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Foreword

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

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1 Scope

The present document is the technical report on HSDPA (High Speed Downlink Packet Access) Enhancements for Release 6 under the study item: “Radio link performance enhancement”. This TR describes enhancement technologies proposed as candidates of the improvement on HSDPA physical layer. It reports system performance gain and/or other beneficial points for each proposal. It also reports the complexity and some points changed from Release 5 to easily understand the benefits of new technologies. Furthermore, the impacts on the specification in other than physical layer are clarified.

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

2 References

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

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

[1] 3GPP TS 25.214 v5.3.0: “Physical layer procedures (FDD)”

3 Definitions, symbols and abbreviations

3.1 Definitions

3.2 Symbols

3.3 Abbreviations

4 Background and Introduction

HSDPA was introduced in Release 5 to realise high speed data rate on downlink and its work almost finished. However, some new technologies have been already proposed for further enhancements on HSDPA as Release 6. To understand the benefits of each enhancement technology, the motivation, performance, complexity and impacts on other WGs shall be clarified. Therefore, they are described here to make the understanding easy and promote the evaluation work.

5 Overview of Technologies considered as Enhancement

5.1 CQI Enhancement for FDD mode

In Release-5, a fixed CQI reporting rate is used and the reported CQI has been defined to relate to the combination of HS-DSCH transport block size, number of codes and modulation which could be received with a given error probability in one specific 3-timeslot period. It is desirable that sufficient CQI reports are transmitted to allow effective scheduling and MCS selection for transmissions on the HS-DSCH, while at the same time minimizing the uplink interference due to CQI transmissions on HS-DPCCH. Hence different enhancements may be considered:

- Use of additional CQI reports during periods of downlink activity and periodic reporting only at other times
- Introduction of CQI requests triggered through a layer 1 message to obtain on demand CQI updates
- Enabling the UE to store its derived CQI values for a defined period, and report an average of those values

The technologies are described in the following sections will be studied separately as well as in combination.

5.1.1 Enhanced CQI Reporting

The technology described as “Enhanced CQI Reporting” extends the Release 5 feedback cycle based CQI scheme by introducing tuneable reporting rates through additional CQI reports during periods of downlink activity and fewer reports at other times. The additional CQI reports are initiated implicitly with every ACK and/or NACK and through the possibility of requesting them on demand using fast layer 1 signalling. Requesting CQI reports by means of fast layer 1 signalling is especially advantageous prior to the first packets of a packet call, while implicit ACK/NACK based CQI reports are efficient after the transmission of packets has already started. In addition, a number of successive CQI values (as defined by the Release 5 specifications) may be averaged (i.e. logarithmically with respect to channel quality) at the UE, and the averaged value reported.

The motivation for this technology is to improve the performance of HSDPA. The UL signalling overhead may be able to be reduced, while ensuring that up-to-date CQI information is available at the time of downlink activity for efficient scheduling and rate selection. The scheduling and rate selection may also benefit from the UE basing the CQI report on some measure of the average channel quality rather than on the instantaneous quality. Additionally, by fast layer 1 messages - used to trigger extra CQI transmissions - it may be possible to improve the performance of the first packets of a packet call and to reduce the number of retransmissions. Fast layer 1 signalling is realized by utilizing the redundant area of the channelization code set mapping of the HS-SCCH.

5.2 Dynamic Range Extension for the TDD CQI Report

The principle of the TDD CQI scheme is that the UE reports the transport block size and modulation format that it believes would have maximised the throughput of the previous HS-DSCH transmission, if decoded in isolation. This report covers a small dynamic range compared to the 32dB that can be signalled in FDD. Since, under this definition, no UE can report a coding rate greater than unity with 16-QAM modulation, the current scheme does not distinguish between UEs experiencing very good quality (i.e. able to support uncoded transmissions using 16-QAM modulation) for the purposes of scheduling. Although it is considered extremely unlikely that these conditions will arise very often in practice; however, when they do, clearly it will be of benefit to the NodeB to be able to determine at which UEs these conditions are likely to be maintained. It is expected that UEs experiencing a higher SIR will be more likely to continue experiencing a SIR capable of supporting uncoded 16-QAM transmissions than a UE experiencing a lower SIR. Hence techniques for extending the dynamic range of the CQI report are considered here.

5.3 Multiple Simultaneous Transmissions to a UE in an HSDPA Sub-frame

The Release-5 HSDPA specifications allow only one transmission to a UE within an HSDPA subframe. The restriction of a single transmission to a UE within a subframe may lead to scheduling and transmission inefficiencies when one or more retransmissions for a given UE are pending on one or more HARQ processes and/or when a new transmission needs to be code-multiplexed with one or more retransmissions within a subframe. Providing the flexibility to support multiple simultaneous transmissions to a UE within a subframe has the potential to enhance HSDPA system performance through better exploitation of multi-user diversity.

Thus, the enhancement that allows multiple simultaneous HARQ transmissions to a UE can improve scheduling flexibility and system performance.

5.4 Code Reuse for Downlink HS-DSCH

Downlink OVSF codes are a critical resource factor in defining the capacity of the network. The capacity of HS-DSCH can be limited due to a shortage of available orthogonal codes. The shortage of codes can result due to various reasons including inefficient code space usage by associated DPCH and other dedicated channels. For R'99 data services, an inactivity timer is typically employed to ensure that code resources are released for other users. However, there are certain data applications (e.g. chatty applications, TCP acknowledgements) for which long inactivity timers may be needed in order to ensure low delay. As a result, these applications tend to use up significant fractions of the code space but have very low power requirements. Voice users could also make inefficient use of code space since codes remain assigned during periods of inactivity. This leads to power code imbalance, an effect further compounded by soft handoff on the downlink. Enhancements that provide power benefit (e.g. beamforming) also need corresponding improvements in the code dimension so that the system capacity benefits can be realized. These effects can result in a disproportionately large amount of power available for HS-DSCH as compared to codes.

An enhancement that allows OVSF code reuse without requiring multiple receive antennas can improve downlink capacity in code limited situations.

5.5 Fast Signalling between Node-B and UE

In the Release-5 specifications, the UE can be signalled about MAC-hs and control channel reconfiguration through RRC signalling. However, the RRC signalling is slow due to delays in the radio access network and use of longer TTI for transmission. Moreover, when a control message related to MAC-hs (scheduler, AMC or HARQ etc.) needs to be carried to the UEs, the information is first sent from the MAC-hs in the Node-B to the RRC in the RNC and only then RRC can forward the signalling message to the UE.

This enhancement will help to reduce the delays involved due to RRC signalling between UE and RNC. The objective is to devise fast signalling schemes that allow Node-B to signal various information like control channel reconfiguration and power offsets over the air interface to the UE, without having to use RRC signalling.

5.6 Fast Adaptive Emphasis

The aim of Fast Adaptive Emphasis is to offer the UE a seamless gain of closed loop transmission diversity when it enters in a soft handover region. Infact, in such a region the UE loses transmission diversity gain because the weights are not optimised anymore for the radio link from the HSDPA serving cell.

According to Release 5 specifications, during operation of HSDPA in closed loop transmission diversity with an associated DPCH in soft handover, it is possible to emphasize the radio link from the serving cell that carries HS-PDSCH and HS-SCCH. But if the emphasis is applied in a static manner, the following happens.

- If the serving cell is strongly emphasized, then the associated DPCH permanently suffers from site diversity loss regardless of HSDPA packet activity, and TPC operations increase the downlink transmission power for that UE. If all UEs behave in the same way, the result is an increase of total downlink interference.
- On the other hand, a milder emphasis reduces the impact on DPCH but also reduces the benefit of the transmission diversity for HSDPA, with the effect that the UE may suffer a sudden decrease of throughput as soon as it enters in the soft handover region.

With Fast Adaptive Emphasis, the UE puts emphasis on the serving cell only when it is scheduled for transmission on the HS-PDSCH. The main expected advantages over a static application of the emphasis are the following.

- The UE experiences a seamless HSDPA throughput also when it enters in soft handover because during HSDPA transmission the weights are always optimised for the serving cell.
- The UE enhances the reception of the DPCH, because during HSDPA packet inactivity it will maximise the power received from all the cells of the active set.
- The system will benefit from downlink power reduction because only a small number of UEs (those being scheduled in soft handover) will require a temporary higher downlink transmission power, whereas in the case of a strong static emphasis every UE in soft handover would require a permanent power increase.

For the above reasons, this enhancement is expected to improve performance of HSDPA and reduce downlink transmission power for DPCH when closed loop transmission diversity is used in the soft handover region.

According to release 5 specifications [1], there are no limitations for a UE to use some technique similar to Fast Adaptive Emphasis, but that is left as an implementation choice for every single UE. Instead, full benefit of Fast Adaptive Emphasis is expected only if the UEs are mandated to operate with the same behaviour.

5.7 ACK/NACK Transmit Power Reduction for HS-DPCCH with preamble and postamble

In Release 5, the UE always uses DTX in the ACK/NACK field of the HS-DPCCH except when an ACK or NACK is being transmitted in response to an HS-DSCH transmission.

This means that if the UE fails to detect Part 1 of the HS-SCCH (typical probability ~0.01), the UE will use DTX in the corresponding ACK/NACK field. The Node B must avoid decoding this DTX as ACK if it is to avoid loss of the HS-DSCH TTI at the physical layer. If an HS-DSCH TTI is lost at the physical layer, the only means of recovering the TTI is by higher-layer retransmission, which may be too slow for the delay requirements and buffering capabilities.

The transmission power for ACK messages must therefore be set high enough to reduce the probability of such misinterpretations to a sufficiently low level.

It is therefore desirable to find means by which the Node B can set its ACK detection threshold closer to DTX without resulting in misinterpretations.

Such means would generally give a variety of benefits, including some or all of the following:

- Improved ACK/NACK decoding reliability;
- Reduced uplink transmission power requirements;
- Reduced uplink interference;
- Reduced PAR for uplink transmissions;
- Enhanced cell range for HSDPA;
- Improved UE battery life.

5.8 Fractional dedicated physical channel

The current specifications mandate the set up of dedicated physical channels both in the UL and in the DL for any user operating in HSDPA. However with the development of data-only applications especially for low to medium bit rates, the cost of the dedicated channel may restrict a wider use of HSDPA.

When a user only wants to have streaming, interactive or background service i.e. a data-only service there is still a need from the system perspective to set up a dedicated physical channel in the DL. It is generally foreseen that this downlink dedicated channel will be mainly used to carry RRC signalling and that all the traffic will go through the HSDPA channel. RRC signalling has a minimum data rate however since transmission of RRC signalling is rather infrequent, the physical channel carrying this signalling will be DTX'ed most of the time except for TPC and pilot bits transmission.

As the current standard allows the signalling to be carried on the HS-DSCH transport channel, the dedicated physical channel may be setup in the downlink to carry only layer 1 signalling.

Providing the flexibility to share the dedicated code channels associated to data-only users has the potential to allow for a wider use of the HSDPA system by reducing the code limitation problem. The fractional dedicated physical channel implements the above described concept of code sharing between data-only HSDPA users to carry layer 1 control information.

5.9 HSDPA operation without an associated DPCH (TDD)

In HSDPA operation without an associated DPCH (TDD), the UE shall be able to receive the HS-DSCH transport channel without the requirement for UL, DL or both UL and DL associated DPCH's. This proposal does not mandate operation without associated DPCH's; operation with associated DPCH's is still supported if configured by the network.

There are two primary motivations for HSDPA operation without an associated DPCH (TDD) : increasing system capacity and reducing latency.

The first motivation for HSDPA operation without an associated DPCH (TDD) is to increase system capacity in cases where the network does not have a constant stream of data to send to the UE. Such a situation might arise when the UE application is web browsing, e_mail, FTP, instant messaging or many other typical internet applications. If the associated DPCH is not required for support of the HS-DSCH transport channel and there is a relatively small amount of conversational / streaming class traffic or signalling, the DPCH associated with HS-DSCH in Release 5 might overuse physical resources compared to the alternative of using shared resources.

The second motivation for HSDPA operation without an associated DPCH (TDD) is to reduce latency. In Release 5, when the network wishes to service a UE on the HS-DSCH transport channel, it must first set up a DPCH. This setup procedure (and corresponding teardown procedure) takes time and increases latency. Latency could be reduced in Release 5 by the network keeping the UE in an "HSDPA state" (H-RNTI is assigned and the UE is listening on HS-SCCH) for a period of time longer than a packet call, however this network policy wastes physical resource (for the associated DPCH's) as per the first motivation.

Additionally, in TDD the maximum spreading factor is only 16 and therefore if associated DPCHs are allocated, it will be necessary to fractionate these DPCH allocations in order to minimize the amount of resource set aside for DPCHs to a reasonable level when a large population of HSDPA users are to be serviced. Considering a typical population of the order of 80 HSDPA-active users the number of DPCH's set aside would be equal to 2*80/F, where F is the fractionation level and the "2" arises from UL and DL DPCH's. Values for F of 1, 2 or 4 result in a DPCH overhead of 160, 80 and 40 DPCH's respectively per radio frame and so a higher degree of fractionation would usually apply, which might lead to undesirable latency (this does not apply for low degrees of DPCH fractionation).

The advantages and disadvantages of the following three levels of enhancement from a physical layer perspective are considered :

1. Operation without an associated DL DPCH
2. Operation without an associated UL DPCH
3. Operation without both the DL and UL associated DPCH's

6 Details of Technologies

6.1 CQI Enhancement for FDD mode

6.1.1 Enhanced CQI Reporting

6.1.1.1 Features

The enhanced CQI reporting method builds on the current Release 5 specifications. The specification relating to the method of deriving an individual CQI value by the UE would not be changed. Enhanced CQI reporting may be performed as activity based CQI feedback or NACK based CQI feedback scheme assisted by extra CQI reports requested by fast layer 1 signalling and/or by reporting averaged CQI values.

If CQI feedback is activity-based, CQI information is sent with every ACK or NACK of HS-PDSCH data in addition to periodic reporting whose period is determined through higher layer signalling. Note that due to the bursty nature of data traffic, when a transmission is performed to a UE, it is likely that more transmissions or HARQ retransmissions will occur to the same UE within a short period of time. Therefore, this method makes up-to-date CQI information available to the Node B for future transmissions to the UE.

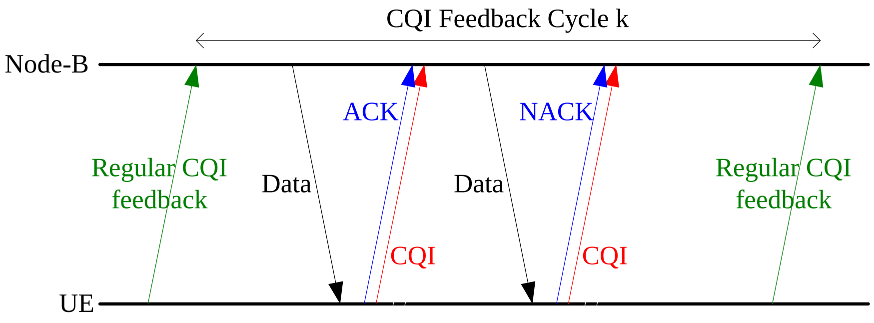


Figure 1: Diagram illustrating activity-based CQI feedback. The additional CQI feedbacks that are triggered by downlink activity are shown in red.

If CQI feedback is NACK-based, CQI information is sent with negative acknowledgement (NACK) of HS-PDSCH data in addition to the Release 5 periodic reporting whose period is determined through higher layer signalling. Figure 2 outlines the scheme.

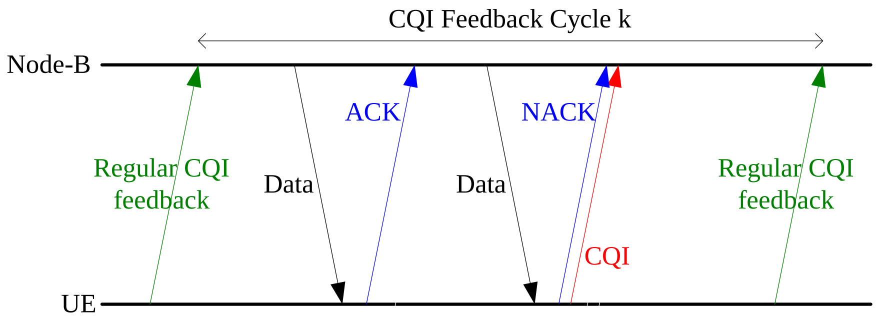
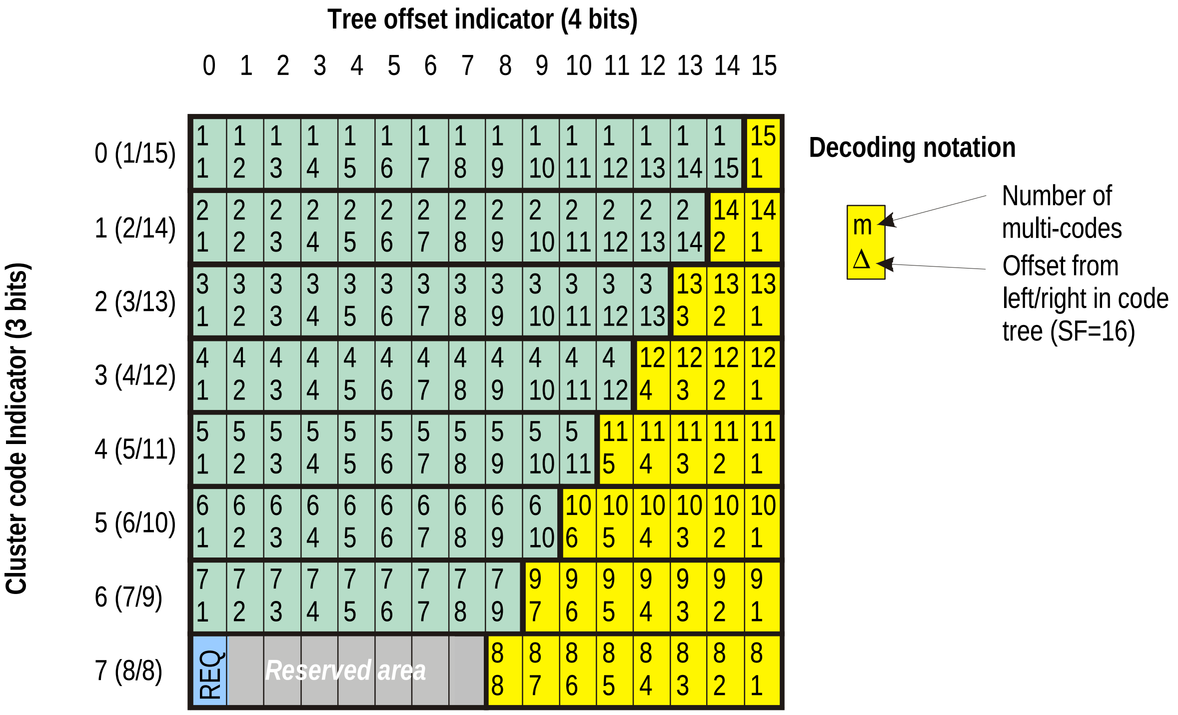


Figure 2. Diagram illustrating NACK-based CQI feedback. The additional CQI feedbacks that are sent along with NACKs of HS-PDSCH data are shown in red.

Both alternatives (NACK based and activity based CQI feedback) can be assisted by extra CQI reports requested by fast layer 1 signalling on demand (ODM). The new layer 1 message, which is signalled on the HS-SCCH utilizes the redundant area of the channelization code-set mapping. Table 1 describes a possible solution and Figure 3 depicts the HSDPA channelization code-set mapping.

Bits [$x_{ccs,1}$, ..., $x_{ccs,7}$]	**Purpose**	**Remarks**
000 0000 … 110 1111	Used by Release-5	Defines the Channelization Code-Set used on the HS-DSCH
111 0000	Unused in Release-5, used for Fast CQI Request	Request an additional CQI report (REQ)
111 0001 … 111 0111	Unused in Release-5	Reserved for future extensions
111 1000 … 111 1111	Used by Release-5	Defines the Channelization Code-Set used on the HS-DSCH

Table 1: Utilization of Channelization Code-Set Mapping for On-Demand CQI Reporting (ODM)



Tree offset indicator (4 bits)

Cluster code Indicator (3 bits)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0 (1/15)	1 1	1 2	1 3	1 4	1 5	1 6	1 7	1 8	1 9	1 10	1 11	1 12	1 13	1 14	1 15	15 1
1 (2/14)	2 1	2 2	2 3	2 4	2 5	2 6	2 7	2 8	2 9	2 10	2 11	2 12	2 13	2 14	14 2	14 1
2 (3/13)	3 1	3 2	3 3	3 4	3 5	3 6	3 7	3 8	3 9	3 10	3 11	3 12	3 13	13 3	13 2	13 1
3 (4/12)	4 1	4 2	4 3	4 4	4 5	4 6	4 7	4 8	4 9	4 10	4 11	4 12	12 4	12 3	12 2	12 1
4 (5/11)	5 1	5 2	5 3	5 4	5 5	5 6	5 7	5 8	5 9	5 10	5 11	11 5	11 4	11 3	11 2	11 1
5 (6/10)	6 1	6 2	6 3	6 4	6 5	6 6	6 7	6 8	6 9	6 10	10 6	10 5	10 4	10 3	10 2	10 1
6 (7/9)	7 1	7 2	7 3	7 4	7 5	7 6	7 7	7 8	7 9	9 7	9 6	9 5	9 4	9 3	9 2	9 1
7 (8/8)	REQ	Reserved area							8 8	8 7	8 6	8 5	8 4	8 3	8 2	8 1

Figure 3: Channelization Code-Set Mapping on HS-SCCH

To report averaged CQI values the current specifications regarding the reporting of CQI values would be enhanced, to enable the network to instruct the UE to store its derived CQI values for a defined period, and to report an average of those values.

The period over which CQI values are stored and averaged is defined as a number of sub-frames, $N_{CQI\text{-}av}$. $N_{CQI\text{-}av}$ could be signalled explicitly or implicitly by the network, or predefined. If implicit signalling of $N_{CQI\text{-}av}$ is used, this may be related to the signalling of the CQI feedback cycle, *k*.

When $N_{CQI\text{-}av} = 1$, the UE reports the most recently-derived integer CQI value, relating to the 3-slot reference period ending 1 slot before the start of the first slot in which the reported CQI value is transmitted, as per the Release 5 specifications.

When $N_{CQI\text{-}av} > 1$, the UE reports the mean of the derived integer CQI values relating to a number $N_{CQI\text{-}av\text{-}subset}$ of the $N_{CQI\text{-}av}$ consecutive 3-slot reference periods ending 1 slot before the start of the first slot in which the reported CQI value is transmitted. Setting $N_{CQI\text{-}av\text{-}subset}$ to a value less than $N_{CQI\text{-}av}$ allows the UE to avoid deriving a CQI value in every reference period during the $N_{CQI\text{-}av}$ sub-frames.

If $N_{CQI\text{-}av\text{-}subset} < N_{CQI\text{-}av}$, the exact value of $N_{CQI\text{-}av\text{-}subset}$ relative to $N_{CQI\text{-}av}$ may be implementation-dependent, but restrictions may be specified regarding its valid range and the particular pattern of reference periods which is included in the calculation of the mean. Details of such restrictions are FFS, but one example could be as follows:

- $N_{CQI\text{-}av\text{-}subset}$ shall be greater than 1 and greater than or equal to $N_{CQI\text{-}av}/2$, *and*
- the $N_{CQI\text{-}av\text{-}subset}$ reference periods for which CQI values are derived and included in the calculation of the mean shall not be separated by more than 6 timeslots

It is not envisaged that the use of $N_{CQI\text{-}av} > 1$ would require any new specifications in relation to processing of received CQI information at the Node B. However, for the purposes of evaluating the reporting of averaged CQI values, the following general kind of behaviour is assumed:

For creating a downlink packet schedule in the timeslot t_{sched}, it is assumed that the Node B derives a downlink channel quality metric, $CQ(t_{sched})$, as a function of previously-received CQI reports and previously-recorded downlink power levels on the associated DPCCH, P_{dch}. In general, this can be represented as:

$$CQ(t_{sched}) = F\left(CQI, P_{dch}\right) \qquad (6.1.1.1)$$

The downlink power level is assumed to be approximately inversely proportional to the downlink channel quality for the non-soft-handover case.

It is further assumed here for the purposes of evaluation that $F(CQI, P_{dch})$ uses the average downlink power recorded over the most recent L slots, calibrated according to the most recent CQI report, which is derived from the mean of $N_{CQI\text{-}av}$ successive CQI values at the UE (or $N_{CQI\text{-}av\text{-}subset}$ CQI values within a period of length $N_{CQI\text{-}av}$ subframes, as described above). This results in the following expression:

$$CQ(t_{sched}) = 10^{CQI(T_{last})} . \frac{\sum_{i=-3N_{CQI-av}}^{i=-1} P_{dch}\left(3T_{last} + i\right)}{3N_{CQI-av}} . \frac{L}{\sum_{j=1}^{j=L} P_{dch}(t_{sched} - j)} \qquad (6.1.1.2)$$

Here $CQI(T_{last})$ is the most recent CQI report, which is assumed to describe the UE's channel measurement in subframe $T_{last} - 1$.

A better option is to derive the Logarithm of the channel quality, which is particularly convenient as the channel quality values transmitted in CQI reports are quantised with approximately 1dB steps. In this case a suitable expression is:

$$Log(CQ(t_{sched})) = CQI(T_{last}). + \frac{\sum_{i=-3N_{CQI-av}}^{i=-1} Log\left[P_{dch}\left(3T_{last} + i\right)\right]}{3N_{CQI-av}} - \frac{\sum_{j=1}^{j=L} Log(P_{dch}(t_{sched} - j))}{L} \qquad (6.1.1.3)$$

In this evaluation, the number of slots over which the downlink power is averaged at the Node B is suggested to be L=2 (since this has been found to give slightly better results than L=1).

6.1.1.2 Evaluation and Benefits

The main benefits of the enhanced CQI reporting are expected to lie in the following areas:

- Reduction of UL signalling overhead due to greater ability to use low CQI reporting rates.
- Improved MCS selection and scheduling.
- Performance improvement of the first packets of a packet call by using the feature to request extra CQI transmissions by fast layer 1 signalling.
- Improved tracking of channel conditions in case a UE is in SHO.
- Improved performance when the UE is not in SHO
- Reduction of radio link reconfiguration messages.
- Reduced delay due to more suitable choice of MCS and scheduling

The reduction in UL signalling overhead for the DL activity based reporting scheme depends on the fraction of time downlink transmissions are actually scheduled to a mobile. The improvement in MCS selection would apply to all transmissions including the first transmission of the first packet of a burst by requesting CQI messages on demand by fast layer 1 signalling. For the NACK based reporting scheme, the reduction in UL signalling overhead will be greater than with activity based reporting. The improvement in MCS selection would apply to all retransmissions. However, the impact of not having CQI feedback with ACKs on system throughput has to be evaluated.

The performance compared to Release 5 periodic feedback scheme, has been investigated in the simulations shown in Figure 4 to 8 using the simulation assumptions given in Table 2.

Parameter	**Value**	**Comment**

carrier frequency	2.19 GHz	
SAW channels	6	Using Stop-And-Wait Protocol
HARQ	Full IR, Partial IR, or Chase Combining	Depending on initial code rate
max. number of transmissions	4	
UE multi-code capability	15 codes	
MCS level	30 MCS levels used	According to the TF in the CQI feedback
HS-SCCH, HS-DPCCH transmission	Ideal	
channel estimation	Ideal	
roundtrip delay	6 TTI	
delay between CQI measurement and time of availability for HS-DSCH	3 TTI	
delay between CQI on demand request and time of availability for HS-DSCH	4 TTI	
traffic model	open-loop traffic model for HSDPA	see TR25.848
packet size	1500 bytes	
packet call size	Pareto with cut-off, $\alpha = 1.1$, $k = 4.5$ kbytes, $m = 2$ Mbytes	
reading time	Geometrical distribution $\mu = 5$ s	
channel model	1 path Rayleigh	
UE velocity	3 km/h	
Release 5 CQI update interval k	40 TTI	
Simulation time	10000 packets per *SIR* value	

Table 2: Simulation Assumptions for Figure 4-16

Figure 4 shows the retransmission statistics compared to Release 5. It can be seen that the number of retransmissions is reduced. For a mean SIR of 12 dB the number of transmitted bits per HS-DSCH channel usage can be increased by 18%. For the simulation we assume a flat Rayleigh fading channel with 3 km/h UE velocity. The cyclic CQI reports are sent with k=40. Node B requests an additional CQI value using fast signalling on the HS-SCCH only, if the last CQI is older than 10 TTIs and if the waiting data corresponds to more than 6 TTIs according to the current CQI. Figure 5 shows a comparison of the average packet call throughput. Typically a gain between 0.5 and 1 dB is achieved versus Release 5.

Figure 6 shows the cumulative distribution of the packet delay. The packet delay is defined as time difference between arrival of a packet in the RLC transmit buffer and successful decoding at the receiver. The 95-percentile of packet delay is 22.2 ms compared to 31.0 ms for Release 5.

Figure 7 and 8 show the transmitted amount of data per channel usage and the throughput increase per channel usage. It can be seen that the investigated scheme makes very efficient use of HS-DSCH and requires notably less HS-DSCH resources to transmit a given amount of data compared to Release 5. This is the case in the whole investigated range. The relative savings are in the order of 15%. The HS-SCCH usage is reduced by the amount of 2 to 12% compared to the HS-SCCH usage for Release 5. This shows, that the extra CQI values requested on demand do not cause potential HS-SCCH shortages.

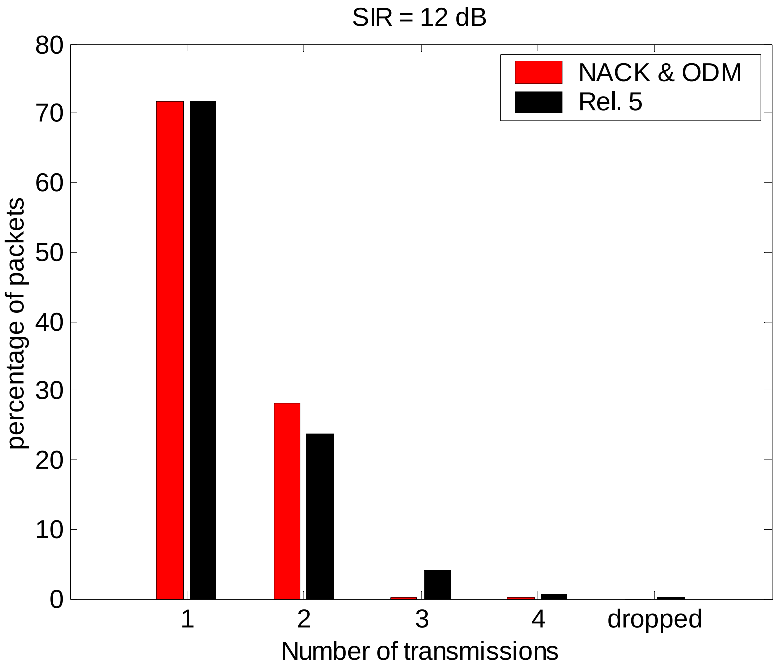


Figure 4: Retransmission statistic for SIR = 12 dB

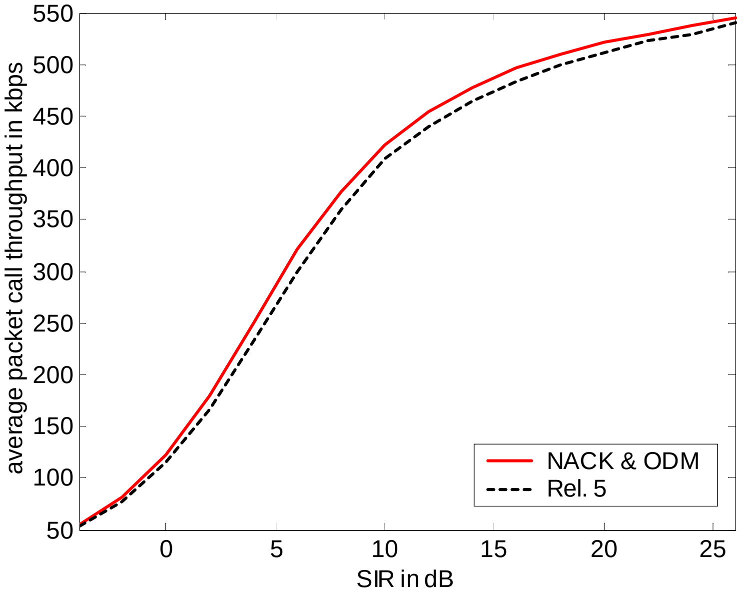


Figure 5: Average packet call throughput comparison

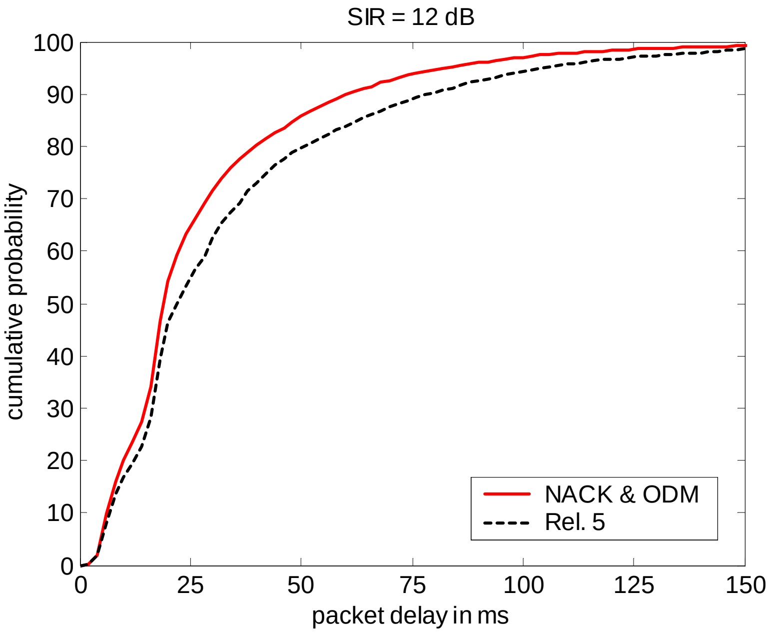


Figure 6: Cumulative distribution function of packet delay (SIR = 12 dB)

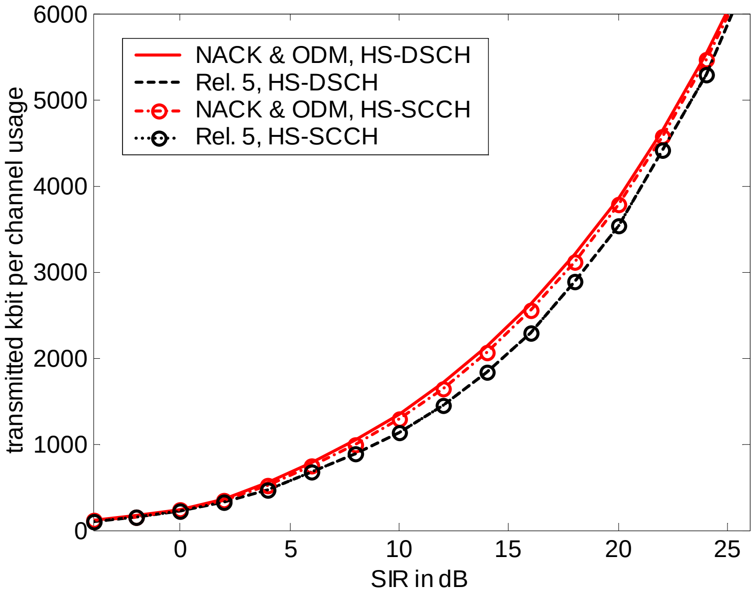


Figure 7: Transmitted amount of data per channel usage

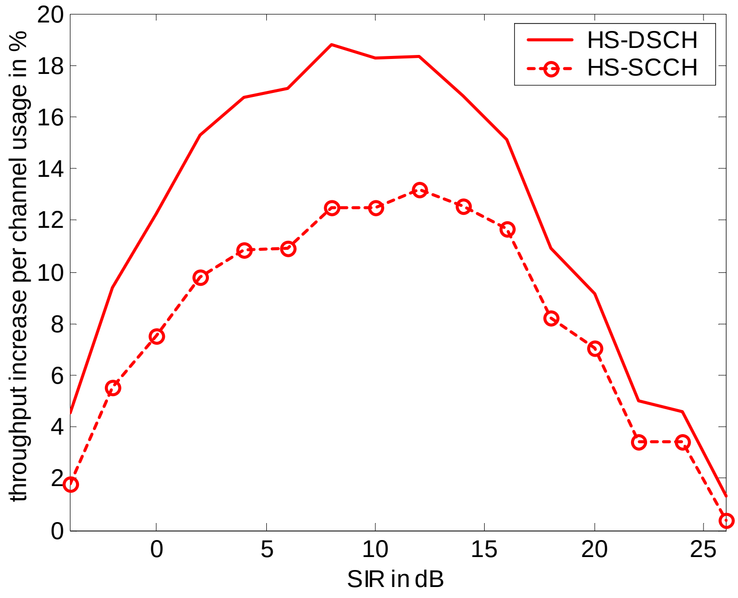


Figure 8: Throughput increase per channel usage

The simulation assumptions for the results shown in Figure 9-16 are the same as stated in Table 2. However the used channel model is Pedestrian A (3 km/h) or Vehicular A (30 km/h).

Figure 9,10,11 and 12 show the results for the Pedestrian A channel model. We compare the NACK & ODM scheme using cyclic CQI reports with interval k=40. The resulting throughput performance versus *SIR* is given in Fig. 9. It can be seen that the NACK & ODM scheme improves the average packet call throughput over a large range of *SIR* values with respect to Rel. 5, *k* = 40. The enhanced scheme using k=40 achieves a similar throughput performance to Rel. 5 using k=20.

Fig. 10 depicts the cumulative distribution function of packet delay for *SIR* = 6 dB. The NACK & ODM scheme with k = 40 outperforms Rel. 5, *k* = 40 (e.g., it reduces the 90%-ile from 574 ms to 372 ms) and has approximately the same performance as Rel. 5, *k* = 20 (90%-ile of 330 ms).

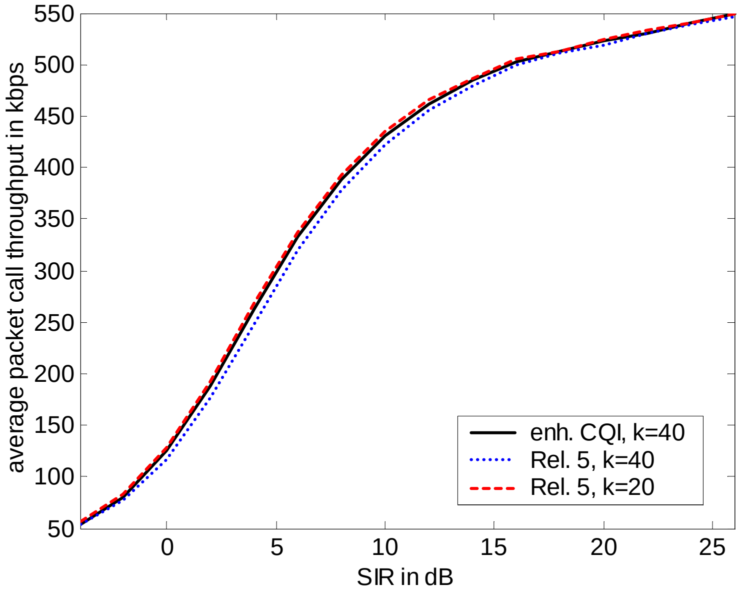


Figure 9: Average packet call throughput comparison (Pedestrian A, 3km/h)

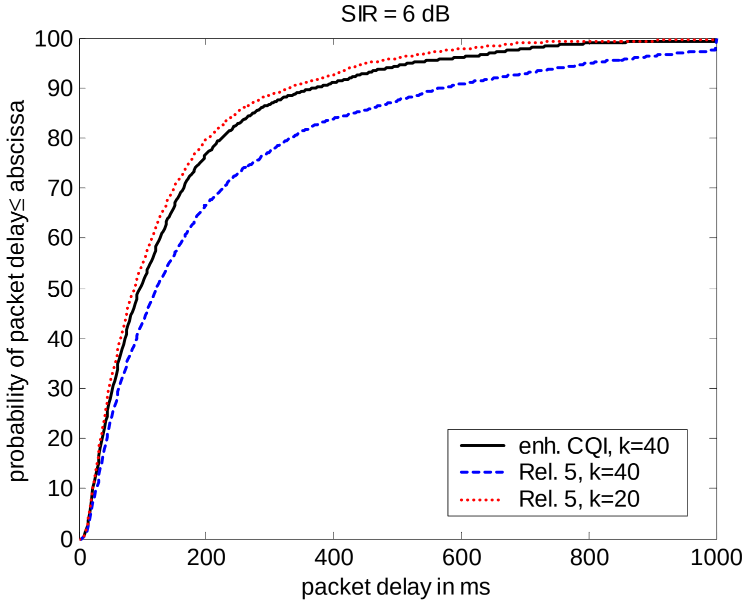


Figure 10: Cumulative distribution function of packet delay (Pedestrian A, 3 km/h)

Fig. 11 and 12 address the efficiency of the schemes for Pedestrian A (3 km/h). Figure 11 shows the relative throughput increase in the downlink. The black curves use Rel. 5, $k = 40$ as reference, the blue curves Rel. 5, $k = 20$. The HS-DSCH and HS-SCCH curves deviate due to the use of CQI on demand, which causes additional HS-SCCH usage without transmitting data. The enhanced CQI scheme provides about 14% throughput gain per HS-DSCH usage and about 8% throughput gain per HS-SCCH usage compared to Rel. 5, $k = 40$. Thus for a given amount of data per user less downlink resources are required and aggregate cell throughput is increased. Even compared to Rel. 5, $k = 20$, we see notable throughput gain per HS-DSCH usage, ranging up to 7% while approximately the same HS-SCCH resources are required (throughput difference less than ± 4%).

Fig. 12 considers the frequency of the uplink CQI message. The presented throughput increase per UL channel usage is calculated as the difference between the throughput of the NACK & ODM scheme per CQI usage for k=40 and the throughput of the Rel. 5 scheme for k=20 (k=40) per CQI usage over the throughput of the Rel. 5 scheme for k=20 (k=40) per CQI usage. It can be seen, that due to the additional on-demand and NACK-based CQI messages the throughput per channel usage of the enhanced scheme is reduced for equal values of k. If we compare the enhanced CQI scheme to Rel. 5, $k = 20$, we see that for $SIR \geq 5$ dB additionally less CQI reports are required. Furthermore, for -3 dB $\leq SIR \leq 18$ dB less ACK/NACK transmissions are required (since HS-DSCH throughput is increased). Thus in total the uplink interference is reduced.

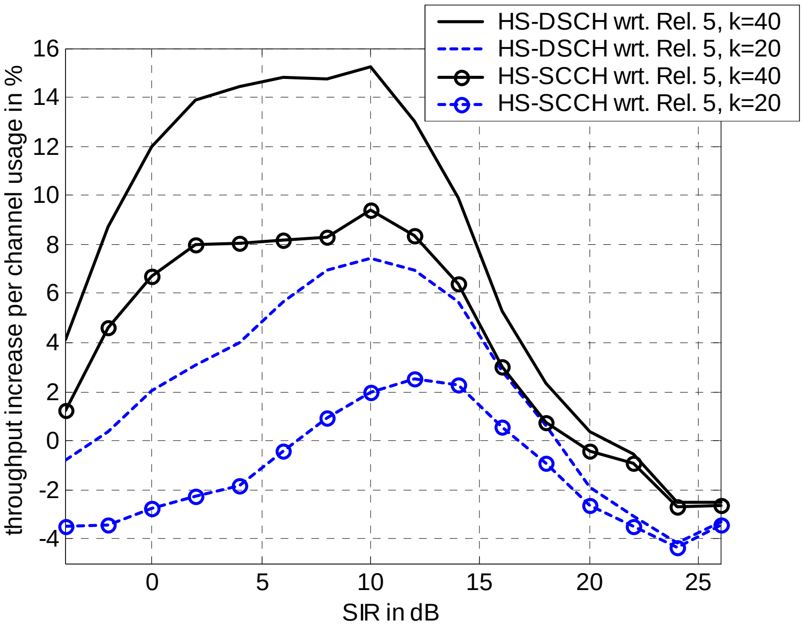


Figure 11: Throughput increase per DL channel usage for NACK & ODM with k=40 (Pedestrian A, 3 km/h)

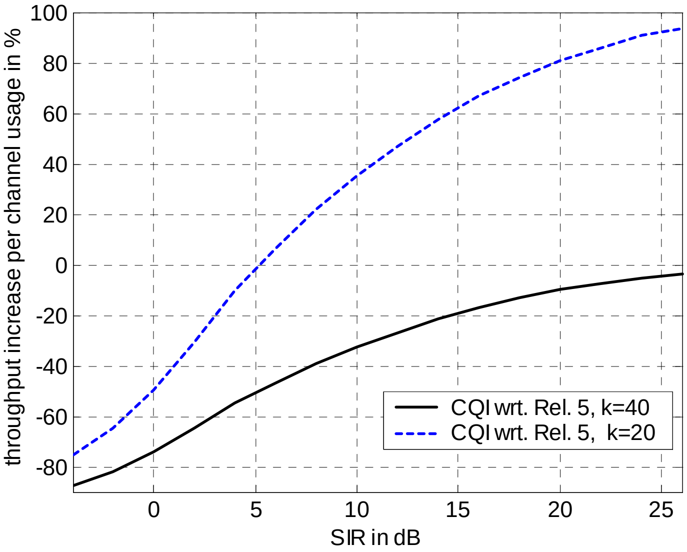


Figure 12: Throughput increase per UL channel usage for NACK & ODM with k=40 (Pedestrian A, 3 km/h)

Figure 13,14,15 and 16 show the performance for the Vehicular A channel (30 km/h). We compare the NACK & ODM scheme using cyclic CQI reports with interval k = 20 to the Rel. 5 CQI reporting using a k = 10 and k = 5.

As depicted in Fig. 13 all schemes provide approximately the same throughput. In the lower *SIR* range, however the NACK & ODM scheme and Rel. 5, k=5 perform better in terms of average packet call throughput than Rel. 5, k=10.

Fig. 14 depicts the cumulative distribution function of packet delay for *SIR* = 6 dB. It can be seen that the 90%-ile of packet delay can be reduced from 300 ms to 209 ms when compared to Rel. 5, k=10 and performs similar to Rel. 5, k=5.

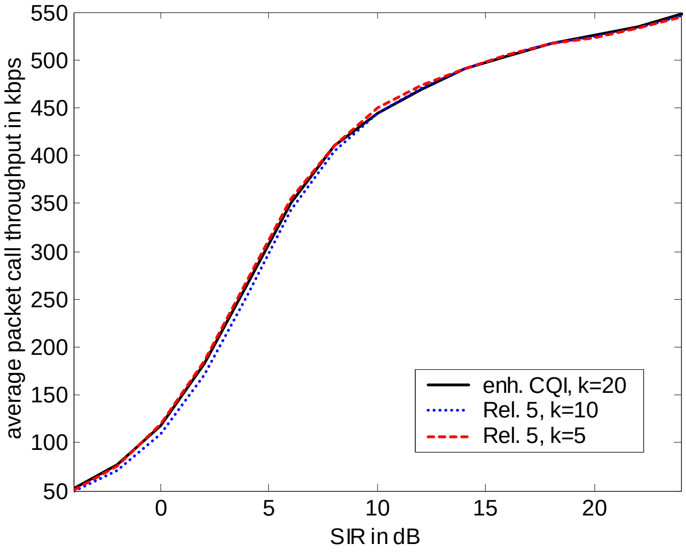


Figure 13: Average packet call throughput comparison (Vehicular A, 30 km/h)

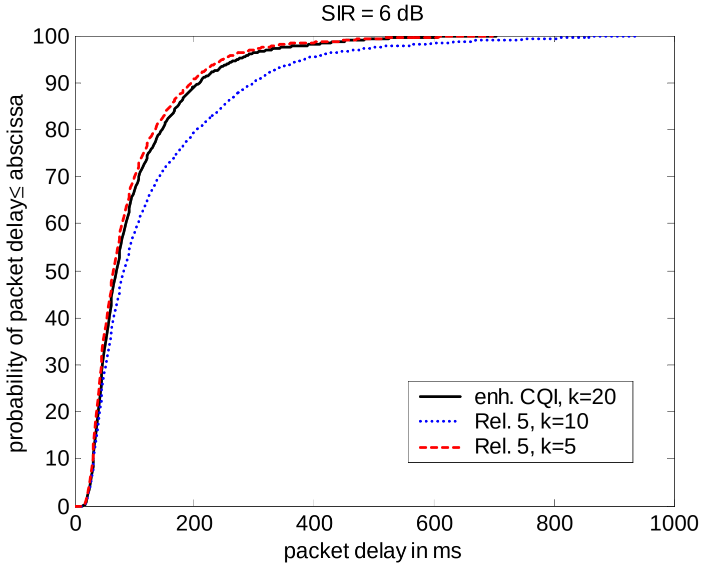


Figure 14: Cumulative distribution function of packet delay (Vehicular A, 30 km/h)

Fig. 15 and 16 address the efficiency of the schemes. Figure 15 shows that NACK & ODM increases the throughput per HS-DSCH usage for all *SIR* values. A gain of up to 12% is achieved when compared to Rel. 5, $k = 10$. The corresponding throughput increase per HS-SCCH is also constantly positive and has a maximum of 8%. When compared to Rel. 5, $k = 5$ the gains are smaller and range up to 4% for HS-DSCH.

Fig. 16 considers the frequency of the uplink CQI. The presented throughput increase per UL channel usage is calculated as the difference between the throughput of the NACK & ODM scheme per CQI usage for k=20 and the throughput of the Rel. 5 scheme for k=5 (k=10) per CQI usage over the throughput of the Rel. 5 scheme for k=5 (k=10) per CQI usage. Compared to Rel. 5, $k = 5$, the throughput increase is up to 295%, i.e., for a given amount of data the number of CQI transmissions remains approximately the same for very low SIR and is reduced to only 25% for high SIR. Additionally, the reduced number of ACK/NACK transmissions due to the throughput increase per HS-DSCH usage further reduces the uplink HS-DPCCH usage.

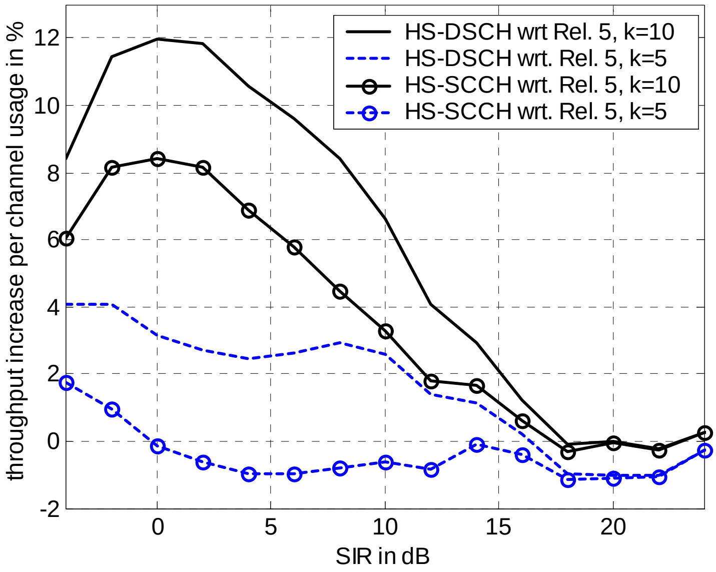


Figure 15: Throughput increase per DL channel usage for NACK & ODM with k=20 (Vehicular A, 30 km/h)

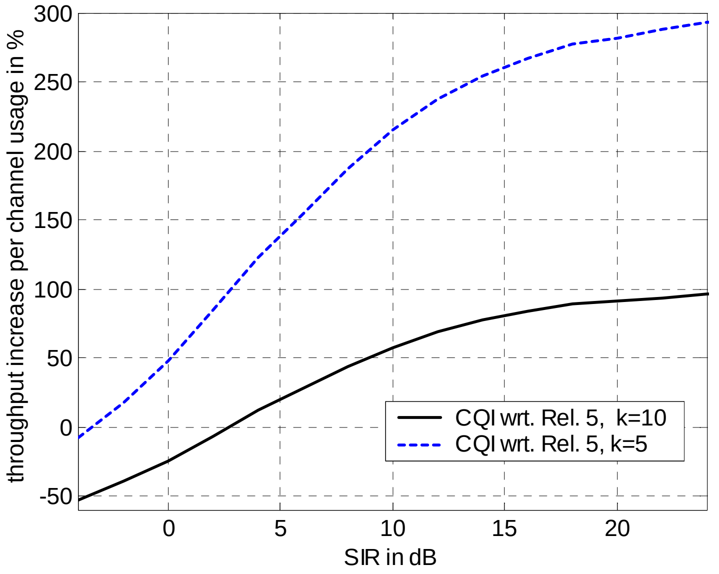


Figure 16: Throughput increase per UL channel usage for NACK & ODM with k=20 (Vehicular A, 30 km/h)

Further results for 3 and 30 km/h UE speed are shown in Figure 17 and 18, respectively. The simulation assumption is shown in Table 3. In case of 3 km/h, the NACK-Based feedback with 40 sub-frames has same performance as periodic feedback with 1 sub-frame reporting. In case of 30 km/h, the NACK-Based feedback with 10 sub-frames has same performance as periodic feedback with 1 sub-frame reporting. According to these results, it is enough to set the value larger than 1 as feedback cycle *k* to get best performance.

Parameter	Explanation/Assumption	Comments
Cellular layout	Hexagonal 19 cells, No Sectors	
Site to Site distance	2800 m	
Antenna pattern	Omni	
Propagation model	$L = 128.1 + 37.6\ Log_{10}(R)$	R in kilometers
Power allocated to HSDPA transmission(HS-PDSCH)	80 % of total cell power	
Slow fading	As modeled in UMTS 30.03, B 1.4.1.4	
Std. deviation of slow fading	8 dB	
Correlation between sites	0.5	
Correlation distance of slow fading	50 m	
Carrier frequency	2000 MHz	
BS antenna gain	0 dB	
UE antenna gain	0 dBi	
UE noise figure		Thermal noise neglected
Max. # of retransmissions	8	Retransmissions by fast HARQ
Fast HARQ scheme	6ch-SAW, Chase combining	MCS can be changed between retransmissions unless same TBS is kept
Specify Fast Fading model	1 path Rayleigh	
# of Ues	20	
# of codes for HS-PDSCH	10	
ACK/NAK repetition	None	
HS-SCCH, HS-DPCCH transmission	Error free	
Channel estimation	Ideal	
CQI transmission delay	1 sub-frame	From measurement to reception at Node-B
Scheduling delay	1.5 slots	From decision at the scheduler to HS-SCCH transmission
Scheduler	Proportional Fairness	
MCS level	QPSK&1/4 (MCS 1), QPSK&1/2 (MCS 2), QPSK&3/4 (MCS 3), 16QAM&1/2 (MCS 4), 16QAM&3/4 (MCS 5)	
Traffic model	Arrival at Node-B every 20 sub-frames, same data size for each packet and each user	
Simulation time	5 sec	Simulation result is averaged by five times

Table 3: Simulation Assumption for Figure 17-20

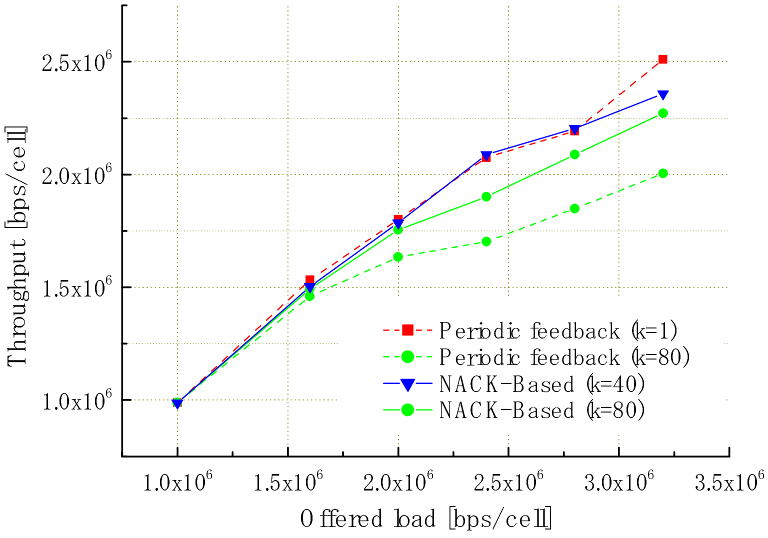


Figure 17: NACK-Based CQI feedback - Throughput performance at 3 km/h

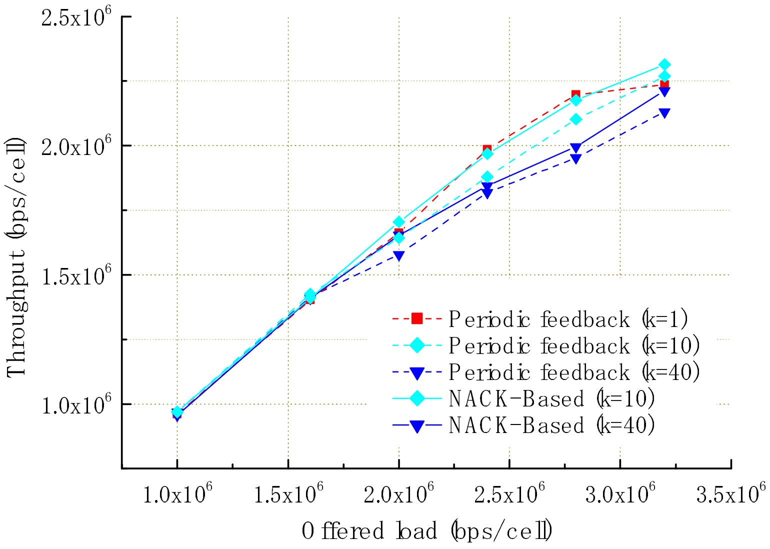


Figure 18: NACK-Based CQI feedback - Throughput performance at 30 km/h

The Figure 19 and 20 show the error probability of the retransmission except the data transmitted with MCS1. From these results, it is understood that suitable MCS is selected for the retransmission by NACK-Based feedback.

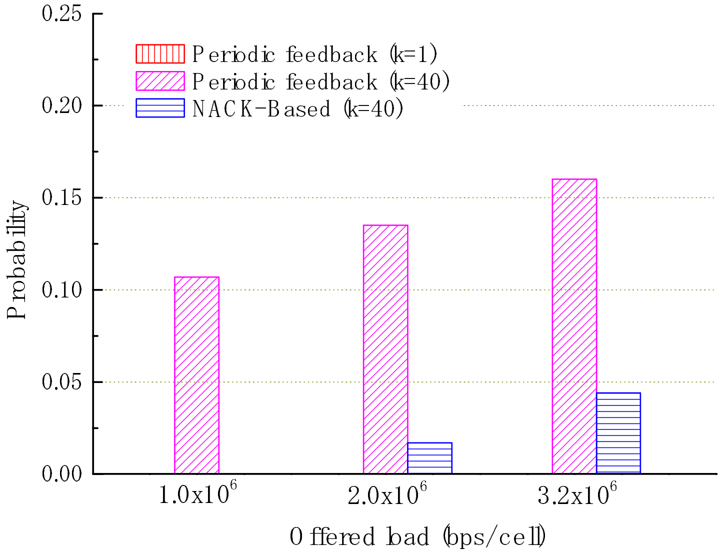


Figure 19: NACK-Based CQI feedback – Retransmission error probability at 3 km/h

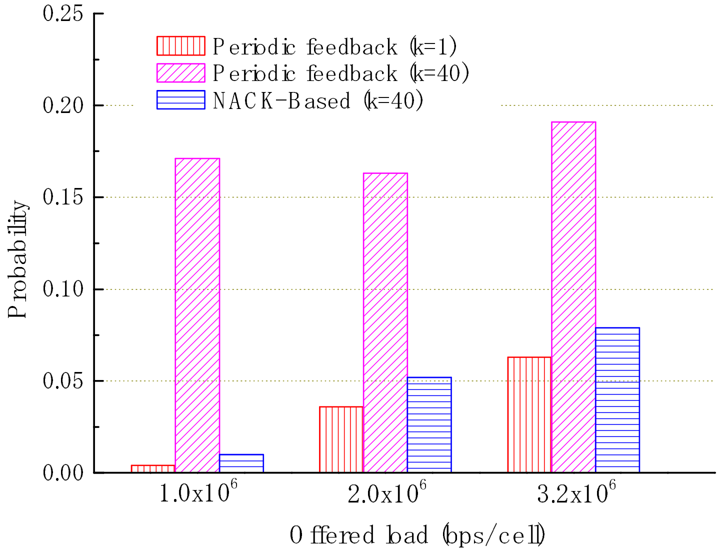


Figure 20: NACK-Based CQI feedback – Retransmission error probability at 30 km/h

Table 4 shows the UL signalling overhead. The value indicates received Eb/Io of UL DPCCH and/or HS-DPCCH for each feedback scheme under the simplifying assumption that the received power of both channels are the same, and that other cell interference is negligible. Some other assumption is shown below. Besides, in case of periodic feedback, all UEs in soft handover area transmit CQI reporting every sub-frame.

According to the Table 4, NACK-Based feedback has about 1 dB gain from periodic feedback.

Assumption
Number of UEs : 100
Percentage of UEs in SHO : 30%

Feedback cycle k [sub-frames]	No feedback	Periodic feedback	NACK-Based feedback	
			M=1*^{2}	M=15*^{2}
40 (1*^{1})	4.13 dB	2.92 dB	4.01 dB	3.95 dB
10 (1*^{1})		2.75 dB	3.7 dB	3.65 dB

Note 1: k=1 for periodic feedback in case of SHO
Note 2: The variable *M* is a number of UEs that receive HS-PDSCH in same sub-frame.

Table 4: Comparison of received Eb/Io

The following Figures illustrate the benefits of reporting an averaged value of CQI.

Figure 21 and 22 show simulation results for a single-path Rayleigh fading channel, in non-SHO, for various values of CQI feedback cycle, *K*, and CQI averaging period, N_{CQI-av}. The offered load and throughput shown are both in terms of user-data.

The derivation of channel quality for scheduling is as described in equation 6.1.1.2 above, using the downlink DPCCH power with a calibration derived from the most recent CQI report. A streaming traffic model and a proportional-fair scheduler are used.

In principle, it may be possible for the Node B to determine the speed of movement (or rate of change of channel) for each UE. In this case the parameters for CQI reporting and the scheduling policy could both be optimised with respect to speed. However, it is also desirable to consider the case where the Node B has no knowledge of the speed of individual UEs. Therefore the following results are for an arbitrary mixture of high and low speeds, where half the UEs have a speed of 3kmph and the other half have a speed of 120kmph.

Figure 21 shows that the total throughput is independent of the CQI feedback cycle, *K*. This confirms that the channel tracking based on power control is effective for long reporting periods. This Figure also shows that increasing the value of N_{CQI-av} from 1 to 40 increases the maximum throughput by about 10%. This benefit is obtained irrespective of the CQI feedback cycle.

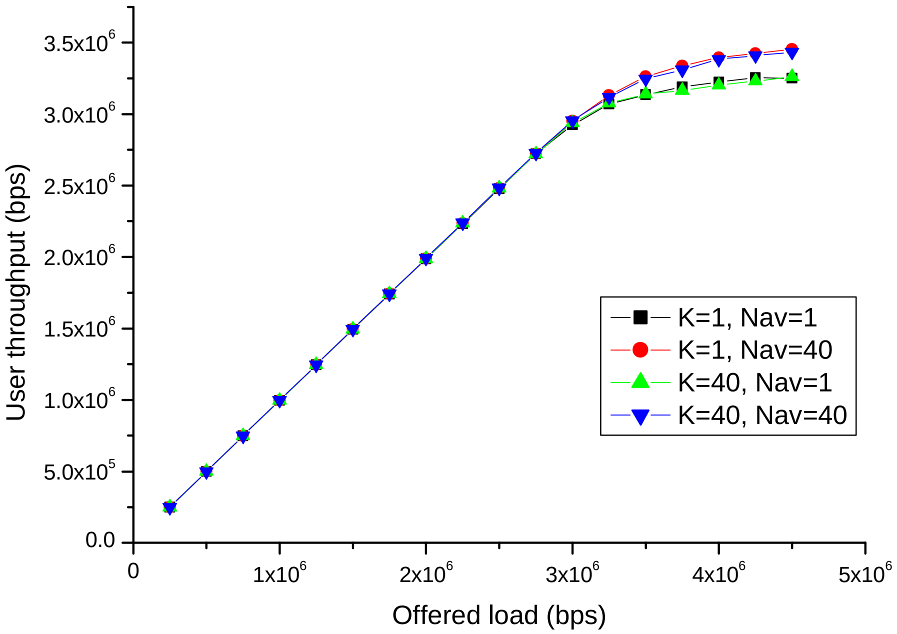


Figure 21: Total throughput, mixed UE speeds, 3km/h and 120km/h, non-SHO

Note that the black and green curves are almost identical, as are the red and blue curves.

Similarly **Figure** 22, shows that the packet delay under the same conditions is substantially independent of the CQI feedback cycle. Increasing the value of $N_{CQI\text{-}av}$ from 1 to 40 reduces the delay, particularly at high loads.

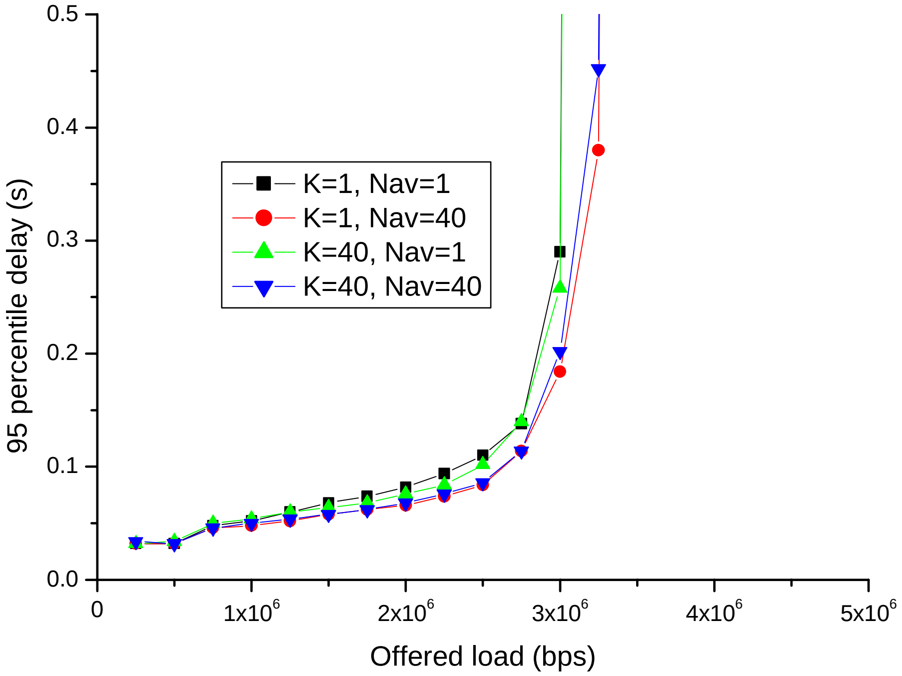


Figure 22: 95 percentile delay, mixed UE speeds, 3km/h and 120km/h, non-SHO

Figure 23 shows simulation results for a Vehicular A channel model for different values of CQI averaging period, N_{CQI-av}. with a CQI feedback cycle, *K* = 40TTIs. The offered load and throughput shown are both in terms of user-data.

The traffic model, scheduler and method for derivation of channel quality for scheduling are all as for Figures 21 and 22.

Figure 23 shows that increasing the duration of the CQI averaging period, N_{CQI-av}, from 1 to 20 TTIs increases the maximum throughput by about 10% in the Vehicular A channel. This benefit is obtained irrespective of the mix of UE speeds, confirming that network knowledge of UE speeds is not necessary in order to benefit from the reporting of an averaged value of CQI.

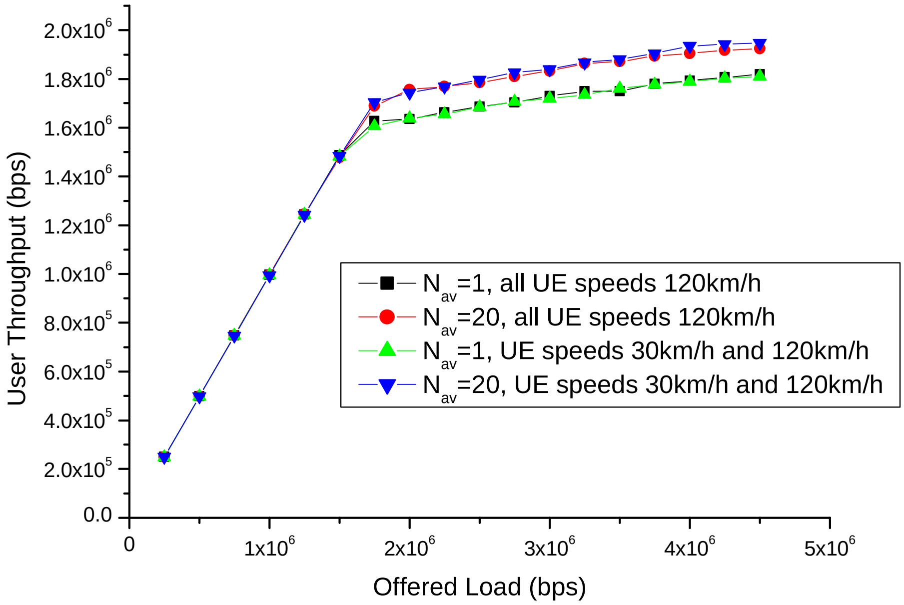


Figure 23: Total throughput in Vehicular A channel, K=40 TTIs

Figure24 and 25 consider the following aspects:

- sensitivity to CQI transmission errors;
- suitable values for $N_{CQI\text{-}av\text{-}subset}$ (the number of the $N_{CQI\text{-}av}$ subframes for which a CQI value is derived at the UE).

Figure24 and 25 show separate results for the following cases:

- a CQI transmission error rate of 0.01;
- CQI reports equal to the average of CQI values relating to every other sub-frame during the $N_{CQI\text{-}av}$ subframe averaging period (i.e. $N_{CQI\text{-}av\text{-}subset} = N_{CQI\text{-}av}/2$).

It can be seen that neither of these factors have any significant effect on performance.

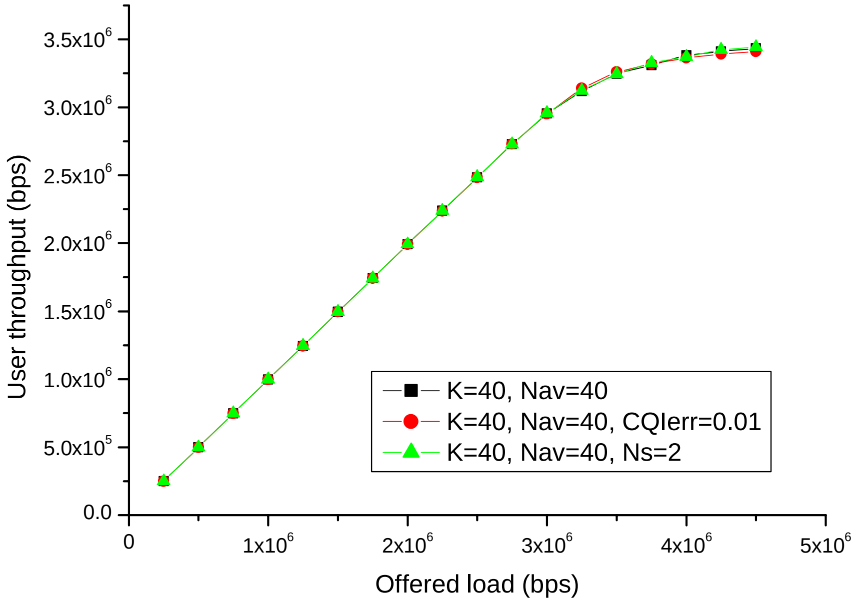


Figure 24: User throughput, mixed UE speeds, 3km/h and 120km/h, non-SHO, CQIerr = Error rate of CQI transmission, Ns = Separation between CQI measurements at UE (in subframes)

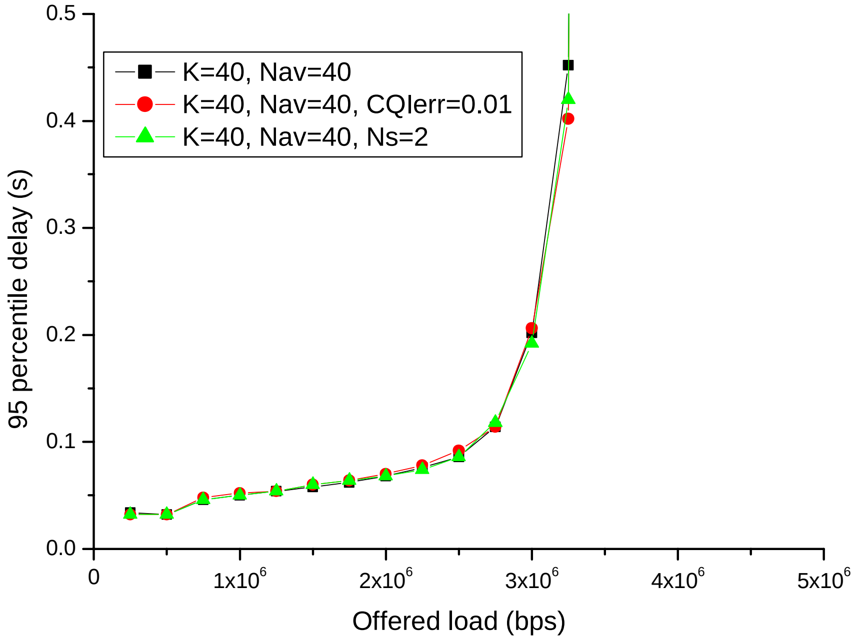


Figure 25: 95 percentile delay, mixed UE speeds, 3km/h and 120km/h, non-SHO, CQIerr = Error rate of CQI transmission, Ns = Separation between CQI measurements at UE (in subframes)

The results presented above show that, when the UE is not in soft handover, increasing the averaging period for CQI reports can increase HSDPA throughput and reduce packet delay, without the Node B having any knowledge of the speed of individual UEs.

The performance of reporting averaged CQI values can also be examined in terms of the RMS error between the channel quality value used for selecting an MCS for an HS-DSCH packet transmission and the actual channel quality during transmission of the HS-DSCH packet. Ideally, this RMS error should be as small as possible.

The following simulation assumptions are used for the evaluation of the RMS error performance:

- Pedestrian A channel model.
- Power-tracking of DL DPCH (with inner loop power control only) used by Node B to interpolate between CQI reports: MCS selection using channel quality derived according to equation 6.1.1.3 with L = 1.
- 3-timeslot delay between choice of MCS and start of HS-DSCH packet transmission.
- 4% error rate (AWGN) on UL TPC commands in non-SHO; 7% error rate on UL TPC commands in SHO.
- Power balancing according to TS25.433 in SHO cases.
- CQI values derived by UE in each subframe and averaged over 1 or 40 subframes
- 1% transmission error rate for CQI reports

The results are shown in Figures 26 and27.

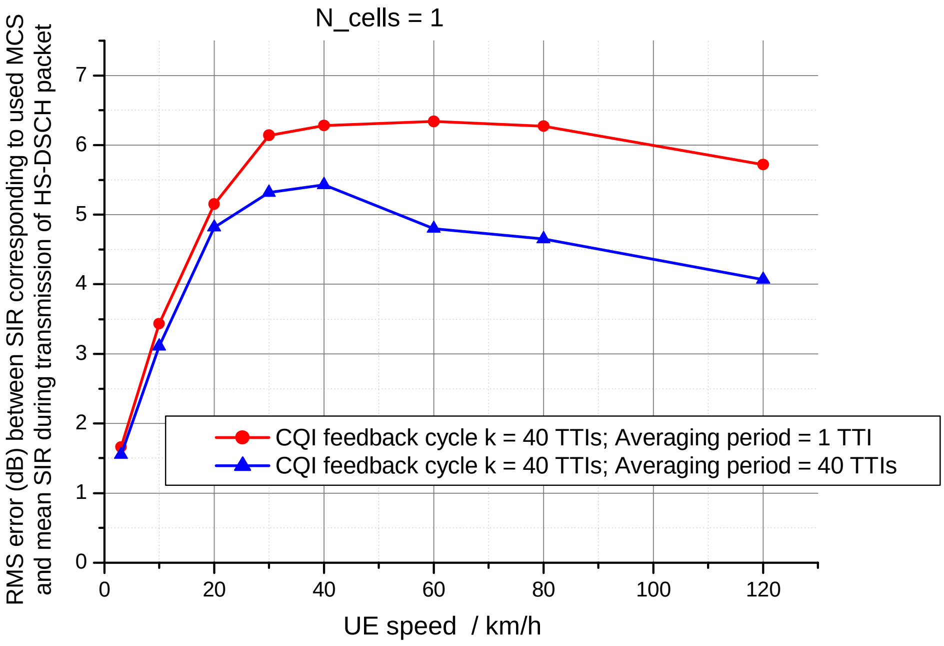


Figure 26: RMS error between SIR used for MCS selection and actual SIR during HS-DSCH transmission (non-SHO)

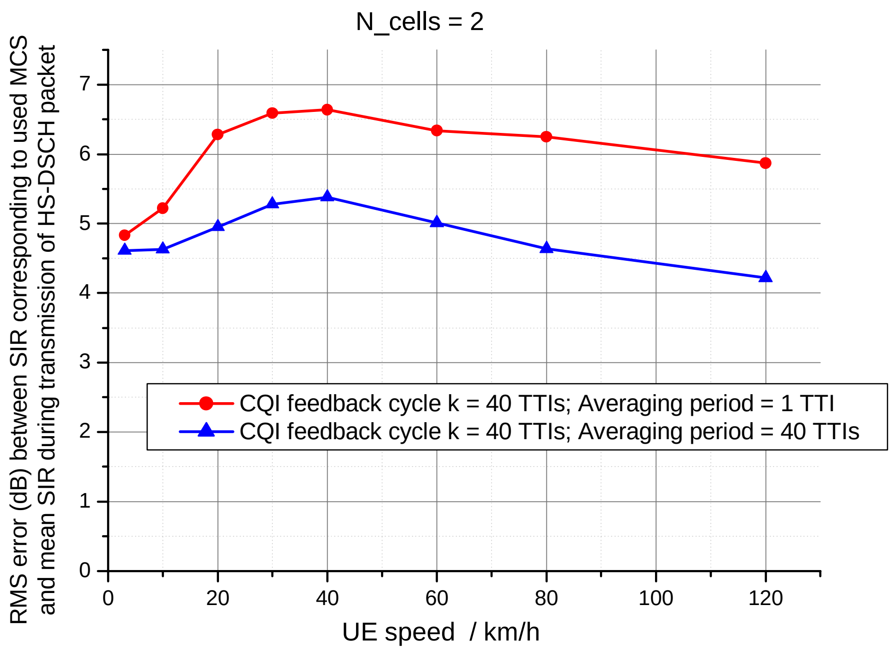


Figure27: RMS error between SIR used for MCS selection and actual SIR during HS-DSCH transmission – Soft handover (2 cells)

The results in Figures 26 and 27 show that when the CQI feedback cycle *k* is 40 subframes, the RMS error in the channel quality value used for MCS selection is significantly reduced (by up to 30% or 1.7dB) when the UE transmits averaged CQI reports is instead of non-averaged CQI reports.

The averaged CQI reports enable the Node B to perform a more accurate calibration of its downlink power level in terms of the most suitable corresponding MCS. This becomes increasingly advantageous as the UE's speed increases.

Note that performance as good as averaging could be achieved if a non-averaged CQI value is reported every subframe, and suitable processing is done by the Node B. However, in this case the performance improvement cannot be achieved without transmitting CQI reports more frequently in the uplink, causing more UL interference and reduced UE battery life. A guide to the reduction in uplink interference which is achieved by reducing the CQI reporting rate is shown in Table 4. Further analysis is FFS.

Averaging at the UE is beneficial in that it enables improved performance to be achieved with reduced-rate CQI reporting. A reasonable upper-bound for the averaging period duration would be the length of the CQI feedback cycle, *k*.

Further simulation results showing the performance of reporting averaged CQI values are given in Figures 28 and 29 for the Vehicular A channel. Other simulation assumptions are as above. The RMS error between the channel quality value used for selecting an MCS and the actual channel quality during HS-DSCH packet transmission should be as small as possible.

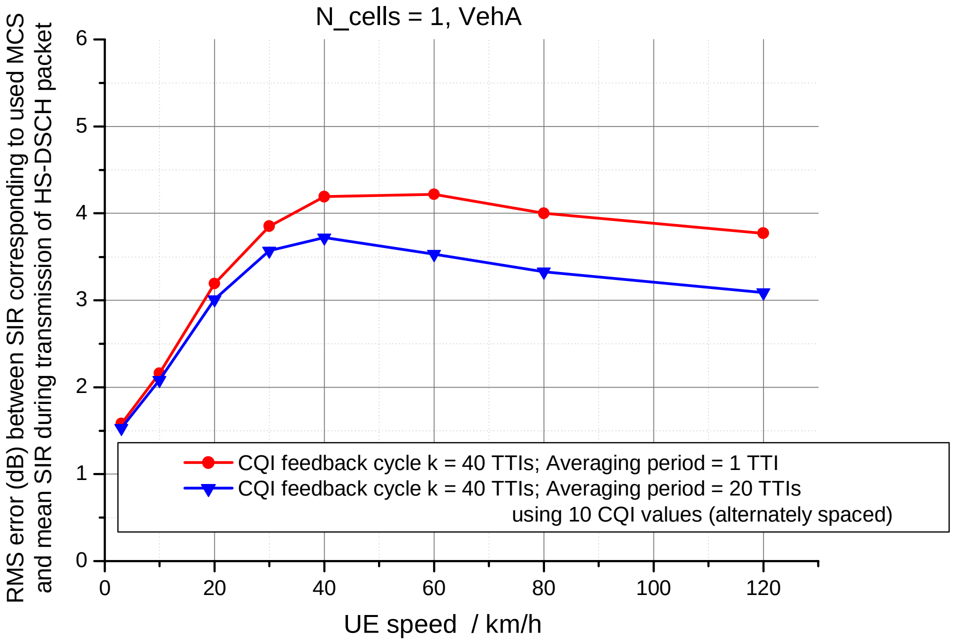


Figure 28: RMS error between SIR used for MCS selection and actual SIR during HS-DSCH transmission – non-SHO, Vehicular A channel model

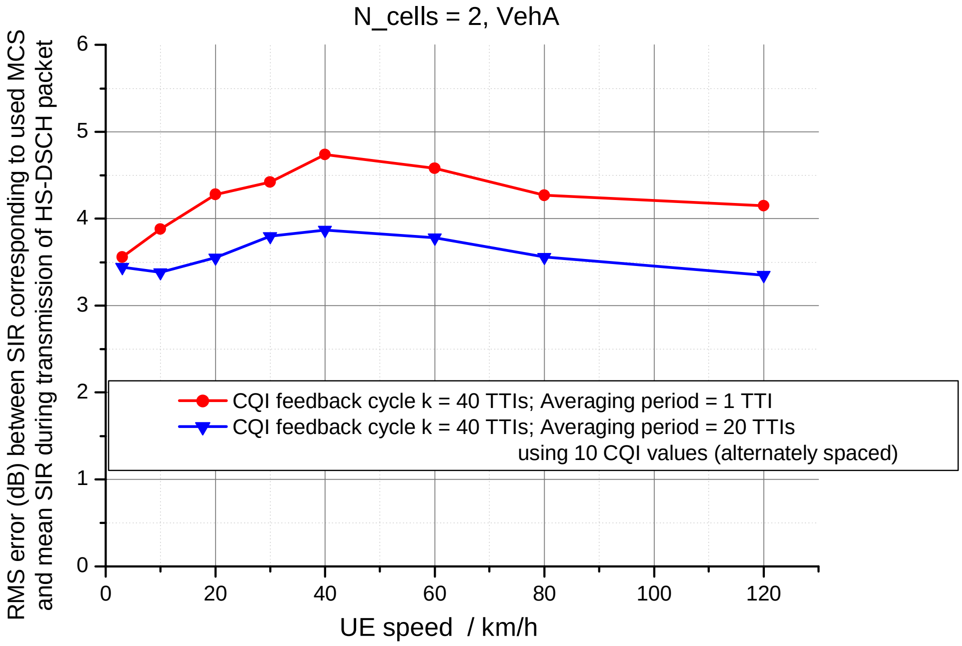


Figure 29: RMS error between SIR used for MCS selection and actual SIR during HS-DSCH transmission – Soft handover (2 cells), Vehicular A channel model

Another case worth examining is that when the Node B's DPCH transmit power reaches its maximum allowed limit at times, and therefore does not always follow accurately the changes in downlink channel quality.

The general assumptions are as above. For the best performance the RMS error between the channel quality estimated at time t_{sched} (using Equation 6.1.1.3) and the average channel quality during the HS-DSCH packet transmission needs to be minimised.

The maximum power limit set for the DL DPCH is varied in order to vary the proportion of the time for which the DPCH is saturated at its maximum allowed transmit power and not responding to the power control commands received from the UE.

The results are shown in **Figure** 30 for a range of UE speeds from 3km/h to 120km/h.

Note that N_av is the CQI averaging period in subframes.

N_rep is the delay from latest CQI report to selecting the MCS; a delay of 40 TTIs from the latest CQI report to selecting the MCS is equivalent to the worst-case delay in the case of a feedback cycle of 40 TTIs, or the average delay in the case of a feedback cycle of 80 TTIs.

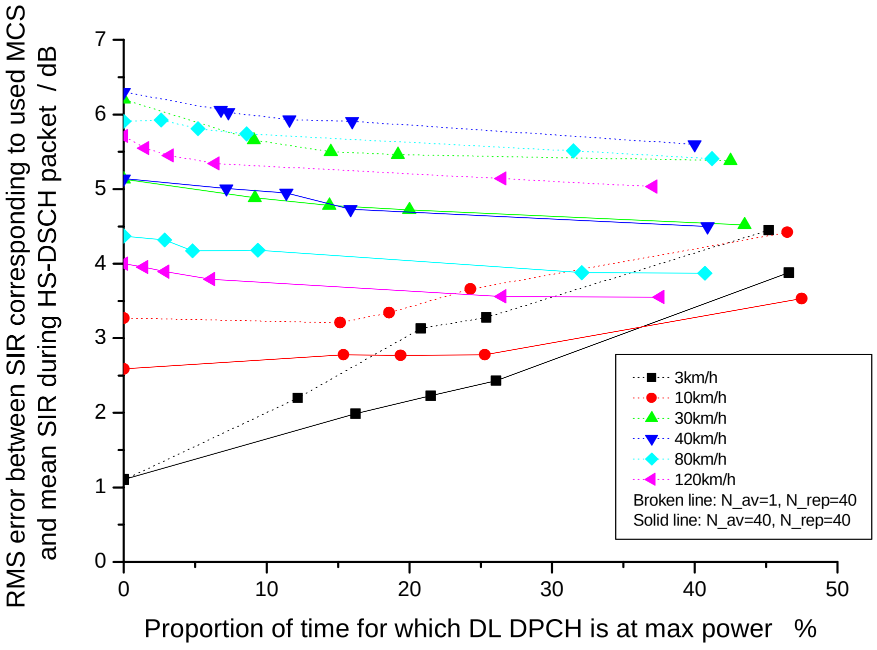


Figure 30: Performance of CQI averaging with DL DPCH power limitation

The results in **Figure** 30 show that the RMS error in the channel quality value used for MCS selection is significantly reduced at all UE speeds when an averaged CQI report is transmitted compared to the case when non-averaged CQI reports are transmitted. This continues to be the case even when the DL DPCH reaches its maximum allowed power for a significant proportion of the time.

Duration of CQI averaging period

The most useful gains from CQI averaging can be achieved with averaging periods considerably shorter than the CQI feedback cycle. This reduces the length of time over which the UE needs to carry out the averaging.

The recommended duration of the CQI averaging period for each value of CQI feedback cycle is shown in Table 5. Note that a CQI averaging period of 1 TTI is identical to the Release 5 CQI reporting scheme.

Table 5: Recommended CQI averaging periods

CQI feedback cycle, *k* (TTIs)	Recommended CQI averaging period (TTIs)
1	1
2	1
4	1
5	1
10	5
20	10
40	20
80	20

As an example for the case of *k* = 40, Figure31 shows that an averaging period of 20 TTIs using 10 CQI values computed in alternate TTIs gives equivalent performance to an averaging period of 40 TTIs.

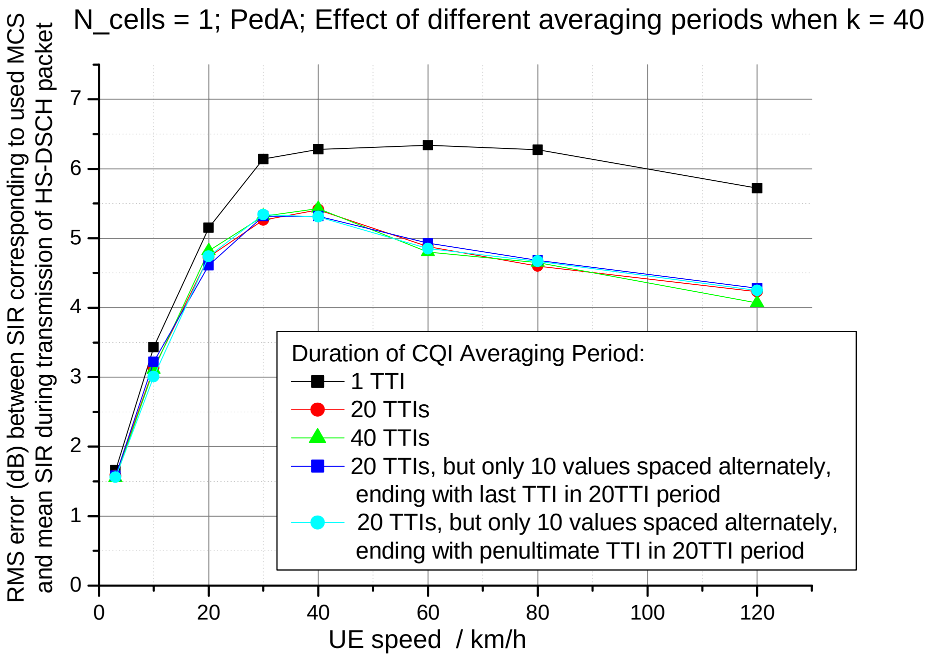


Figure 31: Effect of different CQI averaging periods when CQI feedback cycle k = 40 TTIs

This means that the UE would never need to store more than 10 CQI values for the purpose of averaging.

Other considerations

As stated already above the expected benefits of variable and averaged CQI reporting are improved system performance, a reduced number of retransmissions, improved MCS selection, scheduling and a reduction in UL signalling. However some additional operations compared to Release 5 have to be introduced:

UE side

- The UE transmits CQI reporting not only periodically, but also whenever it receives HS-PDSCH (activity-based), or whenever it receives HS-PDSCH in error (NACK-based) and whenever it receives a fast layer 1 signalling message (ODM).

- In case of using repetition, if the report timings of NACK-based and ODM partially overlap the UE executes only the report which starts first.
- In case of using repetition, if the report timings of periodic scheme and enhanced scheme partially overlap the UE executes only periodic reporting.
- The UE will need to compute an average of CQI values, derived from a stored sequence of no more than 10 values from a period no longer than 20 TTI.
  The UE would only be required to use averaging for regular CQI reports governed by the signalled feedback cycle, and not for any additional “on-demand” or “NACK-based” reports.

Node B side

- In addition to the Release 5 periodic scheme, the Node B receives a CQI field in HS-DPCCH at the same sub-frame as ACK/NACK or NACK and decodes this field always (activity-based) or whenever it detects a NACK (NACK-based).
- In addition to the Release 5 periodic scheme, the Node B receives and decodes the CQI information which is initiated by fast layer 1 requests. Furthermore some additional complexity needs to be added to the scheduler (vendor specific) e.g. a reference implementation may request an additional CQI value using fast signalling on the HS-SCCH only if the last CQI is older than some 10 TTIs and if the waiting data corresponds to more than 6 TTIs according to the current CQI.
- In case of using repetition, the Node B determines when to expect a CQI report by considering whether CQI reports due to periodic, NACK-based and ODM scheme overlap or not.

6.1.1.3 Impacts on other WGs

Basically, it doesn't impact on any other WGs to introduce enhanced CQI reporting. However, if we need the switch to turn these functions on/off, NBAP and RRC signalling may be needed like signalling of feedback cycle *k*. The following specific requirements have been identified:

- For the sake of backwards compatibility (for example if a Release 6 UE is being served by a Release 5 Node B), the use of CQI averaging should be able to be signalled by the UTRAN.

Currently no performance requirements are defined in TS25.101 for CQI reporting using a CQI feedback cycle longer than 2ms. Consequently, the introduction of CQI averaging would have no impact on the current RAN WG4 performance requirements. It is for discussion in RAN WG4 whether an additional performance requirement should be developed for CQI reporting using a feedback cycle longer than 2ms, and if such a performance requirement should also include CQI averaging.

6.2 Dynamic Range Extension for the TDD CQI Report

6.2.1 Features

6.2.1.1 Use of unused CQI values

UE cannot report CQIs that correspond to a code rate greater than unity (since the probability of a transport block error when the HS-DSCH is decoded in isolation would be unity). Since resource-independent transport block size values have been adopted for TDD, this means that the full range of available transport block sizes cannot be signalled for most resource allocations. Indeed, the only case where the full range can be used is if resources that would allow the maximum throughput for the UE class are being used.

It is proposed that these unused CQI values be used to extend the dynamic range of the CQI report. Each transport block size step above that which corresponded to uncoded transmissions (or as near as is allowed by the granularity of available transport block sizes) would represent a step of Δ dB less receive power that the UE could tolerate whist still supporting uncoded transmissions, where Δ is either signalled by the network, or fixed at some appropriate value. Note that the transport block size corresponding to no coding will be different depending on whether QPSK or 16-QAM is recommended by the UE.

6.2.2 Evaluation and Benefits

6.2.2.1 Example

As an example the following case can be considered:

A 2.0 Mb/s capability UE has received a HS-DSCH transmission consisting of 40 codes. The SIR is sufficiently high that it believes that an uncoded 16-QAM transmission could have been supported for that transmission and would have given the highest throughput. The UE would therefore normally report a RTBS index of 56 (corresponding to 6681 bits) and a RMF of 16-QAM, which actually corresponds to a code rate of 0.949. If instead, however, it reported a RTBS index of 57 (7098 bits), this would be interpreted by the NodeB as meaning that uncoded 16-QAM transmissions could be supported with a HS-DSCH power reduction of 0 dB. Similarly, a RTBS index of 58 would be interpreted as meaning uncoded 16-QAM transmissions could be supported with a power reduction of Δ dB, a RTBS index of 59 corresponding to a reduction of 2Δ dB, and so on.

6.2.2.2 Advantages

The advantages of this scheme are as follows:

- Where the UE is reporting a CQI that corresponds to a code rate other than the highest possible code rate, then the Δ parameter does not need to be factored in by the NodeB. In the event that the NodeB wishes to continue using the current transmit power, it does not have to re-interpret the reported CQI. Any existing scheme for deriving the CQI is thus unaffected. Since this will be the normal case, this is a significant advantage over a scheme using the equivalent FDD “Γ” parameter.
- If it is desired to power control the HS-DSCH, the reported tolerable power offset can be used directly for this, rather than the NodeB having to interpret the reported CQI for the signalled value of Γ.
- Most likely, a value for Δ (e.g. 1 dB) can be specified rather than being signalled. Hence the NodeB would not have to determine what would be an appropriate value for the current channel conditions.

6.2.2.3 Disadvantages

The disadvantages are as follows:

- Where the full throughput of the UE class is being utilised, then no spare RTBS values remain to allow power offsets to be signalled.

6.3 Multiple Simultaneous Transmissions to a UE in an HSDPA Subframe

6.3.1 Features

Multiple simultaneous transmissions are performed using different HARQ processes. For example, in a given HSDPA subframe, retransmission on HARQ process #1 and a new transmission on process #2 may be performed to the same UE if this flexibility is introduced. Another example is the simultaneous retransmissions of pending blocks on HARQ process #2 and HARQ process #4. For each of the transmissions to the same UE within the same subframe, there will be a corresponding HS-SCCH transmission. Each HS-SCCH will carry the control information pertinent to only one of the HARQ processes and therefore there would be no change to the current HS-SCCH specifications.

In order to support such a feature, the UE will now need to be able to decode Part II of more than one HS-SCCH simultaneously. (Recall that, currently, the UE will anyway have to decode Part I of all HS-SCCHs that are configured for it.) If Part I “passes” (based on whatever soft metric the UE uses) for more than one HS-SCCH, then the UE will proceed to decode Part II for those HS-SCCHs. Also, the UE will begin to buffer data on the codes corresponding to the codes signalled on all the HS-SCCHs that passed. Upon decoding Part II of the HS-SCCHs, the UE will know the correspondence between codes and HARQ process and appropriate HARQ combining with any previous transmissions and Turbo decoding may follow. The UE complexity in terms of number of codes on which it can receive transmission and the total number of bits it can buffer can be adhered to as in Release 5. For example, a UE that is only 5-code capable can still use the feature as long as the sum of the codes used for each of the simultaneous transmissions is less than or equal to 5. Similarly, the UE buffer limitations are met if the sum of the coded bits sent on all the simultaneous transmissions is less than the UE buffer capacity. The UE will need to be capable of feeding back more than one ACK or NACK to the Node B simultaneously. The exact mechanism of signalling the multiple ACK/NACKs, as well as the uplink interference generated due to such signalling and its reliability, is for further study.

The Node B scheduler can currently (Release 5) transmit to more than one user simultaneously via code division multiplexing. Adoption of this feature by a Node-B will imply that it can also schedule simultaneous transmissions to the same UE within a TTI. For each user that is scheduled simultaneously, transmission attributes (e.g. HARQ process, TFRI, codes, etc.) are selected in a manner consistent with the UE category. In particular, if the Node-B chooses to schedule simultaneous transmissions to a UE, it will have to ensure that the transmissions are within the permissible capabilities (such as code capability, buffer limitations, etc.) of the UE. The Node-B will also have to be able to detect feedbacks with multiple simultaneous ACKs or NACKs. Note that, in Rel’5, the Node B scheduler has to ensure that once a UE is selected on one HARQ process in a subframe, it cannot be selected again on another HARQ process for that subframe. With the introduction of this feature, this restriction on the scheduler is removed.

6.3.2 Evaluation and Benefits

An evaluation of the benefits, as also that of a possible increase in UE or Node-B complexity, is FFS.

6.3.3 Impacts on other WGs

The introduction of such a feature may require the introduction of multiple CCTrCHs. This, as also additional impacts, is FFS.

6.4 Code Reuse for Downlink HS-DSCH

6.4.1 Features

The Release-5 specifications allow the OVSF code space to be expanded through the use of one or more Secondary Scrambling Codes (SSCs). Two possible code reuse techniques that explore both the use of SSCs and/or multi-antenna scheduling techniques to achieve effective management of resultant interference are outlined here.

6.4.1.1 Partial Code Reuse

In this scheme, only the codes set aside for HSDPA are candidates for reuse (Figure 32). Reusing the codes set aside for dedicated channel users is not an option on account of the cross interference. This approach does not expand the code space to the maximal extent but has the advantage of maintaining orthogonal transmissions to the dedicated channel users, thereby leaving the interference to them unchanged. The basic transmission approach suggested here is to simultaneously schedule data intended for different UEs by utilizing two transmit antennas and reusing the available OVSF space for HSDPA UEs. The fundamental principle exploited in the simultaneous scheduling of multiple users with code reuse is to ensure that users selected on each antenna have good “cross-antenna rejection”, i.e., a user scheduled on antenna 1 has a strong channel from that antenna and a comparatively weak channel from antenna 2. Users on antenna 2 are selected in the same manner. This will keep the cross interference experienced by each user low. With sufficient load, pairs of users that satisfy this condition can be found in the cell with high probability. The power distribution across the two antennas can be performed in a number of ways. A useful method is to split the total cell power equally across the two antennas (in a manner similar to STTD and CLTD Mode-1).

Changes to CQI measurement and reporting procedures by the UE may be required for specific proposals aimed at partial code reuse, and is for further study.

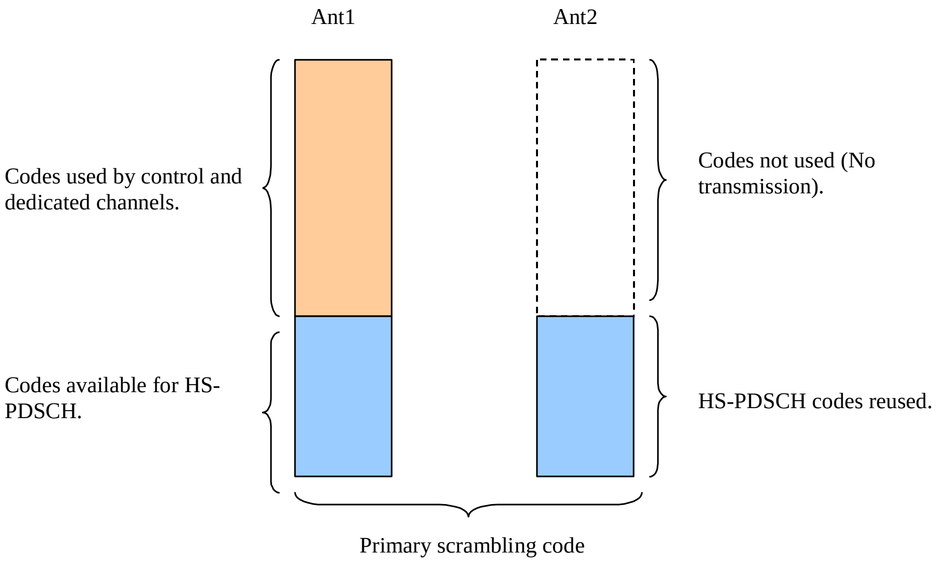


Figure 32: Partial Code Reuse Scheme.

6.4.1.2 Full Code Reuse

If a secondary scrambling code is activated, then the entire OVSF code space on the SSC is available. So HSDPA users can be scheduled on a part of the Primary Scrambling Code (PSC) space originally assigned and the *entire SSC code space*. The introduction of a SSC allows full reuse of the OVSF code space and can be achieved in the following ways:

1) Introduction of SSC on Same Antenna(s) as PSC: The use of a SSC on the same antenna(s) as a Primary Scrambling Code (PSC) may lead to excessive interference to UEs on both the PSC and the SSC since the instantaneous channel gains on the desired signal and interference components are perfectly correlated. Multi-user detection techniques can be applied to cancel out the resulting interference, albeit at the cost of additional UE complexity.

2) Introduction of Antenna Specific SSC: This allows cross antenna interference rejection through scheduling, in a manner similar to that in 6.4.1.1above, in addition to the interference rejection benefits of the SSC itself.

Although dedicated channel users on the PSC get the processing gain benefit in rejecting SSC interference, unlike in 6.4.1.1, some additional interference due to the SSC cannot be avoided. This increase in interference will therefore have to be offset by increasing the power allocation to dedicated channel users. Although this does result in a reduction in the overall power fraction left for the data users, the increase in the code space available due to the introduction of the SSC still results in system capacity improvement in code-limited situations.

Changes to CQI measurement and reporting procedures by the UE may be required for specific proposals aimed at full code reuse, and is for further study.

6.4.2 Evaluation and Benefits

FFS

6.4.3 Impacts on other WGs

FFS

6.5 Fast Signalling between Node-B and UE

6.5.1 Features

In the Release-5 specifications, the UE can be signalled about MAC-hs and control channel reconfiguration through RRC signalling. However, the RRC signalling is slow due to delays in the radio access network and use of longer TTI for transmission. Therefore, fast signalling schemes that allow Node-B to signal various information like control channel reconfiguration and power offsets over the air interface to the UE, may help to reduce the delays involved due to RRC signalling between UE and RNC. Such fast signalling may allow for faster adaptation to changing resources (e.g., power availability, etc.) at the Node-B or UE. Examples of these parameters include:

1) HS-SCCH set to be monitored

2) Repetition factor of ACK/NACK: N_acknack_transmit

3) Channel Quality Indicator (CQI) feedback cycle *k*.

4) Repetition factor of CQI: N_cqi_transmit

5) Measurement power offset Γ

Moreover, information about configuration and reconfiguration of the number of HARQ processes can be carried using fast signalling. Similarly, information about the maximum number of HARQ retransmission attempts can also be signalled using fast signalling.

Fast signalling messages can be carried on, e.g., the HS-SCCH. Since HS-SCCH uses 2.0ms subframe and UE is monitoring HS-SCCH in every subframe, it provides a fast way of signalling HSDPA related physical layer and MAC-hs, which are currently signalled through higher layer signalling, to the UE.

The exact mechanism used for fast signalling using HS-SCCH is for further study. For example, the UE ID field can be extended in order to include fast message identifiers. In this case, the UE ID and signalling message identifier share the same ID space. When a UE sees an identifier specific to a signalling message, it will interpret the contents of the HS-SCCH accordingly. The UE ID field can be used for both the dedicated signalling messages and common signalling messages. For common signalling purpose, a single ID can be used to identify the signalling message sent to multiple UEs. Alternately, one of the values in the redundant area of the channelization code-set mapping can be used to indicate to the UE that the data on the HS-SCCH is a fast signalling message. The 29 information bits in Part II of the HS-SCCH is then used to signal the message identifier and its corresponding value.

The MAC-hs signalling entity can be part of the scheduling/priority handling functionality in the MAC-hs as shown in Figure 33.

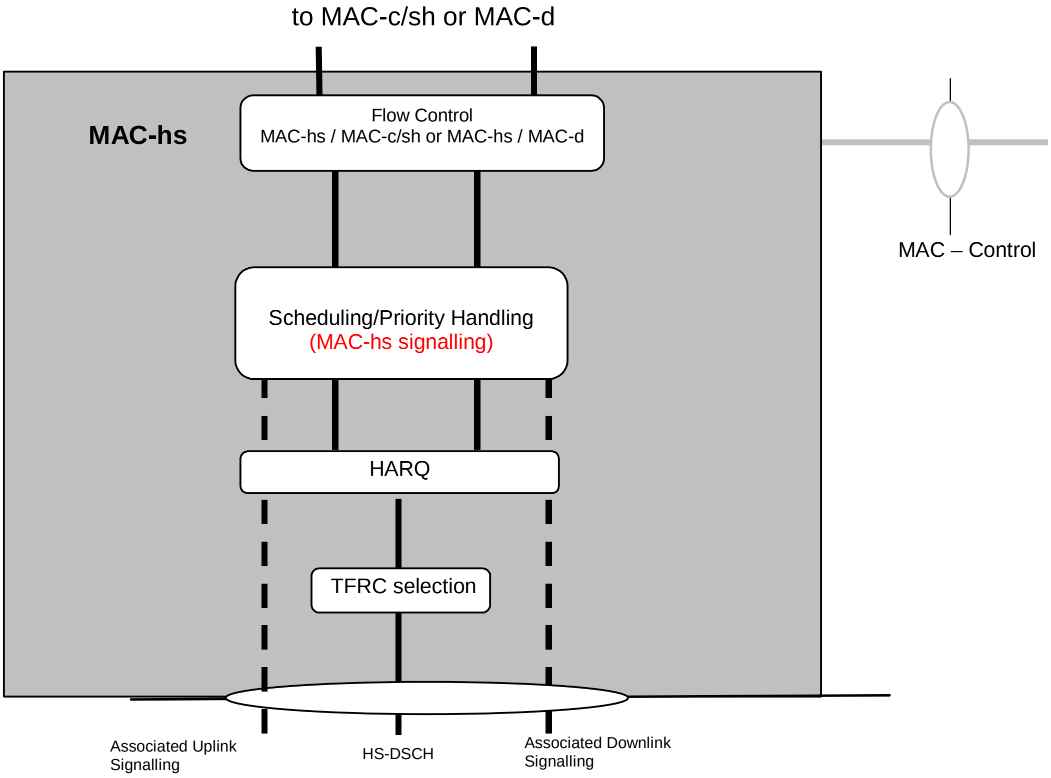


Figure33. MAC-hs function.

6.5.2 Evaluation and Benefits

FFS

6.5.3 Impacts on other WGs

FFS

6.6 Fast Adaptive Emphasis

6.6.1 Features

A UE receiving HSDPA service will be able to work under the condition of Fast Adaptive Emphasis when it uses closed loop transmission diversity and has an associated DPCH in soft handover.

The method works by making the UE compute the FBI information, used to control the transmission diversity weights located in the node-Bs, with different aims depending on whether there is or there is not packet activity on the HS-PDSCH for that UE. After that, the FBI information is transmitted according to Release 5 specifications.

More precisely the behavior is the following.

- If the UE detects control information directed to it in one of the monitored HS-SCCH channels, then it begins computing the FBI information in order to maximize the power received only from the HSDPA serving cell.

- On the other hand, if the UE does not detect information directed to it on the HS-SCCH channels during N_{TTI} sub-frames (where N_{TTI} is the minimum inter-TTI distance managed by the UE), then it begins computing the FBI information in order to maximize the total power received from all the cells in the active set.

Using the above adaptive method, the gain of transmission diversity for HSDPA is expected to be similar to the gain in non soft handover region, so that a seamless service can be offered. And at the same time, the impact on the DPCH is reduced with respect to the case of using a not-adaptive emphasis method.

6.6.2 Evaluation and Benefits

FFS

6.6.3 Impacts on other WGs

FFS

6.7 ACK/NACK Transmit Power Reduction for HS-DPCCH with preamble and postamble

6.7.1 Features

The technology for ACK/NACK Detection Threshold Reduction helps the Node B to distinguish between DTX and ACK on the HS-DPCCH without requiring a large ACK transmit power.

6.7.1.1 Summary of technology

This technology uses 4 codewords in the ACK/NACK field, with the ACK and NACK codewords being identical to those used in Release 5.

ACK: 1 1 1 1 1 1 1 1 1 1

NACK: 0 0 0 0 0 0 0 0 0 0

PREAMBLE (”PRE”): 0 0 1 0 0 1 0 0 1 0

POSTAMBLE (”POST”): 0 1 0 0 1 0 0 1 0 0

For the first HS-DSCH TTI in each packet-burst, the UE transmits a PRE codeword in an HS-DPCCH HARQ-ACK field when it detects the HS-SCCH control information, prior to transmitting the HARQ-ACK message. This gives the Node B a minimum of 2 TTIs in which to detect DTX, instead of only 1.

After the UE has transmitted a HARQ-ACK message, the UE usually transmits a POST message in the following HARQ-ACK field, unless another HS-DSCH packet is detected in either of the next 2 valid corresponding subframes.

The exact circumstances in which a UE transmits the PRE and POST codewords depend on the current value of the repetition parameter *N_acknack_transmit* and the UE capability *InterTTI*, and are described in more detail in the following section.

6.7.1.2 Details of technology

a) With single ACK/NACK transmission (i.e. no repetition, *N_acknack_transmit* = 1)

Figure 34 shows the behaviour for the case when *N_acknack_transmit* = 1. For clarity, the HS-DPCCH and HS-SCCH sub-frames corresponding to the HS-DSCH sub-frame “N” are both given the same sub-frame designation, “N”.

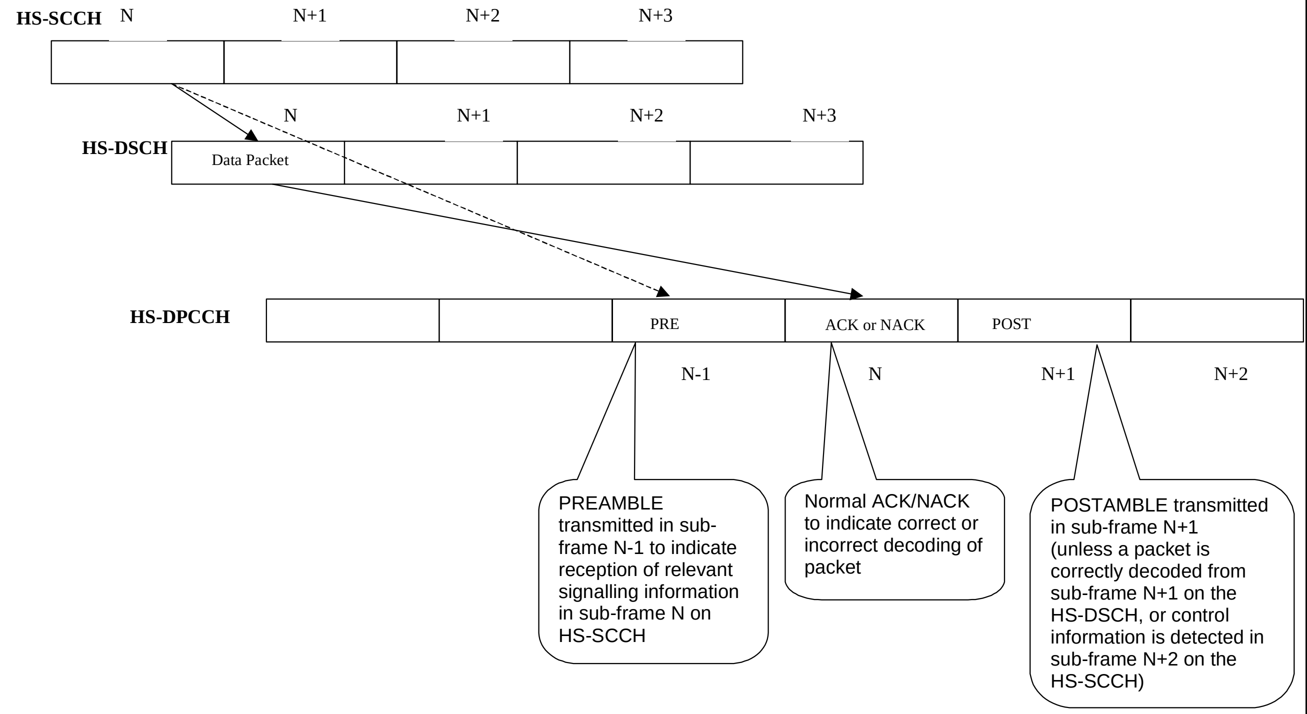


Figure 34: Scheme operation when N_acknack_transmit = 1

The two parts of this scheme are as follows:

- When the UE detects control information for it in sub-frame N on the HS-SCCH, the UE transmits a preamble (PRE) in sub-frame N-1 on the HS-DPCCH (unless an ACK or NACK is to be transmitted in sub-frame N-1 as a result of a packet in an earlier sub-frame on the HS-DSCH);
- After decoding the HS-DSCH packet and transmitting the hybrid ARQ ACK/NACK in sub-frame N on the HS-DPCCH, if the UE's InterTTI capability is 1 the UE transmits a postamble (POST) in sub-frame N+1 on the HS-DPCCH (unless a packet is detected in sub-frame N+1 on the HS-DSCH in which case ACK/NACK is sent, or HS-SCCH control information is detected in subframe N+2 in which case PRE is sent).

(Note that if the UE's InterTTI capability is > 1, there is no need to transmit the POST in sub-frame N+1, because an HS-DSCH packet could not be received in sub-frame N+1 on the HS-DSCH.)

In sub-frames N+2 onwards on the HS-DPCCH, the UE goes back to using DTX in the ACK/NACK field (unless new relevant control information is detected on the HS-SCCH).

The operation of the scheme is further illustrated in the State Diagram in **Figure** 35. The labels on the state-transition arrows show the signal which is sent when the given state transition occurs.

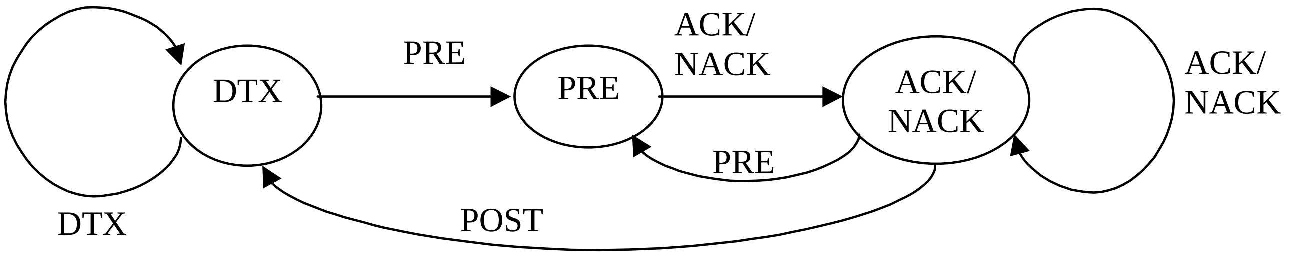
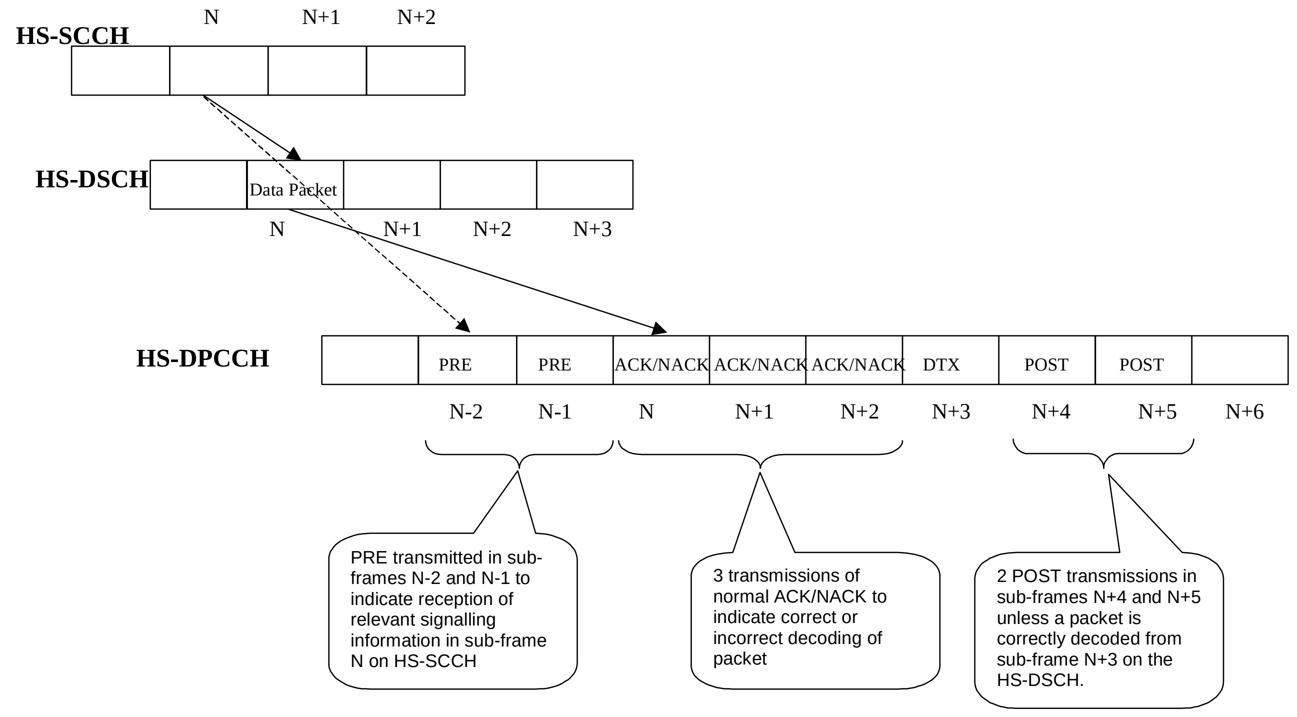


Figure 35: State diagram of scheme for ACK detection threshold reduction

b) With repetition of ACK/NACKs (i.e. when N_acknack_transmit > 1)

Figure 36 shows the behaviour when N_acknack_transmit > 1, for the specific example of N_acknack_transmit = 3.



PRE transmitted in sub-frames N-2 and N-1 to indicate reception of relevant signalling information in sub-frame N on HS-SCCH

3 transmissions of normal ACK/NACK to indicate correct or incorrect decoding of packet

2 POST transmissions in sub-frames N+4 and N+5 unless a packet is correctly decoded from sub-frame N+3 on the HS-DSCH.

Figure 36: Scheme operation when N_acknack_transmit > 1 (3 in this example)

Two slight modifications are made compared from the behaviour when N_acknack_transmit = 1:

- When the UE detects control information for it in sub-frame N on the HS-SCCH, the UE transmits a PRE in sub-frame N-2 as well as sub-frame N-1 on the HS-DPCCH (unless an ACK/NACK is transmitted in these sub-frames as a result of an earlier packet on the HS-DSCH);

  (Note that the UE never transmits a PRE earlier than sub-frame N-2 in response to detecting control information on the HS-SCCH even if N_acknack_transmit = 3 or 4).

- After decoding the HS-DSCH packet the UE transmits the hybrid ARQ ACK/NACK in sub-frames N to N+N_ack_transmit-1 on the HS-DPCCH (as currently specified).

- If the UE's InterTTI capability is ≤ N_acknack_transmit then the UE does the following:
  - transmit a HARQ Postamble (POST) in the slot allocated to HARQ-ACK in HS-DPCCH subframe $n + 2{*}\mathit{N\_acknack\_transmit} - 1$, unless an ACK, NACK or PRE is to be transmitted in this subframe, and
  - if $\mathit{N\_acknack\_transmit} > 1$, transmit a HARQ Postamble (POST) in the slot allocated to HARQ-ACK in HS-DPCCH subframe $n + 2{*}\mathit{N\_acknack\_transmit} - 2$, unless an ACK, NACK or PRE is to be transmitted in this subframe.

Note that no more than two POST's may be transmitted following detection of control information on the HS-SCCH, DTX being used in when there is nothing to send in the intervening sub-frames, as shown in the example in **Figure** 36.

In sub-frames N+2*N_acknack_transmit onwards on the HS-DPCCH, the UE goes back to using DTX in the ACK/NACK field (unless new relevant control information is detected on the HS-SCCH).

6.7.2 Evaluation and Benefits

6.7.2.1 Simulation assumptions

The following simulation assumptions are used for this evaluation:

2GHz carrier frequency
Pedestrian A channel – Rayleigh fast fading, classical Doppler spectrum, no shadowing
Rx diversity at Node B: 2 uncorrelated antennas
Channel estimation: 3 slots up to 40km/h, 1 slot at higher speeds
4% error rate (AWGN) on DL TPC commands
UL power control step size 1dB, algorithm 1
UL DPCCH SIR target set to give 4% TPC error rate; same SIR target in SHO as for non-SHO.
Interference in UL modelled as AWGN
Static ACK/NACK decision threshold
Average HS-SCCH failure rate = 0.01.

6.7.2.2 Performance targets

We consider two sets of performance targets, referred to here for simplicity as the “Tight Requirements” and “Relaxed Requirements” as follows:

Tight requirements without PRE/POST:

P(ACK->NACK) ≤ 0.01 (where the notation “P(ACK->NACK)” refers to the probability that a transmitted ACK is decoded as a NACK.)
P(NACK->ACK) ≤ 0.0001
P(DTX->ACK) ≤ 0.01

Tight requirements with PRE/POST:

P(ACK -> (NACK or PRE or POST)) ≤ 0.01
P(NACK -> ACK) ≤ 0.0001
P((PRE or POST or DTX) -> ACK) ≤ 0.01

Relaxed requirements without PRE/POST:

P(ACK->NACK) ≤ 0.01
P(NACK->ACK) ≤ 0.001
P(DTX->ACK) ≤ 0.1

Relaxed requirements with PRE/POST:

P(ACK -> (NACK or PRE or POST)) ≤ 0.01
P(NACK -> ACK) ≤ 0.001
P((PRE or POST or DTX) -> ACK) ≤ 0.1

The Relaxed Requirements are generally considered sufficient for “difficult” radio conditions such as high speeds or SHO.

6.7.2.3 Simulation Results

6.7.2.3.1 Soft Handover

Figure37 shows simulation results for SHO with N_acknack_transmit = 2 for the Relaxed Requirements. For the PRE/POST scheme, two different HS-DSCH traffic loadings (20% and 80%) are shown, as this affects the ratio between packets which are first in a burst and those which are immediately preceded by other packets. The traffic model used specifies the probability of a packet being sent to the UE in any given sub-frame. No correlation is assumed between packet transmissions.

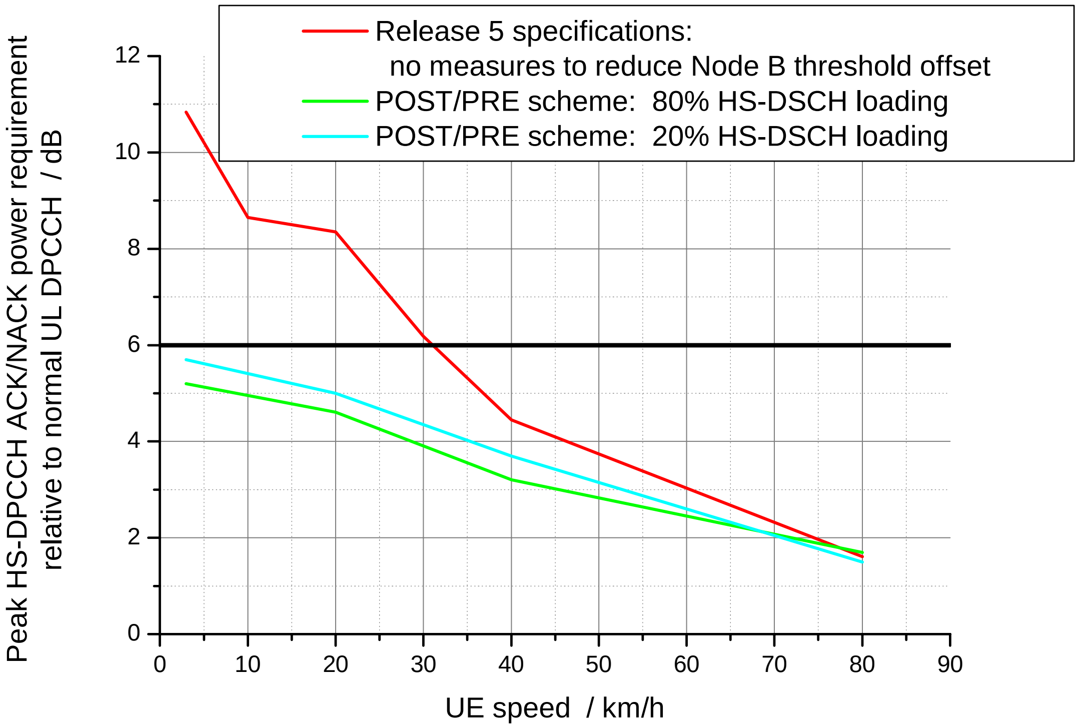


Figure37: SHO, Relaxed Requirements, N_acknack_transmit = 2

It can be seen from **Figure**37 that the PRE/POST scheme meets the Relaxed Requirements at all UE speeds and at both high and low loadings, without requiring a larger HS-DPCCH power offset than can be signalled according to the Release 5 specifications (where the maximum offset is 6dB).

Figure 38 shows the power required to meet the Tight Requirements with N_acknack_transmit = 2.

It can be seen from **Figure** 38 that the PRE/POST scheme can even meet the Tight Requirements in SHO at UE speeds above about 45km/h (where the effect of time-diversity is greater relative to the fading rate), although this may not be a necessary requirement.

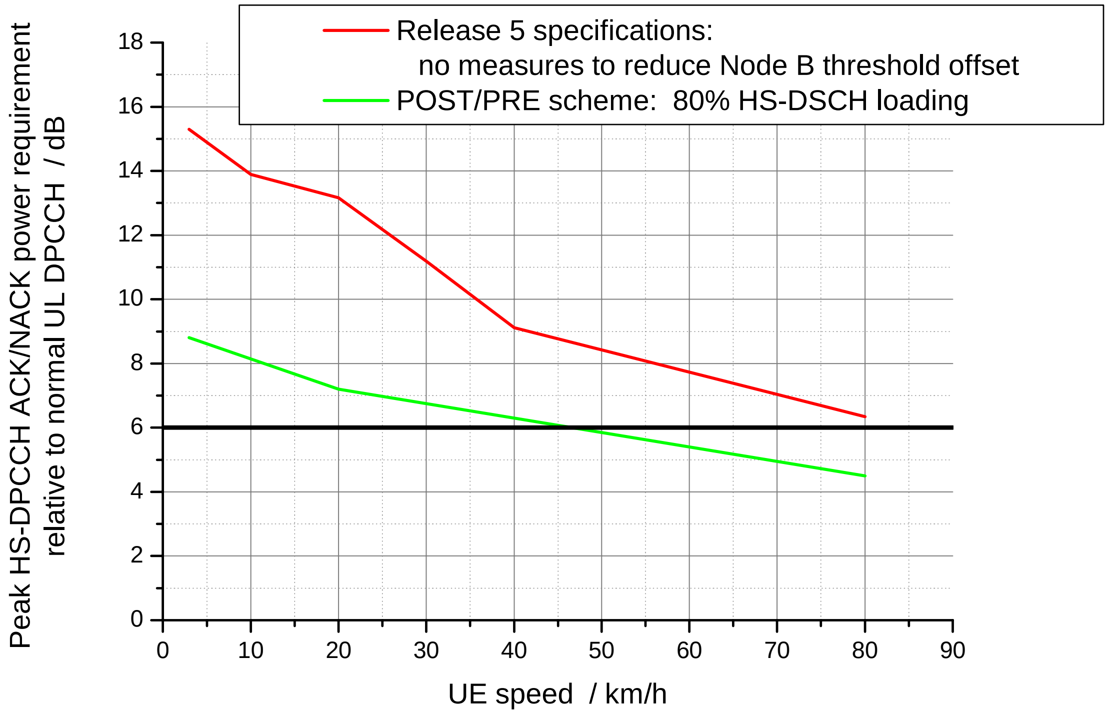


Figure 38: SHO, Tight Requirements, N_acknack_transmit = 2

6.7.2.3.2 Non Soft Handover

The PRE/POST scheme also gives benefit in non-SHO situations, as shown in **Figure** 39 for the Tight Requirements, with N_acknack_transmit set to 1.

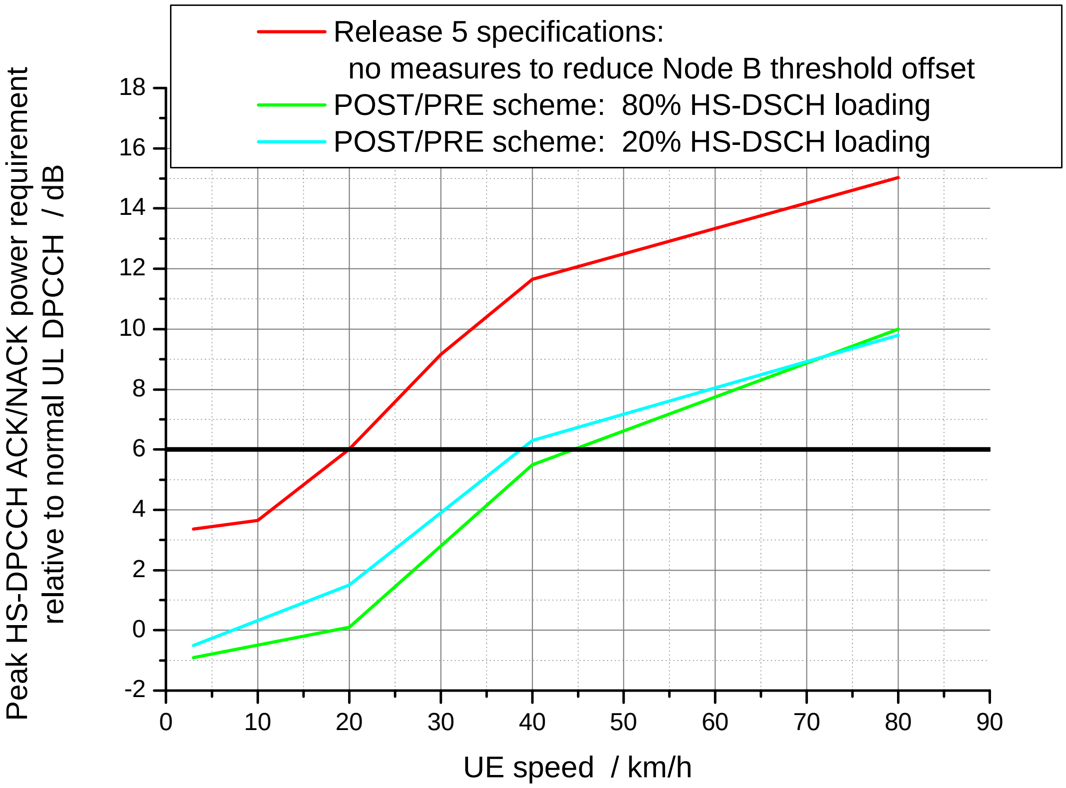


Figure 39: Non-SHO, Tight Requirements, N_acknack_transmit = 1

It can be seen from **Figure** 39 that the PRE/POST scheme enables the Tight Requirements to be met at speeds up to 40km/h, instead of only 20km/h with the Release 5 specifications.

Figure 40 shows the power requirements for the Relaxed Requirements. It can be seen that the PRE/POST scheme enables the Relaxed Requirements to be met at all UE speeds, without requiring the use of repetition. (By contrast, the Release 5 specifications would need the use of repetitions at UE speeds higher than about 35km/h in order to meet the Relaxed Requirements).

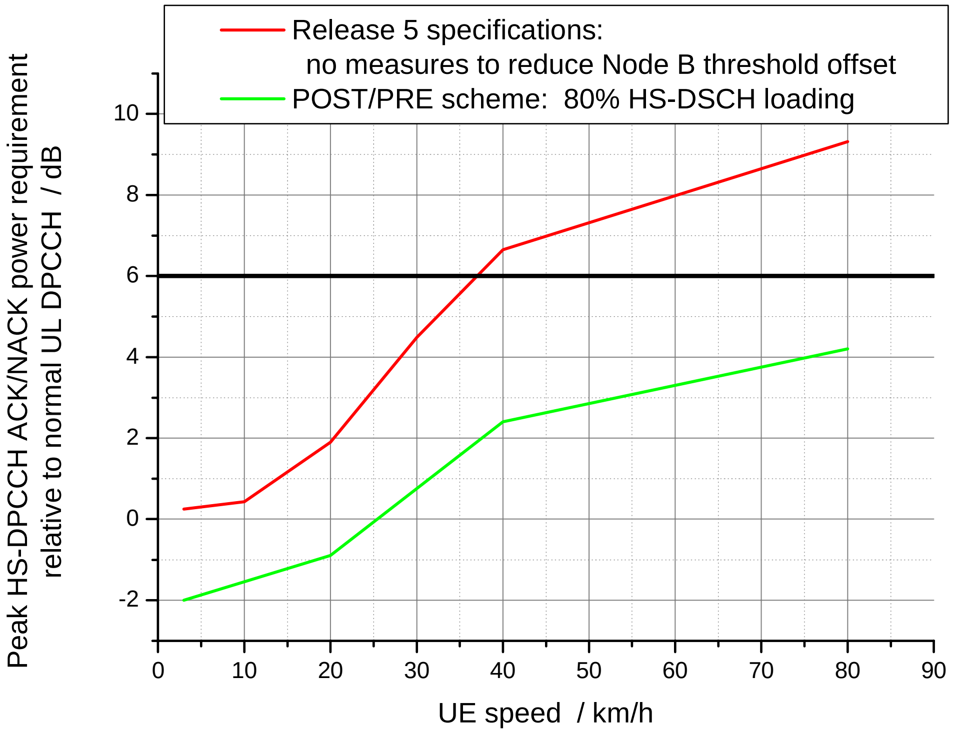


Figure 40: Non-SHO, Relaxed Requirements, N_acknack_transmit = 1

In addition to improving the decoding performance of the ACK/NACK signalling, the PRE/POST scheme enables the Node B to distinguish between the UE having failed to detect the HS-SCCH signalling and the UE having detected the HS-SCCH signalling but failed to decode the HS-DSCH packet.

If the UE has failed to detect the HS-SCCH signalling, the UE will transmit either POST, or PRE, or DTX in 2 consecutive slots, whereas a NACK (or PRE+NACK for the first packet in a burst) would be transmitted if the UE had detected but failed to decode the packet. If full IR is being used, the error rate between PRE/POST/DTX+DTX and NACK is of interest. In the simulations presented here, a maximum error rate of 0.03 is achieved in all circumstances, both for PRE/POST/DTX+DTX -> NACK and for NACK->PRE/POST/DTX+DTX.

This enables the Node B to select the best redundancy version with a high degree of confidence.

6.7.2.4 Summary

Simulation results presented here show that the PRE/POST scheme achieves the following:

- “Relaxed Requirements” met at all UE speeds in SHO, without needing more than 1 ACK/NACK repetition;
- “Tight Requirements” met in SHO at UE speeds above 45km/h;
- When not in SHO, “Tight Requirements” met with no repetitions at all speeds up to 40km/h (compared to only 20km/h with Release 5 specifications);
- “Relaxed Requirements” met without repetitions at speeds higher than 40km/h when not in SHO.
- Worst-case error rate of 0.03 achieved for distinguishing between failed HS-SCCH detection and failed HS-DSCH CRC.

6.7.3 Impacts on other WGs

The POST and PRE messages are physical-layer signals which have no impact on higher layers.

In order to switch the PRE/POST scheme on and off, a higher layer signalling parameter would be required in the RRC and NBAP protocols.

The current performance requirements in TS25.104 for HS-DPCCH ACK/NACK detection cover two cases: ACK False Alarm, P(DTX->ACK), and ACK Mis-detection, P(ACK->NACK or DTX). Performance requirements for NACK mis-detection are not included, as simulation results presented to RAN WG4 showed that the NACK power requirement is typically at least 16dB lower than the ACK power requirement, which is consistent with simulation results presented in RAN WG1.

Correspondingly, in the case of the PRE/POST scheme, it is unlikely to be necessary to define performance requirements for P(PRE->ACK) or P(POST->ACK).

It is for discussion in RAN WG4 whether new values of the performance requirements for ACK False Alarm should be defined to reflect the fact that, with the PRE/POST scheme, the Node B would always have at least two TTIs in which to detect DTX instead of only one. Similarly consideration could be given to whether new values of the performance requirements for ACK Mis-detection should be defined to reflect the lower ACK transmit power requirement with the PRE/POST scheme. Any definition of new requirements would be able to re-use much of the work which has already been done in RAN WG4 with respect to the scenarios and assumptions for HS-DPCCH detection.

No performance requirements are currently defined in TS25.104 for any values of N_acknack_transmit>1. It is for discussion in RAN WG4 whether an additional performance requirement should be developed for N_acknack_transmit>1, and if such a performance requirement should also include the PRE/POST scheme.

6.8 Fractional dedicated physical channel

6.8.1 Features

6.8.1.1 Rationale and high level description

The current specifications mandate the set up of dedicated physical channels both in the UL and in the DL whenever a user is configured to use HS-SCCH(s) and HS-PDSCH(s). In case such Ues are not doing any conversational types of services i.e. interactive, background and streaming types of service, the corresponding DPCH will carry pilots and TPC bits (control part) and possibly the associated RRC signalling which will be DTX’ed for most of the connection. Such types of users are named HSDPA data-only users in the following.

The purpose of the Fractional Dedicated Physical Channel (F-DPCH) is to share given codes among HSDPA data-only users to allow a more efficient management of the code resource. The following requirements apply :

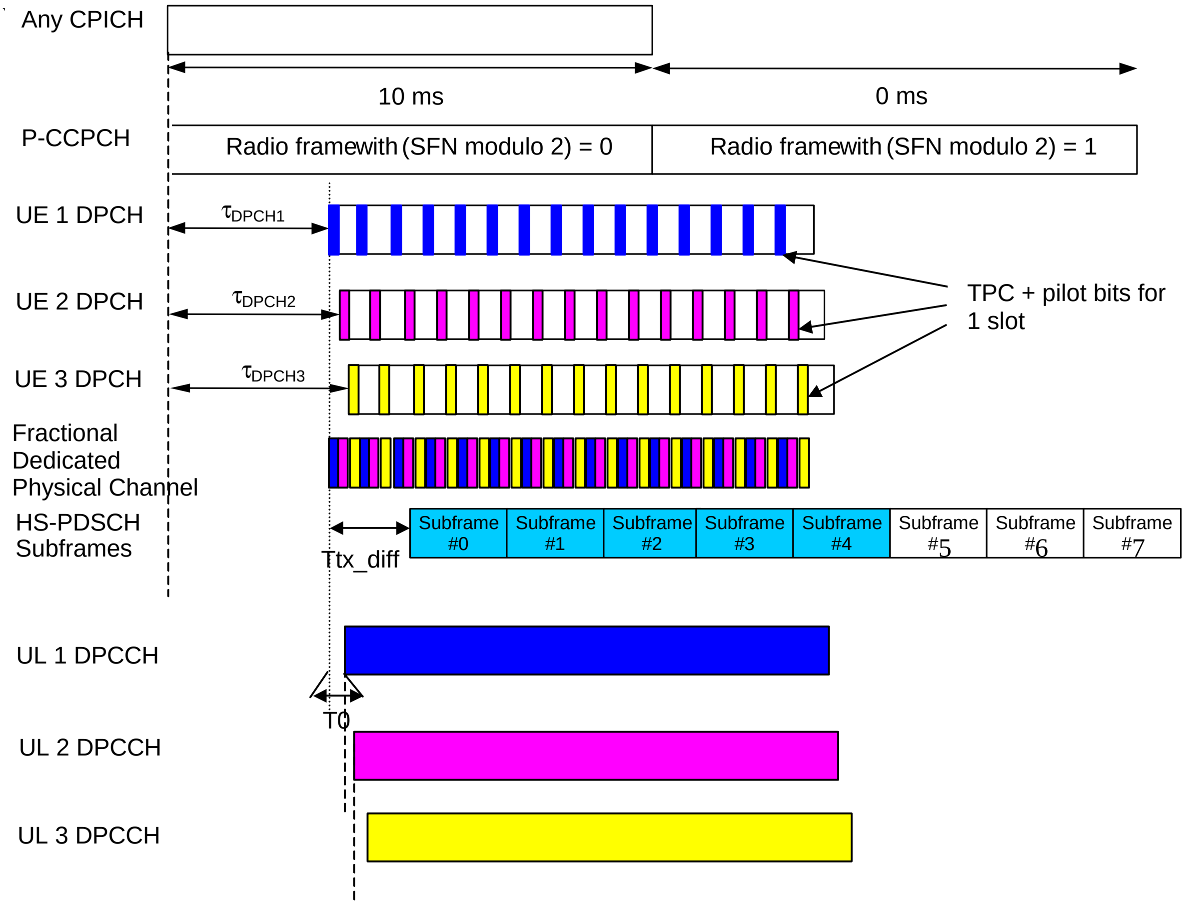
- UL timing is kept unchanged

- UL inner loop power control periods are maintained
- layer 1 synchronisation should – if possible- not be affected
- UL dedicated channel can be established in association to F- DPCH in the DL to avoid reconfiguration when switching to F-DPCH
- Downlink power control can be applied on F-DPCH to avoid transmitting at the maximum power

In order to fulfil these requirements and maximise the number of UE which can be multiplexed on one code, it is assumed that :

- *DCCH signalling* is carried on HS-DSCH
- *UE specific TPC bits* are present to maintain UL power control loop for each UE
- *Pilot bits* are present to allow the F-DPCH to be power controlled and allow DL synchronisation to be maintained by each UE.

The fractional dedicated channel can also be seen as a shared power control channel i.e. one code is shared between different users to carry power control and pilot bits. The principle is illustrated on the figure below.



DPCH1, DPCH2 and DPCH3 illustrate the dedicated channels associated to HS-SCCH(s) and HS-PDSCH(s) for 3 different UEs configured to use HS-SCCH and HS-PDSCH with no conversational service and DCCH signalling mapped onto HS-DSCH. When the DL timings of these channels are properly chosen, it appears that the code dimension is not necessary to distinguish between the UEs.

A single code is sufficient to carry TPC and pilot bits associated to these HSDPA UEs and still maintain the same periodicity of one slot for the transmission of these information in the downlink.

Note that the number 3 was chosen for illustrative purposes. The exact number of UEs mapped on such a channel will depend on the chosen structure.

In cases where the phase reference for the DL DPCH is a CPICH (primary or secondary), it is for further study whether it is necessary for the F-DPCH to carry dedicated pilot bits. If only TPC bits are transmitted, the number of TPC bits could be the same as in Rel-99, or could be increased to equal the number of pilot bits in Rel-99.

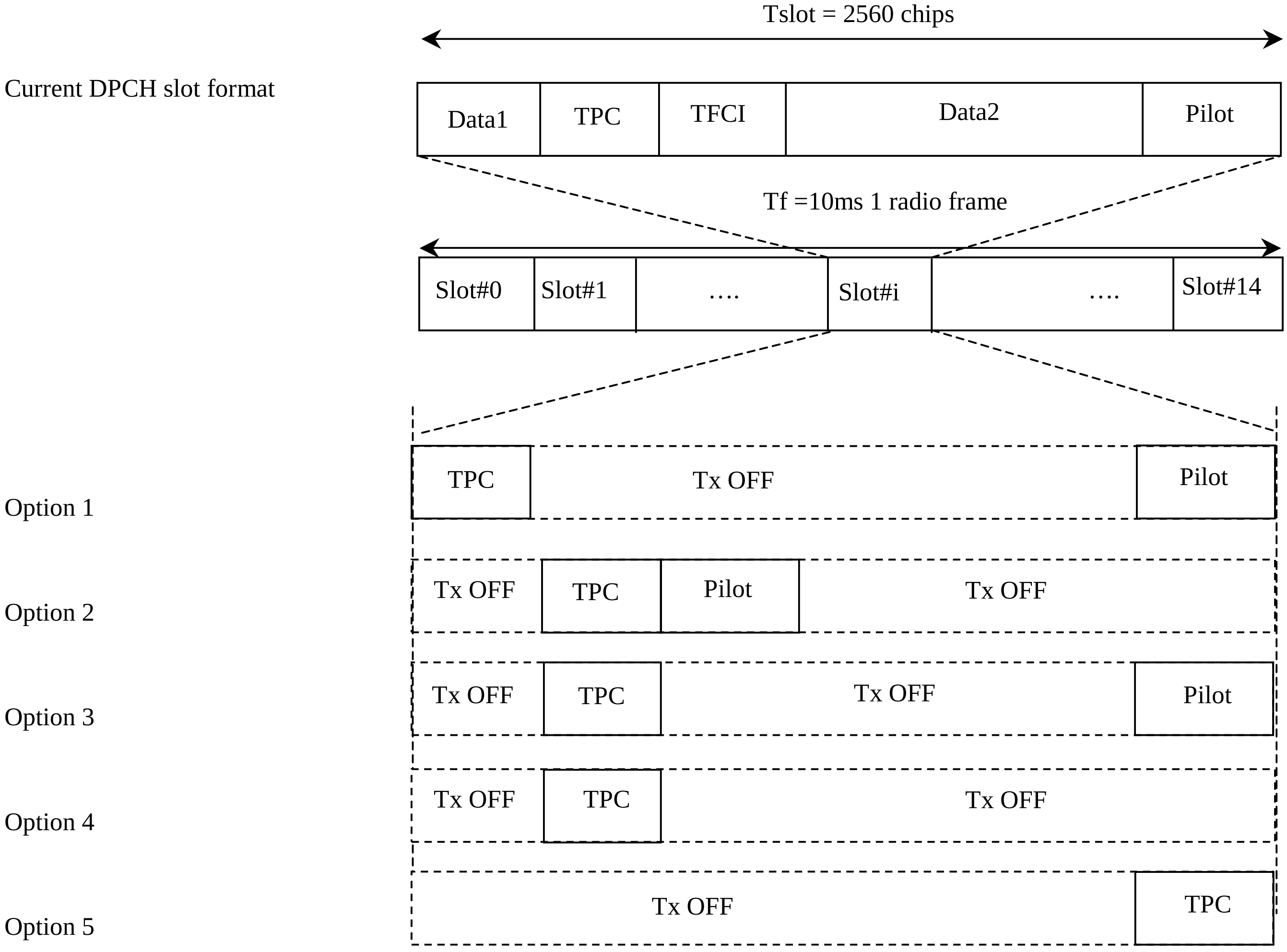
6.8.1.2 F-DPCH slot structure

F-DPCH follows the same frame structure as existing physical channels, a 10 ms frame divided into 15 slots.

In the following several slot structures are discussed :

- Option 1 : pilot position is unchanged, TPC bits are advanced in time
- Option 2 : TPC position is unchanged, pilots are advanced in time
- Option 3 : same as current
- Option 4 : No pilot bits; TPC position unchanged
- Option 5 : No pilot bits; TPC position moved to end of slot

These options are illustrated below



In the following, we consider that the relative timing between F-DPCH and UL DPCH for a given UE is the same as the current relative timing between DPCH and UL DPCH. This is made possible by keeping the frame and slot structure as currently seen from the UE.

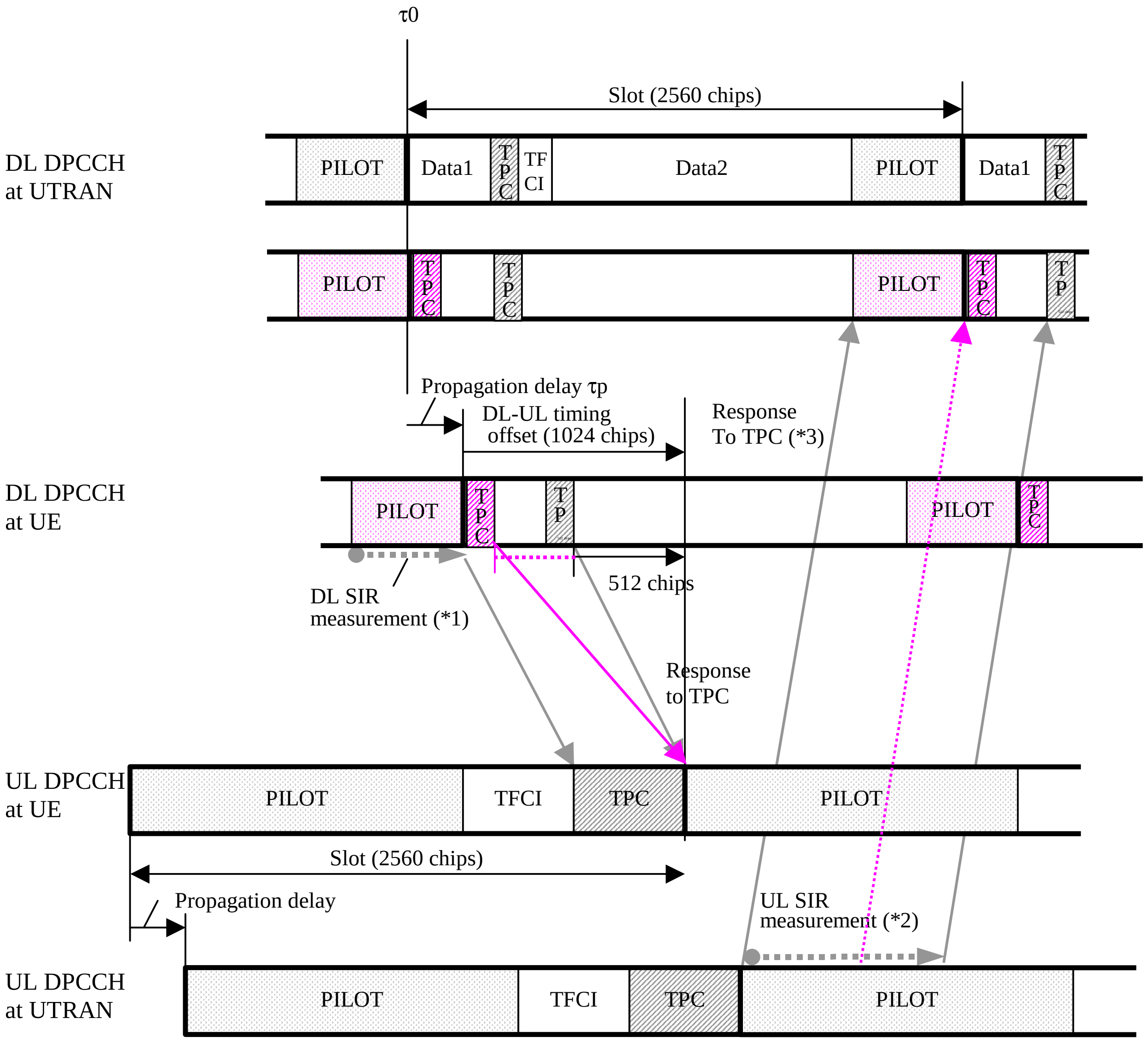
6.8.1.2.1 Option 1 : pilot position is unchanged, TPC bits are advanced in time

In this configuration, DL power control is not impacted as both UE processing timing (from reception of DL pilots to UL TPC command setting) and UTRAN processing time (from reception of UL TPC command to DL power change) is not affected by this change.

However as the position of DL TPC bits is modified both UE and UTRAN processing time for UL power control will be affected.

- UE processing time (from reception of DL TPC command to UL power change) : this time increases from 512 chips to 512 + size of Data1 field chips
- UTRAN processing time is decreased by the same amount i.e. the size of Data1 field (768 chips = 0.2ms at SF = 128 or 64 and 896 chips = 0.23ms)

These changes are illustrated on the following figure (taken from annex B of 25.214)



UTRAN processing time depends on the SIR estimation accuracy one wants to obtain. The current slot format give UTRAN processing time of Tslot + Tdata1 –T0 – 2 τp which becomes Tslot – T0 – 2 τp

This means that the cell radius for which a one slot delay can be achieved is further reduced compared to the current situation.

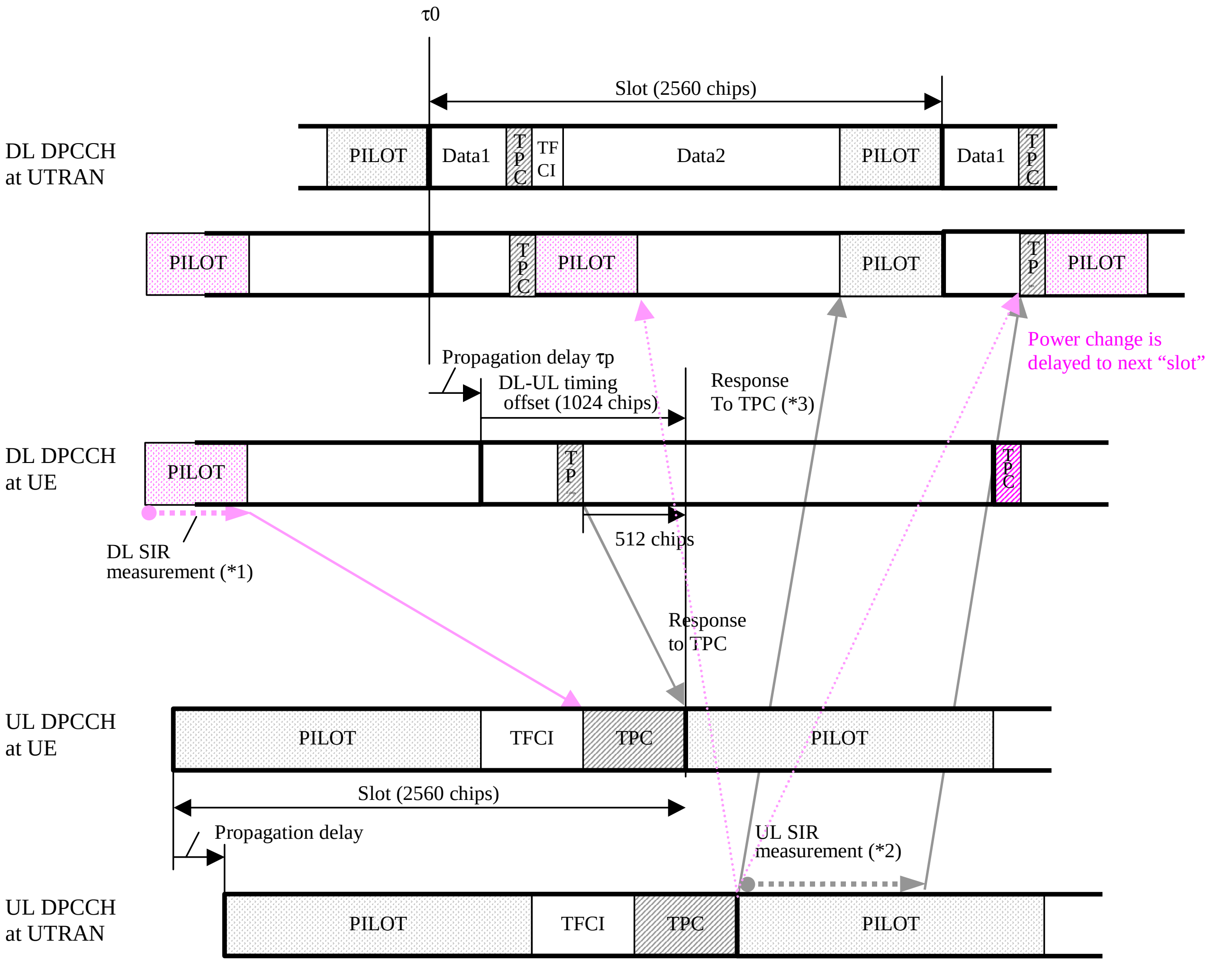
6.8.1.2.2 Option 2 : TPC position is unchanged, pilot bits are advanced in time

In this configuration, UL power control is not impacted as both UE processing time (from reception of DL TPC to UL pilot change) and UTRAN processing time (from reception of UL pilot to DL TPC command setting) is not affected by this change.

However as the position of pilot bits is modified both UE and UTRAN processing time for DL power control will be affected.

- UE processing time (from reception of DL pilots to UL TPC command setting) : increased by size of TFCI + data2. The UE has enough processing time but information is less accurate.
- UTRAN processing time (from reception of UL TPC command to DL power change) : decreased by size of TFCI +data2. This means that the power change will be delayed to the next slot.

These changes are illustrated on the following figure



The impact on UTRAN processing is a delay in the power change, compared to the current implementation (assuming we are in a case where a one slot delay can be achieved), the power change will only be delayed by the size of pilot + data1 field (see above figure) i.e. 200/266µs depending on the size of the pilot field.

The objective is that the F-DPCH is power control by the UEs such that each group of TPC + pilots bits intended for one UE is transmitted at the relevant power for this UE. With option 2 this is possible however more investigation is needed on the expected cell sizes for which a one delay as in R99 is achievable.

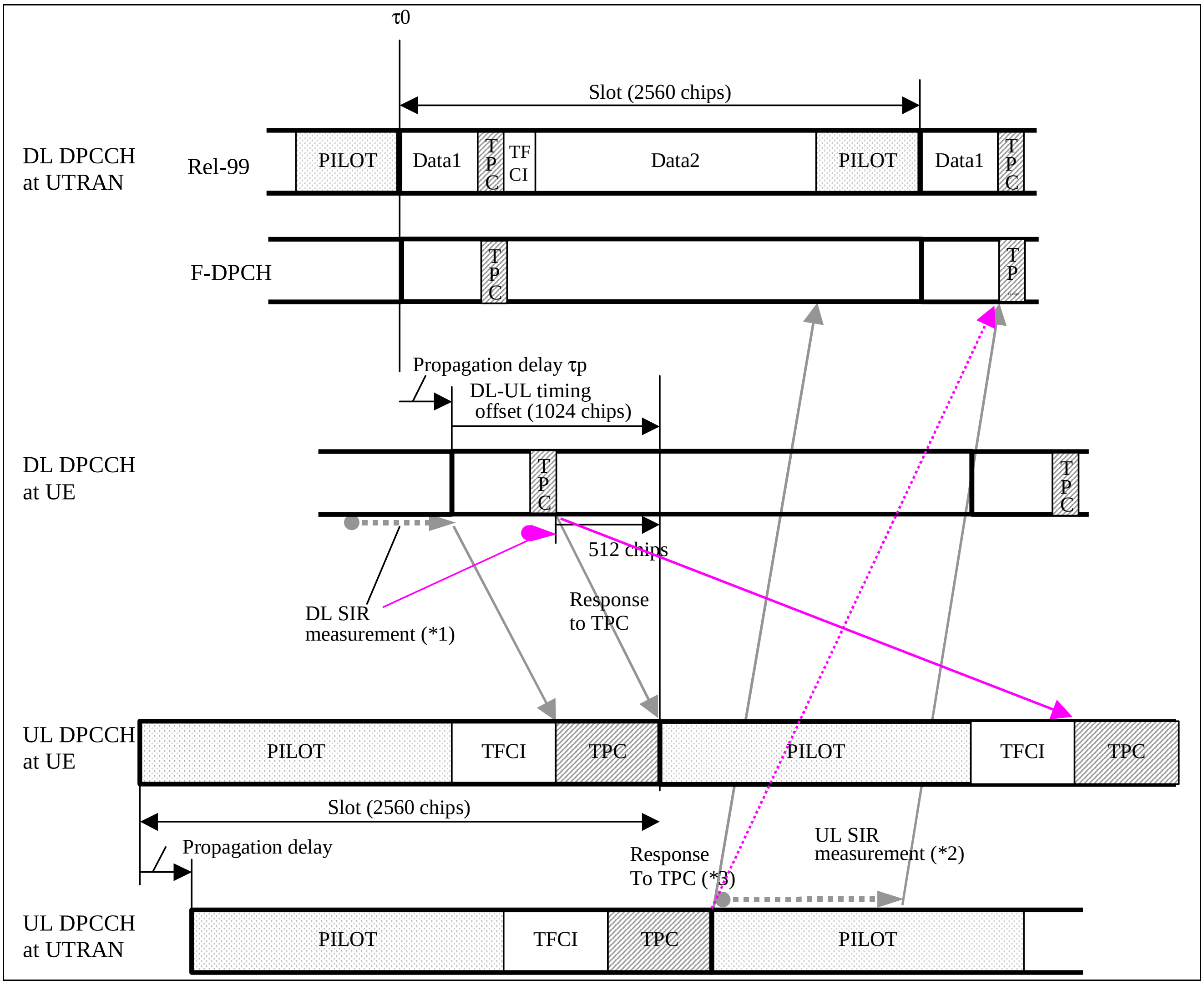
6.8.1.2.3 Option 3 : Same slot structure as DPCH

The main advantage with this approach is that UL and DL power control loop are not affected at all. However since there is a fixed time offset between pilot and TPC field intended for a given UE, this option will considerably limit the number of UE which can be multiplexed in the same time slot duration.

At SF = 128 there are 28 bits between TPC and pilot bits, this limits the number of UEs which can be multiplexed in a one time slot duration to 2.

With option 3 it seems the gain in terms of OVSF codes consumption is lost i.e. 2 UEs on 1 SF = 128 F-DPCH code is equivalent to 2 UEs on SF = 256 dedicated codes (carrying only DCCH signalling).

6.8.1.2.4 Option 4 : no pilot bits, TPC position unchanged



This configuration has the following effects on the processing time available for the UE and Node B:

Uplink power control:

1. Time available for the UE to decode the TPC command and change the UL transmit power is unchanged.
2. Time available for the Node B to measure the UL SIR and derive the TPC command is unchanged.

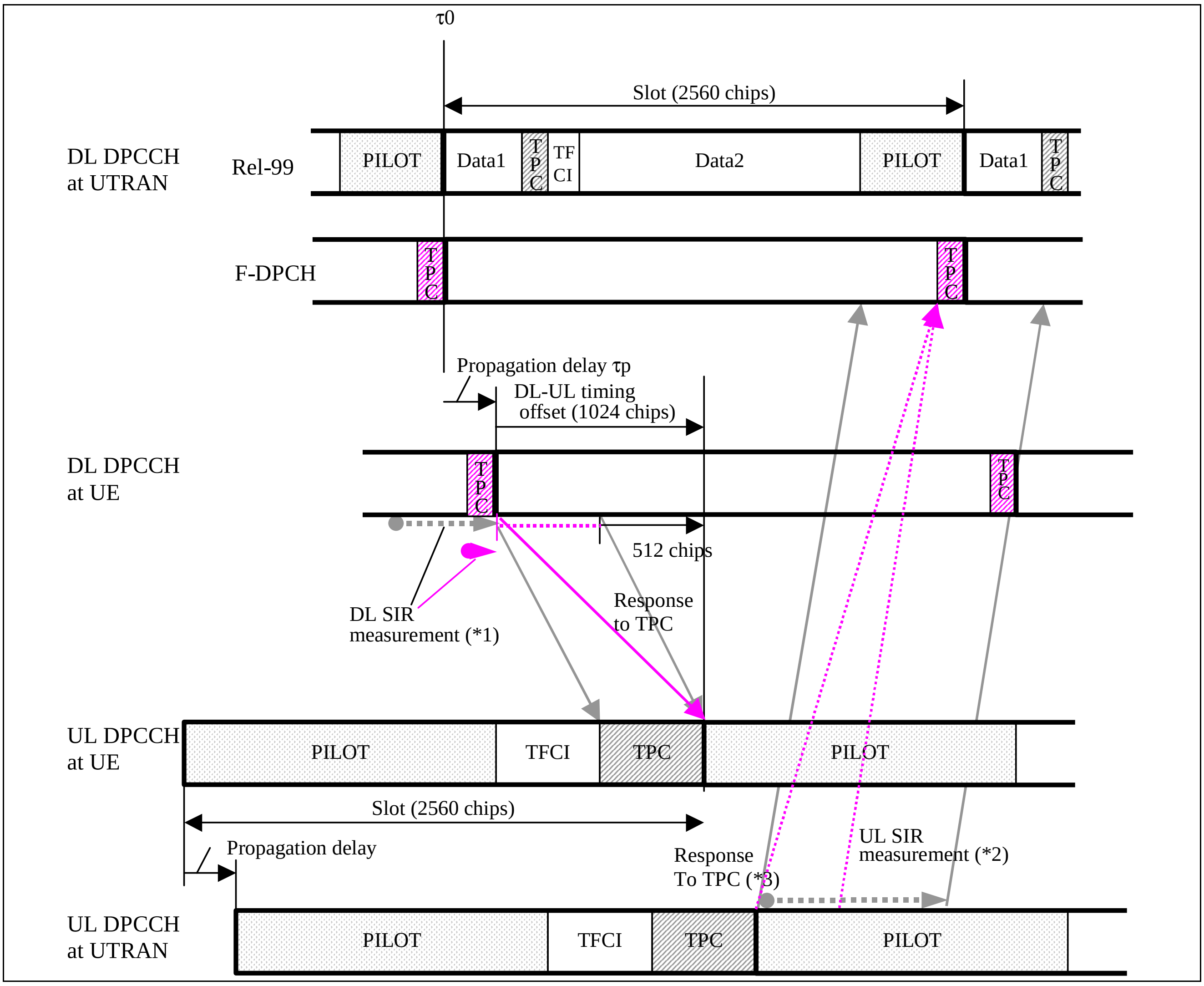
Downlink power control:

3. Time available for the Node B to decode the TPC command received from the UE and adjust the downlink transmit power is increased by $T_{pilot} + T_{data1}$.
4. Time available to the UE to measure the DL SIR and derive the TPC command to transmit in the UL is removed.

Therefore the loop delay for the uplink power control is maintained as in Rel-99, but the loop delay for the downlink power control is increased by 1 slot. This is the same as for “Option 2” as described above, and fully satisfies the requirements set out in section 6.8.1.1.

6.8.1.2.5 Option 5 : no pilot bits, TPC position moved to end of slot

In this configuration, the DL TPC field to the end of the timeslot. This gives the UE sufficient time to perform the DL SIR measurement and derive the TPC command to transmit on the UL DPCCH.



This has the following effects on the processing time available for the UE and Node B:

Uplink power control:

1. Time available for the UE to decode the TPC command and change the UL transmit power is increased.
2. Time available for the Node B to measure the UL SIR and derive the TPC command is reduced by T_{data1} + T_{TPC}.

Downlink power control:

3. Time available for the Node B to decode the TPC command received from the UE and adjust the downlink transmit power is increased.
4. Time available to the UE to measure the DL SIR and derive the TPC command to transmit in the UL is unchanged.

Therefore this configuration maintains the loop delay for the downlink power control as in Rel-99. In addition, it may be possible to maintain the loop delay at 1 slot for the uplink power control, but with reduced accuracy for the Node B’s SIR estimate. Alternatively, the loop delay for the uplink power control may be increased by 1 slot (particularly if larger numbers of TPC bits are used).

This is similar in effect to “Option 1” as described above.

6.8.1.3 Relationship with existing UTRAN features

In the following, relationship with existing UTRAN features is discussed.

6.8.1.3.1 Transmit diversity

6.8.1.3.1.1 General considerations

In the framework of release 5, the dedicated channel associated to users configured to use HS channels may employ one of the following transmit diversity mode

- STTD
- closed loop mode 1.

The assumption could therefore be that F-DPCH would not support closed loop mode 2 for consistency with currently allowed configurations.

Other options could be envisaged such as e.g.

- F-DPCH does not support Tx diversity
- F-DPCH supports all Tx diversity modes.

6.8.1.3.1.2 Compatibility with STTD

Example slot formats for F-DPCH given in section 6.8.1.2 largely reuse the current slot formats of the downlink DPCCH. Some are fully compatible with STTD. Some optimisation may be needed to ensure that all bits transmitted to a given user can be STTD encoded together if this is deemed necessary otherwise a similar principle as for SF = 512 may be applied.

6.8.1.3.1.3 Compatibility with Closed loop mode 1

UTRAN may apply different weights to the F-DPCH transmitted on each antenna in a similar way as what would be done in absence of DPDCH transmission. This implies that the node B may have to switch antenna weights several times per slot if UEs multiplexed onto the same F-DPCH require it.

As uplink /downlink timing relationships are not modified, the same adjustment modes may be applied. However some impact should be expected on UE or node B processing time depending on the slot format chosen for F-DPCH.

Associated uplink is unchanged therefore feedback information can be transmitted as in the current specifications.

The use of closed loop transmit diversity mode 1 with F-DPCH slot formats without pilot bits is FFS

6.8.1.3.2 Scrambling code mapping

With regards to scrambling code mapping, no particular restriction apply to F-DPCH, it could be mapped either to the primary scrambling code or to a secondary scrambling code.

It is recommended that no further restriction apply to F-DPCH compared to DPCH when considering scrambling code mapping of the channels that need to be received by a given UE (F-DPCH and HS channels).

6.8.1.3.3 Compressed mode

Uplink transmission is not modified by the introduction of F-DPCH therefore compressed mode may be applicable in the uplink for certain mobility cases depending on the UE capabilities. There are no expected changes with regards to the use of compressed mode in the uplink linked to the introduction of the F-DPCH.

In the downlink, referring to compressed mode may not be appropriate as such as no transport channel is transmitted on the F-DPCH. However a specific mode where transmission to a given UE is interrupted according to certain parameters is needed in order to allow the UE to perform measurements on another frequency or UTRAN mode or RAT.

The use of this specific mode, where the gaps could be described using the same parameters as the existing compressed mode, is compatible with the frame and slot structures described in section 6.8.1.2. The exact duration of the transmission gap will be dependant on the TPC and/or pilot bits position and might differ from the existing.

The need for power control recovery mechanisms as used in release 99, release 4 and release 5 is ffs. F-DPCH as described in section 6.8.1.2 is compatible with these mechanisms.

6.8.1.3.4 Beamforming

F-DPCH as currently proposed carries a TPC field and in some cases a pilot field. Formats which contain a pilot field are compatible with beamforming based on the use of dedicated pilot bits as phase reference.

No restriction applies in terms of scrambling code mapping therefore any of the F-DPCH formats in section 6.8.1.2 could be used also for beamforming based on a S-CPICH.

Dynamic aspects of beamforming on the F-DPCH e.g. UE mobility between beams are ffs.

6.8.1.3.5 Power control

The purpose of the F-DPCH is to be able to control the uplink dedicated channel of several UEs using the same code in the downlink. Therefore it should be designed in such a way that impacts to uplink power control due to the replacement of a downlink DPCH by several F-DPCHs, are minimized.

Regarding power control of the F-DPCH itself, several options can be envisaged

- Use closed loop power control as for an existing dedicated channel. As there is no transport channel carried on the physical channel it will not be possible to maintain an outer loop power control in the same manner as with the existing dedicated channels.
    - This can be solved either by using a fixed SIR target in the UE or by updating the outer loop using a estimation of the physical channel BER.
    - Note that this is not different from the scenario already allowed by the standard where a DPCH is set up for an HSDPA UE that does not have any speech service and for which the DCCH is mapped onto the HS-DSCH. Exact power control aspects of this scenario need to be checked.
- Alternative power control schemes with different UE and node B behaviours could be envisaged such as e.g. the scheme used to power control S-CCPCH or PDSCH

In release 5, an associated DPCH may also be used for HS-SCCH power control. A corresponding mechanism should be considered when F-DPCH is introduced to support HS-SCCH power control.

6.8.1.3.6 Soft handover

As a UE mapped onto an F-DPCH does not have any conversational service active and receives data via the HS-PDSCH, the possibility of not systematically requiring the SHO could be studied.

F-DPCH as described in section 6.8.1.2 may be used in a soft handover situation from a physical layer and UE reception point-of-view. The uplink dedicated channel is not modified by the introduction of F-DPCH and there is no intention to require the extension of the UE receiving window when introducing F-DPCH into UTRAN.

It should be noted the use of soft handover on F-DPCH may have an impact on the gain in terms of code tree consumption. Indeed maintaining the UE receiving window requires that a given UE is multiplexed with a given timing offset with regards to the C-PICH frame boundary when it is added onto an existing F-DPCH code. If this timing offset is already occupied by another UE, the support of soft handover for this UE on F-DPCH requires to setup a new F-DPCH code in the new active set cell.

In the same manner than in the downlink the possibility of not systematically requiring the SHO in the uplink could be studied.

Power control aspects when considering soft handover in the uplink, e.g. uplink DPCH power control in the downlink from all the cells receiving the uplink transmission, are also ffs.

6.8.2 Evaluation and benefits

6.8.2.1 Gain in code tree consumption

The number of UE which can be multiplexed on a single code obviously depends on the chosen spreading factor for F-DPCH.

In the following, a fixed SF is considered whether F-DPCH should have variable (i.e. through synchronous reconfigurations) is FFS, this is not precluded by the current description.

The number of UE which can be multiplexed on a single code also depends on the desired number of TPC and pilots bits. In the following, we have considered existing number of pilots bits from 25.211)

Structure	SF	Nb symb/slot (tot)	Nb TPC symb	Nb Pilot symb	Nb Ues per code
1	128	20	1	2	6
2	128	20	1	4	4
3	64	40	1	4	8
4	32	80	2	4	13

For the cases when only TPC bits are transmitted, the number of UEs which can be multiplexed on a single code is as shown in the following Table. Format 1 assumes the same number of TPC bits as in the Rel-99 slot formats, while Format 2 assumes the same number of TPC bits as Rel-99 pilot bits.

Structure	**SF**	**Bits per slot**	**F-DPCH with only TPC bits (Format 1)**			**F-DPCH with only TPC bits (Format 2)**		
			TPC bits per slot	**Pilot bits per slot**	**UEs per code**	**TPC bits per slot**	**Pilot bits per slot**	**UEs per code**
5	256	20	2	0	**10**	2	0	**10**
6	128	40	2	0	**20**	4	0	**10**
7	128	40	2	0	**20**	8	0	**5**
8	64	80	4	0	**20**	8	0	**10**
9	32	160	4	0	**80**	8	0	**20**

These values have to be compared with equivalent code tree consumption of data-only HSDPA users with a dedicated physical channel carrying DCCH signalling only. Each of these UEs consume one SF = 256 code for 3.4kbps SRB(see 34.108 section 6.10.2.4.1.2).

6.8.3 Impact on other WGs

Introduction of F-DPCH in the specifications will have an impact on 25.331, 25.433 and eventually 25.423. Details are FFS.

6.9 HSDPA operation without an associated DPCH (TDD)

6.9.1 Features

6.9.1.1 Operation without an associated DL DPCH

For 3.84Mcps TDD the associated DL DPCH serves few specific layer 1 purposes during HS-DSCH operation.. Two exceptions to this are; a) the absence of the DL DPCH would mean that other methods for monitoring of in/out-of sync operation would need to be sought, and b) if S-CCPCH were used solely in place of DPCH then there would be some L1 impact in that closed loop power control is not supported for this physical channel. Otherwise there seems little consequence resulting from the removal of the associated DL DPCH.

For 1.28Mcps TDD, and in addition to the aforementioned issues for 3.84Mcps, the DL DPCH can be used for carrying TPC and SS signaling for power control and closed loop synchronisation control of uplink channels. Therefore for the case that closed loop uplink power control and/or closed loop uplink synchronisation control is to be enabled, an adequate physical layer solution for carrying this DL signaling will need to be clarified. The periodicity and rate of the TPC and SS feedback is a function of the downlink resources allocated to carry TPC/SS. The feedback rate may increase or decrease with respect to the case where an associated DL DPCH is present, depending on the degree of fractionation that was applied to the DL DPCH.

6.9.1.2 Operation without an associated UL DPCH

For both 3.84Mcps and 1.28Mcps TDD the UL DPCH may be used to carry TPC information for the purposes of controlling the power of one or more DL DPCH’s or PDSCH’s (depending upon the TPC association mapping configured by higher layers).

Removal of the associated UL DPCH only, whilst retaining the DL DPCH, would necessitate that TPC commands for the associated DL DPCH are carried on other UL physical channels. This of course only applies if the associated DL DPCH remains present. The periodicity and rate of the TPC feedback is a function of the uplink resources allocated to carry TPC. The feedback rate may increase or decrease with respect to the case where an associated UL DPCH is present, depending on the degree of fractionation that was applied to the UL DPCH.

In 1.28Mcps TDD, a means of ensuring that sufficient UL transmissions are made during periods of HS-SICH inactivity to enable node B to adequately maintain UL synchronisation control will need to be clarified.

For both modes, in the absence of the UL DPCH, current node B procedures (if based on UL DPCH) may no longer be able to monitor UL in/out-of sync. and other methods would need to be sought.

6.9.1.3 Operation without both the UL and DL associated DPCH’s

In the case that both the associated UL and DL DPCH’s are removed, the closed loop power control considerations discussed in sections 6.1.1.1 and 6.1.1.2 typically do not apply. Normal procedures (as described within the current specifications) would apply for other non DPCH physical channels.

For 1.28Mcps TDD, in the event of a transmission pause on HS-DSCH and if closed loop uplink synchronisation control is to be enabled there will be a need to clarify the issues of transmitting SS bits in the DL, and of ensuring sufficient UL transmissions for effective operation. This does not apply during periods of HS-DSCH activity where SS bits may be conveyed on HS-SCCH based upon HS-SICH.

For both modes, in the absence of the UL and DL DPCH, current node B and UE procedures may no longer be able to monitor in/out-of sync. and other methods would need to be sought.

6.9.2 Evaluation and Benefits

6.9.2.1 Operation without an associated DL DPCH

FFS

6.9.2.2 Operation without an associated UL DPCH

FFS

6.9.2.3 Operation without both the UL and DL associated DPCH's

FFS

6.9.3 Impacts on other WGs

6.9.3.1 Operation without an associated DL DPCH

From higher layer perspectives the absence of a DCH in one or both link directions raises questions as to the RRC state in which the UE resides when operating HS-DSCH, and the subsequent mobility management techniques that apply

Additionally, the associated DL DPCH may be used to convey RRC signaling information or to carry DL data. Removal of the associated DL DPCH would therefore require that this DL traffic is mapped to other physical channels. Examples of such mappings are:

- DCCH / DTCH→ FACH → S-CCPCH
- DCCH / DTCH→ DSCH → PDSCH
- DCCH / DTCH → HS-DSCH → HS-PDSCH
- DCCH / DTCH → DCH → DPCH (another non-associated DL DPCH)

The mapping of a DCCH or DTCH logical channel previously mapped to DCH/DPCH onto other transport and physical channels is already supported within the existing specifications. However, RAN WG2 may wish to identify and address issues surrounding HS-DSCH operation without any DL DCH/DPCH (as opposed to the fractionated DPCH currently supported within release 5).

In summary it is suggested that the following issues may be of interest to RAN WG2:

- the use of FACH, DSCH and HS-DSCH transport channels for dedicated logical channels in place of a DL DCH mapped to (potentially fractionated) DPCH resource, considered in the context of HS-DSCH operation
- consideration on the RRC state that applies in the case that no DCH transport channel exists in the DL direction when using HS-DSCH

6.9.3.2 Operation without an associated UL DPCH

From higher layer perspectives the absence of a DCH in one or both link directions raises questions as to the RRC state in which the UE resides when operating HS-DSCH and the subsequent mobility management techniques that apply.

Additionally, in some network configurations the UL DPCH may be used to carry application layer signaling related to downlink transfer using HS-DSCH, such as TCP acknowledgements or to carry RRC signaling information. In such circumstances it is clear that removal of the associated UL DPCH would necessitate that such traffic is mapped onto other resources. Examples of such mappings are:

- DCCH / DTCH → USCH → PUSCH
- DCCH / DTCH → RACH → PRACH
- DCCH / DTCH → DCH → DPCH (another non-associated UL DPCH)

The mapping of a DCCH or DTCH logical channel previously mapped to DCH/DPCH onto other transport and physical channels is already supported within the existing specifications. However, RAN WG2 may wish to identify and address issues surrounding HS-DSCH operation without any UL DCH/DPCH (as opposed to the fractionated DPCH currently supported within release 5).

In summary it is suggested that the following issues may be of interest to RAN WG2:

- the use of RACH and/or USCH transport channels for dedicated logical channels in place of an UL DCH mapped to (potentially fractionated) DPCH resource, considered in the context of HS-DSCH operation

- consideration on the RRC state that applies in the case that no DCH transport channel exists in the UL direction when using HS-DSCH

6.9.3.3 Operation without both the UL and DL associated DPCH's

In the absence of the DL and UL associated DPCH's and of any other established DPCH's, there is a question as to which RRC state (cell_DCH / cell_FACH) HS-DSCH operation could take place in. Currently within RAN WG2 the absence of any DCH transport channel would indicate that the UE is residing in cell_FACH state. However, mobility techniques differ between cell_DCH and cell_FACH state and the applicability of these to HS-DSCH operation would require further investigation within RAN WG2.

It is suggested that the following issues may be of interest to RAN WG2:

- consideration of the RRC state that applies in the case that no DCH transport channel exists in either the UL or the DL direction when using HS-DSCH
- the performance and applicability of mobility techniques in these RRC states when using HS-DSCH

7 Conclusion

A number of techniques have been proposed in the study of "HSDPA Enhancements". In particular, some of these techniques have been considered in detail, namely:

- CQI Enhancement for FDD Mode
- ACK/NACK Transmit Power Reduction for HS-DPCCH with Preamble and Postamble
- Fractional Dedicated Physical Channel

Simulation results at both link and system level have shown that HSDPA performance can be improved through CQI Enhancement. HSDPA throughput improvements of at least 10% have been demonstrated compared to Release 5, as well as improvements in the number of retransmissions, packet delay, uplink interference and suitability of MCS selection.

Simulations for ACK/NACK Transmit Power Reduction for HS-DPCCH with Preamble and Postamble have shown that HS-DPCCH ACK/NACK decoding reliability can be improved, enabling HS-DPCCH transmit power to be reduced by up to 4dB in non-SHO and 6dB in SHO.

The Fractional Dedicated Physical Channel enables data users to share the code resources of one dedicated physical channel carrying layer 1 signalling for each user. A number of slot formats have been proposed by which the benefits can be achieved.

Annex A:
Change history

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
2002-11		R1-021443			Initial TR skeleton presented for discussion		0.0.1
2003-02	RAN1#31	R1-030373			Modification on the scope and some technical texts inclusion	0.0.1	0.0.2
2003-03		R1-030380			Editorial correction (in title of section 6.1)	0.0.2	0.0.3
2003-03		R1-030382			Clean version	0.0.3	0.1.0
2003-05	RAN1#32	R1-030634			Addition of 5.7, 5.8, 6.7, Annex A, Modification of 6.1.1, 6.1.3	0.1.0	0.2.0
2003-10	RAN1#34	R1-031149			Update of copyright part Inclusion of following documents: R1-030964, R1-031037, R1-031038, R1-031074, R1-031073	0.2.0	0.2.1
2003-10	RAN1#34	R1-031174			Collection of some editorial errors	0.2.1	0.2.2
2003-11	RAN1#35	R1-031383			Clean version	0.2.2	0.3.0
2003-11	RAN1#35	R1-031418			Inclusion of following documents: R1-031220 with removing “easily” R1-031310 R1-031314 except second text proposal and adding a note for fig. 12 & 16 R1-031293 with removing a sentence in 6.1.3.1 and 6.1.3.2	0.3.0	0.3.1
2003-12	RAN1#35	R1-031425			Inclusion of following documents: R1-031440 R1-031390	0.3.1	0.3.2
2004-02	RAN1#35	R1-040201			Inclusion of following documents: R1-031384 R1-031385 R1-031386	0.3.2	0.3.3
2004-02	RAN1#36	R1-040384			Clean version	0.3.3	0.4.0
2004-05	RAN1#37	R1-040649			Inclusion of following documents: R1-040528 R1-040529 R1-040647 R1-040568 except last two paragraphs	0.4.0	0.4.1
2004-05	RAN1#37	R1-040657			Clean version	0.4.1	0.5.0
2005-05	RAN#24	RP-040222			Presented at RAN#24	0.5.0	1.0.0