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Technical Report

3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
Study on Dedicated Channel (DCH) enhancements for UMTS
(Release 12)

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Contents

Foreword

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1 Scope

The present document captures design options, evaluation results and analysis from the study item on "DCH enhancements for UMTS" described in [2].

The work under this study intends to capture the merits and feasibility of DCH Enhancements in terms of the reduction in the average required power per user on the downlink and the average RoT consumed on the uplink. An evaluation of the increase in UE data throughput in a mixed voice-data traffic scenario when DCH enhancements were applied is also conducted.

The following enhancements are considered in the study:

- DL Physical Layer Enhancements
    - DL DPCCH Slot Format Optimization
    - DL DPDCH Frame Early Termination
    - DL ACK Indicator design for UL FET
    - DPCH Time Domain Multiplexing
    - Reduced power control rate schemes
    - Node B DTX/UE DRX Mechanisms
- UL Physical Layer Enhancements
    - UL DPCCH Slot Format Optimization
    - UL Frame Early Termination
    - UL ACK Indication for DL Frame Early Termination
    - DTCH/DCCH time compression
    - Reduced power control rate schemes
    - UE DTX/Node B DRX mechanisms

Additionally, the following aspects are also investigated:

- UE Power Consumption Efficiency
- Impact on Network implementation
- Impact on UE implementation
- Impact on specifications

2 References

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

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] RP-122029: "Proposed study item on DCH enhancements for UMTS".

[3] "Enhanced HSDPA Mobility Performance: Quality and Robustness for VoIP Service", Qualcomm Inc. (http://www.qualcomm.com/media/documents/)

[4] 3GPP TS 25.212, "Multiplexing and channel coding (FDD)".

[5] R1-123809: "Introducing Enhancements to CS voice over DCH", Qualcomm Inc.

[6] R1-130513: "Scenarios for DCH enhancement", Huawei, HiSilicon.

[7] R1-131606: "Robustness of SRBs on HSPA, Nokia Siemens Networks.

[8] 3GPP TS 34.108: "Common test environments for User Equipment (UE); Conformance testing".[9] 3GPP TS 25.101: "User Equipment (UE) radio transmission and reception (FDD)".

[10] 3GPP TR 25.903: "Continuous connectivity for packet data users".

[11] 3GPP TS 25.214: "Physical layer procedures (FDD)".

[12] 3GPP TS 25.308: "High Speed Downlink Packet Access (HSDPA); Overall description; Stage 2".

[13] R2-123282: "Signaling radio bearers with Multiflow HSDPA", Nokia Siemens Networks.

[14] 3GPP TS 25.321: "Medium Access Control (MAC) protocol specification".

[15] 3GPP TS 25.211: "Physical channels and mapping of transport channels onto physical channels (FDD)".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in TR 21.905 [1] and the following apply.
A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

3.2 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply.
An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

BE	Best Effort
BLER	
DCH	Dedicated Channel
ET	Early Termination
ETI	Early Termination Indicator
FET	Frame Early Termination
S-DCH	Shared Dedicated Channel
TPC CER	Transmit Power Control Command Error Rate

4 DCH enhancements

4.1 UpLink (UL) physical layer enhancements

Uplink performance of DCH in UMTS system can be improved in several ways. A basic enhancement to UL DCH would be introduction of Frame Early Termination (FET). Since in UMTS R99 Circuit-Switched (CS) traffic, the target BLER for speech service is usually 1%, it is not always necessary to receive all slots within the TTI for a successful block decoding. Once the receiver successfully decodes the data (i.e. CRC passes), it may ask the transmitter to stop transmission immediately, i.e., even before the TTI ends, which reduces transmit power consumption without impact to the reception quality. A number of modifications in UL improve the chance of FET and UE's battery consumption. These modifications include for example changes to UL DPCCH slot format to maintain ILPC timeline, changes to TPC rate to accommodate ACK signalling, or compression/repetition in UL. In the following, solutions are presented that incorporate these modifications to improve UL DPCH performance.

4.1.1 UL Frame Early Termination (FET)

4.1.1.1 Option 1: Repetition of 10ms TTI frame

In this solution, the UL TTI is compressed and repeated twice to improve the chance of FET. Several other modifications are introduced to assist with FET. These modifications are described in this clause.

UL FET allows for termination of UL transmission and reception upon successful decoding of UL transport block at the Node-B. The Node-B receiver attempts to decode the UL transport block at multiple occasions within each TTI, prior to complete reception of the transport block. Upon successful decoding, the Node-B sends an ACK signal, allowing the UE to terminate (DTX) its UL DPDCH transmission. The UL DPCCH carries TPC bits required for DL DCH transmission; hence, UL DPCCH continues to be transmitted until the DL DCH transmission has also decoded early, after which UL DPCCH is also terminated.

4.1.1.1.1 Outer Loop Power Control (OLPC) algorithm in UL

In the UL, the OLPC is changed to assist FET by targeting an earlier slot during TTI. This is shown in Figure 4.1.1.1.1-1, where the parameter OLPC_TARGET_SLOT specifies the location within the entire transport block (combined repeated transport blocks) at which OLPC targets a specified BLER. The value of OLPC_TARGET_SLOT in this study is 14, i.e., targeting the end slot of the first block. OLPC updates the SIR target at the Node-B whenever a successful decoding attempt occurs for any transport channel (a CRC pass), or if decoding fails (no CRC pass) in all decoding attempts up to, and including, the final decoding attempt no later than specified by OLPC_TARGET_SLOT.

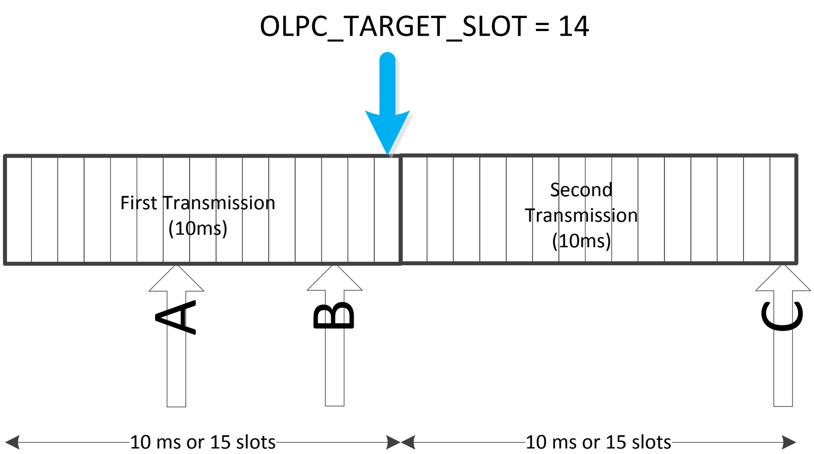


Figure 4.1.1.1.1-1: OLPC and multiple decoding attempts

For example, Figure 4.1.1.1.1-1 shows multiple decoding attempts marked as A,B,and C, with OLPC_TARGET_SLOT specifying location B within the transport block to target BLER. Table 4.1.1.1.1-1describes when OLPC is updated under different scenarios.

Table 4.1.1.1.1-1: OLPC Operation

Decoding Attempt A	Decoding Attempt B	Decoding Attempt C	OLPC SIR Update
CRC Pass	Not tried	Not tried	Update as a CRC Pass – immediately after A
CRC Fail	CRC Pass	Not tried	Update as a CRC Pass – immediately after B
CRC Fail	CRC Fail	CRC Pass	Update as a CRC Fail – immediately after B
CRC Fail	CRC Fail	CRC Fail	Update as a CRC Fail – immediately after B

4.1.1.1.2 UL DTCH/DCCH compression and repetition

To improve the probability of successful early decoding of UL packets, the uplink DTCH and DCCH packets are compressed and repeated twice. At the MAC layer, the packets received every 20ms (for DTCH) and 40ms (for DCCH) are repeated twice. The duplicate packets are passed to the physical layer, configured with a TTI value half of the original, i.e., DTCH packets are configured with 10ms TTI and DCCH packets are configured with 20ms TTI; see Figure 4.1.1.1.2-1. All physical-layer specific parameters like rate matching, 1st and 2nd layer interleaver parameters, spreading factor, etc. are derived from the configured 10ms or 20ms TTI values, according to the current 3GPP specification 3GPP TS 25.212 [4].

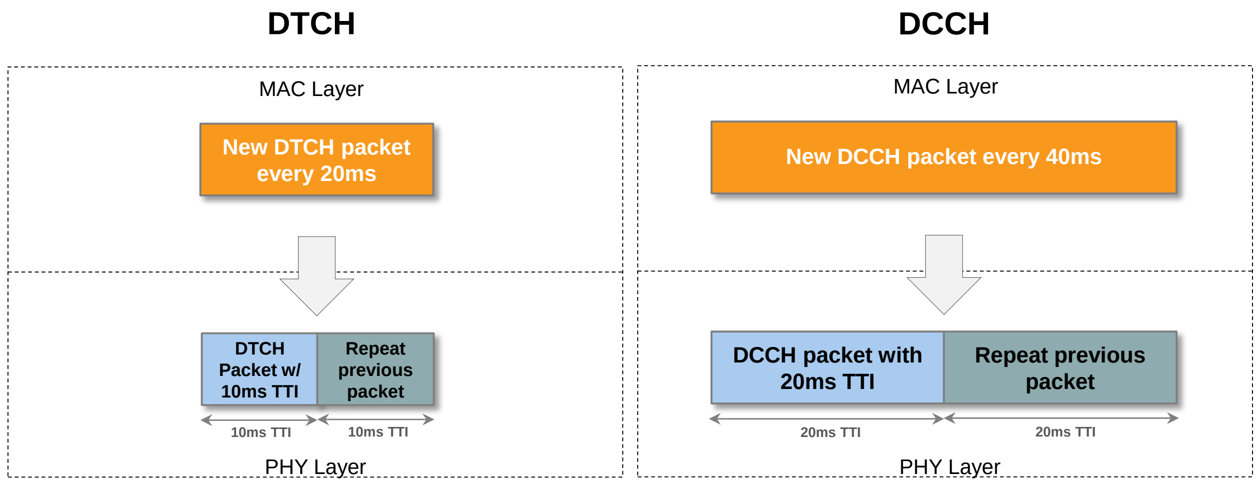


Figure 4.1.1.1.2-1: UL DTCH packet repetition at MAC layer

4.1.1.2 Option 2: New rate matching and interleaving chains

Once UE is informed the successful decoding by BS, it can stop remaining transmission before TTI ends to save transmit power. Early Termination Indicator (ETI) is transmitted every two slots in this example, and a positive value indicates successful decoding by the receiver. In case 750Hz transmit power control rate is used, the spare TPC bits can be used for conveying the ETI. Figure 4.1.1.2-1 shows an example of the early termination flow. As seen, the UE performs some decoding attempts and got a successful decoding. It then informs BS to stop remaining transmission by sending ACKs.

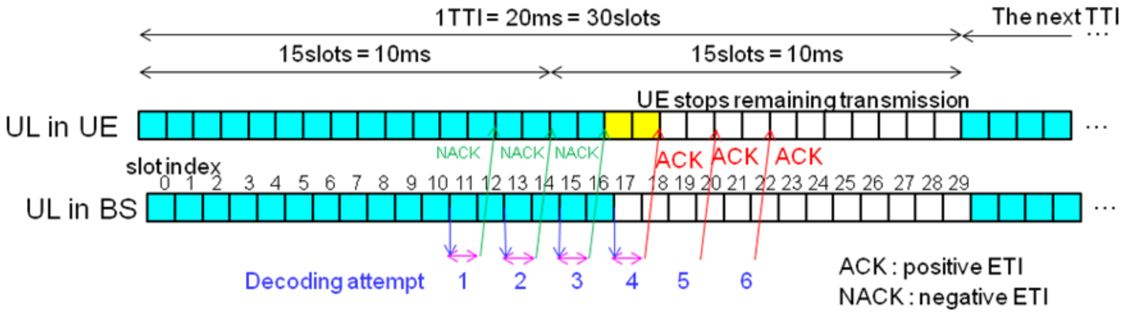


Figure 4.1.1.2-1: An example of UL data transmission with Early Termination (ET)

When both DL and UL data transmission are early terminated, DPCCH can be also terminated with negligible degradation of system performance. As shown in Figure 4.1.1.2-2, UE stops UL DPCCH transmission from slot 18 to slot 26. The period is called *ET gap*.

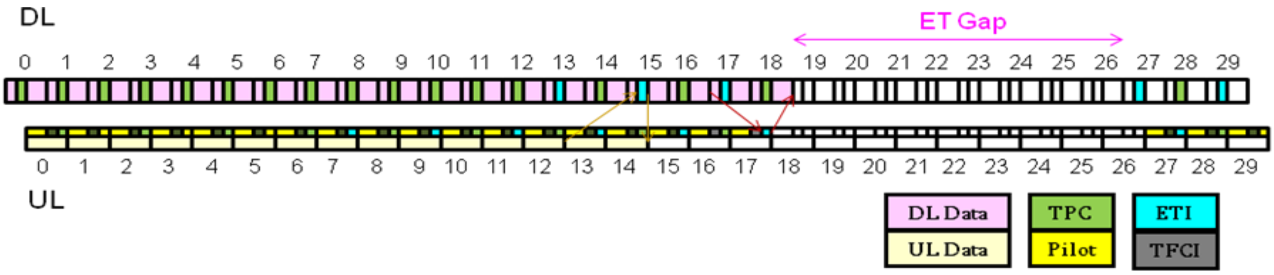


Figure 4.1.1.2-2: An example of ET Gap

4.1.1.2.1 Encoding procedure of UL Early Termination (ET)

An example of modified encoding procedure for CS links to facilitate early termination is illustrated in Figure 4.1.1.2.1-1. The details of each block are described in the following subclauses.

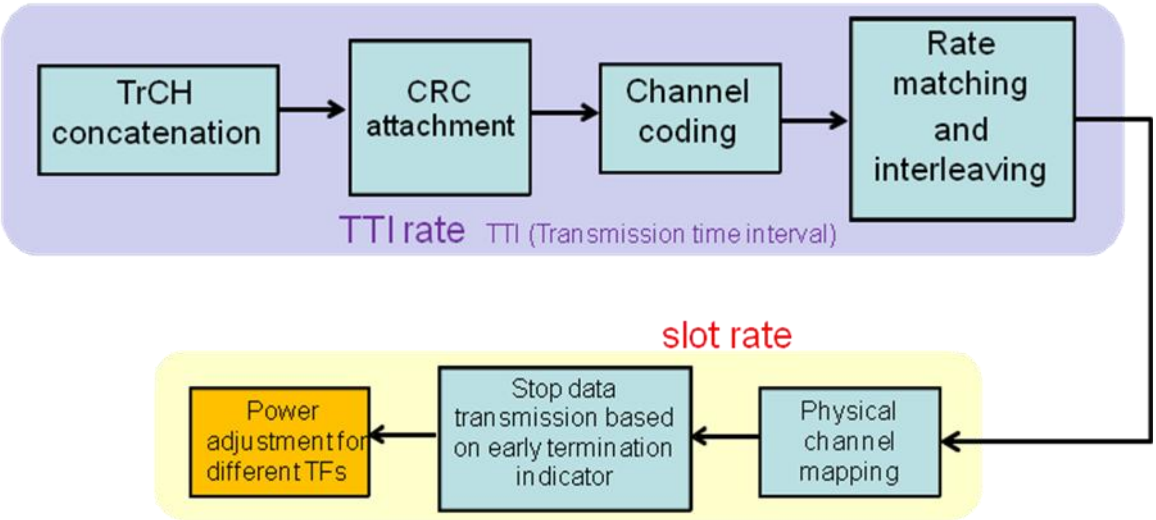


Figure 4.1.1.2.1-1: Block diagram of UL encoding procedure

4.1.1.2.2 Transport block concatenation for single TrCH

For the sake of a simpler encoding and decoding chain, the transport blocks usually carried on separate Transport Channels (TrCH) in current R99 are instead concatenated into a single transport block, carried on one single TrCH. For example, there are 4 TrCHs for AMR fixed 12.2k, as shown in Table 4.1.1.2.2-1.

Table 4.1.1.2.2-1: TrCHs for AMR fixed 12.2k

Logical channel type	DTCH Class A	DTCH Class B	DTCH Class C	DCCH
TTI(ms)	20	20	20	40

20ms TTI is applied in the above procedure. To simplify the procedure and to guarantee DCCH BLER, DCCH is transmitted twice within its 40ms TTI. When DCCH is transmitted, the four transport blocks are multiplexed into a single TrCH; otherwise the other three transport blocks are multiplexed together.

4.1.1.2.3 CRC attachment

TFCI-based transmission is commonly applied in UL. In legacy system, 12-bit CRC is attached to the TrCH for DTCH Class A. For the new TrCH described above, 16-bit CRC is suggested since it carries more information bits than the TrCH for DTCH Class A. In case of speech muting (i.e. no information bits to be transmitted), CRC is not attached due to TFCI-based transmission. It is noted that TFCI early decoding has to be implemented in Node-B to realize early termination.

4.1.1.2.4 Channel coding

The R99 convolutional code is reused for the modified encoding chain.

4.1.1.2.5 Rate matching and interleaving

Rate matching and interleaving mechanisms are modified and are illustrated in Figure 4.1.1.2.5-1.
The procedure is performed by TTI basis and there is no radio frame segmentation as in the current R99.
In the legacy system, flexible spreading factor is applied. The smaller the spreading factor is, the more is the number of bits can be transmitted within a TTI, which implies more bits can be collected in an earlier stage to increase the chance of early termination. Simulation results show that a fixed spreading factor value of 32 is preferable by early termination. In this case, if the number of encoded bits is not greater than the number of available physical bits (i.e. the number of bits which can be transmitted by the used DPDCH), intra-coded-block interleaving is applied followed by repetition. The purpose is to transmit the first copy of the coded block as earlier as possible. On the other hand, if the number of encoded bits is greater than the number of available physical bits, puncturing is applied first followed by intra-coded-block interleaving. The puncturing mechanism in current R99 can be used, and the block interleaver of second interleaving in current R99 can be used for interleaving both in puncturing case and in repetition case.

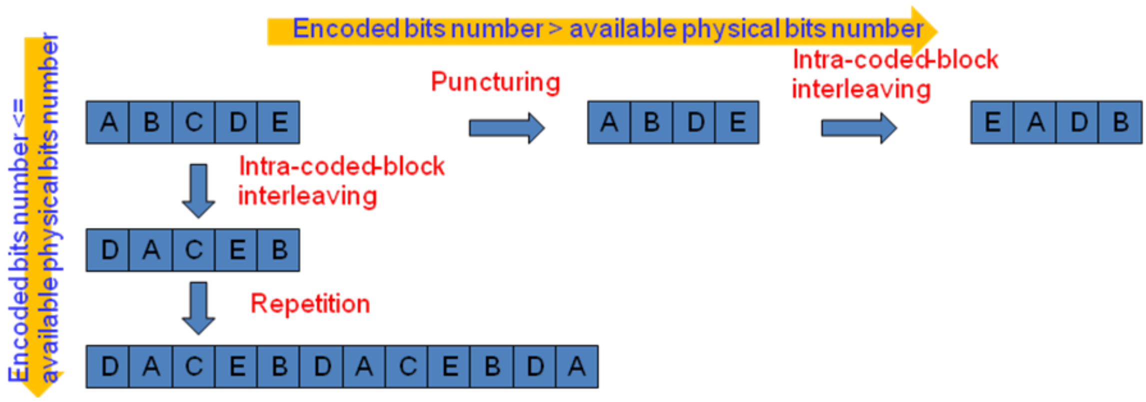


Figure 4.1.1.2.5-1: Rate matching and interleaving

4.1.1.2.6 Physical channel mapping

This follows the original R99 procedure including modulation and spreading.

4.1.1.2.7 Stop data transmission based on early termination indicator

This is the most important block for the early termination feature. Once UE is informed the successful decoding by BS, it can stop remaining transmission before TTI ends to save transmit power. Early Termination Indicator (ETI) is transmitted every two slots in this example, and a positive value indicates successful decoding by the receiver.
In case 750Hz transmit power control rate is used, the spare TPC bits can be used for conveying the ETI.
Figure 4.1.1.2.7-1 shows an example of the early termination flow. As seen, the UE performs some decoding attempts and got a successful decoding. It then informs BS to stop remaining transmission by sending ACKs.

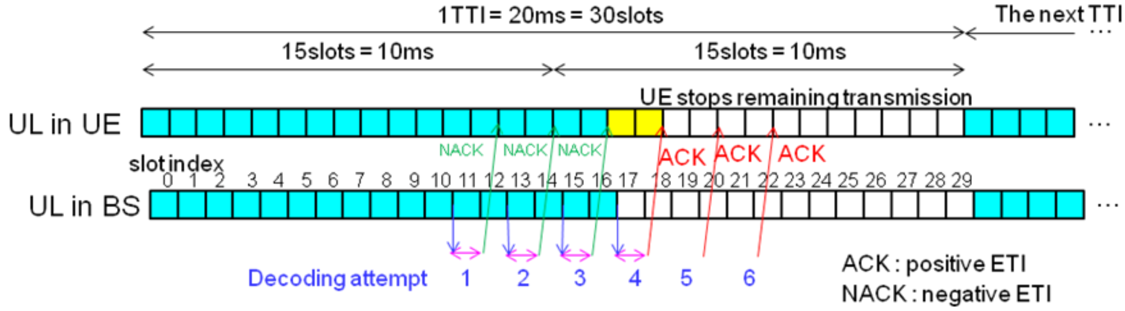


Figure 4.1.1.2.7-1: Example of UL data transmission with Early Termination (ET)

There are several advantages when the proposed early termination mechanism works with the optimized transmit power control rate as proposed. First, the spare TPC symbols in UL DPCCH due to slower TPC rate can be reused to convey the early termination indicators, so that there is no need of introducing a new uplink channel. Likewise in the uplink direction, when the spare TPC symbols in DL DPCCH are used for ETIs, these ETI symbols can also be used for DL SINR estimation when the optimized DPCH slot format is used so that there is no wasted power.

4.1.1.2.8 Power adjustment

Table 4.1.1.2.8 shows the DPDCH/DPCCH power ratio when early termination is used.

Table 4.1.1.2.8 : DPDCH/DPCCH power ratio

Packet	Null	SID	Full
β_d / β_c	0/15	7/15	14/15

4.1.1.2.9 Early Termination (ET) of both DL and UL data transmission

When both DL and UL data transmission are early terminated, DPCCH can be also terminated with negligible degradation of system performance. As shown in Figure 4.1.1.2.9, UE stops UL DPCCH transmission from slot 18 to slot 26. The period is called *ET gap*.

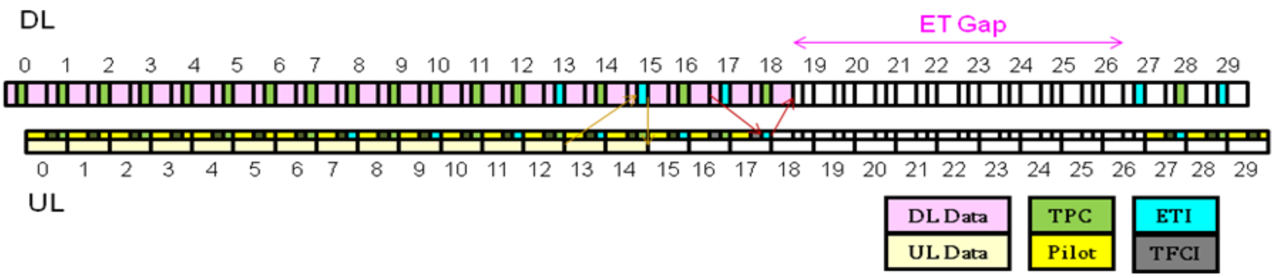


Figure 4.1.1.2.9: Example of UL data transmission with Early Termination (ET)

4.1.1.2.10 TFCI based transmission

The original TFCI (10, 32) code is still applied with early decoding. The maximum number of TFC for 12.2k services is 16, which means only 4 bits out of 10 TFCI bits are valid. When 4 bits are encoded to 32 bits, the probability of a successful decoding before the whole 32 bits are fully collected is quite high. Whenever BS tries to decode the data, it first performs early decoding for TFCI. This is called TFCI early decoding.

4.1.2 UL DPCCH slot format optimization

4.1.2.1 Option 1: Removing TFCI fields

To assist UL FET, TFCI information needs to be delivered to Node-B as early as possible. To this end, the TFCI is transmitted on a new channel during the first two slots of DPDCH TTI, in a format similar to the CQI transmission on HS-DPCCH. This new control channel, referred to as FET-DPCCH, reuses the design of HS-DPCCH, with the CQI being replaced by TFCI and the ACK being used to enable DL FET. This new channel implies that TFCI need not be carried on the UL DPCCH anymore, so UL DPCCH shall use slot-format 1, with 8 pilot bits and 2 TPC bits in each slot, and no TFCI bits.

UL DPCCH channel may also use a new slot format, called slot format 5, which is identical to slot-format 1 except that the two TPC bits are placed before, instead of after, the 8 pilot bits. The motivation for this enhancement is to preserve the ability to achieve 1 slot delay for the inner-loop power control (ILPC) in downlink, as explained in Figures 4.1.2.1-1 and 4.1.2.1-2. Slot format 5 is designed to maintain the ILPC timeline when dedicated pilots in the DL DPCCH channel are removed as part of a proposed DL DPCCH enhancement for DL overhead optimization.

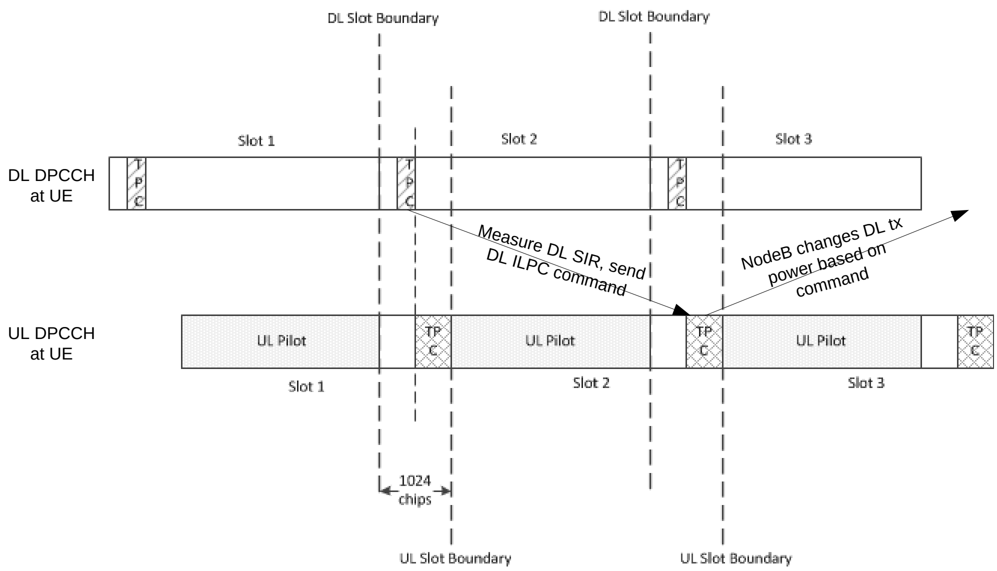


Figure 4.1.2-1: Extra slot of ILPC delay caused by TPC-based DL SIR measurement

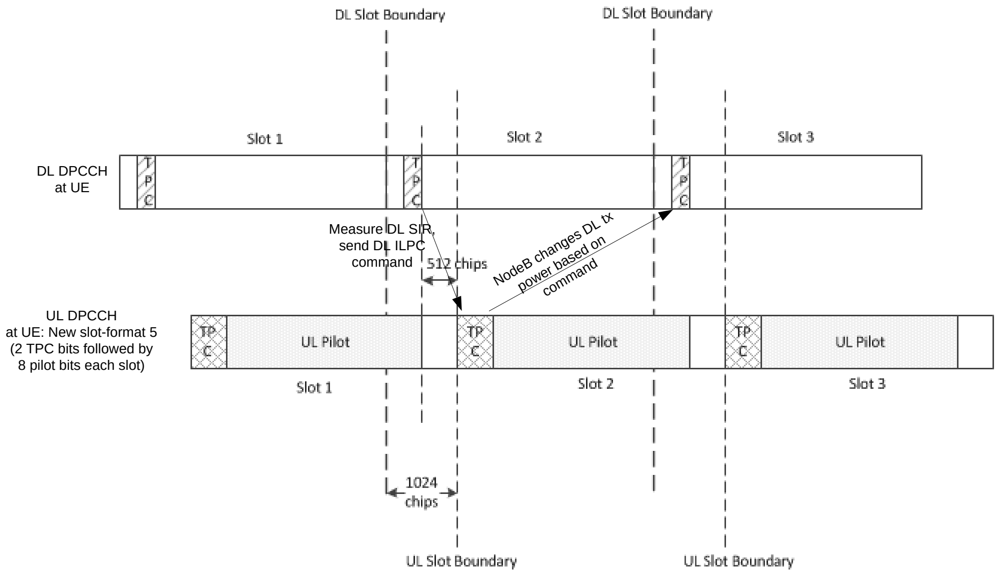


Figure 4.1.2-2: New UL DPCCH slot-format 5 and its use in achieving 1 slot DL ILPC delay

4.1.2.2 Option 2: Reusing legacy UL DPCCH slot format

With reduced TPC rate, the spared TPC fields in UL DPCCH can be reused for ACK and thus, the legacy UL DPCCH slot format can be reused.

4.1.2.3 Option 3: Relocation of TFCI fields

Alternatively, the TFCI information bits could be reduced to 5 to 7 bits and could be delivered to Node-B in the first 7 slots of UL DPCCH, while the FET ACK/NACK indication is transmitted in the remaining slots, as explained in clause 4.1.3.2. The slot format of UL DPCCH is identical to slot format 0A except that the TFCI information and the FET ACK/NACK indication are transmitted in a TDM manner within a 20ms TTI.

For this new uplink DPCCH format, the existing DPCCH slot format #0A in the Table 2 of 3GPP TS 25.211 [15] could be reused, except that the TFCI and the FET ACK are sharing the same field and that the transmitted slots per radio frame are extended to 15. The DPCCH fields for the new uplink DPCCH are re-captured in Table 4.1.3.2-1.

Table 4.1.2.3-1: DPCCH fields for new uplink DPCCH

Slot Format #i	Channel Bit Rate (kbps)	Channel Symbol Rate (kbps)	SF	Bits/ Frame	Bits/ Slot	N_{pilot}	N_{TPC}	N_{TFCI} / N_{ACK}	N_{FBI}	Transmitted slots per radio frame
0A	15	15	256	150	10	5	2	3	0	15

4.1.3 UL ACK indication for DL frame Early Termination (ET)

4.1.3.1 Option 1: New FET control channel

The FET-DPCCH is a new UL channel that reuses the structure of HS-DPCCH channel to carry TFCI information and the ACK signal for DL FET. The TFCI information is encoded using the (20,5) Reed Muller code currently used for CQI encoding in the HS-DPCCH channel, and is transmitted during the first two slots of DTCH TTI. Subsequent slots after TFCI is sent are dedicated to transmission of the ACK signal. This is illustrated in Figure 4.1.3.1-1. With the DL enhancement of 2-user TDM as described in clause 4.2.2, the DL packet only occupies a 10ms duration, and hence the Ack signal is not needed during the second 10ms duration of the UL packet.

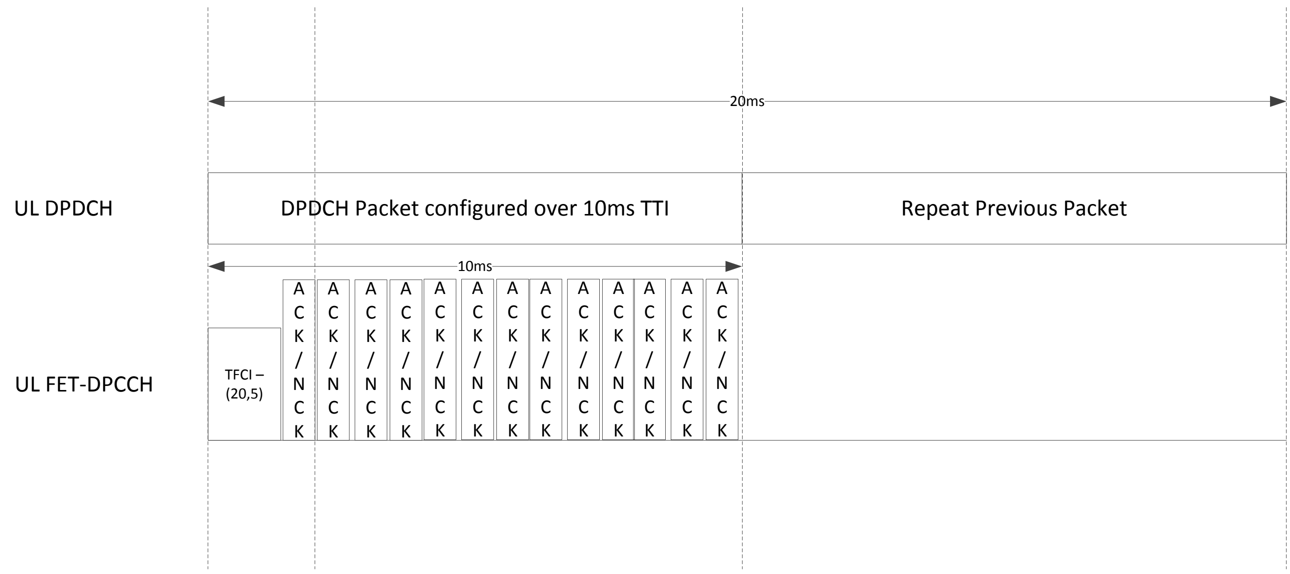


Figure 4.1.3.1-1: New UL control channel (FET-DPCCH)

4.1.3.2 Option 2: TDM of FET ACK and TFCI in DPCCH

An alternative approach to transmit the ACK message on the UL is to TDM the ACK message with UL PDCCH.
To this end, the new uplink DPCCH format described in clause 4.1.2.3 is used as depicted in Figure 4.1.3.2-1. The TFCI information and the FET ACK/NACK indication are transmitted in a TDM manner within a 20ms TTI, where the TFCI is transmitted to the Node-B as early as possible to assist DL FET, for example, in the first 7 slots while the FET ACK/NACK indication is transmitted in the remaining slots.

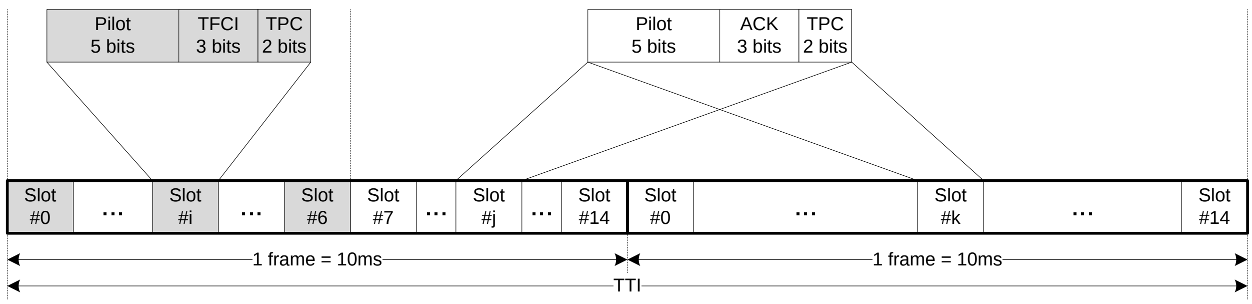


Figure 4.1.3.2-1: Frame structure for new uplink DPCCH

The relationship between the ACK pattern and FET ACK/NACK indication is presented in Table 4.1.3.2-2.

Table 4.1.3.2-2: ACK bit pattern for DPCCH

ACK bit pattern	FET ACK/NACK indication
111	ACK
000	NACK

The TFCI is encoded using a (20, 5) or (20, 7) code depending on the number of TFCI information bits.
The coding procedure is as shown in Figure 4.1.3.2-2.

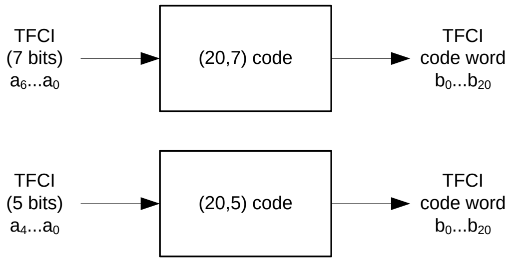


Figure 4.1.3.2-2: Channel coding of TFCI information bits

The code words of the (20, 5) code are a linear combination of the 5 basis sequences denoted $M_{i,n}$ defined in the Table 4.1.3.2-3 (same as the Table 15A of 3GPP TS 25.212 [4]). The code words of the (20, 7) code are a linear combination of the basis sequences denoted $M_{i,n}$ defined in the Table 4.1.3.2-4 (same as the Table 15C of [4]) for $n \in \{0,1,3,4,5,7,10\}$.

The TFCI information bits a_0, a_1, a_2, a_3, a_4 or $a_0, a_1, a_2, a_3, a_4, a_5, a_6$ (where a_0 is LSB and a_6 is MSB) correspond to the TFC index (expressed in unsigned binary form) defined by the RRC layer to reference the TFC of the CCTrCH in the associated DPCH radio frame.

The output code word bits b_i are given by:

for the (20, 5) code, $$b_i = \sum_{n=0}^{4} (a_n \times M_{i,n}) \bmod 2$$

for the (20, 7) code, $$b_i = \left(\sum_{n=0}^{1} (a_n \times M_{i,n}) + \sum_{n=2}^{4} (a_n \times M_{i,n+1}) + a_5 \times M_{i,7} + a_6 \times M_{i,10} \right) \bmod 2$$

where $i = 0, \ldots, 19$, and $b_{20} = 0$.

Table 4.1.3.2-3: Basis sequences for (20, 5) code

i	$M_{i,0}$	$M_{i,1}$	$M_{i,2}$	$M_{i,3}$	$M_{i,4}$
0	1	0	0	0	1
1	0	1	0	0	1
2	1	1	0	0	1
3	0	0	1	0	1
4	1	0	1	0	1
5	0	1	1	0	1
6	1	1	1	0	1
7	0	0	0	1	1
8	1	0	0	1	1
9	0	1	0	1	1
10	1	1	0	1	1
11	0	0	1	1	1
12	1	0	1	1	1
13	0	1	1	1	1
14	1	1	1	1	1
15	0	0	0	0	1
16	0	0	0	0	1
17	0	0	0	0	1
18	0	0	0	0	1
19	0	0	0	0	1

Table 4.1.3.2-4: Basis sequences for (20, 7) TFCI code

I	Mi,0	Mi,1	Mi,2	Mi,3	Mi,4	Mi,5	Mi,6	Mi,7	Mi,8	Mi,9	Mi,10
0	1	0	0	0	0	0	0	0	0	0	0
1	0	1	0	0	0	0	0	0	0	0	0
2	0	0	0	1	0	0	0	0	0	0	0
3	0	0	0	0	1	0	0	0	0	0	0
4	0	0	0	0	0	1	0	0	0	0	0
5	0	0	0	0	0	0	0	1	0	0	0
6	0	0	0	0	0	0	0	0	1	0	1
7	0	0	0	0	0	0	0	0	0	1	1
8	1	0	1	0	0	0	1	1	1	0	1
9	1	1	0	1	0	0	0	1	1	1	1
10	0	1	1	0	1	0	0	0	1	1	1
11	1	0	1	1	0	1	0	0	0	1	0
12	1	1	0	1	1	0	1	0	0	0	0
13	1	1	1	0	1	1	0	1	0	0	0
14	0	1	1	1	0	1	1	0	1	0	1
15	0	0	1	1	1	0	1	1	0	1	0
16	0	0	0	1	1	1	0	1	1	0	1
17	1	0	0	0	1	1	1	0	1	1	1
18	0	1	0	0	0	1	1	1	0	1	0
19	1	1	1	1	1	1	1	1	1	1	1

4.1.3.3 Option 3: FET ACK using spared TPC symbols

To realize early termination, Early Termination Indicator (ETI) is required. In case of 750Hz TPC rate, the spared TPC symbols are used to transmit ETI. An example of ETI feedback is illustrated in Figure 4.1.3.3-1. As seen, UE collects data slot 0 to slot 6 and performs BTFD. If the data is successfully decoded (i.e. CRC passed), a positive ETI is sent in UL DPCCH in slot 7 to inform Node-B to terminate DL data transmission. Otherwise, a negative ETI is sent in UL DPCCH in slot 7 to inform Node-B. The ETIs can be sent every two slots in UL DPCCH from slot 1 to slot 29.
An ETI feedback mask can also be defined to indicate which slots ETI can be sent in. For example, a feedback mask [7:2:27] means ETIs can be sent every two slots in slot 7 to slot 27, and the corresponding early decoding attempts occur every two slots starting from slot 6 to slot 26.

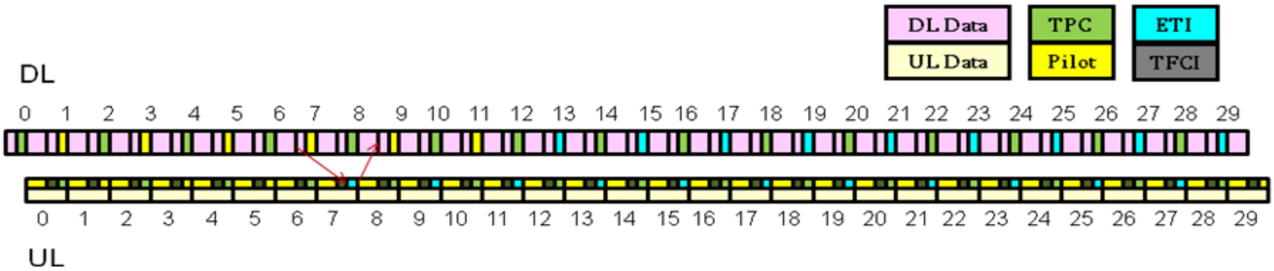


Figure 4.1.3.3-1: Example of ETI feedback for DL data transmission based on 750Hz TPC rate

In case of dynamic TPC Rate (i.e., TPC symbols are only replaced by ETI according to the defined ETI feedback mask), the TPC rate will not be constant. As shown in Figure 4.1.3.3-2, the ETI feedback mask is [7:2:27], and there is one period with TPC rate 1500Hz and the other one period with TPC rate 750Hz.

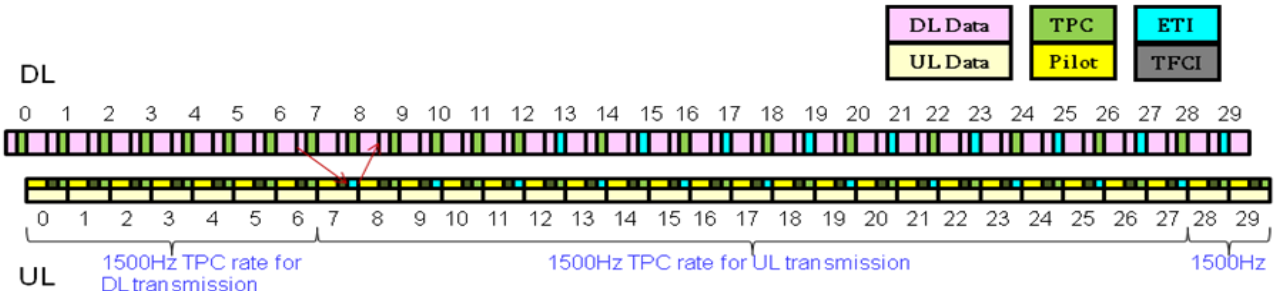


Figure 4.1.3.3-2: Example of ETI feedback for DL data transmission based on dynamic TPC rate

4.2 Downlink physical layer enhancements

4.2.1 Downlink Frame Early Termination (FET)

4.2.1.1 Option 1: Shortened TTI

A key aspect of the study item is frame early termination, which provides both link-efficiency and battery life improvements. On the downlink, decoding is attempted at several intermediate points in time prior to reception of the complete 10ms packet; eg, every slot starting after the 3rd slot. The initial slots are skipped since they contain insufficient data for successful decoding. The early decoding will often succeed, owing to the excess SNR inherent in a power-controlled link. On success, the UE sends an Ack signal to inform the Node-B to stop its DL DPDCH transmission, thus achieving link efficiency gain. The DL DPCCH carries TPC bits that are required by the UE to make uplink transmissions; hence the DL DPCCH continues to be transmitted. Note that when the new pilot-free slot-format is used for DL DPCH, the DL DPCCH only carries only the TPC bits, which occupy a small fraction of each slot. Hence the UE can obtain DRX battery life savings by waking up only to read these TPC bits. If the uplink voice frame has also been decoded early, even the DL DPCCH transmissions are unnecessary (assuming no other UL transmissions are needed; i.e., not in a multi-RAB call), and the entire DL DCH transmission can be DTXed. This allows further DRX battery savings as well as link-efficiency savings from reduced DL transmissions. In this situation, the DL DPCCH transmission is resumed a few slots prior to the start of the next DL voice packet, to allow the UE receiver filters to refresh their states on waking up from DRX.

4.2.1.1.1 DCCH indicator bit, choice of CRC length and transport channels

On the downlink, each DCCH packet is multiplexed with two DTCH packets as shown in Figure 4.2.4.1-2. Hence the DTCH may be decoded early while DCCH has not yet decoded. In this situation, the UE must avoid sending the Ack requesting Node-B to turn off the DL DPDCH, so as to avoid losing the DCCH packet. To assist the UE in recognizing this situation, a single DCCH indicator bit is appended to each DL DTCH packet prior to CRC attachment, as shown in Figure 4.2.1.1.1. Thus, the TBSs usually used with R99 voice on the DL must all be increased by 1 bit.
This bit is required because slot-formats for voice on downlink do not usually include TFCI signaling (i.e., UE uses BTFD), so there is no existing mechanism to identify whether DCCH is present. UE receiver-only mechanisms such as detecting energy in DCCH bits are likely to be unreliable, especially at the very early DTCH decode attempts.
The DCCH indicator bit is unnecessary on the uplink, since the uplink relies on TFCI transmission by UE rather than on blind transport format detection by Node-B receiver.

Early decoding increases the overall probability of false CRC pass, because there are multiple decoding attempts made, and a false CRC pass could happen on any of them, further false CRC passes are also more likely at earlier decoding attempts where there is less information available to the decoder. To combat this issue, a larger CRC size can be used. Currently AMR voice over DCH usually uses 12 bit CRC for DTCH and 16 bit CRC for DCCH. The 16 bit CRC could also be used for DTCH in order to support FET, on both the uplink and downlink.

Currently AMR voice frames consist of separate classes of bits (class A,B,C for AMR12.2K and class A,B for AMR5.9K), which are separately encoded and carried on separate transport channels, and CRC protection is used only for the class-A bits. If the same approach is used in conjunction with FET, the BER of the class B and C bits may be higher than that in current systems if the voice frame transmission is terminated upon successful early decoding of class-A bits. To avoid this problem, the class A,B and C bits are concatenated together and jointly encoded on a single transport channel, both on uplink and downlink.

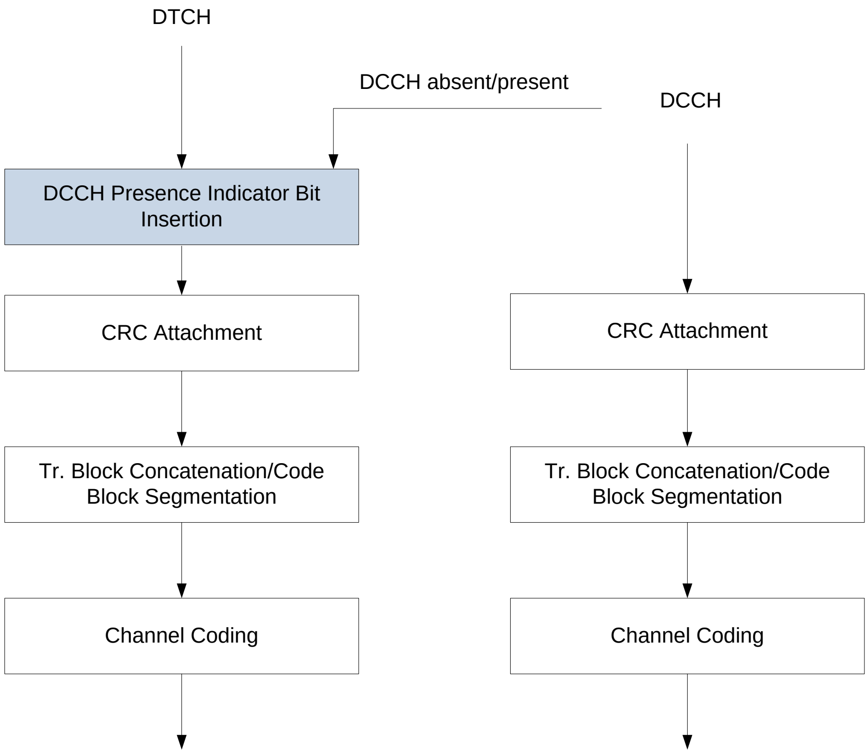


Figure 4.2.1.1.1: In-band signaling of DCCH presence/absence

4.2.1.2 Option 2: New rate matching and interleaving

For UMTS R99 circuit-switched traffic, the target BLER for speech service is at the order of 0.01. In most cases, it is not necessary to receive all slots within TTI for a successful block decoding. Once the receiver successfully decoded the data (i.e. CRC passed), it may ask the transmitter to stop transmission immediately before TTI ends, which reduces transmit power consumption but has no impact to the receiving quality. The mechanism is more power efficient and can support more Circuit Switched (CS) speech links simultaneously. In addition, CS links with Early Termination (ET) introduce less interference to other communication links and hence can contribute to the quality of HSPA services.

4.2.1.2.1 Encoding procedure of DL Early Termination (ET)

An example of modified encoding procedure for CS links to facilitate ET is illustrated in Figure 4.2.1.2.1-1. The following subclauses describe the detail of each block.

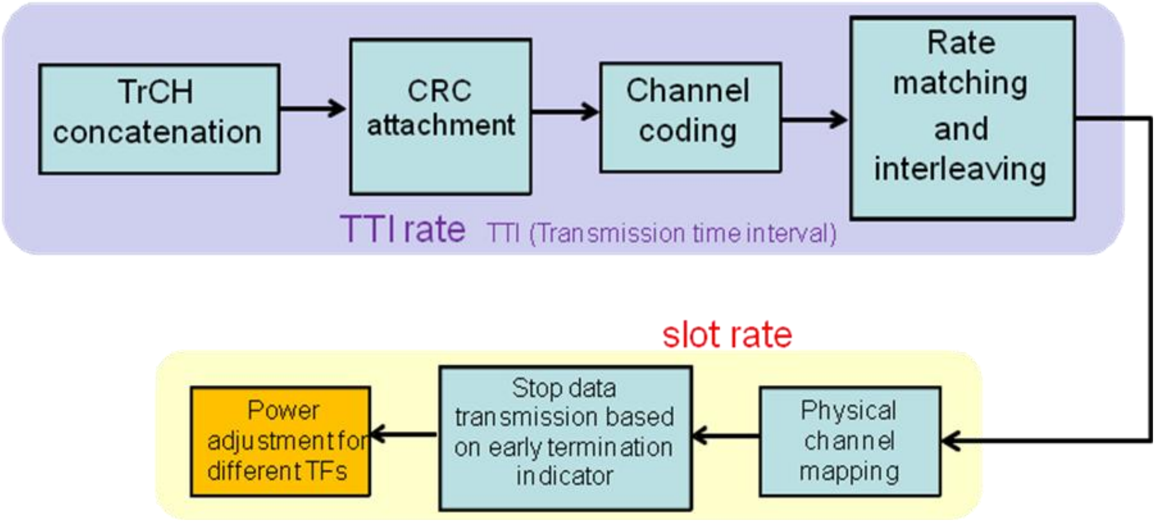


Figure 4.2.1.2.1-1: Block diagram of DL encoding procedure

4.2.1.2.2 Transport block concatenation for single TrCH

For the sake of a simpler encoding and decoding chain, the transport blocks usually carried on separate transport channels (TrCH) in current R99 are instead concatenated into a single transport block, carried on one single TrCH. For example, there are 4 TrCHs for AMR 12.2k, as shown in Table 4.2.1.2.2-1.

Table 4.2.1.2.2-1: TrCHs for AMR 12.2k over R99 DCH

Logical channel type	DTCH Class A	DTCH Class B	DTCH Class C	DCCH
TTI(ms)	20	20	20	40

20ms TTI is applied in the above procedure. To simplify the procedure and to guarantee DCCH BLER, DCCH is transmitted twice within its 40ms TTI. When DCCH is transmitted, the four transport blocks are multiplexed into a single TrCH; otherwise the other three transport blocks are multiplexed together.

4.2.1.2.3 CRC attachment

BTFD is suggested for the modified encoding chain because we observed that BTFD-based slot format is more power efficient compared to TFCI-based slot format. In this case, CRC is always attached for RX decoding. To achieve an acceptable false detection rate, 16-bit CRC is suggested. For the speech Mute case, i.e., there is no information bit to be transmitted, all the CRC are zero.

4.2.1.2.4 Channel coding

The R99 convolutional code is reused for the modified encoding chain.

4.2.1.2.5 Rate matching and interleaving

Rate matching and interleaving mechanisms are modified and are illustrated in Figure 4.2.1.2.5-1. The procedure is performed on a TTI basis and there is no radio frame segmentation as in the current R99. If the number of encoded bits is less than or equal to the number of available physical bits (i.e. the number of bits which can be transmitted by the used DPDCH), the intra-coded-block interleaving is applied and repetition is performed afterward. The purpose is to transmit the first copy of the coded block as earlier as possible. On the other hand, if the number of encoded bits is greater than the number of available physical bits, puncturing is applied and then intra-coded-block interleaving is performed. The puncturing mechanism in current R99 can be used, and the block interleaver of second interleaving in current R99 can be used for interleaving both in puncturing case and in repetition case.

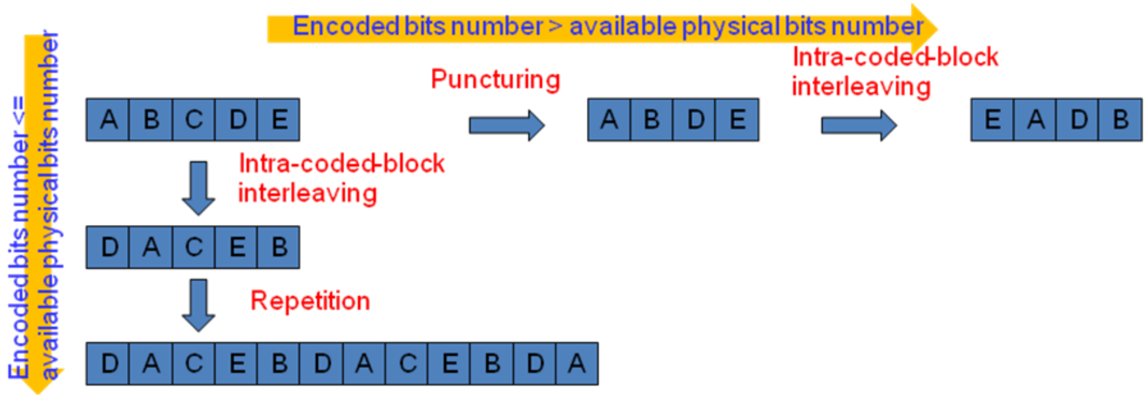


Figure 4.2.1.2.5-1: Rate matching and interleaving

4.2.1.2.6 Physical channel mapping

This follows the original R99 procedure including modulation and spreading.

4.2.1.2.7 Stop data transmission based on early termination indicator

This is the most important block for the early termination feature. Once BS is informed the successful decoding by UE, it can stop remaining transmission before TTI ends to save transmit power. Early Termination Indicator (ETI) is transmitted every two slots in this example, and a positive value indicates successful decoding by the receiver. In case 750Hz transmit power control rate is used, the spare TPC bits can be used for conveying the ETI.
Figure 4.2.1.2.7-1 shows an example of the early termination flow. As seen, the UE performs some decoding attempts and got a successful decoding. It then informs BS to stop remaining transmission by sending ACKs.

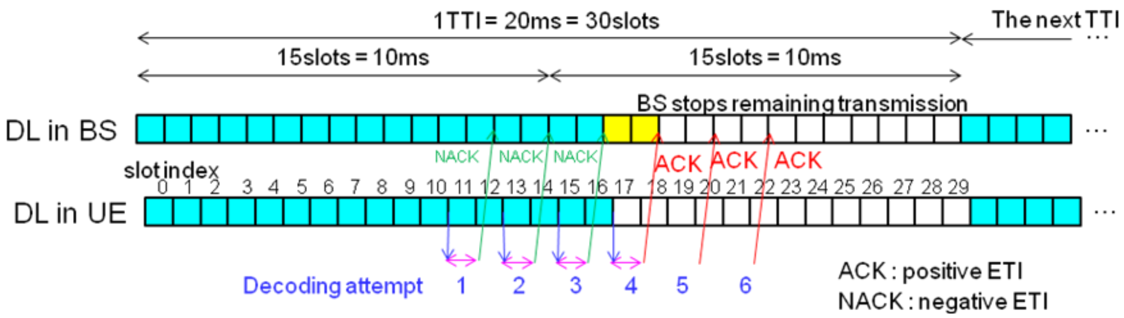


Figure 4.2.1.2.7-1: Example of DL data transmission with early termination

There are several advantages when the proposed early termination mechanism works with 750Hz transmit power control rate. First, the spare TPC symbols in UL DPCCH due to slower TPC rate can be reused to convey the early termination indicators, so that there is no need of introducing new uplink channel. Likewise in the uplink direction, when the spare TPC symbols in DL DPCCH are used for ETIs, these ETI symbols can also be used for DL SINR estimation when the optimized DPCH slot format is used so that there is no wasted power.

4.2.1.2.8 Power adjustment

In this example, DTX bits are not inserted into DPDCH and power adjustment is applied instead. The basic idea is to have more power on the coded block with more coded bits. The final applied DPDCH power is proportional to the number of coded bits. DPDCH power is maintained by power control. Based on packet types, different DPDCH power adjustment is introduced. The concept is similar to β_d/β_c in UL. Table 4.2.1.2.8-1 shows a DPDCH power adjustment example. For example, it is assumed X dB Ec/Ior is to be applied on DPDCH in specific slot in absence of DPDCH power adjustment. Based on this table, if packet type is Full, the adjusted DPDCH power is X dB. If the packet type is SID, the adjusted DPDCH power is (X-6.29), and if the packet type is Null, the adjusted DPDCH power is X-10.4 dB.

Table 4.2.1.2.8-1 : DPDCH power adjustment example

Packet	Null	SID	Full
DPDCH power adjustment (dB)	-10.48	-6.29	0

4.2.1.2.9 Early termination of both DL and UL data transmission

When both DL and UL data are early terminated, DPCCH can be also terminated with negligible degradation of system performance. As shown in Figure 4.2.1.2.9-1, BS stops UL DPCCH transmission from slot 19 to slot 26. The period is called *ET gap*.

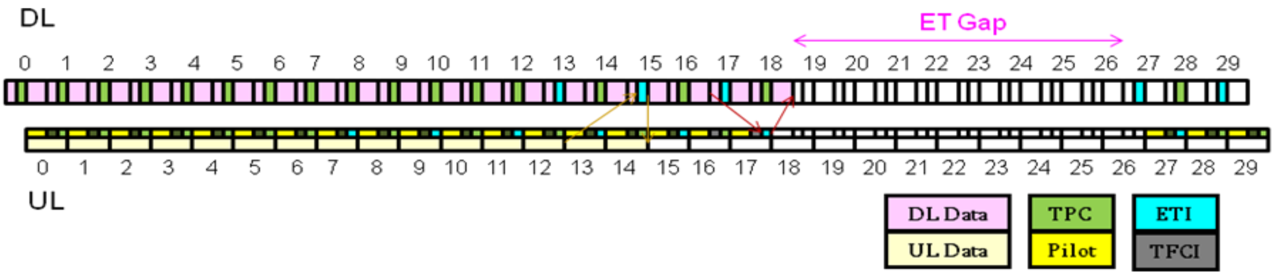


Figure 4.2.1.2.9-1: Example of DL data transmission with early termination

4.2.1.2.10 TFCI based or BTFD based transmission

BTFD-based transmission is the most popular in the legacy DL system and hence is also used in the proposed DL early termination scheme. In this case, BS tries every possible TFC candidates at each decoding attempt.
Note that DL ET is also feasible for TFCI-based transmission.

4.2.1.3 Option 3: Reusing legacy TTI

In clause 4.2.1.1 FET Option 1, DL transmission occurs over 10ms TTIs, and two users share the same spreading code. In this solution, the key difference is that DL transmission still uses 20ms TTIs. In comparison to FET Option 1, this approach does not require user pairing, at the expense of less gating opportunity for UE.
This solution follows mostly the principles outlined in other solutions, with specific changes to slot format, encoding, and rate matching as described in this clause.

The design uses 20ms TTI for voice frames, just as in current R99. The only change required to the current R99 slot-formats is to eliminate the pilot bits. The spreading factor in this design is the same as that in the current R99, as described in clause 4.2.2.1.

4.2.1.3.1 Joint encoding and FET

As in FET Option 1, the class-A,B and C bits in AMR full-rate frames are concatenated together and sent on a single transport channel; thus there are only two transport channels, one for DTCH (carrying voice frames) and one for DCCH (carrying SRB). Similar to FET Option 1, the DTCH uses 16-bit CRC and rate 1/3 convolutional encoding. In contrast to FET Option 1, however, the DCCH indicator bit in clause 4.2.1.1.1 is not required, due to a modification in the rate-matching scheme to be described next.

4.2.1.3.2 Pseudo-flexible RM: Sharing DCCH bits with DTCH

Currently voice over R99 downlink uses fixed Rate-Matching (RM), as a result of which the bit positions reserved for DCCH cannot be re-used by DTCH even when DCCH does not carry a transport block. This simplifies the complexity of BTFD procedure at the UE, since the transport-channel de-multiplexing operation does not need to be repeated for each BTFD hypothesis. Flexible rate-matching as defined in current R99 does allow some reuse of DCCH bit positions for DTCH when DCCH does not carry a transport block, but currently requires transmission of TFCI to avoid the extra BTFD complexity due to the loss of the above-mentioned simplification possible in fixed RM. Pseudo-flexible RM combines the merits of both the fixed and flexible RM schemes. In pseudo-flexible RM, the transmitter operation is similar to the current fixed-RM scheme, however the RM attributes used are different, depending on whether or not DCCH transport channel is present or not. Specifically, the RM attributes signalled to the UE as in current R99 are used when DCCH transport block is transmitted, whereas when DCCH is not transmitted, the RM attribute of the DCCH transport channel is set to zero. This is illustrated in Figure 4.2.1.3.2-1.

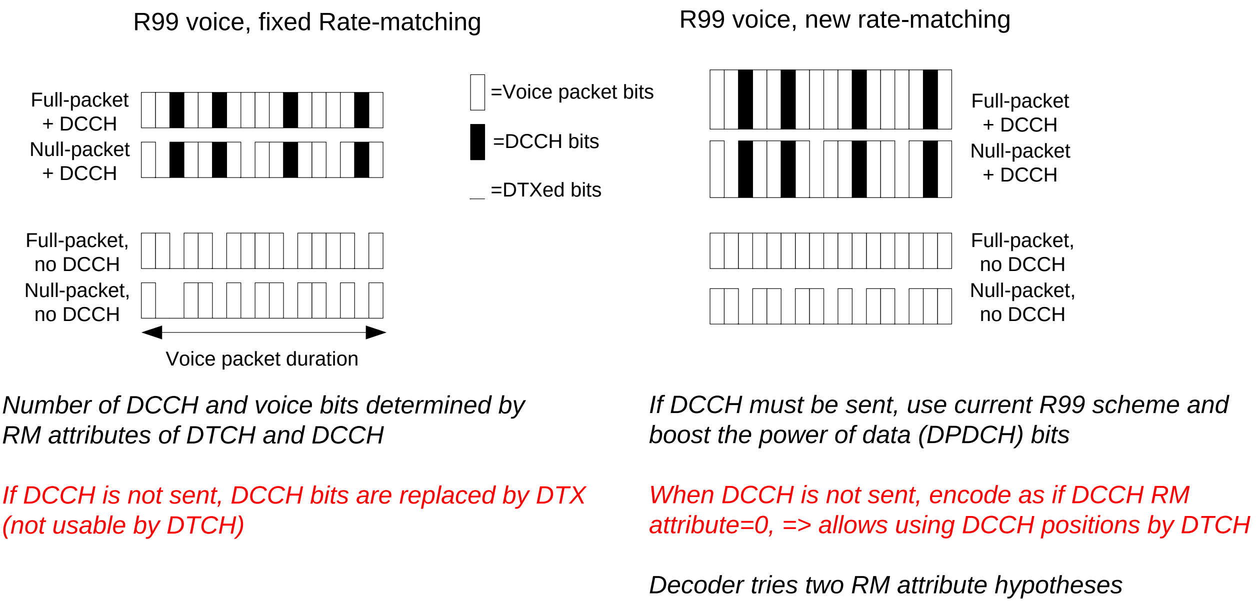


Figure 4.2.1.3.2-1: Comparing R99 fixed RM and pseudo-flexible RM

The advantage of pseudo-flexible RM is to allow using DCCH bit positions by DTCH when DCCH does not carry a transport block. This makes more DPDCH bits available to the voice packets, thus allowing increased repetition which improves performance of FET. At the same time, there is only a modest increase in UE decoding complexity:
The UE first decodes under the hypothesis that DCCH is absent, and if unsuccessful, repeats under the hypothesis that DCCH is present. If early decoding is attempted, the hypothesis that DCCH is present needs to be tested only at a subset of the early decoding attempts; eg, it could be tested only at the last attempt when the whole DTCH packet has been received. This is because under this hypothesis, both DTCH and DCCH must decode early for FET to be possible, and this is unlikely until most of the transmission has been completed. Since DCCH packet transmission is fairly rare (1-2%), the extra complexity of this scheme is small. Thus, BTFD is still possible and there is no need to signal the TFCI.

The DCCH presence indication bit as in FET Option 1 is not required, since the UE automatically detects whether or not the DCCH has been transmitted based on which of the two hypotheses succeeds. Thus there is no need for in-band signalling of DCCH presence via a DCCH-indicator bit appended to the DTCH packet as in clause 4.2.1.1.1.

4.2.2 DL DPCCH slot format optimization

A significant portion of power in downlink Circuit-Switched (CS) voice transmission over DCH is consumed on dedicated pilots, used for received Signal to Noise Ratio (SNR) measurements and power control. However, SNR measurements could also be performed on other control channel (DPCCH) or data channel (DPDCH) symbols, eg; using the TPC bits instead of pilots. This eliminates the need for dedicated pilots for power control. The freed-up pilot bit positions can be re-allocated to data bits. As shown in Figure 4.2.2 for a voice-only scenario, on the downlink, close to 24% of the total power profile is spent on transmitting dedicated pilots. Hence, significant improvements in link efficiency and inter-cell interference can be achieved by this enhancement. To this end, new slot-formats are defined in which pilot bits are eliminated.

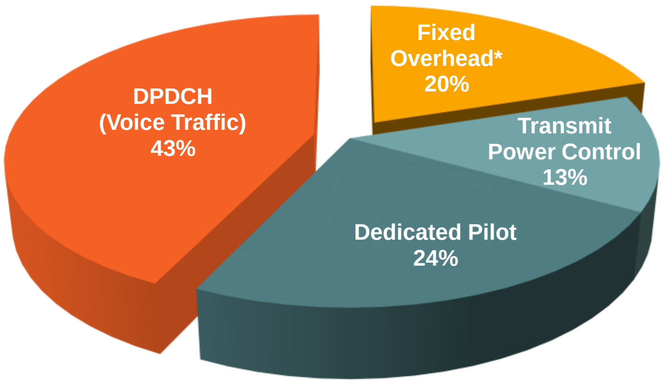


Figure 4.2.2: Distribution of DL transmit power when CS voice is transmitted on DCH. Fixed overhead includes common pilot and broadcast channels

4.2.2.1 Option 1: Removal of dedicated pilots

The design uses 20ms TTI for voice frames, just as in current R99. The only change required to the current R99 slot-formats is to eliminate the pilot bits. The spreading factor in this design is the same as that in the current R99. The new slot formats are described in Table 4.2.2.1.

Table 4.2.2.1: Enhanced DL DPCH slot formats

Vocoder	Slot Format #i	Channel Bit Rate (kbps)	Channel Symbol Rate (ksps)	SF	Bits/ Slot	DPDCH Bits/Slot		DPCCH Bits/Slot			Transmitted slots per radio frame
						N_{Data1}	N_{Data2}	N_{TPC}	N_{TFCI}	N_{Pilot}	N_{Tr}
AMR 5.9K	25	30	15	256	20	2	16	2	0	0	15
AMR 12.2K	26	60	30	128	40	6	32	2	0	0	15

4.2.2.2 Option 2: Removal of dedicated pilots and optimizing TPC field

The downlink DPCH (DL Dedicated Physical Channel) is a time multiplex of DL DPDCH (Dedicated Physical Data Channel) and DL DPCCH (Dedicated Physical Control Channel). DL DPCCH occupies considerable ratio of the DL DPCH. For example, in slot format #8, it is commonly observed in field trials that DPCCH occupies 15% of the slot. Therefore, the downlink DPCCH can be further optimized to improve the efficiency of data transmission. The existing design on DL DPCH slot format is tightly coupled with both downlink and uplink transmission power control. Therefore optimizations of the DPCH slot format shall take account of quality of SINR estimation, error rate of transmit power control command and round trip delay thereof, as described in the following sessions.

In this clause, 4 new DL DPCH slot formats (#17, #18, #19 and #20) are proposed, as shown in Table 4.2.2.2-1. The new slot formats are transformations of the legacy slot format #8 with pilot fields being removed, as illustrated in Figure 4.2.2.2-1.

Table 4.2.2.2-1: The proposed new DL DPCH slot formats

Slot Format #i	Channel Bit Rate (kbps)	Channel Symbol Rate (ksps)	SF	Bits/ Slot	DPDCH Bits/Slot		DPCCH Bits/Slot			Transmitted slots per radio frame
					N_{Data1}	N_{Data2}	N_{TPC}	N_{TFCI}	N_{Pilot}	N_{Tr}
17	60	30	128	40	6	32	2	0	0	15
18	60	30	128	40	4	32	4	0	0	15
19	60	30	128	40	38	0	2	0	0	15
20	60	30	128	40	36	0	4	0	0	15

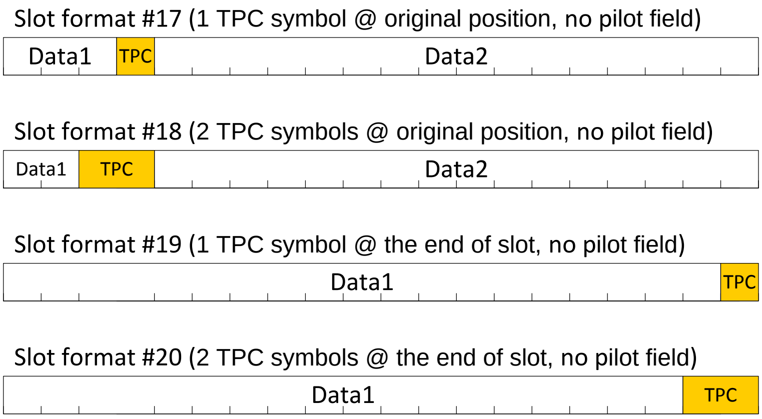


Figure 4.2.2.2-1: Illustration of the proposed new DL DPCH slot formats

Slot format #17 is a transformation of slot format #8 with pilot field being replaced by data2 field.

Slot format #18 is similar to slot format #17 but 2 TPC symbols are transmitted. Since the number of TPC symbols is doubled in slot format #18, the TPC power offset can be reduced by 3dB (compared with slot format # 17) to achieve similar link performance (i.e. TPC command error rate, DTCH BLER and required DL DPCH_Ec/Ior) as slot format #17. With such characteristic, slot format #18 reduces the Node-B transmit power variation across symbols and reduces the chance of being limited by the maximum transmit power of Node-B.

Once the pilot filed is removed, TPC bits are the only bits in the DPCCH for BTFD-based scenarios. The TPC field can also be located at the end of the slot, which produces slot format #19 and slot format #20.

Since the DL DPCH slot format is tightly coupled with downlink and uplink transmission power control, the downlink and uplink transmission power control loop are modified for the aforementioned new slot formats as described below.

Figure 4.2.2.2-2 illustrates the UL/DL TPC timing for slot format #8, which assumes 1 slot delay of DL TPC and 2 slot delay of UL TPC.

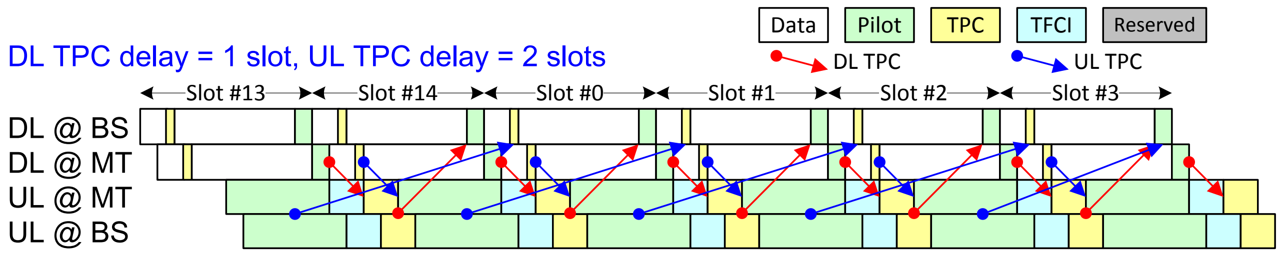


Figure 4.2.2.2-2: TPC timing diagrams for legacy DL DPCH slot format #8

Figure 4.2.2.2-3 illustrates the UL/DL TPC timing for slot format #17. The delay of DL TPC and UL TPC is 2 slots now since the position of TPC field remains unchanged.

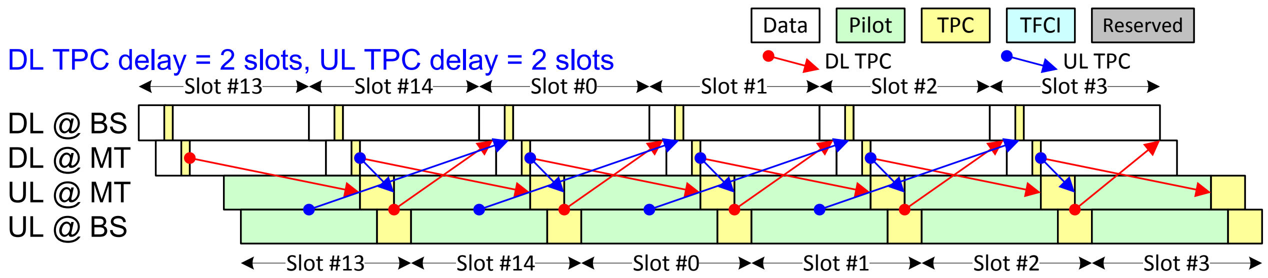


Figure 4.2.2.2-3: TPC timing diagrams for proposed new DL DPCH slot format #17

Figure 4.2.2.2-4 illustrates the UL/DL TPC timing for slot format #20. The DL TPC delay is 1 slot and UL TPC delay is 2 slots, which are the same as the legacy format.

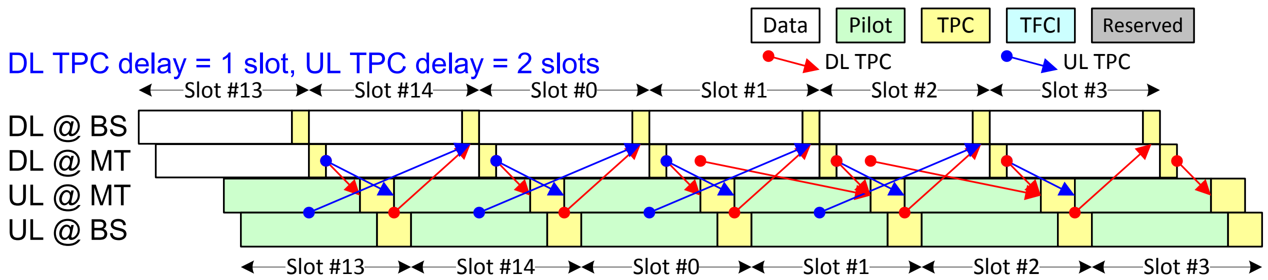


Figure 4.2.2.2-4: TPC timing diagrams for proposed new DL DPCH slot format #20

In case of slot formats #17 and #18, the DL DPCH power update occurs at the beginning of each slot. In case of slot formats #19 and #20, the DL DPCH power update starts at the TPC field which is located at end of each slot.

4.2.3 DL ACK indication for UL Frame Early Termination (FET)

4.2.3.1 Option 1: ACK as part of DL DPCCH

As a result of the DL enhancement of pilot-free slot-format, the DL DPCCH only carries TPC bits. A new field could be introduced in the DL slot-format to carry the Ack. This would increase the code-rate on the DTCH, but avoid having to reserve an OVSF code for the ACK channel. Alternatively, the ACK could be I-Q multiplexed with the TPC symbols, since the TPC symbols always have identical I and Q bits. In either case, the choice of modulation scheme for the ACK symbol – BPSK or on-off keying – should be investigated, based on the achieved UL FET statistics and the ACK power required in each case. The ACK transmit power is computed by applying a configurable offset to the DPDCH power, similar to the currently configured DPCCH/DPDCH power offsets. If a separate field is introduced in the DL slot format for ACK channel, then the choice of the width of this field must be studied. A longer ACK duration increases the ACK delay, which erodes the gains from UL FET, and also increases the impact on the code rate of DL DTCH, which could affect DL link efficiency. On the other hand, a shorter ACK duration could necessitate the use of unacceptably large ACK power offsets.

4.2.3.2 Option 2: ACK on a new code channel

This design option is similar to the current E-HICH design. A new code channel carries ACKs for multiple users, distinguished by orthogonal signature sequences. This avoids impact to DL DTCH code rate that results from TDM-ing the ACK with TPC on the DL DPCCH, at the cost of an extra code channel, which is however shared among multiple users. The current E-HICH spans 2ms or 8ms duration depending on the E-DPDCH TTI. However, the E-DPDCH HARQ structure allows the E-HICH to be transmitted in the intervals between successive HARQ transmissions, whereas there are no such intervals on the UL DPDCH. Hence, a longer duration ACK increases the ACK delay and lowers the link gains from UL FET, thus even 2ms ACK duration may be unacceptably long. Thus, alternatives such as a 1-slot or 2-slot ACK could be considered. It is also possible to consider shorter ACKs, for example, a half-slot ACK, that would use a new set of 20 orthogonal signature sequences instead of the current 40 sequences used by E-HICH and E-RGCH. This channel could still support 40 users, TDM-ed across the first and second half of each slot.

4.2.3.3 Option 3: ACK using spared TPC symbols

To realize early termination, early termination indicator (ETI) is required. In case of 750Hz Transmit Power Control (TPC) rate, the spared TPC symbols are used to transmit ETI. Figure 4.2.3.3-1 illustrates an example of how the ETI feedback works for UL data transmission. In this example, BS collects data slot 0 to slot 10, performs TFCI-based or BTFD-based ET procedure. Once the data is successfully decoded, a positive ETI is sent in DL DPCCH in slot 13 to inform UE that UL data can be terminated. Otherwise, a negative ETI is sent in DL DPCCH in slot 13 to inform UE. The ETIs can be sent every two slots in DL DPCCH from slot 1 to slot 29. An ETI feedback mask can also be defined to indicate which slots ETI can be sent in. For example, a feedback mask [13:2:29] means ETIs can be sent every two slots in slot 13 to slot 29, and the corresponding early decoding attempts occur every two slots starting from slot 10 to slot 26.

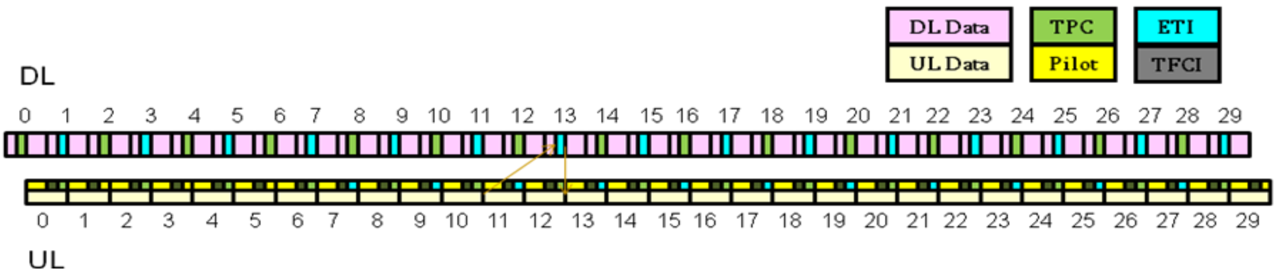


Figure 4.2.3.3-1: Example of ETI feedback for UL data transmission based on 750Hz TPC rate

In case of dynamic TPC Rate i.e., TPC symbols are only replaced by ETI according to the defined ETI feedback mask, the TPC rate will not be constant. As shown in Figure 4.2.3.3-2, the ETI feedback mask is [13:2:29], and there is one period with TPC rate 1500Hz and the other one period with TPC rate 750Hz.

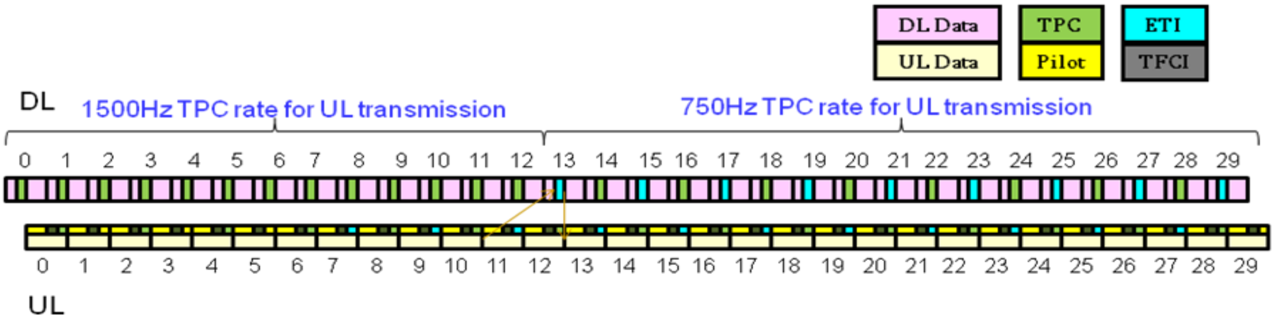


Figure 4.2.3.3-2: Example of ETI feedback for UL data transmission based on dynamic TPC rate

4.2.4 DPCH Time Domain Multiplexing (TDM)

4.2.4.1 Option 1: TDM at TTI Level

A key aspect of the study item is frame early termination, which provides both link-efficiency and battery life improvements. An important enhancement to enable these gains on the downlink is the design in which two users are time-division multiplexed onto a single channelization code. This allows for transmitting a packet over a shorter time period, which combined with the uplink enhancements, results in significantly shorter active transmission periods, thus, less inter- and intra-cell interference due to concurrent active transmissions. Figure 4.2.4.1-1 shows user pairing in DL using new DL DPCH slot formats. Here, pairs of slot formats are used to DTX one user while the other user performs full transmission, in alternate turns. The TPC symbols for the two users are TDM-ed in each slot.
This allows TPC to be continuously sent to each user, while DPDCH is only sent in alternate 10ms radio frames.
The reduction of TTI for voice packets from 20ms to 10ms is achieved by halving of the Spreading Factor (SF) used in R99, thus preventing excessive puncturing that would result if the same spreading factor was used. However, overall code-space utilization is kept unchanged since two voice UEs share each OVSF code. Table 4.2.4.1-1 shows the new slot-formats 17 through 20 thus created to serve as an enhanced replacement for the current slot-format 2, achieving both the goals of pilot-free slot format and TDM-ing of two users on a single OVSF code. In Figure 4.2.4.1-1, UE1 uses slot-format 17 in the first 10ms and slot-format 18 in the next one, while UE2 uses slot-format 20 in the first 10ms and slot-format 19 in the next one. The halving of the SF also halves the DCCH TTI from 40ms to 20ms. Each DCCH packet is multiplexed with two consecutive DTCH packets which are transmitted in two 10ms frames separated by a 10ms DPDCH transmission gap, as explained in Figure 4.2.4.1-2. The new slot-formats 21 through 24 in Table 4.2.4.1-1 are designed to serve as an enhanced replacement for the current slot-format 8, just as slot-formats 17 through 20 serve to replace the current slot format 2.

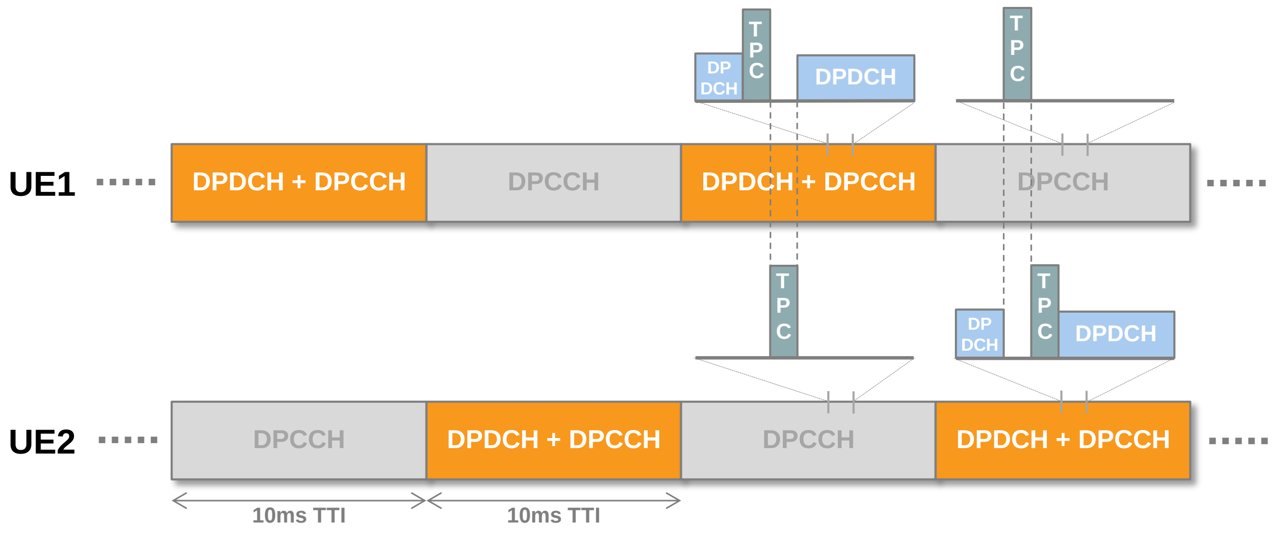


Figure 4.2.4.1-1: Time-Division Multiplexing of two UEs on a single channelization code

Table 4.2.4.1-1: Enhanced DL DPCH slot formats

Vocoder	Slot Format #i	Channel Bit Rate (kbps)	Channel Symbol Rate (ksps)	SF	Bits/ Slot	DPDCH Bits/Slot		DPCCH Bits/Slot			Transmitted slots per radio frame N_{Tr}
						N_{Data1}	N_{Data2}	N_{TPC}	N_{TFCI}	N_{Pilot}	

AMR 5.9K	17	60	30	128	40	4	32	4, last 2 are DTXed	0	0	15
AMR 5.9K	18	60	30	128	40	4 DTX	32 DTX	4, last 2 are DTXed	0	0	15
AMR 5.9K	19	60	30	128	40	4	32	4, first 2 are DTXed	0	0	15
AMR 5.9K	20	60	30	128	40	4 DTX	32 DTX	4, first 2 are DTXed	0	0	15
AMR 12.2K	21	120	60	64	80	12	64	4, last 2 are DTXed	0	0	15
AMR 12.2K	22	120	60	64	80	12 DTX	64 DTX	4, last 2 are DTXed	0	0	15
AMR 12.2K	23	120	60	64	80	12	64	4, first 2 are DTXed	0	0	15
AMR 12.2K	24	120	60	64	80	12 DTX	64 DTX	4, first 2 are DTXed	0	0	15

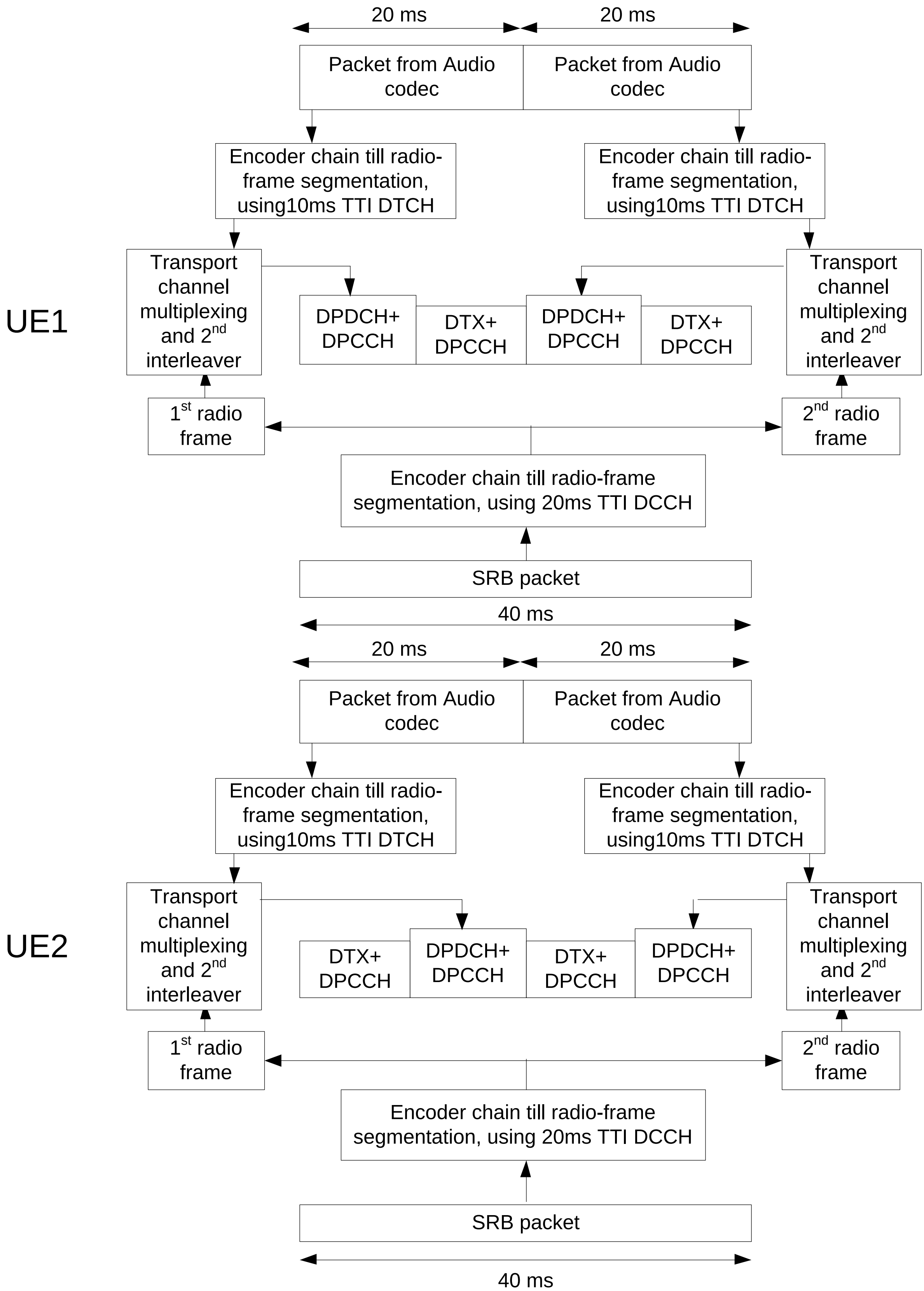


Figure 4.2.4.1-2: Multiplexing of DTCH and DCCH for two UEs sharing a single channelization code

4.2.4.2 Option 2: TDM at slot level

Technologies such as Receive Diversity (RxD), interference cancellation, and the DCH enhancements mentioned thus far have been proved to significantly reduce the required transmit power and allow base station to support more and more active users simultaneously. However, the maximum number of supported users per cell is also constrained by the channelization (OVSF) code resource. In current specification, one user occupies one OVSF code, and with the maximum spreading factor (SF) of 256 the maximum number of CS voice users per scrambling code is 256 (not considering control channels, HSPA services and other 3G services). In reality, for the sake of smaller power allocation, spreading factor 128 is the most common setting for AMR+DCCH applications, which means an even tighter constraint on the cell capacity(i.e. less than 128 users per cell).

The use of secondary scrambling code is one remedy in the current specification to address the above issue. However, due to non-orthogonality between the two scrambling codes, huge interference is introduced between users on primary scrambling code and secondary scrambling code.

Assuming all channelization codes can be used for voice transmission, the effective number of CS voice users per scrambling code is 128 (128 codes x 1 user/code) when SF128 is used. However, if one SF64 code is shared by 3 users, the number of effective users becomes 192 (64 codes x 3 users/code), which means one scrambling code can support 192 users without loss of OVSF code orthogonality. The code rate loss is roughly $3/(128/64) = 1.5 \approx 1.76$dB, which can be compensated by removing the dedicated pilot fields. Although the opportunity of data transmission for one user is now once per 3 slots, the control part can still be transmitted at each slot to guarantee a smooth uplink control. The concept of time-slot division for 3 users is illustrated in Figure 4.2.4.2-1.

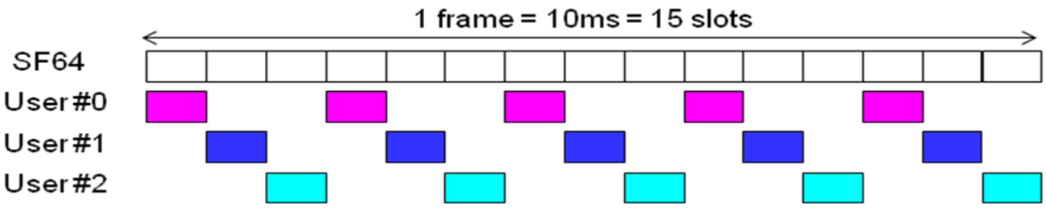


Figure 4.2.4.2-1: Illustration of time-slot division for 3 users in 1 channelization code with SF=64

In reality, control channels also occupy the channelization code resource. Assuming one SF16 code is reserved for the common control channels, for legacy system the effective number of CS voice users per scrambling code now becomes 128 -8 = 120 (assuming no HSPA users). With TDM, the number of effective users becomes 120x3/2=180.

When considering HSDPA service as well and assuming 10 SF16 codes are reserved for HSDPA users, for legacy system the effective number of CS voice users per scrambling code becomes at most 40. With TDM the number of maximum effective users can increase to 40x3/2 = 60 users.

New DL DPCH slot formats are proposed to facilitate DPCH TDM as shown in Table 4.2.4.2-1 and Figure 4.2.4.2-2.

Table 4.2.4.2-1: New DL DPCH Slot Formats with TDM

Slot Format #i	SF	DPDCH Bits/Slot		DPCCH Bits/Slot	Transmitted slot index per radio frame
		N_{Data1}	N_{Data2}	N_{TPC}	
21	64	12	62	6, last 4 are DTXed	{0,3,6,9,12}
		12 DTX	62 DTX	6, last 4 are DTXed	{1,2,4,5,7,8,10,11,13,14}
22	64	12	62	6, first 2 and last 2 are DTXed	{0,3,6,9,12}
		12 DTX	62 DTX	6, first 2 and last 2 are DTXed	{1,2,4,5,7,8,10,11,13,14}
23	64	12	62	6, first 4 are DTXed	{0,3,6,9,12}
		12 DTX	62 DTX	6, first 4 are DTXed	{1,2,4,5,7,8,10,11,13,14}

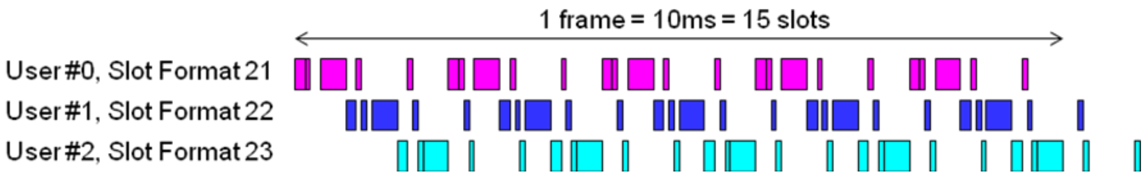


Figure 4.2.4.2-2: Illustration of DL DPCH slot formats for TDM of three users

4.2.5 Considerations of frame timing for DPCH Time Domain Multiplexing solutions

4.2.5.1 Background

The DL timing for a user can be one out of 150 positions relative to the frame timing, as shown in Figure 4.2.5-1.

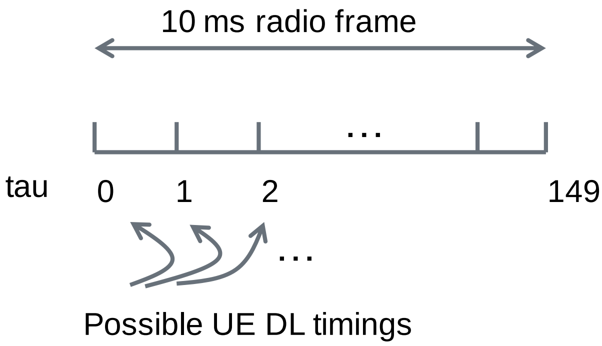


Figure 4.2.5-1: DL timing positions (3GPP TS 25.212 [4])

For a user changing from one cell to the other the DL timing as well as the UL timing of the previous cell will be inherited in the new cell, as shown in Figure 4.2.5-2.

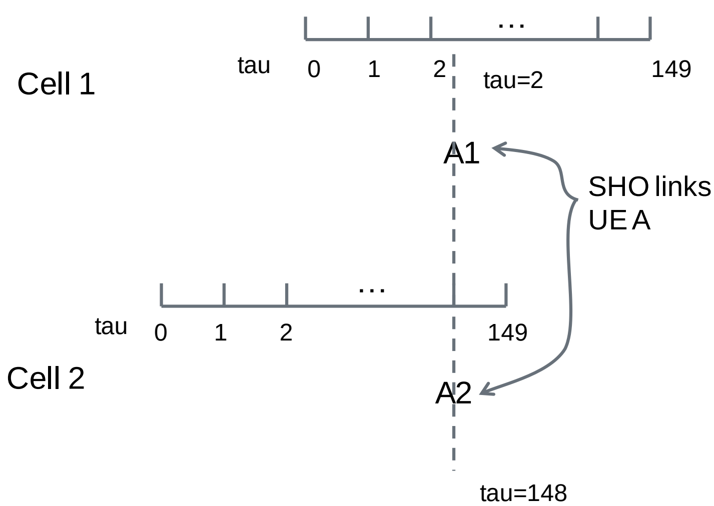


Figure 4.2.5-2: DL timing in a new cell when a user A is handed over from cell 1 to cell 2

4.2.5.2 Pairing of users

In user pairing as proposed in clause 4.2.4.1 or clause 4.2.4.2, two or three users may be using the same DCH spreading code. This operation is transparent to the users, as they are configured by the RNC to use certain TF and are not aware of the paired user. The RNC is responsible for establishing paired users, and giving paired users the same frame timing. An obvious approach for the RNC to find pairable users is to configure only new users entering CELL_DCH state with a timing which is fitting an already active unpaired user. Another approach would be to perform a radio bearer reconfiguration for an already active user. The latter solution is considered to be impractical, given the associated signalling overhead for the network and the impact on user experience because of user-plane interruptions.

In the following, a quantitative analysis of the possibility to execute pairing of frame-timings is provided. The analysis is carried out for pairing of two and of three users. A pessimistic scenario where the RNC has no possibility to choose frame timings is examined first. The second scenario provides for more realism by showing the possibilities when users are emerging in a cell and can be given suitable frame timings by the RNC.

4.2.5.2.1 Pairing of long-lived users

Assuming that all users in a cell have entered the cell by way of HO with random timing, the amount of users that can be paired or remain unpaired is shown in Figure 4.2.5-3. As in this scenario no new calls are placed that allow the RNC to choose an arbitrary frame timing, the ability of the RNC to create user pairings is limited to the cases where two UEs happen to have the same timing.

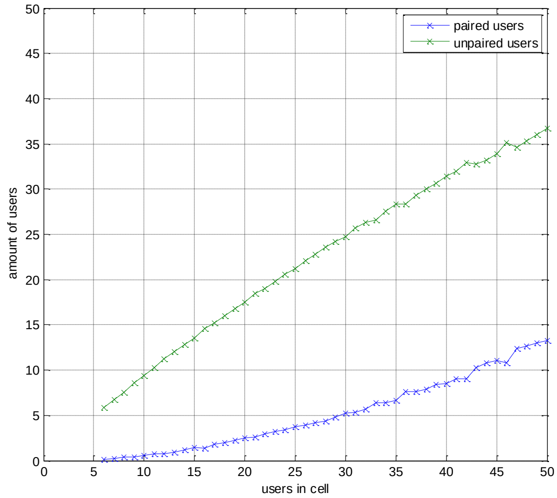


Figure 4.2.5-3: Number of paired and unpaired users. Up to two users are paired

It can be see that for e.g. 50 concurrent voice users only 6-7 pairs can be formed, while 37 users remain unpaired, leading to a wastage of half as many SF128 codes. The corresponding amount of lost SF 16 codes compared to perfect pairing is shown in Figure 4.2.5-4.

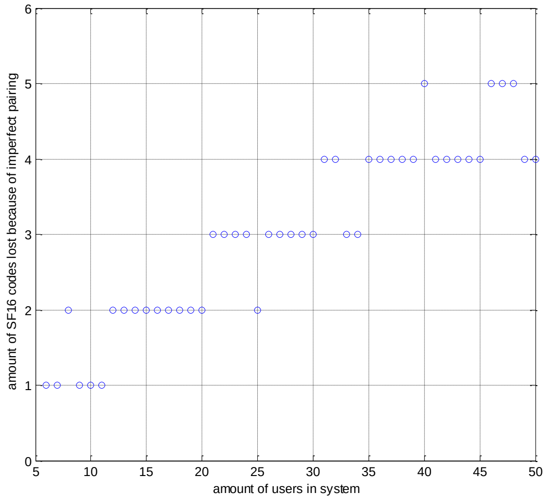
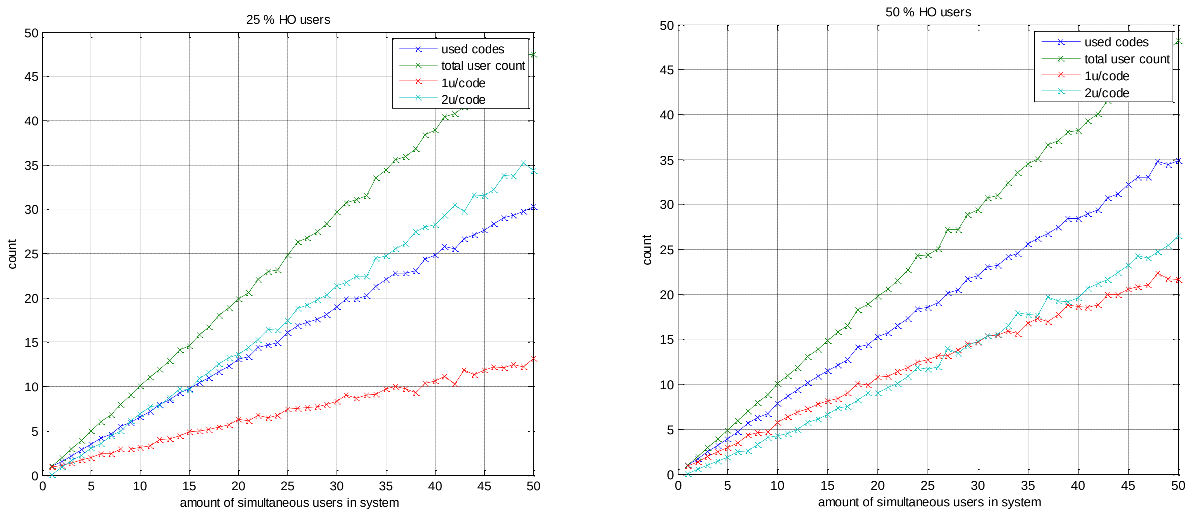


Figure 4.2.5-4: Number of SF16 codes lost because of imperfect pairing (pairing of up to two users was considered)

4.2.5.2.2 Pairing of short-lived users

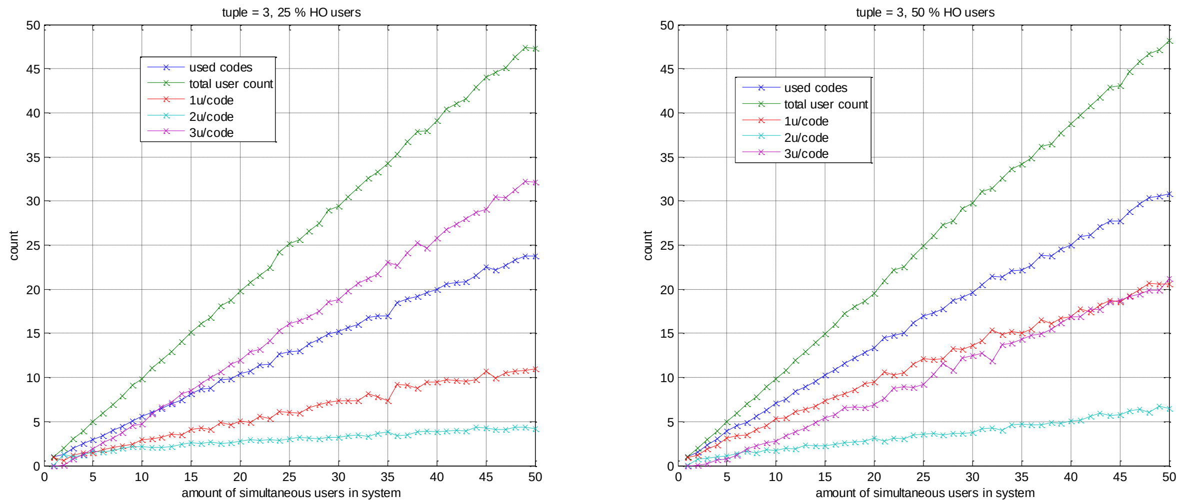
The amount of unpaired users is lower but still significant when considering a scenario where users emerge in the system, and are given frame timings matching those of yet unpaired users. In that situation users may remain unpaired, because there are an odd number of users in the system. They also may remain unpaired, because a certain percentage of users have moved into the cell from outside. The actual amount of users remaining unpaired then is shown in Figure 4.2.5-5a. For the simulation carried out an assumption was made that 25% or 50% of all users are HO users and hence could not be assigned a desired frame timing, but were given random timing. After providing those HO users with their timing, pairing was performed when still possible.



NOTE: Up to two users may share one code.
The lifetime of a user is assumed to be 2min here, while the user inter-arrival time is controlling the mean amount of users in the system.

Figure 4.2.5-5a: Number of paired and unpaired users for bursty traffic

The same analysis for up to three users on one code is shown in Figure 4.2.5-5b.



NOTE: Up to three users share one code.

Figure 4.2.5-5b: Number of paired and unpaired users for bursty traffic

It can be seen that a large portion of users is not able to be fit into the code sharing. The impact on system capacity of those unpaired users can be further illustrated by displaying the amount of free SF16 codes after pairing is performed. One SF16 code may carry close to 10% of the cell's DL throughput.

For the evaluation it was assumed that a R99 voice user consumes one SF128 code, while for pairing, one code allocation consumes a SF64 code. Figure 4.2.5-6a shows the amount of free codes for a HO percentage of 25%. Perfect pairing (which would require radio bearer reconfigurations) has the same performance as R99 for up to two users sharing the same code, as is expected, and for sharing of up to three users per code improves availability of SF16 codes, compared to R99, also as expected. However when considering the pairs that can be formed without radio bearer reconfiguration, according to Figures 4.2.5-5a and 4.2.5-5b, for TDM of two users one or more SF16 codes is lost, while TDM of three users just matches R99 performance.

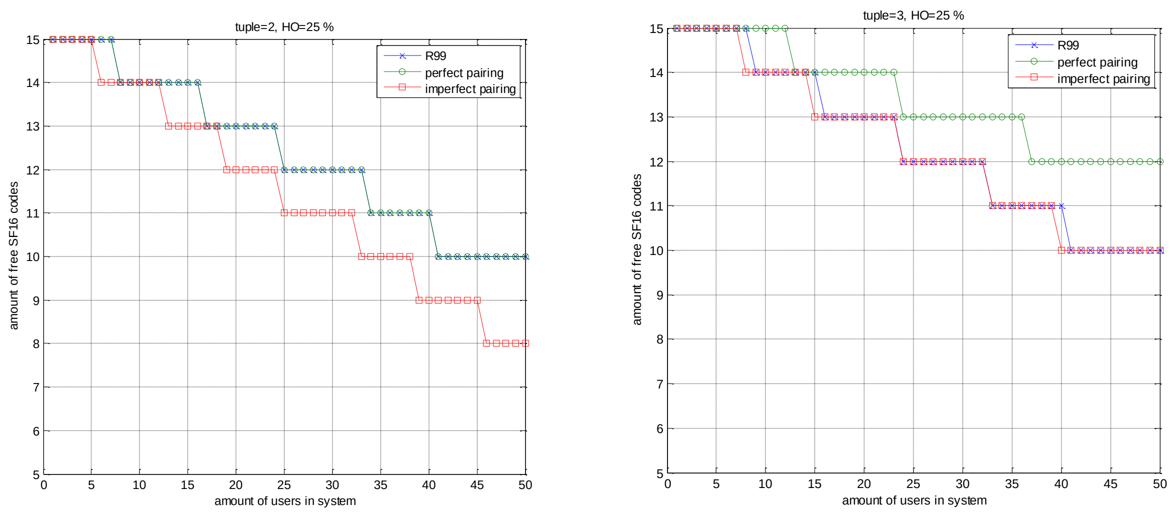


Figure 4.2.5-6a: 25% HO users: Perfect but unrealistic vs. imperfect but realistic pairing, for pairs holding 2 users (left), or 3 users (right)

In case of a larger HO percentage, also TDM of three users with realistic pairing leads to a loss of one SF16 code, see Figure 4.2.5-6b.

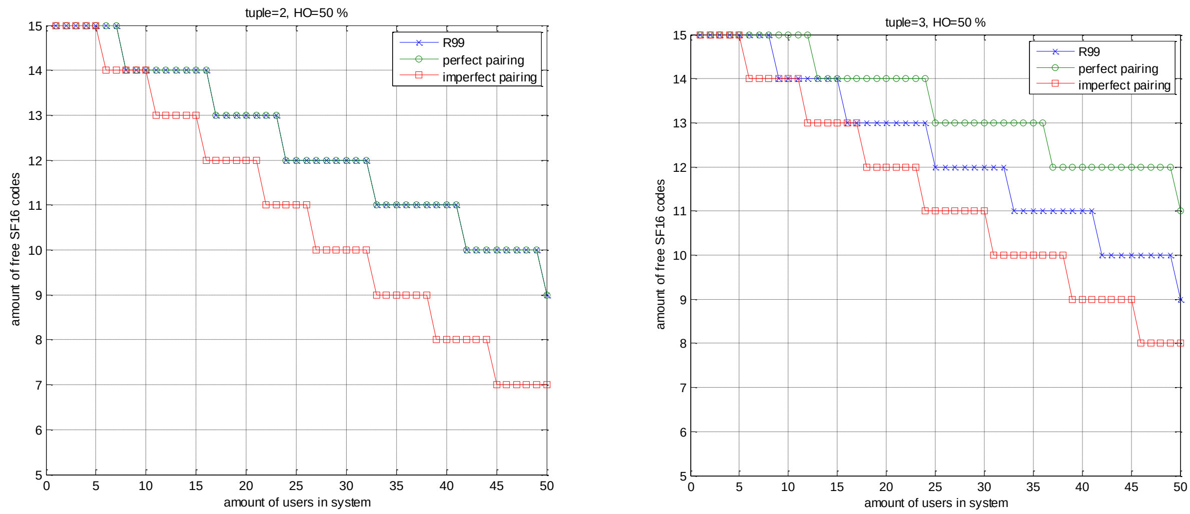


Figure 4.2.5-6b: 50% HO users: Perfect but unrealistic vs. imperfect but realistic pairing, for pairs holding 2 users (left), or 3 users (right)

4.2.5.3 Pairing of traversing users

As users are maintaining their timing while traversing through cells, the operation of pairing may lead to a "timing contagion" in the network, or pairing may not be performed at the price of reduced codespace.

The effect of timing contagion can be best explained by an example:

Assume two users A and B are paired in a cell 1. User A may enter SHO with cell 2, while user B may enter SHO with cell 3. In case a user C in cell 2 happens to have the same tau as A, they may be paired. Otherwise the RNC will need to wait for a new user D to appear in cell 2 to be paired with A, shown in Figure 4.2.5-7. Now users D, A, B all have the same timing and may move further to new cells.

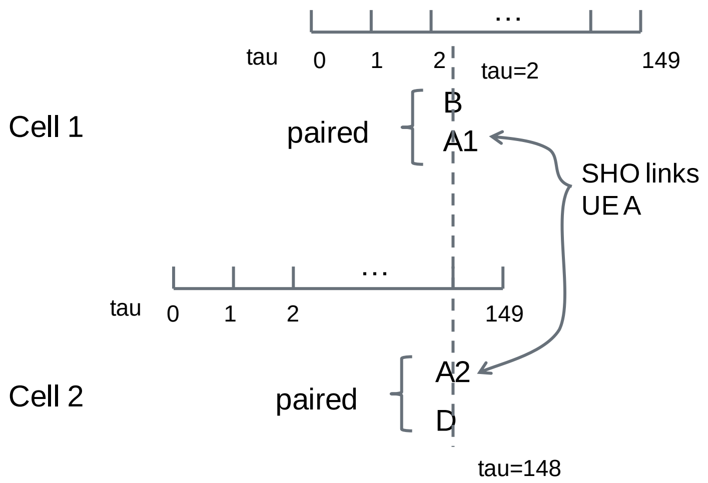


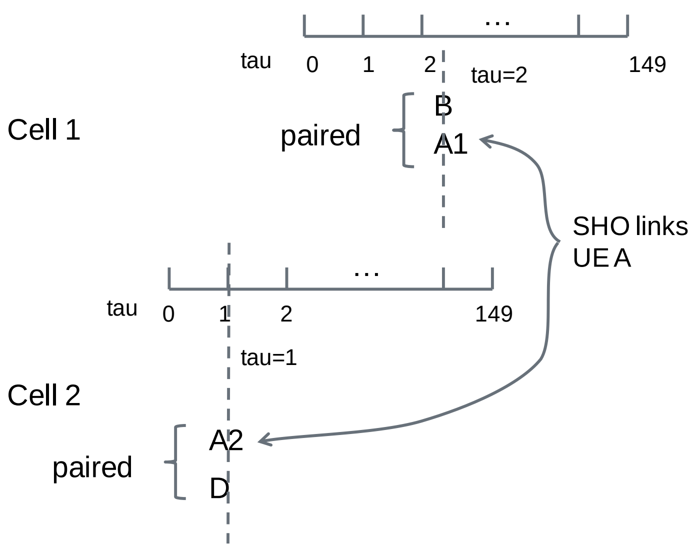
Figure 4.2.5-7: Pairing in SHO with legacy timing

From above example we observe not only that timing contagion – after some time all users in the network may have the same timing – is a real possibility, but also that a pairing partner of a traversing user may not be available, leading to codespace shortage or to expensive RBR reconfigurations.

Timing contagion can be avoided by not pairing users entering a cell as part of a HO with new users. The penalty for doing so is the reduced available code space, further degrading the already impaired situation as described in above clause.

4.2.5.4 Pairing with extended soft combining window

A solution to the availability of pairing partners is to extend the soft combining window. This allows the RNC to assign the UE a timing of its own choosing when the UE ventures into a new cell. Then the RNC can choose a timing that is suitable to already present users. As an example, in Figure 4.2.5-8 UE A is given a different timing in cell 2 to allow it being paired with UE D.



NOTE: UE A can be paired with any available UE in cell 2

Figure 4.2.5-8: pairing in SHO with extended SHO combining period

Thus, with a Soft combining window of 15 slots at the UE greatly reduced pairing complexity is available to the network, at no signalling cost, and at 100% pairing efficiency.

4.2.5.4.1 Effect of extended soft combining window on UE battery saving

From a DL interference perspective there is little difference between synchronized DL SHO links, and DL SHO links that are delayed by a considerable amount, because the repetitive decoding attempts will succeed as soon as enough energy has been gathered by the UE, regardless of whether the energy was gathered on synchronized links or not.

It can be argued that an extended SHO window will negatively impact the DRX battery savings of the otherwise time multiplexed radio frame structure of enhanced R99. This is true, and on average of 50% reduction of the DRX cycle can be expected for about 25% of UEs in SHO, depending on the network parameterization. However, it needs to be kept in mind that without user pairing at high loads the capacity is halved, as the amount of users is limited by the availability of spreading codes. Hence, the alternative to imposing a slight reduction in DRX cycle length (where nevertheless FET is still available) is to impose a DRX cycle of 100% for some users – not letting them connect at all because of code shortage.

The design puts most requirements on the UE, even though the extended buffer requirements are mild as only despread symbols need to be stored.

4.2.5.4.2 Effect of extended soft combining window on delay budget

The soft combining has no real impact on the voice delay budget since the proposed time extension always falls within the allotted delay budget for a voice service.

4.2.5.4.3 Effect on UL timing

In general the UL timing is synchronous to the DL. In legacy systems, when a UE is traversing cells as the DL timing remains constant, so does the UL timing.

With the proposed extended SHO the UE will assume a new DL timing after it has entered a new cell and is exiting SHO. This means that the UL timing needs to be adjusted, e.g. when the UE is exiting SHO or dropping the link that was the reference for the UL. An impact on higher layers can be avoided as also here the allotted delay budget for voice services is larger than the UL timing shifts.

4.2.5.5 Conclusion on user paring

Pairing of users in enhanced R99 is plagued with availability of suitable pairing partners, leading to reduction of overall capacity because of reduced code space availability.

A solution is to extend the soft combining window. This allows the RNC to assign the UE a timing of its own choosing when the UE ventures into a new cell. Then the RNC can choose a timing that is suitable to already present users. Thus, greatly reduced pairing complexity is available to the network, at no signalling cost, and at 100% pairing efficiency.

While the UE thus receives DL transmission of two timings, it will maintain the UL timing in relation to the oldest active DL timing.

4.2.6 Code-space and UE power efficient Signalling Radio Bearer (SRB) design

One of the motivating factors for the proposals on enhancements to legacy R99 DCH design is the introduction of power savings at the UE, made possible by techniques of FET and user pairing. For user pairing, two users will be time-multiplexed onto the same code resources, shortening transmission intervals to individual users. Another quoted benefit inherent to DCH and available to enhanced R99 is its robustness in HO situations, and hence its importance to the transmission of Signalling Radio Bearers (SRBs).

However, in the proposal of enhanced R99 described in R1-123809 [5], FET is not applicable when SRBs are also multiplexed into the data transmissions, as explained later in this document. A somewhat different angle on bringing enhanced R99 power savings to SRB transmissions is taken in R1-130513 [6] where a proposal was made for investigating SRB-only DCH. Another overview of the options to transmit SRBs efficiently especially for voice services is provided in R1-131606 [7].

Consequently we propose to introduce an SRB design that is power efficient, inherits DCH robustness, and is applicable and beneficial to both enhanced R99 channels and HSDPA.

4.2.6.1 Shared DCH for SRB

Long lasting battery life is an important aspect in user experience, and in turn designs that enable power savings at the UE are very sought after.

Classic DCH design involves continuous transmission by the cell to the UE, whereas in time-multiplexed schemes the UE is required to listen only at defined instances, and hence can switch of receiver circuitry otherwise.

For the enhanced R99 proposal the user-pairing time-multiplexed design of voice data transmissions presented in R1-123809 [5] has been motivated by the possibility to allow switching off the UE every other TTI.

In a straightforward extension of this approach we propose to time-multiplex different users' SRB transmissions onto one code resource shared by these users. Then infrequent SRB data can be statistically multiplexed, allowing for higher burst rates and UE DRX savings without affecting code space availability.

This newly designed physical channel for SRBs, the so-called shared DCH (S-DCH), shared by a number of users, would be applicable to any UMTS system and service and not limited to voice service alone. It could be applied to enhanced R99 proposals, as well as any traffic delivered utilizing HSPA radio.

4.2.6.1.1 SRB on DCH design as used since R99

In UMTS, SRBs carried over DCH are taking a format described in clause 5.10.2.4.1.2.2.1.1 of 3GPP TS 34.108 [8]: SRB data is carried over the logical channel DCCH, which is multiplexed with the DTCH in the transport channel DPCH. The DPCH is the mapped onto the physical channel DPDCH. The format of the multiplexing is illustrated in Figure 4.2.6-1.

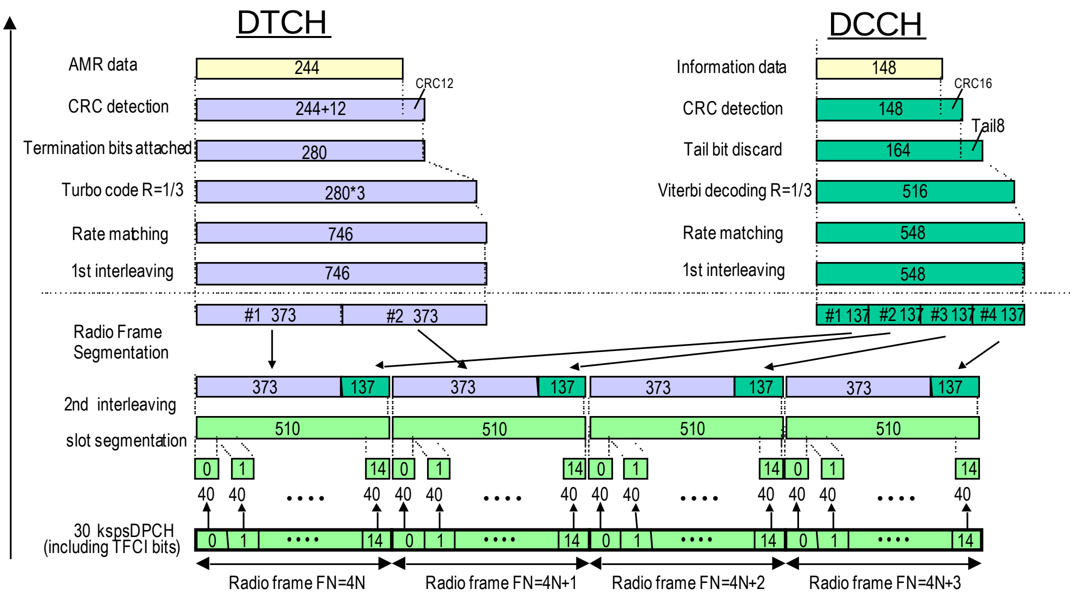


Figure 4.2.6-1: R99 DL DPCH construction for 12.2kbps speech [(adapted from Fig. A.5 in 3GPP TS 25.101 [9])

For SRBs transported on DCH, the existing RLC/MAC structures always provide 148-bit transport blocks (see Figure 4.2.6-1, right side) for L1 processing. After channel coding the transport block's 516 bits are fed to rate matching.
The slot format design for the radio frames in the example is specified as shown in Table 4.2.6-1.

Table 4.2.6-1: Physical channel parameters (see 3GPP TS 25.101 [9], clause 6.10.2.4.1.4.2.2)

DPCH Downlink	**DTX position**		**Fixed**
	Spreading factor		**128**
	DPCCH	Number of TFCI bits/slot	0
		Number of TPC bits/slot	2
		Number of Pilot bits/slot	4
	DPDCH	Number of data bits/slot	34
		Number of data bits/frame	510

That is, every slot carries a certain amount DPDCH data, all slots being the same.

4.2.6.1.2 Shared DCH design

In this design, it is proposed to introduce a new physical channel for carrying the DCCH, the *shared DCH* channel.
For this new channel radio frames are composed of two possible slot formats: The first carries a UE identifier and data while all other slots carry only data. A UE ID in the first slot allows UEs which are not addressed to DRX for the rest of the frame. Power control information can be carried either in F-DPCH channels, or in enhanced R99 channels. TFCI information may not be necessary as there is only one valid TB size for the SRB.

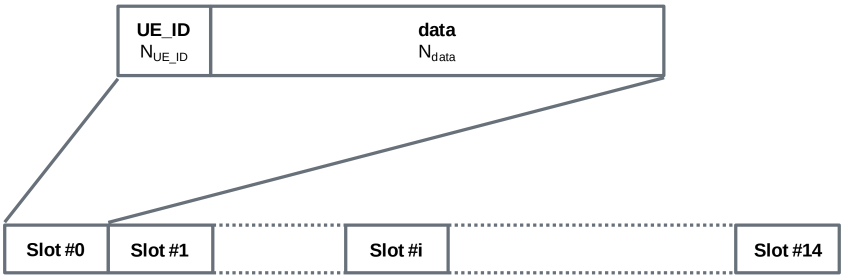


Figure 4.2.6-2: New proposed shared DCH: slot format for the first slot of the radio frame

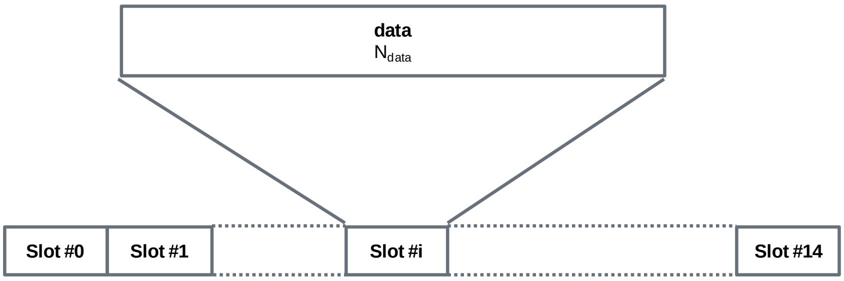


Figure 4.2.6-3: New proposed shared DCH: slot format for all other slots of the radio frame

As an example one may consider a UE which is configured in the downlink direction with voice user data mapped to HSDPA, and with SRBs mapped to the shared DCH described above. The shared DCH slot formats allow carrying more data than the presently defined formats for DCH carrying SRB and voice. This means that SRB can be delivered much faster, thus significantly improving latency (traditional SRB over DCH data rate is 3.4 kbps and the TTI is 40 ms, i.e. a transport block is split over 4 radio frames, the transmission can start once per 40 ms and the transmission duration is 40 ms, see Figure 4.2.6-1). In addition, the RNC can allocate more time on the S-DCH for users with high signalling need (during mobility procedures, for example), if needed, such that longer SRB payloads can be delivered in a timely manner.

Table 4.2.6-2 shows the preferred spreading factor and TTI length combinations that can be used for radio frames. Other possible combinations are shown in Table 4.2.6-3. The 148-bit transport block after encoding and rate matching could be fitted to less than 200 bits, but it may be desirable to use at least close to 400 bits to ensure good coding protection. The most attractive combinations would use 10 ms TTI for best latency and thus the most attractive combinations are SF128 and SF256 with 10 ms TTI, but the SF256 suffers from reduced coding protection.

Table 4.2.6-2: Overview of preferred DL DPCH spreading factor and TTI length

SF	TTI	L1 bits/TTI	Comment
128	10 ms	600	All encoded bits can be sent

Table 4.2.6-3: Examples of other potential DL DPCH spreading factor and TTI length combinations

SF	TTI	L1 bits/TTI	Comment
128	20 ms	1200	Unnecessarily large
256	10 ms	300	Reduced coding protection
256	20 ms	600	All encoded bits can be sent
512	10 ms	150	TB does not fit
512	20 ms	300	Reduced coding protection
512	40 ms	600	All encoded bits can be sent

An example of the slot formats for SF128 is shown in Table 4.2.6-4 below.

Table 4.2.6-4: DL DPCH slot format

Slot Format #i	Channel Bit Rate (kbps)	Channel Symbol Rate (ksps)	SF	Bits/ Slot	sDCHBits/Slot			Transmitted slots per radio frame N_{Tr}
					N_{data}	N_{UE_ID}	N_{TFCI} N_{data}	
25	60	30	128	40	28	12	0	1
26	60	30	128	40	40	0	0	14

Using a combination of slot formats 25 and 26 to transmit an SRB transport block, L1 processing will then dispose of 588 encoded SRB data bits and 12 UE_ID bits. Rate matching will then be adapted to provide these 588 bits, thus resulting in additional protection. This is shown in Figure 4.2.6-4.

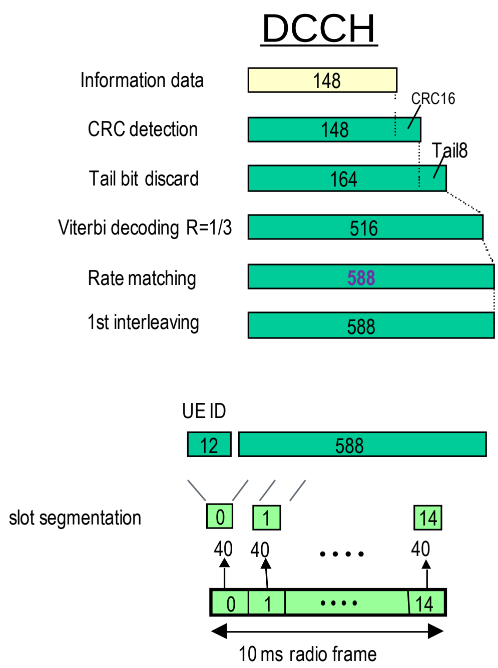


Figure 4.2.6-4: SRB to physical channel mapping with S-DCH slot format

4.2.6.1.2.1 Performance considerations of the S-DCH design

In Figure 4.2.6-5, a comparison of forward error correction codes applied for data and UE ID fields of S-DCH channel in case of the UE ID field (12, 3) code is shown. The (12, 3) code used is shown in Table 4.2.6-5.

Table 4.2.6-5: An Exemplary (12, 3) code for UE ID field

Code word No.	c0	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11
1	0	0	0	0	0	0	0	0	0	0	0	0
2	1	1	1	1	1	1	0	0	0	0	0	0
3	1	1	1	0	0	0	1	1	1	0	0	0
4	1	1	1	0	0	0	0	0	0	1	1	1
5	1	0	0	1	1	0	1	1	0	1	0	0
6	0	1	1	1	1	0	1	1	0	0	1	1
7	1	0	0	0	0	1	1	1	0	0	1	1
8	1	0	0	1	1	0	0	0	1	0	1	1

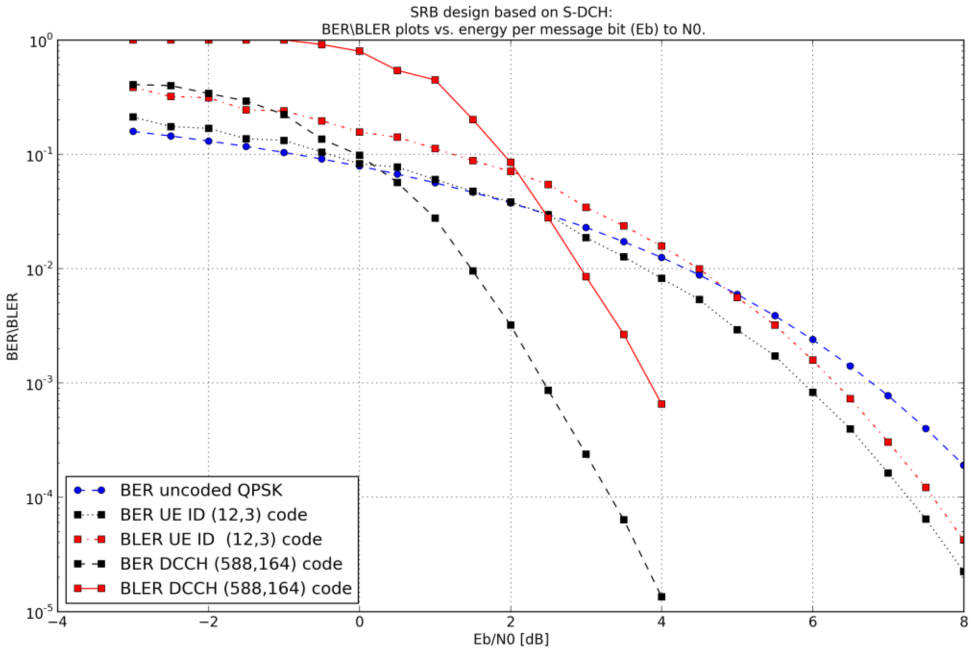


Figure 4.2.6-5: Comparison of Forward Error Correction codes applied for data and UE_ID fields of S-DCH channel in case of UE_ID field (12, 3) code

A FEC code gain for BLER = 0.01 is visible for the DCCH (data) field with respect to the UE ID field. Its value is approximately equal to 1 dB. This means that for equal BLER performance the UE-ID field should be power-boosted by 1 dB. Alternatively, the UE-ID field could be extended (and the data field shortened) for better coding protection at equal power as the data field. Studies show that it is possible to use the full first slot for the UE-ID and only the remaining 14 slots for data, without really affecting the BLER for the data.

4.2.6.1.3 Shared DCH for HSPA

When mapping SRBs to DCH while data is transported by HSPA channels, the system's architecture is shown in Figure 4.2.6-6.

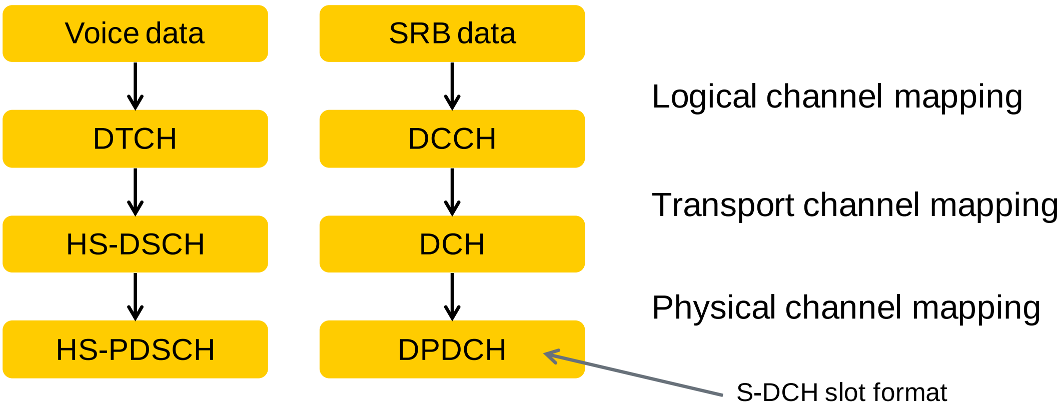


Figure 4.2.6-6: System architecture when configuring HSDPA with SRBs on S-DCH

It is noted that the S-DCH could be introduced also formally as a new transport or physical channel.

4.2.6.1.4 Shared DCH for HSPA with CPC

In Rel-7 discontinuous reception and transmission (DRX and DTX) was introduced as part of the CPC package. The benefits as reported in 3GPP TR 25.903 [10] lie in the reduced UE battery consumption and larger system capacity.

DRX/DTX and circuit switched always-on DCH are mutually exclusive. The shared DCH however can be easily combined with DRX and DTX.

Recall that as laid out in 3GPP TS 25.214 [11], clause 6C, in DRX the UE needs to monitor only every n-th subframe the HS-SCCH and a few other channels in order to detect new transmissions and keep track of the active set (see clause 6C.3 in 3GPP TS 25.214 [11]). The DRX duty cycle is configured by the RNC, even though the Node-B may de-activate DRX usage by means of HS-SCCH orders.

For transmitting the SRBs on S-DCH while DRX is enabled we note that the RNC is already aware of the DRX duty cycles and simply needs to address the UE only when it is listening. Likewise, the UE also needs to decode the S-DCH when awake.

4.2.6.1.5 Shared DCH for enhanced R99

For the proposed enhanced R99 design as show in Figure 4.2.6-7, DPDCH FET cannot be carried out in all cases if SRB data is present. The reason is that DTCH and DCCH (which carries the SRB) are interleaved in the DPDCH: Terminating the DPDCH transmission would also leave DCCH bits untransmitted. Thus terminating the DPDCH with FET can be done only if also DCCH has been successfully received as well. This is the background of the proposal of [5] to introduce in-band signalling of the presence of the DCCH.

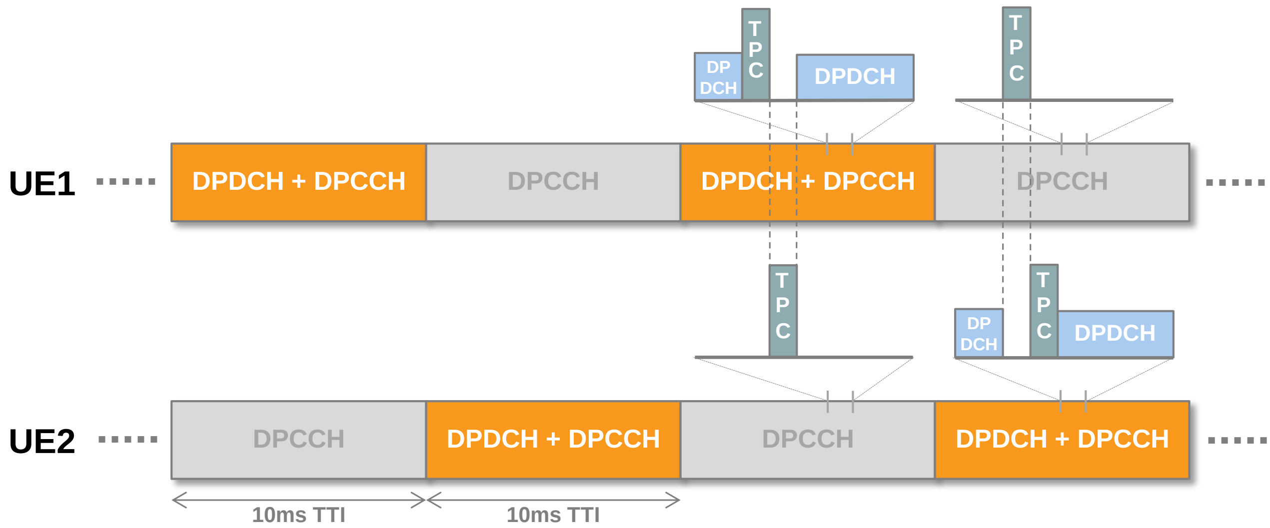


Figure 4.2.6-7: User pairing on the Downlink using new DL DPCH slot formats

The benefit of the new shared DCH is thus not only in bringing time multiplexing battery savings for DCH based SRBs, but also in that it frees the enhanced R99 DPCH from the need to carry SRB data. Then in-band signalling for the presence of the DCCH can be omitted, and FET can be applied consistently. When using this configuration, the system's architecture is shown in Figure 4.2.6-8.

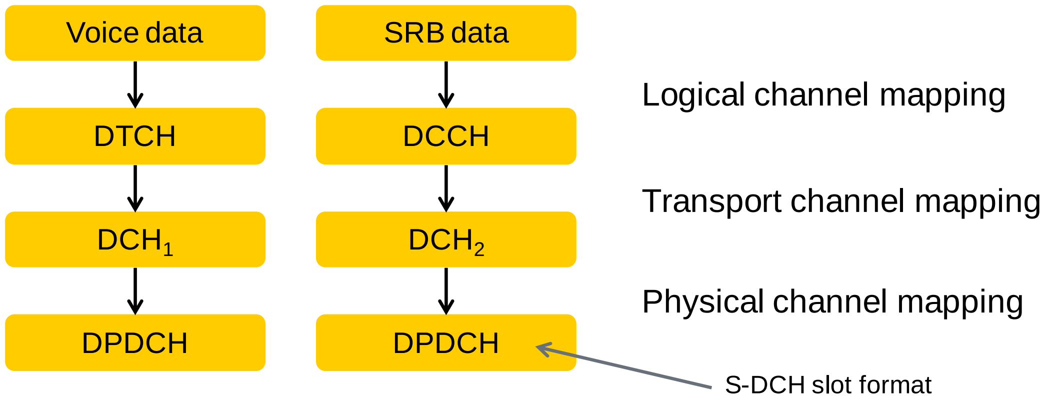


Figure 4.2.6-8: System architechture when configuring enhanced R99 with SRB on S-DCH

5 MAC layer eEnhancements

No enhancements to MAC layer were proposed for study.

6 UE power consumption efficiency

The proposed enhancements to DCH provide significant opportunity to gate the modem transceiver and thus improve UE power consumption. The gating opportunity is a consequence of the design of DCH channels on the UL and DL, in a way that UL transmission can be terminated earlier through FET and DL transmission completes faster due to shorter TTI and also FET.

Table 6-1 shows the average percentage of time the UE could potentially shut off its transceiver in Solution 1 and Solution 3. The OLPC target in Solution 1 is set to be at slot 15 with BLER target of 15% and 1%, in UL and DL, respectively. In Solution 3, the OLPC target is set to be at slot 30 in DL with BLER target of 1%, and slot 15 in UL with BLER target of 15. As can be seen in this analysis, in Solution 1, the UE can shut off its transceiver about 63% of the time. In Solution 3, the UE gating opportunity reduces to 34%. The reduction of gating opportunity in Solution 3 is due to increased TTI duration in DL transmission in this solution to 20ms, as compared to 10ms in Solution 1. The trade-off is that Solution 3 in comparison to Solution 1 shows relatively improved performance in DL, at the expense of increased power consumption on the UE side. In both solutions however, a significant improvement can be achieved in power consumption due to gating of UE transceiver.

Table 6-1: UE gating opportunity with AMR 12.2k traffic

Channel	Average UE Modem Gating Opportunity – Solution 1	Average UE Modem Gating Opportunity – Solution 3
PA3	63.12%	34.85%
PB3	63.13%	34.85%
VA30	63.92%	35.16%
VA120	62.29%	32.85%

Table 6-2 gives the estimated UE gating performance analysis for Solution 4, with OLPC target set at slot 30 and BLER target of 1%, in both UL and DL. As can be seen in this table, averaged across all channels and packet types with 50% voice, the overall average UE gating in Solution 4 is obtained to be 40.3%.

Table 6-2: UE gating opportunity with AMR 12.2k traffic

Packet Type	Average UE Modem Gating Opportunity – Solution 4
PA3, PB3, VA30, VA120 (equally-weighted average)	40.3%

7 Voice over HSPA (VoHSPA)

7.1 General overview of CS VoHSPA

In VoHSPA, a feature available as part of Rel-7, CS voice services are made available on top of packet-switched HSPA. The ability to share the same resources with PS data traffic and the greater link efficiency of HSDPA compared to R99 then directly translates to increased voice user capacity in the downlink.

The basic operation of VoHSPA only requires (in addition to HSDPA and HSUPA) a de-jitter buffer in the RNC and UE. In addition, a number of HSPA-related techniques can be applied to guarantee mobility robustness, and benefit from battery saving and capacity gains with VoHSPA:

- CPC (DTX, DRX) (reducing interference in the uplink, saving UE battery time)
- Enhanced F-DPCH (removal of code limitations)
- SRB over HS & E-UL (advantages of HSPA also for SRB)
- HS-SCCH less operation (control overhead for small packets)
- Enhanced Serving Cell Change (eSCC), (faster and more robust HO)
- QoS Aware Scheduler
- Bi-Casting (shorter voice interruption at times of serving cell change)
- RLC Duplicate Packet Detection for RLC UM (enabling the implementation of bi-casting in the UTRAN)
- Dynamic transition to 10ms TTI in the uplink (enhancing coverage)

To meet the stringent requirements of voice services and to ensure robustness, advanced UE receivers are required for VoHSPA. However, UE receiver performance improvements defined and implemented for HSDPA traffic can also be used for voice services when voice is delivered with HSDPA radio.

7.2 VoHSPA details

7.2.1 Serving Cell Change (SCC), enhanced SCC, and Node-B-terminated bicasting

Some concerns have been expressed on CS VoHSPA potentially presenting reliability problems for call maintenance during Serving Cell Change (SCC) procedure. In "Enhanced HSDPA Mobility Performance: Quality and Robustness for VoIP Service", Qualcomm Inc. [3] (is this publicly available, please ? Where ? How to procure ?, it is shown that robustness issues during SCC may arise in extreme mobility scenarios, such as urban canyon (Manhattan grid).

In extreme radio conditions where the serving link deteriorates very fast the user plane connectivity may be affected as the link adaptation may not react fast enough to maintain the target BLER, or because of the interruption in link connectivity that may occur during a SCC. In the worst case the link will deteriorate so fast that the RNC can no longer communicate to the UE a new target cell via RRC messages over the original link as part of the SCC. Thus, in the above described scenario there is a higher risk of voice interruptions or call drops.

One approach to tackle these two issues of call drop and user plane interruption is to fine-tune the parameters to accelerate the execution of the SCC procedure. In this case, a trade-off can be observed: If the network is parameterized to react to rapidly-changing channel conditions, it will be able to cope with the degradation of the CPICH Ec/No of the serving cell in urban canyon environments. However, in macro cell environments, there will be an increased risk of a ping-pong handover effect.

Alternatively, the network can perform an enhanced serving cell change (eSCC), which has been standardized in Rel-8 and is described in 3GPP TS 25.308 [12]. The eSCC procedure features the concept of target cell pre-configuration, which adds robustness to the HS-DSCH SCC procedure by allowing the network to send the HS-DSCH SCC command over the source cell as an RRC message and/or over the target cell as an HS-SCCH order.

Yet another technique to reduce the amount of lost packets is to bicast the voice packets from the RNC to the source and target cells during the SCC procedure. With bicasting the UE will still receive the packets only from one cell at a time, but the availability of the data immediately prior to the switch in the source cell and immediately after the switch in the target cell is ensured.

As shown in "Enhanced HSDPA Mobility Performance: Quality and Robustness for VoIP Service", Qualcomm Inc. [3] (is this publicly available, please ? Where ? How to procure ?, the above approaches and their combination lead to almost gapless and error-free voice connectivity during a serving cell change.

7.2.2 Mobility

The DCH enhancements discussed in clause 4 are intended to build on the well-established Voice over DCH technology. The main advantage is an increased capacity whilst maintaining the robustness advantages of soft handover.

For HSPA, there are a number of ways to address the robustness in mobility to achieve a near-error free performance.

In addition to the established and well researched techniques, the introduction of Multiflow has opened the door to bringing even larger robustness for voice services as shown in [13]:

Call drop: With Multiflow+SRB, the concept of the Serving Cell Change (SCC) involves only reconfiguring already established links. Hence, a call drop can be made very improbable, just as in R99 SHO. Bicasting can also be applied for SRBs with Multiflow as well.

User plane connectivity: In Multiflow, a large number of options exist to manage user plane connectivity during SCC, e.g.:

- plain Multiflow RNC-based selection of the better link,
- active buffer management of the cells when one link becomes unavailable,
- Node-B- or UE-terminated bicasting,
- hybrid versions of the above.

It is possible to bring about a "graceful handover" of an active voice connection. At first, a Multiflow link is established to the target, but data continues to be routed only over the source. Eventually, the voice data will be bicasted through both links, and finally only through the target. Such an approach allows for a way to balance robustness versus link efficiency.

7.2.3 Capacity

Voice over HSPA (VoHSPA) capacity was evaluated in the Rel-7 " Continuous Connectivity for Packet Data Users" study item, from which the uplink DTX, downlink DRX, new DL slot format and HS-SCCH less HSDPA transmission were adopted to Rel-7 specifications. The evaluation results are documented in 3GPP TR 25.903 [10] clauses 4.2.2.4.4 and 4.8.2.3 respectively for uplink and downlink.

8 Simulation assumptions

8.1 Simulation assumptions for Voice over HSPA (VoHSPA)

8.1.1 Link simulation assumptions for VoHSPA

8.1.1.1 Link simulation assumptions for downlink VoHSPA

The baseline downlink simulation assumptions for the evaluation of VoHSPA are given in Table 8.1.2.

Table 8.1.2: Baseline link simulation assumptions for evaluation of downlink VoHSPA.

Parameter	Value
Physical Channels	HS-PDSCH, HS-SCCH, F-DPCH, E-HICH
TBS [bits]	See Tables 8.1.6, 8.1.7 (The TBS is shown in 'TBS on DL' column)
Number of H-ARQ Processes	6
Maximum number of H-ARQ Transmissions	4
H-ARQ operating point	10 % BLER after first transmission
Traffic Source	Packet generated every 20ms
Number of Rx Antennas	1
Channel Encoder	3GPP Rel-6 Turbo Encoder
Turbo Decoder	Log MAP
Number of iterations for turbo decoder	8
Channel Estimation	Realistic
Inner Loop Power Control for F-DPCH	ON
Inner Loop PC Step Size for F-DPCH	±1 dB
Inner Loop PC Delay	2 slots
SIR target for F-DPCH ILPC	Set to achieve 4% F-DPCH BER
DL TPC Error Rate (for TPC sent on UL DPCCH)	4 %
HS-SCCH power control	ON, targeting 1% BLER
E-HICH power offset to F-DPCH	Set to achieve Ack misdetection rate of 5% and false-Ack rate of 0.2%
Propagation Channel	PA3, PB3, VA30, VA120: ITU. See Table 8.1.4 for power-delay profiles.
Geometry	[-3,0,3,6,9,12]dB
Rake Finger Configuration	Frequency and time tracking loops are disabled, fingers are assigned at fixed delays to be described together with simulation results
UE Receiver Type	Type 2
Active set size	1

Table 8.1.3: Frequency of occurrence of AMR packet types for 50% voice activity factor

Packet	Probability
FULL	0.5
SID	0.0625
NULL	0.4375

Table 8.1.4: Power-delay profiles for ITU channels

Channel	Relative Path delays (in nanoseconds)	Relative Path powers (dB)
PA	0,110,190,410	0,-9.7,-19.2,-22.8
PB	0,200,800,1200,2300,3700	0,-0.9,-4.9,-8.0,-7.8,-23.9
VA	0,310,710,1090,1730,2510	0,-1,-9,-10,-15,-20

Table 8.1.6: TBS to be used for VoHSPA for different Vocoder packets

Vocoder, packet type	#bits at vocoder output	#bits for header overheads				Total payload	TBS on DL (octet aligned)	TBS on UL (note 2)
		Octet alignment	PDCP header	RLC UM header	MAC Header (note 1)			
AMR12.2k, full	244	4	8	8	24	288	288	296
AMR12.2k and 5.9k, SID	39	1	8	8	24	80	120	120
AMR5.9k, full	118	2	8	8	24	160	160	160

NOTE 1: MAC header refers to MAC-ehs header on DL and MAC-i/is header on UL.
NOTE 2: UL TBS assumes use of E-DCH TBS table 0 for 2ms TTI as specified in 3GPP TS 25.321 [14]

Table 8.1.7: TBS to be used for VoIP for different Vocoder packets

Vocoder, packet type	#bits at vocoder output	#bits for header overheads				Total payload	TBS on DL (octet aligned)	TBS on UL (note 2)
		Octet alignment	RoHC header	RLC UM header	MAC Header (note 1)			
AMR12.2k, full	244	4	32	8	24	312	312	318
AMR12.2k and 5.9k, SID	39	1	32	8	24	104	120	120
AMR5.9k, full	118	2	32	8	24	184	184	185

NOTE 1: MAC header refers to MAC-ehs header on DL and MAC-i/is header on UL.
NOTE 2: UL TBS assumes use of E-DCH TBS table 0 for 2ms TTI as specified in 3GPP TS 25.321 [14]

8.1.1.2 Link simulation assumptions for uplink VoHSPA

The baseline uplink simulation assumptions for the evaluation of VoHSPA are given in Table 8.1.8.

Table 8.1.8: Baseline link simulation assumptions for evaluation of uplink VoHSPA.

Parameter	Value
Physical Channels	E-DPDCH, E-DPCCH, DPCCH, HS-DPCCH
E-DCH TTI [ms]	2
TBS [bits]	See Table 8.1.6 (The TBS is shown in 'TBS on UL' column)
Modulation	QPSK
Number of physical data channels and spreading factor	1xSF4 for AMR 12.2k Full packet; 1xSF8 for AMR 5.9k Full packet; 1xSF16 for SID packet
Puncturing Limit (PL_non_max)	0.66
20*log10(βed/βc) [dB]	8
20*log10(βec/βc) [dB]	2
20*log10(βhs/βc) [dB]	2: UE not in SHO 4: UE in SHO
HS-DPCCH transmission modeling	CQI transmitted once every 8ms, ACK transmitted once every 20ms.
Number of H-ARQ Processes	8
Traffic Source	New packet generated every 20ms.
Maximum number of H-ARQ Transmissions	4
H-ARQ operating point	1 % Residual BLER after 4 H-ARQ attempt
Number of Rx Antennas	2
Channel Encoder	3GPP Rel-6 Turbo Encoder
Turbo Decoder	Log MAP
Number of iterations for turbo decoder	8
DPCCH Slot Format	1 (8 Pilot, 2 TPC)
Channel Estimation	Realistic
Inner Loop Power Control	ON
Outer Loop Power Control	ON
Inner Loop PC Step Size	±1 dB
OLPC SIR-target up-step on packet error	0.5dB
UL TPC Delay (sent on F-DPCH)	2 slots
UL TPC Error Rate (sent on F-DPCH)	4 %
Propagation Channel	PA3, PB3, VA30, VA120: ITU. See Table 8.1.4 for power-delay profiles
Rake Finger Configuration	Frequency and time tracking loops are disabled; fingers are placed at fixed delays to be described together with simulation results.
Node-B Receiver Type	Rake
Active set size	1, 2 (soft handover)
Link imbalance in soft handover	0dB

8.1.2 Link performance metrics for VoHSPA

8.1.2.1 Link performance metrics for downlink VoHSPA

a) Average Transmit Ec/Ior for each TBS, for each of: HS-PDSCH, HS-SCCH, E-HICH, F-DPCH.

b) Average of total Transmit Ec/Ior for all downlink physical channels, for each TBS.

c) Average of total Transmit Ec/Ior (the result of (b)) across TBS, weighted by their frequency of occurrence shown in Table 8.1.3. For the Null packet, the Transmit Ec/Ior to be used is obtained from the result of (b) for the SID packet but excluding the contribution of the HS-PDSCH and HS-SCCH to the transmit Ec/Ior.

d) Average number of HARQ transmissions for each TBS.

e) BER of TPC bits sent on F-DPCH.

f) Miss-detection and false-Ack rate for E-HICH

g) HS-SCCH BLER.

8.1.2.2 Link Performance metrics for uplink VoHSPA

a) Average of total Received Ec/No for all uplink physical channels, for each packet type.

b) Average of total Received Ec/No (the result of (a)) across all TBS, weighted by their frequency of occurrence shown in Table 8.1.3. For the Null packet, the received Ec/No to be used is obtained from the result of (a) for the SID packet but excluding the contribution of the E-DPDCH and E-DPCCH to the Rx Ec/No.

c) Average number of HARQ transmissions

d) BER of TPC bits sent on UL DPCCH.

8.1.3 System simulation assumptions for VoHSPA

8.1.3.1 System simulation assumptions for downlink VoHSPA

The baseline downlink system simulation assumptions for the evaluation of VoHSPA are given in Table 8.1.9.

Table 8.1.9: Downlink system Ssmulation assumptions for VoHSPA

Parameters	Values and comments
Cell Layout	Hexagonal grid, 19 Node B, 3 sectors per Node B with wrap-around
Inter-site distance	1000 m
Carrier Frequency	2000 MHz
Path Loss	L=128.1 + 37.6log10(R), R in kilometers
Penetration loss	10 dB
Log Normal Fading	Standard Deviation : 8dB Inter-Node-B Correlation: 0.5 Intra-Node-B Correlation: 1.0
Max BS Antenna Gain	14 dBi
Antenna pattern	= 70 degrees, *Am* = 20 dB
Number of UEs/cell	BE: 4 Voice: 0, 8, 16, 24, 32 ,40, 48 UEs dropped uniformly across the system
Channel Model	ITU: PedA3, VA30 See Table 8.1.4 for power-delay profiles.
CPICH Ec/Ior	-10 dB
UE Antenna Gain	0 dBi
UE noise figure	9 dB
Thermal noise density	-174 dBm/Hz
Maximum Sector Transmit Power	43 dBm
Soft Handover Parameters	R_{1a} (reporting range constant) = 6 dB
Number of H-ARQ processes	6
H-ARQ operating point	10 % BLER after first transmission Max number of Transmissions = 4
Maximum active set size	3
Common channel power including C-PICH	20%
HS-SCCH and HS-DSCH	Up to 15 SF-16 codes per carrier for HS-PDSCH HS-SCCH transmit power being driven by 1% HS-SCCH BLER. 0.5dB fixed margin is applied to CQI for rate control.
CQI	9 slot CQI delay CQI estimation noise is Gaussian with mean of 0 dB and variance of 1dB CQI Decoding at Node-B is ideal.

F-DPCH	1500Hz 2 slot delay +1dB/-1dB step size SIR target set to achieve 4% error rate
F-DPCH Limits	Maximum Ec/Ior = -10dB
E-HICH	E-HICH power offset to F-DPCH set to achieve Ack misdetection rate of 5% and false-Ack rate of 0.2%
Scheduling Type	Proportional Fair for BE users; Delay sensitive Qos based scheduling for voice users
Scheduling delay bound for VoHSPA UEs	100ms
Voice codec	AMR 12.2kbps, AMR 5.9kbps, See Table 8.1.6 for TBS sizes
Voice activity	0.5 (see Table 8.1.10)
SID	Every 160ms during voice inactivity See Table 8.1.6 for TBS size
UE receiver type	For VoHSPA UEs: Type 2 (Type 3i optional) For BE UEs: Type 3i

AMR is modeled based on a two stage Markov model with two Active and Inactive states, where in the Active state, only Full packets are generated, and in the Inactive state, SID packets are generated with SID packet being generated once every 160 ms. The transition probability between the two Active and Inactive states is shown in Table 8.1.10.

Table 8.1.10: Transition probability of Active and Inactive states for AMR traffic

State n-1	P(State n-1 ≠ State n)
Active	1%
Inactive	1%

8.1.3.2 System simulation assumptions for uplink VoHSPA

The baseline uplink system simulation assumptions for the evaluation of VoHSPA are given in Table 8.1.11.

Table 8.1.11: Uplink System Simulation Assumptions for VoHSPA

<table>
<tr><th>Parameters</th><th colspan="2">Values and comments</th></tr>
<tr><td>Cell Layout</td><td colspan="2">Hexagonal grid, 19 Node B, 3 sectors per Node B with wrap-around</td></tr>
<tr><td>Inter-site distance</td><td colspan="2">1000 m</td></tr>
<tr><td>Carrier Frequency</td><td colspan="2">2000 MHz</td></tr>
<tr><td>Path Loss</td><td colspan="2">L=128.1 + 37.6log10(R), R in kilometers</td></tr>
<tr><td>Penetration Loss</td><td colspan="2">10dB</td></tr>
<tr><td>Log Normal Fading</td><td colspan="2">Standard Deviation : 8dB
Inter-Node B Correlation: 0.5
Intra-Node B Correlation :1.0
Correlation Distance: 50m</td></tr>
<tr><td>Antenna pattern</td><td colspan="2">= 70 degrees, A_m = 20 dB</td></tr>
<tr><td>Channel Model</td><td colspan="2">PA3, VA30 (ITU channels). See Table 8.1.4 for power-delay profiles.
Fading across all pairs of antennas is completely uncorrelated</td></tr>
<tr><td>Maximum UE EIRP</td><td colspan="2">23 dBm</td></tr>
<tr><td>Uplink system noise</td><td colspan="2">–103.16 dBm</td></tr>
<tr><td rowspan="4">HS-DPCCH</td><td>CQI Feedback Cycle</td><td>1 TTI</td></tr>
<tr><td>□$_{ACK}$ [dB]</td><td>2 (no SHO)
4(SHO)</td></tr>
<tr><td>□$_{NACK}$ [dB]</td><td>2 (no SHO), 4 (SHO)</td></tr>
<tr><td>□$_{CQI}$ [dB]</td><td>2 (no SHO), 4(SHO)</td></tr>
<tr><td>E-DPCCH C/P</td><td colspan="2">0dB</td></tr>
<tr><td>Soft Handover Parameters</td><td colspan="2">R_{1a} (reporting range constant) = 6 dB,</td></tr>
<tr><td>Traffic Source</td><td colspan="2">Voice packets generated every 20ms</td></tr>
<tr><td>TBS</td><td colspan="2">See Table 8.1.6</td></tr>
<tr><td>Modulation</td><td colspan="2">QPSK</td></tr>
<tr><td>DPCCH Slot format</td><td colspan="2">8pilot bits, 2TPC bits</td></tr>
<tr><td>UE distribution</td><td colspan="2">Uniform over the area</td></tr>
<tr><td>Number of Voice UEs per cell</td><td colspan="2">0, 8, 16, 24, 32, 40, 48</td></tr>
<tr><td>Number of BE users per cell</td><td colspan="2">4</td></tr>
<tr><td>Node-B Receiver</td><td colspan="2">2 Rx-Rake (Pilot Weighted Combining - PWC)</td></tr>
<tr><td>Uplink HARQ</td><td colspan="2">2ms TTI, Max # of transmission =4 targeting 1% residual BLER after 4 HARQ.</td></tr>
<tr><td>Number of HARQ processes</td><td colspan="2">8</td></tr>
<tr><td>ILPC</td><td colspan="2">1500Hz ILPC rate
2 slot feedback delay
+1dB/-1dB step size
4% error rate</td></tr>
<tr><td>OLPC</td><td colspan="2">1% target residual BLER after 4 HARQ
+0.5dB when packet decoding error</td></tr>
</table>

Target RoT	6dB	
E-DCH Scheduling Delays	Period	2ms
	Uplink SI delay	6 slots
	DL Grant delay	As per 3GPP TS 25.321 [14]
Scheduling Type	Proportional Fair for BE users; Delay sensitive Qos based scheduling for voice users	
Scheduling delay bound for VoHSPA UEs	100ms	

8.1.4 System performance metrics for VoHSPA

8.1.4.1 System performance metrics for downlink VoHSPA

a) Average cell throughput vs. Number of VoHSPA users per cell.

b) Average power per cell used by VoHSPA users

c) Average power per cell used by BE users

d) CDF of the run-lengths of consecutive VoHSPA packet errors.

e) Percentages of VoHSPA users with Active set size of 1,2,3.

f) Percentage of VoHSPA users with BLER > 3%

g) CDF of packet delay for VoHSPA users.

8.1.4.2 System performance metrics for uplink VoHSPA

a) Average cell throughput vs. Number of VoHSPA users per cell.

b) Average RxEc/No per cell used by VoHSPA users

c) Average RxEc/No per cell used by data users

d) CDF of the run-lengths of consecutive voice packet errors.

e) Percentages of VoHSPA users with Active set size of 1, 2, 3.

f) Percentage of VoHSPA users with BLER > 3%

g) CDF of RoT per cell.

h) CDF of packet delay for VoHSPA users.

8.2 Simulation assumptions for voice over R99 and DCH enhancements

Four representative solutions are evaluated in this study. The solutions studied are differentiated by the physical layer changes needed to support the enhancements, as described in Table 8.2 below.

Table 8.2: Representative FET designs evaluated in this study

DCH Enhancements	Solution 1	Solution 2	Solution 3	Solution 4
4.1.1 UL Frame Early Termination	Option 1	Option 2	Option 1	Option 2
4.1.2 UL DPCCH Slot Format Optimization	Option 1	Option 2	Option 1	Option 2
4.1.3 UL ACK Indication for DL Frame Early Termination	Option 1	Option 3	Option 1	Option 3
4.2.1 DL Frame Early Termination	Option 1	Option 2	Option 3	Option 2
4.2.2 DL DPCCH Slot Format Optimization	Option 1	Option 2	Option 3	Option 2
4.2.3 DL ACK Indication for UL Frame Early Termination	Option 1 or 2	Option 3	Option 1 or 2	Option 3
4.2.4 DPCH Time Domain Multiplexing	Option 1	Option 2	No	No

8.2.1 Link simulation assumptions for voice over R99 DCH

8.2.1.1 Link simulation assumptions for Downlink voice over R99 DCH

The link simulation settings for downlink are shown in Table 8.2-1. Each simulation consists of transmissions of a payload whose bits are generated randomly at each TTI but whose size (TBS) is fixed over the entire simulation. The possible TBSs and their encoding details for AMR 12.2kbps and 5.9kbps codecs are shown in Table 8.2-3.

Table 8.2-1: Link Level Simulation Parameters for Downlink voice over R99 DCH

Parameter	Value
Physical Channels	DPCH, P-CPICH, P-CCPCH, PICH, and 16 OCNS codes
Modulation	QPSK
DCH traffic type	AMR12.2K or 5.9K voice frames
DCH transport channels	DTCH carries a fixed size AMR transport block every TTI. DCCH (carrying SRBs) is configured but not transmitted.
(DTCH, DCCH) TTIs	(20,40)
DTCH TBS and encoding	See Table 8.2-3
DCH rate-matching	Fixed positions. See Table 8.2-3 for rate-matching attributes

Transmit powers for physical channels	DPCH : Determined via power control P-CPICH : Ec/Ior = -10dB P-CCPCH : Ec/Ior = -12dB PICH : Ec/Ior = -15dB OCNS : OVSF indices and relative powers of the 16 codes are as in 3GPP TS 25.101 [9] (Rel-11, Table C6). Total power of all OCNS codes is fixed in each slot = Ior- $\sum_c P_c$, where P_c = average power of channel c in that slot. Summation is over all channels except OCNS. Ior is a fixed constant power (eg, 20 Watts), and geometry = Ior/No, where No = variance of the AWGN.
DPCCH/DPDCH power offsets	Offsets PO1,PO2,PO3 for TPC, TFCI, pilots respectively are all equal, with value 3dB for AMR12.2K and 0dB for AMR5.9K. Power offset of 0dB for AMR12.2K is optional.
DPCH slot format	AMR12.2K: 8, AMR5.9K: 2. See Table 8.2-2
DL DPCH ILPC rate	1500Hz
DPCH ILPC up-down power step-size	1dB
Command error rate for TPC up-down commands transmitted on uplink	4%
DPCH ILPC feedback delay	1 slot
DPCH ILPC gain change boundary within slot	Start of first DPCCH pilot symbol
DPCH ILPC SNR estimation	Realistic
DPCH maximum and minimum power limits	ILPC is over-ridden if neccesary so that Ec/Ior for non-DTXed DPDCH symbols is within the range [-40dB, -10dB].
OLPC BLER target	1% residual BLER (after all decoding attempts)
OLPC SIR-target up-step on packet error	0.5dB
Number of Rx Antennas	1
Channel Encoder	3GPP Rel-6 Convolutional coder
Channel estimation for DCH demodulation	Realistic, based on P-CPICH
Transport format detection	Ideal
Propagation Channel	ITU: PA3, PB3, VA30, VA120. See Table 8.1.4 for power-delay profiles
Rake Finger configuration	Frequency and time tracking loops are disabled. Delays of assigned fingers are located at fixed delays to be described together with simulation results.
UE Receiver Type	1-Rx Rake (Pilot-weighted Combining (PWC) across fingers)
Active set size	1,2 (soft handover)
Link imbalance in soft handover	0dB
Geometry	0,3,6,9,12 dB (when not in soft handover); -3,0,3dB (for soft handover) In soft handover, geometry = Ior1/No, and link imbalance=Ior1/Ior2, where Ior1,Ior2 are the Ior values for the two cells in the active set.

Table 8.2-2: DL DPCH slot format

Slot Format #i	Channel Bit Rate (kbps)	Channel Symbol Rate (ksps)	SF	Bits/ Slot	DPDCH Bits/Slot		DPCCH Bits/Slot			Transmitted slots per radio frame N_{Tr}	Vocoder
					N_{Data1}	N_{Data2}	N_{TPC}	N_{TFCI}	N_{Pilot}		
8	60	30	128	40	6	28	2	0	4	15	AMR12.2K
2	30	15	256	20	2	14	2	0	2	15	AMR5.9K

Table 8.2-3: Voice packets simulated on DL

Air interface	Vocoder	Packet	TBS= N_{info}	CRC size= N_{crc}	Encoding	Slot for-mats	Number of encoded bits punctured by rate-matching = N_{punc} (note 1)	Rate-matching Attributes (note 2)	Packet Frequency (note 3)
R99	AMR12.2K	Full-A	81	12	Conv 1/3	8	13	180,175,234,180	0.5
R99	AMR12.2K	Full-B	103	0	Conv 1/3	8	21	180,175,234,180	
R99	AMR12.2K	Full-C	60	0	Conv 1/2	8	-34	180,175,234,180	
R99	AMR12.2K	SID	39	12	Conv 1/3	8	8	180,175,234,180	0.0625
R99	AMR12.2K	Null	0	12	Conv 1/3	8	3	180,175,234,180	0.4375
R99	AMR5.9K	Full-A	55	12	Conv 1/3	2	85	180,174,230	0.5
R99	AMR5.9K	Full-B	63	0	Conv 1/3	2	83	180,174,230	
R99	AMR5.9K	SID	39	12	Conv 1/3	2	67	180,174,230	0.0625
R99	AMR5.9K	Null	0	12	Conv 1/3	2	23	180,174,230	0.4375

NOTE 1: Negative number indicates repetition. Definition of N_{punc} is illustrated in Figure 8.2-1. Its value depends on rate-matching attributes.

NOTE 2: Rate matching attributes are listed in the order (DTCH-A, DTCH-B, DTCH-C, DCCH) for AMR12.2kbps, and in the order (DTCH-A,DTCH-B,DCCH) for AMR 5.9kbps codec. For both codecs, the DCCH is configured for 40ms TTI with TBS=148, N_{crc}=16 and convolutional encoding with rate 1/3.
Even though DCCH is not transmitted, these parameters are required to determine the rate-matching pattern for the packets that are transmitted.

NOTE 3: Packet frequencies are used as weights to average the TxEc/Ior values obtained from simulations for each packet type, to obtain an overall TxEc/Ior for the given vocoder and air-interface. The frequencies in Table 8.1.3 correspond to 50% voice activity factor.
The Full-A,B,C packet types for AMR vocoder are all transmitted together, and hence have the same frequency.

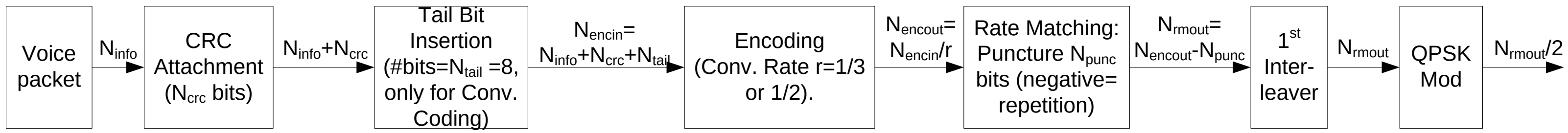


Figure 8.2 -1: Encoding and modulation of voice packets for downlink, showing number of bits at each stage

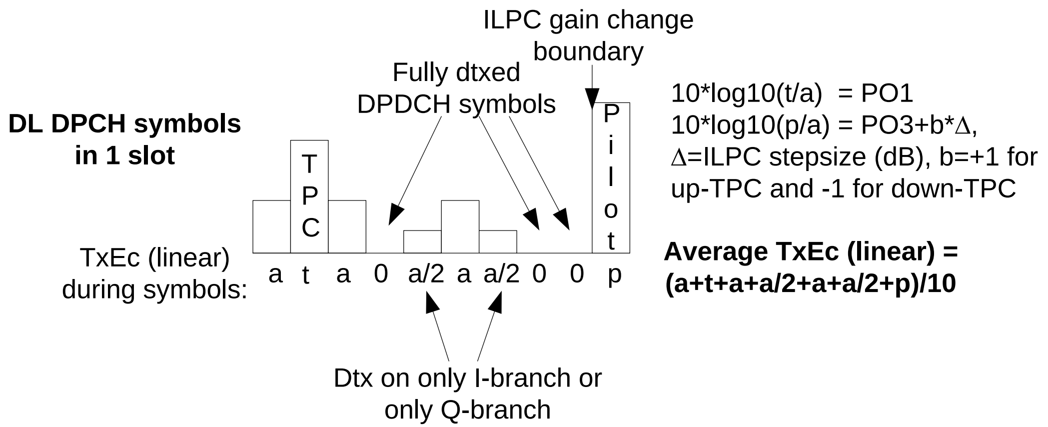


Figure 8.2-2: Showing DL TxEc/Ior calculation accounting for power-offsets and DTX.

8.2.1.2 Link simulation assumptions for Uplink voice over R99 DCH

Link level simulation parameters for uplink are shown in Table 8.2-4.

Table 8.2-4: Link Level Simulation Parameters for Uplink voice over R99 DCH

Parameter	Value
Physical Channels	DPCCH, DPDCH
Modulation	BPSK
DCH traffic type	AMR12.2K and 5.9K
DCH transport channels	DTCH carries a fixed size AMR transport block. DCCH is not transmitted.
(DTCH, DCCH) TTIs	(20,40)ms
DTCH TBS and spreading factor	See Table 8.2-5
DCH rate-matching	Since DCCH is not transmitted, rate-matching punctures or repeats encoded DTCH packet so as to fill up all available DPDCH bits in the TTI, in accordance with 3GPP TS 25.212 [4]
Puncturing Limit (PL)	0.66
DPDCH/DPCCH power ratio	Specified for each TFC as in Table 8.2-8.
DPCCH slot format	0 (6 pilots, 2 TFCI, 2 TPC bits per slot).
UL DPCH ILPC rate	1500Hz
ILPC up-down power step-size	1dB
Command error rate for TPC up-down commands transmitted on downlink	4%
DPCH ILPC feedback delay	2 slots
OLPC BLER target	1% residual BLER after 20ms
OLPC SIR-target up-step on packet error	0.5dB
OLPC delay	2 radio-frames
Number of Rx Antennas	2
Channel Encoder	3GPP Rel-6 Convolutional coder
Channel estimation for DCH demodulation and ILPC SNR estimation	Realistic
Transport format detection	Realistic (TFCI errors impact DTCH BLER)
Propagation Channel	ITU: PA3, PB3, VA30, VA120. See Table 8.1.4 for power-delay profiles
Node-B Receiver Type	2-Rx Rake (Pilot-weighted Combining (PWC) across fingers)
Rake Finger Configuration	Frequency and time tracking loops are disabled. Delays of assigned fingers are located at fixed delays.
Active set size	1,2 (soft handover)
Link imbalance in soft handover	0dB

Table 8.2-5: Voice packets simulated on UL and corresponding spreading factors

Vocoder	Packet	TBS= N_{info}	CRC size= N_{crc}	Rate matching attributes (note)	DPDCH Spreading factor
AMR12.2K	Full (A,B,C)	(81,103,60)	(12,0,0)	180,175,234,180	64
AMR12.2K	SID	39	12	180,175,234,180	256
AMR12.2K	Null	0	0	180,175,234,180	DPDCH not sent
AMR5.9K	Full (A,B)	(55,63)	(12,0)	180,170,180	128
AMR5.9K	SID	39	12	180,170,180	256
AMR5.9K	Null	0	0	180,170,180	DPDCH not sent

NOTE: Rate matching attributes are listed in the order (DTCH-A, DTCH-B, DTCH-C, DCCH) for AMR12.2kbps, and in the order (DTCH-A,DTCH-B,DCCH) for AMR 5.9kbps codec.
For both codecs, the DCCH is configured for 40ms TTI with TBS=148, N_{crc}=16 and convolutional encoding with rate 1/3.
Even though DCCH is not transmitted, these parameters are required to determine the rate-matching pattern for the packets that are transmitted.

8.2.2 Link Performance Evaluation Metrics

8.2.2.1 Link Performance metrics for downlink voice over R99 DCH

a) DPCH TxEc/Ior averaged over entire simulation, for each packet type.
The averaging accounts for DTX and DPCCH/DPDCH power offsets, as shown in Figure 8.2-2.

b) Average of (a) across packet types, weighted by their frequency of occurrence shown in Table 8.1.3.
This is the metric used for comparing different voice codecs and physical layers.

c) Decoding block error rate for each simulation (each packet type).

d) BER of TPC bits sent on DL DPCCH.

8.2.2.2 Link Performance metrics for uplink voice over R99 DCH

a) Average Received Ecp/No of DPCCH per channel type per packet type. No is the variance of AWGN.

b) Total Average Received Ec/No for data plus control channels (DPDCH+DPCCH).

c) Decoding block error rate

d) BER of TPC bits sent on UL DPCCH.

8.2.3 System simulation assumptions

8.2.3.1 System simulation assumptions for Downlink

8.2.3.1.1 Simulation assumptions for Downlink voice over R99 DCH

Table 8.2-6: Downlink System Simulation Assumptions for R99 CS Voice

Parameters	Comments
Traffic	RAB: AMR12.2K, AMR5.9K; SRB: not transmitted
TBS on DTCH	Null: 0, SID: 39; Full-AMR12.2K: (81,103,60) for DTCH-A,B,C; Full-AMR5.9K: (55,63) for DTCH-A,B.
RM attributes	AMR12.2K: 180,175,234,180 for DTCH-A,B,C, DCCH. AMR5.9K: 180,174,230 for DTCH-A,B, DCCH.Using fixed position rate matching in both cases.
DL DPCH Slot format	Slot format 8 for AMR12.2K and 2 for AMR 5.9K
Encoder	1/3, 1/3, 1/2 rate convolutional code for Class A,B,C (Class-C only for AMR12.2K codec)
CRC	12-bit CRC on Class A
OLPC	1% target BLER +0.5dB when packet decoding error
ILPC	1500Hz 1 slot delay +1dB/-1dB step size 4% error rate
DL DPCH TxEc/Ior limits	Maximum = -10dB, minimum = -40dB.

AMR is modeled based on a two stage Markov model with two Active and Inactive states, where in the Active state, only Full packets are generated, and in the Inactive state, SID and NULL packets are generated with SID packet being sent after every 7 NULL packets. The transition probability between the two Active and Inactive states is shown in Table 8.1.10. The AMR Markov model described above is used for both uplink and downlink.

8.2.3.1.2 General system assumptions for Downlink

The system simulation assumptions for the mixed CS voice on DCH and BE data over HSDPA are listed in Table 8.2-7.

Table 8.2-7: DL System Simulation Assumptions for mix of CS voice on DCH and BE data on HSDPA

Parameters	Comments
Cell Layout	Hexagonal grid, 19 Node B, 3 sectors per Node B with wrap-around
Inter-site distance	1000 m
Carrier Frequency	2000 MHz
Path Loss	L=128.1 + 37.6log10(R), R in kilometers
Penetration loss	10 dB
Log Normal Fading	Standard Deviation : 8dB Inter-Node B Correlation:0.5 Intra-Node B Correlation :1.0
Max BS Antenna Gain	14 dBi
Antenna pattern	$A(\theta) = -\min\left[12\left(\frac{\theta}{\theta_{3dB}}\right)^2, A_m\right]$ θ_{3dB} = 70 degrees, Am = 20 dB
Number of UEs/cell	BE: 4 Voice: 0, 8, 16, 24, 32 ,40, 48 UEs dropped uniformly across the system
Channel Model	100% PA3 (ITU), 100% VA30 (ITU). See Table 8.1.4 for power-delay profiles Fading across all pairs of antennas is completely uncorrelated.
CPICH Ec/Ior	-10 dB
Total Overhead power including C-PICH	20%
UE Antenna Gain	0 dBi
UE noise figure	9 dB
UE Receiver	Type 3i for BE UE. MRC-Rake with 1 receive antenna for Voice UE.
Thermal noise density	-174 dBm/Hz
Maximum Sector Transmit Power	43 dBm
Soft Handover Parameters	R_{1a} (reporting range constant) = 6 dB
HS-DSCH	Up to 15 SF-16 codes per carrier for HS-PDSCH HS-SCCH transmit power being driven by 1% HS-SCCH BLER. 0.5dB fixed margin is applied to CQI for rate control.
CQI	9 slot CQI delay CQI estimation noise is Gaussian with mean of 0 dB and variance of 1dB CQI Decoding at Node-B is ideal.
Number of H-ARQ processes	6
Maximum number of HARQ transmissions	4
Maximum active set size	3

DL Scheduling	Proportional Fair

8.2.3.1.3 Simplified simulation methodology for HSDPA throughput from voice-only simulation

A simplified simulation methodology may also be used in order to evaluate HSDPA data throughput by modeling only voice users in the system simulations. This is done by estimating the data throughput as a function of the power and number of codes available for HSDPA after accounting for the power and codes used by the overhead channels and by the circuit-switched voice UEs. This methodology is described as follows:

The radio resources shared by CS voice and HSDPA data include both transmit power and OVSF codes. In system simulations, the set of OVSF codes used by CS voice users is determined once the active set for each user is computed. Power used by each CS voice user is determined by inner/outer loop power control which maintains voice quality. When CS voice and HSDPA data coexist, the QoS of CS voice has a priority over HSDPA data. Hence available power and OVSF code of HSDPA data is then determined after the allocation of CS voice power and code.

In this simplified model, we use the following steps in modelling HSDPA throughput, where only CS voice needs to be simulated in system simulation

- **Step 1:** Fix DL Node-B transmit power to the maximum as P_{max}
- **Step 2:** Running CS voice only in a system simulation, compute the averaged OVSF code C_{voice} and average DL voice power P_{voice} per cell as follows

  $C_{voice} = \sum_n C(n)/N, \quad P_{voice} = \sum_n P(n)/N$

  where n is the cell index, N is the total number of cells, the summations run over all cells in the simulation, and C(n), P(n) are respectively the number of OVSF codes (in units of SF512) and transmit power used by voice users in cell n.

- **Step 3:** Calculate available SF16 OVSF code and power for HSDPA as

  $C_{hs} = \lfloor (512 - C_{comm} - C_{voice})/32 \rfloor$, $P_{hs} = P_{max} - P_{comm} - P_{voice}$

  where C_{comm} =24 and P_{comm}= 0.2 P_{max} are respectively the OVSF code and power used for common channels.

  Then using C_{hs} and P_{hs} as the index, interpolate the HSDPA power vs. code vs. throughput tables shown in Tables 8.2-7A and 8.2-7B to get the corresponding HSDPA throughput. These tables are also displayed as mapping curves in Figures 8.2-3, 8.2-4.

Note that power compression for CS voice users is needed whenever the total power of voice users exceeds the upper bound of Node-B transmit power. Considering the slot averaged power from all voice users is P_{voice}, and the maximum transmit power of Node-B is P_{max}, thus $P_{comp} = P_{max} - P_{voice}$ is the power that needs to be compressed. Voice UEs with maximum slot averaged power are compressed. Here we select voice UEs with maximum DL Ec/Ior which have $P_{voice\_max} > P_{comp}$, where P_{voice_max} is the sum of the powers of the selected voice UEs. Each UE's power is then compressed with a scaling factor $(P_{voice\_max} - P_{comp})/P_{voice\_max}$.

Table 8.2-7A: DL Mapping Table for PA3(ITU)

Mapping power (% of max) and number of SF-16 OVSF codes to HSDPA throughput (Mbps)															
Available Power\ Code	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
80%	6.5	6.3	6.1	5.8	5.5	5.2	5.0	4.6	4.3	3.9	3.5	3.0	2.4	1.8	0.9
70%	6.1	6.0	5.7	5.5	5.2	4.9	4.7	4.4	4.0	3.7	3.3	2.9	2.3	1.7	0.9
60%	5.7	5.5	5.3	5.1	4.8	4.6	4.4	4.1	3.8	3.5	3.1	2.7	2.2	1.6	0.9
50%	5.2	5.1	4.9	4.7	4.5	4.2	4.1	3.8	3.5	3.2	2.9	2.5	2.1	1.6	0.9
40%	4.7	4.5	4.3	4.2	4.0	3.8	3.7	3.4	3.2	3.0	2.7	2.3	1.9	1.5	0.8
30%	4.0	3.8	3.7	3.6	3.5	3.3	3.1	3.0	2.8	2.6	2.3	2.0	1.7	1.3	0.8
20%	3.1	3.0	2.9	2.9	2.8	2.6	2.6	2.4	2.3	2.1	1.9	1.7	1.5	1.2	0.7
10%	1.9	1.9	1.9	1.8	1.8	1.7	1.7	1.6	1.6	1.5	1.4	1.2	1.1	0.9	0.5

Table 8.2-7B: DL Mapping Table for VA30(ITU)

Mapping power (% of max) and number of SF-16 OVSF codes to HSDPA throughput (Mbps)															
Available Power\ Code	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
80%	3.6	3.5	3.4	3.3	3.1	3.0	2.8	2.7	2.5	2.3	2.1	1.8	1.5	1.2	0.7
70%	3.4	3.3	3.2	3.1	2.9	2.8	2.7	2.5	2.3	2.1	1.9	1.7	1.5	1.2	0.7
60%	3.1	3.0	2.9	2.8	2.7	2.6	2.5	2.3	2.2	2.0	1.8	1.6	1.4	1.1	0.7
50%	2.8	2.7	2.6	2.5	2.5	2.3	2.2	2.1	2.0	1.8	1.7	1.5	1.3	1.0	0.6
40%	2.4	2.4	2.3	2.2	2.2	2.1	2.0	1.9	1.8	1.7	1.5	1.3	1.1	0.9	0.6
30%	2.0	2.0	1.9	1.9	1.8	1.7	1.7	1.6	1.5	1.4	1.3	1.2	1.0	0.8	0.5
20%	1.5	1.5	1.4	1.4	1.4	1.3	1.3	1.3	1.2	1.1	1.0	1.0	0.8	0.7	0.4
10%	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.6	0.5	0.3

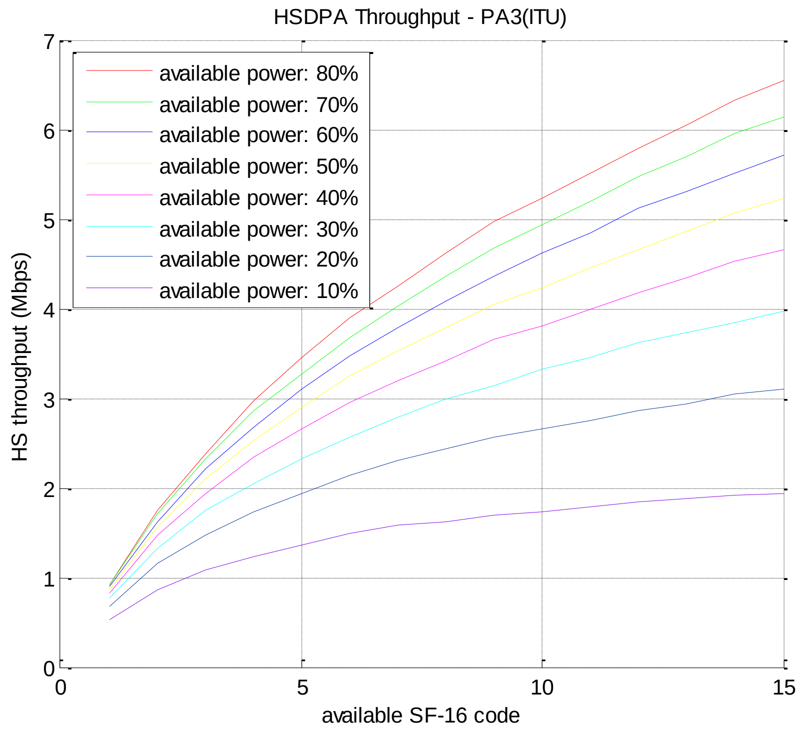


Figure 8.2-3: HSDPA Mapping, PA3(ITU).

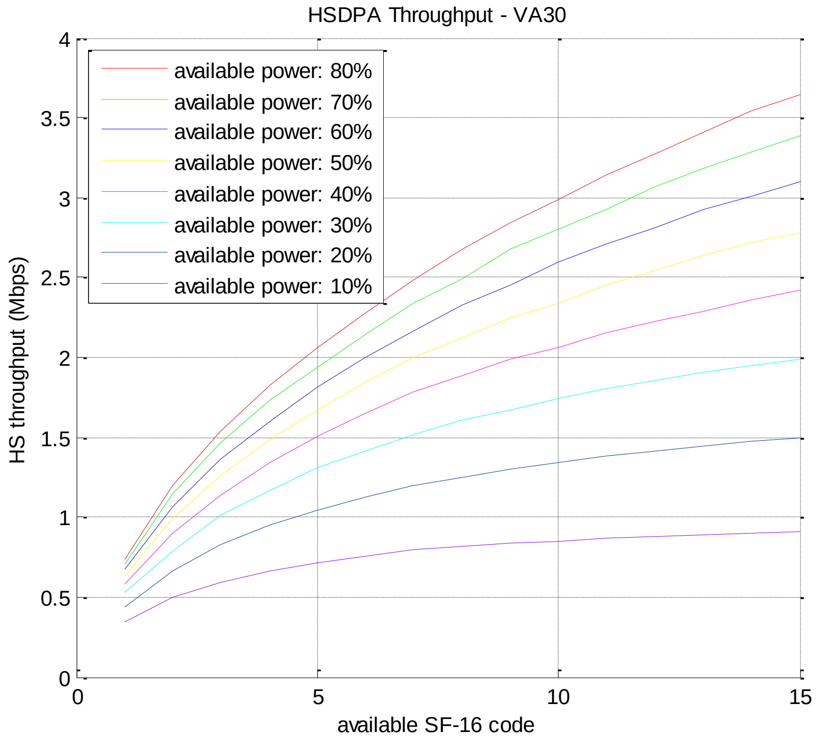


Figure 8.2-4: HSDPA mapping, VA30 (ITU)

8.2.3.1.4 Link-to-system mapping for DCH

This clause describes the downlink DCH link-to-system mapping methodology to be used for the evaluation of DCH enhancements. Similar methodology also applies to the link-to system mapping for uplink DCH.

Step 1: Obtain the mapping curves from DPCH RX SINR to DTCH BLER from link level simulations.

Step 1-1 : DPCH RX slot SINR calculation

The DPCH RX slot SINR (*dpch_slot_sinr_lin*) is calculated as follows:

$$dpch\_slot\_sinr\_lin = \frac{dpch\_pwc\_sp}{intra\_cell\_pwc\_np + inter\_cell\_pwc\_np}$$

, where dpch_pwc_sp stands for power of (signal part after PWC), which is calculated by

$$dpch\_pwc\_sp = SF * \left\{ \sum_{r=1}^{R} \sum_{a=1}^{A} \left[\sqrt{DPCH\_Ec(a)} * \sum_{f=1}^{F(a)} \left| h_{avg}(a,f,r) \right|^2 \right] \right\}^2$$

, intra_cell_pwc_np stands for PWCed intra-cell interference power, which is calculated by

$$intra\_cell\_pwc\_np = \sum_{r=1}^{R} \sum_{a=1}^{A} \left\{ \hat{I}or(a) * \sum_{f=1}^{F(a)} \sum_{\substack{f2=1, \\ f2 \neq f}}^{F(a)} \left| h_{avg}(a,f,r) \right|^2 \cdot \left| h_{avg}(a,f2,r) \right|^2 \right\}$$

, inter_cell_mrc_np stands for PWCed inter-cell interference power, which is calculated by

$$inter\_cell\_pwc\_np = \sum_{r=1}^{R} \sum_{a=1}^{A} \left\{ \left[\sum_{f=1}^{F(a)} \left| h_{avg}(a,f,r) \right|^2 \right] * \left[Ioc + \sum_{\substack{c=1 \\ c \neq a}}^{C} \hat{I}or(c) * \sum_{f=1}^{F(c)} \left| h_{avg}(c,f,r) \right|^2 \right] \right\}$$

All these abbreviations are defined as follows:

$$\begin{array}{ll} r = \text{RX antenna index}; & \text{t} = \text{TX antenna index}; \\ \text{R} = \text{\# of RX antennas}; & \text{T} = \text{\# of TX antennas}; \\ f = \text{finger(path) index}; & \text{h} = \text{channel impulse response}; \\ \text{F} = \text{\# of fingers}; & \text{A} = \text{\# of active set cells}; \\ \text{C} = \text{\# of all cells}; & \text{SF} = \text{DPCH spreading factor}; \\ \text{a} = \text{active set cell index}; & \text{c} = \text{cell index (First A} \in \text{active set)}; \\ \text{x} = \text{fader sample index}; & \text{X} = \text{\# of fader samples / slot} \\ \text{Ioc} = \text{Thermal noise}; & \hat{\text{I}}\text{or} = \text{BS TX power observed @ UE}; \\ \text{h}_{\text{avg}} = \text{Norm \& Avg of CIR}; & \text{DPCH\_Ec} = \text{DPCH TX power observed @ UE}; \end{array}$$

and $h_{avg}(c,f,r)$ is defined as

$$h_{avg}(c, f, r) = \sqrt{\frac{1}{X} \cdot \sum_{x=1}^{X} \sum_{t=1}^{T(c)} \left(\left| h(c, f, t, r, n) \right|^2 / T(c) \right)}$$

If RX finger number is different to multipath number, corresponding modifications are required.

Step 1-2 : DPCH RX TTI SINR calculation.

DPCH RX TTI SINR is obtained by averaging DPCH RX slot SINR across all slots in the TTI.

Step 1-3 : Mapping curve generation

Given different channel models and different geometry, simulations are performed to get curves that map DPCH RX SINR to DTCH BLER.

Step 2: System level simulation

For each UE, DPCH RX TTI SINR is calculated every TTI and is used to obtain the DTCH BLER using the mapping curves generated in Step 1. The DTCH BLER is used to determine whether the instantaneous speech block is successfully decoded or not. Outer loop power control is simulated to adjust the target SINR accordingly. Inner loop power control is simulated based on the simulated TPC rate.

8.2.3.2 System simulation assumptions for Uplink

8.2.3.2.1 Simulation assumptions for Uplink voice over R99 DCH

Table 8.2-8: Uplink System Simulation Assumptions for R99 CS Voice

Parameters	Comments			
Traffic Type	RAB: AMR12.2K; AMR5.9K SRB: not transmitted			
TBS, Spreading Factor and DPDCH Power Boost	Packet	TBS	Spreading Factor	DPDCH/DPCCH power ratio(dB)
	Full-AMR12.2K	(81,103,60) for DTCH-A,B,C	64	-0.5993
	SID-AMR12.2K	39	256	-6.6199
	Null-AMR12.2K	0	DPDCH DTXed	N/A
	Full-AMR5.9K	(55,63) for DTCH-A,B	64	-2.694
	SID-AMR5.9K	39	128	-6.6199
	Null-AMR5.9K	0	DPDCH DTXed	N/A
TTI Configuration	20ms			
Encoder	rate of 1/3, 1/3, 1/2 convolutional code for Class A,B,C			
CRC	12-bit CRC on Class-A and on SID frames.			
Modulation	BPSK			
DPCCH slot format	0 (6 pilots, 2 TPC, 2 TFCI bits per slot)			
TFCI Decoding Error Modeling	0% error rate			
OLPC	1% target residual BLER at TTI end +0.5dB when packet decoding error			
ILPC	1500Hz ILPC rate 2 slot feedback delay +1dB/-1dB step size 4% error rate			

8.2.3.2.2 General system assumptions for Uplink

The system simulation assumptions for the mixed CS voice on DCH and BE data over HSUPA are listed in Table 8.2-9.

Table 8.2-9: UL System Simulation Assumptions for mix of CS voice on DCH and BE data on HSUPA

Parameters	Comments	
Cell Layout	Hexagonal grid, 19 Node-Bs, 3 sectors per Node B with wrap-around	
Inter-site distance [m]	1000	
Carrier Frequency	2000 MHz	
Path Loss	L=128.1 + 37.6log10(R), R in kilometres	
Log Normal Fading	Standard Deviation : 8dB Inter-Node B Correlation: 0.5 Intra-Node B Correlation :1.0 Correlation Distance: 50m	
Antenna pattern	= 70 degrees, Am = 20 dB	
Channel Model	100% PA3 (ITU), 100% VA30 (ITU). See Table 8.1.4 for power-delay profiles.	
Penetration loss [dB]	10	
Maximum UE EIRP	23 dBm	
Uplink system noise	–103.16 dBm	
HS-DPCCH	CQI Feedback Cycle	1 TTI
	Δ_{ACK} [dB]	2 (not in SHO), 4 (in SHO)
	Δ_{NACK} [dB]	2 (not in SHO), 4 (in SHO)
	Δ_{CQI} [dB]	2 (not in SHO), 4 (in SHO)
βec/ βc	15/15	
Soft Handover Parameters	R1a (reporting range constant) = 6 dB	
UE distribution	Uniform over the area	
Number of UEs per sector	4 (BE users on E-DCH) 0, 8, 16, 24, 32, 40, 48 (CS Voice on DCH)	
Node-B Receiver	MRC Rake (2 antennas per cell)	
Uplink HARQ	2ms TTI,Max # of transmissions =4,Target BLER=1% after 4th transmission, 8 HARQ processes.	
Maximum active set size	3	
Inner Loop Power Control Delay	2 slots	
Outer Loop Power Control Delay [radio frames]	2	
UL TPC Error Rate [%]	4	
HSUPAScheduling Delays	Period	2ms
	Uplink SI delay	6 slots
	DL Grant delay	As per 3GPP TS 25.321 [14]
Scheduling Type	Proportional Fair	
Target RoT	6dB	

A simplified simulation methodology may also be used in order to evaluate HSUPA data throughput by modeling only voice users in the system simulations.
This is done by estimating the data throughput as a function of the fraction of RoT available for HSDPA after accounting for the power used by the overhead channels and by the circuit-switched voice UEs. This methodology is described as follows:

In UL system simulation, CS voice and HSUPA data services share the load of the cell together. With increasing number of CS voice users, load of CS voice is also increasing which means less available load for HSUPA data users. Assuming the load of the cell is fixed, HSUPA throughput can be calculated as a function of available HSUPA load.
Here a simplified way in mapping the HSUPA throughput is provided with the following steps:

- **Step 1:** Assume fixed Io_{total} on each cell, based on the target RoT in Table 8.2-9.
- **Step 2:** Simulating the CS voice only case, compute the long term averaged load of CS voice as

  $L_{voice} = Io_{voice\_mean}/Io_{total}$; where $Io_{voice\_mean} = \sum_n Io_{voice}(n)/N$, where n is the cell index, N is the total number of cells, the summations run over all cells in the simulation, and $Io_{voice}(n)$ is the total received power from voice users in cell n.
- **Step 3:** Calculate available load for HSUPA user by as Lhs = 1- L_{voice} – 1/RoT, and use it to interpolate the HSUPA load vs. throughput table shown in Table 8.2-10 and Figure 8.2-5 to compute the HSUPA throughput.

Table 8.2-10: HSUPA load vs throughput (kbps) mapping for ITU channels

HSUPA Load	10%	20%	30%	40%	50%	60%	70%	80%
HSUPA Throughput(PA3)	34.35	288.13	557.77	846.55	1172.83	1552.94	1963.71	2338.79
HSUPA Throughput(VA30)	35.59	171.21	385.96	597.76	810.85	1036.84	1274.61	1521.69

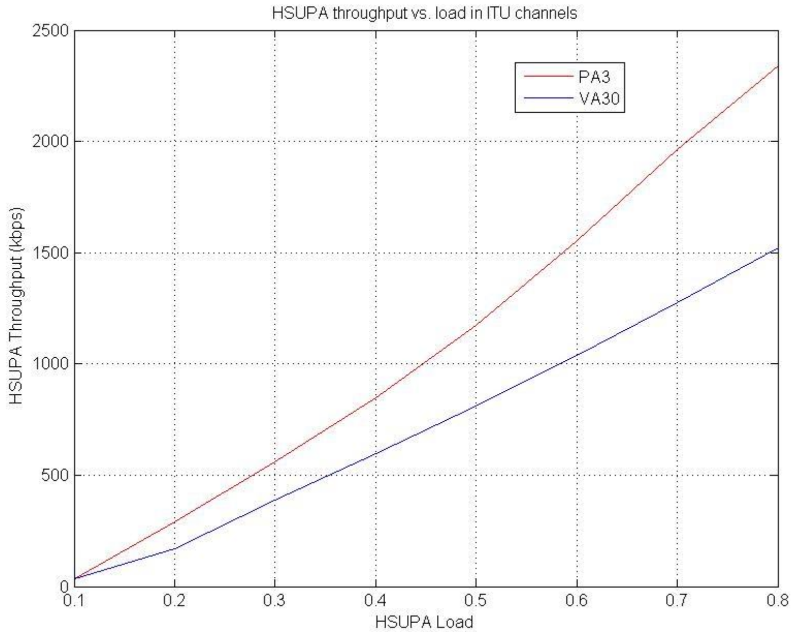


Figure 8.2-5: HSUPA mapping in ITU channels

8.2.4 System performance evaluation metrics

8.2.4.1 System performance metrics for downlink voice over R99 and enhanced DCH

a) Average cell throughput vs. Number of voice users per cell.

b) Average power per cell used by voice users

c) Average power per cell used by HS-PDSCH & HS-SCCH

d) CDF of the run-lengths of consecutive voice packet errors.

e) Percentages of voice users with Active set size of 1,2,3.

f) Percentage of voice users with BLER > 3%

g) CDF of packet delay for voice users.

8.2.4.2 System performance metrics for uplink voice over R99 and enhanced DCH

a) Average cell throughput vs. Number of voice users per cell.

b) Average RxEc/No per cell used by voice users

c) Average RxEc/No per cell used by data users

d) CDF of the run-lengths of consecutive voice packet errors.

e) Percentages of voice users with Active set size of 1,2,3.

f) Percentage of voice users with BLER > 3%

g) CDF of RoT per cell.

h) CDF of packet delay for voice users.

8.2.5 Link simulation assumptions for voice over enhanced DCH (Solution 1 and 3)

8.2.5.1 Link simulation assumptions for Downlink voice over enhanced DCH

8.2.5.1.1 Pilot-free DPCCH slot formats

The new pilot free DPCCH slot formats are listed in Table 8.2-11.

The slot formats 17-24 are used in pairs corresponding to the TDM of two users over a 20ms period. Figure 8.2-6 illustrates the slot formats for a pair of AMR5.9k users. Only one user of a pair of TDM users is evaluated in the link simulations. Slot formats 17 and 18 are to be used for the AMR 5.9K codec, and slot formats 21 and 22 are to be used for the AMR 12.2K codec. The DPCCH/DPDCH power offsets used are the same as those in the baseline assumptions as described in Table 8.2-1.
The TTI reduction causes higher setpoints for each UE, although average power spent by Node-B does not increase since the number of UEs to which simultaneous transmission is required is halved. Hence, the maximum TxEc/Ior setting for use with these slot formats can be appropriately increased compared to that used for R99 DCH as listed in Table 8.2-1.

Table 8.2-11: New DL DPCH slot formats

Vocoder	Slot Format #i	Channel Bit Rate (kbps)	Channel Symbol Rate (ksps)	SF	Bits/ Slot	DPDCH Bits/Slot		DPCCH Bits/Slot			Transmitted slots per radio frame
						N_{Data1}	N_{Data2}	N_{TPC}	N_{TFCI}	N_{Pilot}	N_{Tr}
AMR 5.9K	17	60	30	128	40	4	32	4, last 2 are DTXed	0	0	15
AMR 5.9K	18	60	30	128	40	4 DTX	32 DTX	4, last 2 are DTXed	0	0	15
AMR 5.9K	19	60	30	128	40	4	32	4, first 2 are DTXed	0	0	15
AMR 5.9K	20	60	30	128	40	4 DTX	32 DTX	4, first 2 are DTXed	0	0	15
AMR 12.2K	21	120	60	64	80	12	64	4, last 2 are DTXed	0	0	15
AMR 12.2K	22	120	60	64	80	12 DTX	64 DTX	4, last 2 are DTXed	0	0	15
AMR 12.2K	23	120	60	64	80	12	64	4, first 2 are DTXed	0	0	15
AMR 12.2K	24	120	60	64	80	12 DTX	64 DTX	4, first 2 are DTXed	0	0	15

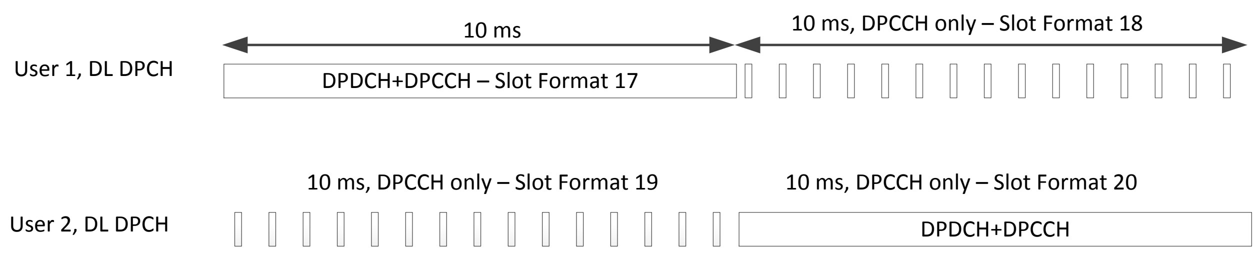


Figure 8.2-6: Slot Formats used with TDM of two users – AMR5.9K

8.2.5.1.2 DPDCH Frame Early Termination (FET)

Frame Early Termination (FET) is an enhancement in which the receiver attempts early decoding of the packet, i.e., decoding prior to complete reception of the packet. An ACK feedback mechanism informs the transmitter of successful early decoding, and the transmission is terminated upon reception of the ACK. Since the false CRC-pass rate increases due to increase in the number of early decoding attempts, a 16 bit CRC is used for error detection (using the 16 bit CRC polynomial defined in 3GPP TS 25.212 [4]).
DL FET parameters are listed in 8.2-12.

Table 8.2-12: DL FET Parameters

Parameter	Value
Channel Encoding	Joint coding for AMR Class A,B,C bits
Early decode attempts	Once every slot, starting after receiving the first 2ms (=3 slots) of the transport block
Early termination modelling	DTX entire-DL-DPCCH and DL-DPDCH upon receiving ack, except for warm up period where only DL DPCCH is transmitted
Number of warm up slots for DPCCH	0,1
CRC Size	16, 12 (optional)

The ACK feedback timeline is shown in Figure 8.2-7.

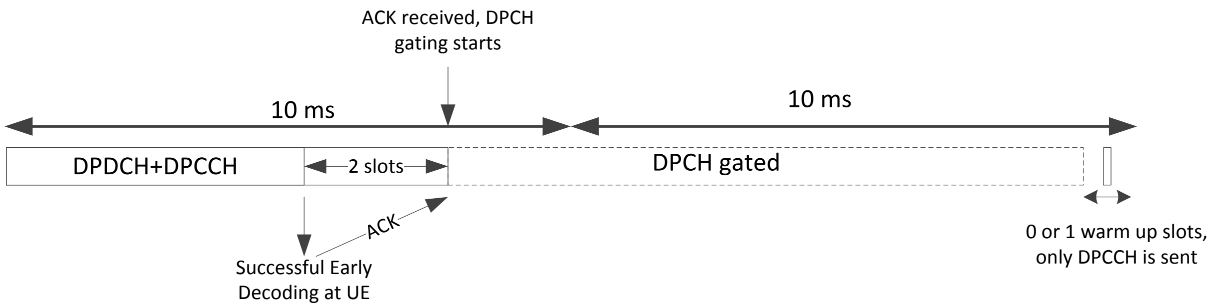


Figure 8.2-7: DL FET

The OLPC operation is modified to account for successful early decoding attempts in FET. A successful early decoding event results in a reduction of the SIR target. The receiver does not attempt any further decode attempts once the frame has successfully decoded.
The SIR target is increased if the packet fails in all decoding attempts, including early decoding instances and final decoding after the entire packet has been observed.

During warm up slots, only DPCCH is transmitted to assist ILPC with tracking the channel, if necessary.

Ideal ACK decoding is assumed for simplicity. A 2 slot delay is assumed for ACK message. The parameters pertaining to the ACK modeling are shown in Table 8.2-13.

Table 8.2-13: ACK channel modelling in DL

Parameter	Value
Early decode ack-delay —See Figure 8.2-7.	2 slots
Early decode Ack miss rate	0%
Early decode false-Ack rate	0%

The rate matching parameters to be used with the new slot formats are specified in Table 8.2-14. Figure 8.2-8 shows DL bit pipeline and defines the parameters specified in Table 8.2-14. A single transport channel is used to carry all DTCH packets. This ensures that all bits are protected by CRC, as opposed to the current scheme where the Full voice packet is subdivided into separately encoded packets, some of which are not protected by the CRC. Using the current scheme would result in higher BER for the bits that are not protected by CRC if the packet is terminated when the bits that are protected by CRC are early decoded.

Table 8.2-14: DTCH rate matching parameters

Vocoder	Transport block	TBS= N_{info}	CRC size = N_{crc}	Encoding	Slot formats+	Number of encoded bits punctured by rate-matching N_{punc}*	Rate-matching Attributes (DTCH, DCCH)
AMR12.2K	Full-joint A,B,C+CI**	245	16	Conv 1/3	21,22	-83	205,180
AMR12.2K	SID+CI	40	16	Conv 1/3	21,22	-20	205,180
AMR12.2K	Null+CI	1	16	Conv 1/3	21,22	-8	205,180
AMR5.9K	Full-joint A,B+CI	119	16	Conv 1/3	17,18	99	218,230
AMR5.9K	SID+CI	40	16	Conv 1/3	17,18	45	218,230
AMR5.9K	Null+CI	1	16	Conv 1/3	17,18	18	218,230

NOTE 1: Negative number indicates repetition. Definition of N_{punc} is illustrated in Figure 8.2-8, and its value depends on the rate-matching attributes.
NOTE 2: A pair of slot-formats indicates slot-formats used in alternate 10ms TTIs.
NOTE 3: CI = control indicator = 1 bit indicating presence or absence of DCCH; so that UE, on successful early decoding of DTCH, requests Node-B to early-terminate DPDCH if and only if DCCH is absent.

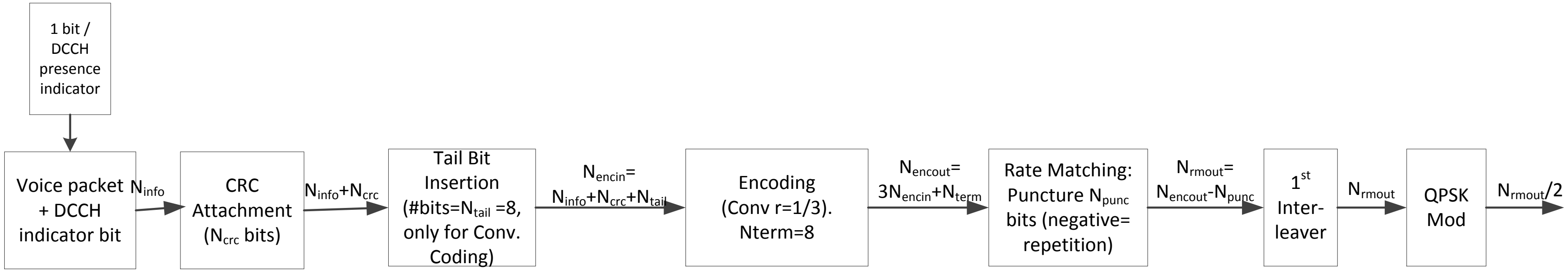


Figure 8.2-8: Encoding and modulation of voice transport blocks for downlink, showing number of bits at each stage

8.2.5.2 Link simulation assumptions for Uplink voice over enhanced DCH

8.2.5.2.1 DPDCH Frame Early Termination (FET)

UL FET is similar to DL FET in principle; upon early decoding of data transport channel, an ACK message is sent to terminate UL transmission. Since false CRC pass rate increases by increasing the number of early decoding attempts, 16 bit CRC is used for error detection. The UL FET parameters are listed in Table 8.2-15.

Table 8.2-15: UL FET Parameters

Parameter	Value
Channel Encoding	Joint coding for Class A,B,C bits in AMR full packet
Early decode attempts	Once every slot
Early termination modelling	DTX entire UL-DPCCH and UL-DPDCH upon receiving ack, except during warmup periods where only UL-DPCCH is sent.
Warm up period (slots)	0,1

The ACK feedback timeline for UL FET is shown in Figure 8.2-9.

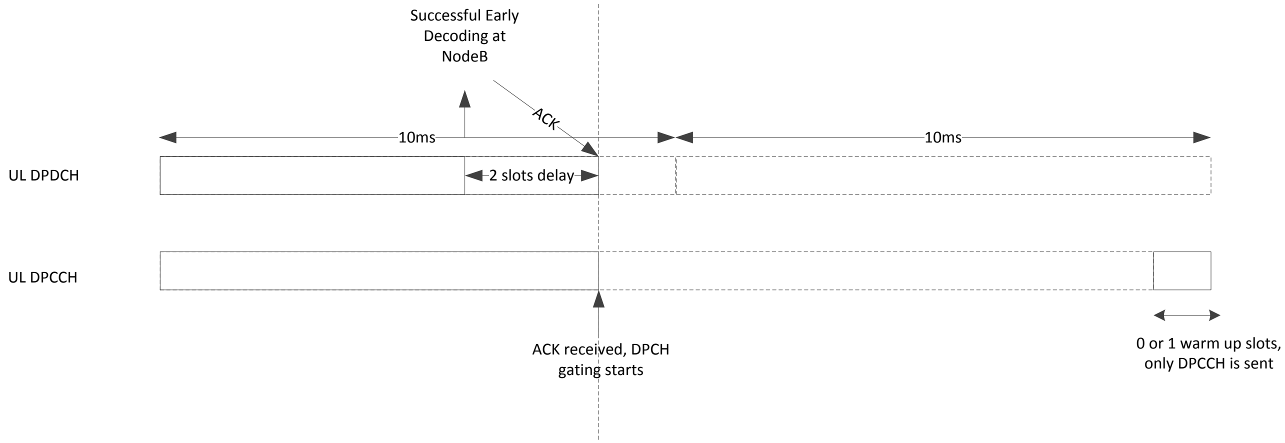


Figure 8.2-9: UL FET

Warm up slots in UL DPCCH are provisioned to enhance channel tracking in presence of FET.

In the UL, the OLPC is modified to assist FET by targeting to achieve a certain BLER value at a particular FET attempt. The BLER value is chosen such that the overall final BLER after all decoding attempts is less than or equal to desired block error rate for the voice traffic, and the slot at which BLER target is enforced may be an earlier slot in the TTI. This is shown in Figure 8.2-10, where the parameter OLPC_TARGET_SLOT specifies the location within the entire transport block (combined repeated transport blocks) at which OLPC targets a specified BLER. The values of OLPC_TARGET_SLOT and BLER in this study are TBD. OLPC updates the SIR target at the Node-B whenever a successful decoding attempt occurs for any transport channel (a CRC pass), or if decoding fails (no CRC pass) in all decoding attempts up to, and including, the decoding attempt happening at OLPC_TARGET_SLOT.

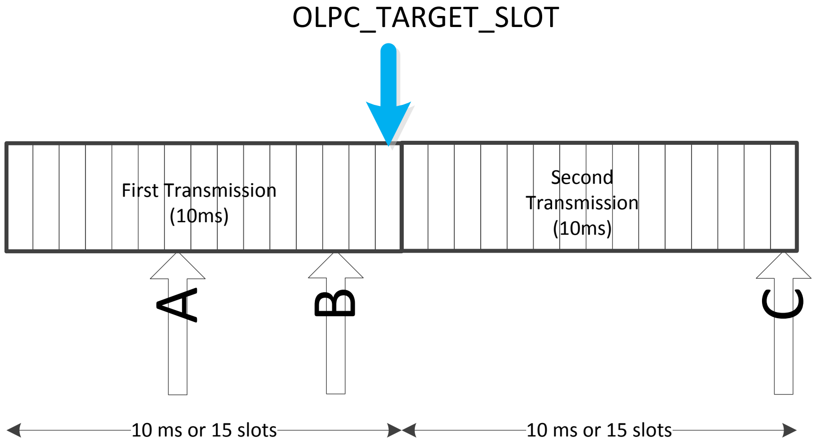


Figure 8.2-10: OLPC and Multiple Decoding Attempts

The details of the OLPC operation are shown in Table 8.2-16.

Table 8.2-16: OLPC Operation

Decoding Attempt A	Decoding Attempt B	Decoding Attempt C	OLPC SIR Update
CRC Pass	Not tried	Not tried	Update as a CRC Pass – immediately after A
CRC Fail	CRC Pass	Not tried	Update as a CRC Pass – immediately after B
CRC Fail	CRC Fail	CRC Pass	Update as a CRC Fail – immediately after B
CRC Fail	CRC Fail	CRC Fail	Update as a CRC Fail – immediately after B

The ACK channel for UL FET is assumed to be ideal for the purpose of this study for the sake of simplicity. A 2ms delay for ACK message is assumed. The parameters pertaining to the ACK modeling are shown in Table 8.2-17.

Table 8.2-17: ACK channel modelling in UL

Parameter	Value
Early decode ack-delay. See Figure 8.2-9.	2 slots
Early decode Ack miss rate	0%
Early decode false-Ack rate	0%

8.2.5.2.2 Uplink DTCH / DCCH compression and repetition

In the uplink, the compression and repetition of the DTCH/DTCH allows for more efficient FET operation. This is achieved by configuring the DTCH channel with 10ms TTI, along with a repetition at the MAC layer. Figure 8.2-11 shows the UL compression using 10ms TTI and transport block retransmission at MAC layer.

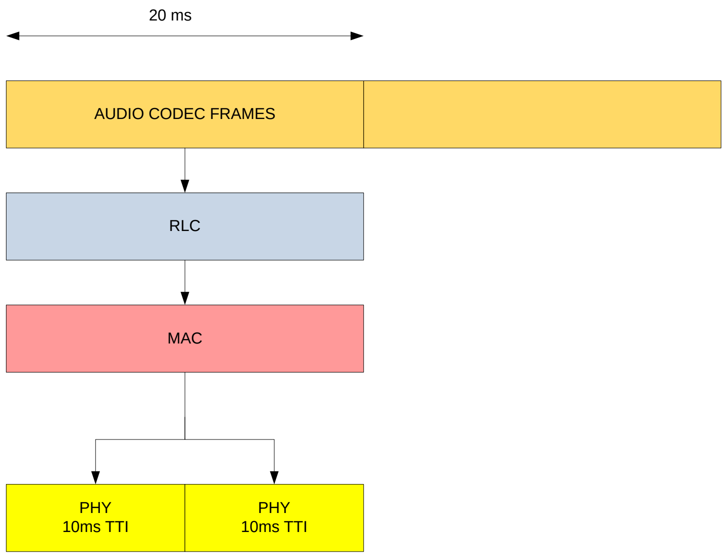


Figure 8.2-11: Transport block repetition at MAC Layer in UL

The beta gain factors in dB along with spreading factors used in UL are listed in Table 8.2-18 for the different TFCs. Optimization of the beta gain factors has been performed while taking the uplink DTCH / DCCH compression and repetition into account.

Table 8.2-18: Voice transport blocks simulated on UL with enhanced DCH, and corresponding spreading factors

Vocoder	Transport block	TBS= N_{info}	CRC size= N_{crc}	DPDCH Spreading factor	DPDCH/DPCCH beta gain factors (dB)
AMR12.2K	Full	244	16	32	2.694
AMR12.2K	SID	39	16	128	-5.46
AMR5.9K	Full	118	16	64	-0.5993
AMR5.9K	SID	39	16	128	-5.46
NOTE: For Null transport block, DPDCH is entirely DTXed, and decoding is based on TFCI information.					

*

8.2.5.2.3 FET-DPCCH

The FET-DPCCH is an uplink channel that carries the UL TFCI, and the ACK information for DL FET. The first 2 slots of FET-DPCCH are allocated to TFCI information, which is encoded using the mechanism in use for CQI encoding in HS-DPCCH channel based on (20, 5) Reed Muller codes. The ACK information can be sent in subsequent slots as shown in Figure 8.2-12 and is encoded in the same way as the HARQ-ACK in the HS-DPCCH channel. TFCI information is sent at the beginning to allow Node-B to decode UL transport block format earlier.

Tables 8.19 and 8.20 list other parameters pertaining to the FET-DPCCH channel.

Table 8.2-19: TFCI Control Channel Slot Format

Slot Format	Channel Bit Rate	Channel Symbol Rate	SF	Bits/Slot
0	15	15	256	10

Table 8.2-20: TFCI Control Channel Parameters

Parameter	Value
TFCI encoding	(20,5) Reed Muller Code
Multiplexing	Sent using a new channelization code on the UL
Transmission	Transmitted over the first 2 slots of every 20ms TTI
Power offset w.r.t pilot	0dB

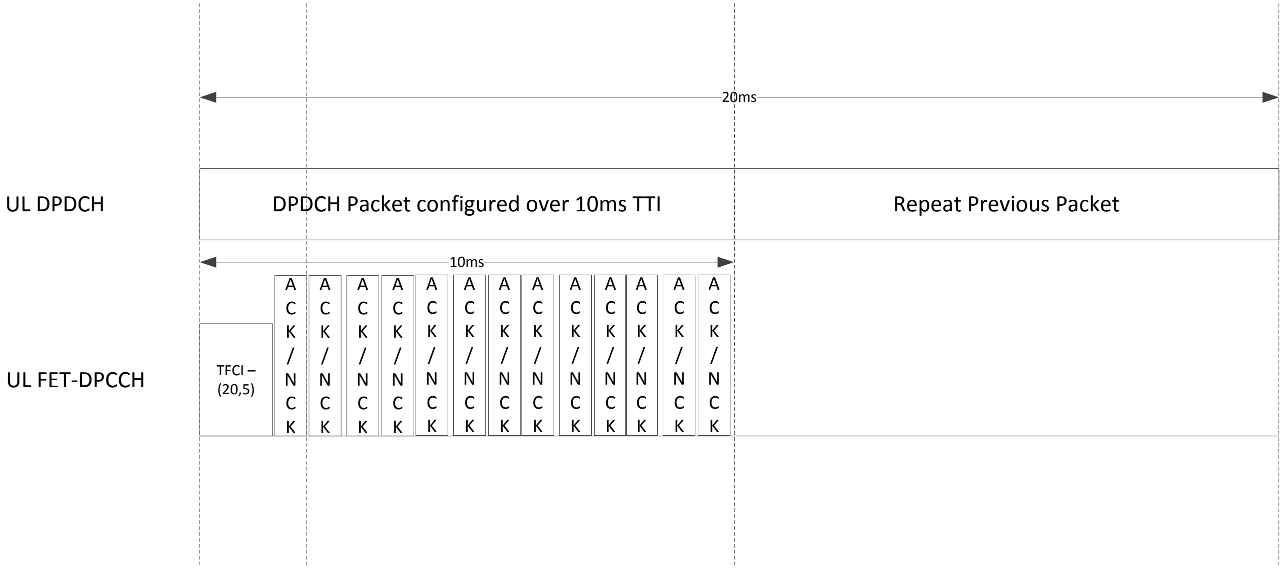


Figure 8.2-12: TFCI Control channel carrying TFCI and ACK information on UL

8.2.6 Link simulation assumptions for voice over enhanced DCH (Solution 2 and 4)

8.2.6.1 Link simulation assumptions for Downlink voice over enhanced DCH

8.2.6.1.1 New proposed slot formats

Table 8.2.6-1 lists 4 new proposed DL DPCH slot formats (#17, #18, #19 and #20). DL DPCH slot format #17 is the default one if new proposed slot format is used.

Table 8.2.6-1 - The proposed new DL DPCH slot formats

Slot Format #i	Channel Bit Rate (kbps)	Channel Symbol Rate (ksps)	SF	Bits/ Slot	DPDCH Bits/Slot		DPCCH Bits/Slot			Transmitted slots per radio frame
					N_{Data1}	N_{Data2}	N_{TPC}	N_{TFCI}	N_{Pilot}	N_{Tr}
17	60	30	128	40	6	32	2	0	0	15
18	60	30	128	40	4	32	4	0	0	15
19	60	30	128	40	38	0	2	0	0	15
20	60	30	128	40	36	0	4	0	0	15

Table 8.2.6-2 and Figure 8.2.6-1 describes the proposed DL DPCH slot formats when TDM is introduced. Slot format #21 is the default simulated one if TDM is used.

Table 8.2.6-2: New DL DPCH Slot Formats with TDM

Slot Format #i	SF	DPDCH Bits/Slot		DPCCH Bits/Slot	Transmitted slot index per radio frame
		N_{Data1}	N_{Data2}	N_{TPC}	
21A	64	12	62	6, last 4 are DTXed	{0,3,6,9,12}
21B	64	12 DTX	62 DTX	6, last 4 are DTXed	{1,2,4,5,7,8,10,11,13,14}
22A	64	12	62	6, first 2 and last 2 are DTXed	{0,3,6,9,12}
22B	64	12 DTX	62 DTX	6, first 2 and last 2 are DTXed	{1,2,4,5,7,8,10,11,13,14}
23A	64	12	62	6, first 4 are DTXed	{0,3,6,9,12}
23B	64	12 DTX	62 DTX	6, first 4 are DTXed	{1,2,4,5,7,8,10,11,13,14}

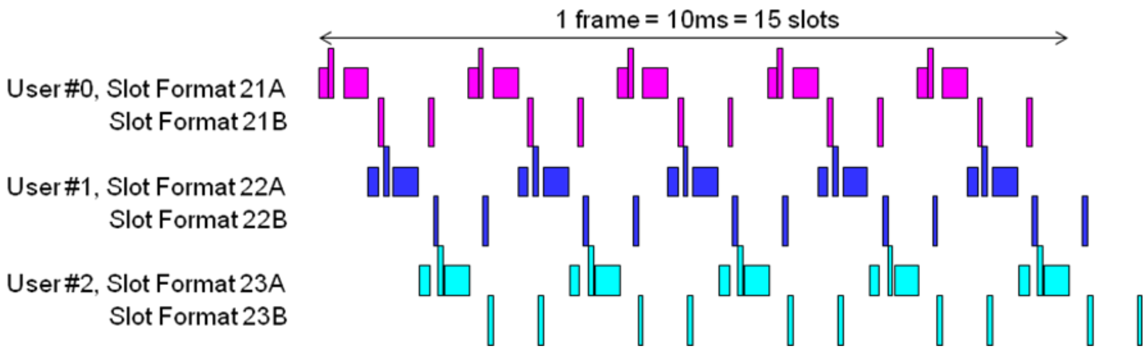


Figure 8.2.6-1: Illustration of DL DPCH slot formats for TDM of three users

8.2.6.1.2 Early Termination

ETI feedback error rate is assumed to be 0 for simplicity. The receiver decoding attempts are assumed slot 2 to slot 29 within a TTI, and the early termination indicator feedback delay is assumed 2 slots. As shown below, UE has no successful decoding until it collects data of slot 0~slot 9. According to the ETI feedback procedure, Node-B terminates DPDCH after slot 12. Since ET indicator transmission mechanism is still under discussion. To isolate the ET performance and the ETI mechanisms, it is assumed ETI can be transmitted in some way.

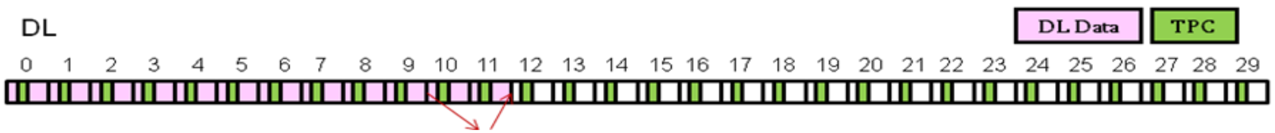


Figure 8.2.6-2: An example of ET for DL data transmission with new DL DPCH slot format

When DL and UL data transmission are both early terminated, DPCCH can be also terminated with negligible impact to system performance. Since UL is not simulated in DL performance simulation, Node-B is assumed to be able to stop DPCCH transmission as long as Node-B terminates DPDCH transmission for simplicity. The period is called ET Gap. One slot is used for power control warm up before entering the next TTI. ET Gap is shown in the below figure.

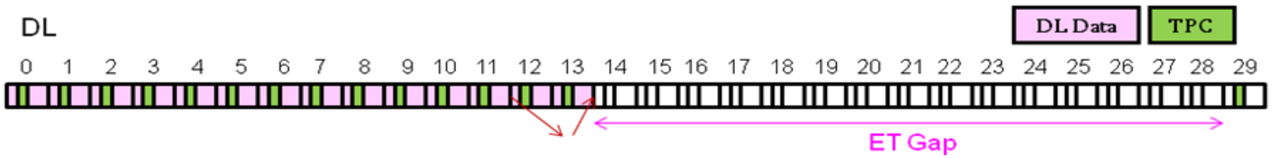


Figure 8.2.6-3: An example of ET for DL data transmission with new DL DPCH slot format

Table 8.2.6-3 lists parameters specific to ET. Additional parameters are listed in Table 8.2.6-4.

Table 8.2.6-3: ET related parameters

Parameter	Description
ETI feedback error rate	0%
ETI feedback delay	2 slots
Decoding attempts	slot 2~ slot 29
ET Gap warm up slot number	1
CRC size	16

Table 8.2.6-4: some other parameters

Parameter	Description
Speech codec	AMR 12.2k
TFCI or BTFD	BTFD
TPC rate	1500Hz
RX finger assignment	The unit is 1/8 chip PA : [0, 3, 6, 13] PB : [0, 6, 25, 37, 71, 114] VA : [0, 10, 22, 33, 53, 77]
CE mechanism	PWC
CE average symbol length	29 symbols
DPDCH power adjustment ("Final DPDCH Tx power" = "DPDCH Tx power" + "DPDCH power adjustment")	-10.48 dB for "Null" -6.29 dB for "SID" 0 dB for "Full"

8.2.6.1.3 Others

Table 8.2.6-5 lists some additional parameters. In this table, E-WCDMA stands for WCDMA with DPCH optimizations including DPCH slot format optimization, dynamic TPC, and early termination. Note that 1.5dB TPC PO is used for "E-WCDMA + TDM" for fair comparison, otherwise there will be bias against the other two schemes (Legacy and E-WCDMA) in terms of TPC CER. Since three UEs share one DPCH channel in TDM, the maximum DPDCH Ec/Ior is relaxed from -10dB to -7dB in simulation.

Table 8.2.6-5 – Additional parameters

Parameter	Value
Speech codec	AMR 12.2k
TPC PO	3dB for "Legacy" and "E-WCDMA" 1.5dB for "E-WCDMA + TDM"
Max Ec/Ior	-10dB for "Legacy" and "E-WCDMA" -7dB for "E-WCDMA + TDM"
TFCI or BTFD	BTFD
CE mechanism	PWC
CE average symbol length	29 symbols

8.2.6.2 Link simulation assumptions for Uplink voice over enhanced DCH

8.2.6.2.1 TFCI based transmission

The original TFCI (10, 32) code is still applied with early decoding. The maximum number of TFC for 12.2k services is 16, which means only 4 bits out of 10 TFCI bits are valid. When 4 bits are encoded to 32 bits, the probability of a successful decoding before the whole 32 bits are fully collected is quite high. Whenever Node-B tries to decode the data, it first performs early decoding for TFCI. This is called TFCI early decoding.

8.2.6.2.2 Early Termination (ET)

ETI feedback error rate is assumed to be 0 for simplicity. The receiver decoding attempts are assumed slot 6 to slot 29 within a TTI, and the early termination indicator feedback delay is assumed 2 slots. As shown below, Node-B has no successful decoding until it collects data of slot 0~slot 9. According to the ETI feedback procedure, UE terminates DPDCH after slot 12. Since ET indicator transmission mechanism is still under discussion. To isolate the ET performance and the ETI mechanisms, it is assumed ETI can be transmitted in some way.

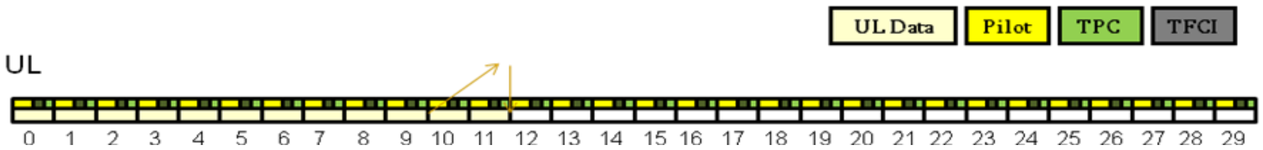


Figure 8.2.6-4: Example of ET for UL data transmission

When DL and UL data transmission are both early terminated, DPCCH can be also terminated with negligible impact to system performance. Since DL is not simulated in UL performance simulation, UE is assumed to be able to stop DPCCH transmission as long as UE terminates DPDCH transmission for simplicity. The period is called ET Gap. One slot is used for power control warm up before entering the next TTI. ET Gap is shown in the below figure.

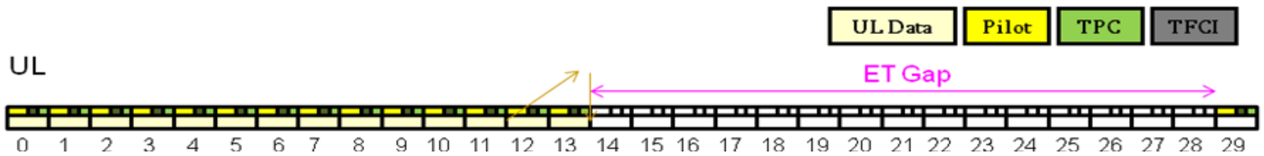


Figure 8.2.6-5: Example of ET for UL data transmission

Table 8.2.6-6 lists simulation parameters specific to ET. Additional parameters are listed in Table 8.2.6-7.

Table 8.2.6-6: Simulation parameters

Parameter	Description
ETI feedback error rate	0%
ETI feedback delay	2 slots
Decoding attempts	slot 6~ slot 29
ET Gap warm up slot number	1
CRC size	16

Table 8.2.6-7 – Additional parameters

Parameter	Description
Speech codec	AMR 12.2k
TFCI or BTFD	TFCI
TPC rate	1500Hz
RX finger assignment	The unit is 1/8 chip PA : [0, 3, 6, 13] PB : [0, 6, 25, 37, 71, 114] VA : [0, 10, 22, 33, 53, 77]
CE mechanism	PWC
CE average symbol length	29 symbols
β_d/ β_c for NULL, SID, FULL	{DTX, 7/15, 14/15}
DPDCH spreading factor	32 for "SID", and "Full"

8.2.7 Link Performance Evaluation Metrics for voice over enhanced DCH

Table 8.2-21 shows the metrics to be evaluated for each simulation, in order to judge the merits of the proposed enhancements. Note that these metrics include all the metrics described in the assumptions for baseline R99 evaluation as described in clause 8.2.2, so as to allow comparison against the baseline, as well as additional metrics to quantify FET performance and gating statistics. For the proposed uplink enhancement that involves a new UL TFCI and Ack channel design, Table 8.2-22 shows the metrics to be evaluated to capture the link performance of the new channel.

Table 8.2-21: Performance Metrics

Metric	Definition	Link	Unit/ Scaling
DPCH Tx Ec/Ior per TFC	Average power spent on DPDCH and DPCCH, combined, for each TFC, relative to total transmit Ior. The averaging is performed over the entire simulation duration, including all DTX and turned-off (gated) periods. OCNS power profile is used to maintain a total Ior of 1.	DL	dB
Average DPCH Tx Ec/Ior	Average power spent on combined DPDCH and DPCCH relative to total transmit Ior, averaged across all TFCs according to their respective frequencies.	DL	dB
Received Ecp/No per TFC	Average received Ecp/No for DPCCH per TFC, where averaging includes DTX and turned off (gated) periods.	UL	dB
Received Ec/No per TFC	Average received Ec/No for DPCH, including DPCCH+DPDCH+FET-DPCCH per TFC, where averaging includes DTX and turned off (gated) periods, for each TFC.	UL	dB
Average Ec/No	Total average received Ec/No for DPCH, including DPCCH+DPDCH+FET-DPCCH, where averaging includes DTX and turned off (gated) periods, averaged across all TFCs. A 2dB power offset is assumed for the FET-DPCCH channel.	UL	dB
Total BLER	Block error rates for all early decoding attempts for DPDCH averaged across all TFCs, according to TFC frequencies.	DL/UL	Percentage
FET decoding BLER statistics	Residual BLER at early decoding attempts, defined as total number of simulated transport blocks that resulted in a failed CRC check in each early decoding attempt, divided by the total of number of simulated transport blocks.	DL/UL	Percentage
UE transceiver gating statistics	Average amount of time UE transmitter is gated.	UL	Percentage
TPC error rate	TPC decoding bit error rate	DL/UL	Percentage

Table 8.2-22: FET-DPCCH channel Metrics

Metric	Definition	Link	Unit/Scaling
TFCI decoding error rate	TFCI decoding error rate on FET-DPCCH channel	UL	Percentage
ACK missed detection	Rate of missed detection for the ACK message	UL	Percentage
ACK false alarm	Rate of false alarm for the ACK message	UL	Percentage

8.2.8 System simulation assumptions for voice over enhanced DCH (Solution 1 and 3)

The system simulation assumptions for voice over enhanced DCH are in line with those for voice over R99, so as to enable comparison between the two. Thus, most parts of clauses 8.2.3 and 8.2.4 also apply for voice over enhanced DCH. The only parts that don't apply are certain parameter value assumptions listed for R99 DCH in Tables 8.2-6 and 8.2-8 (eg, the DL rate-matching attributes) which are actually identical to the corresponding values assumed in the link simulation assumptions for R99 DCH.
Since the corresponding link simulation assumptions for enhanced DCH are different, this change needs to be also reflected in the system simulation assumptions for enhanced DCH. These changes are captured in Tables 8.2-23 and 8.2-24.

Table 8.2-23: Downlink System Simulation Assumptions for CS Voice over enhanced DCH - Changes relative to Table 8.2-6

Parameters	Comments
TBS on DTCH	Null: 1, SID: 40; Full-AMR12.2K: 245 for DTCH; Full-AMR5.9K: 119 for DTCH.
RM attributes	AMR12.2K: 205, 180 for DTCH, DCCH. AMR5.9K: 218, 230 for DTCH, DCCH. Using fixed position rate matching in both cases.
DL DPCH Slot format	As in Table 8.2-11
Encoder	1/3 rate convolutional code
CRC	16-bit CRC
DL DPCH TxEc/Ior limits	Maximum = -6.24dB (AMR12.2kbps) and -6.65dB (AMR5.9kbps), minimum = -40dB.

Table 8.2-24: Uplink System Simulation Assumptions for CS Voice over enhanced DCH - Changes relative to Table 8.2-8

Parameters	Comments
TBS, Spreading Factor and DPDCH Power Boost	As in Table 8.2-18
TTI Configuration	10ms with 2 repetitions
Encoder	rate 1/3 convolutional code
CRC	16-bit CRC for Full and SID frames
DPCCH slot format	1 (8 pilots, 2 TPC)

8.2.9 System simulation assumptions for voice over enhanced DCH (Solution 2 and 4)

For those system simulation assumptions, which are specific to enhanced DCH or other than those in clause 8.2.3 and clause 8.2.4, they can be found in clause 8.2.6 "Link Simulation Assumptions".

9 Link evaluation results

9.1 Link evaluation results: Downlink, Solutions 1 and 3

This clause presents link evaluation of downlink DCH enhancements described as 'Solution 1' and 'Solution 3' in clause 8.

9.1.1 Additional assumptions

The maximum TxEc/Ior of non-DTXed chips is set to -10dB for R99. Since Solution 3 uses 20ms TTI just like the existing R99, and it uses the same value of maximum TxEc/Ior as the corresponding R99 simulation. However, Solution 1 uses a 10ms TTI, and hence uses an increased value. The amount of the increase is 3.76dB for AMR 12.2kbps codec and 3.35dB for AMR 5.9kbps codec. For Solution 3, early-decoding was attempted once every 3 slots (at slots indexed 3, 6 ... 30), so that the number of decoding attempts is similar to that used in Solution 1.

9.1.2 Link efficiency of AMR 12.2kbps codec

Figures 9.1.2-1,2 show the link-efficiency for active-set sizes of 1 and 2 respectively, for R99 and Solutions 1 and 3 assuming 50% voice activity factor. Figures 9.1.2-3,4 show the link-efficiency gains over R99 realized by Solutions 1 and 3. In most cases, there is a gain of around 2dB from Solution 1 and around 2.6dB from Solution 2, which is fairly insensitive to geometry. The case of PA3 channel without handover is an exception for Solution 1, which provides lower gain in this case, which further reduces at lower geometry. This is due to the lack of multipath diversity in the PA3 channel, together with the loss of time-diversity and the discontinuity in inner-loop power control inherent in Solution 1 due to the fact that the data is carried only on alternate 10ms radio frames. Handover provides more diversity and hence this behaviour is not seen when active-set size is 2. Figures 9.1.2-5-8 shows the same quantities as Figures 9.1.2-1-4 respectively, but separately for different AMR packet types. The DCH enhancements yield much more gain for the Null packet when compared to the Full packet, since the pilot overhead is higher for Null packet. However, the overall gain at 50% voice activity factor is dominated more by the gain of the Full packet, since the Full packet consumes much more power than the Null packet. The link gains are also summarized in Table 9.1.2-1

Table 9.1.2-1: Summary of link gains for AMR 12.2kbps codec

Packet-type	Link efficiency gains (dB)- Solution 1			Link efficiency gains (dB)- Solution 3		
	PA3, no SHO	PB3,VA30, VA120 no SHO	SHO	PA3, no SHO	PB3,VA30, VA120 no SHO	SHO
Full	0.2 – 1.1	1.3 – 1.4	1.3 – 1.5	1.9 – 2.1	2	1.9 – 2
SID	1.9 – 3	4.0 – 4.1	4 – 4.4	4.4 – 4.5	4.6 – 4.7	4.5 – 4.6
Null	5.9 – 6.2	6.6 – 6.8	6.4 - 6.8	6.5 – 6.7	6.9	6.6 – 6.9
Average	0.9 – 1.8	2 – 2.2	1.9 – 2.2	2.5 – 2.7	2.6 – 2.7	2.6

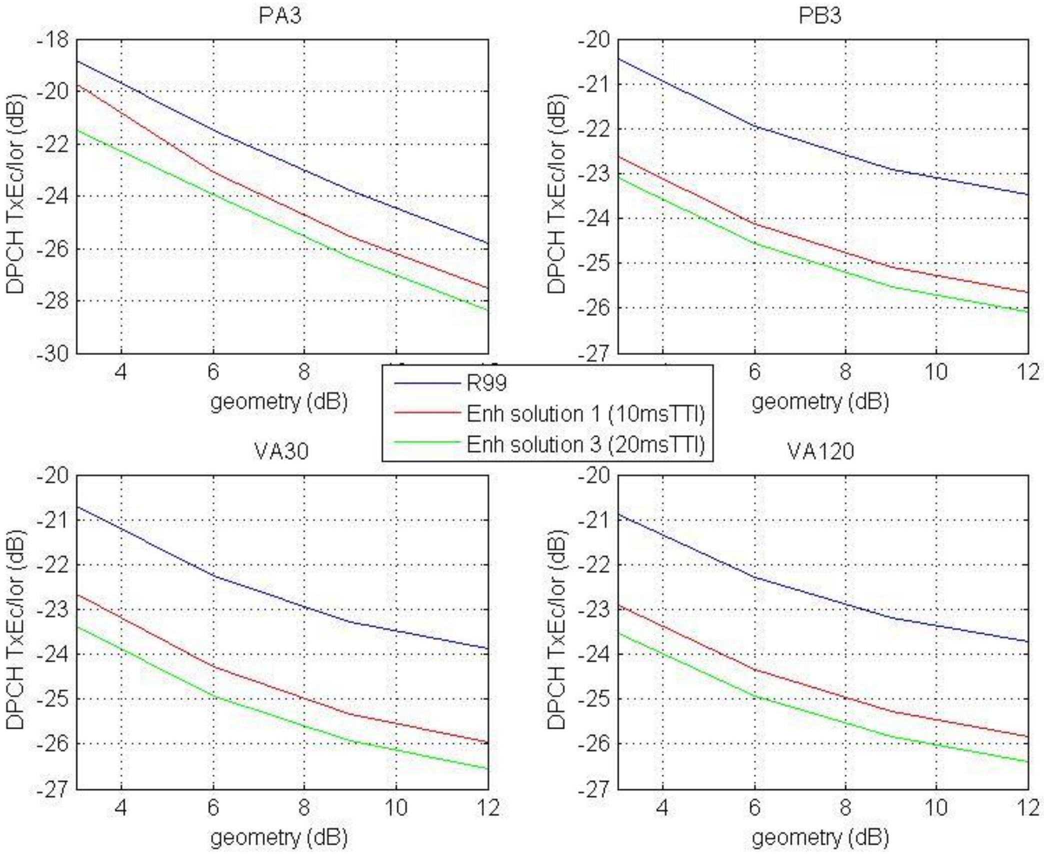


Figure 9.1.2-1: Link efficiency of R99, Solution 1 and Solution 3 for 50% voice activity factor, Active-set size=1

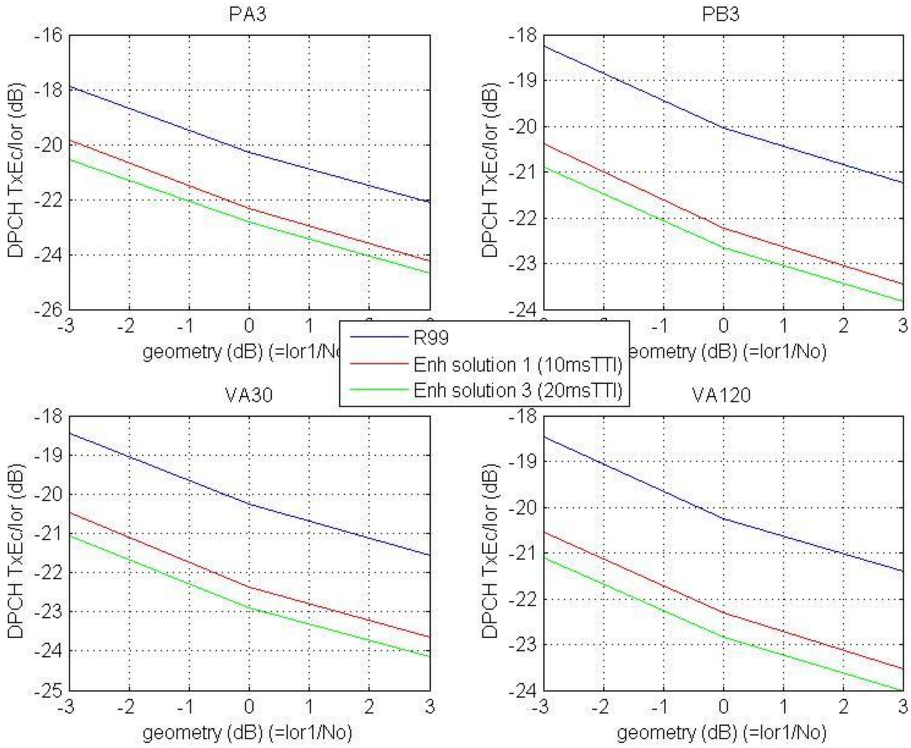


Figure 9.1.2-2: Link efficiency of R99, Solution 1 and Solution 3 for 50% voice activity factor, Active-set size=2

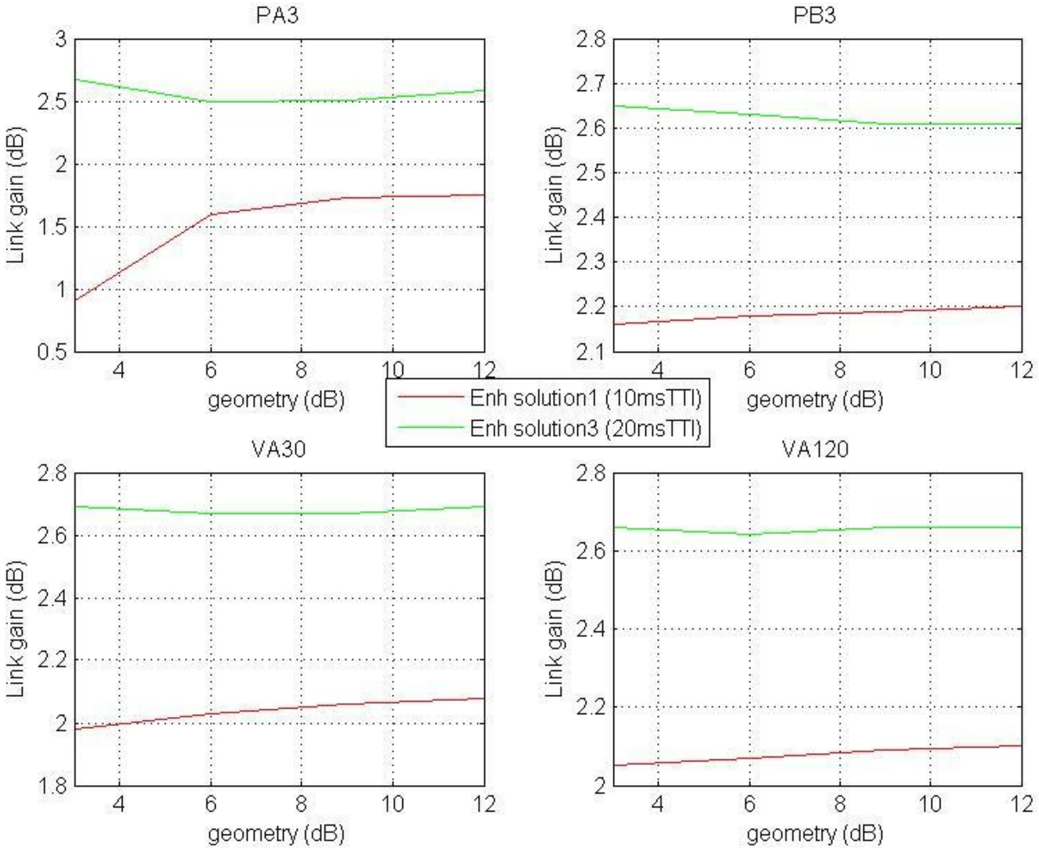


Figure 9.1.2-3: Link efficiency gain of Solutions 1, 3 over R99 for 50% voice activity factor, Active-set size=1

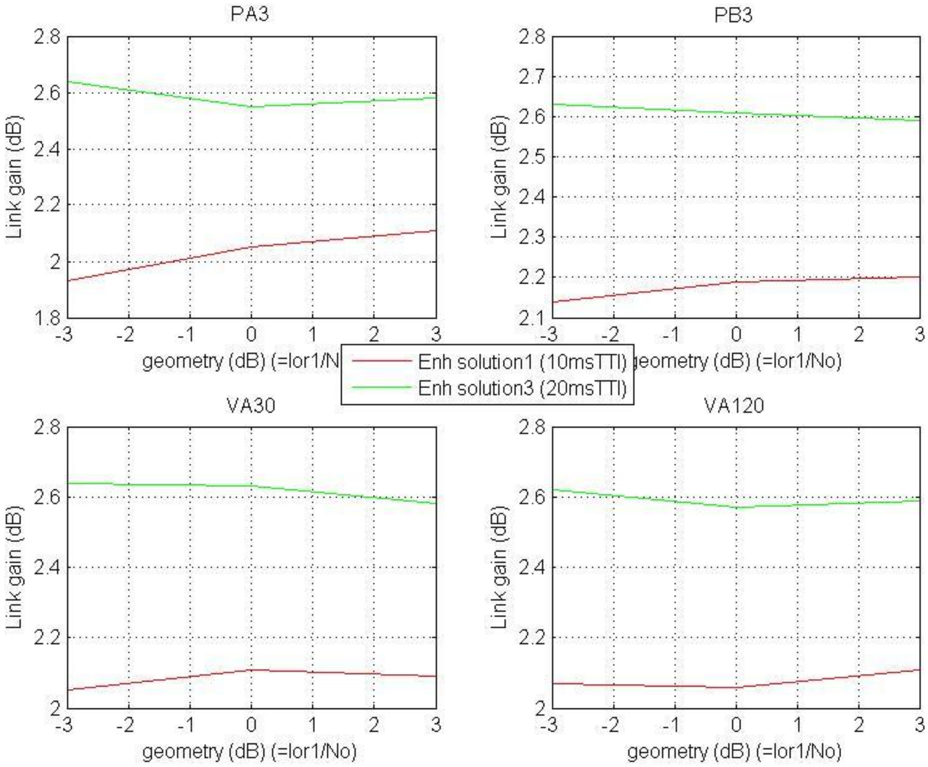


Figure 9.1.2-4: Link efficiency gain of Solutions 1, 3 over R99 for 50% voice activity factor, Active-set size=2

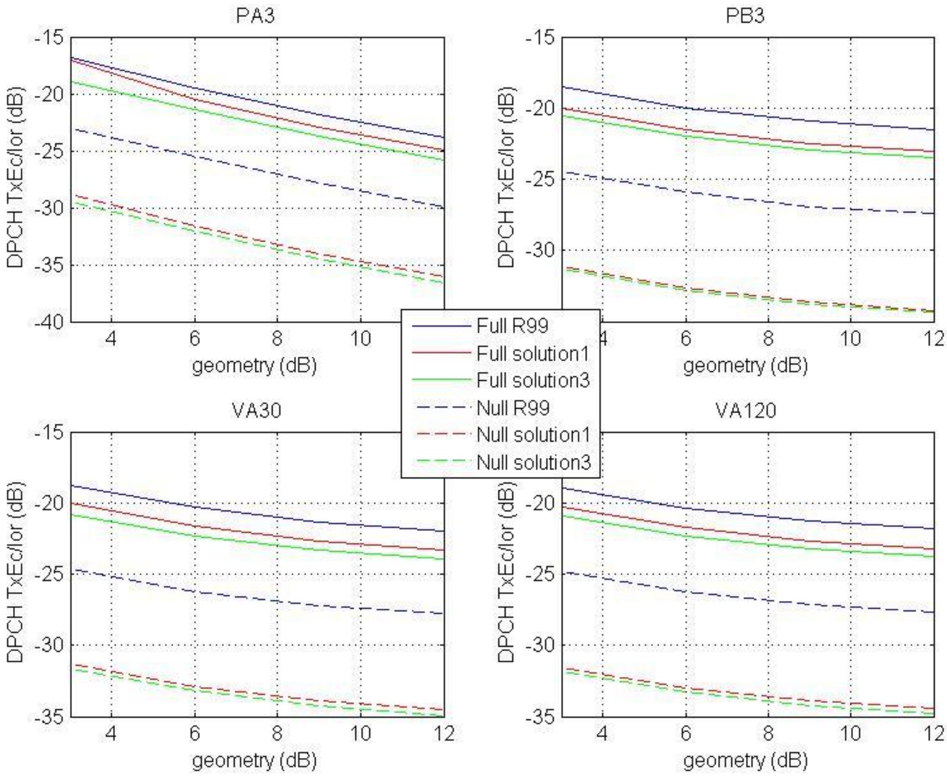


Figure 9.1.2-5: Link efficiency of R99, Solution 1 and Solution 3 for AMR12.2kbps Full and Null packets, Active-set size=1

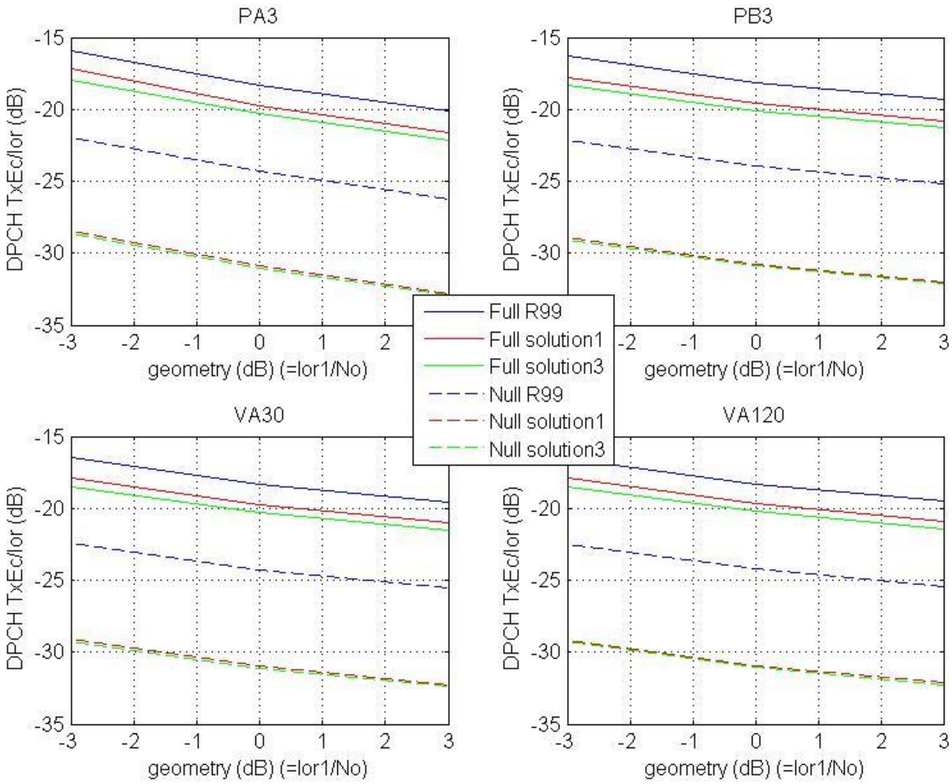


Figure 9.1.2-6: Link efficiency of R99, Solution 1 and Solution 3 for AMR12.2kbps Full and Null packets, Active-set size=2

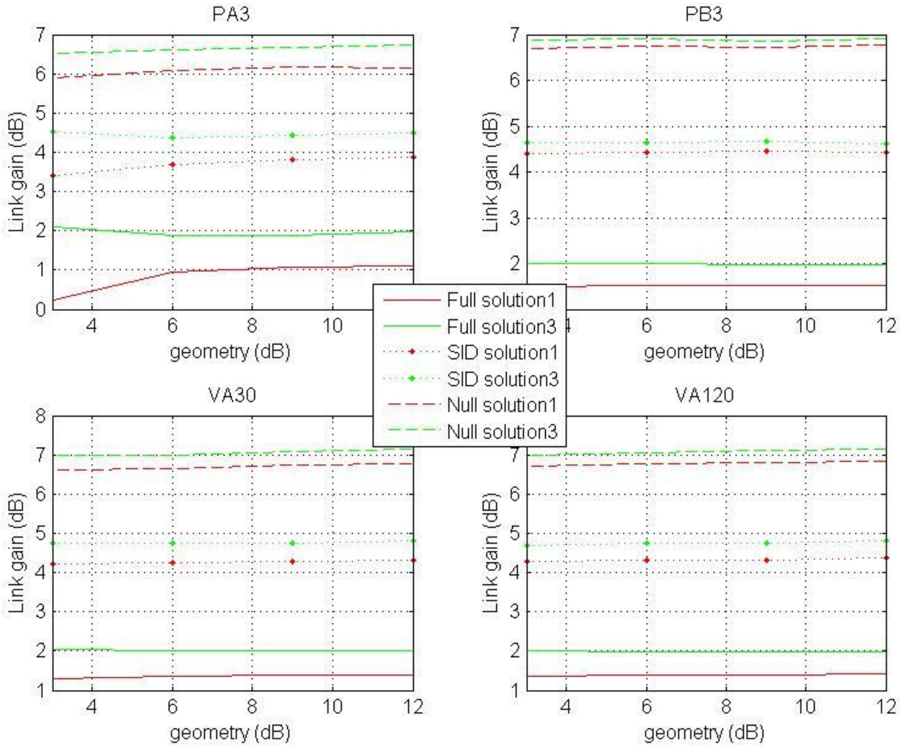


Figure 9.1.2-7: Link efficiency gain of Solutions 1, 3 over R99 for AMR12.2kbps packets, Active-set size=1

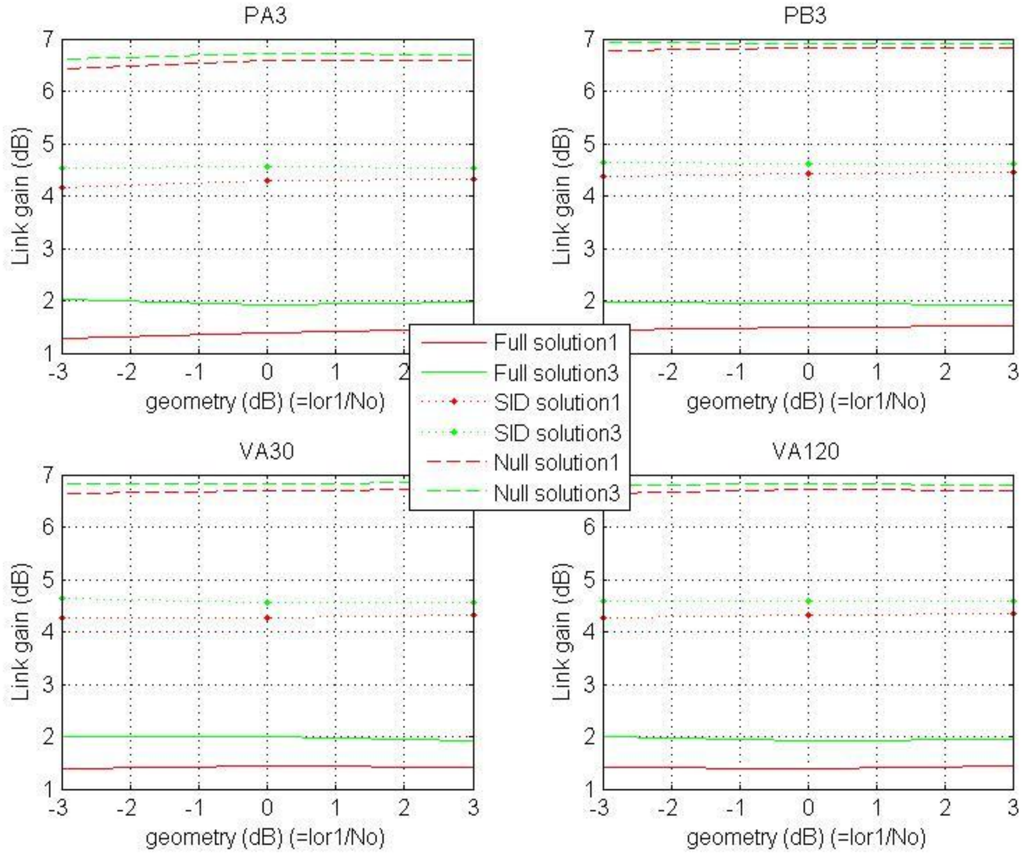


Figure 9.1.2-8: Link efficiency gain of Solution 1 over R99 for AMR12.2kbps packets, Active-set size=2

9.1.3 Average decoding time and packet BLER for AMR 12.2kbps codec

Both Solutions 1 and 3 incorporate FET, and their average decoding times in slots is shown in Figures 9.1.3-1,2 respectively for active-set size of 1,2, when voice activity factor is 50%. Figures 9.1.3-3,4 show the decoding times separately for each DL packet type. Since Solution 1 uses a 10ms TTI while Solution 3 uses a 20ms TTI, the decoding time is much larger than (approximately double) that in Solution 3. The smaller packets also decode earlier.

As in the case of link efficiency (clause 9.1.2), the decoding time is mostly insensitive to channel model and geometry, with the exception that Solution 1 has lower decoding time for PA3 at low geometry. This can be explained by noting that the poor diversity may make the channel go into a very deep fade, causing the setpoint to rise too high thus producing excess SNR that can be exploited to enable earlier decoding. The cumulative decoding success rate after successive early-decode attempts is shown in Figure 9.1.3-5, and also demonstrates the same trends as a function of channel model and geometry.

The target BLER of 1% for the voice packets was achieved in all cases simulated except for the PA3 channel in absence of soft handover for geometry of 3dB. Even in this case, the BLER was only slightly higher, i.e. 1-1.3% depending on the packet-type.

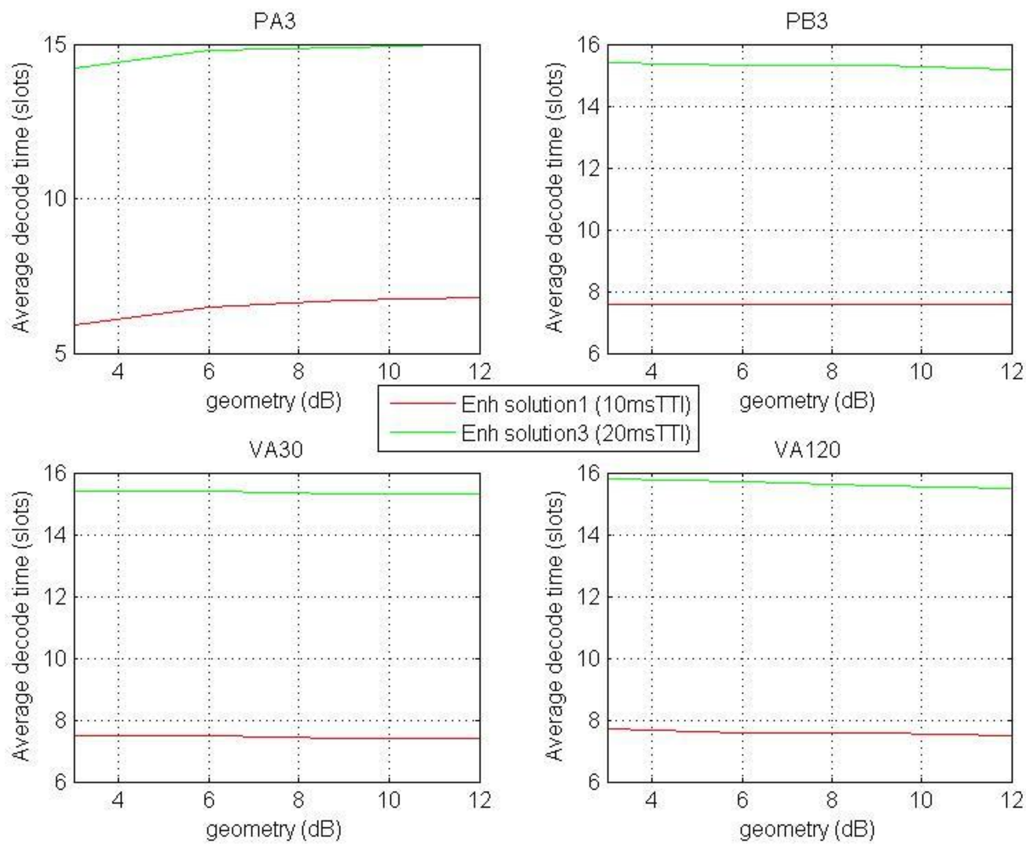


Figure 9.1.3-1: Average decoding time for Solutions 1, 3 for 50% voice activity factor, Active-set size=1

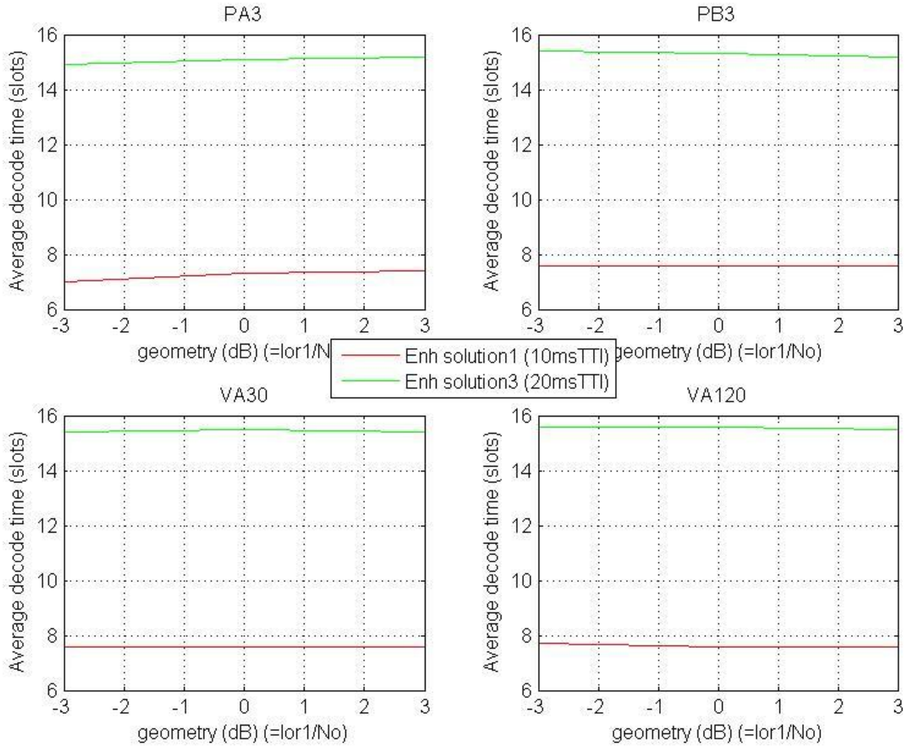


Figure 9.1.3-2: Average decoding time for Solutions 1, 3 for 50% voice activity factor, Active-set size=2

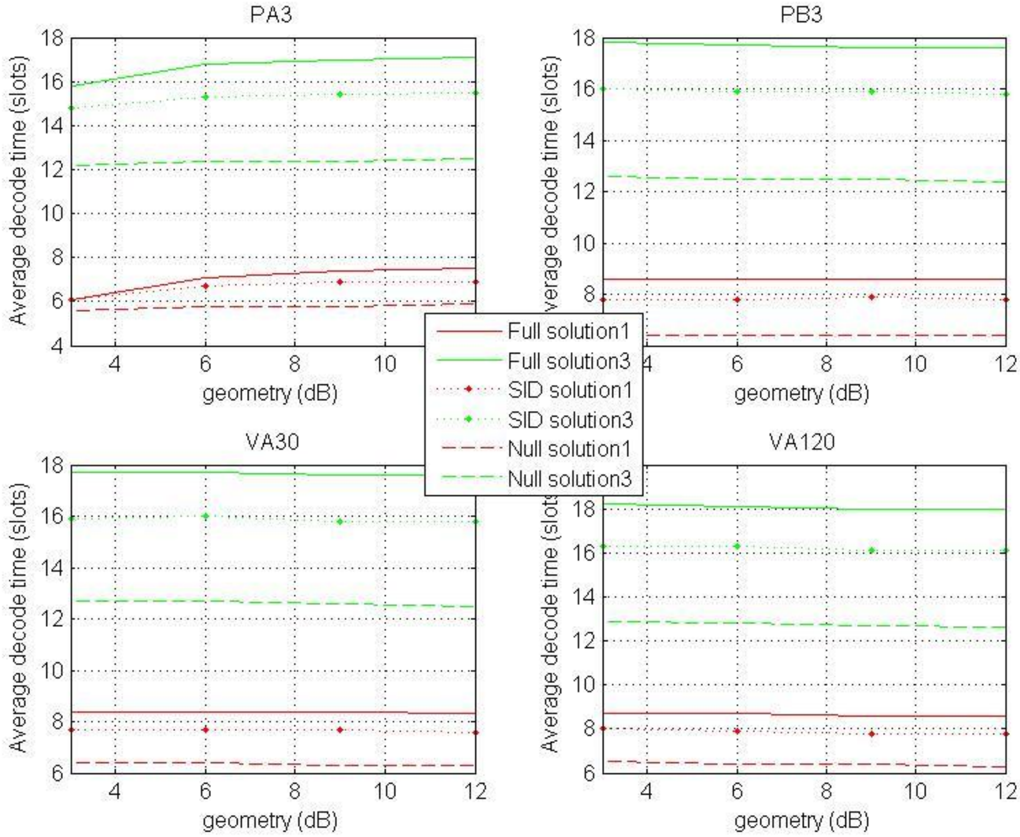


Figure 9.1.3-3: Average decoding time for Solutions 1, 3 for AMR 12.2kbps codec packets, Active-set size=1

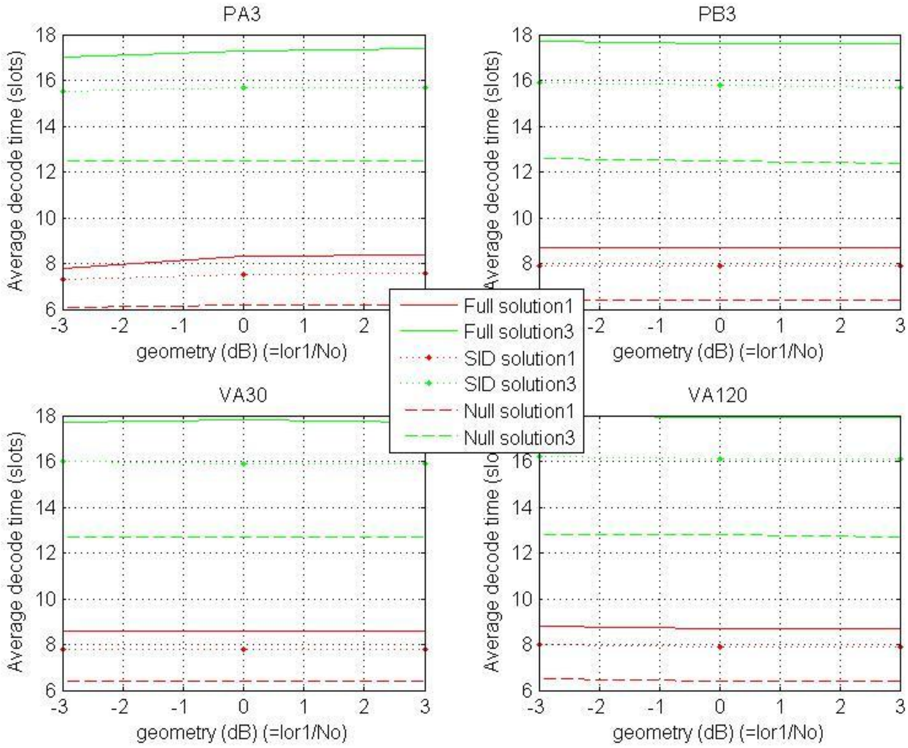


Figure 9.1.3-4: Average decoding time for Solutions 1, 3 for AMR 12.2kbps codec packets, Active-set size=2

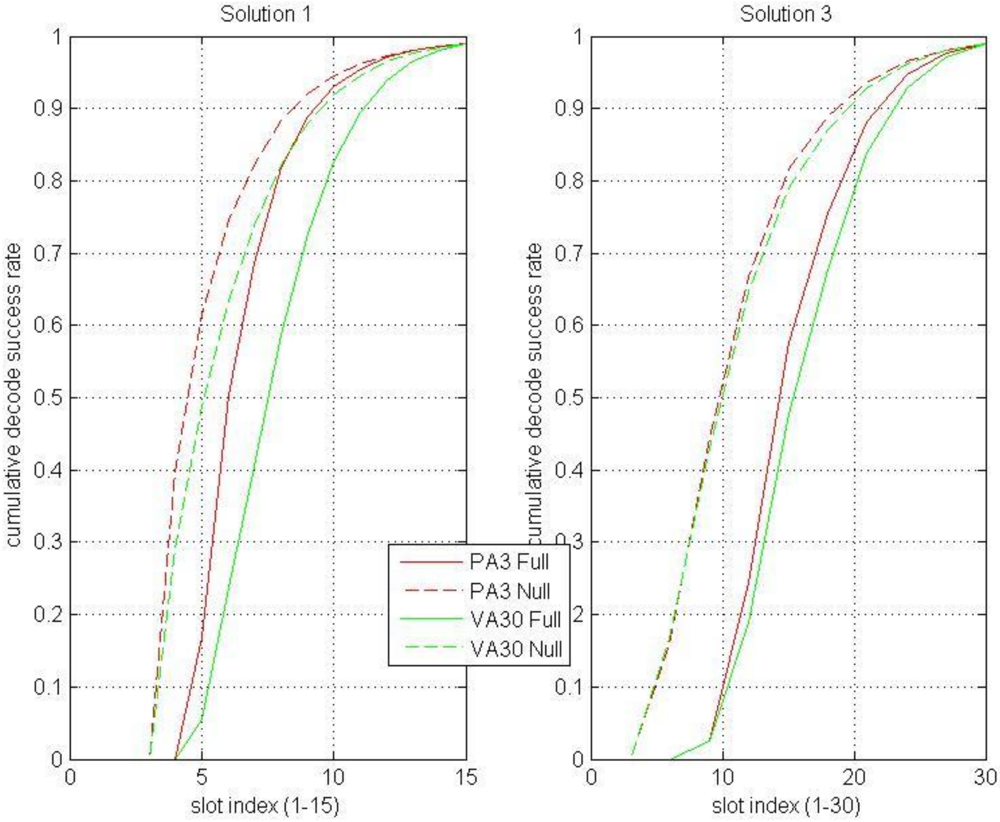


Figure 9.1.3-5: Decode success rate for Solutions 1,3 for AMR 12.2kbps codec packets, Active-set size=1, 6dB geometry

9.1.4 TPC BER for AMR 12.2kbps codec

The TPC BER is shown in Figures 9.1.4-1, 2 respectively for active-set size of 1, 2, when voice activity factor is 50%. Figures 9.1.4-3, 4 show the TPC BERs separately for each DL packet type. The TPC BERs for R99 and Solutions 1 and 3 are fairly close; Solution 1 is slightly better than R99 while Solution 3 is slightly worse.

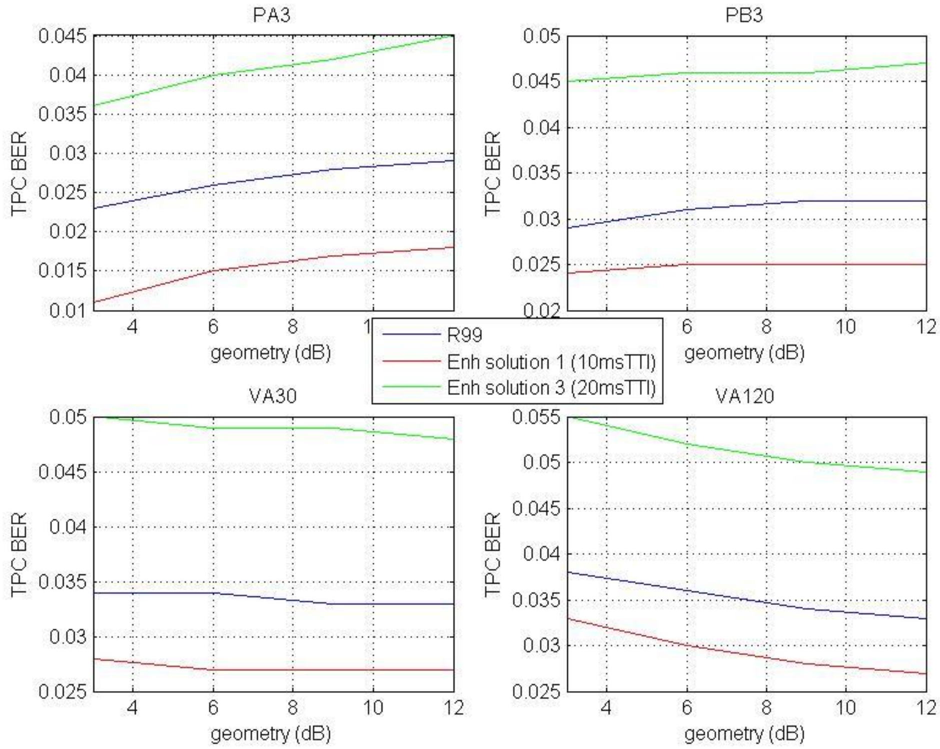


Figure 9.1.4-1: TPC BER for R99 and Solutions 1, 3 for 50% voice activity factor, Active-set size=1

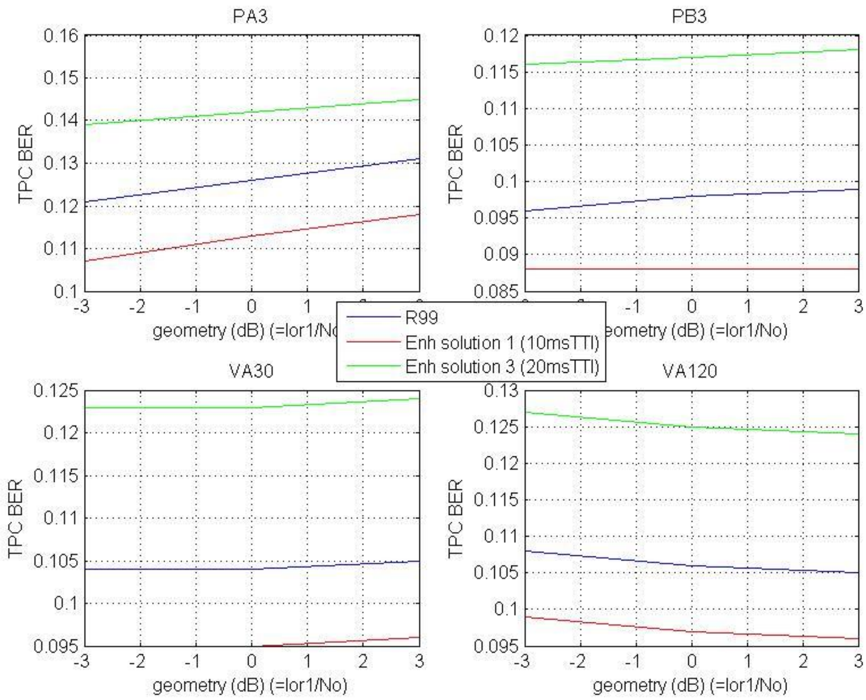


Figure 9.1.4-2: TPC BER for R99 and Solutions 1, 3 for 50% voice activity factor, Active-set size=2

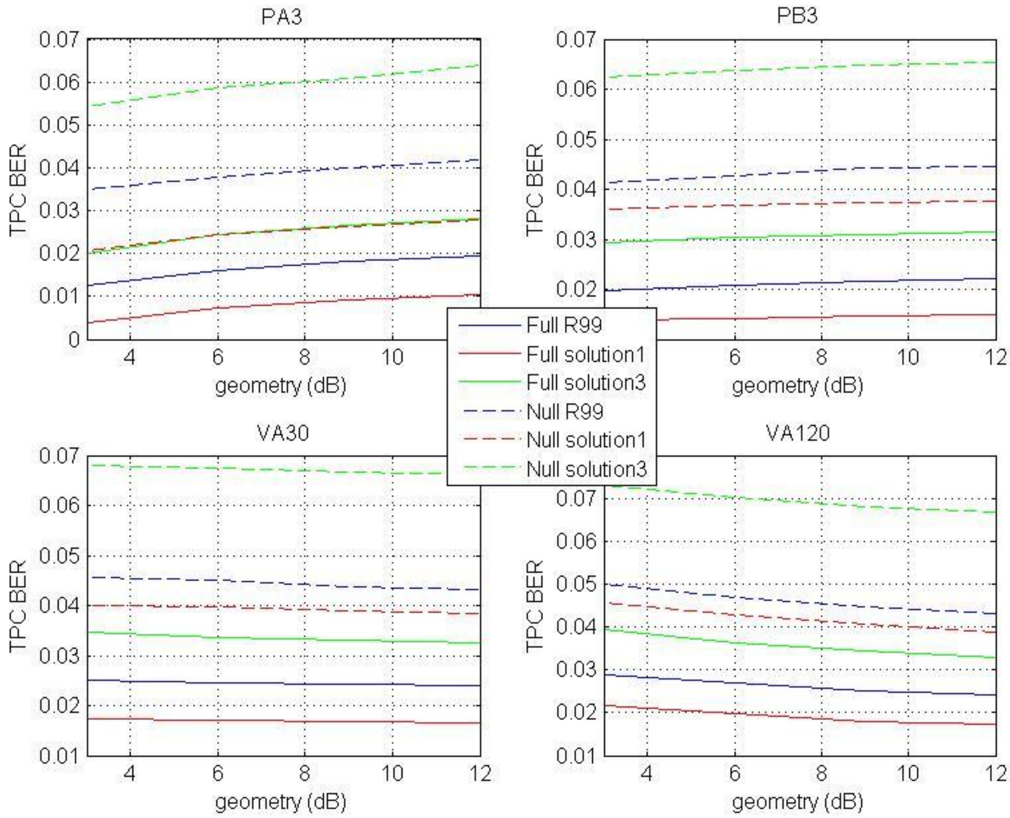


Figure 9.1.4-3: TPC BER for R99 and Solutions 1, 3 for AMR 12.2kbps codec packets, Active-set size=1

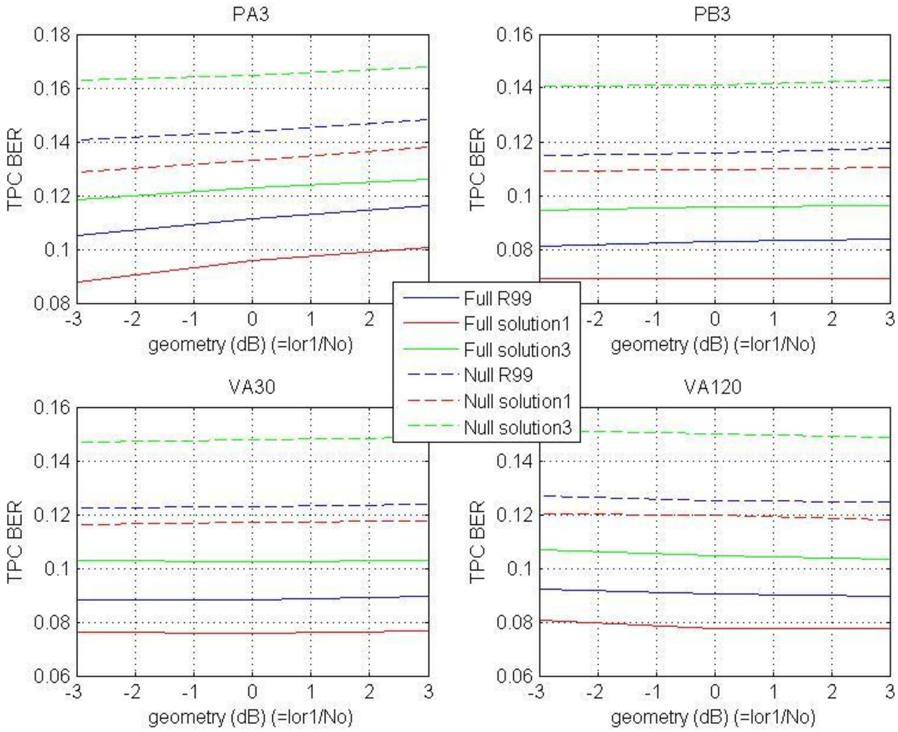


Figure 9.1.4-4: TPC BER for R99 and Solutions 1, 3 for AMR 12.2kbps codec packets, Active-set size=2

9.1.5 Link efficiency of AMR 5.9kbps codec

Figures 9.1.5-1,2 show the link-efficiency for active-set sizes of 1 and 2 respectively, for R99 and Solutions 1 and 3 assuming 50% voice activity factor. Figures 9.1.5-3,4 show the link-efficiency gains over R99 realized by Solutions 1 and 3. In most cases, there is a gain of around 2dB from Solution 1 and around 3.5dB from Solution 2, which is fairly insensitive to geometry. The case of PA3 channel without handover is an exception for Solution 1, which provides lower gain in this case, which further reduces at lower geometry. This is due to loss of diversity and discontinuous inner-loop power control, just as observed in the case of AMR 12.2kbps codec (clause 9.1.2). Figures 9.1.5-5 to 8 show the same quantities as Figures 9.1.5-1-4 respectively, but separately for different AMR packet types. The link gains are also summarized in Table 9.1.5-1.

Table 9.1.5-1: Summary of link gains for AMR 5.9kbps codec

Packet-type	Link efficiency gains (dB)- Solution 1			Link efficiency gains (dB)- Solution 3		
	PA3, no SHO	PB3,VA30, VA120 no SHO	SHO	PA3, no SHO	PB3,VA30, VA120 no SHO	SHO
Full	0.7 – 1.2	1.6 – 1.7	1.6 – 1.8	2.6 – 2.8	2.8	3.1 – 3.3
SID	2.2 – 2.7	3.1 – 3.2	2.9 – 3.2	3.9 – 4.1	4.1 – 4.2	4.4 – 4.6
Null	4 – 4.6	4.9 – 5	4.7 – 5.1	5.6 – 6.1	6 – 6.1	6.1 – 6.5
Average	1.2 – 1.8	2.1 – 2.3	2.1 – 2.3	3.1 – 3.3	3.3 – 3.5	3.6 – 3.8

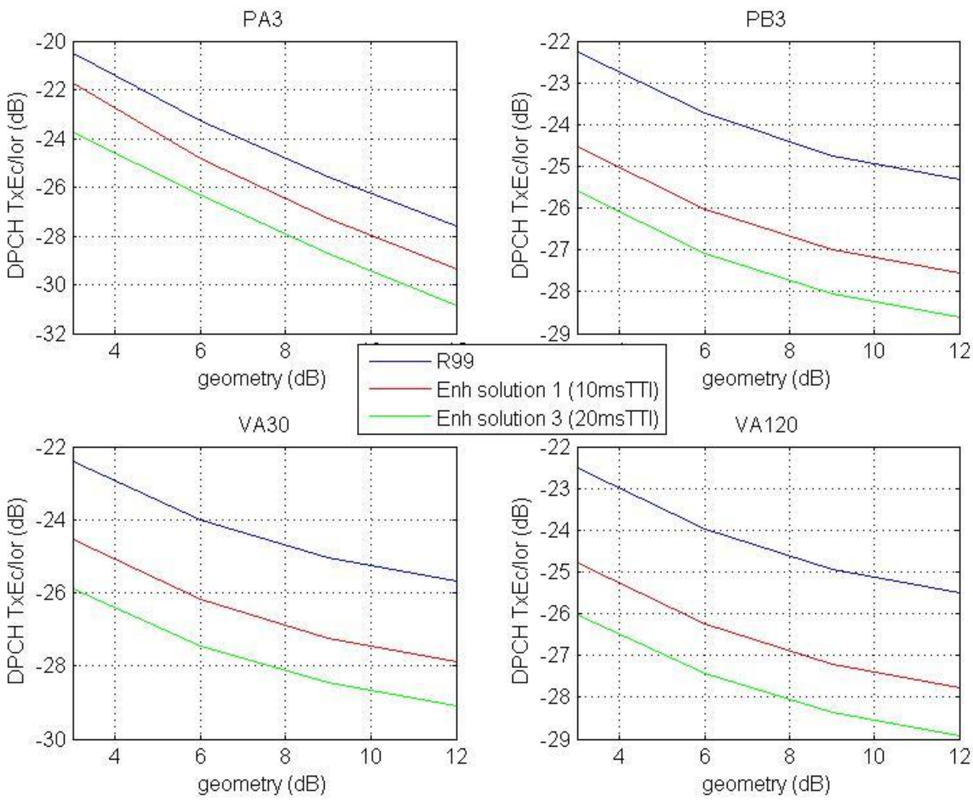


Figure 9.1.5-1: Link efficiency of R99, Solution 1 and Solution 3 for 50% voice activity factor, Active-set size=1

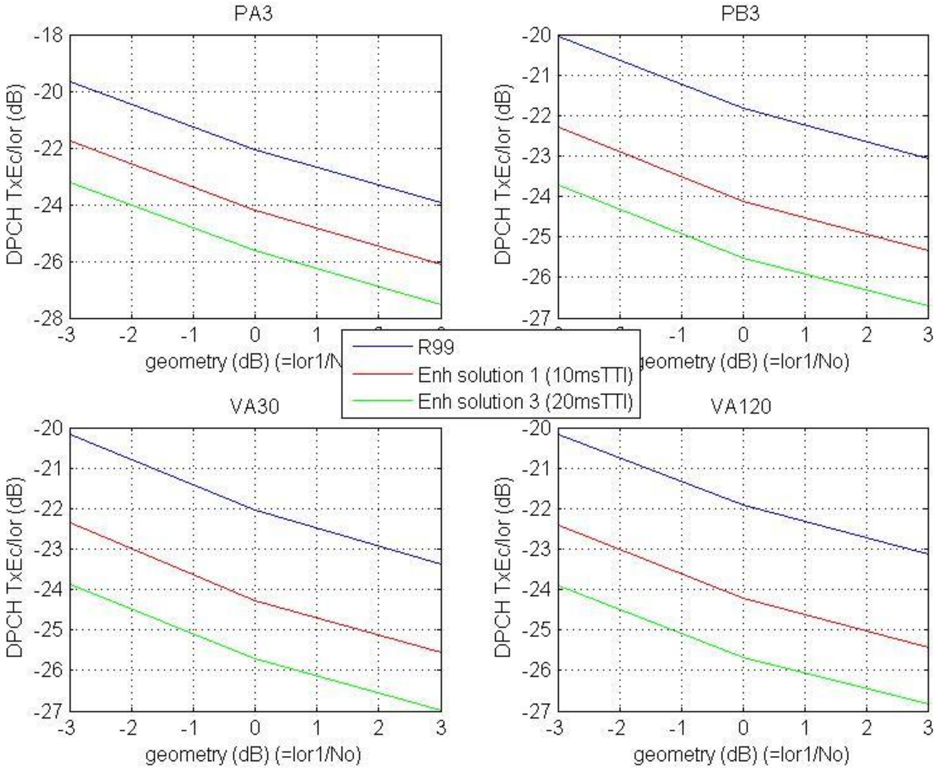


Figure 9.1.5-2: Link efficiency of R99, Solution 1 and Solution 3 for 50% voice activity factor, Active-set size=2

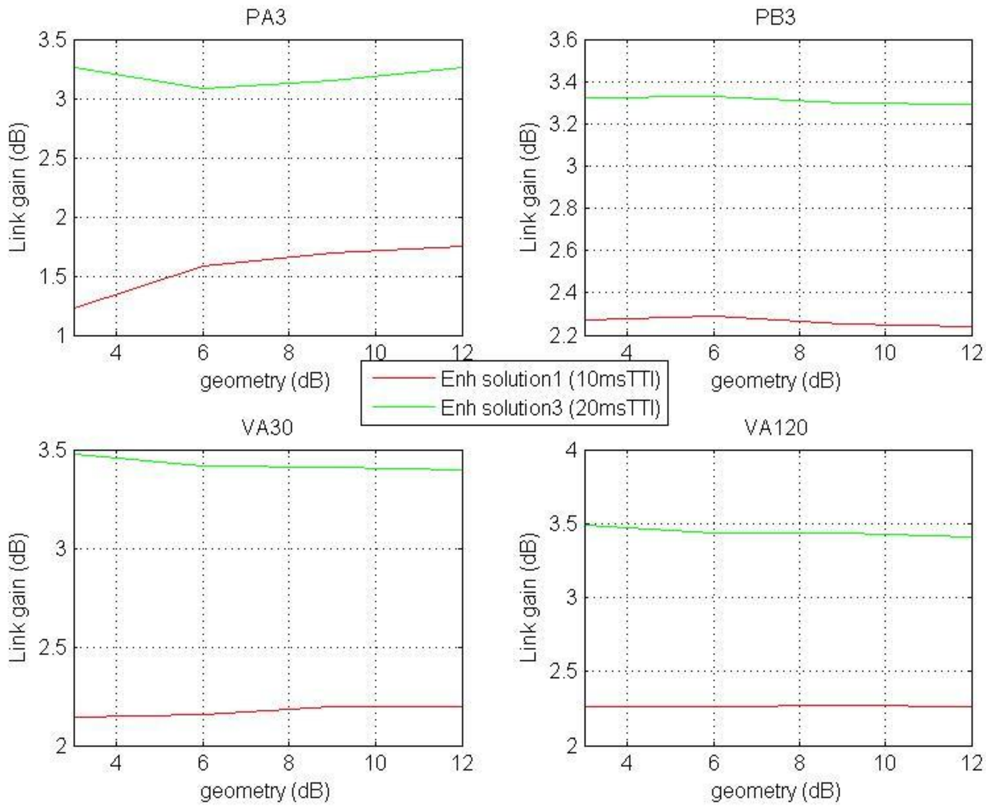


Figure 9.1.5-3: Link efficiency gain of Solutions 1, 3 over R99 for 50% voice activity factor, Active-set size=1

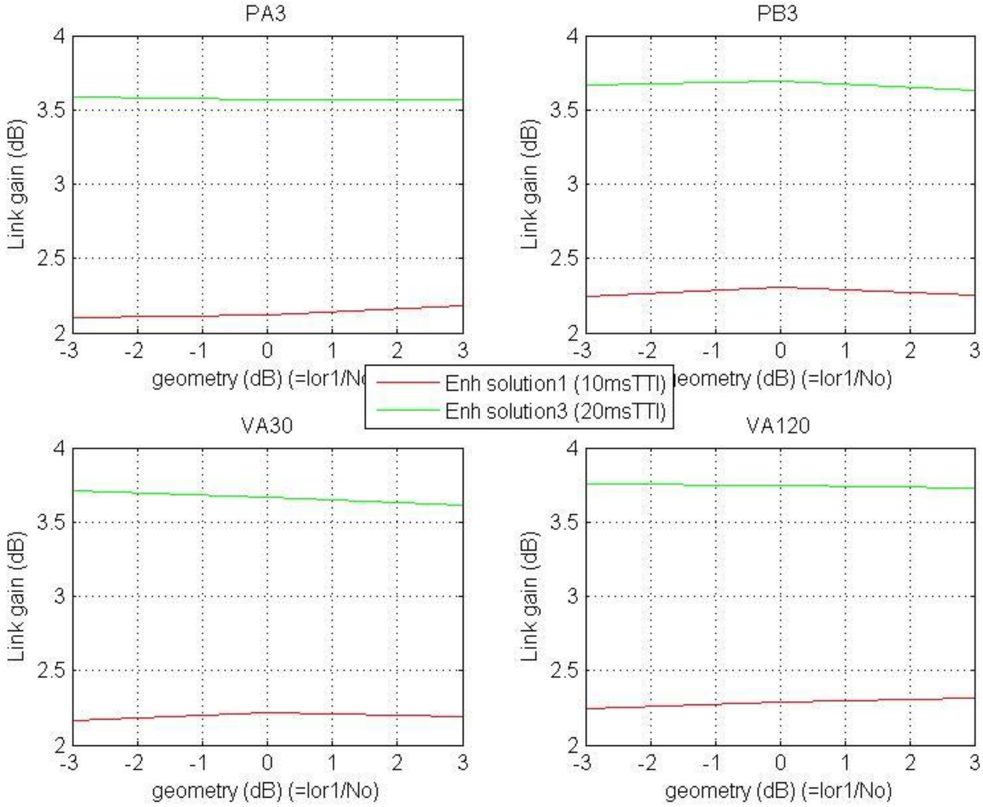


Figure 9.1.5-4: Link efficiency gain of Solutions 1, 3 over R99 for 50% voice activity factor, Active-set size=2

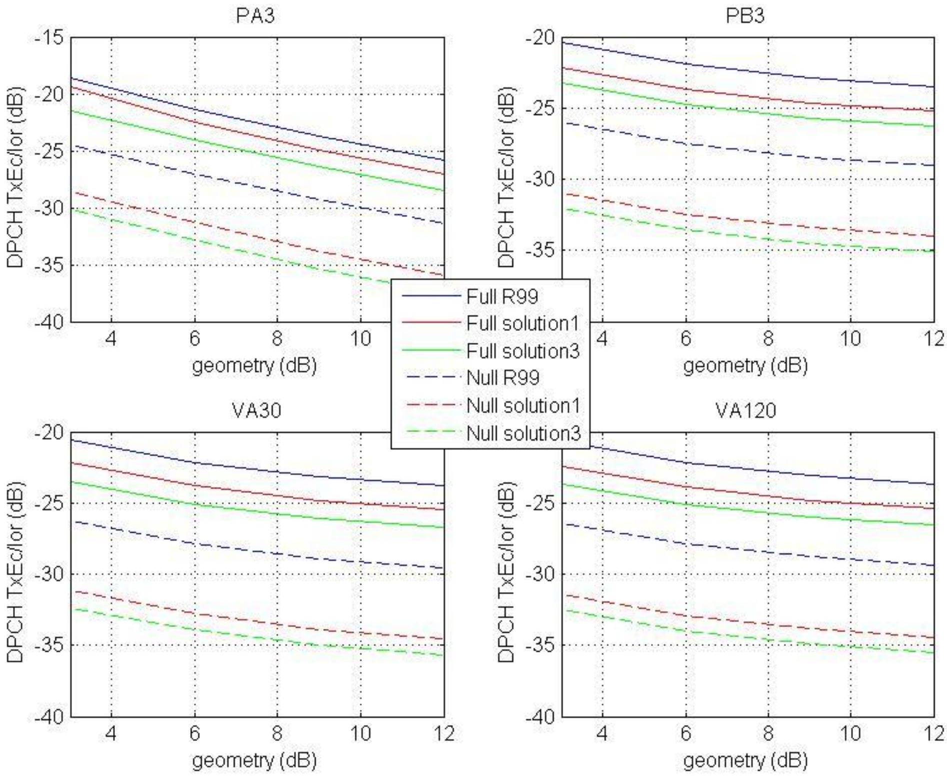


Figure 9.1.5-5: Link efficiency of R99, Solution 1 and Solution 3 for AMR5.9kbps Full and Null packets, Active-set size=1

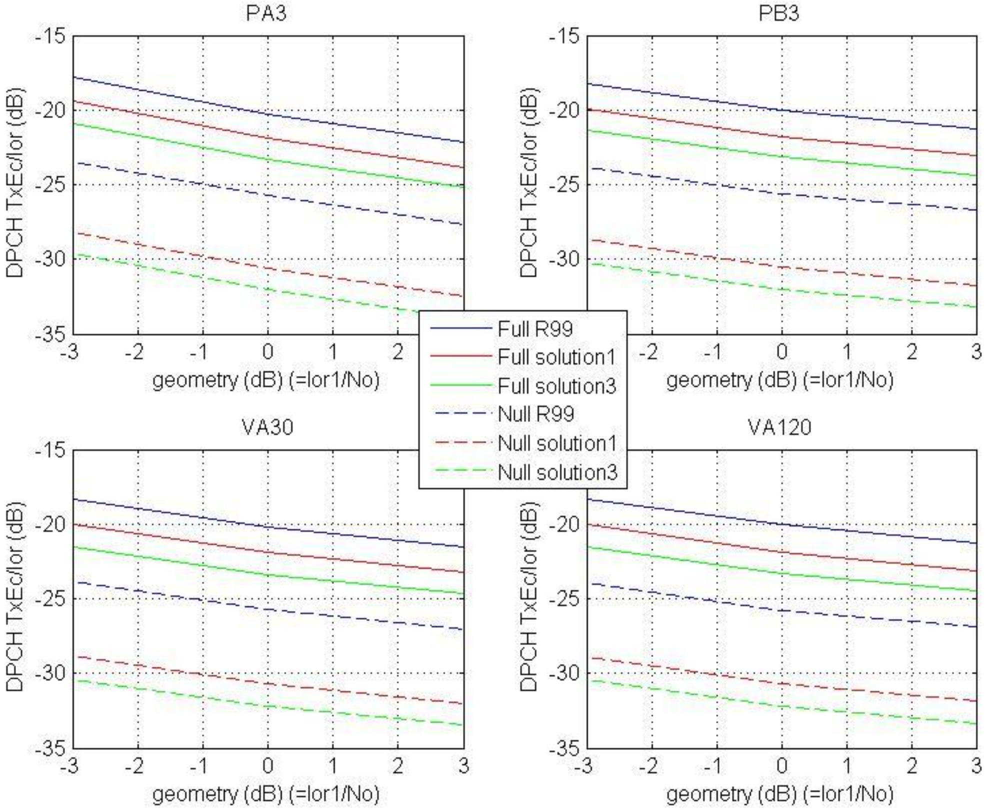


Figure 9.1.5-6: Link efficiency of R99, Solution 1 and Solution 3 for AMR5.9kbps Full and Null packets, Active-set size=2

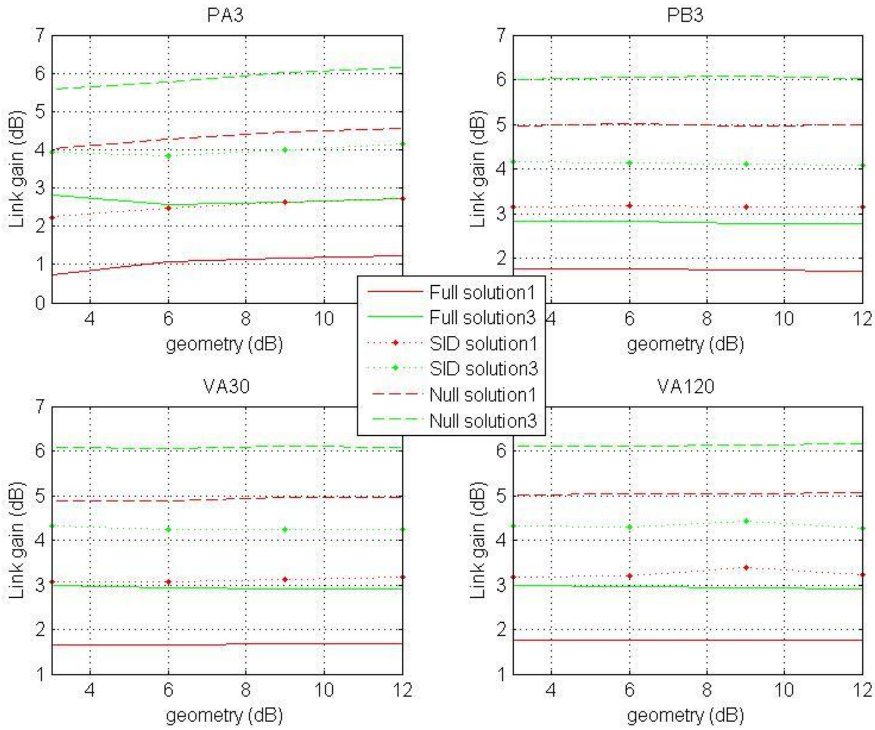


Figure 9.1.5-7: Link efficiency gain of Solutions 1, 3 over R99 for AMR5.9kbps packets, Active-set size=1

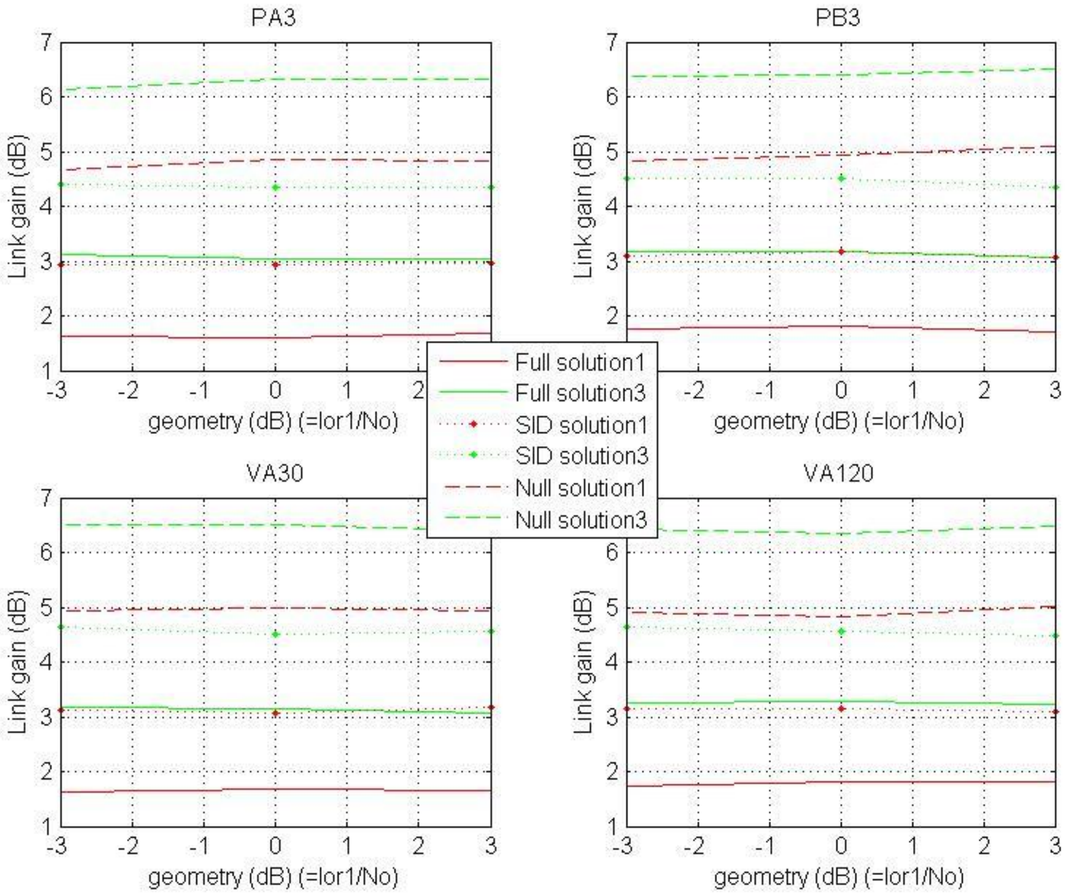


Figure 9.1.5-8: Link efficiency gain of Solution 1 over R99 for AMR5.9kbps packets, Active-set size=2

9.1.6 Average decoding time and packet BLER for AMR 5.9kbps codec

Both Solutions 1 and 3 incorporate FET, and their average decoding times in slots is shown in Figures 9.1.6-1,2 respectively for active-set size of 1,2, when voice activity factor is 50%. Figures 9.1.6-3,4 show the decoding times separately for each DL packet type. Since Solution 1 uses a 10ms TTI while Solution 3 uses a 20ms TTI, the decoding time is much larger than (approximately double) that in Solution 3. The smaller packets also decode earlier.

As in the case of link efficiency (clause 9.1.5), the decoding time is mostly insensitive to channel model and geometry, with the exception that Solution 1 has lower decoding time for PA3 at low geometry. This is due to more excess SNR caused due to poor diversity, just as observed for the case of the AMR 12.2kbps codec (clause 9.1.3).

The target BLER of 1% for the voice packets was achieved in all cases simulated except for the PA3 channel in absence of soft handover for geometry of 3dB. Even in this case, the BLER was only slightly higher, i.e. 1-1.3% depending on the packet-type.

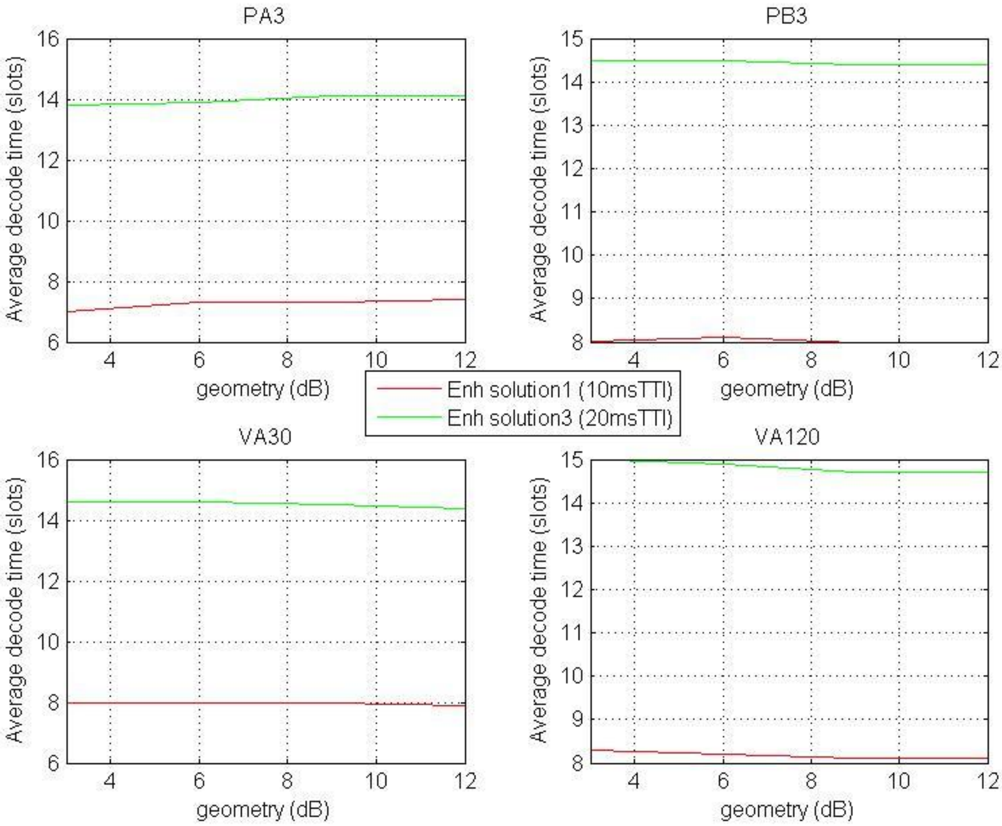


Figure 9.1.6-1: Average decoding time for Solutions 1, 3 for 50% voice activity factor, Active-set size=1

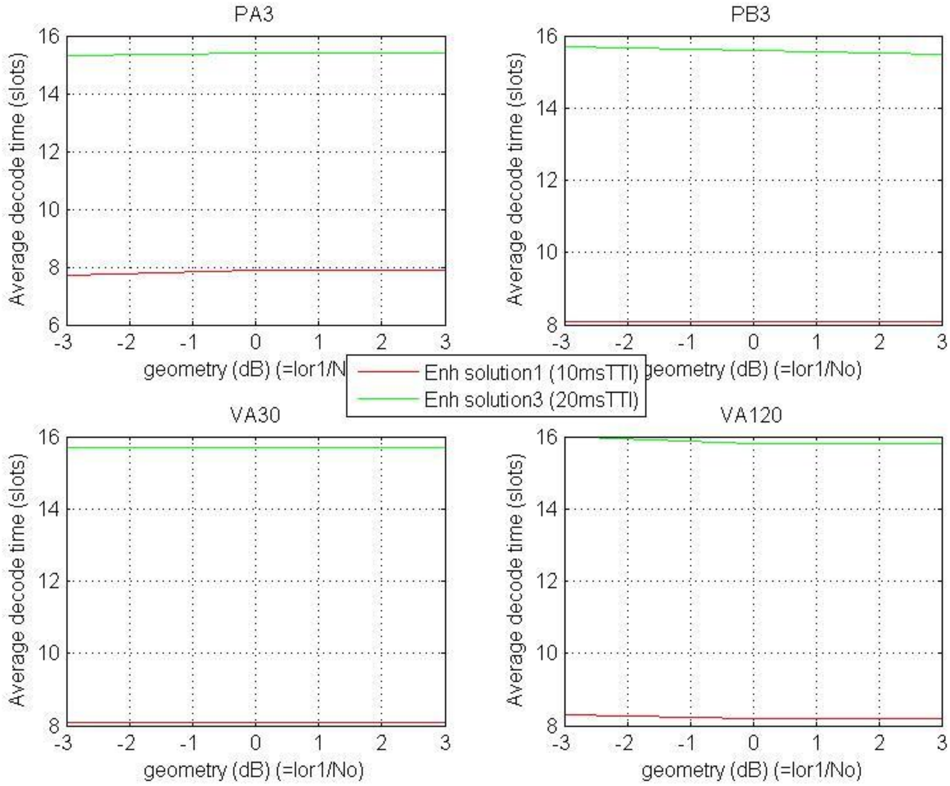


Figure 9.1.6-2: Average decoding time for Solutions 1, 3 for 50% voice activity factor, Active-set size=2

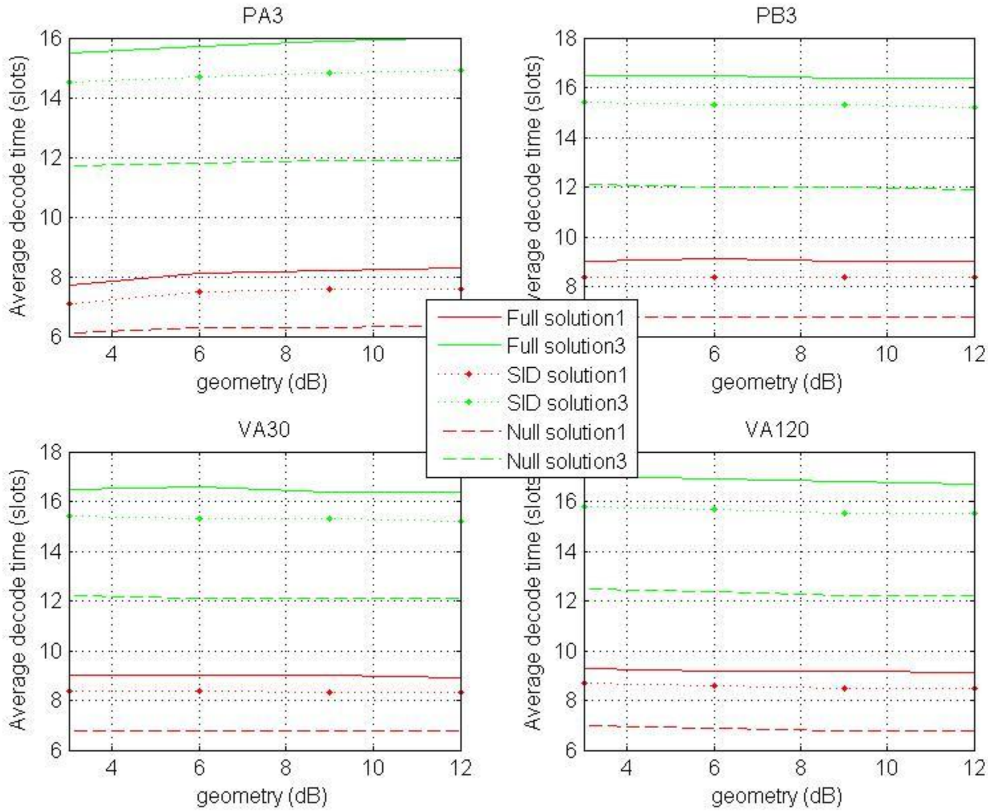


Figure 9.1.6-3: Average decoding time for Solutions 1, 3 for AMR 5.9kbps codec packets, Active-set size=1

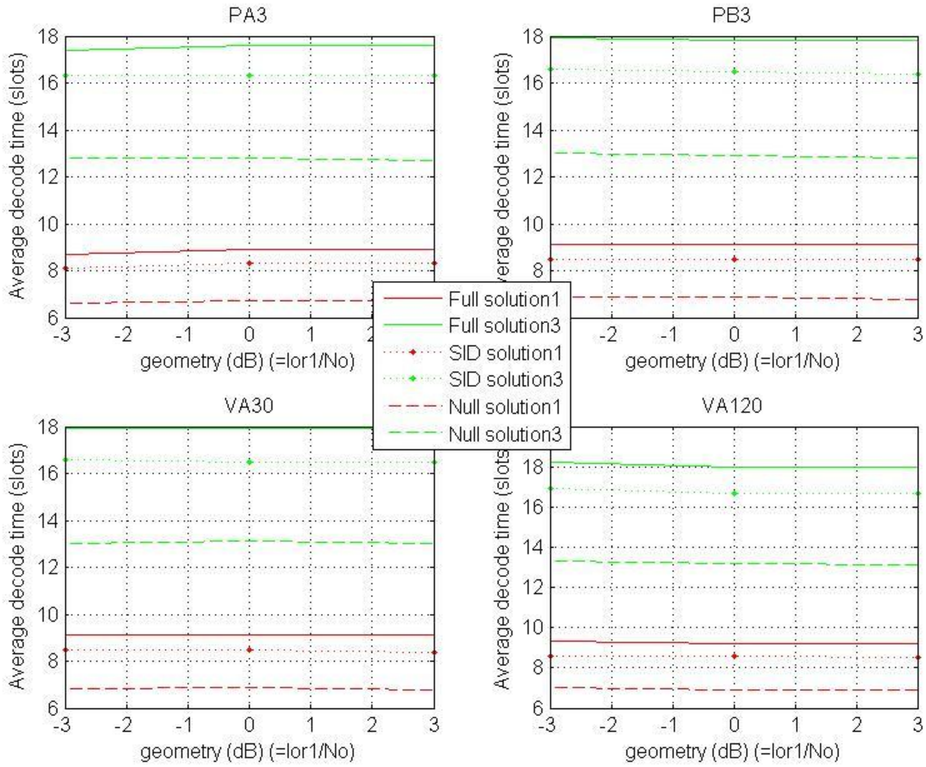


Figure 9.1.6-4: Average decoding time for Solutions 1, 3 for AMR 5.9kbps codec packets, Active-set size=2

9.1.7 TPC BER for AMR 5.9kbps codec

The TPC BER is shown in Figures 9.1.7-1,2 respectively for active-set size of 1,2, when voice activity factor is 50%. Figures 9.1.7-3,4 show the TPC BERs separately for each DL packet type. The TPC BERs for R99 and Solutions 1 and 3 are fairly close; Solution 1 is slightly better than R99 while Solution 3 is slightly worse.

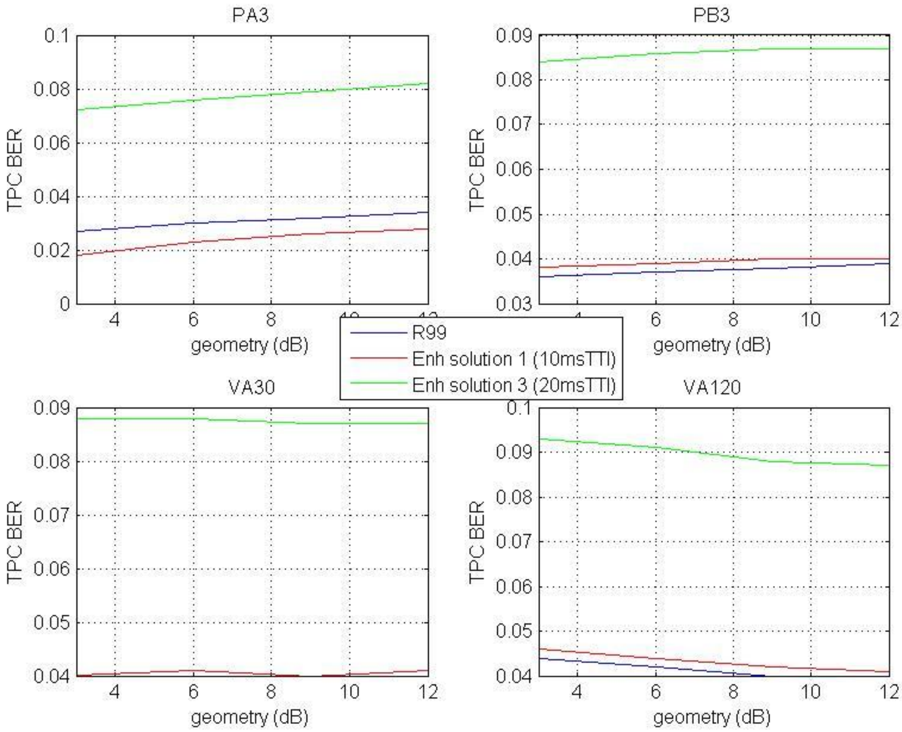


Figure 9.1.7-1: TPC BER for R99 and Solutions 1, 3 for 50% voice activity factor, Active-set size=1

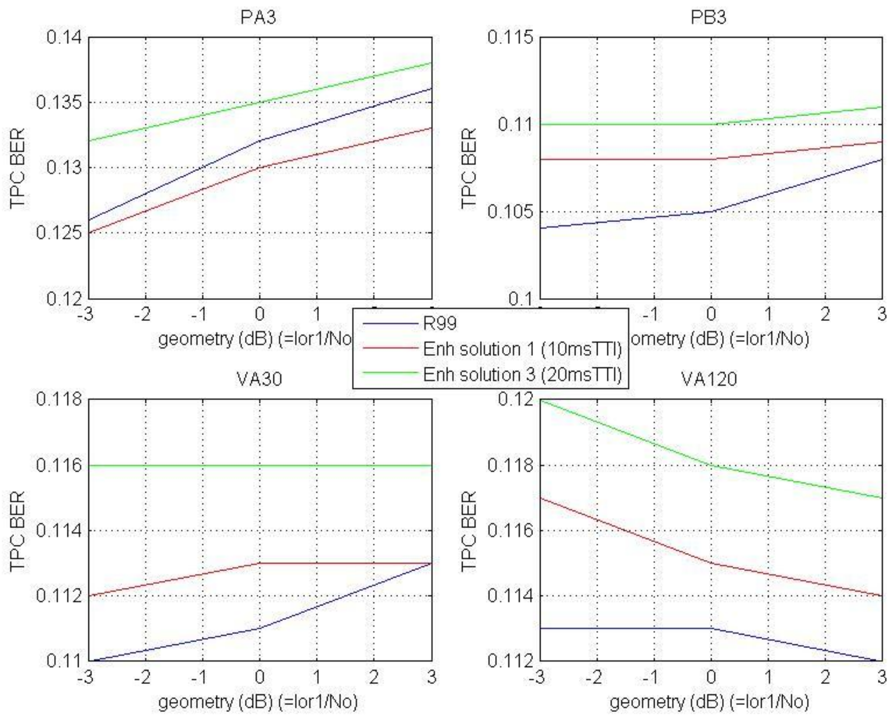


Figure 9.1.7-2: TPC BER for R99 and Solutions 1, 3 for 50% voice activity factor, Active-set size=2

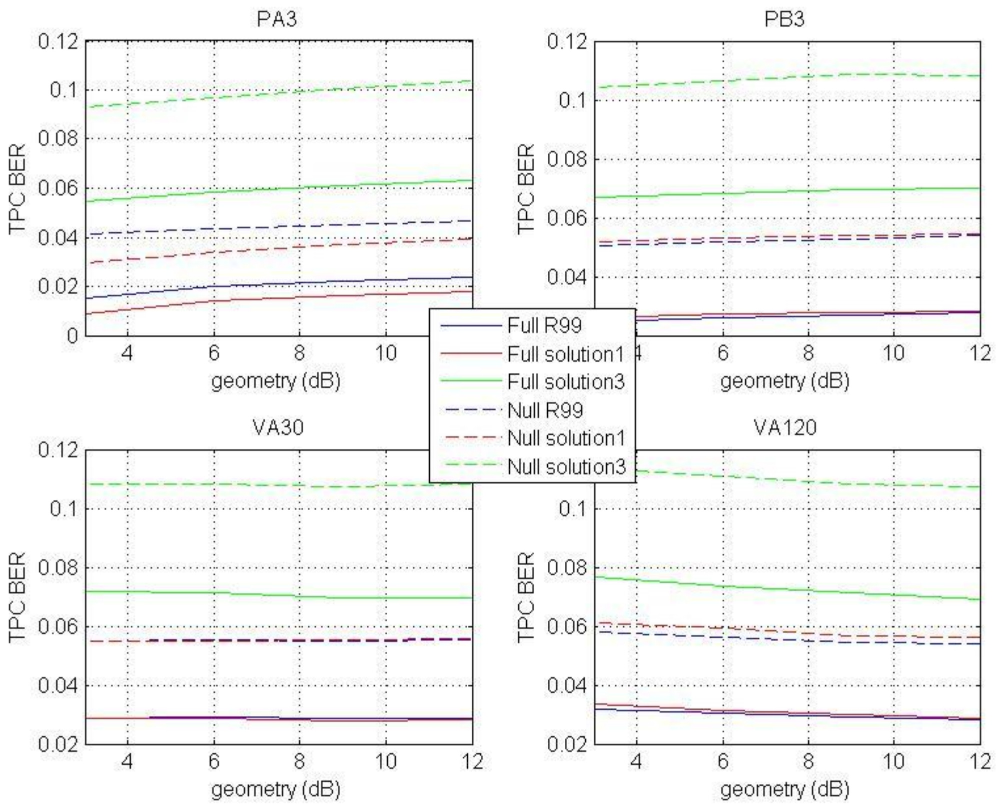


Figure 9.1.7-3: TPC BER for R99 and Solutions 1, 3 for AMR 5.9kbps codec packets, Active-set size=1

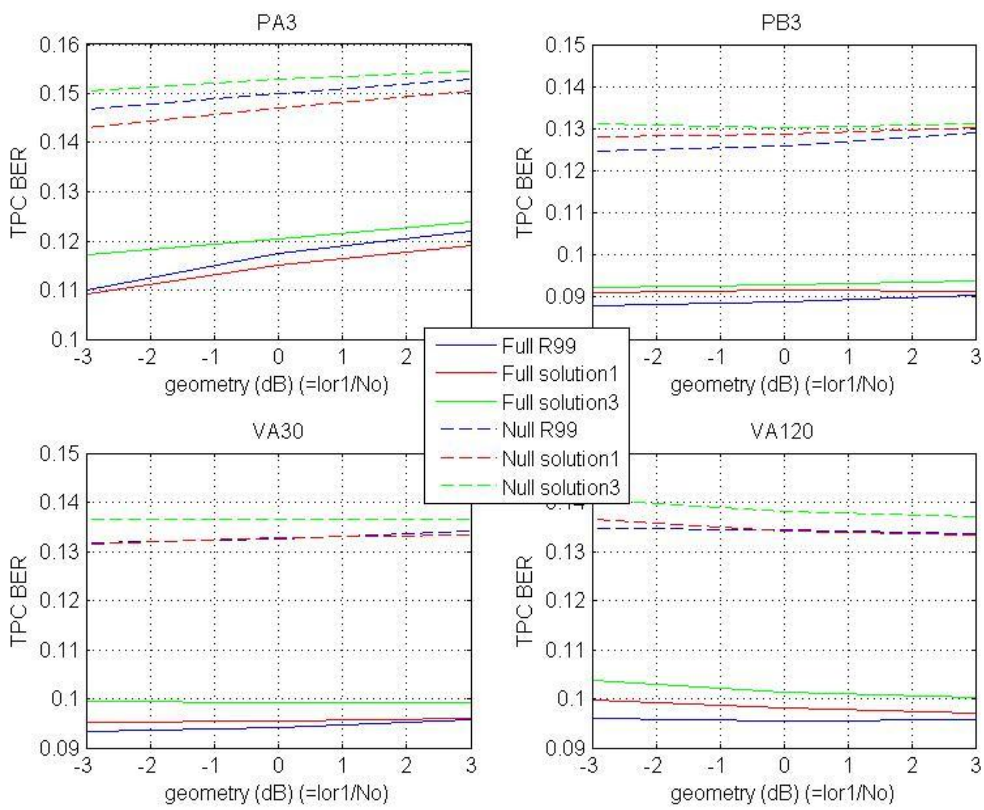


Figure 9.1.7-4: TPC BER for R99 and Solutions 1, 3 for AMR 5.9kbps codec packets, Active-set size=2

9.2 Link evaluation results: Downlink, Solutions 2 and 4

This clause presents link evaluation of downlink DCH enhancements described as 'Solution 2' and 'Solution 4' in clause 8. For better understanding, "E-WCDMA with TDM" stands for "Solution 2" and "E-WCDMA" stands for "Solution 4" in this clause.

Figure 9.2-1, Figure 9.2-2 and Figure 9.2-3 show the performance of DPCH Tx Ec/Ior, BLER and TPC CER respectively for the aforementioned three schemes for the case of single active set cell. In case of two active set cells, the simulation results are presented in Figure 9.2-4 (averaged DPCH Tx Ec/Ior in linear domain over two cells), Figure 9.2-5 and Figure 9.2-6 (averaged TPC CER over two cells).

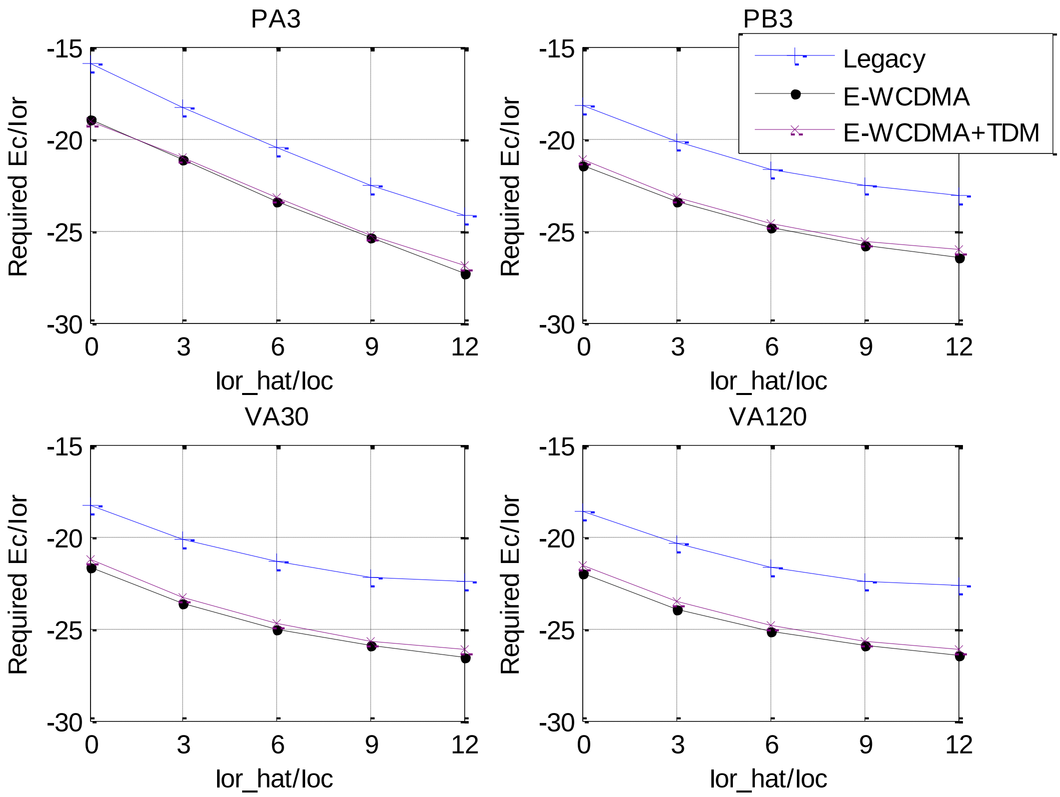


Figure 9.2-1: DPCH Ec/Ior performance (single cell)

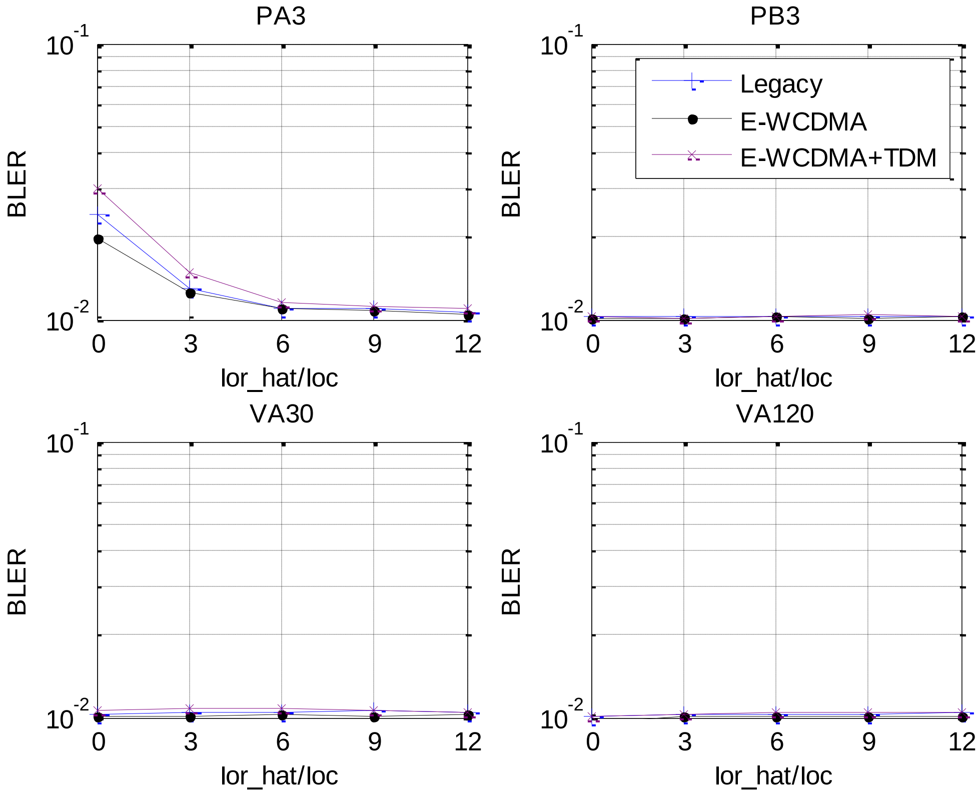


Figure 9.2-2: DTCH BLER performance (single cell)

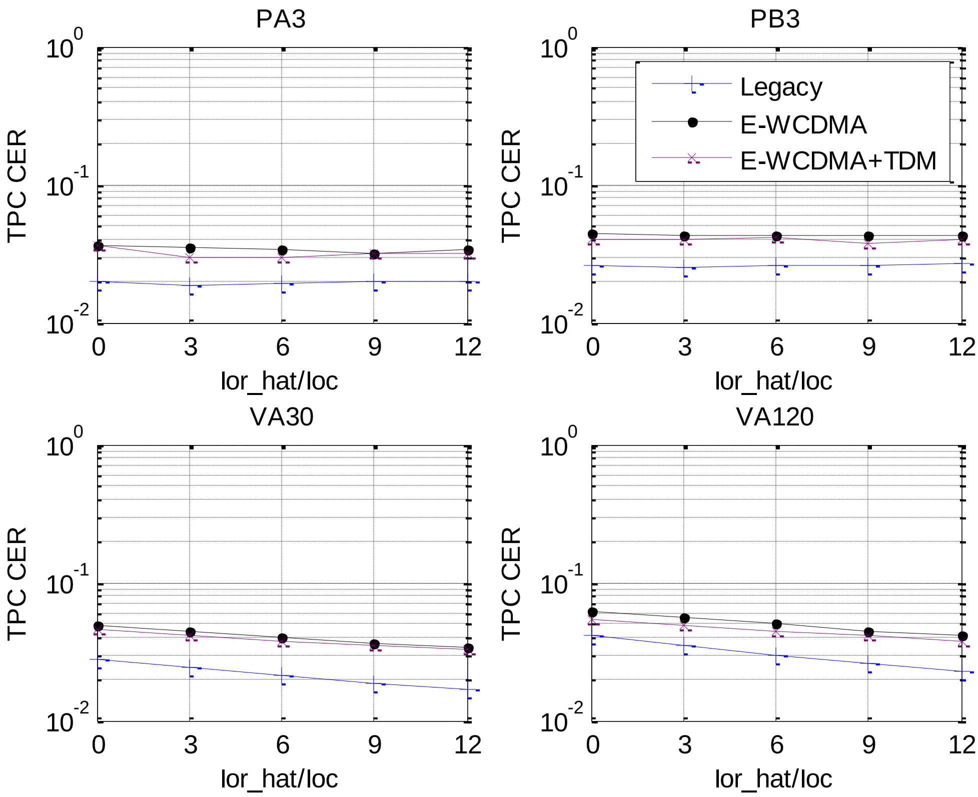


Figure 9.2-3: TPC CER performance (single cell)

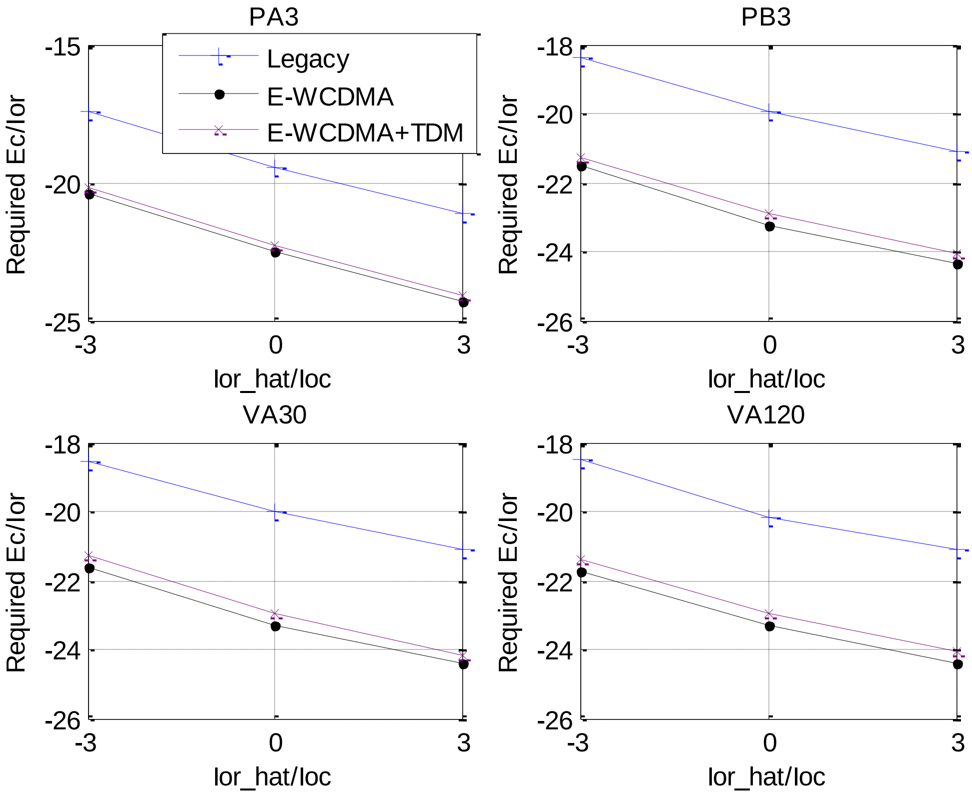


Figure 9.2-4: DPCH Ec/Ior performance (two active set cells)

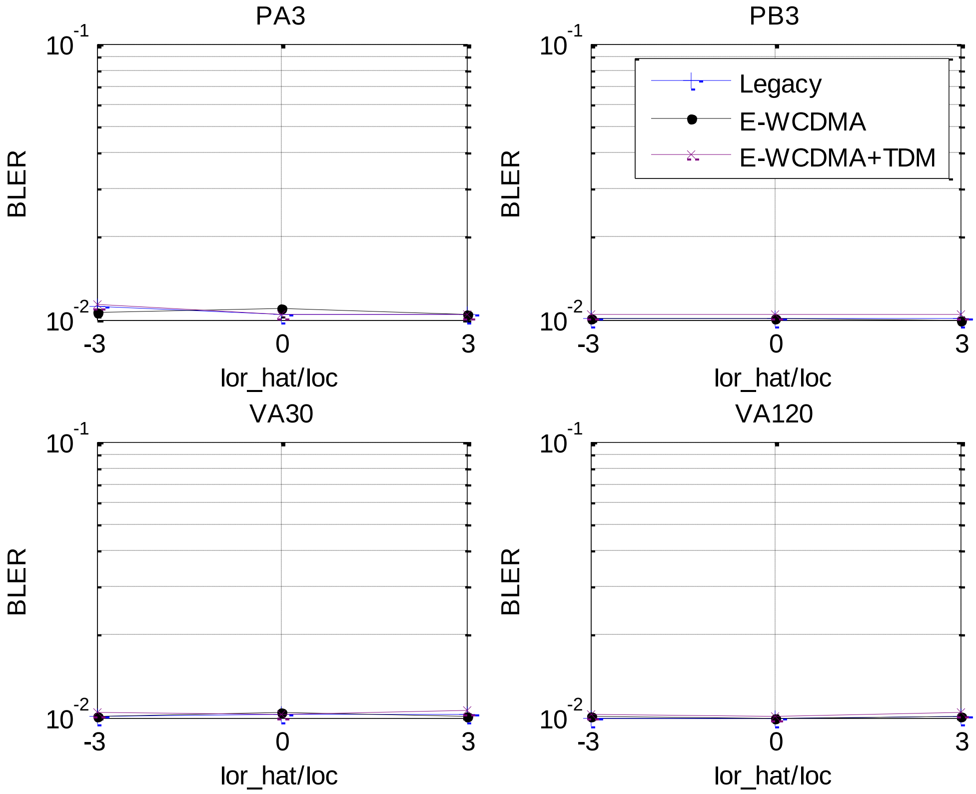


Figure 9.2-5: DTCH BLER performance (two active set cells)

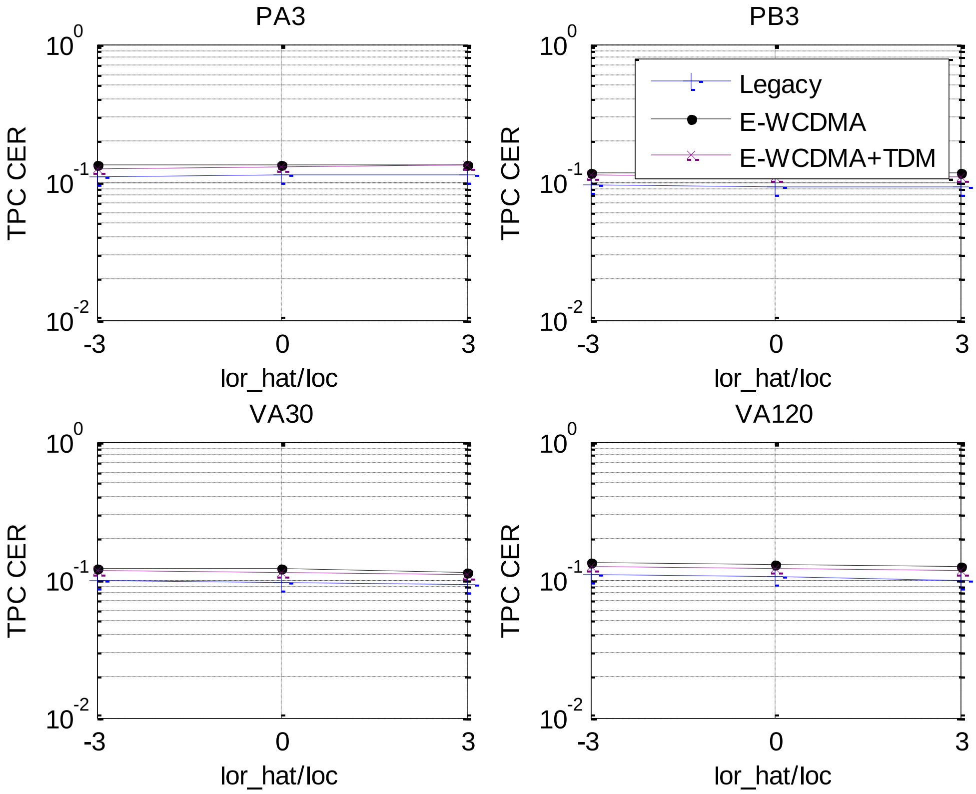


Figure 9.2-6: TPC CER performance (two active set cells)

The averaged Ec/Ior reduction gain for E-WCDMA and E-WCDMA with TDM against the legacy R99 system is summarized in Table 9.2-1 for single cell case and in Table 9.2-2 for two active set cells case. The reduction gain (in dB) is averaged over different geometry in dB domain.

Table 9.2-1: Averaged DPCH Tx Ec/Ior reduction gain in dB (averaged over packet types) (single cell)

Average DPCH Tx Ec/Ior reduction gain (dB)	PA3	PB3	VA30	VA120	Averaged over channels
E-WCDMA	2.95	3.26	3.69	3.53	3.36
E-WCDMA + TDM	2.83	2.97	3.34	3.19	3.08

Table 9.2-2: Averaged DPCH Tx Ec/Ior reduction gain in dB (averaged over packet types) (two active set cells)

Average DPCH Tx Ec/Ior reduction gain (dB)	PA3	PB3	VA30	VA120	Averaged over channels
E-WCDMA	3.10	3.22	3.23	3.23	3.20
E-WCDMA + TDM	2.86	2.95	2.91	2.87	2.90

As seen in Table 9.2-1, E-WCDMA introduces an average of 3.36dB DPCH Tx Ec/Ior reduction gain. With DPCH TDM, the reduction gain drops to 3.08dB, since TDM is designed to relieve the constraints on code resource rather than power resource. In this case, such 0.28dB loss of DPCH Tx Ec/Ior is traded into 50% more effective users.

Moreover, Figure 9.2-7 ~ Figure 9.2-12 show the early termination statistics for different packet types. Geometry is 6dB and cell number is one. Table 9.2-3 and Table 9.2-4 provide the averaged required slots for successful early decoding. The average is over different channel models and different geometry.

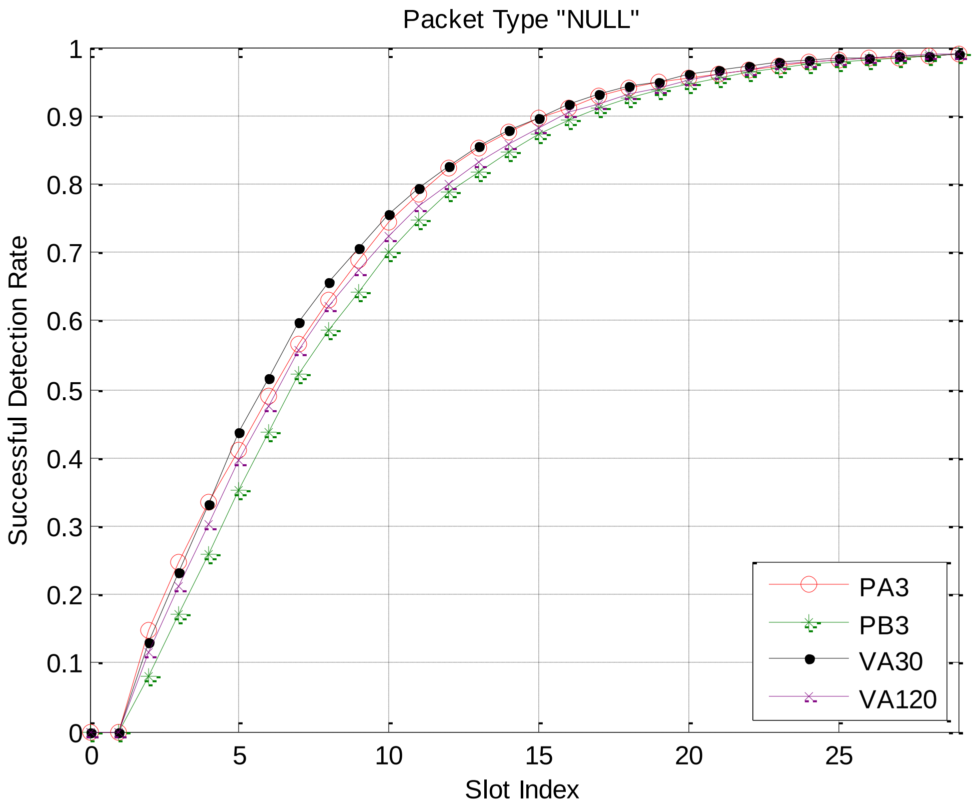


Figure 9.2-7: Early termination statistics for packet type "NULL" for E-WCDMA

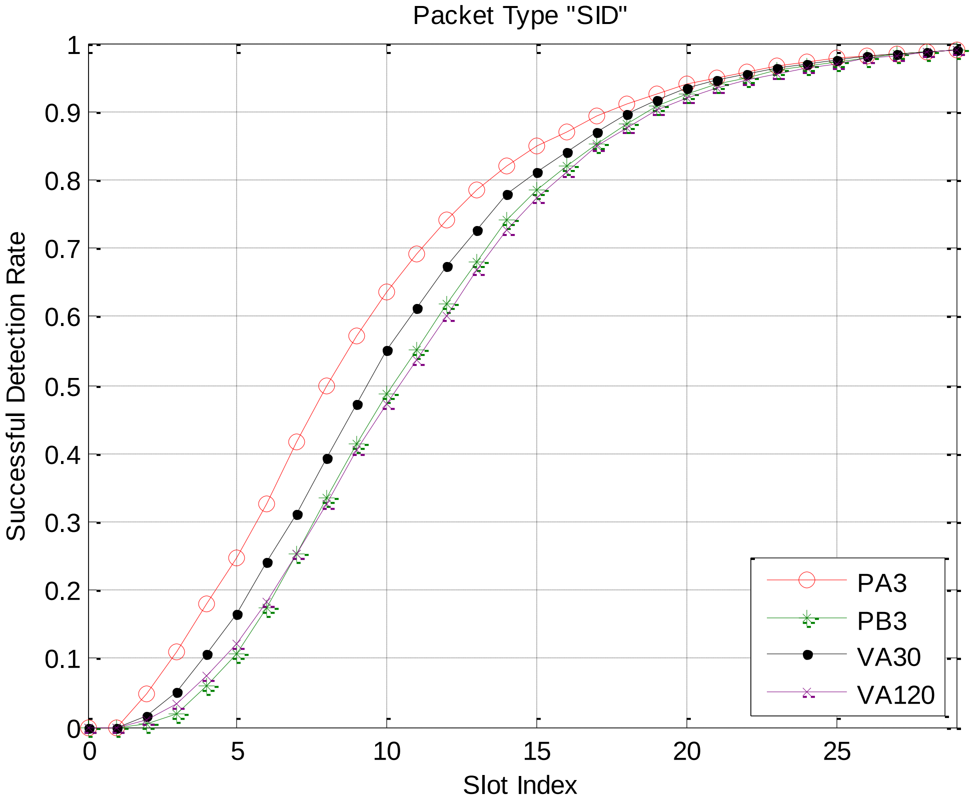


Figure 9.2-8: Early termination statistics for packet type "SID" for E-WCDMA

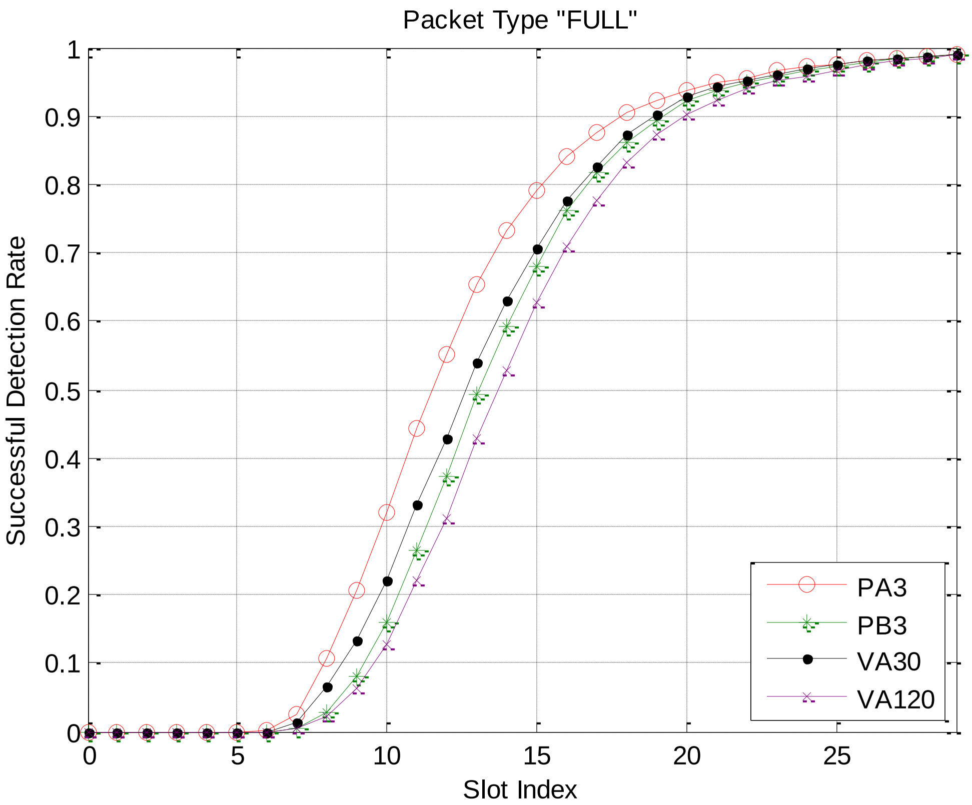


Figure 9.2-9: Early termination statistics for packet type "FULL" for E-WCDMA

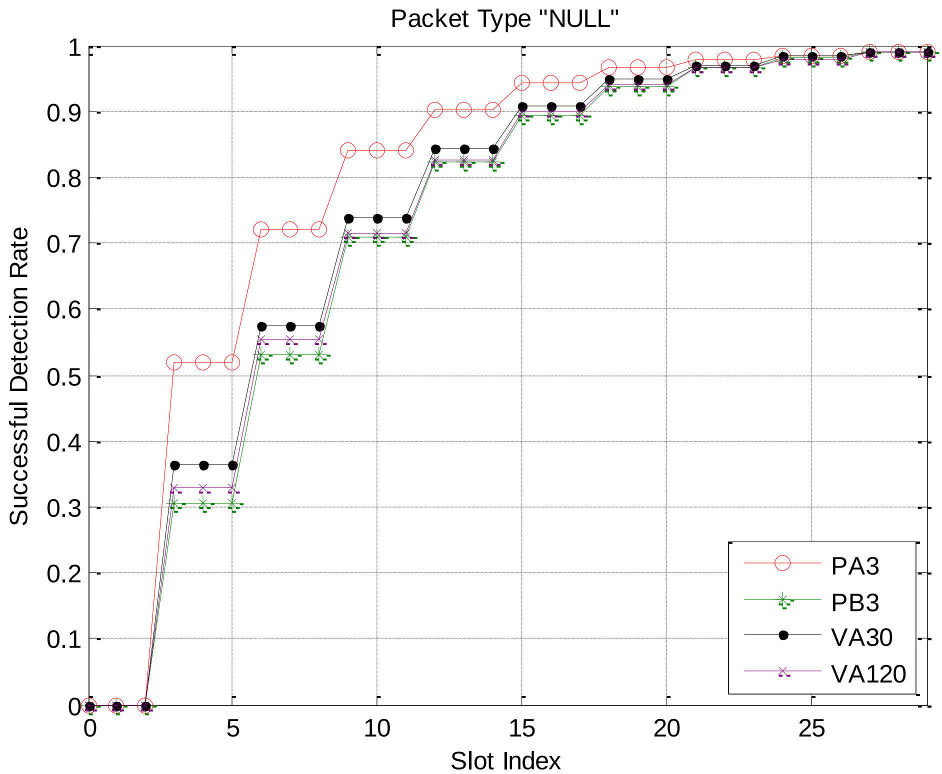


Figure 9.2-10: Early termination statistics for packet type "NULL" for E-WCDMA with TDM

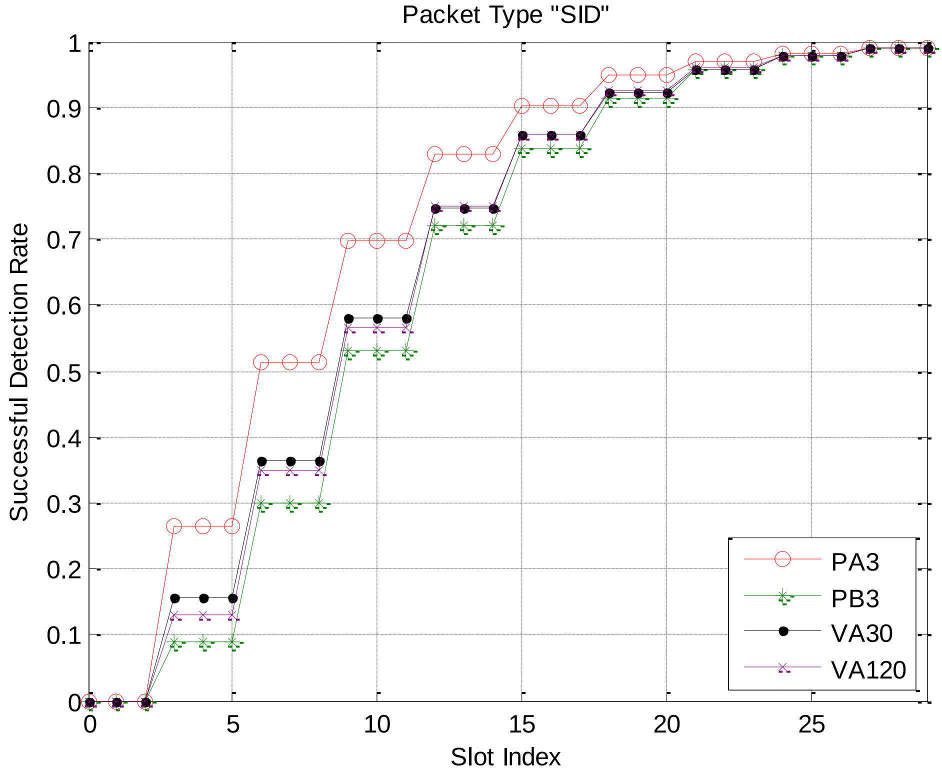


Figure 9.2-11: Early termination statistics for packet type "SID" for E-WCDMA with TDM

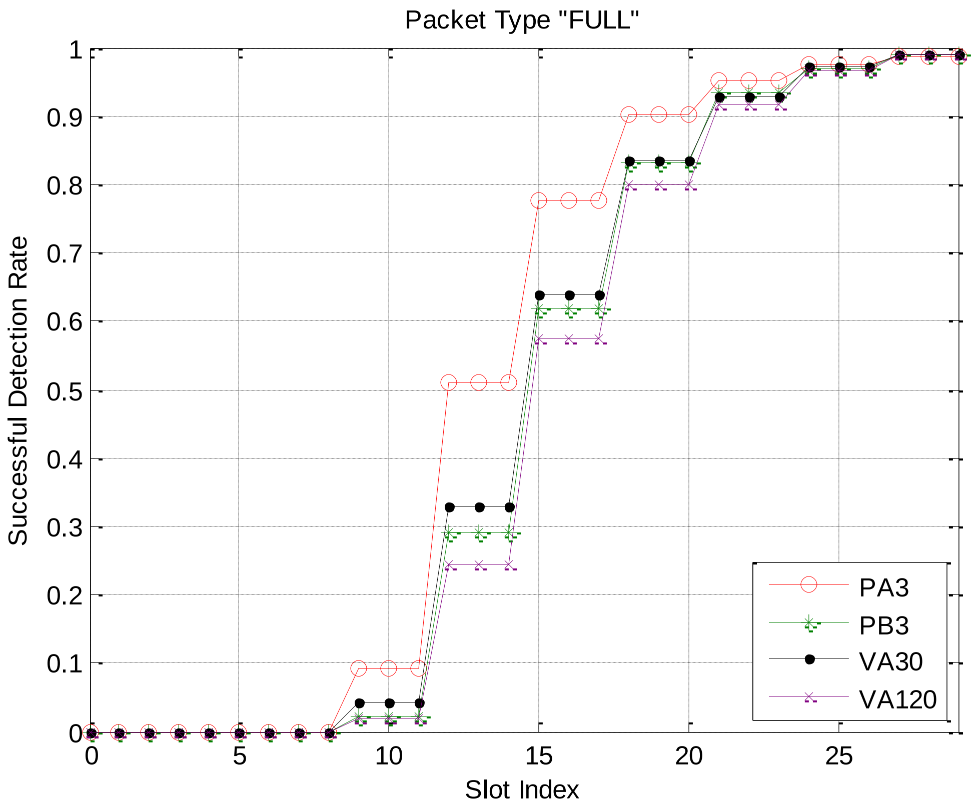


Figure 9.2-12: Early termination statistics for packet type "FULL" for E-WCDMA with TDM

Table 9.2-3: Averaged required slots for successful early decoding for E-WCDMA

Packet Type	NULL	SID	FULL
Averaged required slots for successful early decoding	9.4	12.1	15.3

Table 9.2-4: Averaged required slots for successful early decoding for E-WCDMA with TDM

Packet Type	NULL	SID	FULL
Averaged required slots for successful early decoding	9.0	11.4	16.7

9.3 Link evaluation results: Downlink, others

In addition to complete "Solution 1" ~ "Solution 4", some features are simulated alone to make the report more comprehensive.

9.3.1 Simulation results for Pilot-Free DPCCH slot format

This clause shows the link simulation results on the DL DTCH BLER, TPC command error rate and DPCH Ec/Ior for the new slot format #17 and #18 proposed in clause 4.2.2, compared with those of legacy slot format #8. The link level simulation results of slot format #19 and #20 are quite similar to those of slot formats #17 and 18 respectively and hence are not presented here. Simulation settings of the legacy slot format are listed in clause 8. Additional simulation settings which are specific to the proposed new slot formats are listed in Table 9.3.1-1 and Table 9.3.1-2.

Table 9.3.1-1 Additional simulation assumptions for the proposed new slot formats

DL DPCH slot format	Number of TPC symbols	Number of Pilot symbols	TPC power offset (dB)
Slot format #8 (1TPC/2PL)	1	2	3
Slot format #17 (1TPC/0PL)	1	0	3
Slot format #18 (2TPC/0PL)	2	0	0

Table 9.3.1-2 – Additional parameters

Parameter	Description
Speech codec	AMR 12.2k
RX finger assignment	The unit is 1/8 chip PA : [0, 3, 6, 13] PB : [0, 6, 25, 37, 71, 114] VA : [0, 10, 22, 33, 53, 77]
CE mechanism	PWC
CE average symbol length	29 symbols

Figure 9.3.1-1 and Figure 9.3.1-2 show the simulation results on DL DTCH BLER for single link and 2-cell soft handover respectively. As seen the DL DTCH BLERs are similar among different DL DPCCH slot formats, and the results indicate that pilot removal has no performance degradation to the DL DTCH BLER.

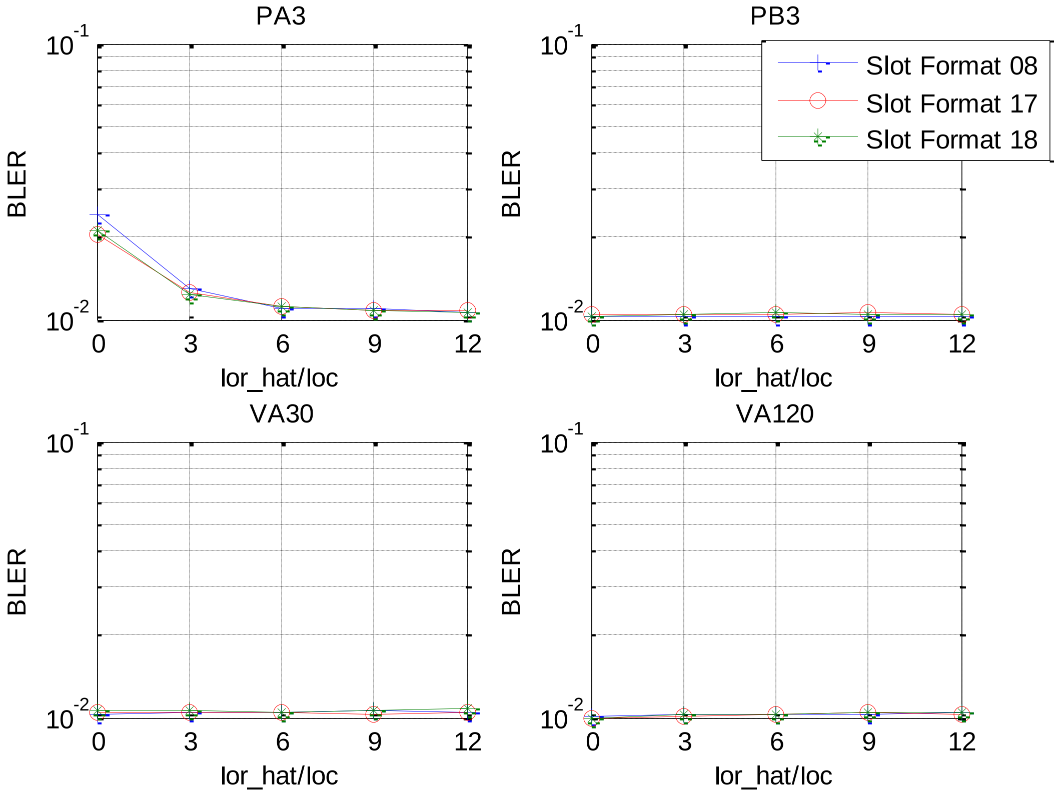


Figure 9.3.1-1 - DL DTCH BLER (single link)

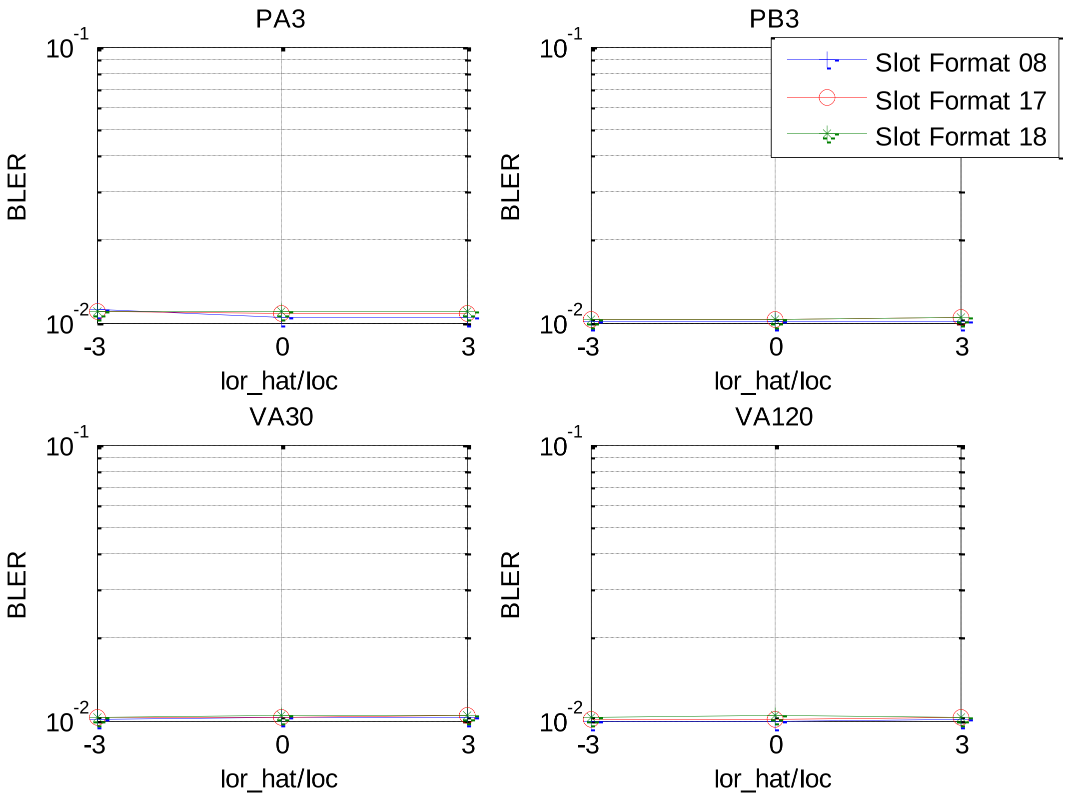


Figure 9.3.1-2 - DL DTCH BLER (2-cell soft handover)

Figure 9.3.1-3 and Figure 9.3.1-4 show the simulation results on DL cell averaged TPC command error rate for single link and 2-cell soft handover respectively. Similarly, the TPC CERs are quite similar among different slot formats, which indicates that pilot removal has no performance impact to the decoding of TPC.

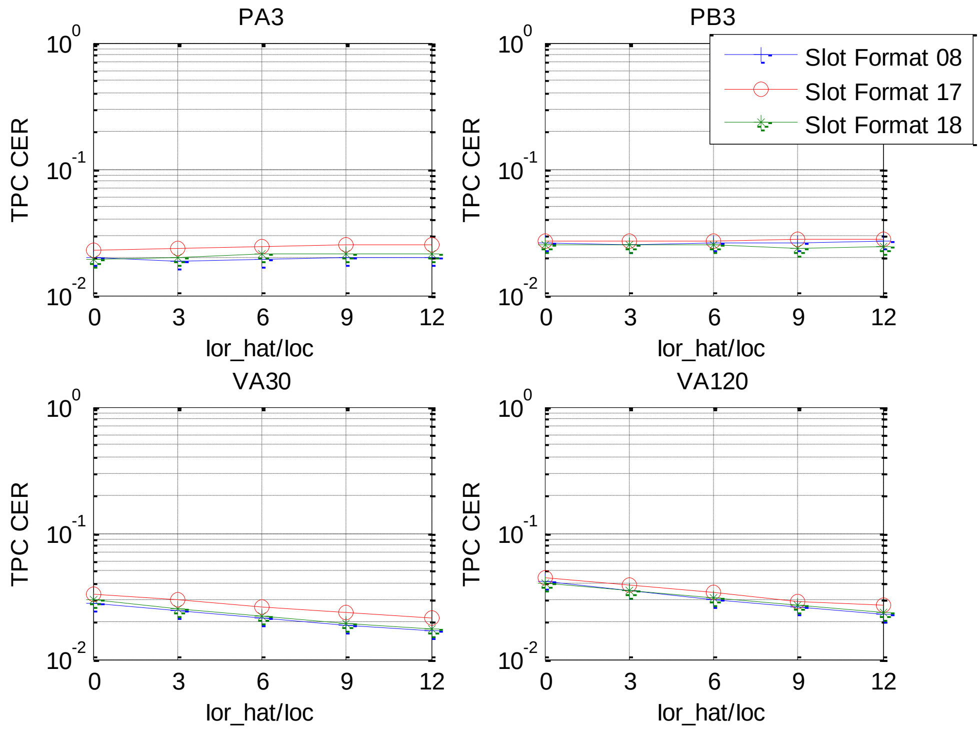


Figure 9.3.1-3 - TPC command error rate (single link)

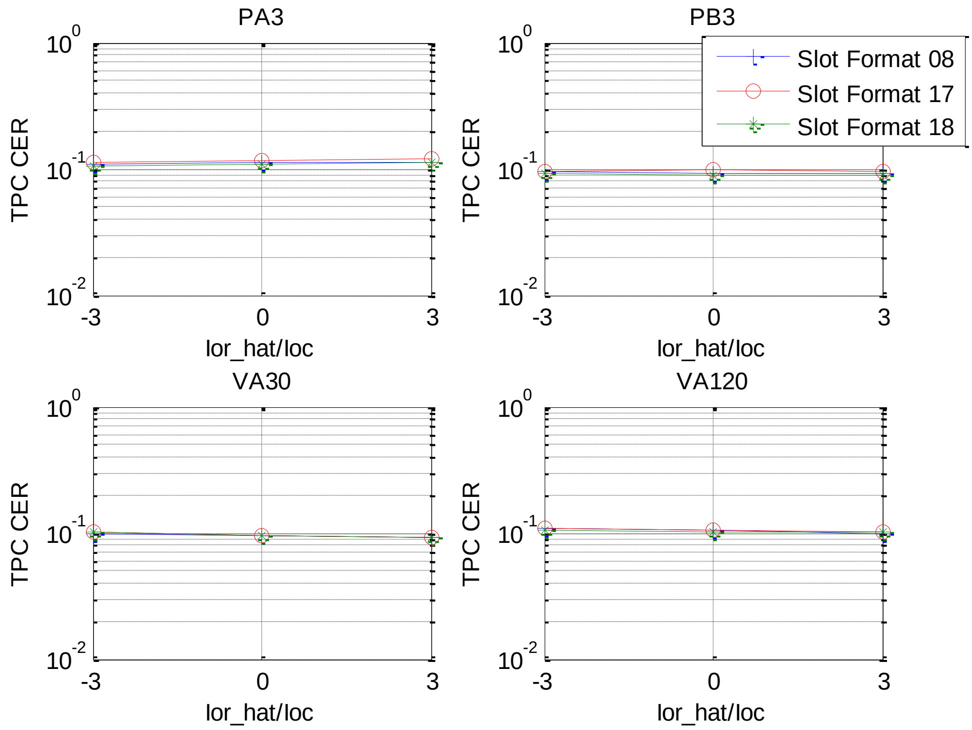


Figure 9.3.1-4 - TPC command error rate (2-cell soft handover)

Figure 9.3.1-5 and Figure 9.3.1-6 show the results of transmit power consumption in terms of the required downlink DPCH Ec/Ior for single link and 2-cell soft handover respectively. Note that the required DPCH Ec/Ior in SHO is averaged over all cells in active set, but not combined.

As seen in Table 9.3.1-3 and Table 9.3.1-4, the power reduction gain from different pilot removal solutions are quite similar and the gain is about 1.2 dB for single link and 1.0 dB for 2-cell soft handover, compared with slot format #8, respectively.

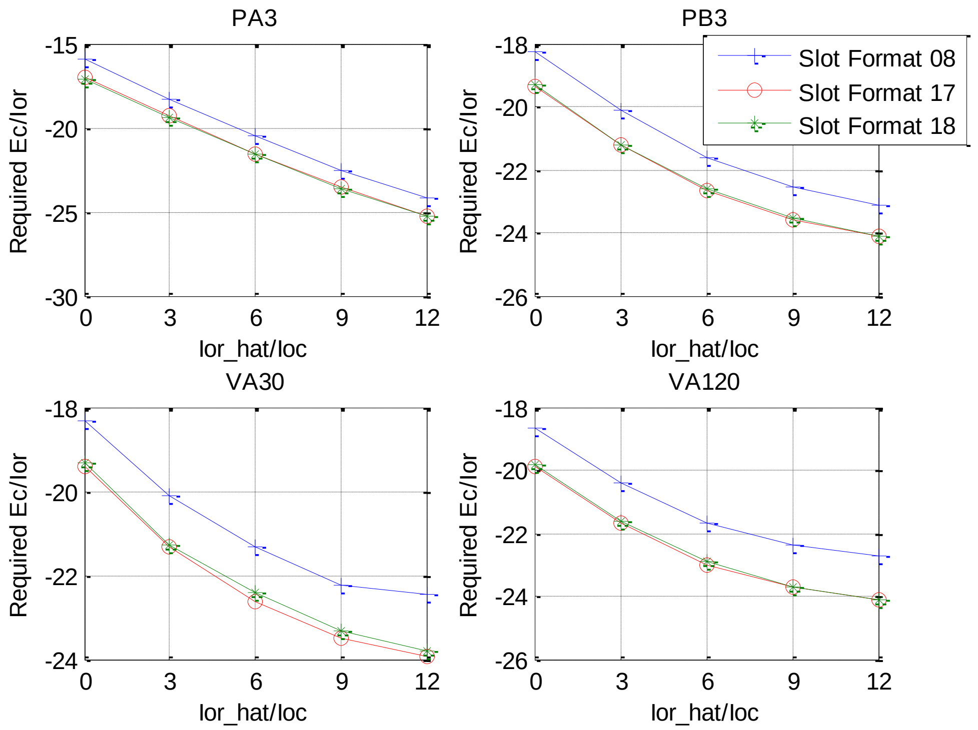


Figure 9.3.1-5 - Required downlink DPCH Ec/Ior (single link)

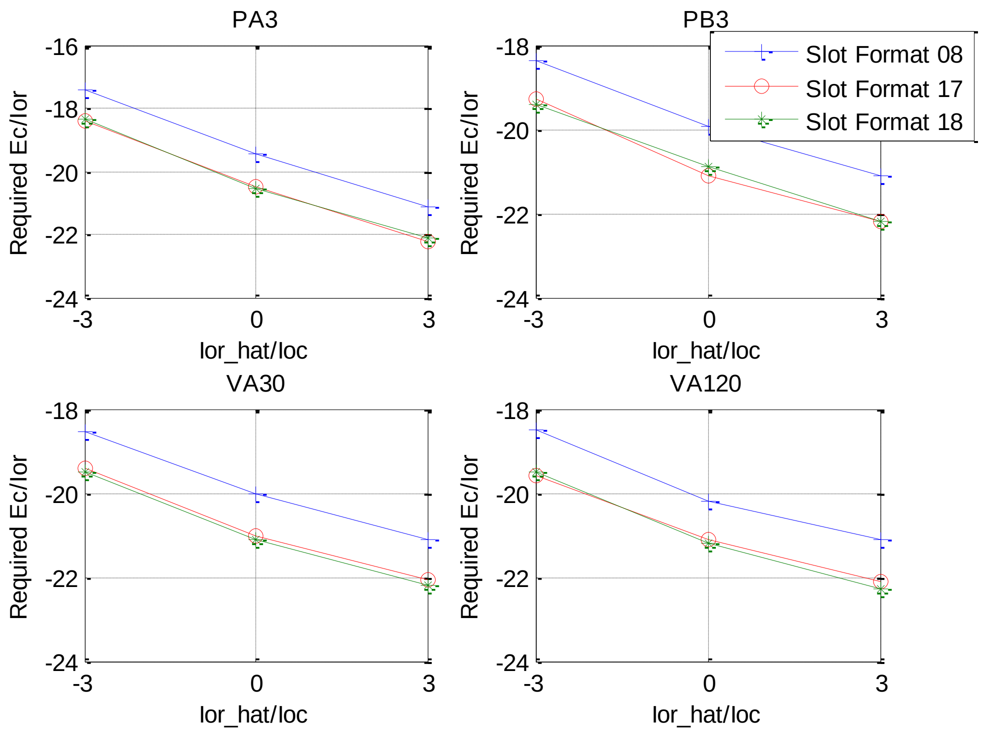


Figure 9.3.1-6 - Required downlink DPCH Ec/Ior (2-cell soft handover)

Table 9.3.1-3 Power reduction gain for the slot format #17 over slot format #8

Slot Format #17	Power Reduction Gain (dB)	
Fader Models	Single link	2-cell soft handover
PA3	1.07	1.06
PB3	1.07	1.06
VA30	1.27	0.94
VA120	1.29	1.00

Table 9.3.1-4 Power reduction gain for the slot format #18 over slot format #8

Slot Format #18	Power Reduction Gain (dB)	
Fader Models	Single link	2-cell soft handover
PA3	1.10	1.03
PB3	1.01	1.02
VA30	1.14	1.04
VA120	1.25	1.07

9.3.1.1 Impact on SINR estimation mechanism

Table 9.3.1.1.1 shows a comparison of link performance due to impact of pilot removal on SIR estimation.
In this comparison, the performance of SIR estimation based on joint TPC and dedicate pilot in DPCCH is compared against SIR estimation based on TPC fields alone. As can be seen from this table, there is little loss introduced by pilot removal due to worse SINR estimation in comparison of joint TPC+pilot SIR estimation. However, the power reduction gain from pilot removal is larger than the loss.

Table 9.3.1.1.1 DL systems comparison for TPC based SINR, CLPC delay = 0 slot with TPC + DPCCH pilot bits based SINR estimation, CLPC delay = 0 slot

Geometry	TPC, CLPC delay = 0 slot, Tx Ec/Ior [dB]	TPC + DPCCH pilot bits, CLPC delay = 0 slot, Tx Ec/Ior [dB]	Gain [dB]
G0	-14.58	-14.74	0.16
G3	-18.61	-18.70	0.08
G6	-20.91	-21.35	0.43
G9	-22.27	-22.96	0.69
G12	-23.11	-23.99	0.88

9.3.2 Simulation results for DL Frame Early Termination (FET) as described in clause 4.2.1 along with Legacy DPCCH slot format

The system level simulation results of FET Option 2 based on Slot Format #8 are provided.

Link performance of Legacy R99 with "Slot Format #8" and that of ET with "Slot Format #8" are presented in Figure 9.3.2-1 ~ Figure 9.3.2-6. DPCH Tx Ec/Ior performance is shown in Figure 9.3.2-1, BLER in Figure 9.3.2-2, and TPC CER in Figure 9.3.2-3 for single cell case. DPCH Tx Ec/Ior performance is shown in Figure 9.3.2-4, BLER in Figure 9.3.2-5, and TPC CER in Figure 9.3.2-6 for two cells case. DPCH Tx Ec/Ior is averaged in linear domain for two cells. TPC CER is also averaged for two cells. The average Ec/Ior reduction gain for ET with "Slot Format #8" against Legacy R99 with "Slot Format #8" is summarized in Table 9.3.2-1. The reduction gain (in dB) is averaged over different geometry in dB domain.

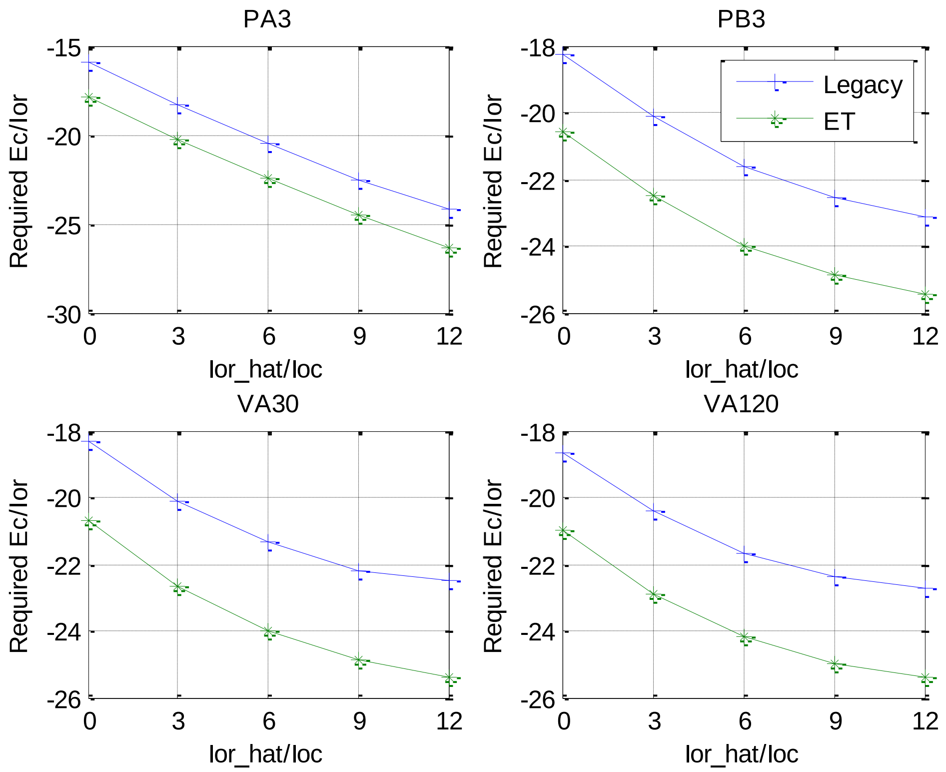


Figure 9.3.2-1 DPCH Ec/Ior performance for single cell case

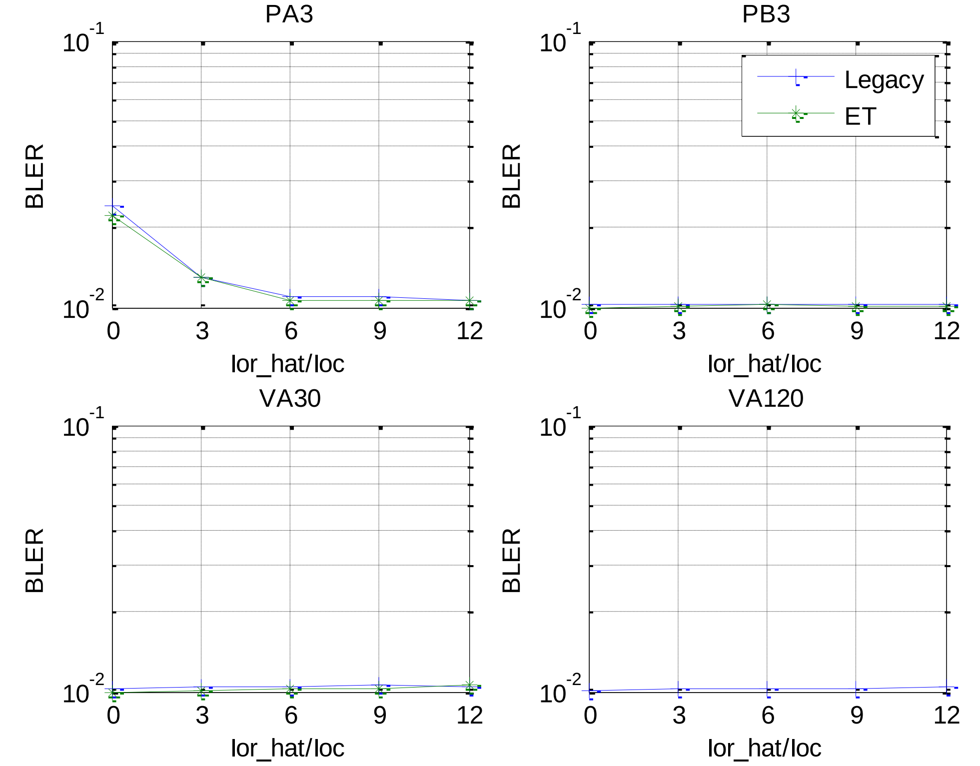


Figure 9.3.2-2 DTCH BLER performance for single cell case

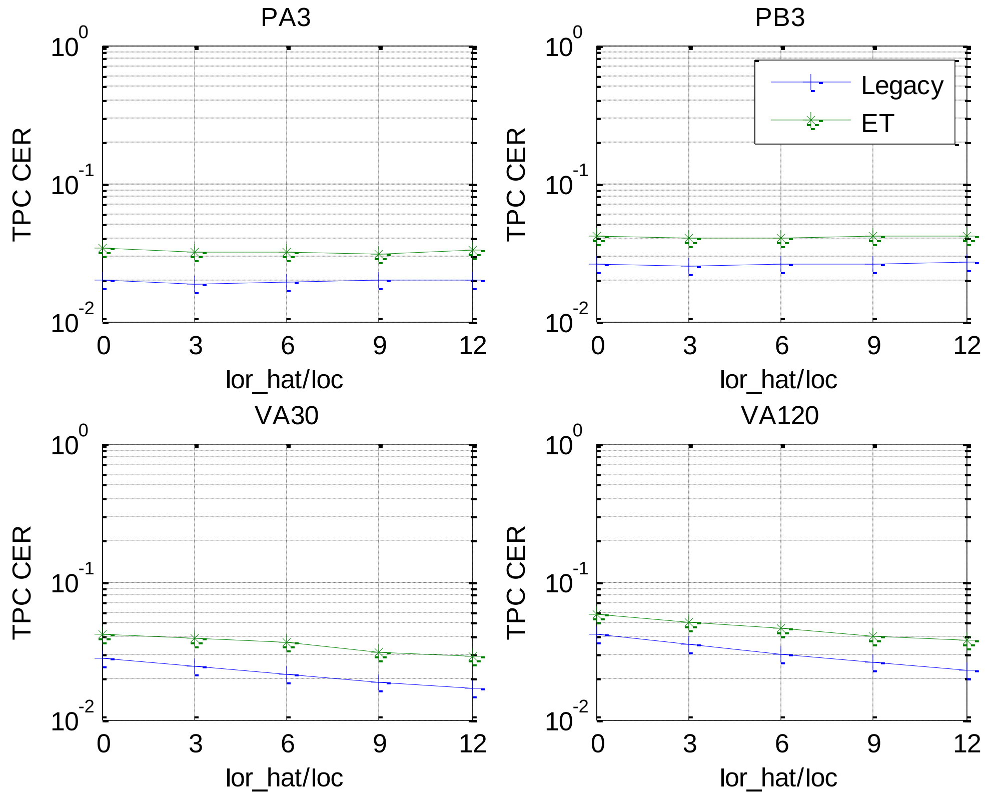


Figure 9.3.2-3 TPC CER performance for single cell case

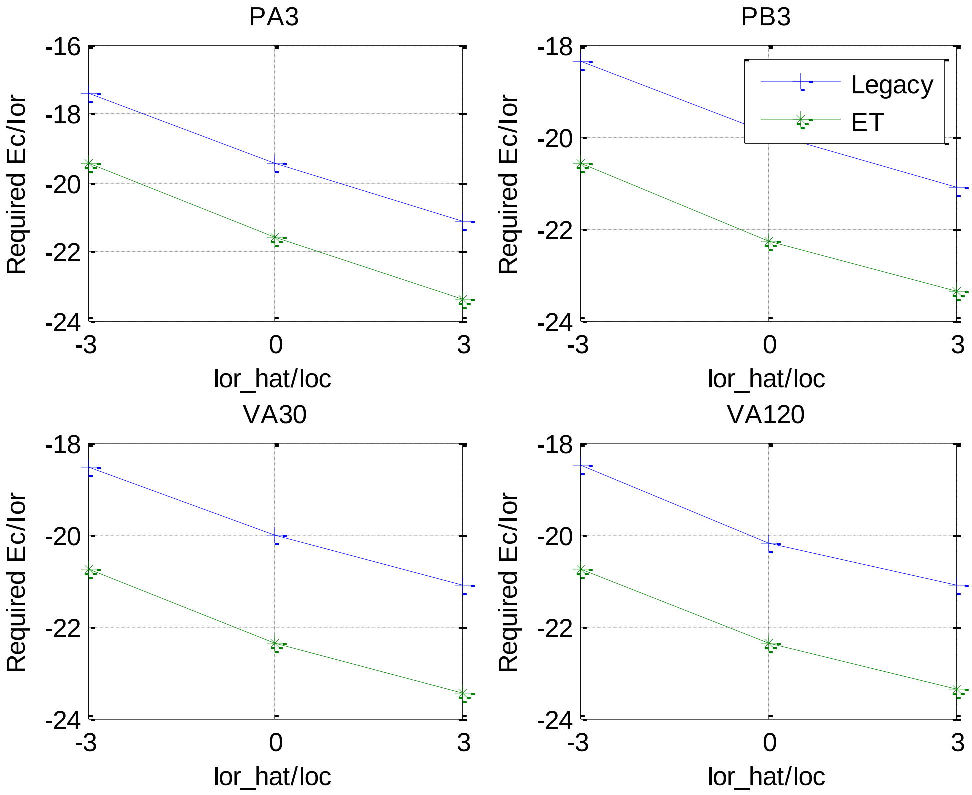


Figure 9.3.2-4 DPCH Ec/Ior performance for two cells case

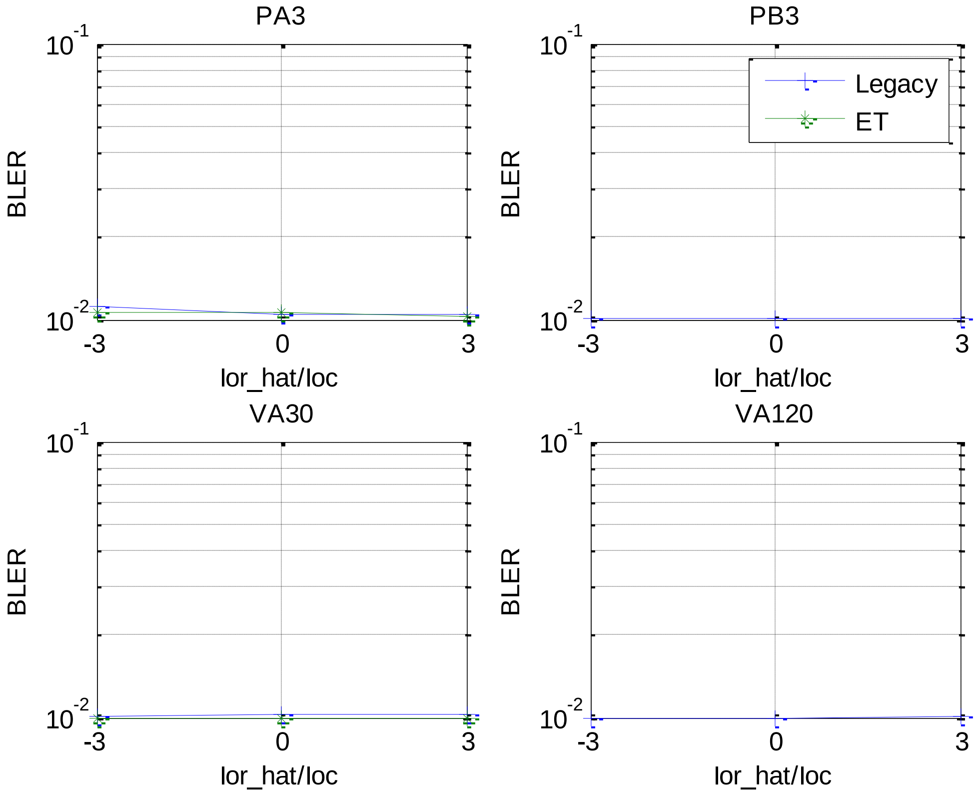


Figure 9.3.2-5 DTCH BLER performance for two cells case

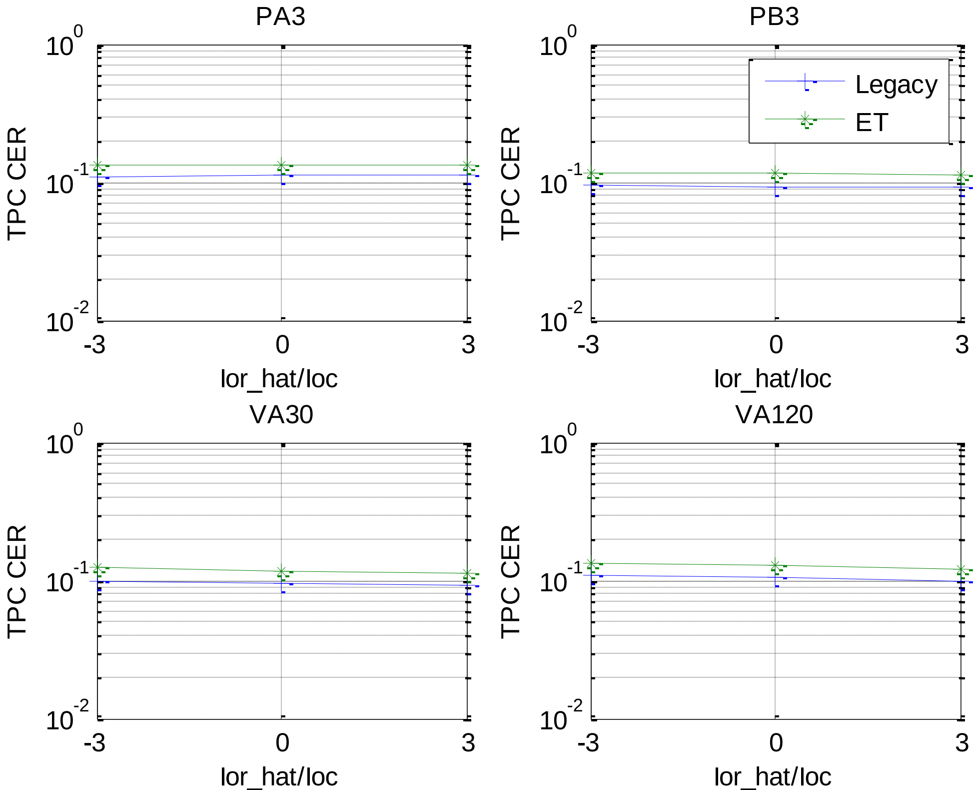


Figure 9.3.2-6 TPC CER performance for two cells case

Table 9.3.2-1 - Average DPCH Tx Ec/Ior reduction gain for average over packet types

		PA3	PB3	VA30	VA120
Average DPCH Tx Ec/Ior reduction gain	**Single cell**	2.01	2.33	2.64	2.51
	Two cells	2.17	2.27	2.31	2.23

It is observed 2.01dB ~ 2.64dB Ec/Ior benefit can be obtained in single cell and 2.17dB ~ 2.31dB Ec/Ior benefit in two cells by the proposed scheme.

Moreover, Figure 9.3.2-7 ~ Figure 9.3.2-9 show the early termination statistics for different packet types. Geometry is 6dB and cell number is one. Comparing these three figures, it is found that if the packet size is smaller, early termination may happen earlier. Table 9.3.2-2 provides the averaged required slots for successful early decoding.
The average is over different channel models and different geometry.

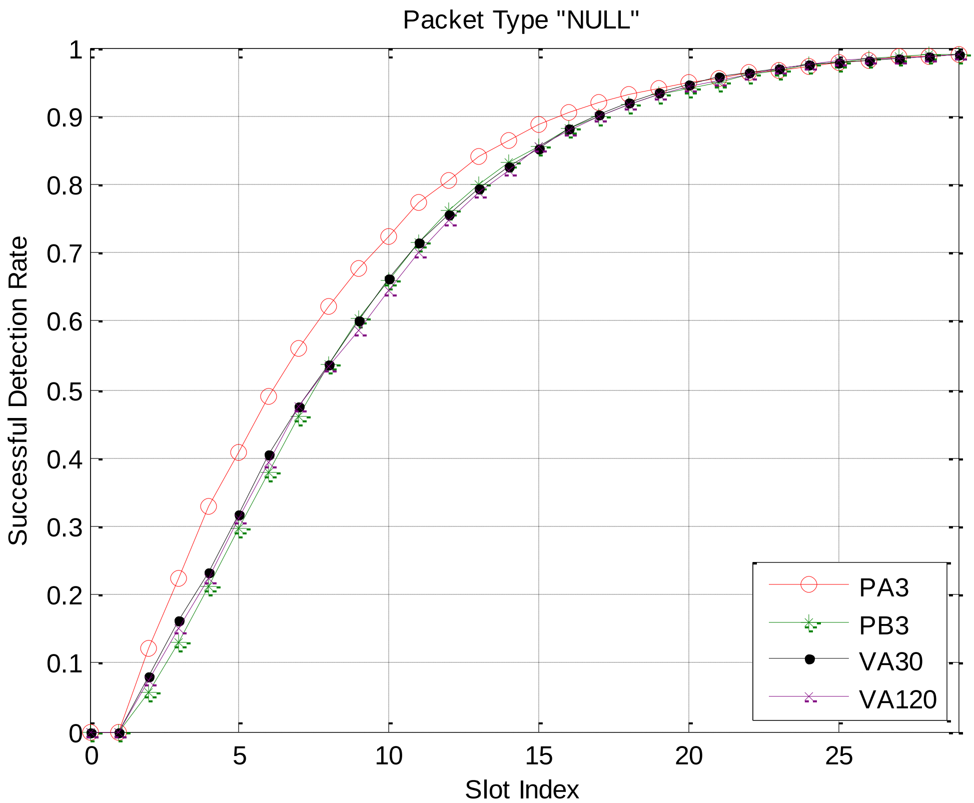


Figure 9.3.2-7 Early termination statistics for packet type "NULL"

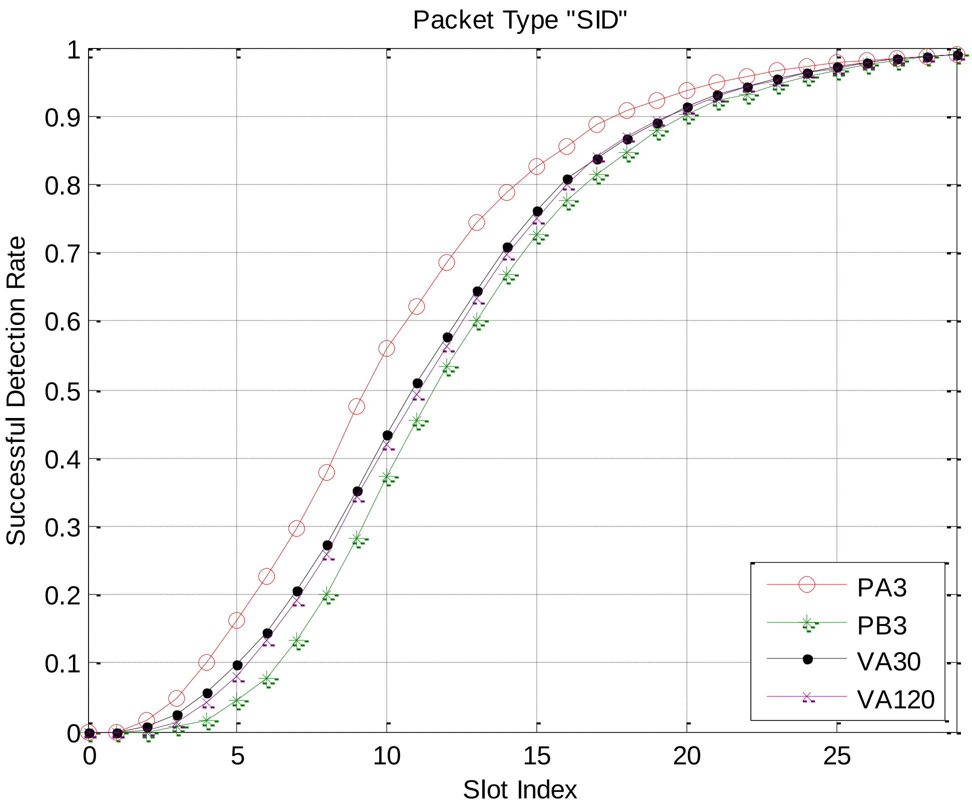


Figure 9.3.2-8 Early termination statistics for packet type "SID"

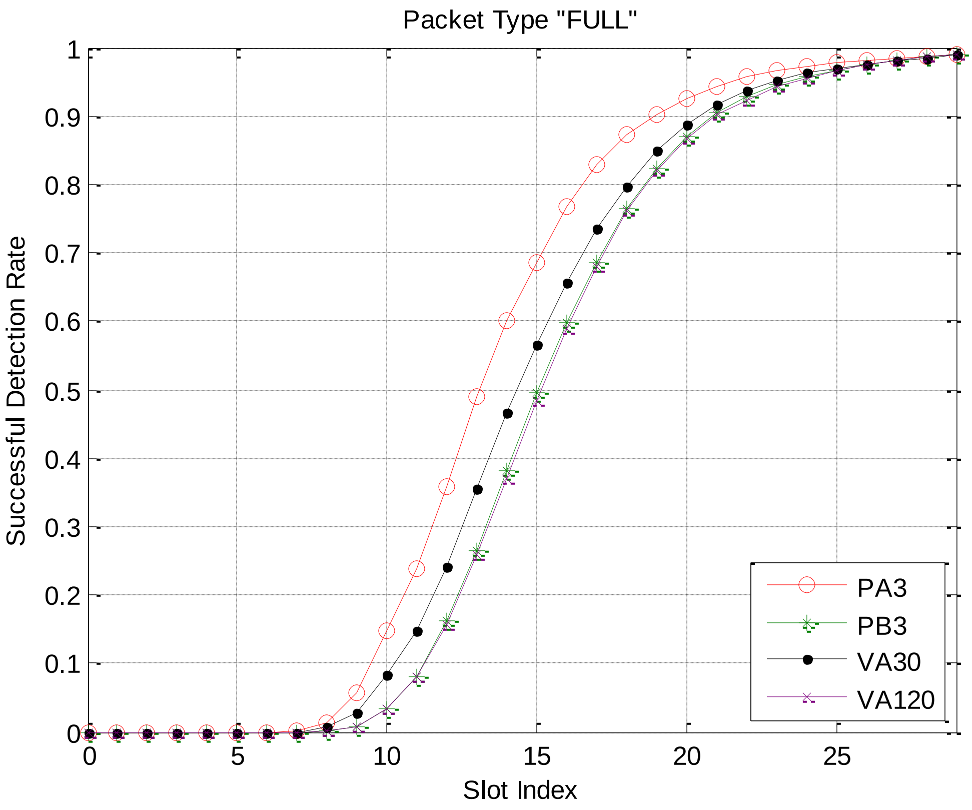


Figure 9.3.2-9 Early termination statistics for packet type "FULL"

Table 9.3.2-2 - Averaged required slots for successful early decoding

Packet Type	NULL	SID	FULL
Averaged required slots for successful early decoding	10.1	13.2	16.7

9.4 Uplink link evaluation results: Solution 1

This clause presents link evaluation of uplink DCH enhancements described in clause 8 (Solution 1). Several scenarios are considered, including active size 1 and 2, ILPC rate of 750Hz and 1500Hz, and the two codecs AMR12.2kbps and AMR5.9kbps are studied.

9.4.1 Finger assignment assumptions

The Rake finger assignment assumed for UL evaluation of Solutions 1 are shown in Table 9.4.1-1.

Table 9.4.1-1: Rake finger assignment in ITU channels

Channel	Path delays (in 1/8th of a chip)
PA	0,7
PB	0,7,25,37,71,114
VA	0,10,22,33,53,77

9.4.2 Link efficiency of AMR 12.2kbps codec

In Figure 9.4.2-1 and Figure 9.4.2-2, the performance of Solution 1 in UL are compared with legacy R99 in SHO and no SHO scenarios with active set size of 1 and 2 for AMR 12.2kbps. Two cases for ILPC rates, 1500Hz and 750Hz, are considered. The averaging is performed assuming 50% voice activity. It is observed that a significant improvement in average Ec/No is expected due to enhancements outlined in Solution 1.
It should be noted that the UL in Solution 3 is unchanged and similar gains are expected in Solution 1 also.

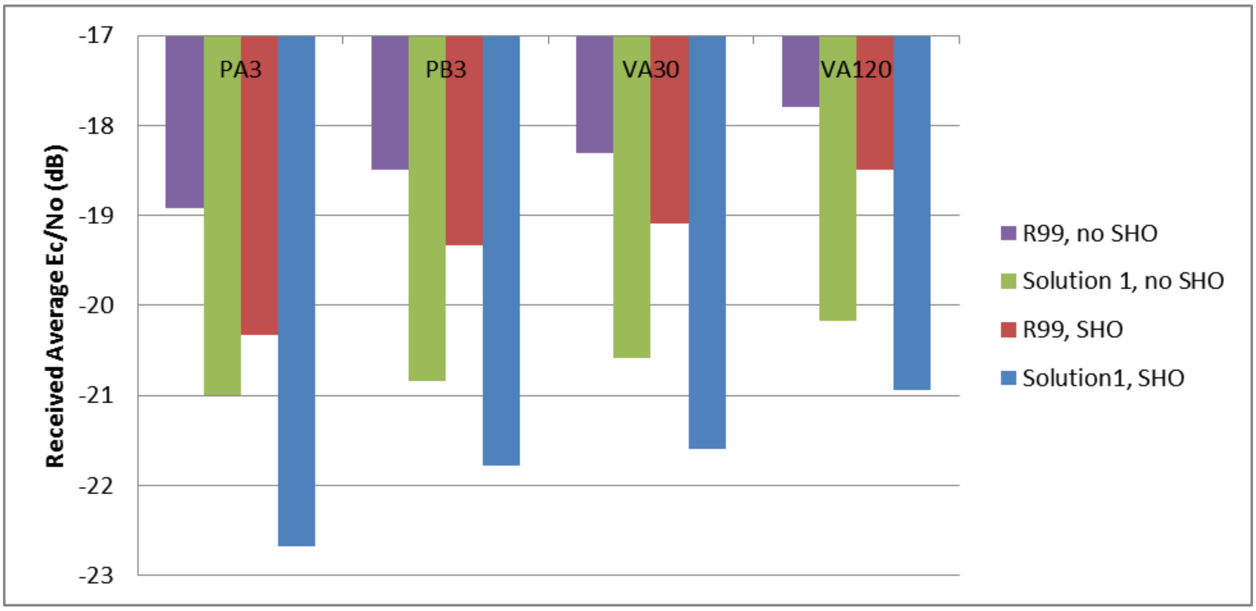


Figure 9.4.2-1: Comparison of UL Average Ec/No of AMR 12.2k traffic with 1500Hz ILPC

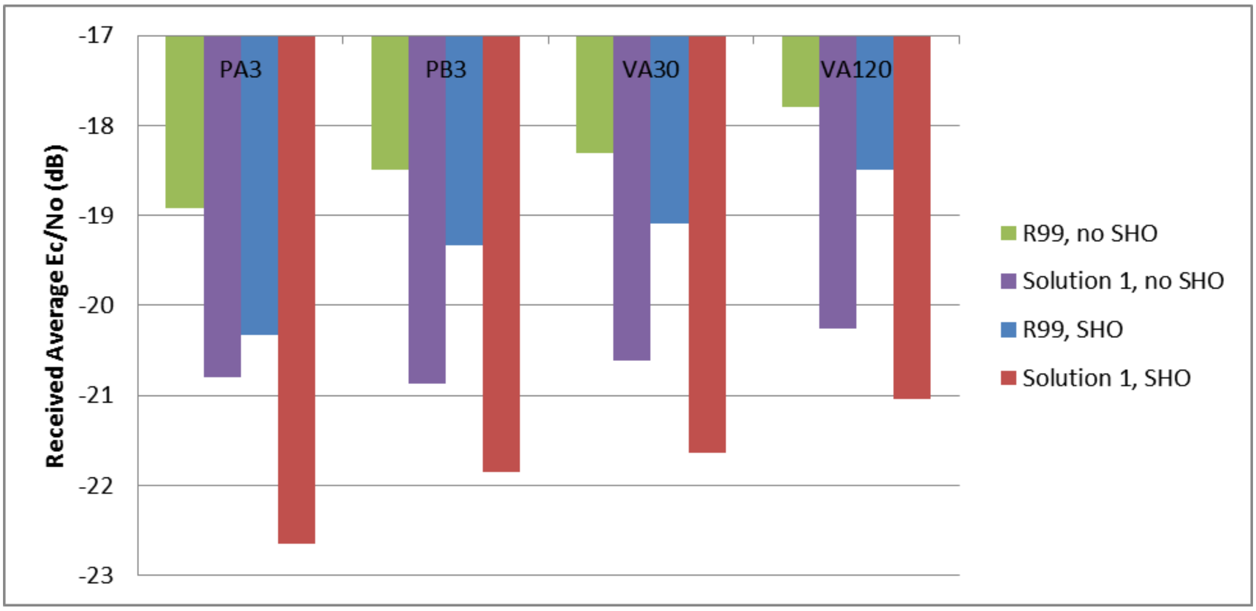


Figure 9.4.2-2: Comparison of UL Average Ec/No of AMR 12.2k with 750Hz ILPC

For completeness, Tables 9.4.2-1 and 9.4.2-2 show total BLER rate and TPC error rate for all scenarios studied. Here, it can be seen that final BLER is converging to 1% target in all scenarios, and TPC error rates are within the 5% limit for which T2P values were designed.

Table 9.4.3-1: Total BLER and TPC error rate for AMR 12.2k traffic without SHO

	no SHO					
	R99		Solution 1, 1500 Hz		Solution 1, 750Hz	
Channel	Total BLER	TPC error rate	Total BLER	TPC error rate	Total BLER	TPC error rate
PA3	0.01	0.01685	0.00145	0.0199	0.0039	0.01855
PB3	0.0101	0.0274	0.00095	0.03095	0.00205	0.02775
VA30	0.0101	0.0383	0.00775	0.0398	0.00945	0.03675
VA120	0.0101	0.04975	0.00685	0.04745	0.0094	0.04325

Table 9.4.3-1: Total BLER and TPC error rate for AMR 12.2k traffic with SHO

	SHO					
	R99		Solution 1, 1500 Hz		Solution 1, 750Hz	
Channel	Total BLER	TPC error rate	Total BLER	TPC error rate	Total BLER	TPC error rate
PA3	0.01005	0.06525	0.0006	0.06405	0.0019	0.06025
PB3	0.01015	0.06045	0.0006	0.06105	0.00135	0.05715
VA30	0.0101	0.06345	0.0016	0.06375	0.0026	0.06
VA120	0.01015	0.06825	0.00325	0.0656	0.0017	0.0591

Finally, Figures 9.4.2-3 and 9.4.2-4 show a CDF of success rates for FET for AMR12.2kbps codec. FET statistics do not include the NULL packet, which can be terminated potentially in Solution 1 (or 3) after the first two slots of the TTI, when the TFCI transmission carried over FET-DPCCH is completed. These figures show that the statistics of FET are not quite sensitive to channel profile, and in a significant percentage of time, even larger packets terminate earlier than 10ms (the weight of FULL packets in this averaging is about 88%, since NULL packets are excluded).

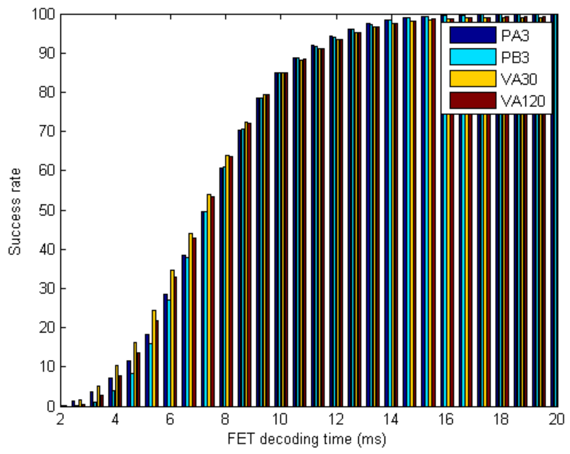


Figure 9.4.2-3 : Average FET success rate statistics at various decoding attempts for AMR 5.9K codec (single link, 1500Hz ILPC)

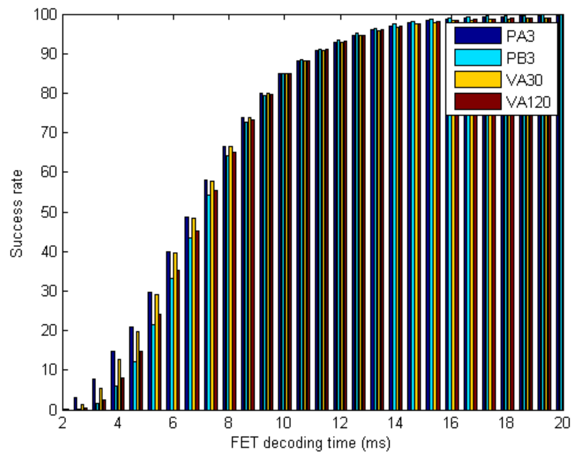


Figure 9.4.2-4 : Average FET success rate statistics at various decoding attempts for AMR 5.9K codec (single link, 750Hz ILPC)

9.4.3 Link efficiency of AMR 5.9kbps codec

In Figure 9.4.3-1 and Figure 9.4.3-2, the performance of Solution 1 in UL are compared with legacy R99 in SHO and no SHO scenarios with active set size of 1 and 2 for AMR 5.9kbps traffic. Two cases for ILPC rates, 1500Hz and 750Hz, are considered. For AMR 5.9kbps also, the averaging is performed assuming 50% voice activity.
It is observed that a significant improvement in average Ec/No is expected due to enhancements outlined in Solution 1. Compared to AMR12.2kbps, the gain for AMR5.9kbps is slightly higher. This is because the shorter packets in AMR 5.9kbps improve the chance of FET.

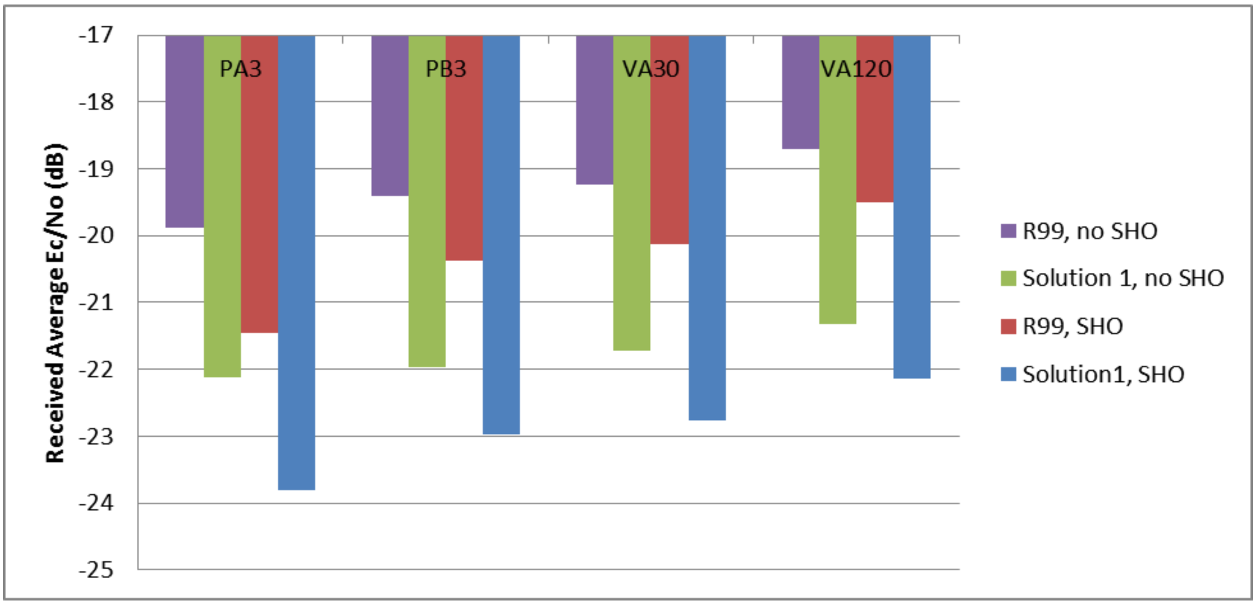


Figure 9.4.3-1: Comparison of UL Average Ec/No of AMR 5.9k traffic with 1500Hz ILPC

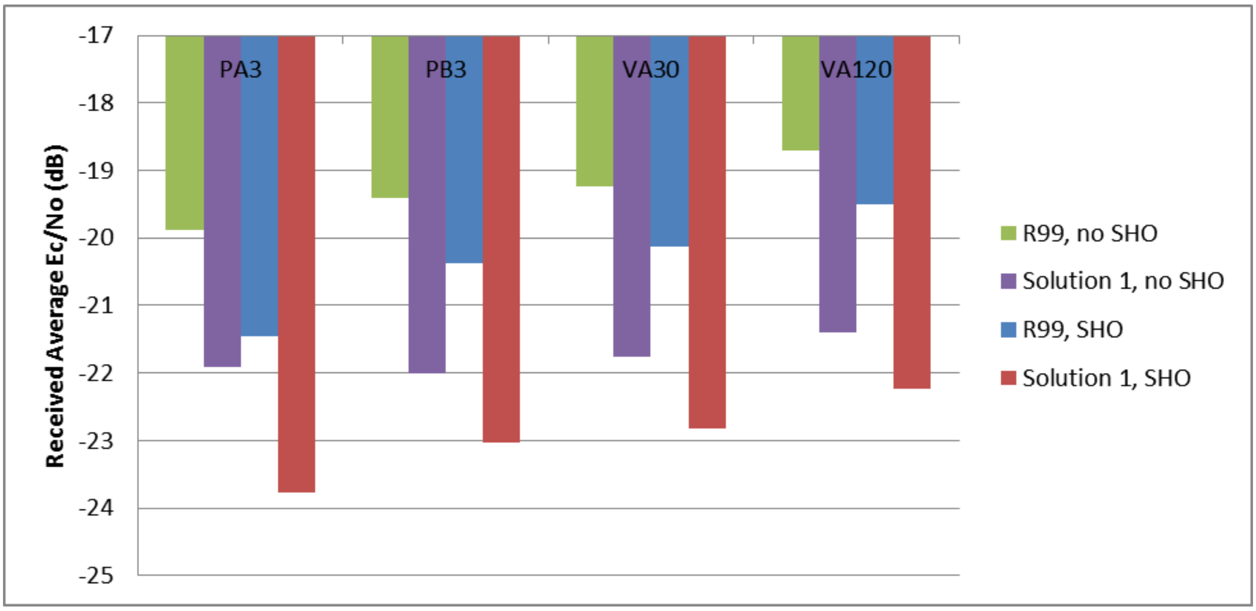


Figure 9.4.3-2: Comparison of UL Average Ec/No of AMR 5.9k with 750Hz ILPC

For completeness, Tables 9.4.3-1 and 9.4.3-2 show total BLER rate and TPC error rate for all scenarios studied. It can be seen that final BLER is converging to 1% target in all scenarios, and TPC error rates are within the 5% limit for which T2P values were designed.

Table 9.4.3-1: Total BLER and TPC error rate for AMR 5.9k traffic without SHO

	no SHO					
	R99		Solution 1, 1500 Hz		Solution 1, 750Hz	
Channel	Total BLER	TPC error rate	Total BLER	TPC error rate	Total BLER	TPC error rate
PA3	0.01	0.0206	0.00145	0.0192	0.0039	0.01795
PB3	0.0101	0.03225	0.0009	0.0299	0.00205	0.027
VA30	0.0101	0.0439	0.00755	0.03895	0.00955	0.03835
VA120	0.0101	0.0552	0.00675	0.0467	0.00925	0.0425

Table 9.4.3-2: Total BLER and TPC error rate for AMR 5.9k traffic with SHO

	SHO					
	R99		Solution 1, 1500 Hz		Solution 1, 750Hz	
Channel	Total BLER	TPC error rate	Total BLER	TPC error rate	Total BLER	TPC error rate
PA3	0.01005	0.0805	0.0006	0.0638	0.00195	0.05955
PB3	0.0102	0.07685	0.0006	0.06025	0.0015	0.0563
VA30	0.01015	0.0789	0.0015	0.0628	0.0027	0.05935
VA120	0.0101	0.08215	0.00095	0.06275	0.002	0.05865

Figures 9.4.3-3 and 9.4.3-4 show a CDF of success rates for FET for AMR5.9kbps codec. Like AMR1.2kbps case, FET statistics do not include the NULL packet, which can be terminated potentially in Solution 1 (or 3) after the first two slots of the TTI, when the TFCI transmission carried over FET-DPCCH is completed. These figures again show that the statistics of FET are not quite sensitive to channel profile, and in a significant percentage of time, even larger packets terminate earlier than 10ms (the weight of FULL packets in this averaging is about 88% , since NULL packets are excluded).

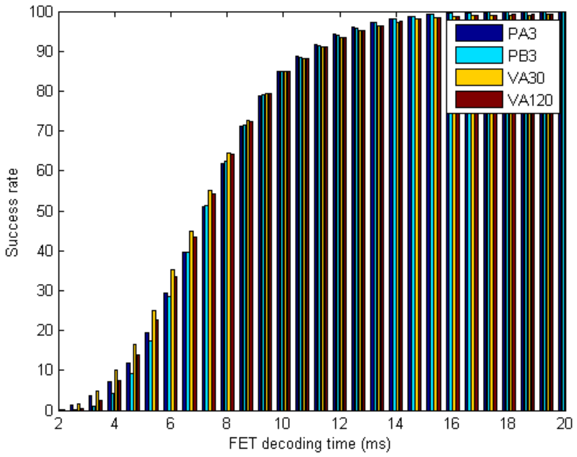


Figure 9.4.3-3 : Average FET success rate statistics at various decoding attempts for AMR 5.9K codec (single link, 1500Hz ILPC)

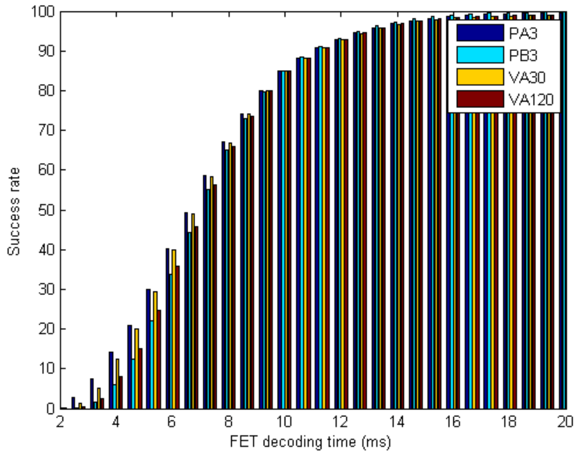


Figure 9.4.3-4 : Average FET success rate statistics at various decoding attempts for AMR 5.9K codec (single link, 750Hz ILPC)

9.4.4 Summary of link efficiency gains due to Solution 1

The expected gains due to enhancements proposed in Solution 1 are summarized in Tables 9.4.4-1 and 9.4.4-2. As can be seen, consistent improvements in the order of 2dB or more are expected in all scenarios and channel conditions due to proposed enhancements in UL as outlined in Solution 1.

Table 9.4.4-1: Gains in Average Ec/No due of Solution 1 compared to legacy R99 for AMR 12.2k traffic

AMR 12.2k	no SHO		SHO	
Channel Type	Gain in Average Ec/No (dB), 1500Hz ILPC	Gain in Average Ec/No (dB), 750Hz ILPC	Gain in Average Ec/No (dB), 1500Hz ILPC	Gain in Average Ec/No (dB), 750Hz ILPC
PA3	2.0897	1.8899	2.339047	2.310301
PB3	2.342	2.3751	2.450368	2.512044
VA30	2.2696	2.2998	2.5023	2.54951
VA120	2.3718	2.4614	2.456392	2.54972

Table 9.4.4-2: Gains in Average Ec/No due of Solution 1 compared to legacy R99 for AMR 5.9k traffic

AMR 5.9	no SHO		SHO	
Channel Type	Gain in Average Ec/No (dB), 1500Hz ILPC	Gain in Average Ec/No (dB), 750Hz ILPC	Gain in Average Ec/No (dB), 1500Hz ILPC	Gain in Average Ec/No (dB), 750Hz ILPC
PA3	2.229076	2.036732	2.360793	2.316231
PB3	2.567704	2.614807	2.593719	2.658994
VA30	2.486812	2.52216	2.634028	2.687321
VA120	2.603401	2.691662	2.623237	2.717659

9.5 Uplink link evaluation results: Solution 2

This clause presents link evaluation of uplink DCH enhancements described in clause 8 (Solution 2).

In this clause, the simulation results for UL ET based on TFCI transmission are presented. The simulation results of Legacy R99 based on TFCI transmission are also presented for comparison.

Link performance of Legacy R99 and that of ET are presented in Table 9.5-1 and Table 9.5-2 for "single link" case, and in Table 9.5-3 and Table 9.5-4 for "two links SHO (soft handover)" case, respectively. The Ec/No benefit for ET against Legacy R99 is summarized in Table 9.5-5.

Table 9.5-1 - Link Performance for "single link" case of Legacy R99 based on TFCI transmission

Channel Type	Averaged Received Ecp/No of DPCCH (dB)	Averaged Received Ec/No (dB)	Averaged BLER	Averaged TPC CER
PA3	-20.4	-18.7	0.0104	0.0088
PB3	-22.1	-20.3	0.0102	0.0096
VA30	-22.0	-20.3	0.0104	0.0169
VA120	-22.0	-20.2	0.0102	0.0237

Table 9.5-2 - Link Performance for "single link" case of ET based on TFCI transmission

Channel Type	Averaged Received Ecp/No of DPCCH (dB)	Averaged Received Ec/No (dB)	Averaged BLER	Averaged TPC CER
PA3	-22.3	-20.6	0.0104	0.0096
PB3	-24.1	-22.3	0.0102	0.0107
VA30	-24.2	-22.4	0.0102	0.0194
VA120	-24.2	-22.5	0.0102	0.0275

Table 9.5-3 - Link Performance for "two links SHO" case of Legacy R99 based on TFCI transmission

Channel Type	Averaged Received Ecp/No of DPCCH (dB)	Averaged Received Ec/No (dB)	Averaged BLER	Averaged TPC CER
PA3	-23.4	-21.7	0.0102	0.0432
PB3	-23.3	-21.6	0.0102	0.0263
VA30	-23.1	-21.4	0.0105	0.0304
VA120	-22.9	-21.2	0.0100	0.0355

Table 9.5-4 - Link Performance for "two links SHO" case of ET based on TFCI transmission

Channel Type	Averaged Received Ecp/No of DPCCH (dB)	Averaged Received Ec/No (dB)	Averaged BLER	Averaged TPC CER
PA3	-25.0	-23.3	0.0107	0.0323
PB3	-25.3	-23.6	0.0109	0.0255
VA30	-25.3	-23.5	0.0105	0.0295
VA120	-25.0	-23.2	0.0102	0.0395

Table 9.5-5 - Link Performance of ET based on TFCI transmission

Ec/No benefit (dB)	PA3	PB3	VA30	VA120
Single link	1.9	2.0	2.1	2.3
Two links SHO	1.6	2.0	2.1	2.0

As seen in Table 9.5-5, the proposed ET scheme introduces 1.6dB to 2.3dB Ec/No gain depending on the fading channels and different link number.

Moreover, Figure 9.5-1 and Figure 9.5-2 show the early termination statistics for packet types "SID" and "FULL". From Figure 9.5-1, when receiver collects data of slot 0 ~ slot 6, it tries to decode the speech data, and the successful detection rate is around 0.1 for every channel model when the transmitted packet type is "SID". ACK is then transmitted for successful detection; otherwise NACK is sent. At slot 29, the accumulated successful detection rate is close to 0.99, which means BLER is close to 0.01. Comparing these two figures, it is found that if the packet size is smaller, early termination may happen earlier. Moreover, Table 9.5-6 provides the averaged required slots for successful early decoding. The average is over different channel models. UL is based on TFCI decoding. To realize early termination, TFCI early decoding is also necessary. To have reliable decoding result, TFCI decoding is performed after 7 slots are collected. Since there is no CRC for NULL, whenever TFCI results is NULL, NULL is claimed and early termination request is sent. Therefore, 7 slots are required for successful early decoding on packet type "NULL".

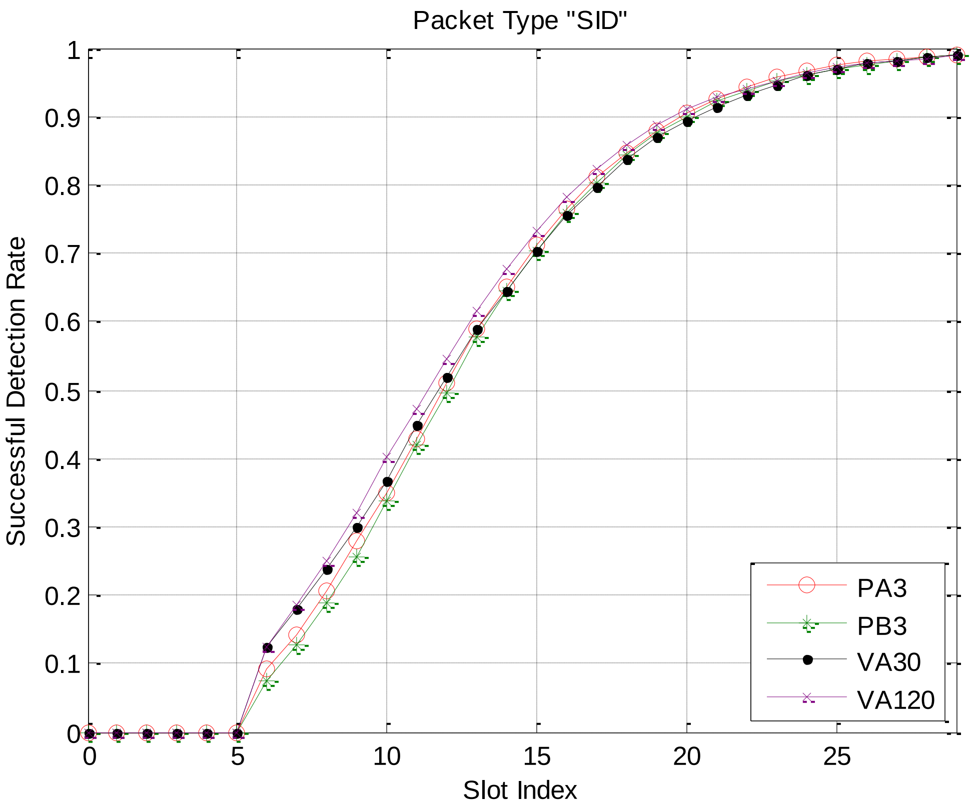


Figure 9.5-1 Early termination statistics for packet type "SID"

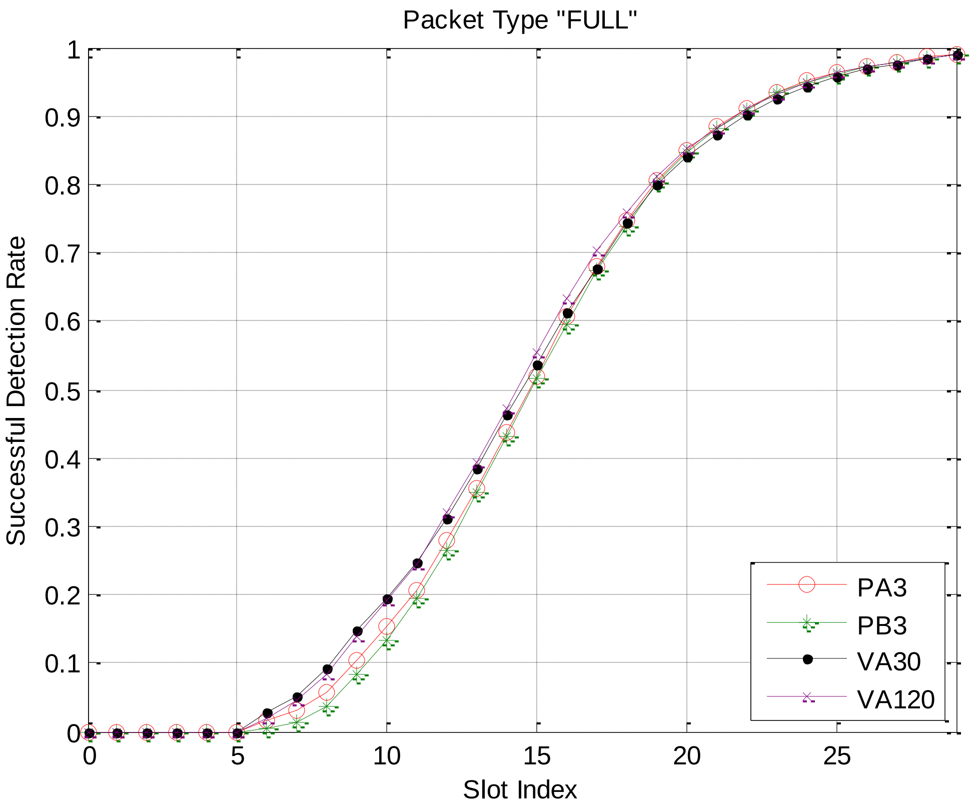


Figure 9.5-2 Early termination statistics for packet type "FULL"

Table 9.5-6 - Averaged required slots for successful early decoding

Packet Type	NULL	SID	FULL
Averaged required slots for successful early decoding	7	14.0	16.4

10 System evaluation results

10.1 System evaluation results: Downlink, Solutions 1 and 3

This clause presents system evaluation of downlink DCH enhancements described as 'Solution 1' and 'Solution 3' in clause 8.

10.1.1 Average cell throughput vs. number of voice users per cell

Here we show the performance of HSDPA BE UE performance under mixed CS voice and BE UE scenario. Both Solution 1 and Solution 3 are compared against R99, with throughput gain summarized in Table 10.1-1.

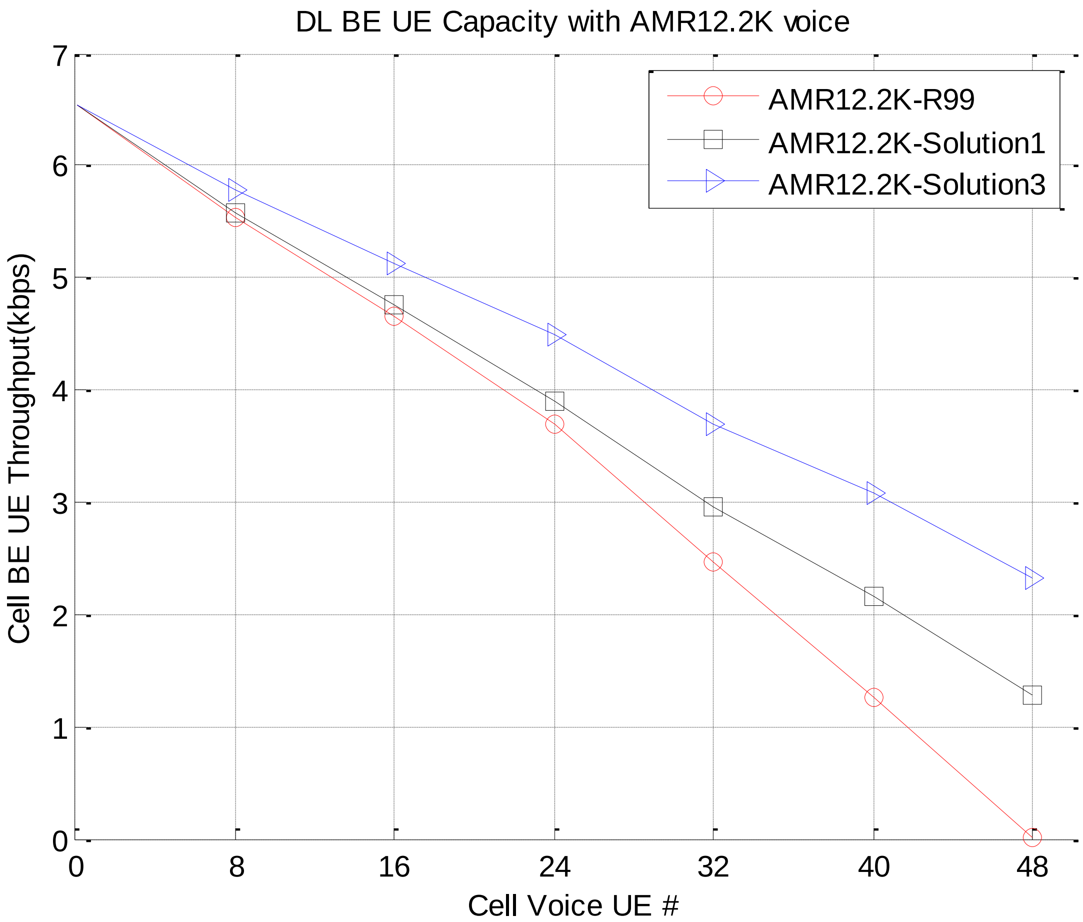


Figure 10.1-1: BE UE cell throughput with AMR 12.2 kbps CS voice UE, PA3

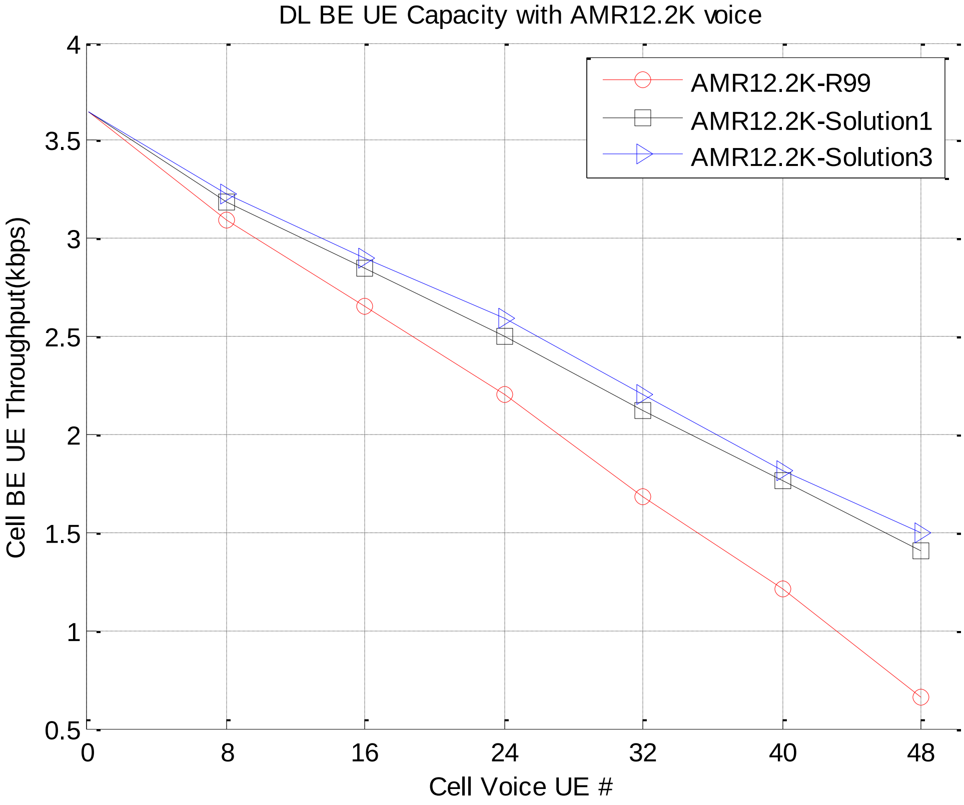


Figure 10.1-2: BE UE cell throughput with AMR 12.2 kbps CS voice UE, VA30

Table 10.1-1: BE UE Throughput Gain Summary

Voice UE #	PedA 3km/h		VehA 30km/h	
	Solution 1	Solution3	Solution 1	Solution3
8	0.58%	4.28%	3.02%	4.42%
16	2.22%	9.81%	7.37%	9.24%
24	5.79%	21.62%	13.42%	17.27%
32	20.47%	50.34%	25.73%	30.67%
40	71.10%	144.16%	45.97%	50.55%
48	Inf	Inf	111.61%	126.86%

10.1.2 Average Tx Ec/Ior per cell used by CS voice and BE users

Voice users Tx Ec/Ior is listed in in Table 10.1-2, for R99, DCH Enhancement Solution 1 and Solution 3.

The averaged Tx Ec/Ior per cell used by HSDPA is decreasing with more voice users, as shown in Table 10.1-2. And with more DCH enhancement voice users, the relative gain for the HSDPA Tx Ec/Ior is increasing, due to more available power left to transmit HSDPA data. This explains that DCH enhancement can effectively bring up the HSDPA BE UE throughput, as indicated by Table 10.1-1.

Table 10.1-2: Voice User Tx Ec/Ior

Voice UE #	PA3			VA30		
	R99	Solution 1	Solution 3	R99	Solution 1	Solution 3
8	13.75%	9.90%	7.02%	11.51%	6.99%	6.04%
16	26.12%	18.77%	13.51%	22.14%	13.42%	11.48%
24	38.96%	27.96%	20.01%	32.65%	19.73%	16.91%
32	54.52%	38.75%	27.89%	45.60%	27.47%	22.34%
40	67.66%	47.67%	34.20%	56.39%	33.93%	27.77%
48	80.00%	58.77%	41.21%	67.70%	40.77%	33.20%

Table 10.1-3: BE User Tx Ec/Ior

Voice UE #	PA3			VA30		
	R99	Solution 1	Solution 3	R99	Solution 1	Solution 3
8	65.95%	69.05%	72.93%	68.33%	72.50%	73.76%
16	53.39%	59.53%	65.86%	57.59%	65.74%	68.20%
24	40.38%	49.78%	59.13%	46.98%	59.14%	62.64%
32	24.70%	38.47%	50.99%	33.92%	51.13%	57.08%
40	11.61%	29.27%	44.57%	23.05%	44.49%	51.52%
48	0.00%	18.01%	37.37%	11.66%	37.43%	45.95%

10.1.3 Percentages of voice users with active set size of 1,2,3

Table 10.1-4 shows the statistics of the active set sizes for different numbers of voice users.

Table 10.1-4: Active set size statistics

Active Set Size #		1	2	3
Voice UE #	8	54.90%	24.93%	20.18%
	16	55.44%	24.65%	19.91%
	24	55.36%	25.25%	19.39%
	32	55.95%	24.93%	19.13%
	40	55.54%	25.36%	19.10%
	48	55.33%	25.54%	19.13%

10.1.4 Percentage of voice users with BLER > 3%

The outage performance is defined as the percentage of voice users with BLER over 3%. It is observed that for both R99 and DCH Enhancement, the outage is limited, except that for R99 with 48 voice UEs where voice power reaches the upper bound of available Ec/Ior. For VA30, the outage was not detectable.

Table 10.1-5: Outage User Percentage

Voice UE #	PA3			VA30		
	R99	Solution 1	Solution 3	R99	Solution 1	Solution 3
8	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
16	0.00%	0.11%	1.10%	0.00%	0.00%	0.00%
24	0.07%	0.07%	0.73%	0.00%	0.00%	0.00%
32	0.11%	0.11%	0.77%	0.00%	0.00%	0.00%
40	0.13%	0.31%	1.23%	0.00%	0.00%	0.00%
48	97.88%	1.43%	0.80%	0.00%	0.00%	0.00%

10.2 System evaluation results: Downlink, Solutions 2 and 4

This clause presents system evaluation of downlink DCH enhancements described as 'Solution 2' and 'Solution 4' in clause 8. For better understanding, "E-WCDMA with TDM" stands for "Solution 2" and "E-WCDMA" stands for "Solution 4" in this clause. Based on the simulation settings listed in clause 8, the percentage of voice users with active set size of 1, 2 and 3 is listed in Table 10.2-1.

Table 10.2-1: Percentage of voice users with active set size of 1, 2 and 3

Active Set Size	Percentage (%)
1	54.17
2	25.29
3	20.54

Figure 10.2-1 and Figure 10.2-2 show the results of average cell throughput with different numbers of voice users per cell for legacy R99 system, E-WCDMA and E-WCDMA with TDM. The calculation of HSDPA throughput is based on the simplified simulation methodology for HSPA throughput model in clause 8. As seen in the figures, the HSDPA throughput of E-WCDMA with TDM is highest when the number of voice users per cell is larger than eight.

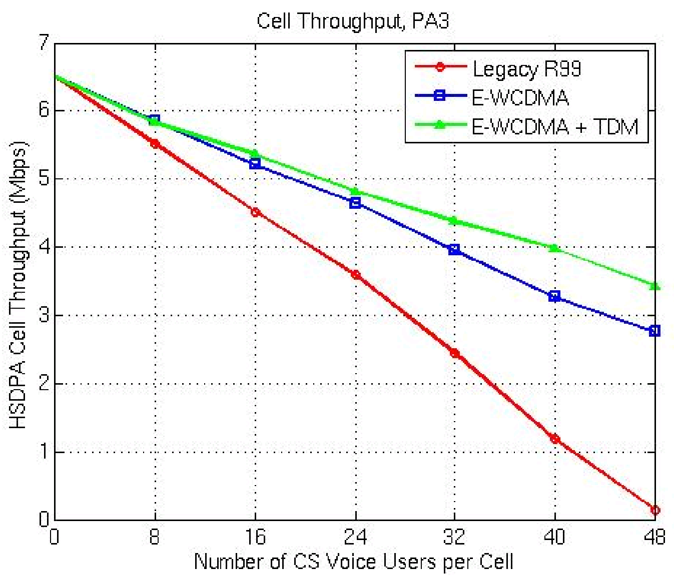


Figure 10.2-1: HSDPA throughput v.s. Number of voice users per cell for legacy R99, E-WCDMA and E-WCDMA with TDM in PA3

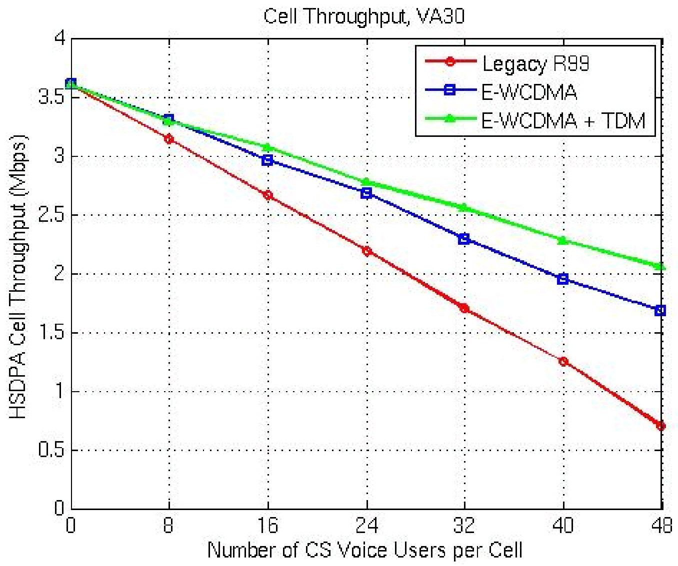


Figure 10.2-2: HSDPA throughput v.s. Number of voice users per cell for legacy R99, E-WCDMA and E-WCDMA with TDM in VA30

Table 10.2-2: BE UE throughput gain summary

Voice UE #	PedA 3km/h		VehA 30km/h	
	E-WCDMA	E-WCDMA with TDM	E-WCDMA	E-WCDMA with TDM
8	6.21%	5.88%	5.19%	4.74%
16	15.31%	18.65%	11.61%	15.41%
24	29.48%	34.37%	22.41%	26.50%
32	61.56%	79.29%	34.08%	49.65%
40	176.41%	236.54%	56.17%	82.34%
48	1828.30%	2299.64%	139.43%	192.47%

The Tx Ec/Ior per cell used by voice users in PA3 and VA30 are shown in Figure 10.2-3 and Figure 10.2-4. As seen in the figures, there is a loss in Tx Ec/Ior used by voice users in E-WCDMA with TDM when compared with those of E-WCDMA. However, Table 10.2-3 presents that more SF-16 codes can be saved for HSDPA when TDM is introduced. Due to more effective usage of code resouce, the throughput in E-WCDMA with TDM is higher when the number of voice users per cell is lager than eight.

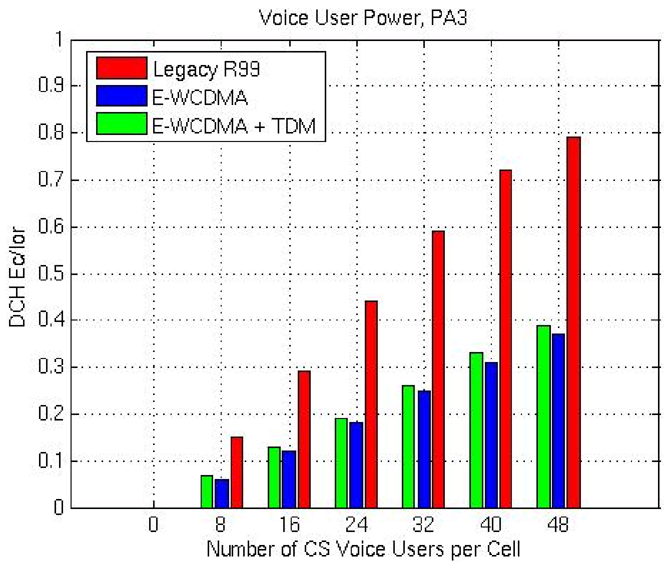


Figure 10.2-3: Tx Ec/Ior per cell used by voice users in PA3

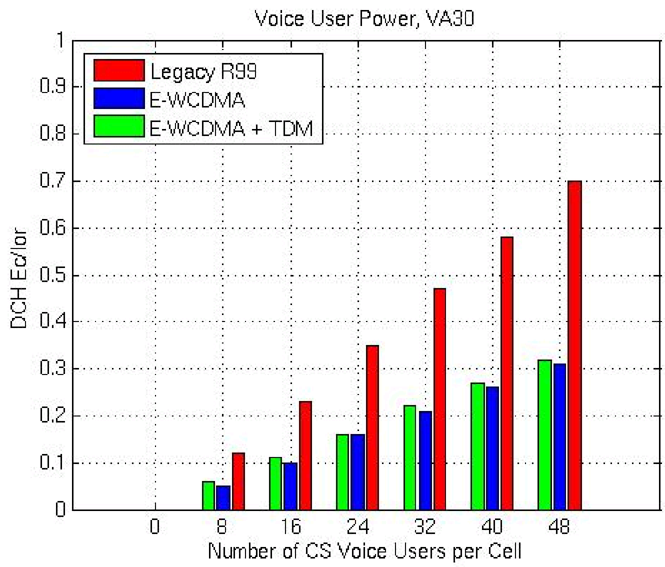


Figure 10.2-4: Tx Ec/Ior per cell used by voice users in VA30

Table 10.2-3: Available SF-16 OVSF code for HSDPA

Number of voice users per cell	E-WCDMA	E-WCDMA with TDM
	PA3 / VA30	PA3 / VA30
8	13	13
16	11	12
24	10	11
32	8	10
40	7	9
48	50 available SF-16 OVSF code for HSDPAuser	8

In addition, the percentage of voice users with BLER larger than 3% is also provded in Table 10.2-4.
It can be observed from the table, compared with legacy R99, the outage performance is much better in E-WCDMA with TDM when the number of voice users per cell is large.

Table 10.2-4: Outage performance for voice users

Fader Models	Number of voice users per cell	8	16	24	32	40	48
PA3	Legacy R99	0.07%	0.00%	0.00%	0.11%	2.12%	23.17%
	E-WCDMA	0.00%	0.00%	0.10%	0.00%	0.00%	0.01%
	E-WCDMA+ TDM	0.00%	0.07%	0.02%	0.07%	0.12%	0.02%
VA30	Legacy R99	0.00%	0.00%	0.00%	0.00%	0.00%	0.04%
	E-WCDMA	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	E-WCDMA+ TDM	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

The power reduction gain of average power used by voice users is listed in Table 10.2-5. Compared with legacy R99, the average power reduction gains in E-WCDMA are 3.66 dB and 3.60 dB for PA3 and VA30, respectively. And in E-WCDMA with TDM, the gains are 3.41 dB and 3.32 dB for PA3 and VA30, respectively.

Table 10.2-5: Power reduction gain of average power used by voice users in E-WCDMA and E-WCDMA with TDM

Power Reduction Gains (dB)				
Number of voice users per cell	E-WCDMA		E-WCDMA with TDM	
	PA3	VA30	PA3	VA30
8	3.72	3.87	3.42	3.42
16	3.81	3.63	3.39	3.21
24	3.80	3.50	3.57	3.36
32	3.72	3.51	3.65	3.33
40	3.64	3.56	3.41	3.29
48	3.27	3.51	3.04	3.32

10.3 System evaluation results: Downlink, others

In addition to complete "Solution 1" ~ "Solution 4", some features are simulated alone to make the report more comprehensive.

10.3.1 Simulations results for Pilot-Free slot format as described in clause 4.2.2.2 without FET

This clause shows the system level simulation results on the average cell throughput and average power per cell used by voice users for the new slot format #17, compared with those of legacy slot format #8. The simulation settings are listed in clause 8.

Based on the simulation settings listed in clause 8, the percentage of voice users with active set size of 1, 2 and 3 is listed in Table 10.3-1.

Table 10.3-1: Percentage of voice users with active set size of 1, 2 and 3

Active Set Size	Percentage (%)
1	54.17
2	25.29
3	20.54

Figure 10.3-1 and Figure 10.3-2 show the CDF of the run-lengths of consecutive voice packet errors for legacy slot format #8 and new slot format #17 in different numbers of voice users per cell and channel fadings, respectively. As seen in the figures, the run-lengths of consecutive voice packet errors are short in all cases. In both slot format #8 and slot format #17, the probability of single voice packet error is larger than 85%.

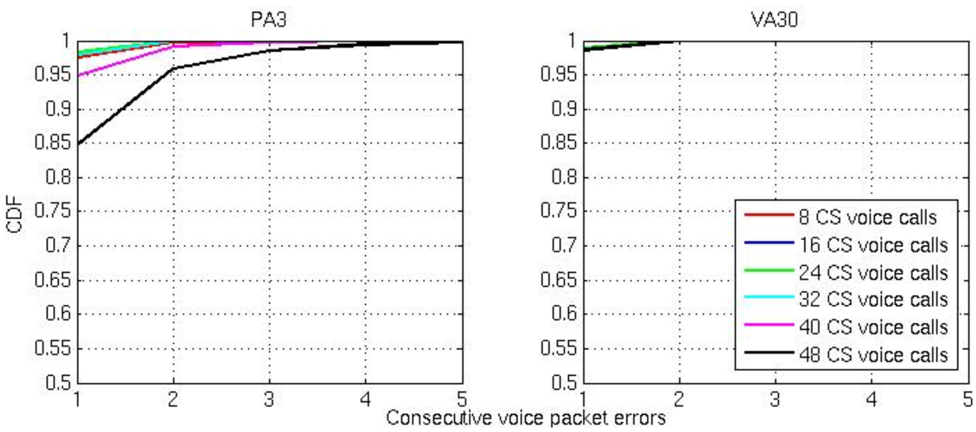


Figure 10.3-1: CDF of the run-lengths of consecutive voice packet errors for slot format #8

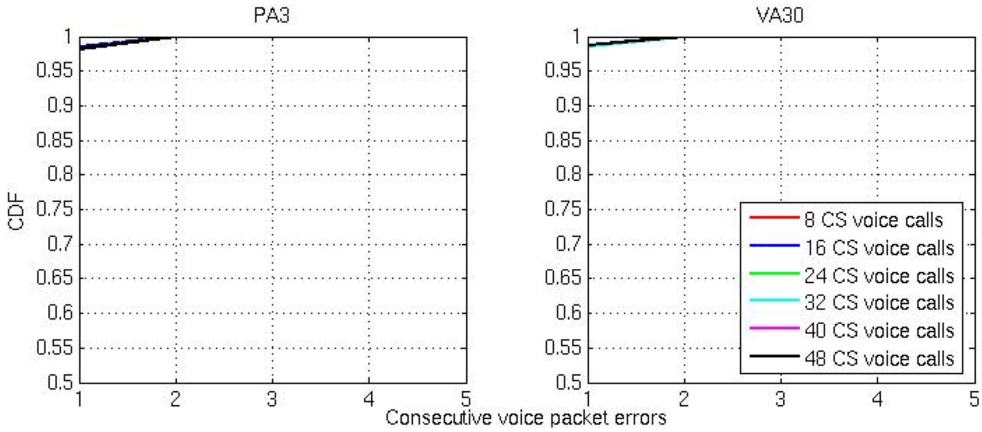


Figure 10.3-2: CDF of the run-lengths of consecutive voice packet errors for slot format #17

Figure 10.3-3 and Figure 10.3-4 show the results of average cell throughput with different numbers of voice users per cell for slot format #8 and slot format #17, respectively. The calculation of HSDPA throughput is based on the simplified simulation methodology for HSPA throughput model in clause 8. The HSDPA cell throughput is larger if slot format #17 is used by voice users.

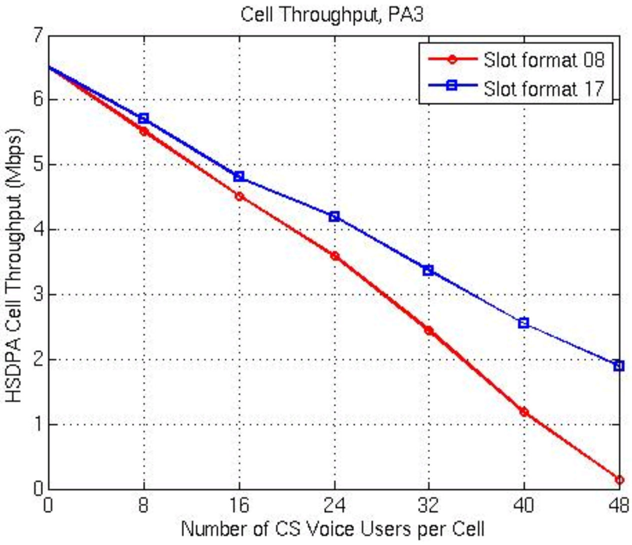


Figure 10.3-3: HSDPA throughput v.s. Number of voice users per cell for slot format #8 and #17 in PA3

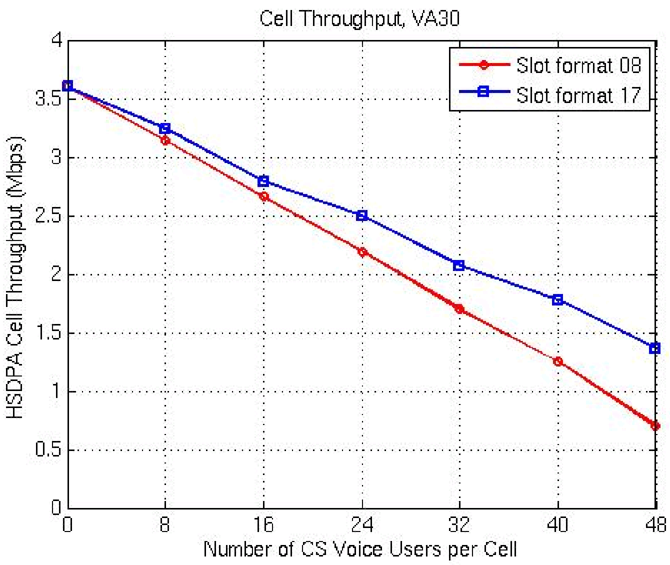


Figure 10.3-4: HSDPA throughput v.s. Number of voice users per cell for slot format #8 and #17 in VA30

In addition, the Tx Ec/Ior per cell used by voice users in PA3 and VA30 are presented in Figure 10.3-5 and Figure 10.3-6. As seen in the figures, the required Tx Ec/Ior for voice users is reduced due to slot format #17.

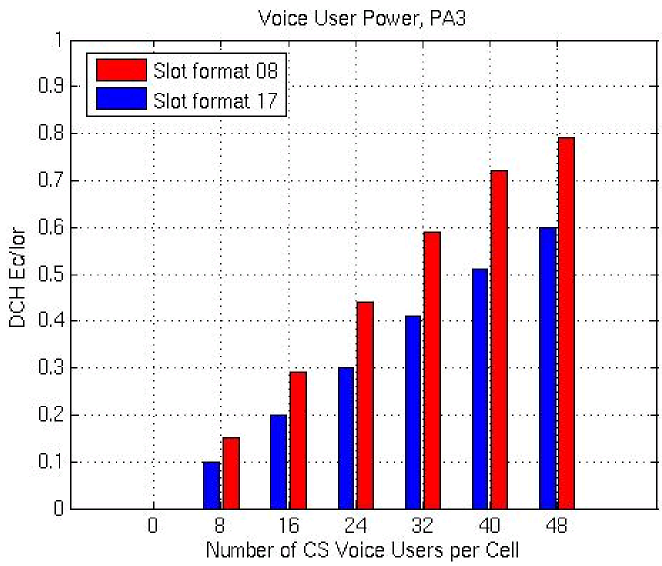


Figure 10.3-5: Tx Ec/Ior per cell used by voice users in PA3

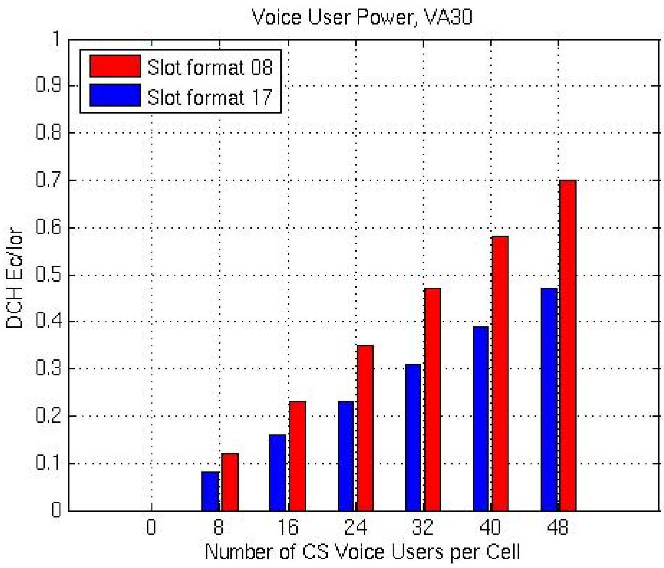


Figure 10.3-6: Tx Ec/Ior per cell used by voice users in VA30

The percentage of voice users with BLER larger than 3% is provided in Table 10.3-2. It's obvious that the outage performance is better when slot format #17 is used.

Table 10.3-2: Outage performance for voice users

Fader Models	Number of voice users per cell	8	16	24	32	40	48
PA3	Slot format #08	0.07%	0.00%	0.00%	0.11%	2.12%	23.17%
	Slot format #17	0.07%	0.00%	0.02%	0.00%	0.01%	0.02%
VA30	Slot format #08	0.00%	0.00%	0.00%	0.00%	0.00%	0.04%
	Slot format #07	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

The power reduction gain of average power used by voice users is listed in Table 10.3-3. As seen in the table, compared with slot format #8, the average power reduction gains due to slot format #17 are 1.57 dB and 1.77 dB for PA3 and VA30, respectively.

Table 10.3-3: Power reduction gain of average power used by voice users in slot format #17

Power Reduction Gains (dB)		
Number of voice users per cell	Fader Model	
	PA3	VA30
8	1.74	1.91
16	1.69	1.74
24	1.69	1.80
32	1.62	1.71
40	1.52	1.73
48	1.18	1.73

10.3.2 Simulation results for FET as described in clause 4.2.1.2 with Legacy DPCCH slot format

The system level simulation results of FET Option 2 based on Slot Format #8 are provided.

Figure 10.3-7 and Figure 10.3-8 show the CDF of the run-lengths of consecutive voice packet errors for Legacy R99 and ET in different numbers of voice users per cell and channel fadings, respectively. Legacy R99 and ET both use Slot Format #8. As seen in the figures, the run-lengths of consecutive voice packet errors are short in all cases. The probability of single voice packet error is larger than 85%.

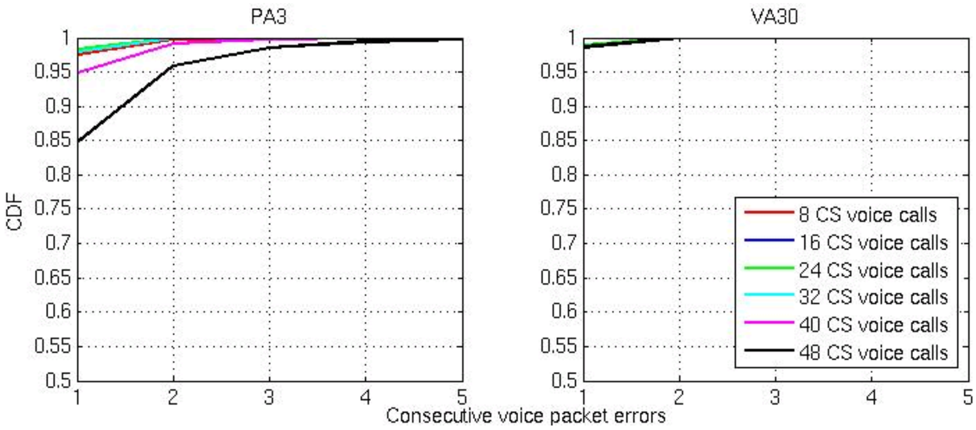


Figure 10.3-7: CDF of the run-lengths of consecutive voice packet errors for Legacy R99 with "Slot Format #8"

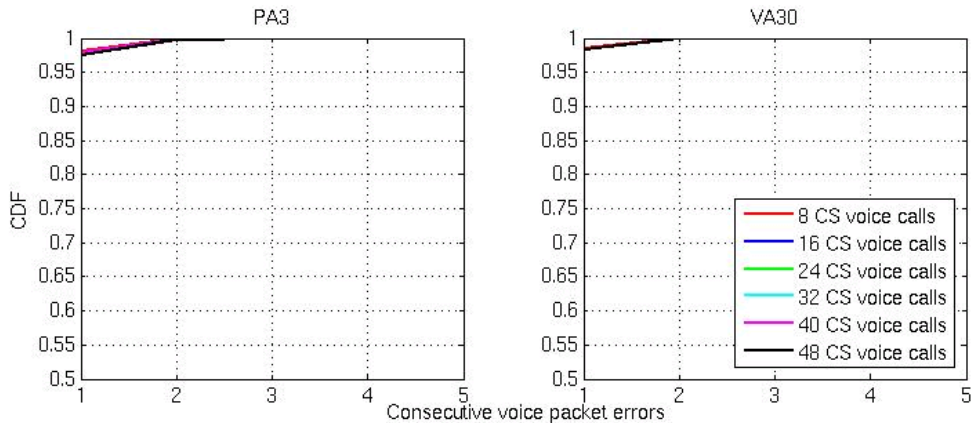


Figure 10.3-8: CDF of the run-lengths of consecutive voice packet errors for ET with "Slot Format #8"

Figure 10.3-9 and Figure 10.3-10 show the results of average cell throughput with different numbers of voice users per cell. The calculation of HSDPA throughput is based on the simplified simulation methodology for HSPA throughput model in clause 8. The HSDPA throughput is higher when ET with "Slot Format #8" is introduced.

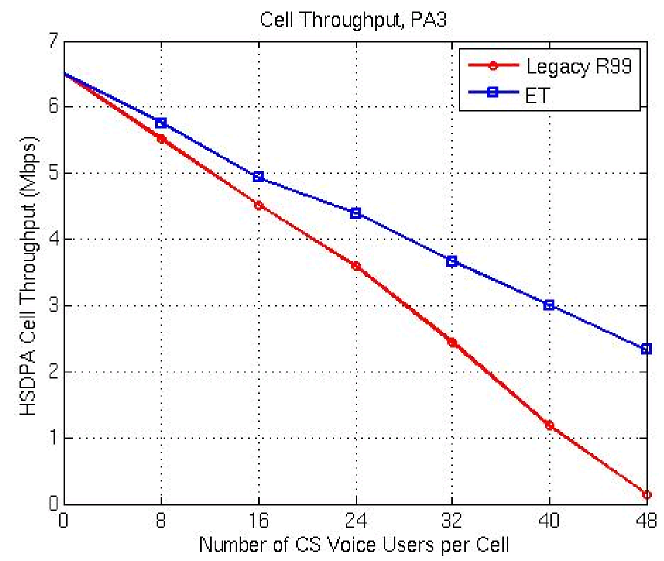


Figure 10.3-9: HSDPA throughput v.s. Number of voice users per cell in PA3

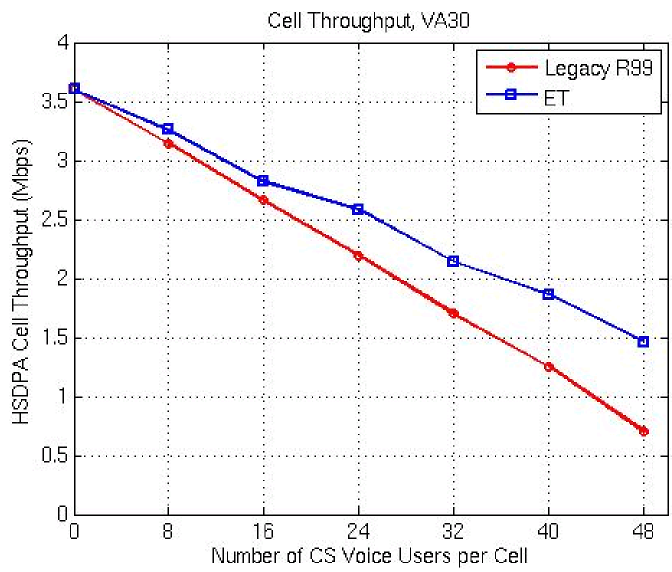


Figure 10.3-10: HSDPA throughput v.s. Number of voice users per cell in VA30

In Figure 10.3-11 and Figure 10.3-12, the Tx Ec/Ior per cell used by voice users in PA3 and VA30 are illustrated. From the figures, it's clear that the required Tx Ec/Ior for voice users is reduced when ET with "Slot Format #8" is used.

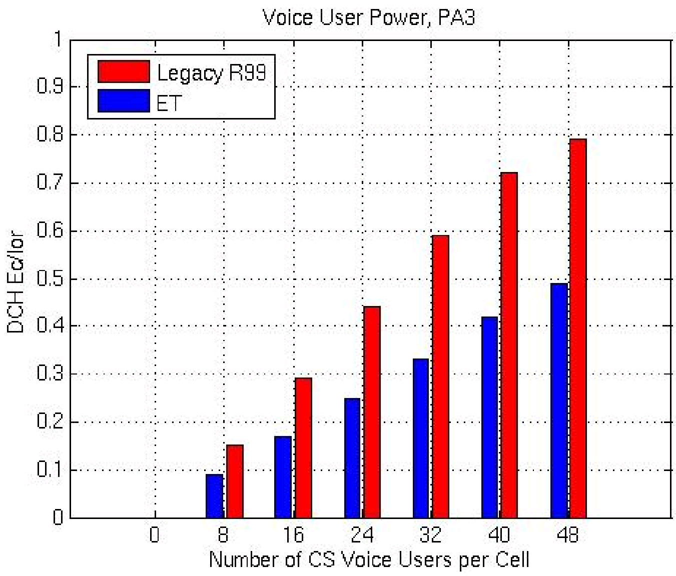


Figure 10.3-11: Tx Ec/Ior per cell used by voice users in PA3

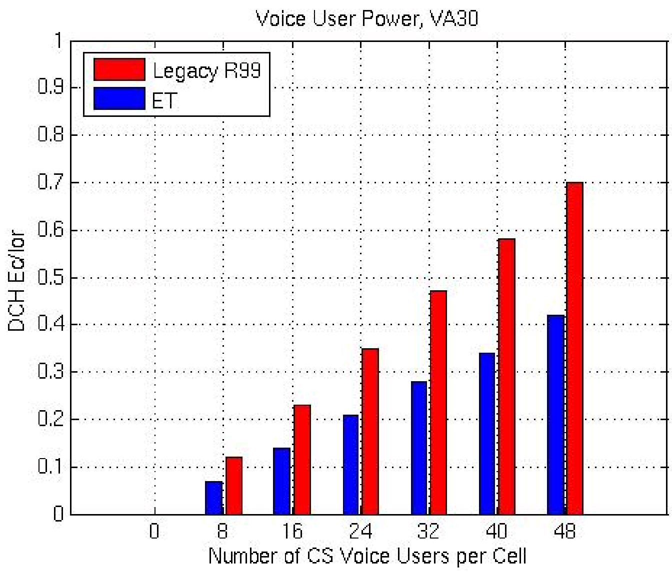


Figure 10.3-12: Tx Ec/Ior per cell used by voice users in VA30

The percentage of voice users with BLER larger than 3% is provided in Table 10.3-4. It can be observed that the outage performance is better in ET with "Slot Format #8".

Table 10.3-4: Outage performance for voice users

Fader Models	Number of voice users per cell	8	16	24	32	40	48
PA3	Legacy R99	0.07%	0.00%	0.00%	0.11%	2.12%	23.17%
	Early termination	0.15%	0.04%	0.15%	0.05%	0.09%	0.15%
VA30	Legacy R99	0.00%	0.00%	0.00%	0.00%	0.00%	0.04%
	Early termination	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

The power reduction gain of average power used by voice users is listed in Table 10.3-5. Compared with Legacy R99 with "Slot Format #8", the average power reduction gains are 2.37 dB and 2.28 dB for PA3 and VA30 in ET with "Slot Format #8", respectively.

Table 10.3-5: Power reduction gain of average power used by voice users for ET with "Slot Format #8"

Power Reduction Gains (dB)		
Number of voice users per cell	Fader Model	
	PA3	VA30
8	2.40	2.30
16	2.44	2.30
24	2.45	2.35
32	2.52	2.24
40	2.38	2.29
48	2.05	2.19

10.4 System evaluation results: Uplink, Solution 1

This clause presents system evaluation of uplink DCH enhancements described as ‘Solution 1' in clause 8.

10.4.1 Average cell throughput vs. number of voice users per cell

Figures 10.4-1, 10.4-2 provide system performance results for HSUPA BE UE throughput, with given number of R99 CS voice UEs or DCH Enhancement CS voice UEs. There is a significant increase in the BE UE throughput with DCH Enhancement voice, as compared with legacy R99 voice. Throughput gain are summarized in Table 10.4-1.

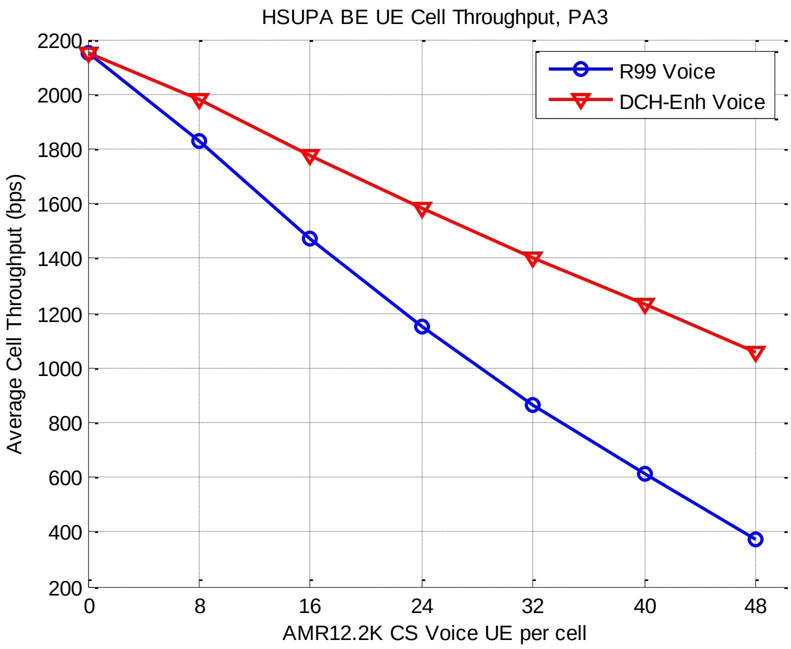


Figure 10.4-1: HSUPA cell throughput with AMR12.2K CS voice, PA3

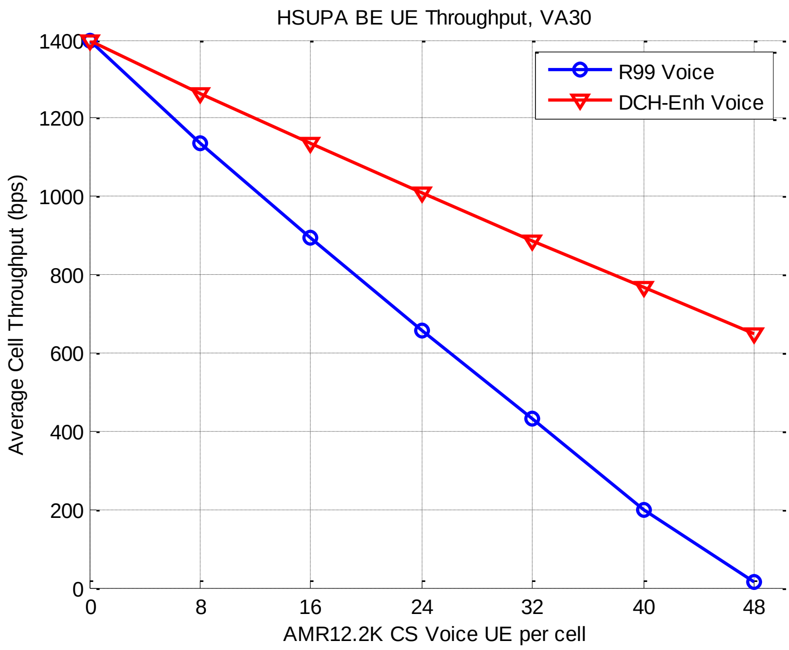


Figure 10.4-2: HSUPA cell throughput with AMR12.2K CS voice, VA30

Table 10.4-1: Throughput Gain Summary – AMR 12.2 kbps voice

Voice UE Number	8	16	24	32	40	48
PA3	8.30%	20.72%	38.12%	61.66%	100.56%	182.57%
VA30	11.04%	27.11%	53.53%	104.92%	283.02%	4420.30%

10.4.2 Average Ec/No per cell used by voice and BE UE

Table 10.4-2 is showing the reduction of Ec/No of CS voice users due to DCH Enhancement.

It is observed that the BE UE Ec/No goes down linear with increasing number of CS voice UE(shown in Table 10.4-3), which fills up the RoT. With the reduction of required Ec/No, DCH enhancement can allow more Ec/No used by HSUPA BE UE. The gain on BE UE Ec/No is increasing more with more DCH enhancement voice users available in the system, which was indicated in Table 10.4-1.

Table 10.4-2: Voice User Ec/No

	PA3		VA30	
Voice UE #	R99	DCH-Enh	R99	DCH-Enh
8	0.34	0.19	0.43	0.22
16	0.68	0.38	0.85	0.43
24	1.03	0.57	1.29	0.65
32	1.37	0.76	1.71	0.87
40	1.72	0.95	2.14	1.09
48	2.08	1.14	2.65	1.30

Table 10.4-3: BE User Ec/No

	PA3		VA30	
Voice UE #	R99	DCH-Enh	R99	DCH-Enh
0	2.93	2.93	2.94	2.94
8	2.60	2.75	2.52	2.73
16	2.27	2.57	2.10	2.52
24	1.92	2.38	1.67	2.30
32	1.59	2.19	1.24	2.09
40	1.24	2.01	0.80	1.87
48	0.88	1.82	0.41	1.65

10.4.3 Percentages of voice users with active set size of 1, 2, 3

Table 10.4-4 shows the statistics of the active set sizes for different numbers of voice users.

Table 10.4-4: Active set size statistics

Active Set Size #		1	2	3
Voice UE #	8	51.97%	25.88%	22.15%
	16	52.96%	25.66%	21.38%
	24	53.58%	26.02%	20.39%
	32	53.45%	27.19%	19.35%
	40	53.68%	26.89%	19.43%
	48	54.31%	26.17%	19.52%

10.4.4 Percentage of voice users with BLER > 3%

Voice outage is an important metric that have impact on voice call quality and user experience. For all cases (PA3 and VA30 channel, R99 and DCH-Enhancement configuration), no voice users with BLER>3% were observed in the system simulations.

10.5 System evaluation results: Uplink, Solution 2

This clause presents system evaluation of uplink DCH enhancements described as 'Solution 2' in clause 8.Based on the simulation settings listed in clause 8, the percentage of voice users with active set size of 1, 2 and 3 is listed in Table 10.5-1.

Table 10.5-1: Percentage of voice users with active set size of 1, 2 and 3

Active Set Size	Percentage (%)
1	54.61
2	25.67
3	19.72

Figure 10.5-1 and Figure 10.5-2 show the CDF of the run-lengths of consecutive voice packet errors for Legacy R99 and ET in different numbers of voice users per cell and channel fadings, respectively. As seen in the figures, the run-lengths of consecutive voice packet errors are short in all cases. In both Legacy R99 and ET, the probability of single voice packet error is higher than 95%.

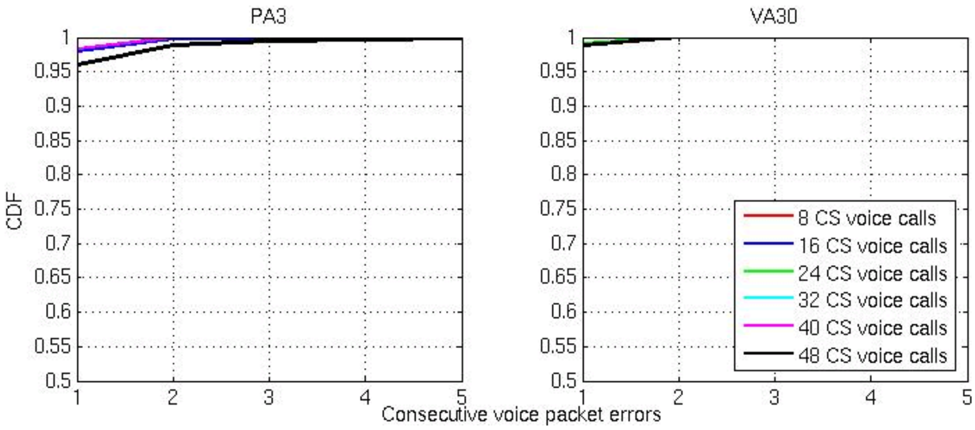


Figure 10.5-1: CDF of the run-lengths of consecutive voice packet errors for legacy R99

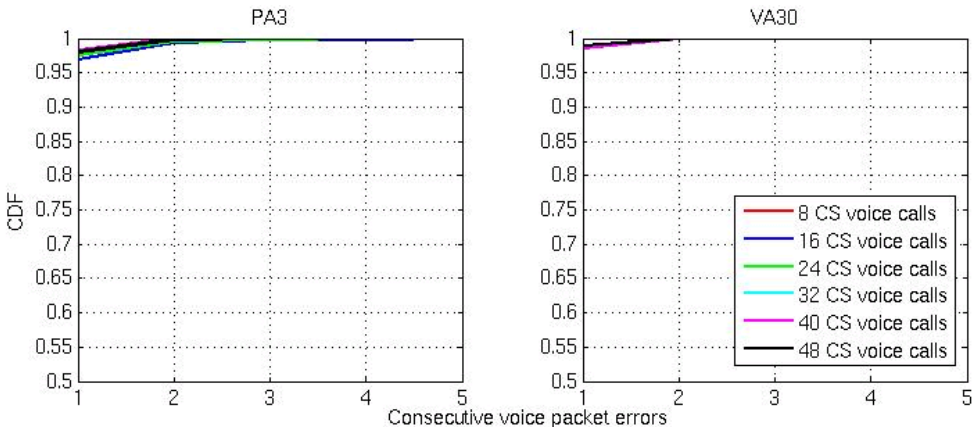


Figure 10.5-2: CDF of the run-lengths of consecutive voice packet errors for early termination

Figure 10.5-3 and Figure 10.5-4 show the results of average cell throughput with different numbers of voice users per cell. The calculation of HSUPA throughput is based on the simplified simulation methodology for HSPA throughput model in clause 8. The HSUPA throughput is higher when ET is introduced.

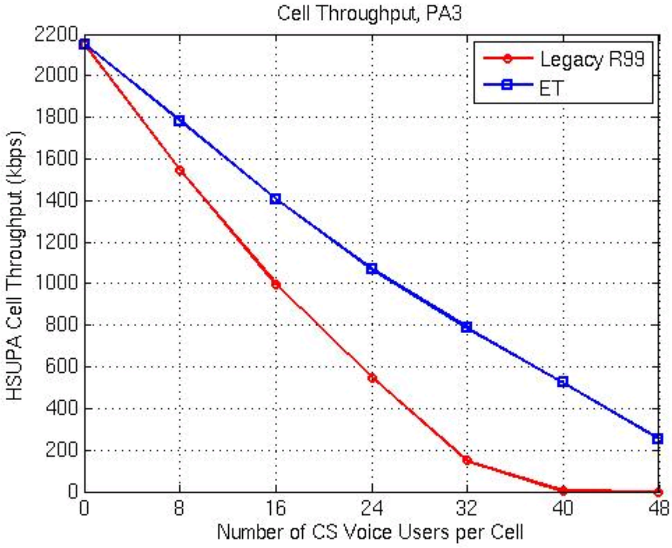


Figure 10.5-3: HSUPA throughput v.s. Number of voice users per cell in PA3

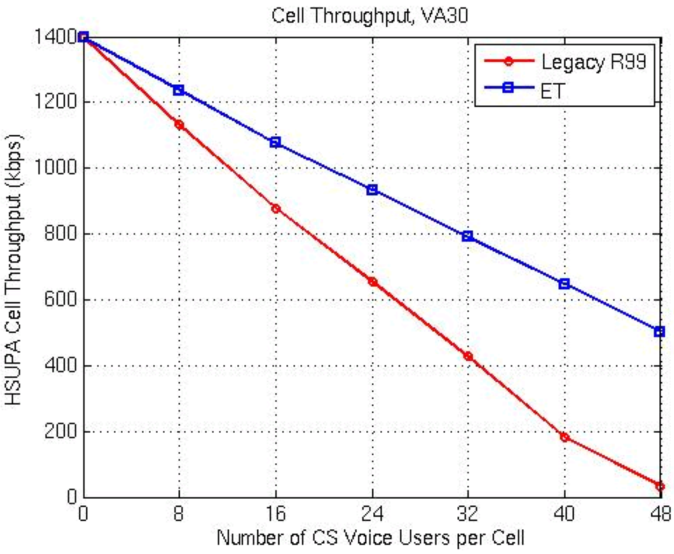


Figure 10.5-4: HSUPA throughput v.s. Number of voice users per cell in VA30

In Figure 10.5-5 and Figure 10.5-6, the average RxEc/No per cell used by voice users are presented for PA3 and VA30, respectively. It's obvious that the required RxEc/No for voice users is significantly reduced by applying ET.

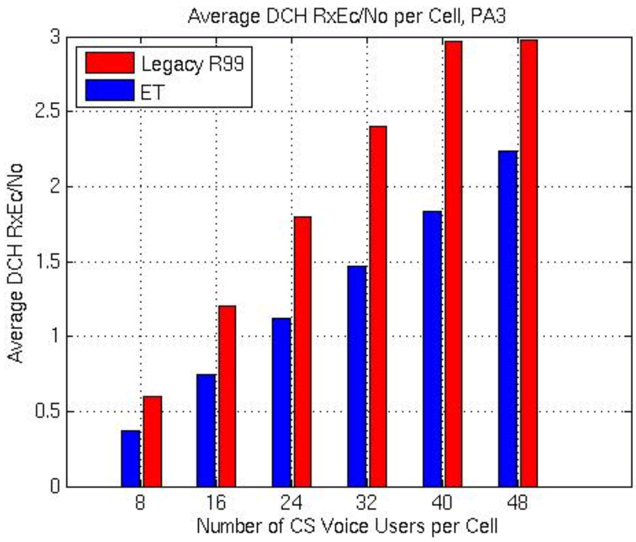


Figure 10.5-5: Average RxEc/No per cell used by voice users in PA3

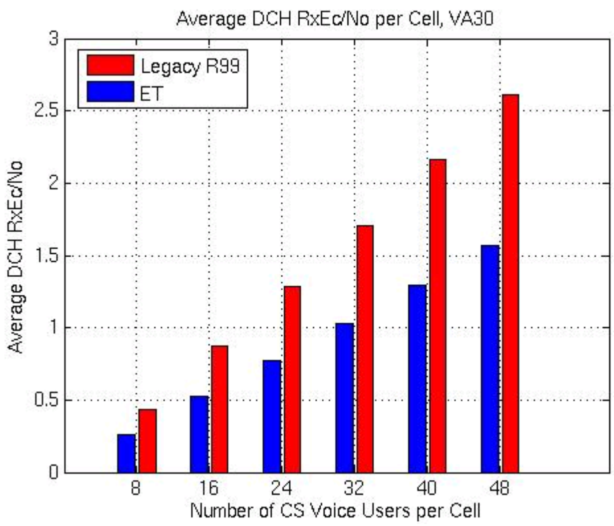


Figure 10.5-6: Average RxEc/No per cell used by voice users in VA30

The percentage of voice users with BLER larger than 3% is provided in Table 10.5-2. It can be observed that the outage percentages are less than 0.7% in all cases.

Table 10.5-2: Outage performance for voice users

Fader Models	Number of voice users per cell	8	16	24	32	40	48
PA3	Legacy R99	0.22%	0.15%	0.05%	0.07%	0.15%	0.63%
	Early termination	0.15%	0.26%	0.32%	0.09%	0.15%	0.18%
VA30	Legacy R99	0.00%	0.00%	0.00%	0.05%	0.03%	0.00%
	Early termination	0.07%	0.04%	0.02%	0.00%	0.04%	0.04%

The average RxEc/No reduction gain is listed in Table 10.5-3. Compared with Legacy R99, the average RxEc/No reduction gains are 1.96 dB and 2.22 dB for PA3 and VA30 in ET, respectively.

Table 10.5-3: Average RxEc/No reduction gain for early termination in PA3 and VA30

Rx Ec/No Reduction Gains (dB)		
Number of voice users per cell	Fader Model	
	PA3	VA30
8	2.12	2.27
16	2.10	2.20
24	2.07	2.20
32	2.14	2.20
40	2.08	2.23
48	1.24	2.21

11 Impact on implementation

In this clause, the required changes and associated complexity to implement the proposed DCH enhancements are discussed.

11.1 Impact on infrastructure implementation

The proposed DCH enhancements require a number of modifications on the part of network in DL and UL that are itemized and discussed in this clause.

11.1.1 New DL DPCH Slot Formats

The DL DPCH Slot Format is specified with parameters N_{data1}, N_{TPC}, N_{TFCI}, N_{data2}, N_{pilot}. DL DPCH slot format modifications require changes to the values specified for these parameters. For example, pilot free slot format corresponds to setting $N_{pilot} = 0$, similar to $N_{TFCI} = 0$ in BTFD.

TDM of users also requires changes in constructing slot formats for users. For example, in clause 4.2.4.1 TDM option 1 for user pairing using 10ms TTI, two users share TPC fields in the slot format.

11.1.2 New UL Slot Formats

In UL, proposed DCH enhancements require reconfiguration of N_{data}, N_{TPC}, N_{TFCI}, N_{pilot} like DL.

In addition, to maintain the ILPC timeline, two solutions are proposed in this study. One described in clause 4.2.2.2 is to reconfigure DL slot format such that TPC fields occupy the position of dedicated pilots in legacy slot format. In another solution described in 4.1.1.1, position of TPC fields in UL DPCCH slot format is changed to the beginning of the slot, instead of the end where TPC fields are located in legacy slot format.

11.1.3 Rate Matching and Multiplexing

The encoding and decoding chains need to be modified to introduce changes to multiplexing and rate matching as introduced in FET Option 2 in clause 4.1.1.2 and 4.2.1.2. The chain of blocks as shown in Figure 1 and Figure 2 in 3GPP TS 25.212 [4] are modified. In DL and UL, the order and mechanisms for multiplexing, encoding, rate matching, and interleaving are changed.

11.1.4 FET ACK indication

11.1.4.1 I-Q multiplexed with the TPC symbols

The main modification is to multiplex TPC bit and ACK bit together.

11.1.4.2 ACK on a new code channel

This is to introduce a new channel to carry ACK signaling for FET. Implementation impact is to possibly allocate a new channelization code in DL, and all associated implementations of slot formats, radio frame construction and data encoding, along with power control mechanisms if the new channel is a shared channel.

11.1.4.3 ACK using spared TPC symbols

The main modification is to transmit TPC bits every alternate slots. In addition, the freed TPC fields every alternate slot are possibly used for ACK signaling, as for example in Solution 2. This solution requires modification of TPC rate and hence changes to ILPC timeline and possible SINR estimation algorithms.

11.1.5 UL FET-DPCCH

For the new channel, Node-B needs to implement a new channel to carry UL FET control information such as TFCI and ACK.

11.1.6 New shared DCH channel for SRB over DCH

Shared DCH is a new channel designed based on legacy DCH. Implementation impact is to allocate a new channelization code in DL, and all associated implementations of slot formats, radio frame construction and data encoding, along with handling power control for the shared channel, and software modifications to signal user ID in control fields of shared DCH.

11.1.7 Frame early termination

Frame early termination requires changes in decoding chain, transmitting and decoding ACK signals on DL and UL, respectively, and DL transceiver termination in response to successful early decoding or receiving ACK signaled on UL.

The decoding chain modifications require multiple trials of decoding the transmitted packet, before the entire TTI worth of data is received. The decoder simply assumes no information is available for unseen portion of the TTI and attempts demultiplexing and decoding of the encoded frame. The main complexity in decoding the packet are in sampling, match filtering, equalization or rake combining, and Viterbi decoding. Complexity in sampling, match filtering, and rake or equalizer processing remain unchanged to enable multiple decoding attempts. Demultiplexing needs to be repeated multiple times, however, the complexity of demultiplexing and de-rate-matching is not considered to be significant.

Aside from symbol processing, Viterbi decoding is the other contributor to complexity. However, since the packet sizes are relatively small in AMR 12.2k, the code length in the worst case of FULL packet is less than 1000 bits. For such short packets, Viterbi decoding is of relatively low complexity, particularly in contrast to decoding larger packet sizes or turbo decoding.

Signaling DL ACK for UL FET requires changes in Node-B to encode and transmit the ACK message. For example, the ACK message may be sent over spare TPC fields (as proposed in clause 4.2.3.3) or be I/Q multiplexed with TPC symbols (as proposed in clause 4.2.3.1). The ACK message on DL may also be sent over a separate DL channel (as proposed in clause 4.2.3.2). On the receive side, Node-B needs also to decode the UL ACK message.

Finally, FET requires the Node-B terminate transmission of DPCH upon receiving UL ACK signal, and potentially terminate receiver processing upon successful early decoding of UL channel. Despite DPDCH transmission can be terminated upon receiving UL ACK message for DL FET, DPCCH channel may need to continue transmission of TPC bits until UL transmission is also decoded and can be terminated.

Another implementation requirement for frame early termination is increased CRC size to allow reliable termination of early decoded frames. CRC size is part of TFC specification and as part of new TFC implementation in proposed DCH enhancements, new CRC sizes can be specified for CS traffic. CRC check impact on complexity due to increase from 12 to 16 is negligible.

11.1.8 User pairing and extended SHO

TDM of multiple users and sharing OVSF codes among multiple users to free code space may require the Node-B to allocate Tau-DPCH in a way such that user pairing is optimized such that fewer codes are used in soft handover scenarios. Relaxing requirements on SHO combining window delay also reduces the complexity of implementation for user pairing in SHO, but may increase UE complexity and reduce the time that UE can apply DRX.

11.2 Impact on UE Implementation

Similar to the network implementation, the proposed DCH enhancements require some modifications at the UE in DL and UL that are itemized and discussed in this clause.

11.2.1 New DL DPCH Slot Formats

In DL, DPCH is specified with parameters N_{data1}, N_{TPC}, N_{TFCI}, N_{data2}, N_{pilot}. DL DPCH slot format modifications require changes to the values specified for these parameters. The UE receiver may need to be reconfigured to collect the relevant bits according to new slot format parameters.

When TDM of users, UE also requires to only process relevant TDM slots (clause 4.2.4.2 TDM option 2), or slot format fields (clause 4.2.4.1 TDM option 1). For example, in clause 4.2.4.1 TDM option 1 for user pairing using 10ms TTI, UE should only process its own portion of TPC fields.

In addition, without dedicated pilot, the SINR estimation in ILPC operation needs to be modified at the UE side. For example, the UE may use TPC bits to measure SINR for the purpose of ILPC operation.

11.2.2 New UL Slot Formats

In UL, proposed DCH enhancements require reconfiguration of N_{data}, N_{TPC}, N_{TFCI}, N_{pilot} like DL. UE should reconfigure its UL slot format. The UL slot formats proposed in this study are already defined in the specification; however, some may not be defined for R99. In that case, UE needs to enable using TFCI-free slot formats for voice traffic.

In addition, UE may need to restructure the fields in UL DPCCH to maintain the ILPC timeline. As mentioned earlier in clause 11.1.2, two solutions are possible as outlined in clause 4.2.2.2 and 4.1.1.1. One is to reconfigure DL slot format such that TPC fields occupy the position of dedicated pilots in legacy slot format. In another solution, position of TPC fields in UL DPCCH slot format is changed to the beginning of the slot, instead of the end where TPC fields are located in legacy slot format.

11.2.3 Rate Matching and Multiplexing

Similar to Node-B side, the encoding and decoding chains need to be modified to introduce changes in multiplexing and rate matching as introduced in FET Option 2 in clause 4.1.1.2 and 4.2.1.2. The affected blocks are shown in Figure 1 and Figure 2 in 3GPP TS 25.212 [4]. The order and mechanisms for multiplexing, encoding, rate matching, and interleaving are changed.

11.2.4 FET ACK indication

11.2.4.1 I-Q multiplexed with the TPC symbols

UE needs to decode the ACK, which is multiplexed with the TPC symbols.

11.2.4.2 ACK on a new code channel

For the new channel, UE needs to implement a new de-spreading chain and corresponding ACK decoding process.

11.2.4.3 ACK using spared TPC symbols

The main modification by this design is to transmit TPC bits every alternate slot. In addition, UE may need to modify encoding of TPC fields in UL DPCCH to use the freed TPC fields every alternate slot possibly for ACK signaling.
In this case, the UE needs to change ILPC timeline for TPC rate reduction, and possibly SINR estimation algorithms.

11.2.5 UL FET-DPCCH

This is to introduce a new channel. Implementation impact is to allocate a new channelization code in UL, and all associated implementations of slot formats, radio frame construction and TFCI/ACK encoding.

11.2.6 New shared DCH channel for SRB over DCH

For the shared DCH, UE in addition to implementing a new de-spreading chain to monitor shared DCH channel, needs to monitor advertised user ID in shared DCH to identify whether there is relevant data sent for UE.

11.2.7 Frame early termination

Like Node-B, frame early termination at UE requires changes in decoding chain, transmitting and decoding ACK signals on UL and DL, respectively, and UL transceiver termination in response to successful early decoding or receiving ACK signaled on DL. Encoding chain remains mostly unchanged on the Node-B side, except for in-band signaling of DCCH presence and increase in CRC length.

The required changes to decoding chain are similar to those required for Node-B. The increase in complexity comes from multiple Viterbi decoding attempts, which is not significant due to short length of the voice packets.

Finally, FET requires the UE to terminate transmission of DPCH upon receiving DL ACK signal, and terminate receiver processing upon successful early decoding of DL channel.

11.3 Overview of feature benefits and complexity

Tables 11.3.1 and 11.3.2 provide an overall overview of the benefits and complexity introduced as part of proposed DCH enhancements.

Table 11.3.1: Overview of features' benefit and complexity in DL

Feature	Discussion of Benefit	Implementation Complexity	
		Network	UE
FET Option 1 with Shortened TTI	- Higher spectral efficiency due to improved chance of decoding - Improved UE power consumption with DTX/DRX	- ACK decoding - Blanking of alternate 10ms radio frames - DTX of early terminated frame	- Multiple Viterbi decoding attempts - DRX operation following successful early decoding - Transmission of ACK
FET Option 2 with New Rate Matching and Interleaving	- Higher spectral efficiency - Improved UE power consumption with DTX/DRX	- TX Encoding chain change - ACK decoding - DTX of early terminated frame	- Decoding chain change - Multiple decoding - DRX operation following successful early decoding
FET Option 3 with Legacy TTI	- Higher spectral efficiency - Improved UE power consumption with DTX/DRX	- ACK decoding - DTX of early terminated frame	- Multiple Viterbi decoding attempts - DRX operation following successful early decoding - Transmission of ACK
DPCH TDM at TTI Level	- Power saving due to DRX in alternate 10ms radio frames - May result in system throughput loss due to increased usage of OVSF codes if user pairing is mishandled	- Handling of user pairing	- DRX operation during alternate 10ms radio frames
DPCH TDM at Slot Level	- Increased max number of voice users - May result in system throughput loss due to reduced coding gain and increased usage of OVSF codes if user pairing is mishandled	- Handling of user pairing	- Slot-wise DRX operation
New DL-DPCH slot format Option 1	- Enables pilot-free slot format - Uses same number of TPC fields as legacy slot format	- Implementation of new slot format	- Implementation of new slot format
New DL-DPCH slot format Option 2	- Enables pilot-free slot format - Allowing for optimization of TPC fields	- Implementation of new slot format	- Implementation of new slot format
DL ACK signalling as part of DL DPCCH	- ACK signalling for UL FET	Multiplex ACK with TPC bits	Monitor and decode the multiplexed ACK
DL ACK signalling on a new code channel	- ACK signalling for UL FET	Introduce a new channel	Monitor and decode new DL channel
DL ACK signalling using spared TPC symbols	- Reduced signalling - Replaced for ACK signalling	Node-B needs to skip sending TPC bits every alternate slot, and send ACK in spare TPC positions when needed.	UE needs to monitor ACK on alternate TPC symbols starting from a predetermined slot number
Shared DCH	- Power saving due to DRX - Faster SRB - Frees code space - Applicable with Enhanced Voice over DCH and with any traffic over HSDPA	- Implementation of new DL channel	- Monitor and decode new DL channel
Extended SHO	- Assists with user pairing at the expense of reduced DRX gains	- Calculate Tau based on user pairing	- Changes to finger combining in soft handover across a large window - Increased buffering at UE

New Rate Matching and Interleaving for FET (Option 2)	- Rate matching optimization in conjunction with FET - New interleaving to enhance FET	- Implementation of new rate matching, channel multiplexing, and interleaving blocks	- Implementation of new de-rate matching, channel demultiplexing, and de- interleaving blocks
Pseudo-Flexible Rate Matching for FET (Option 3)	- Reusing flexible rate matching to enhance FET	- Changes to rate matching based on flexible rate matching functionality	- Changes to de-rate matching block based on flexible de-rate matching block

Table 11.3.2: Overview of features' benefit and complexity in UL

Feature	Discussion of Benefit	Implementation Complexity	
		Network	UE
FET with repetition of 10ms TTI	- Higher spectral efficiency due to improved chance of decoding - Improved UE power consumption with DTX/DRX - Increased chance of FET - Improved battery saving due to more chance of DTX	- Multiple Viterbi decoding attempts - Combining repeated packet across10ms radio frames	- ACK decoding - Packet repetition at MAC layer with 10ms TTI configuration in PHY layer - DTX of early terminated frame
FET with new rate matching and interleaving chains	- Better spectral efficiency - Improved UE power consumption with DTX/DRX	- Decoding chain change including de-rate matching in de-interleaving - Multiple Viterbi decoding	- TX Encoding chain change including rate matching and interleaving - ACK decoding - DTX of early terminated frame
New UL-DPCCH slot format removing TFCI	- Keeps ILPC timeline unchanged - Improved link performance with more pilot symbols	- Implementation of new slot format	- Implementation of new slot format
FET ACK carried over New FET control channel	- Sends TFCI early to enable faster FET - Enables DTX at UE after early termination - Fast transmission of NULL frames to Node-B and early DTX at UE	- Monitor and decode channel based on HS-DPCCH structure	- Implementation of new channel based on HS-DPCCH structure
FET ACK TDM of FET ACK and TFCI in DPCCH	- FET-ACK robustness	- Implementation of new slot format	- Implementation of new slot format
FET ACK using spared TPC symbols	- Signalling re-used for FET control channel	- Node-B needs to skip sending TPC bits every alternate slot, and send ACK in spare TPC positions when needed.	- UE needs to monitor ACK on alternate TPC symbols starting from a predetermined slot number
DTCH/DCCH compression and repetition	- Increased chance of FET - Improved battery saving due to more chance of DTX	- Combining repeated packet across 10ms radio frames.	- Requires packet repetition at MAC layer with 10ms TTI configuration in PHY layer
New Rate Matching and Interleaving for FET (Option 2)	- Rate matching optimization in conjunction with FET - New interleaving to enhance FET	- Implementation of new de-rate matching, channel demultiplexing, and de- interleaving blocks	- Implementation of new rate matching, channel multiplexing, and interleaving blocks

12 Impact on Specifications

12.1 Technical Specification 25.211

3GPP TS 25.211 [15] specifies physical channels and mapping of transport channels onto physical channels. Below, a list of possible impacts on 3GPP TS 25.211 [15] is provided.

12.1.1 Clause 5.2.1.1 – UL DPCCH and DPDCH

No changes needed for UL DPDCH slot format.

UL DPCCH slot format table in Table 2 needs modification to accommodate for TFCI and ACK fields when UL ACK for DL FET is carried over DPCCH using TDM.

12.1.2 UL FET-DPCCH

A new clause 5.2.1.4 is needed to define UL FET-DPCCH channel. The new clause mostly follows the specification of UL HS-DPCCH channel, with the key difference of having TFCI fields in FET-DPCCH in place of CQI fields in HS-DPCCH. The operation of ACK message is described in this subclause, where it is specified how and when the UE transmits the ACK message to the Node-B.

12.1.3 DL DPDCH and DPCCH

New slot formats for DL DPDCH and DL DPCCH channels may need to be defined in Table 11 of clause 5.3.2. Figure 9 of clause 5.3.2 can be updated in relation to new slot format designs.

12.1.4 DL FET ACK Channel

A new channel may need to be specified to communicate the ACK channel on DL for UL FET operation. In this case, a new subclause may be needed to specify the associate slot formats in 3GPP TS 25.211 [15].

12.2 Technical Specification 25.212

3GPP TS 25.212 [4] specifies multiplexing and channel coding. Below, potential impact of DCH enhancement study item on this specification is provided.

12.2.1 Clause 4.2 – General coding/multiplexing of TrCh

Changes to this clause are mainly due to design requirements for frame early termination. The impact is different for different proposed solutions.

For DL FET with Option 1, the channel multiplexing and rate matching steps are similar to legacy R99 as specified in clause 4.2. In UL FET with Option 1, the TTI used for multiplexing is 10ms, and two 10ms radio frames are repeated back to back to construct a 20ms voice frame. The specification of 10ms frame repetition in Uplink can be achieved by adding a new figure after Figure 2 in clause 4.2 to outline the repetition of 10ms frames.

For FET with Option 2, the channel multiplexing, interleaving, and rate matching steps are changed to improve FET, in both DL and UL. Clause 4.2 requires revision in respective sub-clauses to specify new interleaving, multiplexing, and rate matching, CRC concatenation, codeword segmentation, and other corresponding blocks in transmission chain.

For FET with Option 3, a new clause preceding clause 4.2.2.3 and after clause 4.2.2.1 is added to specify concatenation of transport channels prior to channel encoding. The pseudo-flexible rate matching algorithm described in Option 3 can be specified by allowing different rate matching attributes depending on TFC for downlink in clause 4.2.7.2, while the computation of the rate matching attributes remains unaltered.

12.2.2 Clause 4.3.3 – Coding of Transport-Format-Combination Indicator (TFCI)

TFCI encoding strategies may be specified in clause 4.3.3, for example (20,5) encoding specified for CQI encoding in HS channel can be reused for TFCI encoding. Table 8 and Figure 9 may be modified or new tables added to specify these options.

12.2.3 DL FET ACK Channel

A new channel may need to be specified to communicate the ACK channel on DL for UL FET operation. In this case, a new subclause is needed to specify the coding, and physical channel mapping and the operation of FET and ACK timeline in clause 4.2.

12.3 Technical Specification 25.213

TS 25.213 specifies spreading and modulation. Some modifications may be needed to 25.213 to support UL FET-DPCCH channel as a new control channel in UL.

12.3.1 Clause 4.2.1 – Dedicated physical channels

To specify UL FET-DPCCH channel to support ACK for DL FET, Figure 1and Figure 1A need to be updated to include this channel on a separate channelization code. Depending on whether a fixed power ratio for FET-DPCCH with respect to DPCCH is used or this power offset can be signalled from the network, Table 1 may be modified to allow for a new scaling factor β_f.

12.3.2 Clause 4.3.1.2 – Code allocation for dedicated physical channels

Clause 4.3.1.2.1 can be modified to specify the channelization code to be used for FET-DPCCH channel. Similarly, if a new channel in DL is provisioned to carry the ACK channel, the associated channelization code allocations may be specified in this clause.

12.4 Technical Specification 25.214

3GPP TS 25.214 [11] specifies physical layer procedures. Some modifications to this specification may be needed as follows.

12.4.1 Clause 5.2.1.1 – General downlink power control

In DL FET with Option 2, the power ratio between DPDCH and DPCCH is dependent on transport format combination (TFC). Hence, clause 5.2.1 may need to be modified, similar to what is specified for UL in clause 5.1.3, to specify the power offsets between DL DPDCH and DPCCH.

To allow modification of power control rate , clause 5.2.1.1 may be modified other modes of operation in both downlink and uplink.

12.4.2 Appendix B.1 – Power control timing

This clause may be modified to outline the new power control timings with respect to changes to slot formats in DL and UL DPCH channels. Further, informative power control timeline diagrams may be added to outline the power control timing with new power control modes of operation.

13 Conclusion

A detailed link and system study on DCH enhancements was carried out and promising gains were observed both in terms of user throughput when a mix of CS voice and HS users were considered, and also in terms of voice capacity.

The following DCH enhancements were proposed and evaluated in the study:

- DL Physical Layer Enhancements
  - DL DPCCH Slot Format Optimization
  - DL DPDCH Frame Early Termination
  - DL ACK Indicator design for UL FET
  - DPCH Time Domain Multiplexing
  - Reduced power control rate schemes
  - Node B DTX/UE DRX Mechanisms
- UL Physical Layer Enhancements
  - UL DPCCH Slot Format Optimization
  - UL Frame Early Termination
  - UL ACK Indication for DL Frame Early Termination
  - DTCH/DCCH time compression
  - Reduced power control rate schemes
  - UE DTX/Node B DRX mechanisms

For each of the above physical layer enhancements, one or more design options were proposed during the study, and different combinations of these options lead to different designs and performance of DCH Enhancements.

In order to evaluate performance of DCH Enhancements, four solutions which incorporated some or all of the enhancements were proposed. The solutions are differentiated by the physical layer changes needed to support the enhancements, as described in Table 8.2 and is also shown below. The evaluation results of these 4 solutions are used as representatives of the performance for all the FET designs proposed in this study.

Table 13-1: Representative FET designs evaluated in this study

DCH Enhancements	Solution 1	Solution 2	Solution 3	Solution 4
4.1.1 UL Frame Early Termination	Option 1	Option 2	Option 1	Option 2
4.1.2 UL DPCCH Slot Format Optimization	Option 1	Option 2	Option 1	Option 2
4.1.3 UL ACK Indication for DL Frame Early Termination	Option 1	Option 3	Option 1	Option 3
4.2.1 DL Frame Early Termination	Option 1	Option 2	Option 3	Option 2
4.2.2 DL DPCCH Slot Format Optimization	Option 1	Option 2	Option 3	Option 2
4.2.3 DL ACK Indication for UL Frame Early Termination	Option 1 or 2	Option 3	Option 1 or 2	Option 3
4.2.4 DPCH Time Domain Multiplexing	Option 1	Option 2	No	No

13.1 Conclusions on link evaluation results

13.1.1 Conclusions on Downlink DCH enhancements

When the solutions are considered as a whole, the gains in transmit Ec/Ior over R99 CS voice on the downlink ranged from 0.9dB to 3.69dB for AMR 12.2K and from 1.2dB to 3.8dB for AMR 5.9K. The gains are more significant and similar for multipath and vehicular channels and are slightly lower for Pedestrian A channels at low geometries without soft handover.

For DPCH slot format optimization alone, the gains in transmit Ec/Ior for AMR 12.2K ranged from 0.94dB to 1.29dBfor Solution 2. When DL FET alone is considered, the gains in transmit Ec/Ior for AMR 12.2K ranged from 2.01dB to 2.64dB. When TDM was considered, the average gains reduced by around 0.3dB for Solution 2.

However, the TDM feature is designed to relieve the constraints on code resources as opposed to providing larger gains on link efficiency. The use of TDM enables the number of voice users to be increased by around 50%.

13.1.2 Conclusions on Uplink DCH enhancements

When the solutions are considered as a whole, the gains in average Ec/No over R99 CS voice on the uplink ranged from 1.6dB to 2.54dB for AMR 12.2K and from 2.3dB to 2.7dB for AMR 5.9K. The gains are more significant and similar for multipath and vehicular channels and are slightly lower for Pedestrian A channels.

13.2 Conclusions on system evaluation results

System evaluations were considered for a mix of CS voice and HSPA users. The gains were evaluated in terms of user throughput for HS users for a fixed number of CS voice users.

On the downlink, the throughput gains for HSPA users when DCH enhancements was applied to the voice users ranged on average from 20% to 80% at a voice load of 32 voice users per cell.

A summary of the gains obtained from the downlink system evaluations is shown in Table 13.2-1

Table 13.2-1: Summary of Downlink HSDPA user throughput gains for DCH enhancements

Voice UE #	Gains for DCH Enhancements							
	PedA 3km/h				VehA 30km/h			
	Solution 1	Solution 2	Solution 3	Solution 4	Solution 1	Solution 2	Solution 3	Solution 4
8	0.58%	5.88%	4.28%	6.21%	3.02%	4.74%	4.42%	5.19%
16	2.22%	18.65%	9.81%	15.31%	7.37%	15.41%	9.24%	11.61%
24	5.79%	34.37%	21.62%	29.48%	13.42%	26.50%	17.27%	22.41%
32	20.47%	79.29%	50.34%	61.56%	25.73%	49.65%	30.67%	34.08%
40	71.10%	236.54%	144.16%	176.41%	45.97%	82.34%	50.55%	56.17%
48	Inf	2299.64%	Inf	1828.30%	111.61%	192.47%	126.86%	139.43%

On the uplink, the throughput gains for HSPA users when DCH enhancements was applied to the voice users ranged on average from 61.66% to 432.45% at a voice load of 32 voice users.

A summary of the gains obtained from the uplink system evaluations is shown in Table 13.2-2

Table 13.2-2: Summary of Uplink HSUPA user throughput gains for DCH Enhancements

Voice UE #	PedA 3km/h		VehA 30km/h	
	Gains for DCH Enhancements		Gains for DCH Enhancements	
	Solution 1	Solution 2	Solution 1	Solution 2
8	8.30%	15.50%	11.04%	9.29%
16	20.72%	41.26%	27.11%	22.58%
24	38.12%	94.76%	53.53%	42.71%
32	61.66%	432.45%	104.92%	84.85%
40	100.56%	41156.76%	283.02%	256.35%
48	182.57%	Inf	4420.30%	1406.39%

13.3 Comparison with VoHSPA

VoHSPA performance has been evaluated in 3GPP TR 25.903 [10] in clauses 4.2.2.4.4 and 4.8.2.3 respectively for uplink and downlink. The system capacity of VoHSPA is comparable to that of DCH enhancements both in terms of voice capacity and the throughput of HSPA users in a mixed voice-data scenario.

The outage performance of Rel-7 VoHSPA is worse than DCH enhancements; however it is considered that this difference may be reduced by the implementation of enhanced serving cell change or alternatively multiflow HSDPA with bi-casting or by the use of advanced receivers (eg. dual Rx antennas) at the cost of an increase in UE current consumption.

13.4 Impact on Modem current consumption and implementation complexity

In addition to the performance gains, DCH Enhancements affords the UE the opportunity to turn off its transceiver once a voice frame has decoded on the downlink and the uplink thereby improving UE battery life. The UE can gate its transceiver once it successfully decodes the DL channel, transmits the ACK indicator on the uplink and receives the ACK message on the DL indicating successful decoding of UL channel at Node-B.

An analysis on the percentage of time that the transceiver can be gated based on the DL and UL FET statistics was conducted and it was shown that the UE has the opportunity to gate the transceiver around **63%** of the time for Solution 1, around **34%** of the time in Solution 3, and around **40%** of the time in Solution 2 and 4.

The implementation impact of the proposed DCH enhancements has also been considered both from the UE and the UTRAN perspectives. For more details on the impacts to implementation, see clause 11. The impact on the specifications has also been discussed in clause 12. In general, it is considered that the proposed enhancements to DCH operation are not too complex to implement or to specify.

Annex A: Change history

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
2013-01	R1#72				Initial Draft		0.1.0
2013-08	R1#74	R1-133698			Updated clause 8 and 9	0.1.0	0.2.0
2013-08	R1#74	R1-133941			Updated clause 4, 6, 7, 8, 9, 10, 11, 12, 13	0.2.0	0.2.1
2013-08	R1#74	R1-133942			Updated all clauses	0.2.1	0.3.0
2013-08	R1#74	R1-134015			Endorsed version for one step approval by RAN	0.3.0	1.0.0
2013-08	RP-61	RP-131243	-	-	TR v100 submitted to RAN#61 for 1-step approval	1.0.0	1.0.0
2013-08	-	-	-	-	MCC clean-up	1.0.0	1.0.1