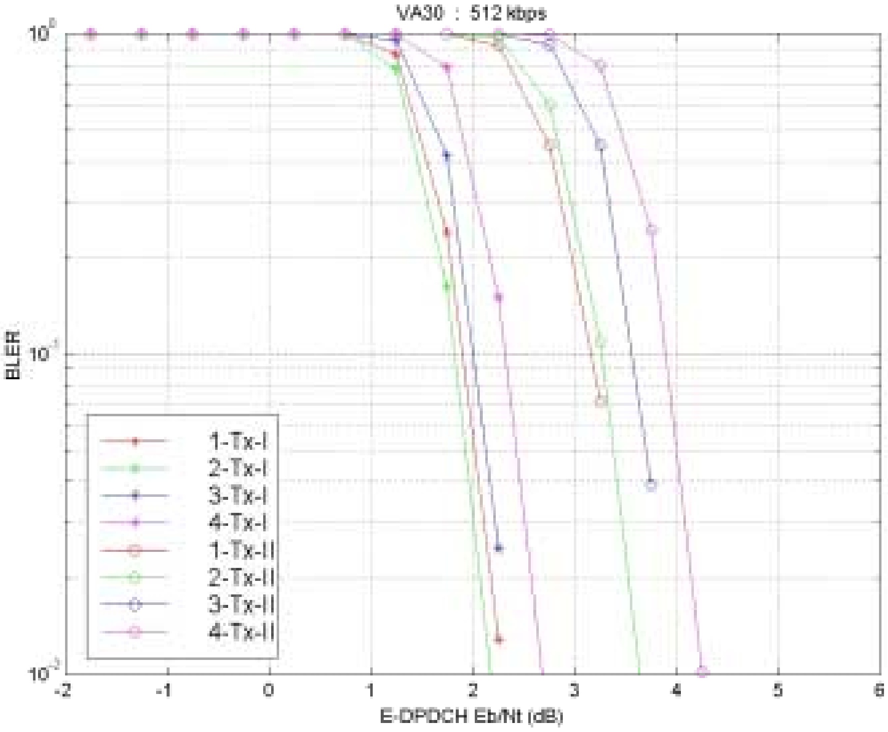

Figure A.2.2.1.8: 512 kbps – VA30

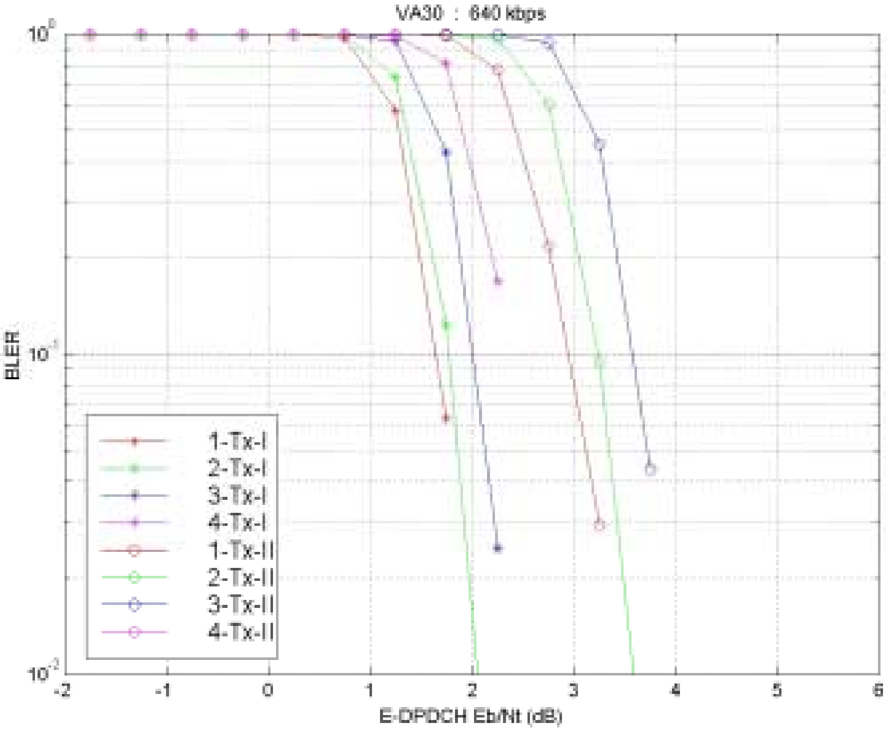

Figure A.2.2.1.9: 640 kbps – VA30

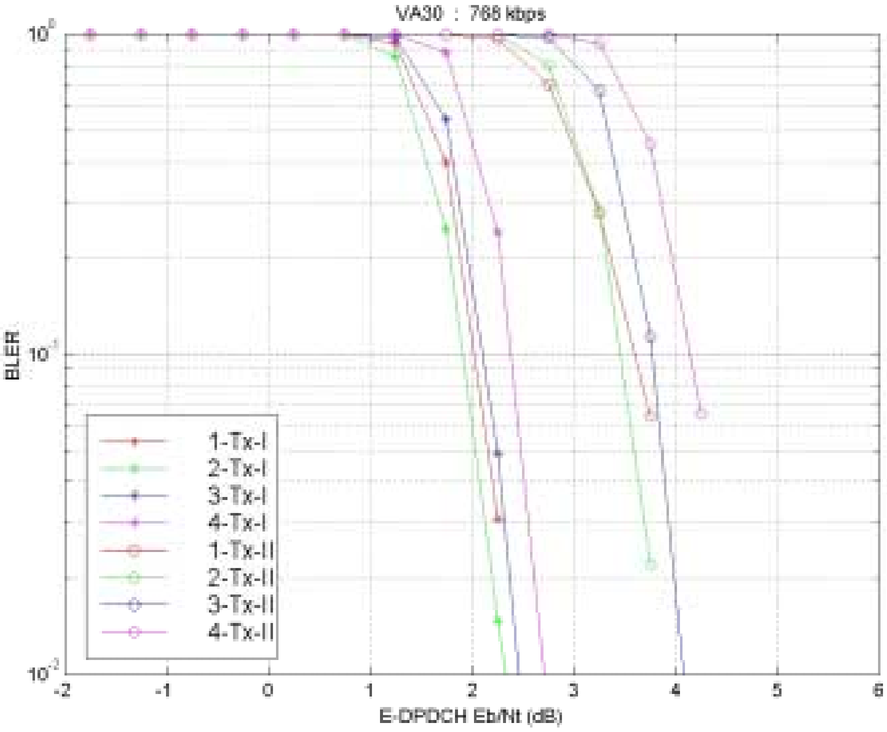

Figure A.2.2.1.10: 768 kbps – VA30

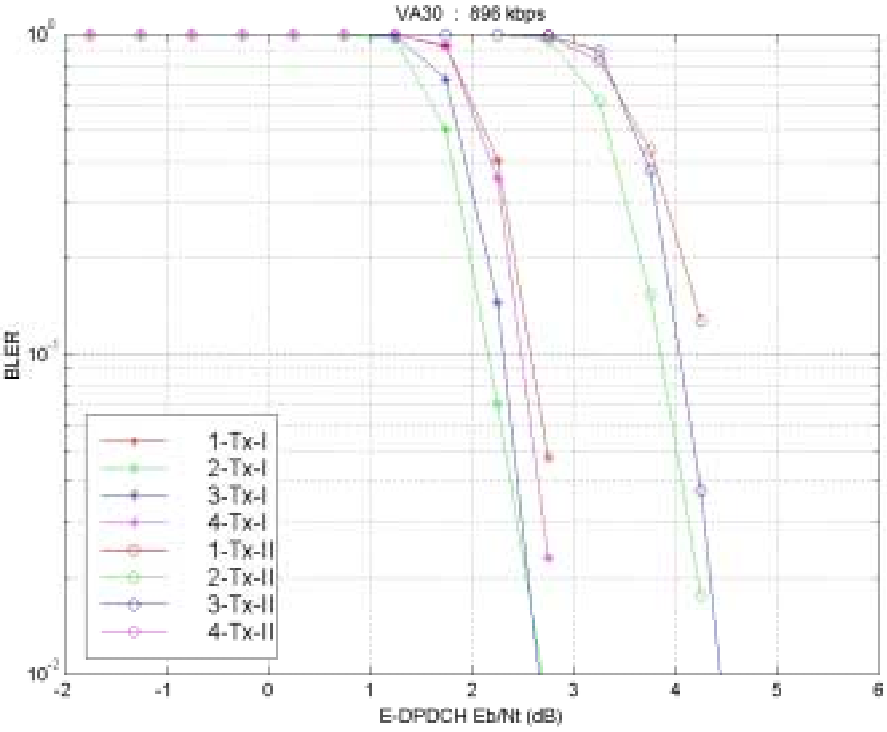

Figure A.2.2.1.11: 896 kbps – VA30

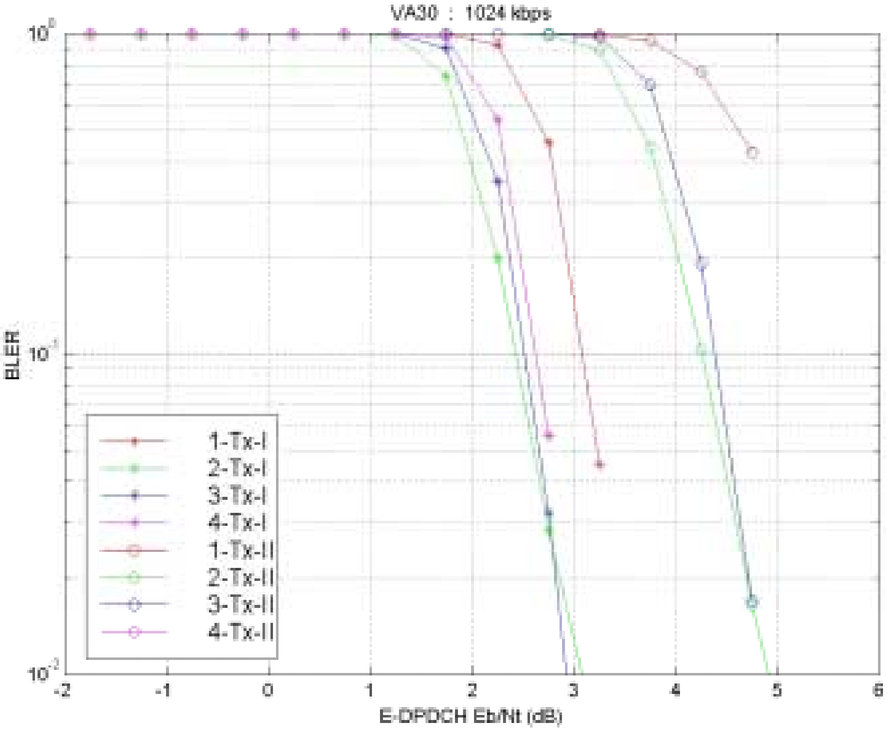

Figure A.2.2.1.12: 1024 kbps – VA30

A.2.2.2 Short-term Link Performance with 10 ms TTI

In this section, the short-term link performance is evaluated for a reference MCS based on 10ms TTI. Without any loss of generality, only 1 TrCH is assumed for E-DCH. Therefore, each TFC translates to a TF. The MCS is shown in Table A.2.2.2.1.

Table A.2.2.2.1

Transport Block Size	**Number of Code Blocks**	**Modulation**	**OVSF Code**	**Code Rate**	β_c	β_{eu}	**Rate after 2 Tx (kbps)**
320(1	1	QPSK	C(4,1)	0.33	15	11	16
640(1	1	QPSK	C(4,1)	0.33	15	15	32
1280(1	1	QPSK	C(4,1)	0.33	15	21	64
1920(1	1	QPSK	C(4,1)	0.33	15	27	96
2560(1	1	QPSK	C(4,1)	0.33	15	30	128
5120	2	QPSK	C(4,1)	0.33	15	42	256
7680	2	QPSK	C(4,1)	0.40	15	53	384
10240	3	QPSK	C(4,1)	0.53	15	60	512
12800	3	QPSK	C(2,1)	0.33	15	67	640
15360	4	QPSK	C(2,1)	0.40	15	75	768
17920	4	QPSK	C(2,1)	0.47	15	84	896
20480	5	QPSK	C(2,1)	0.53	15	95	1024

1) Repetition has been used to achieve the given data rates

Similar to HS-DPCCH, the E-DPDCH/DPCCH power ratio for each TF are indirectly signalled using beta factors. These power offsets were chosen for optimal link performance with a 1% residual BLER target after 2 transmissions across channel models PA3, PB3, VA30 and VA120.

The rest of the simulation assumptions are shown in Table A.2.2.2.2. For the HARQ operation it is assumed that the 1st transmission is self-decodable, while the 2nd transmission is not self-decodable.

Table A.2.2.2.2

Parameter	**Value**
TTI	10 ms
RV sequence	{0,1}
Number of HARQ processes	3
IR Inter-TTI	3
Channel Estimation	On
DPCCH Slot Format	0
Power Control	On
Inner Loop PC Step Size	+/- 1 dB
Outer Loop PC Step Size	+ 0.5 dB
PC feedback delay	1-slot
PC BER	4%
Channels	PA3, PB3, VA30, VA120
Rx antennas	2
Number of fingers	1-PA, 5-PB, 4-VA
Channel estimation	Implementation I
Residual BLER	1%

The short-term Eb/Nt vs. BLER results are generated in the following way:

5. The link simulation is run for a long duration (500,000 TTI)
6. At the end of each TTI, the following statistics are logged:

    a. TTI averaged Rx Eb/Nt
    b. Transmission number (1st vs. 2nd)
        i. The inter-TTI duration is maintained at 20ms.
    c. *Accumulated short-term* Rx Eb/Nt
        i. Summation of TTI averaged Rx Eb/Nt from previous transmissions and current transmission, if the transmission number is greater than 1
        ii. This indicates the Eb/Nt associated with soft combining
    d. Binary metric denoting whether the block is in error or not, after soft-combining and decoding

7. At the end of simulation run:
    a. Four different sets of logs are created, each corresponding to either 1 or 2 transmissions
        i. The logged statistics are separated based upon the transmission number
    b. For each log, the *accumulated short-term* Eb/Nt is placed in bins with a uniform grid, along with the associated binary decoding metric
        i. For each bin, the BLER is computed based upon the binary metrics from all values in the bin
8. The four short-term BLER results denote:
    a. BLER after 1st transmission
    b. BLER after 2nd transmission, conditioned on 1st transmission in error

In this sense, each BLER curve is conditioned on erroneous previous transmission/s. Note that the TTI averaged Rx Eb/Nt (mentioned in step 2a) is defined as:

$$\text{Rx}\ \frac{E_b}{N_t} \;=\; \text{Rx}\ \frac{E_{c,pilot}}{N_t} \;+\; \frac{E_{c,e-dch}}{E_{c,pilot}} \;+\; \frac{\#\ \text{chips per TTI}}{\#\ \text{information bits per payload (including overhead)}}$$

Since there are 8 MCS, 4 channel models and 2 possible transmissions resulting in numerous combinations, only a subset of the link simulation results are shown. Figures A.2.2.2.1 to A.2.2.2.7 show a subset of short-term results after {1, 2} transmissions.

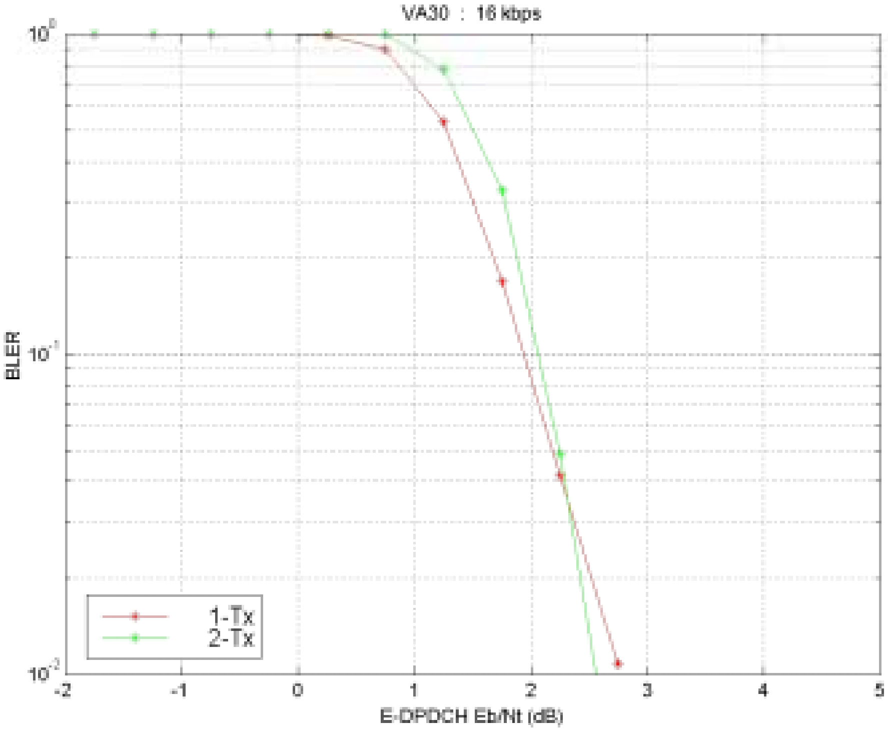

Figure A.2.2.2.1: 16 kbps – VA30

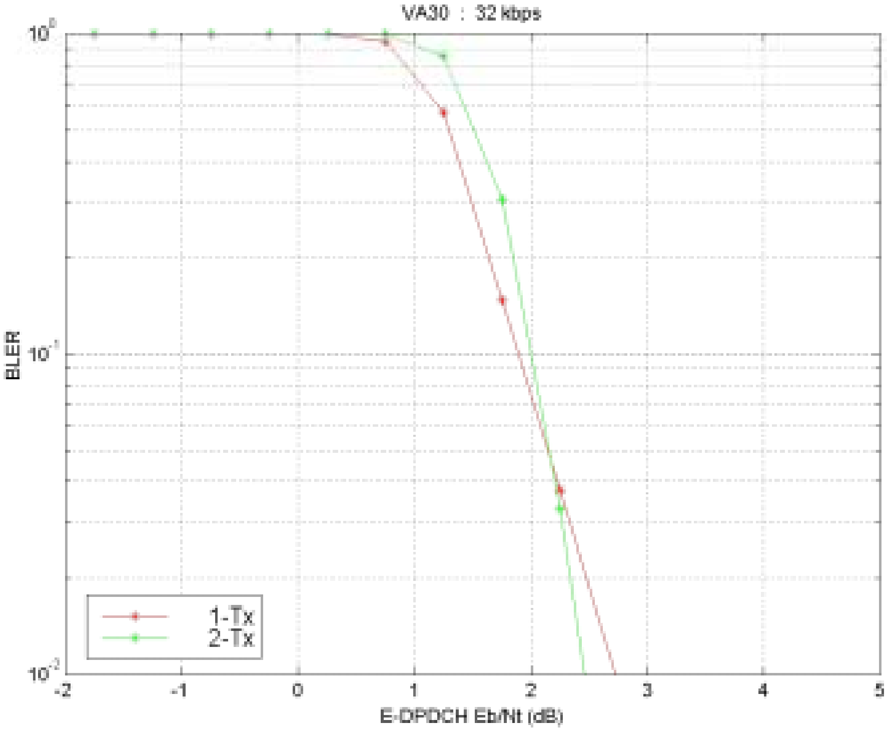

Figure A.2.2.2.2: 32 kbps – VA30

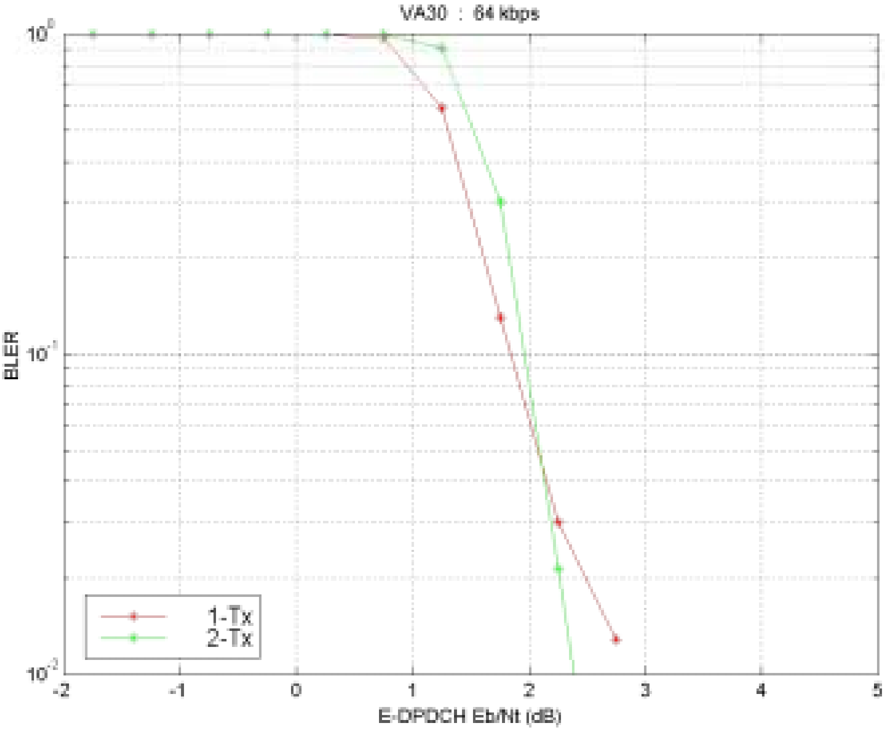

Figure A.2.2.2.3: 64 kbps – VA30

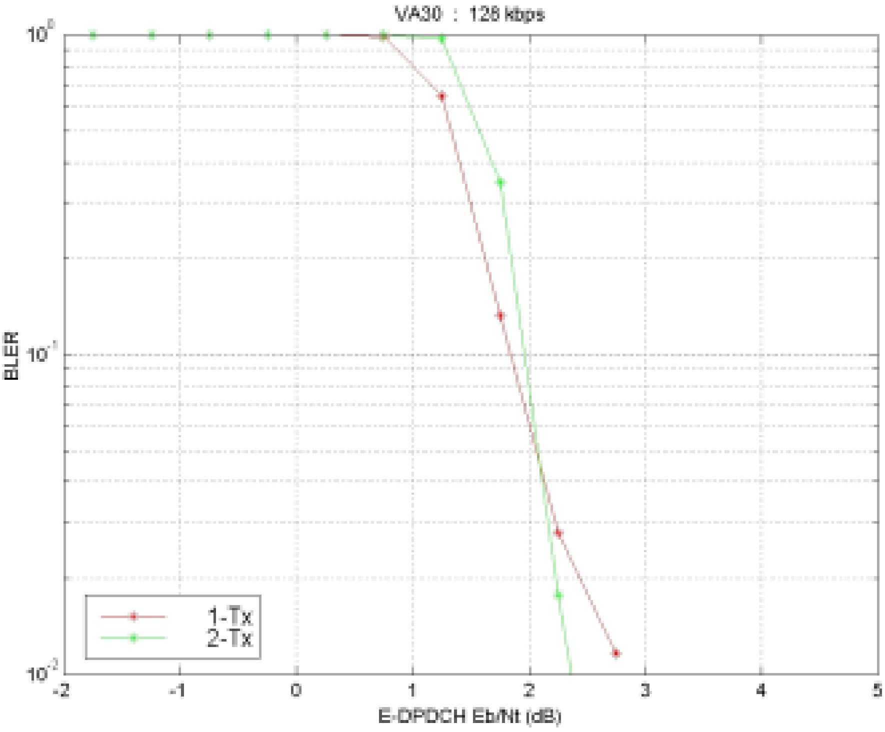

Figure A.2.2.2.4: 128 kbps – VA30

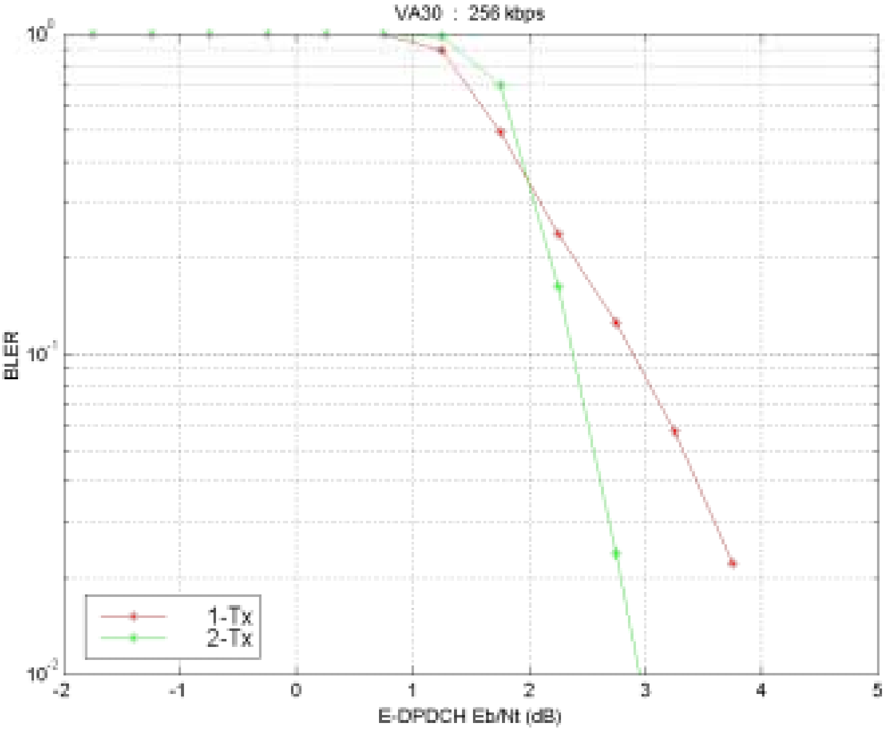

Figure A.2.2.2.5: 256 kbps – VA30

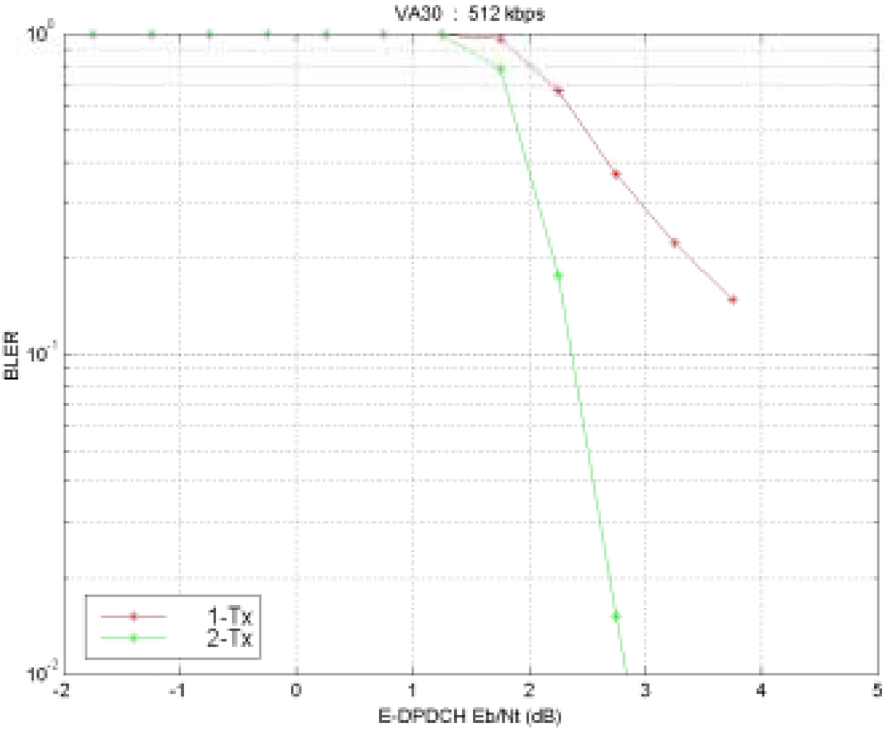

Figure A.2.2.2.6: 512 kbps – VA30

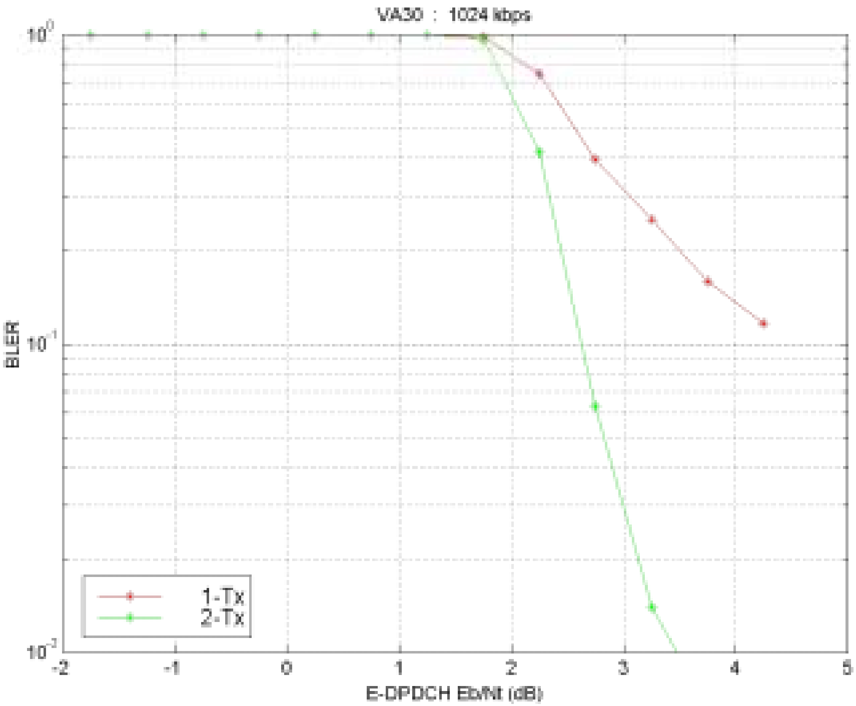

Figure A.2.2.2.7: 1024 kbps – VA30

A.2.3 Link Performance with Different Pilot Overhead

A.2.3.1 Assumptions

To investigate the impact on overall performance due to different pilot power, simulations have been run on different fading channel models and with different β_c/β_d ratios. The simulation assumptions are found in A.2.3.1.1.

Parameter	**Value**
Data rates	336 kbit/s (single E-DPDCH), 1.008 Mbit/s (3 E-DPDCHs). SF 4, 2 ms TTI, and code rate 0.35 for both cases.
Slot format	Slot format 0 (6 pilot, 2 TFCI, 2 TPC bits per slot)
β_c/β_d ratio	Varied.
E_b/N_0 definition	E_b is the total received energy (including both DPDCH and DPCCH) per antenna during a TTI divided by the number of information bits in the TTI.
Channel Models	PedA at 3 km/h; VehA at 3, 30, 120 km/h. 2 GHz carrier frequency.
Channel Estimation	Ideal or non-ideal. Non-ideal channel estimate based on average over multiple slots (2-8 slots for the Doppler range studied herein)
Power control	Non-ideal SIR estimation. Error-free TPC feedback in DL. 1 slot power control delay.
Number of RAKE fingers	Equal to the number of channel taps.
Antenna diversity	2 antenna Rx diversity

Table A2.3.1.1: Simulations assumptions.

A.2.3.2 Results

The performance for different β_c/β_d settings with Pedestrian A at 3 km/h with ideal and non-ideal channel estimation is found in Figure A.2.3.2.1. As seen in the plot, the performance for the lowest DPCCH powers, β_c/β_d=1/15 and to some extent β_c/β_d =2/15, are significantly degraded compared to the higher β_c/β_d settings. For β_c/β_d =3/15 and higher ratios, there is no large spread in performance. The reason for the performance degradation when the β_c/β_d is reduced is mainly due to dissatisfactory SIR estimation for the power control mechanism and to a lesser extent due to degradation in channel estimation.

Similar conclusions, i.e., SIR estimation error is the largest cause of loss at low DPCCH power settings, can be drawn for the Vehicular A channel model at 3 km/h, although the benefit for the channel estimator with a higher DPCCH power setting is somewhat larger than for PedA due to the larger number of paths in the VehA channel model.

Results for Vehicular A at 30 km/h are found in Figure A2.3.2.3. On average, a higher E_b/N_0 is required compared to the 3 km/h case due to a reduced possibility for the power control mechanism to track fast fading. Furthermore, the amount of averaging in the channel estimator is reduced. Hence, the benefits from a higher DPCCH power for the channel estimation is slightly larger than for the 3 km/h case.

In Figure A.2.3.2.4, results for Vehicular A at 120 km/h are plotted. From the plot, it is seen that the power control cannot track the fast fading, making the influence of SIR estimation errors insignificant. Furthermore, as only two slots of averaging is used in the channel estimator, the spread in performance for different β_c/β_d ratios is increased compared to lower Doppler frequencies, thus increasing the benefits with a stronger DPCCH from a channel estimation point of view.

In Table A.2.3.2.1 and Table A.2.3.2.2, the results are summarized for data rates of 336 kbit/s and 1.008 Mbit/s, assuming non-ideal channel and SIR estimation. It is seen that a higher pilot energy is beneficial for the overall performance at both low and high Doppler frequencies. At low Doppler frequencies, the main reason is improved SIR estimation, while at the highest Doppler frequency, the improved quality of the channel estimate dominates.

Table A.2.3.2.1: Difference in performance for some different β_c/β_d settings compared to β_c/β_d = 5/15, which was found to be (close to) the best ratio for 336 kbit/s data rate assuming continuous transmission. Non-ideal channel and SIR estimation.

	β_c/β_d = 2/15		**β_c/β_d = 3/15**		**β_c/β_d = 4/15**	
	10% BLER	**1 % BLER**	**10% BLER**	**1% BLER**	**10% BLER**	**1% BLER**
Pedestrian A, 3 km/h	1 dB	1.4 dB	0.4 dB	1.1 dB	0.1 dB	0.3 dB
Vehicular A, 3 km/h	1.3 dB	1.8 dB	0.5 dB	0.8 dB	0.1 dB	0.3 dB
Vehicular A, 30 km/h	1.8 dB	2.1 dB	0.9 dB	0.9 dB	0.2 dB	0.5 dB
Vehicular A, 120 km/h	2.1 dB	2.2 dB	0.9 dB	1.1 dB	0.3 dB	0.4 dB

Table A.2.3.2.2: Difference in performance for some different β_c/β_d settings compared to β_c/β_d = 6/15, which was found to be (close to) the best ratio for 1.008 Mbit/s data rate. Non-ideal channel and SIR estimation.

	β_c/β_d = 3/15		**β_c/β_d = 4/15**		**β_c/β_d = 5/15**	
	10% BLER	**1 % BLER**	**10% BLER**	**1% BLER**	**10% BLER**	**1% BLER**
Pedestrian A, 3 km/h	0.6 dB	0.9 dB	0.25 dB	0.4 Db	0.05 dB	0.2 dB
Vehicular A, 30 km/h	1.2 dB	1.8 dB	0.6 dB	0.8 dB	0.2 dB	0.4 dB
Vehicular A, 120 km/h	2 dB	2 dB	1.1 dB	1.4 dB	0.5 dB	0.7 dB

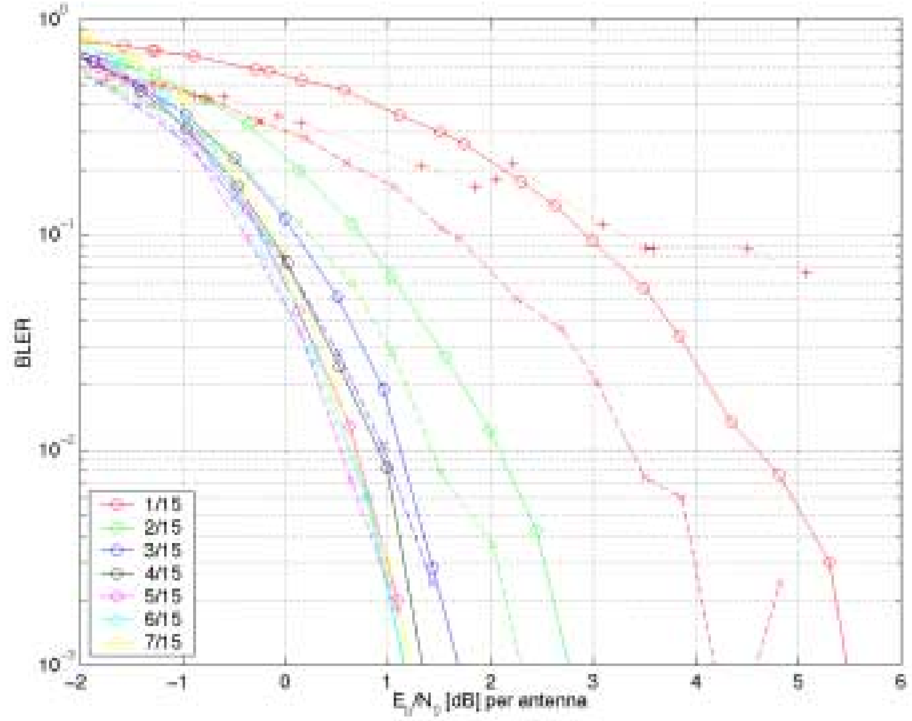

Figure A.2.3.2.1. Results for 336 kbit/s, Pedestrian A at 3 km/h for different β_c/β_d ratios. Ideal (dashed lines) and non-ideal (solid lines) channel estimation, non-ideal SIR estimation. Plotted with a dotted line is the performance without power control for reference.

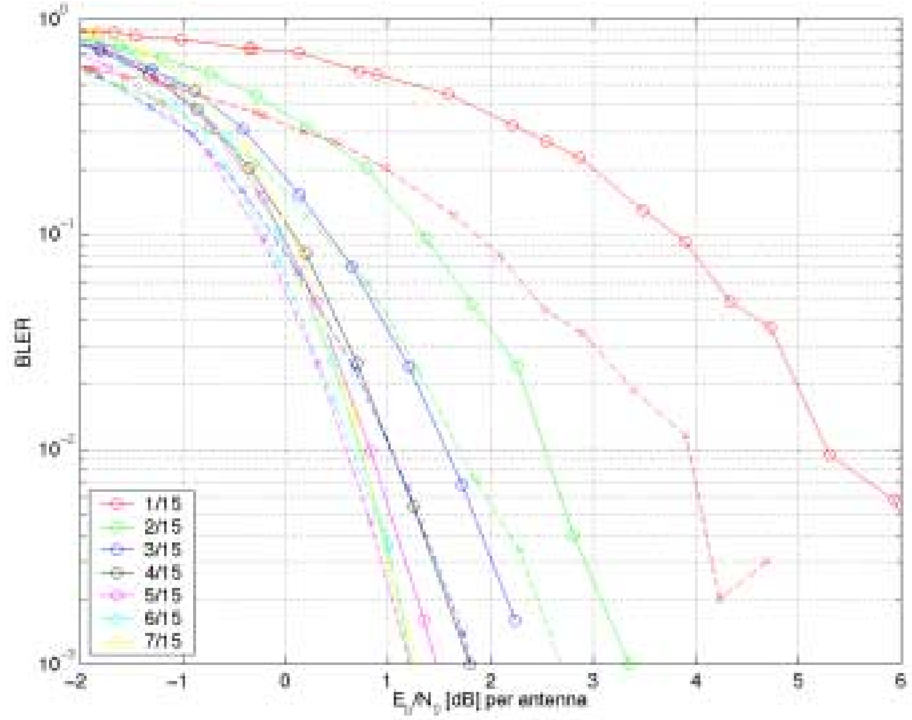

Figure A.2.3.2.2: Results for 336 kbit/s, Vehicular A at 3 km/h for different β_c/β_d ratios. Ideal (dashed lines) and non-ideal (solid lines) channel estimation, non-ideal SIR estimation.

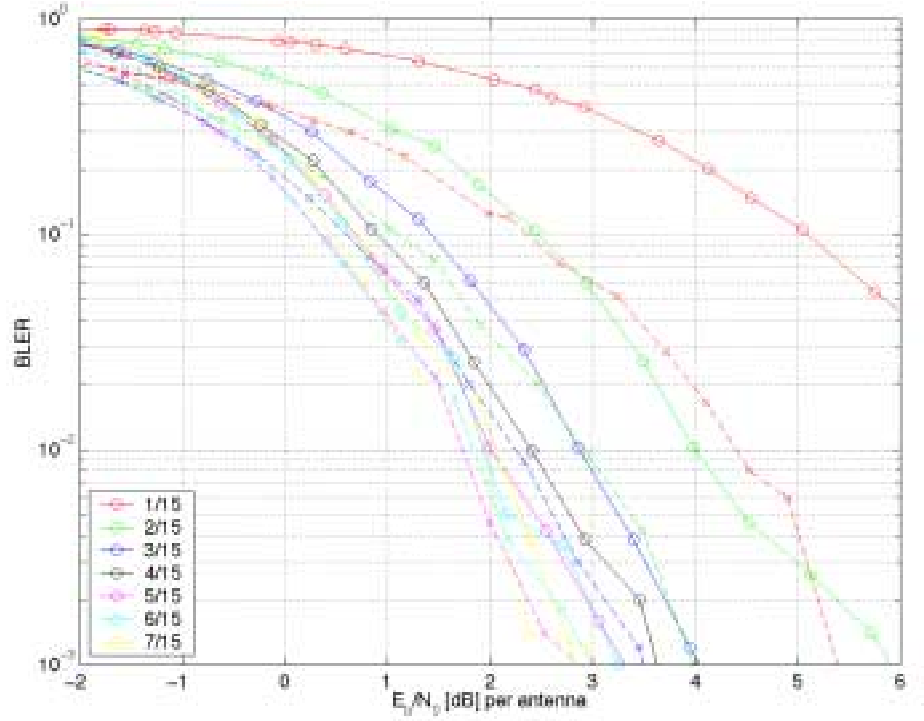

Figure A2.3.2.3: Results for 336 kbit/s, Vehicular A at 30 km/h for different β_c/β_d ratios. Ideal (dashed lines) and non-ideal (solid lines) channel estimation, non-ideal SIR estimation.

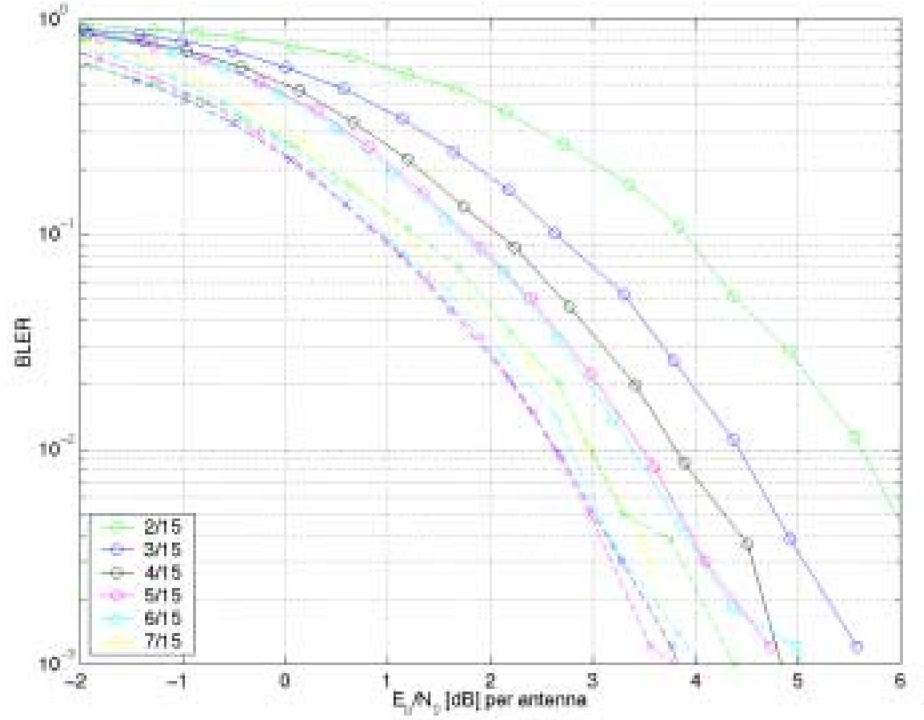

Figure A2.3.2.4: Results for 336 kbit/s, Vehicular A at 120 km/h for different β_c/β_d ratios. Ideal (dashed lines) and non-ideal (solid lines) channel estimation, non-ideal SIR estimation.

A.2.4 Link Performance of Release-99 for System Simulations

The short-term 1% FER values (DPDCH Eb/Nt, where Eb includes CRC overhead as a part of the traffic information bits) for Release-99 uplink with ideal and non-ideal channel estimation is shown in the following Table. The simulation results were obtained without DCCH. In case of ideal channel estimation, ideal SIR metric and ideal finger allocation were assumed. In case of non-ideal channel estimation, non-ideal SIR metric and ideal finger allocation were assumed. It may be noted that these ranges are representative values and may change, dependent on variety of assumptions like type of channel estimator used (e.g. number of slots estimation is performed over, data or non-data assisted estimation), SIR metric for power control, threshold for lock filters, beta values etc.

Table A.2.4.1: Rel-99 short term link performance

	8 kbps		**64 kbps**		**128 kbps**		**384 kbps**	
	Non-ideal	**Ideal**	**Non-ideal**	**Ideal**	**Non-ideal**	**Ideal**	**Non-ideal**	**Ideal**
PA3	2.8-3.3	2.8	1.8-2.0	1.4	1.7-1.9	1.3	1.4-2.0	1.3
PB3	4.0-4.2	3.0	2.7-3.1	1.7	2.6-3.1	1.6	2.4-3.2	1.7
VA30	4.0-4.6	3.0	2.9-3.2	1.7	2.7-3.1	1.6	2.6-3.7	1.7
VA120	4.8-5.2	3.0	3.5-4.1	1.6	3.4-4.1	1.5	3.6-4.0	1.6

A.3 System Simulation Assumptions

As system level simulation tools and platforms differ between companies very detailed specification of common simulation assumptions is not feasible. Yet, basic simulation assumptions and parameters should be harmonized as proposed in the subsequent chapters. Various kinds of system performance evaluation methods may be used.

A.3.1 System Level Simulation Modelling and Parameters

A.3.1.1 Antenna Pattern

The antenna pattern [2] used for each sector, uplink and forward Link, is plotted in Figure A - 1 and is specified by

$$A(\theta) = -\min\left[12\left(\frac{\theta}{\theta_{3dB}}\right)^2, \; A_m\right] \quad \text{where} \quad -180 \le \theta \le 180$$

, θ_{3dB} ***is the 3dB beam width, and*** $A_m = 20dB$ ***is the maximum attenuation.***

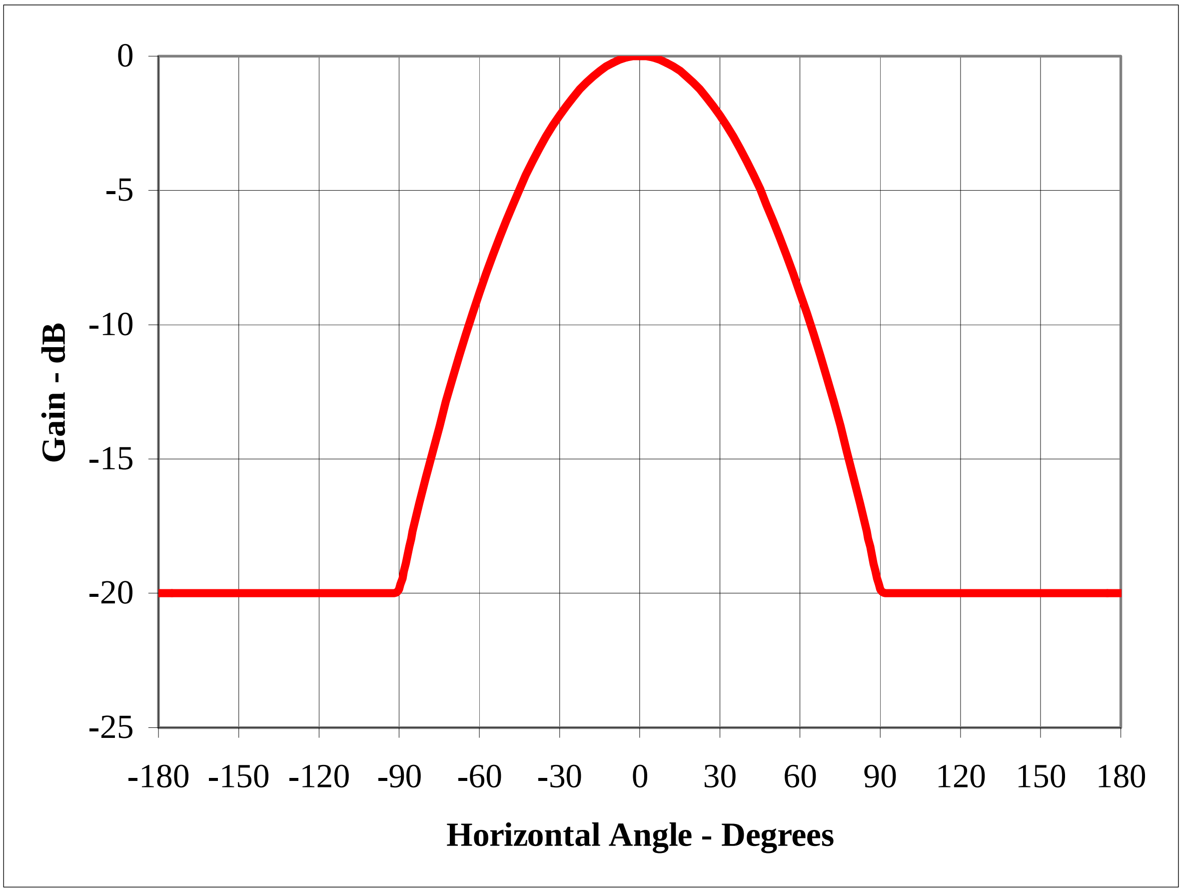

Figure A - 1 - Antenna Pattern for 3-Sector Cells

A.3.1.2 System Level Parameters

Table A - 7 below shows the general system level parameters, to be used both in the reference case, and in the new schemes proposed for Enhanced Uplink DCH. Table A - 8 shows the system level parameters to be used in the reference case.

Table A - 7 – General System Level Simulation Parameters

Parameter	Explanation/Assumption	Comments
Cellular layout	Hexagonal grid, 3-sector sites	
Site to Site distance	2800 m 1000 m	
Antenna pattern	0 degree horizontal azimuth is East 70 degree (-3dB), 20dB front-to-back ratio	Only horizontal pattern specified See Section 3.1.1.
Propagation model	$L = 128.1 + 37.6\ Log_{10}(R)$ (see [6])	R in kilometres
Downlink CPICH power	-10 dB	Relative to the maximum power
Other downlink common channels	-10 dB	Relative to the maximum power
Slow fading	Similar to UMTS 30.03, B 1.4.1.4	
Std. deviation of slow fading	8.0 dB	Log-Normal Shadowing
Correlation between sectors	1.0	
Correlation between sites	0.5	See Annex B
Correlation distance of slow fading	50 m	See D,4 in UMTS 30.03.
Carrier frequency	2000 MHz	
Node B antenna gain plus Cable Loss	14 dBi	
Node B RX diversity	Uncorrelated 2-antenna RX diversity	Maximal ratio combining
UE antenna gain	0 dBi	
Maximum UE EIRP	21 dBm	Also 24 dBm can be simulated additionally, however 21 dBm should be the main case.
BS total Tx power	43 dBm	
Active set size	Up to 3	Maximum size
Uplink system noise	–102.9 dBm	
Specify Fast Fading model	Jakes spectrum where Doppler based on speed.	Generated e.g. by Jakes or by Filter approach
Soft Handover Parameters	Window_add = 4 dB, Window_drop = 6 dB	Window_add: The signal from a BS has to be at highest this amount smaller than the current active set's best BS's signal for a BS to be added in the active set. Window_drop: When the signal from a BS has dropped below the active set's best BS's signal minus this parameter, the BS will be dropped from the active set.

Uplink Power Control	Closed-loop power control delay: one slot	Power control feedback: BER = 4% for a Node-B - UE pair.
Short term average Rise over Thermal (Uplink Received Power Normalized by Thermal Noise Level)	x dB [4]	The percentage of time the short term average rise over thermal is above the x dB target should not exceed 1%. Short term average Rise over thermal for the default two receiving antenna mode is the result of filtering the instantaneous rise ½[(Io1+No)/No + (Io2 + No)/No] with the filter described in Annex C, where the total received signal power at antenna i is defined as Ioi, I=1,2.
Delays between network elements.	Document [7] is resource and starting point for delay information between different network elements for release 5.	

Table A - 8 - System Level Simulation parameters used in the reference rel99/rel4/rel5 case

Parameter	**Explanation/Assumption**	**Comments**
Method included in the reference case	Rel'99 / Rel'4 / Rel'5 System with TFC selection	The parameters defined based on Rel'99 / Rel'4 / Rel'5 specifications
User data rates in TFCS allocated to the UE	TFCS1: 8, 16, 32, 64, 128, 256, 384 kbit/s TFCS2: 8, 16, 32, 64, 128, 256, 384, 768, 1000 kbit/s	One of these two TFCS is to be included in the TFC selection modelling.
TTI	10 ms	Maximum TTI in the TFC
Ptx estimation error in TFC selection	The error is within ±2 dB with 90% certainty.	Error is Log normally distributed around zero mean with std = 1.2159 dB.
Delay for moving TFC into blocked state in TFC selection 9.33 ms + T_{notify} + T_{modify}+ T_{L1_proc} + T_{align_TTI}	60 ms	As defined in current specification, assuming max TTI in the TFC being T_{TTI} =10 ms and no codec which needs rate adjustment.
Delay for moving TFC back into supported state in TFC selection 9.33 ms + T_{notify} + T_{modify}+ T_{L1_proc} + T_{align_TTI}	60 ms	As defined in current specification, assuming max TTI in the TFC being T_{TTI} =10 ms and no codec which needs rate adjustment.

In the proposed schemes for Enhanced Uplink DCH, following parameters are defined in more detail:

- TFC selection method should be used with the same parameters as in the reference case, if there is no clear reason why it does not fit to the scheme.
- Used data rates and transport formats
- Parameters and other details of scheduling

---

[4] Note that the final value for the rise outage threshold and its exact use will be determined later as simulation and analytical results are generated by proponent companies. One reason for having a rise outage threshold is to guarantee acceptable voice call quality and reliable signaling given autonomously or explicitly scheduled data UEs on the Release 99/4/5 or enhanced uplink channel.

A.3.1.3 Signaling Errors

Signaling errors may be modeled and specified as the examples in Table A - 9.

Table A - 9 - WCDMA Signaling Errors

Signaling Channel	Errors	Impact
ACK/NACK channel	Misinterpretation, misdetection, or false detection of the ACK/NACK message	Transmission (frame or encoder packet) error or duplicate transmission
Scheduling related signaling	Misinterpretation of feedback information	Potential transmission errors

For H-ARQ, if an ACK is misinterpreted as a NACK (duplicate transmission), the packet call throughput should be scaled down by (1-p_{ACK}), where p_{ACK} is the ACK error probability. Otherwise the signaling errors will be explicitly modeled to properly account for them.

A.3.1.4 Downlink Modeling in Uplink System Simulation

In addition to modelling CPICH transmission for the purpose of active set selection, only feedback errors for e.g. power control, acknowledgements, scheduling related signaling etc. need to be modeled. Thus explicit modeling of the downlink channels is not required.

A.3.2 Uplink measurement accuracy

Measurement errors for taking instantaneous (e.g. 0.667 ms) samples of Received total wideband power (RTWP), (also called Io), can be modeled as a lognormal process with standard deviation and mean as given below and in keeping with RTWP requirements given in specification 25.133 [8] (see specifically section 9.2 and Annex A.9 in 25.133).

Absolute interference rise error mean: 0

Absolute interference rise error std. dev.: 4 / 1.28

Relative interference rise error mean: 0

Relative interference rise error std dev.: 0.5 / 1.28

A.3.2.1 Uplink power control

Inner loop power control update rate is assumed to be 1500Hz in keeping with release 5. Inner loop power control is applied to all uplink channels including the EUDCH, the proponent should indicate otherwise.

Outer loop power control is needed so that the DPCCH can meet minimum required Ec/Nt. Outer loop power control can be active at all times by using a Rel-99 Zero-block CRC DPDCH which will also keep the DPCCH at the minimum required received Ec/Nt for demodulation of the EUDCH and other uplink control channels

A.3.3 System Simulation Outputs and Performance Metrics

A.3.3.1 Output metrics for data services

The following statistics related to data traffics should be generated and included in the evaluation report for each scheme. If wrap-around is used [9], statistics are collected from all cells, otherwise at least from “center cell(s)”. If wrap-around is not used statistic collection is taken from “center cell(s)” and at least two tiers of cells around the “center cell” site. A frame as used below is also referred to as a transport block and consists of information bits, CRC, and tail bits.

1. **Average cell throughput [kbps/cell]** is used to study the network throughput performance, and is measured as

$$R = \frac{b}{k \cdot T},$$

where *b* is the total number of correctly received data bits in the uplink from all data UEs in the simulated system over the whole simulated time, *k* is the number of cells in the simulation and *T* is the simulated time. In the case of only evaluating the center cell site, k is the number of sectors.

2. **Average packet call throughput [kbps]** for user i is defined as

$$R_{pktcall}(i) = \frac{1}{K}\sum_{k=1}^{K} \frac{\text{good bits in packet call k}}{(t_{end\_k} - t_{arrival\_k})}$$

where *k* = denotes the k^{th} packet call from a group of *K* packet calls where the *K* packet calls can be for a given user *i* , $t_{arrival\_k}$ = first packet of packet call k arrives in queue, and t_{end_k} = last packet of packet k is received by the Node-B. Note for uncompleted packet calls, t_{end_k} is set to simulation end time. The mean, standard deviation, and distribution of this statistic is to be provided.

3. **The packet service session FER** is calculated for all the packet service sessions. A packet service session FER is defined as the ratio

$$FER_{session} = \frac{n_{erroneous\_frames}}{n_{frames}},$$

where $n_{erroneous\_frames}$ is the total number of erroneous frames in the packet service session and n_{frames} is the total number of frames in the packet service session. These individual packet service session FERs from all packet service sessions (from all UEs) form the distribution for this statistic. The mean, standard deviation, and the distribution of this statistic is to be provided.

A Definition of a Packet Service Session: A Packet Service Session contains one or several packet calls depending on the application. Packet service session starts when the transmission of the first packet of the first packet call of a given service begins and ends when the last packet of the last packet call of that service has been transmitted. (One packet call contains one or several packets.) Note, that FER statistics are only collected from those frames during which UE is transmitting data.

4. **The residual FER** is calculated for each user for each packet service session. A packet service session residual FER is defined by the ratio

$$FER_{residual} = \frac{n_{dropped\_frames}}{n_{frames}},$$

where $n_{dropped\_frames}$ is the total number of dropped frames in the packet service session and n_{frames} is the total number of frames in the packet service session. A dropped frame is one in which the maximum ARQ or HARQ re-transmissions have been exhausted without the frame being successfully decoded. In the case of HARQ the proponent should indicate whether he is including RLC initiated re-transmissions or not. The mean, standard deviation, and distribution of this statistic over all the packet service sessions in the simulation is to be provided.

5. **The averaged packet delay per sector** is defined as the ratio of the accumulated delay for all packets for all users received by the sector and the total number of packets. The delay for an individual packet is defined as the time between when the packet enters the queue at transmitter and the time when the packet is received successively by the base station. If a packet is not successfully delivered by the end of a run, its ending time is the end of the run.

6. **The histogram of averaged packet delay per user**. The averaged packet delay is defined as the ratio of the accumulated delay for all packets for the user and the total number of packets for the user. The delay for a packet is defined as in 2.

7. **The scattering plot of data throughput per user vs. its averaged packet delay**. The data throughput and averaged packet delay per user are defined as in 3 and 2, respectively**.**

8. **The uplink TxP** is the ideal measured UE TxP at the UE antenna connector. This is collected from all the UEs at desired intervals. A distribution of these over the simulation time is to be provided.

9. **The noise rise** is defined as the ratio of the total received wideband power and the thermal noise. Noise rise samples are taken every 0.667ms. Mean, std and the 95th percentile of this and the distribution is to be provided.

A.3.3.2 Mixed Voice and Data Services

In order to fully evaluate the performance of a proposal with mixed data and voice services, simulations are repeated with different loads of voice users. The following outputs may be generated and included in the evaluation report.

1. The following cases can be simulated: no voice users (i.e., data only), voice users only (i.e., number of voice users equal to voice capacity), and $\lfloor 0.25N_{max} \rfloor$ or $\lfloor 0.5N_{max} \rfloor$ voice users with data users, where N_{max} is the voice capacity.

2. For each of the above case, all corresponding output metrics defined previously are generated, whenever it is applicable.

In addition, the following output may also be generated and included in the evaluation report:

1. A curve of sector data throughput vs. the number of voice users is generated, where the sector data throughput is defined as above.

A.3.3.3 Voice Services and Related Output Metrics

The following statistics related to voice traffics can be generated and included in the evaluation report.

1. **Voice capacity**. Voice capacity is defined as the maximum number of voice users that the system can support within a sector with certain maximum outage probability. The details on how to determine the voice capacity of a sector are described in Annex D.

2. **Percentage of blocked voice user**

A.3.3.3.1 Voice Model

An example speech (voice) model is specified in Annex D.

A.3.3.4 Packet Scheduler

The voice users' (if simulated together with the data users) transmissions are not scheduled. The data users can be scheduled or allowed to transmit in a random fashion. The exact procedure and its delay and reliability with which a UE gains the right to transmit is to be specified in detail.

A.4 System Simulation Results

A.4.1 Release-99 Performance

A.4.1.1 Release-99 Performance With Full Buffer

A.4.1.1.1 System Setup

The system performance is obtained under the following assumptions:

- Link-level curves used are generated based on the following parameters, where each pair represents (TFC,DPDCH/DPCCH): (8 kbps, 0 dB), (16 kbps, 2 dB), (32 kbps, 4 dB), (64 kbps, 7 dB), (128 kbps, 10 dB), (256 kbps, 13 dB), (384 kbps, 15 dB),
- Maximum data rate is 384 kbps
- 19 Node-B, 3-cell wrap-around layout
- Simulation duration: 200 s
    - Additional warm-up time, during which statistic is not collected: 10 s

A.4.1.1.2 Performance Without TFC Control in AWGN

The following figures present the system performance in AWGN, without TFC control, in terms of average RoT and throughput per user. Figure A.4.1.1.2.2 represents the average RoT as a function of the number of users per cell. It can be seen that as the number of users increases, the RoT increases.

Figure A.4.1.1.2.3 shows the scatter plot of the user throughputs for 5, 10 and 15 users per cell as a function of the best downlink path loss. From this figure it can be seen that as the number of users increases, the cell coverage decreases.

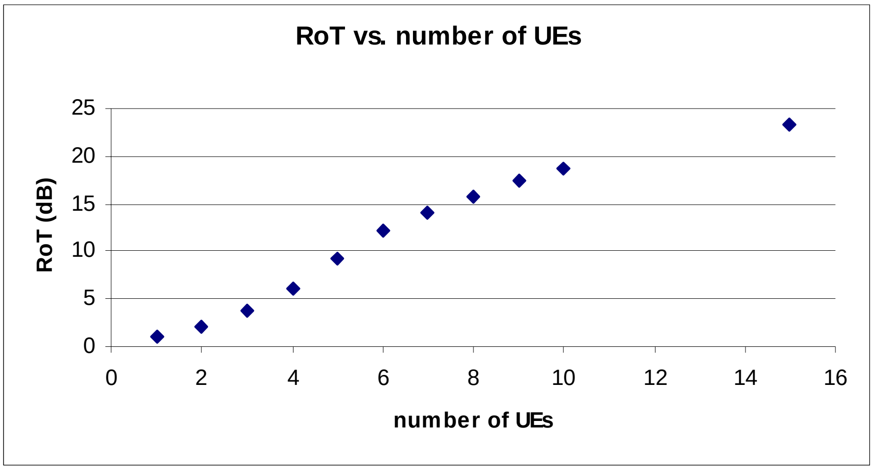

Figure A.4.1.1.2.2 Average RoT as a function of number of users per cell

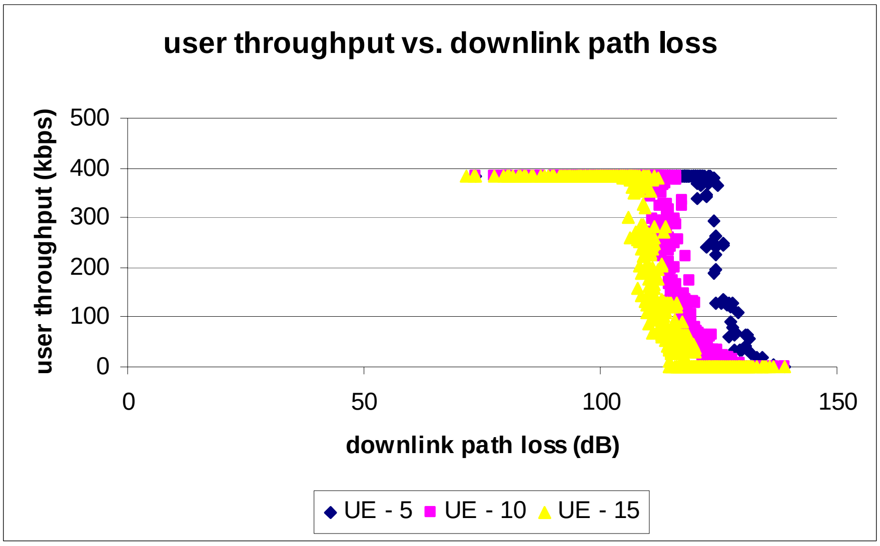

Figure A.4.1.1.2.3 Average user throughput as a function of the best downlink path loss

A.4.1.1.3 Performance With TFC Control in AWGN

In these simulations, the following assumptions are made regarding the DCCH.

- DCCH is present 20% of the time for each UE
- When present, DCCH is transmitted at 3.4 kbps with 40ms TTI
  - The associated TF contains 148 information bits in accordance with 3GPP TS 34.108
- Every 40ms, a decision on the presence or absence of DCCH is made for every UE

Two sets of link level curves are generated for traffic (DTCH), with appropriate rate matching simulating the presence or absence of DCCH.

The TF for DTCH and the corresponding beta factors are listed in Table A.4.1.1.3.1. These values have been derived assuming a received DPCCH Ec/Nt = -21 dB, non ideal channel estimation and unlimited number of fingers; note that outer loop power control is enabled during the simulation (target = 1% BLER) and the actual received DPCCH Ec/Nt may vary. Corresponding link level results can be found in Tdoc R1-031380.

Table A.4.1.1.3.1 TF and the corresponding beta factors

TF	β_c	β_d
8 kbps	15/15	15/15
16 kbps	12/15	15/15
32 kbps	10/15	15/15
64 kbps	7/15	15/15
128 kbps	5/15	15/15
256 kbps	3/15	15/15
384 kbps	3/15	15/15

The following figures present the system performance in AWGN, with TFC control, in terms of average RoT, average cell throughput and throughput per user. Considered scheduler algorithms are Round Robin, Proportional Fair (PF) and long-term downlink signal-to-interference-noise ratio (DL SINR) based. Scheduler related assumptions are given in Tdoc R1-031004.

Figure A.4.1.1.3.1 represents the average RoT as a function of the number of users per cell (5 and 10 users per cell). It can be seen that as the number of users increases, the RoT remains around the same.

Figure A.4.1.1.3.2 and Figure A.4.1.1.3.3 demonstrate the average cell throughput as a function of RoT with 5 users and 10 users per cell respectively. For the same average RoT, DL SINR scheduling provides the highest throughput by prioritizing the users close to the cell center (which typically have higher long-term average SINR and inject less interference into the network than those at the cell boundary) while PF scheduler and Round Robin scheduler yield the same performance. As the number of users increases, for the same average RoT, the average cell throughput decreases as the overhead associated with the DPCCH is increased except for DL SINR. DL SINR can take advantage of multiuser diversity when the average RoT is high enough and a higher throughput can be observed with 10 users.

Figure A.4.1.1.3.4 shows the scatter plot of the user throughputs for 5 and 10 users per cell as a function of the best downlink path loss. From this figure it can be seen that as the number of users increases, the user throughput decreases but the cell coverage stays around the same.

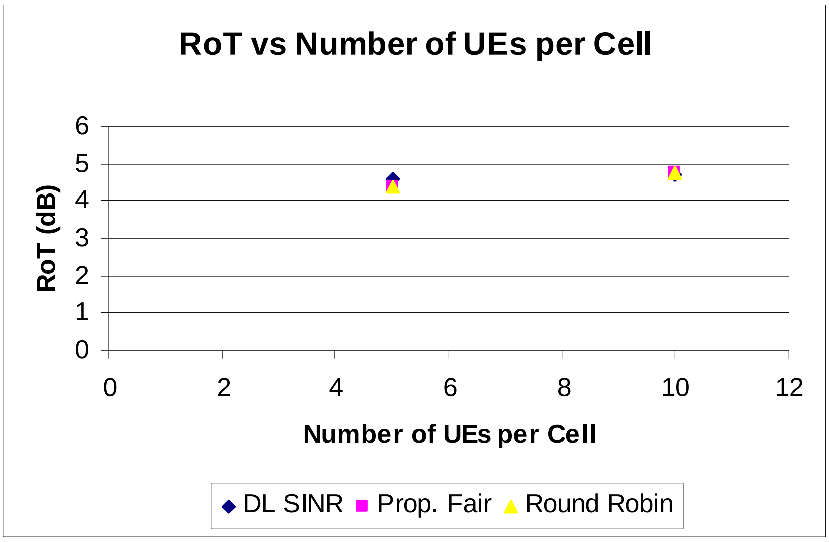

Figure A.4.1.1.3.1 Average RoT as a function of number of users per cell

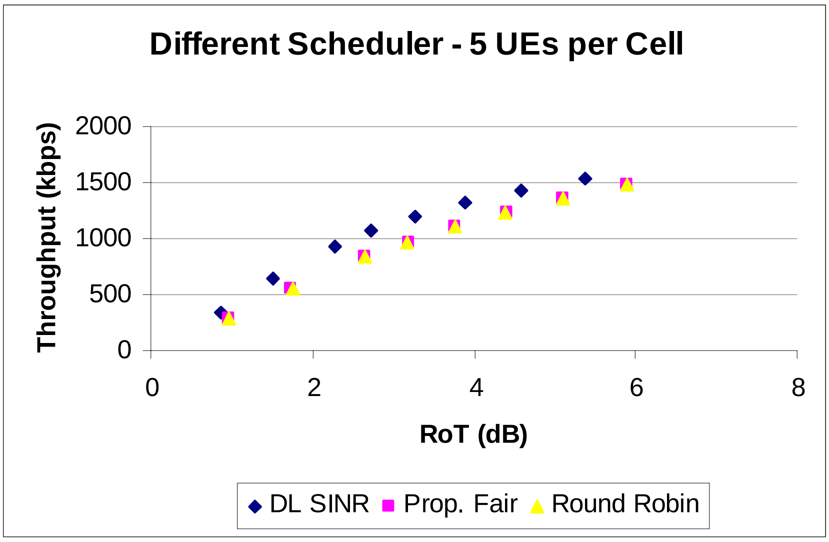

Figure A.4.1.1.3.2 Average cell throughput as a function of RoT – 5 UEs per cell

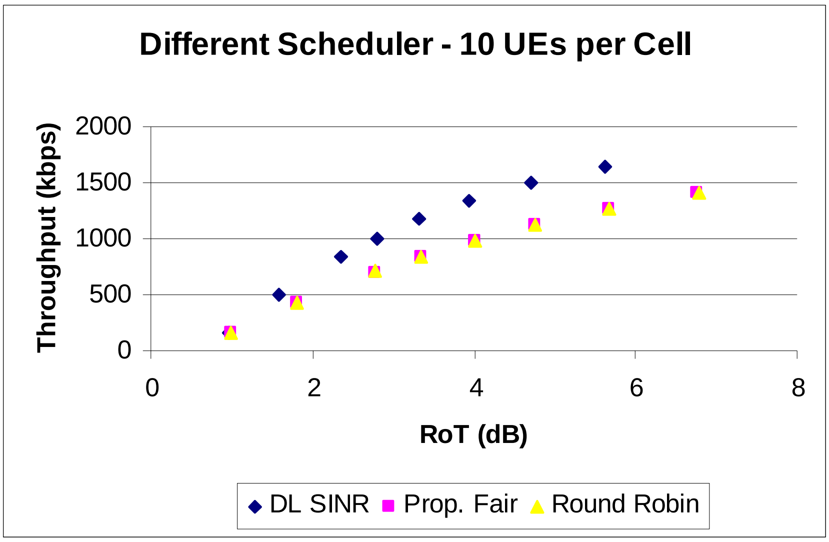

Figure A.4.1.1.3.3 Average cell throughput as a function of RoT -- 10 UEs per cell

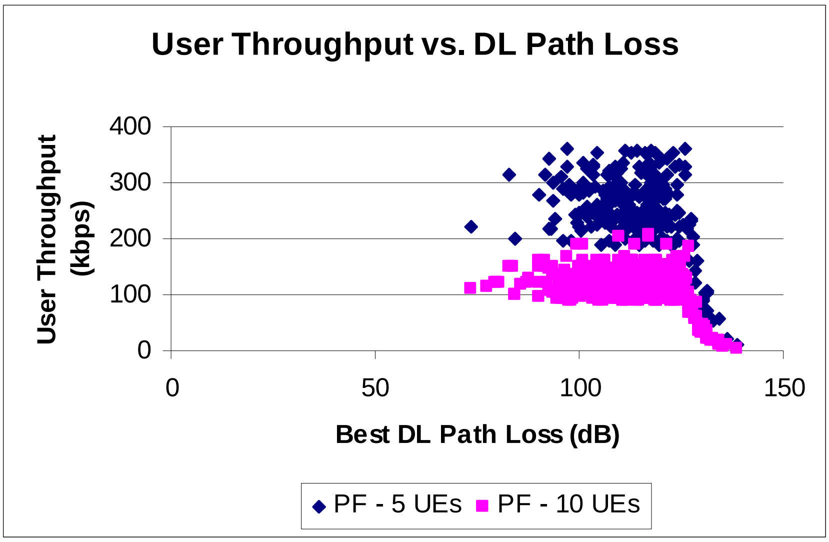

Figure A.4.1.1.3.4 Average user throughput as a function of the best downlink path loss

A.4.1.2 Release-99 Performance With Mixed Traffic Model

A.4.1.2.1 System Setup

The system performances are obtained under the following assumptions:

- Link-level curves used are generated based on the following parameters, where each pair represents (TFC,DPDCH/DPCCH): (8 kbps, 0 dB), (16 kbps, 2 dB), (32 kbps, 4 dB), (64 kbps, 7 dB), (128 kbps, 10 dB), (256 kbps, 13 dB), (384 kbps, 15 dB),
- Traffic model: FTP, Near Real Time Video, Gaming
    - The TCP parameters, as defined in Table A-13, for FTP users are: Mean(τ_2)=50 ms, Mean(τ_3)=50 ms, StdDev(τ_3)=50 ms, τ_4=0 ms if packet is in error after all physical layer retransmissions and τ_4=200 ms otherwise
- Initial FTP state is the reading time, exponentially distributed with mean of 18 s
- The Gaming traffic model parameters are as defined in the Table A-10, for Value Set 2

- Maximum data rate is 384 kbps
- 19 Node-B, 3-cell wrap-around layout
- Simulation duration: 200 s
    - Additional warm-up time, during which statistic is not collected: 10 s

A.4.1.2.2 Performance Without TFC Control in AWGN

The following figures present the system performance in AWGN, without TFC control, in terms of average RoT, throughput per user, packet call throughput per user and packet call delay.Figure A.4.1.2.2.1 represents the average RoT as a function of the number of users per cell. As the number of users increases, the RoT increases, for all traffic models.

Figure A.4.1.2.2.2 shows the scatter plot of the throughputs of the users for 10 users per cell as a function of the best downlink path loss.

Figure A.4.1.2.2.3 presents the packet call throughputs of the users in terms of the best downlink path loss, for 10 users per cell. Packet call throughput is defined as the ratio of the number of correctly received bits and the packet call delay. Packet call delay is the time between two consecutive reading periods. For Gaming users, packet call delay represents the time of a gaming session that includes the time during which the packets are generated (active period), and the time needed for transmission of the data packets accumulated during the active period. For FTP users, packet call delay is the time needed for an FTP file upload. Packet call delays are presented in Figure A.4.1.2.2.4. The packet call delay is shown for FTP and Gaming users only, since the packet call delay for Video users is not specifically defined and is actually equivalent to the simulation duration.

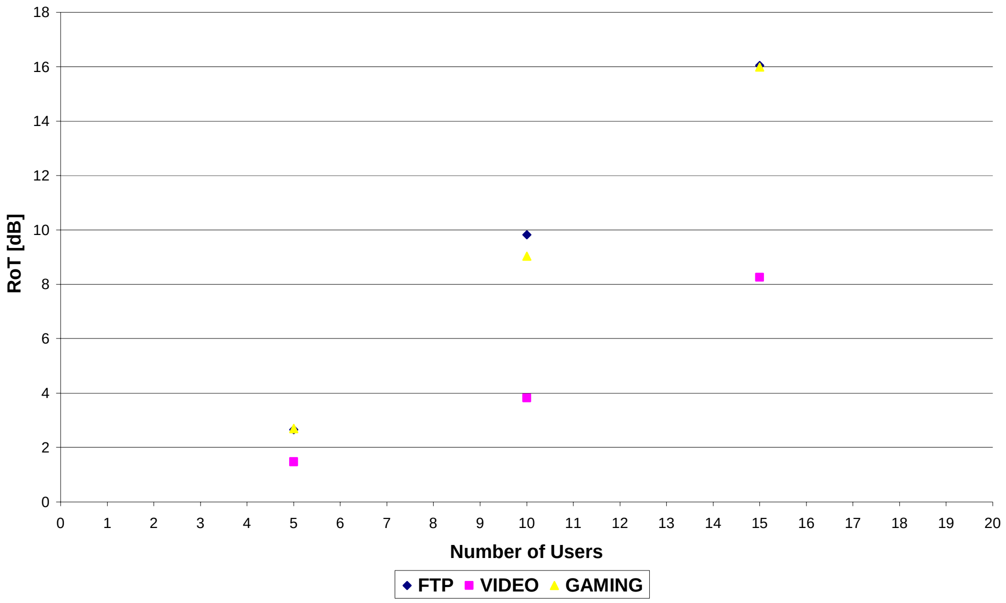

Figure A.4.1.2.2.1: Average RoT as a function of number of users per cell

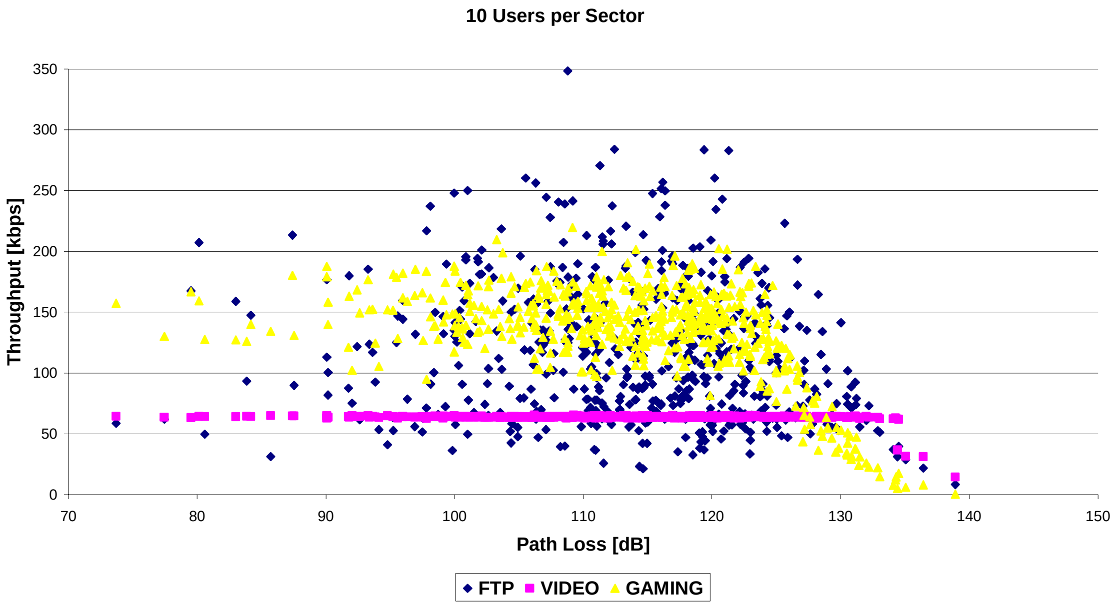

Figure A.4.1.2.2.2: Average user throughput as a function of the best link path loss for the system with 10 users per cell

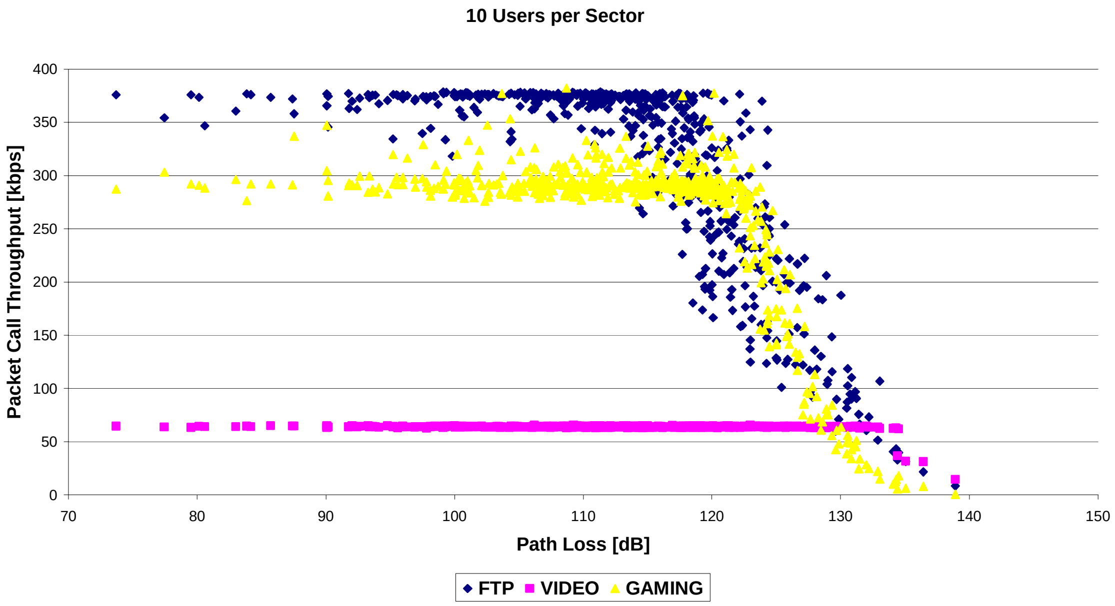

Figure A.4.1.2.2.3: Average packet call throughput as a function of the best link path loss for the system with 10 users per cell

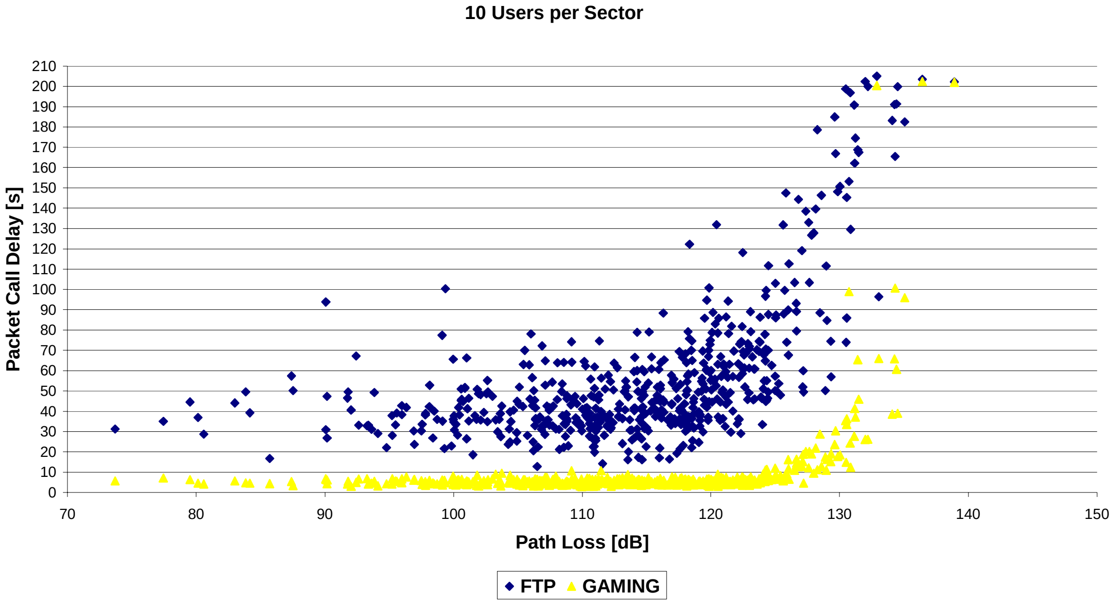

Figure A.4.1.2.2.4: Average packet call delay as a function of the best link path loss for the system with 10 users per cell

A.4.1.3 Release-99 Voice Capacity

A.4.1.3.1 System Setup

The system performance is obtained under the following assumptions:

- TTI: 20ms
- Voice rate: 12.2kbps
- DPDCH/DPCCH for each TF: (12.2 kbps, 0 dB), (SID, -4 dB), (NULL, -7 dB)
- Channel model mix: PA3 30%, PB3 30%, VA30 20% and VA120 30%
- 19 Node-B, 3-cell wrap-around layout
- Simulation duration: 500 s
  - Additional warm-up time, during which statistic is not collected: 10 s
- Rest of simulation assumptions as in Table A-7

A.4.1.3.2 Voice Capacity

Table A.4.1.3.2.1 presents the average Rot and voice outage probability.

Table A.4.1.3.2.1 Average RoT and Voice Outage Probability

Number of UEs per cell	Average RoT (dB)	Voice Outage Probability
45	2.95	0.00%
60	4.67	0.12%
75	7.54	0.47%
90	16.19	8.75%

A.5 Traffic Models

The following types data traffic models will be used in the evaluation study, a) Modified Gaming, b) near real time video and c) FTP. The traffic models are described in the following paragraph.

a) Modified Gaming Model:

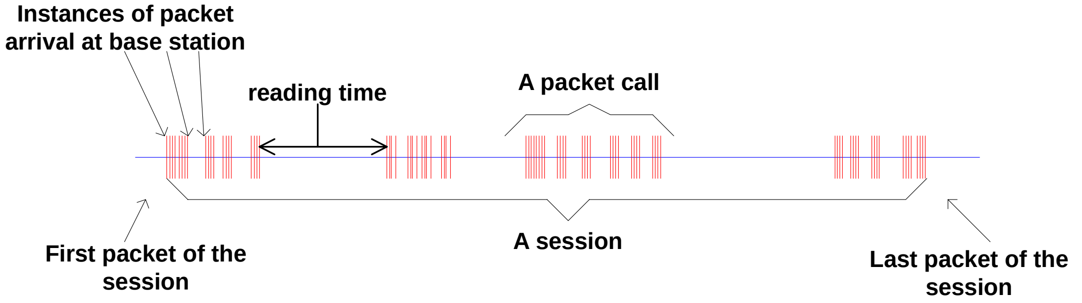

Figure A - 2 - A source packet data model with packets (datagrams) arriving as part of a packet call.

Figure A - 2 shows the source traffic model. Similar to other models it defines a packet call arrival process and within each packet call a datagram arrival process. In this model the packet session arrival process is not specified and it is assumed that packet calls are generated indefinitely (for the duration of the simulation). One may however specify a limited number of packet calls within a packet session together with an arrival probability.

For the packet call arrival process we specify the packet call (time) duration and the reading time (the time between packet calls). The reading time starts at the successful transmission of all datagrams generated during the previous packet call to emulate a closed loop transmission mode; we imagine that the application running on the UE will await acknowledgement from the network peer. Most significantly, this is a measure to ensure burstiness in the UE transmissions since it avoids excessive UE buffer accumulation, and hence continuous-like transmission, during the simulation. For the datagram arrival process we specify the packet size (bits) and the interarrival time between datagrams.

The model for this is largely derived from the so-called "Gaming" measurements [1], and therefore originally using the empirically derived distributions specified therein. However, partly as a consequence of the closed loop modeling in Figure A - 3 and for emulating future services with higher bit rates the distributions were modified slightly. For the packet call distributions, both the packet call duration and reading time have exponential distributions. The datagram size is set to a fixed value and the datagram inter-arrival distribution is a lognormal distribution. An example of the distribution is shown in Figure A - 4.

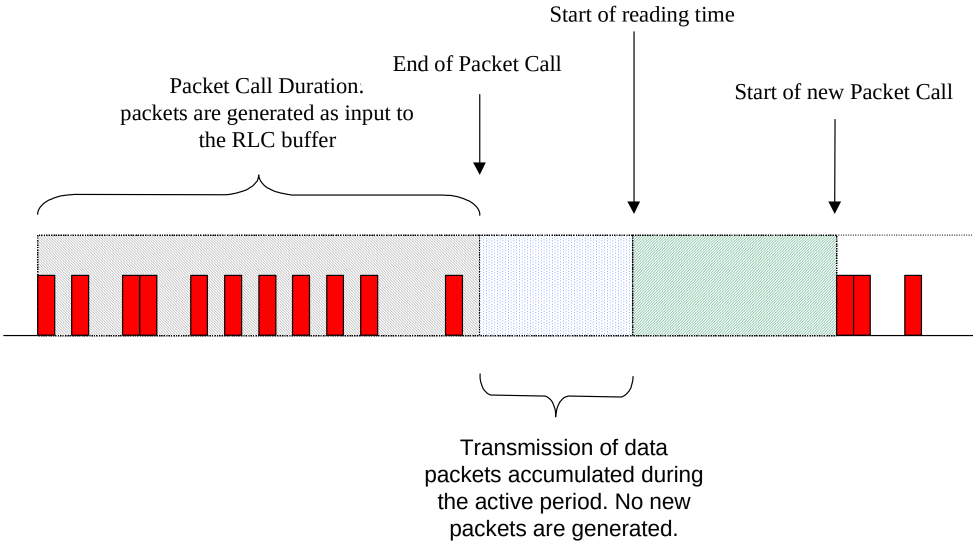

Figure A - 3 - A simple modeling approach to include closed loop transmission mode - the 'reading time' only starts after the UE RLC buffer has been emptied.

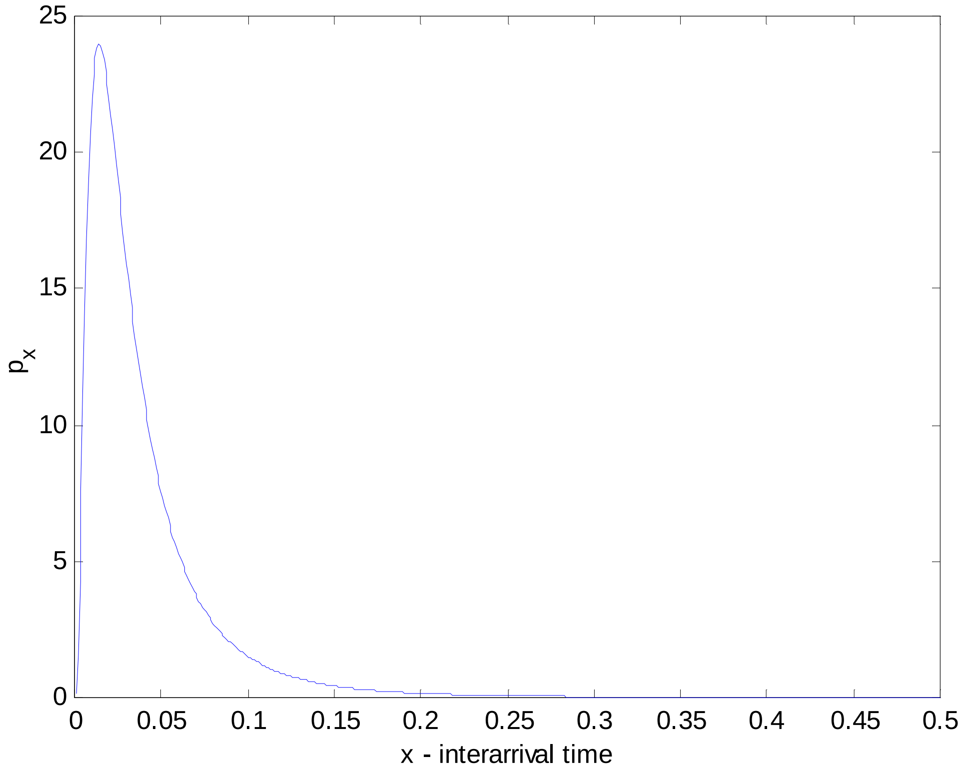

Figure A - 4 - Packet interarrival time distribution for 40 ms mean interarrival time. The packet interarrival distribution is log-normal

The model is very general and can be adjusted easily in terms of required data rates and burstiness by changing the datagram size and the mean data gram interarrival time, equivalently the mean reading time. Table A - 10 shows the parameter settings to be used in the simulations.

Table A - 10 - Parmeter Settings for the Modified Gaming model

Parameter	**Value**		**Comment**
	Value set 1	**Value Set 2**	
Mean packet call duration	5 s	5 s	Exponential distribution
Mean reading time	5 s	5 s	Exponential distribution
Datagram size	576 bytes	1500 bytes	Fixed
Mean datagram interarrival time	40 ms	40 ms	Log-normal distribution, 40 ms standard deviation
Resulting mean data rate during packet call	115 kbps	300 kbps	

The burstiness results mainly from the datagram interarrival time and the packet call reading time, while the bit rate results from the interarrival time and size of the datagrams.

b) Near Real Time Video Model:

The following section describes a model for streaming video traffic on the forward link. Figure A - 5 describes the steady state of video streaming traffic from the network as seen by the base station. Latency of starting up the call is not considered in this steady state model.

A video streaming session is defined as the entire video streaming call time, which is equal to the simulation time for this model. Each frame of video data arrives at a regular interval T determined by the number of frames per second (fps). Each frame is decomposed into a fixed number of slices, each transmitted as a single packet. The size of these packets/slices is distributed as a truncated Pareto. Encoding delay, Dc, at the video encoder introduces delay intervals between the packets of a frame. These intervals are modeled by a truncated Pareto distribution.

The parameter T_B is the length (in seconds) of the de-jitter buffer window in the Node-B used to guarantee a continuous display of video streaming data. This parameter is not relevant for generating the traffic distribution but is useful for identifying periods when the real-time constraint of this service is not met. At the beginning of the simulation, it is assumed that the Node-B’s de-jitter buffer is full with (T_B x source video data rate) bits of data. Over the simulation time, data is “leaked” out of this buffer at the source video data rate and “filled” as reverse link traffic reaches the Node-B. As a performance criterion, the Node-B can record the length of time, if any, during which the de-jitter buffer runs dry. The de-jitter buffer window for the video streaming service is 5 seconds.

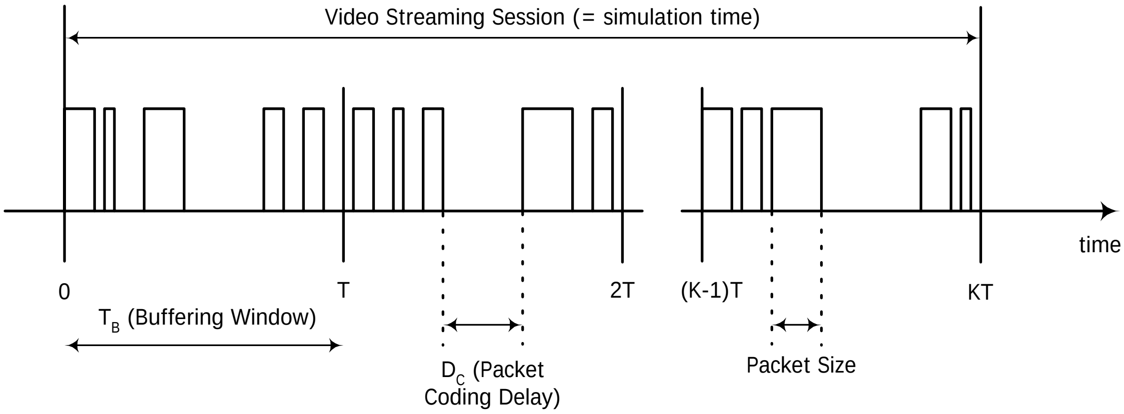

Figure A - 5 - Video Streaming Traffic Model

Using a source video rate of 64 kbps, the video traffic model parameters are defined in Table A - 11.

Table A - 11 - Typical Video Streaming Traffic Model Parameters

Information types	Inter-arrival time between the beginning of each frame	Number of packets (slices) in a frame	Packet (slice) size	Inter-arrival time between packets (slices) in a frame
Distribution	Deterministic (Based on 10fps)	Deterministic	Truncated Pareto (Mean= 100bytes, Max= 250bytes)	Truncated Pareto (Mean= 6ms, Max= 12.5ms)
Distribution Parameters	100ms	8	K = 40bytes $\alpha = 1.2$	K = 2.5ms $\alpha = 1.2$

e) FTP Model:

In FTP applications, a session consists of a sequence of file transfers, separated by *reading times*. The two main parameters of an FTP session are:

1. S : the size of a file to be transferred
2. D_{pc}: reading time, i.e., the time interval between end of download of the previous file and the user request for the next file.

The underlying transport protocol for FTP is TCP. The model of TCP connection will be used to model the FTP traffic. The packet trace of an FTP session is shown in Figure A - 6. The FTP traffic model parameters are shown in Table A - 12.

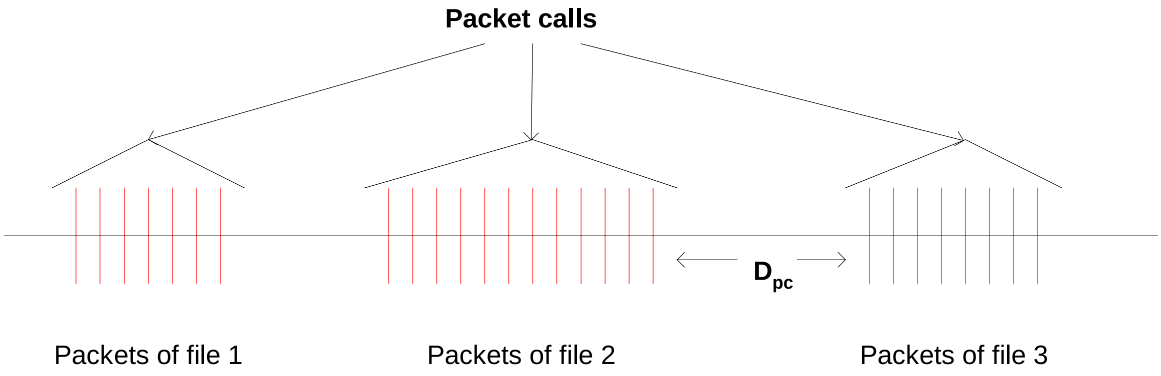

Figure A - 6 - Packet Trace in a Typical FTP Session

Table A - 12 - Typical FTP Traffic Model Parameters

Component	Distribution	Parameters	PDF
File size (S)	Truncated lognormal	Mean = 2 MB Std. Dev.= 0.722MB Max. = 5 MB	$f_x = \frac{1}{\sqrt{2\pi}\sigma x}\exp\left[\frac{-\ln^2(x/\mu)}{2\sigma^2}\right], x \ge 0$ $\sigma = 0.35, \mu = 14.45$
Reading time (D_{pc})	Exponential	Mean = 180 sec.	$f_x = \lambda e^{-\lambda x}, x \ge 0$ $\lambda = 0.006$

Based on the results on packet size distribution [10], 76% of the files are transferred using and MTU of 1500 bytes and 24% of the files are transferred using an MTU of 576 bytes. For each file transfer a new TCP connection is used whose initial congestion window size is 1 segment (i.e. MTU).

The three-way handshake mechanism for TCP connection set-up and release is shown in Figure A-7.

After the call setup process is completed, the procedure for a UE to set up a TCP session is as follows:

1. UE sends a 47-byte[5] SYNC packet and wait for an ACK from remote server.
2. UE starts TCP in slow-start mode (The ACK flag is set in the first TCP segment).

The procedure for a UE to release the TCP session is as follows:

1. UE sets the FIN flag in the last TCP segment.
2. UE receives ACKs for all TCP segments from the remote server and terminates the session.

---

[5] The TCP/IP header of 40 bytes + 7 bytes PPP framing overhead = 47 bytes for the SYNC packet.

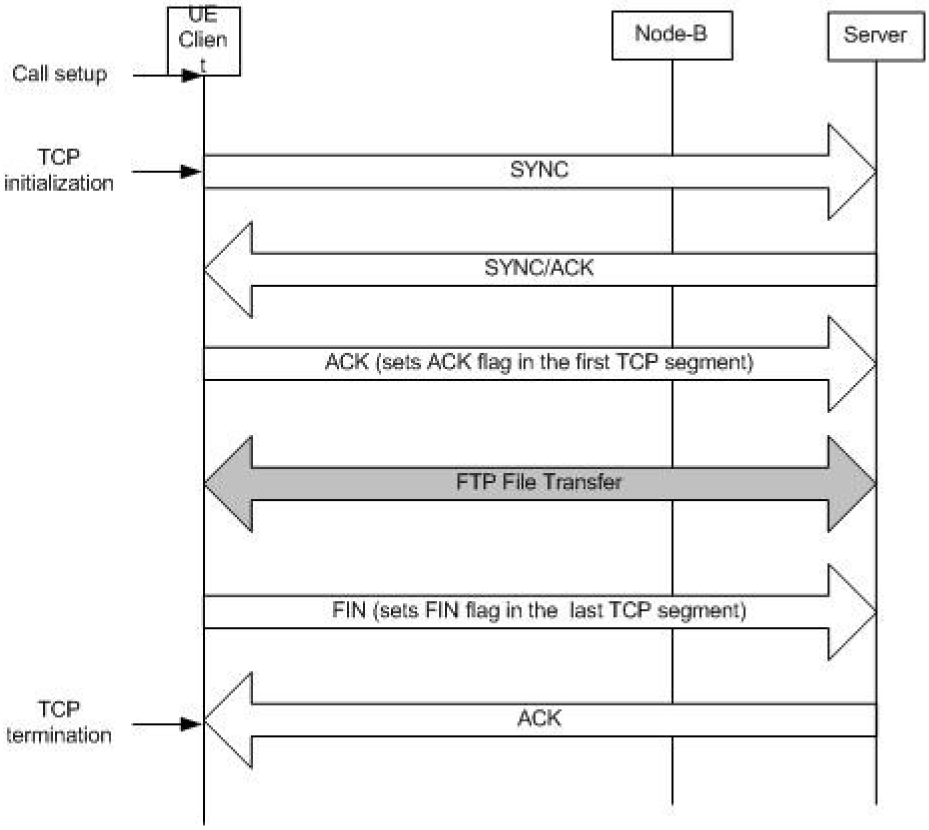

Figure A-7: Modeling of TCP three-way handshake

The amount of outstanding data that can be sent without receiving an acknowledgement (ACK) is determined by the minimum of the congestion window size of the transmitter and the receiver window size. After the connection establishment is completed, the transfer of data starts in slow-start mode with an initial congestion window size of 2 segments. The congestion window increases by one segment for each ACK packet received by the sender. This results in an exponential growth of the congestion window.

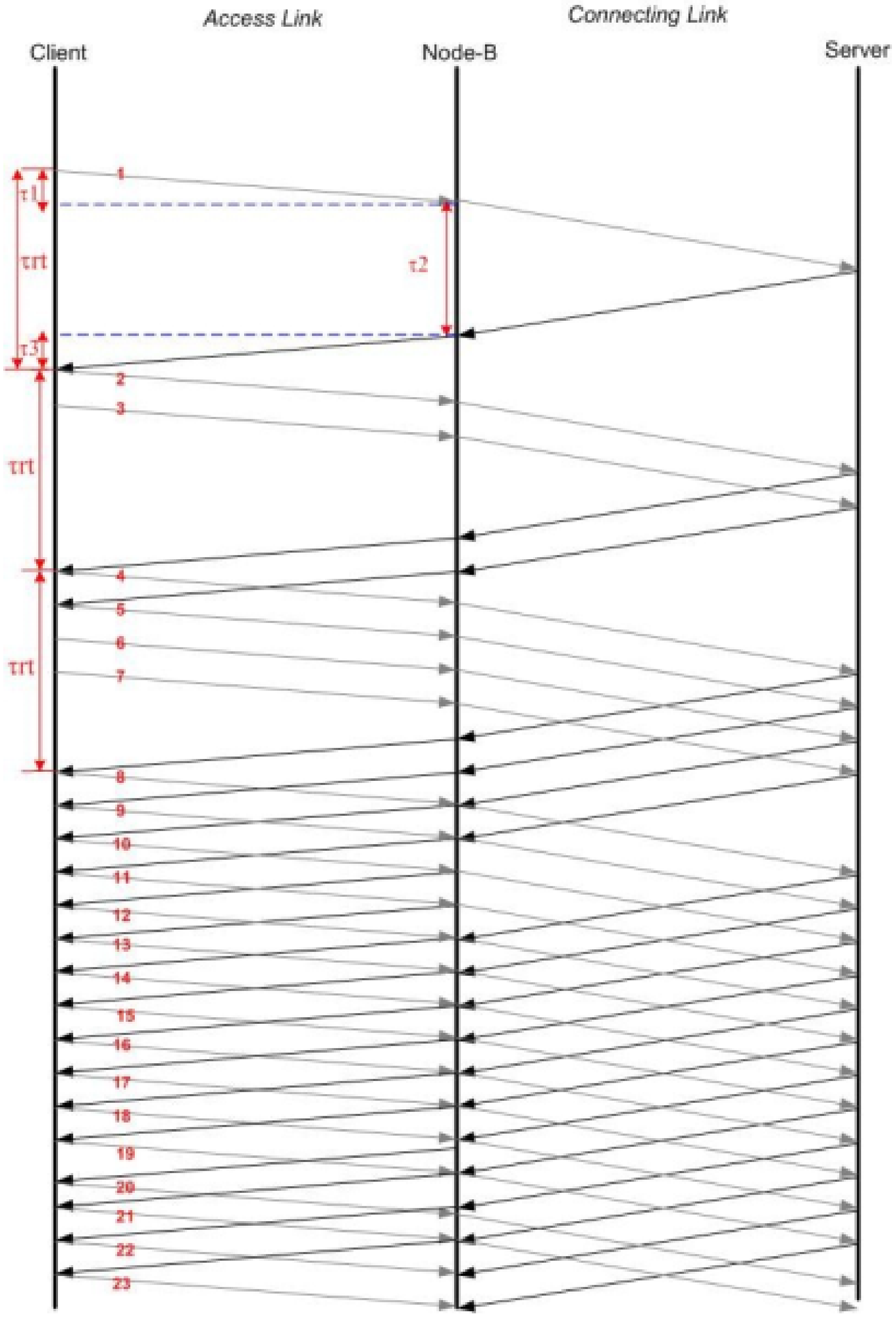

Figure A-8: TCP Flow Control During Slow-Start; τ_l = Transmission Time over the Uplink; τ_{rt} = Roundtrip Time

The round-trip time in Figure A-8, $\tau_{rt,}$ consists of two components:

$$\tau_{rt} = \tau_{cr} + \tau_l \quad \text{,where}$$

- $\tau_{cr} = \tau_2 + \tau_3 + \tau_4$
  - τ_2 = Nominal time taken by a TCP data segment to travel from Node-B to the server plus the time taken by an ACK packet to travel from the server back to Node-B
  - τ_3 = Time taken by the ACK to travel from Node-B to client.
  - τ_4 = Constant delay to account for RLC retransmissions (nominally zero)
- τ_l = Transmission time taken by TCP data segment from the client to Node-B

The individual delay distribution parameters are given in Table A-13.

Table A-13 **Delay components in the TCP model for the RL upload traffic**

Delay component	**Symbol**	**Value**
The uplink transmission time of a TCP data segment from the client to the Node-B	τ_1	Determined by uplink throughput
The sum of the time taken by a TCP data segment to travel from Node-B to the server and the time taken by an ACK packet to travel from the server to Node-B	τ_2	Exponential distribution Mean = x ms.
Time taken by the ACK to travel from Node-B to client	τ_3	Lognormal distribution Mean = y1 ms Standard deviation = y2 ms
Increased delay to account for RLC retransmissions from residual uplink physical layer BLER	τ_4	Constant = 0 ms, if packet is not in error after all physical layer retransmissions = z ms, else

From Figure A-8, during the slow-start process, the UE receives two segments back-to-back after an interval of τ_{cr} for every ACK packet received.

The upload procedure is illustrated in Figure A-9 and described as follows.

1. Let S = size of the FTP upload file in bytes. Compute the number of packets in the file, $N = \lceil S/(MTU-40) \rceil$. W = size of the congestion window of TCP. Initially, W = 2
2. If N>W, then W packets are put into the queue for transmission; otherwise, all packets of the file are put into the queue for transmission in FIFO order. Let P = the number of packets remaining to be transmitted beside the W packets in the window. If P=0, go to step 6
3. Wait until a packet of the file in the queue is transmitted over uplink
4. Schedule arrival of next two packets (or the last packet if P=1) of the file after the packet is successfully ACKed. If P=1, then P=0, else P=P-2
5. If P>0 go to step 3
6. End.

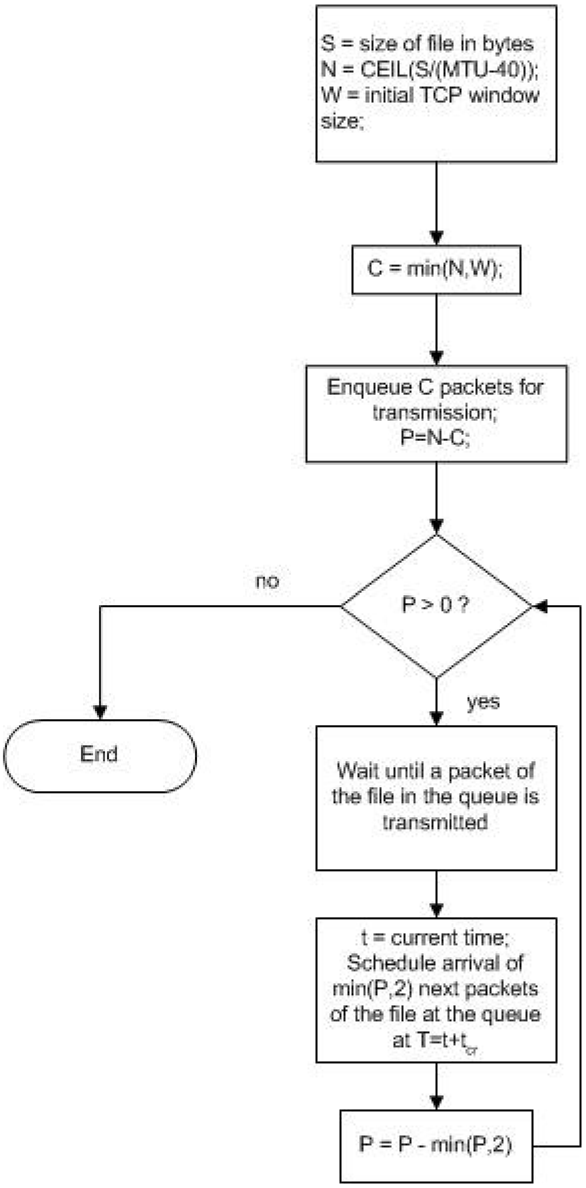

Figure A-9 Packet Arrival Process for the Upload of a File Using TCP

Annex B: Lognormal description

The attenuation between a mobile and the ith cell site is modeled by

$$L_i = k_o D_i^{-\mu} 10^{X_i/10} R_i^2$$

where D_i is the distance between the mobile and the cell site, μ is the path loss exponent and X_i represents the shadow fading which is modeled as a Gaussian distributed random variable with zero mean and standard deviation σ. X_i may be expressed as the weighted sum of a component Z common to all cell sites and a component Z_i which is independent from one cell site to the next. Both components are assumed to be Gaussian distributed random variables with zero mean and standard deviation σ independent from each other, so that

$$X_i = aZ + bZ_i \text{ such that } a^2 + b^2 = 1$$

Typical parameters are $\sigma = 8.9$ and $a^2 = b^2 = 1/2$ for 50% correlation. The correlation is 0.5 between sectors from different cells, and 1.0 between sectors of the same cell.

Annex C: Uplink Rise Outage Filter

To determine average interference rise outage a short term average rise filter is defined.

A simple 3-tap rectangular filter is used to compute the ratio of total uplink received power to thermal noise over a radio frame interval (2 ms). The filter is applied to each set of three Rssi/thermal noise samples computed every 0.67 ms.

Z(k) = (Rssi[j]+Rssi[j+1]+Rssi[j+2])/3, j=3k

where
Rssi = ½[(Io1+No)/No + (Io2 + No)/No]

No – thermal noise

Ion – uplink CDMA interference for antenna n, n=1 primary, n=2 diversity antenna.

Annex D: Speech Source (Markov) Model

The simplified speech source model with an average voice activity of 0.32 is given by

```
IF PrevState=0 then
    IF RAND()<0.01 then
            NewState=1  /* go to voice active state */
    Else
            NewState=0 /* remain in voice inactive state */
Else
    IF RAND()<0.9785 then
            NewState=1  /* remain in voice active state */
    Else
            NewState=0 /* go to voice inactive state */
```

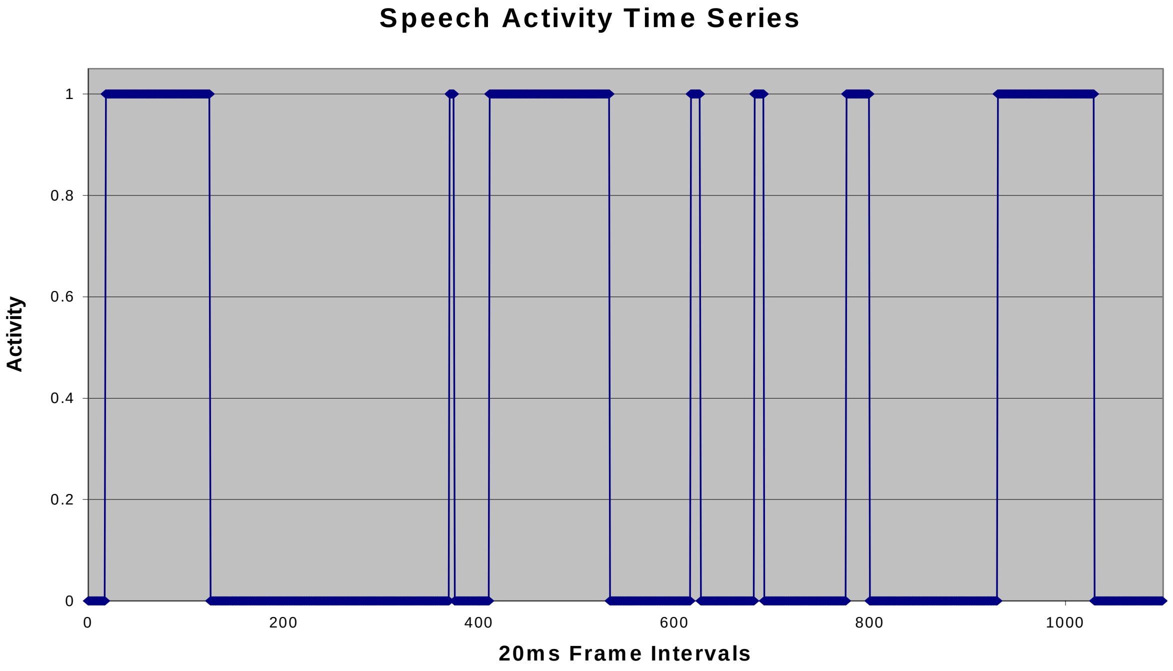

Figure D – 1 - Speech Source Example using simple Markov Model

Voice user’s should meet an outage criteria which can be defined as:

a. average FER being less than 2%,

b. short term FER exceeding 2% no more than 10% of the time.

The short term FER of the voice service is calculated by averaging over 2 seconds. An AMR vocoder with a rate of 12.2 kbps will be used. The uplink voice activity factor should be set to 0.32 by randomly choosing on and off periods of appropriate duration. A simple speech source model is given above.

Annex E: Modeling of the effect of channel estimation errors on Link performance

As mentioned in Section A.1.1, the effect of channel estimation errors on link performance should be modeled for an accurate comparison of different techniques. Two methods for modeling this effect are provided in [13]. The methods described are applicable to the Quasi-static approach discussed further below. We provide below a brief overview of techniques used in [11]:

- Demodulation with imperfect channel estimates affects the SNR of the demodulated symbols. The SNR of the demodulated symbol – as seen by the turbo decoder – can be characterized *analytically*. This SNR is a function of the packet parameters such as transport block size and data rate, transmit data and pilot energies, channel gain, interference power, quality of channel estimates and combining method. Note that all of the parameters would already be generated in a system level simulation and nothing additional needs to be generated for this approach. An *effective* Eb/No for the block is then readily computed (analytically). The probability of error for the transmission is then obtained by using appropriate lookup curves (after adjusting the analytically calculated effective Eb/No by applying the Doppler penalty, puncturing penalty, and other terms, as appropriate). See [11] for more details.

In cases that do *not* involve the use of H-ARQ combining, in addition to the methods in [11], the following method may be used:

- FER Vs traffic Eb/No curves are generated for each TFC, over each fading channel model, via link level simulations. A family of curves is produced for each data rate with each curve being parameterized by the average pilot SNR over the frame. For a single packet transmission in the system simulation, the average pilot

SNR during the frame, and the received traffic channel Eb/No are computed. Performance is read off from the corresponding error curve (one which is parameterized by the same pilot SNR) obtained in the link level simulations, at the received traffic channel Eb/No value observed in the system simulation. If an error curve for this average pilot SNR does not exist for this TFC, the FER curve for this average pilot SNR is interpolated from the curves for pilot SNR immediately above and below this value, and read at the same received traffic Eb/No.

If the effect of channel estimation errors is not modeled, then several techniques, such as the ones in [3], [5] or [6], may be used:

1. Quasi-static approach [5] (QSA) with appropriate Doppler, Demapping, Puncturing penalties.
2. The modelling of link level performance at the system level is done with E_b/N_0 to BLER mapping, called the “Actual Value Interface” (AVI), described in [3].

If a comparison of schemes is based on such models – that do not incorporate the effect of channel estimation errors – then justification should be provided for not accounting for this effect.

Annex F:
Change history

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
10-2002	RAN1 #28bis	R1-02-1218			Initial TR skeleton presented for discussion		0.0.1
10-2002	RAN1 #29	R1-02-1259			Modifications to the document structure	0.0.1	0.0.2
12-2002	RAN1 #30	R1-02-1271 + comments			Requirements to chapter 5 Requirements	0.0.2	0.0.3
12-2002	RAN1 #30	R1-030065			Traffic models to Annex A	0.0.2	0.0.3
12-2002	RAN1 #30	R1-030066			Simulations assumptions to Annex A, B, C and D	0.0.2	0.0.3
01-2003	RAN1 #30	R1-030061			Reference Techniques – Uplink TFCS management by RRC signaling to chapter 6.2 and modification to Table A - 8	0.0.3	0.0.4
01-2003	RAN1 #30	R1-030062			Reference Techniques – TFC selection in UE to chapter 6.3	0.0.3	0.0.4
01-2003	RAN1 #30	R1-030126			Revised Simulations assumptions, changes to Annex A and C	0.0.3	0.0.4
01-2003	RAN1 #30	R1-030005			Added sentence to Editor's Note in chapter 8 about the physical channel timing requirements.	0.0.3	0.0.4
01-2003	RAN1 #30	R1-030131			TR25.896 version 0.0.4 agreed and promoted to 0.1.0	0.0.4	0.1.0
01-2003	RAN1 #30	R1-030150			Correction to Table A - 8 due to wrong implementation of a text proposal in Tdoc R1-030126.	0.1.0	0.1.1
02-2003	RAN1 #31	R1-030311			Revision marks approved.	0.1.1	0.2.0
02-2003	RAN1 #31	R1-030209			E-DCH definitions + additional comment	0.2.0	0.2.1
02-2003	RAN1 #31	R1-030210			Fast DCH Setup	0.2.0	0.2.1
02-2003	RAN1 #31	R1-030325			E-DCH Scheduling, 1st chapter of the text proposal added	0.2.0	0.2.1
02-2003	RAN1 #31	R1-030326			Signalling Method for Fast TFCS Restriction Control	0.2.0	0.2.1
02-2003	RAN1 #31	R1-030330			Hybrid ARQ Overview	0.2.0	0.2.1
02-2003	RAN1 #31	R1-030331			Enhanced uplink DCH physical layer structure – TTI vs HARQ structure	0.2.0	0.2.1
02-2003	RAN1 #31	R1-030332			Multiplexing Alternatives for Uplink Enhancements + additional sentence	0.2.0	0.2.1
02-2003	RAN1 #31	R1-030341			Description of Node B controlled scheduling by fast TFCS restriction control	0.2.0	0.2.1
02-2003	RAN1 #31	R1-030349			A method for Node B controlled scheduling by fast TFCS restriction control	0.2.0	0.2.1
02-2003	RAN1 #31	R1-030332			Correction to the incorrect inclusion of the text proposal	0.2.1	0.2.2
03-2003		R1-030381			Changes approved after an email review	0.2.2	0.3.0
05-2003	RAN1 #32	R1-030563			Text proposal for E-DCH scheduling in SHO	0.3.0	0.3.1
05-2003	RAN1 #32	R1-030592			Node B Controlled Time and Rate Scheduling	0.3.0	0.3.1
05-2003	RAN1 #32	R1-030594			Modifications to Section 7.1	0.3.0	0.3.1
05-2003	RAN1 #32	R1-030598			On HARQ Timing, additional row to table 8.2.1	0.3.0	0.3.1
05-2003	RAN1 #32	R1-030620			Text for TCP Modeling to Annex A.5	0.3.0	0.3.1
05-2003	RAN1 #32	R1-030621			Fast DCH Setup – Synchronization	0.3.0	0.3.1
06-2003					Editorial corrections (8.2.1 and figures A-7 and A-8)	0.3.1	0.3.2
08-2003	RAN1 #33				Addition of modified gaming model's std in table A-10	0.3.2	0.3.3
08-2003	RAN1 #33	R1-030889			Changes approved	0.3.3	0.4.0
08-2003	RAN1 #33	R1-030897			HARQ performance results with and without soft combining	0.4.0	0.4.1
08-2003	RAN1 #33	R1-030899			Changes to HARQ operation during Soft Handover	0.4.0	0.4.1

Change history

Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
08-2003	RAN1 #33	R1-030911			Two new issues to be studied (Impacts of TTI to TFC selection and multiple CCTrCH to higher layers) added to chapter 8.3	0.4.0	0.4.1
08-2003	RAN1 #33	R1-030915			Shorter framesize for improved QoS overview to Chapter 7.4	0.4.0	0.4.1
09-2003	RAN1 #33	R1-030911			Added the text proposal that dropped out from the last version..	0.4.1	0.4.2
09-2003		R1-030890			R'99 voice capacity results to Annex A.4.1.3, modification of Markov model's voice outage criteria to Annex D	0.4.1	0.4.2
09-2003		R1-030891			R'99 cell throughput results with no TFC control, AWGN, full buffer added to Annex A.4.1.1	0.4.1	0.4.2
09-2003		R1-030892			R'99 cell throughput results with no TFC control, AWGN, traffic models added to Annex A.4.1.2	0.4.1	0.4.2
09-2003		R1-030896			HARQ efficiency results	0.4.1	0.4.2
09-2003					Changes approved and sent for RAN#21 for information	0.4.2	1.0.0
10-2003	RAN1 #34				Updated the 2nd page copyright notification	1.0.0	1.0.1
10-2003	RAN1 #34	R1-030989			HARQ performance results in soft handover	1.0.0	1.0.1
10-2003	RAN1 #34	R1-031035			Correction of DL synchronisation delay to 7.3.2	1.0.0	1.0.1
10-2003	RAN1 #34	R1-031045			Node B Controlled Rate Scheduling by Persistence Control	1.0.0	1.0.1
10-2003	RAN1 #34	R1-031097			Chapter structure 9.5 PAR Analysis	1.0.0	1.0.1
10-2003					Corrected broken references and 4 values in Table A – 6	1.0.0	1.0.1
10-2003		R1-031120 + comments			Scheduling overview and scheduling strategies	1.0.1	1.0.2
10-2003		R1-031122			Node B controlled scheduling with scheduling weight	1.0.1	1.0.2
10-2003		R1-031151			Physical layer structures in code domain	1.0.1	1.0.2
10-2003		R1-031130 + comments			Physical layer structures in time domain	1.0.1	1.0.2
10-2003		R1-031131			E-DCH Transport Channel Structure	1.0.1	1.0.2
11-2003	RAN1 #35	R1-031358			Changes of 1.0.1 and 1.0.2 approved by RAN1 #35.	1.0.2	1.1.0
11-2003	RAN1 #35	R1-031173 + comment			Downlink signalling overview	1.1.0	1.1.1
11-2003	RAN1 #35	R1-031223			Physical layer structure and backward compatibility in SHO	1.1.0	1.1.1
11-2003	RAN1 #35	R1-031233			Short-term Link Performance	1.1.0	1.1.1
11-2003	RAN1 #35	R1-031239 first part			Physical layer structure in code domain	1.1.0	1.1.1
11-2003	RAN1 #35	R1-031381			Full Buffer E-DCH Cell Throughput Gain	1.1.0	1.1.1
11-2003	RAN1 #35	R1-031382			E-DCH Cell Throughput Gain with Mixed Traffic Model	1.1.0	1.1.1
12-2003					Corrected Annex C noise rise outage filer	1.1.1	1.1.2
12-2003	RAN1 #35	R1-031256			E-TFC Signalling results to chapter 9.2.4.1	1.1.1	1.1.2
12-2003		R1-031361			Relationship between scheduling and HARQ to chapter 7.1	1.1.1	1.1.2
12-2003		R1-031372			Support for enhanced channel estimation to chapter 7.6	1.1.1	1.1.2
12-2003		R1-031430			PAR results for various multiplexing alternatives to 9.5.1.1	1.1.1	1.1.2
12-2003		R1-031432			Comparison of R'99 and E-DCH schedulers in chapter 9.1.1.1	1.1.1	1.1.2
12-2003		R1-031433			Rel-99 Cell Throughput with TFC Control, Full Buffer and AWGN to Annex A.4.1.1.3	1.1.1	1.1.2
12-2003		R1-031434			Uplink signalling overview to chapter 7.5.2	1.1.1	1.1.2
12-2003		R1-031435			PAR results for case 8 to chapter 9.5.1.1	1.1.1	1.1.2
12-2003		R1-031439			Uplink signalling of scheduling information to chapter 7.1.2.5.1.1	1.1.1	1.1.2
01-2004	R'6 Ad-hoc	R1-040105			Changes of 1.1.1 and 1.1.2 approved by RAN1 R'6 Adhoc	1.1.2	1.2.0
01-2004	R'6 Ad-hoc	R1-040002			HARQ Complexity on 9.2.2.1	1.2.0	1.2.1
01-2004	R'6 Ad-hoc	R1-040010			Comparison between Short Term and ECM Approach to A.1.4.3	1.2.0	1.2.1
01-2004	R'6 Ad-hoc	R1-040022			Node B scheduling of HARQ retransmission, Change to 7.1	1.2.0	1.2.1
01-2004	R'6 Ad-hoc	R1-040079			Enhanced Uplink Scheduling by Availability of the Knowledge of Buffer Status of each UE to other UEs, changes 7.1.2.2&7.1.2.3	1.2.0	1.2.1
01-2004	R'6 Ad-hoc	R1-040086			Compatibility of the enhancements with existing releases, 9.7	1.2.0	1.2.1
01-2004	R'6 Ad-hoc	R1-040095			Link performance with different pilot overhead to A.2.3	1.2.0	1.2.1
02-2004	RAN1 #36	R1-040346			Changes of 1.2.1 approved by RAN1 #36	1.2.1	1.3.0
02-2004	RAN1 #36	R1-040264			Short term LL performance of 2 ms TTI changed to A2.2.1	1.3.0	1.3.1
02-2004	RAN1 #36	R1-040265			Short term LL performance of 10 ms TTI added to A.2.2.2	1.3.0	1.3.1
02-2004	RAN1 #36	R1-040266			E-DCH Link Performance – BPSK vs. 8PSK added to 9.1.5	1.3.0	1.3.1
02-2004	RAN1 #36	R1-040267			System Performance with Full Buffer - E-DCH vs. Rel-99 changed in chapter 9.6.1.1	1.3.0	1.3.1
02-2004	RAN1 #36	R1-040268			System Performance with Traffic Models - E-DCH vs. Rel-99 changed in chapter 9.6.1.2	1.3.0	1.3.1
02-2004	RAN1 #36	R1-040269			Results on shorter frame size to 9.4.1	1.3.0	1.3.1
02-2004	RAN1 #36	R1-040172			On E-DCH scheduling, additional paragraph to 7.1.5.2	1.3.0	1.3.1
02-2004	RAN1 #36	R1-040350			R'99 short term FER table to A.2.4	1.3.0	1.3.1
02-2004	RAN1 #36	R1-040370			E-DCH System performance (rate control) to chapter 9.6.2	1.3.0	1.3.1
02-2004	RAN1 #36	R1-040337			Text correction to PAR section (9.5.1.1)	1.3.0	1.3.1
02-2004	RAN1 #36	R1-040271			Complexity aspects to chapter 9.5.1.2	1.3.0	1.3.1
02-2004	RAN1 #36	R1-040217			PAR Results to 9.5.1.1	1.3.0	1.3.1
02-2004	RAN1 #36	R1-040371			On shorter TTI complexity to chapter 9.4.2	1.3.0	1.3.1

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
02-2004	RAN1 #36	R1-040254			PAR maintaining backwards compatibility (tables 9.5.1.1.xc)	1.3.0	1.3.1
02-2004	RAN1 #36	R1-040347			E-DCH Timing considerations to chapter 8.5	1.3.0	1.3.1
02-2004	RAN1 #36	R1-040363			RAN2 input to chapters 10 (Joint RAN1/RAN2 session)	1.3.0	1.3.1
02-2004	RAN1 #36	R2-040409			DRAC description to chapter 6.4 (Joint RAN1/RAN2 session)	1.3.0	1.3.1
02-2004	RAN3 #41	R3-040257			RAN3 input to chapter 11, merged with RAN2 input in 363	1.3.0	1.3.1
02-2004	RAN1 #36	R1-040372			Conclusions and recommendations to chapter 12	1.3.0	1.3.1
02-2004	RAN1 #36	R1-040345			PAR result for backward compatibility cases (table 9.5.1.1.3b)	1.3.1	1.3.2
02-2004					Editorial correction to figure A-4, axis were wrongly scaled	1.3.1	1.3.2