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Contents

Foreword

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

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x the first digit:

1 presented to TSG for information;

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

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1 Scope

In the past few years, a considerable increase in number of users as well as offered traffic per user has been experienced in HSPA networks, both in the downlink and in the uplink.

In response to this, several features have been standardized in 3GPP. These include multi-carrier HSPA, downlink and uplink CELL_FACH state enhancements, and introduction of downlink and uplink MIMO. However, much of the focus has been on improving downlink performance and further enhancements are needed for the uplink to handle increasing traffic load as well as new traffic types.

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 TR 21.905: "Vocabulary for 3GPP Specifications".

[2] RP-122019: "Study on Further EUL Enhancements".

[3] IETF RFC 2616: "Hypertext Transfer Protocol -- HTTP/1.1".

[4] IETF RFC 2507: " IP Header Compression".

[5] IETF RFC 4996: "RObust Header Compression (ROHC): A Profile for TCP/IP (ROHC-TCP)".

[6] R1-131558: "Further Considerations for HSUPA Rate Adaptation", Ericsson, ST-Ericsson.

[7] R1-122580: "SINR-based scheduling for UL MIMO", Nokia Siemens Networks.

[8] R1-122581: "Simulation results for SINR-based scheduling for UL MIMO", Nokia Siemens Networks.

[9] R1-122582: "SINR-Based scheduling for SIMO and CLTD transmission modes", Nokia Siemens Networks.

[10] R1-131609: "Initial simulation results for SINR-based scheduling and TDM in HSUPA", Nokia Siemens Networks.

[11] R1-130674: "Initial simulation results for SINR-based scheduling in HSUPA", Nokia Siemens Networks.

[12] R1-132612: "Further Details on HSUPA Rate Adaptation", Ericsson, ST-Ericsson.

[13] R1-132613: "Initial Link Simulation Results for HSUPA Rate Adaptation", Ericsson, ST-Ericsson.

[14] IETF RFC 1951: "DEFLATE Compressed Data Format Specification version 1.3".

[15] IETF RFC 1952: "GZIP file format specification version 4.3".

[16] 3GPP TR 36.814: "Evolved Universal Terrestrial Radio Access (E-UTRA); Further advancements for E-UTRA physical layer aspects".

[17] R1-133929: "TP on link level simulation assumptions for Lean Carrier", Ericsson, ST-Ericsson.

[18] R1-132611: "Initial Link Simulation Results for Dedicated Secondary Carrier", Ericsson, ST-Ericsson.

[19] R1-132611: "Initial Link Simulation Results for Dedicated Secondary Carrier", Ericsson, ST-Ericsson.

[20] 3GPP TS 25.214: "Physical layer procedures (FDD)".

[21] 3GPP TS 25.101: "User Equipment (UE) radio transmission and reception (FDD)".

3 Definitions and abbreviations

3.1 Definitions

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

3.2 Abbreviations

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

ACB	Access Class Barring
CLTD	Closed-Loop Transmit Diversity
CSS	Cascading Style Sheets
DSAC	Domain Specific Access Restriction
EAB	Extend Access Class Barring
E-TFC	E-DCH Transport Format Combination
EUL	Enhanced Uplink
HTML	Hypertext Markup Language
IFHO	Inter-Frequency Handover
ILPC	Inner Loop Power Control
IPDC	IP Data Compression
IPHC	IP Header Compression
LZMA	Lempel–Ziv–Markov chain algorithm
MRAB	Multi RAB
OLPC	Outer Loop Power Control
PPAC	Paging Permission with Access Control
RoT	Rise over Thermal
SD	Secondary stream ETFC Offset
SG	Serving Grant
SIMO	Single Input, Multiple Output
SINR	Signal to Interference-plus-Noise Ratio
T2P	Traffic to Pilot
TCP	Transmission Control Protocol
TBS	Transport Block Size
TEBS	Total E-DCH Buffer Status
UPH	UE Power Headroom
WiMAX	Worldwide Interoperability for Microwave Access

4 Objectives of the Study on Further EUL enhancements

This study should fulfill the following objective of identifying potential technical solutions for increasing the uplink capacity, coverage and end user performance (e.g. latency, achievable rates, etc.). The improvements should address following scenarios:

- Improvements to uplink user plane cell capacity with high number of users (high priority).
- Improvements to uplink coverage and latency (lower priority).

Currently identified areas include:

1) Enabling high user bitrates in a mixed-traffic scenario by means of, e.g., a more efficient method of confining high-RoT operation to dedicated secondary carriers.
2) Rate Adaptation to support improved power and rate control for high rates.
3) Improvements to handling of dynamic traffic on EUL, e.g. more efficient grant handling, improvements to the handling of scheduled and non-scheduled data and control transmissions during bursty traffic, etc.
4) Improvements to EUL coverage when using single RAB as well as various multi-RAB combinations.
5) Improvements to current access control mechanism to provide efficient approach for UTRAN in case of uplink overload.
6) Reduce UL control channel overhead for HSPA operation.
7) Mechanisms to perform UL data compression between the UE and the RAN
    - Evaluate compression gains and performance benefits for different types of smartphone traffic. At least UL capacity, signalling load, UE battery and latency should be considered.
    - Mechanisms to selectively enable/disable data compression when traffic is compressible/uncompressible.
8) Low-complexity uplink load balancing solutions, e.g. a fast uplink carrier switching in Cell_DCH state, especially for configurations where the downlink is configured in multicarrier operation while the uplink is in single carrier.

5 Study areas

5.1 Access Control

5.1.1 Background and motivation

Access Control mechanisms include Access Class Barring (Rel-99), DSAC (Rel-6), PPAC (Rel-8) and Extended Access Class Barring (Rel-11).

ACB, DSAC and PPAC rely on the separation of Access Classes 0-15 among barred and not barred. This is indicated in the SIB3, with separate bit strings for ACB, DSAC PS/CS and PPAC. Depending on what kind of barring is applied, the UE may not be allowed to send an RRC Connection Request to setup a connection to any CN domain (ACB), may not be allowed to send an RRC Connection Request or an Initial Direct Transfer to setup a signalling connection to a "barred CN domain" (DSAC), may not be allowed to setup a connection to a "barred CN domain" in order to respond to paging and/or perform a LA/RA registration (PPAC) from idle mode.

Rel-11 Extend Access Class Barring (EAB) provides an additional access class barring mechanism for UEs supporting EAB (the support can be configured in the ME or in the SIM/USIM).

Other mechanisms may be considered, which allow preventing overload of the access channel under critical conditions, spreading access attempts over a larger time frame by means for instance of back-off timers, wait times and persistence values.

In Rel-99, Access Service Class (ASC) allows to configure up to 8 Access Services Classes with different priorities. The Access Service Classes are mapped from the Access Classes (in SIB5 or SIB5bis) for idle mode or correspond to the MAC Logical Channel Priority in case of connected mode. The ASC together with other parameters broadcasted in the System Info will determine the persistence value used by the UE to determine whether to start the L1 PRACH transmission procedure in the present TTI or not.

Other Rel-99 methods for the access control are the back-off timer at reception of AICH NACK and the wait timer in Cell Update Confirm and RRC Connection Reject, which allows postponing Cell Update or next RRC Connection Request by 1 to 15 seconds.

In Rel-10, an extended wait time (up to 30 minutes) for UEs supporting "delay tolerant access" can be applied to the RRC Connection Reject, RRC Connection Release and Signaling Connection Release.

A first finding that can be inferred from this brief description is that the existing methods provide fairly good mechanisms for the access control of users in idle mode. The legacy mechanisms may also be applicable, to a certain extent, to users in CELL_FACH, CELL_PCH and URA_PCH.

5.1.2 Analysis

Table 5.1.2-1 lists the idle and connected mode scenarios and issues which were identified and agreed for analysis. For each scenario which was analyzed, the reason(s) why improved access control mechanisms are needed/not needed are listed.

Table 5.1.2-1: Idle and connected mode scenarios/issues

Scenarios/issue	Decision
SIB3 value tag	The frequent updating of SIB3 might cause the value tag to wrap-around frequently, especially considering the short length of value tag, i.e. value 1-4 for SIB3 value tag and 1-8 for MIB value tag. It is agreed to study this scenario.
Wait Time per CN domain	From the network perspective, when congestion occurs, it might be desirable to delay the idle UE access to PS domain while at the same time to allow UE access to CS domain. It is agreed to study this scenario.
Duration of wait time	Currently the value range of wait time is at most 15 seconds, and the network may want to control some requests for a longer time. It is agreed to study this scenario.
Idle Mode Extended Wait Time	As a solution, there is no issue with the Extended Wait Time. Studying the Wait Time should be sufficient.
Idle Mode Initial Direct Transfer	Some UE implementations may detach from PS whenever they have completed a PS session (e.g. when closing the web browser). If these UEs have DSAC restriction for PS and PPAC, they will be able to initiate a PS attach but not a detach from idle. PPAC could be extended to the detach procedure as well. This scenario seems to represent a corner case. A specific solution would probably not be so useful/effective in case of RAN overload.
PCH, no seamless transition UL data activity (Cell Update with cell update cause "uplink data transmission" and Establishment cause not included)	In case of CELL_PCH or URA_PCH with no seamless transition, the network may want to block the uplink data activity if the network is already congested, however currently it is not possible to block the request. It is agreed to study this scenario
PCH, no seamless transition URA update (only URA)	There is not strong motivation to block this message.
PCH, no seamless transition Cell update (only Cell_PCH, other cell update cases than "uplink data transmission")	There is not strong motivation to block this message.
FACH and PCH seamless transition DTCH transmission	In some scenarios, the uplink DTCH transmission may be seen as lower priority and needs to be blocked separately. It is agreed to study this scenario
FACH and PCH seamless transition Cell Update	There is not strong motivation to block this message.
FACH and PCH seamless transition DCCH on SRB2	There is not strong motivation to block this message, e.g. the reconfiguration messages are critical for state transition (both for successful or unsuccessful cases).
FACH and PCH seamless transition DCCH on SRB3/4	Improvements to DTCH transmissions may be extended to SRB3/4 if needed
CELL_DCH DSAC/PPAC update	The issue may lead to inefficient network congestion control or introduce additional traffic delay for CELL_DCH users. It is agreed to study this scenario
Wait Time for URA and Cell PCH no seamless transition	Same motivations as for Idle mode apply for the Extended Wait Time and no enhancements are required.

5.1.2.1 Idle mode

5.1.2.1.1 SIB3 value tag wrap-around issue

Currently parameters for ACB (Access Class Barring), DSAC (Domain Specific Access Restriction) and PPAC (Paging Permission with Access Control) are included in SIB3. When the network is overloaded, in order to avoid barring a specific category of UEs for a long time and guarantee the fairness between UEs, the network needs to update the SIB3 to rotate the barred ACs (Access Class) from time to time.

However, the frequent updating of SIB3 might cause the value tag to wrap-around frequently, especially considering the short length of value tag, i.e. value 1-4 for SIB3 value tag and 1-8 for MIB value tag.

Here are two use cases for SIB3 value tag wrap-around issue.

Use case 1: State transition from CELL_DCH

Before a UE enters CELL_DCH state, the UE has stored SIB3 and the corresponding value tag from the system information. When the network is overloaded, SIB3 will be updated for access control purposes. However, currently for a CELL_DCH UE, there is no way for it to acquire the latest SIB3.

As a result, after the UE enters IDLE state from CELL_DCH state, it is possible that the current value tag is identical to the previously stored value for SIB3, and then the UE may not re-acquire SIB3 even if SIB3 has been updated. As a consequence, the UE may have out of date barring information.

Use case 2: Cell reselection

A UE in IDLE mode may perform cell reselection procedure. If the UE reselects to a cell for which the UE already has stored valid SIB3, the UE will consider the content of the stored SIB3 unchanged when the value tag of stored SIB3 is the same as the one acquired in MIB of that cell, and thus the UE will have out of date barring information.

5.1.2.1.2 Wait Time

To avoid UE accessing continuously, the network can indicate in the RRC CONNECTION REJECT message a Wait Time to block the subsequent RRC connection request(s) for a period for a UE in IDLE mode. However, currently the Wait Time is common for both PS domain and CS domain. If the UE is first rejected due to a PS access request, the corresponding Wait Time will also prevent UE triggering a CS call request.

In case of network congestion scenarios, the network may want to restrict the UE accessing the PS domain and allow UE accessing the CS domain.

Additionally the wait time value could be extended to allow the network to restrict the UE accesses for longer than the current limitation of 15 seconds. Any extension of the wait time would also need to consider the impact to terminating calls, as currently a UE does not respond to paging requests received from the network whilst the UE wait time timer is running.

5.1.2.2 Connected mode

5.1.2.2.1 SIB3 value tag wrap-around issue

The issue described here is similar to the issue described in 5.1.2.1.1. Three use cases for SIB3 value tag wrap-around issue are identified.

Use case 1: State transition from CELL_DCH

Use case 2: Cell reselection

Regarding the above two use cases, similar considerations as for IDLE mode apply to Connected mode.

Use case 3: Re-entering service area

Currently if the UE is "out of service area", it will perform cell selection procedure in order to find a suitable cell. When a suitable cell is found, the UE considers it as having detected "in service area" and the UE will camp on that cell.

If the UE already has stored a valid SIB3 for the cell, the UE will not update SIB3 if the stored value tag is the same as the value tag for SIB3 from MIB, even though SIB3 may have been updated.

5.1.2.2.2 CELL_PCH/URA_PCH state without seamless transition

5.1.2.2.2.1 Control of UL data activity

In case of URA_PCH or CELL_PCH state without seamless transition to CELL_FACH state, if the UE has PS data to transmit it will send a Cell Update. The network can only control these requests by sending Cell Update Confirm message with a wait time which will consume some radio resources for the unnecessary cell update signalling and will also block CS call attempts.

5.1.2.2.3 CELL_FACH state and CELL_PCH state with seamless transition

5.1.2.2.3.1 Control of DTCH transmission in CELL_FACH and CELL_PCH seamless transition

Currently for CELL_PCH state with seamless transition, a UE may autonomously move to CELL_FACH state and start UL transmission. A UE in CELL_FACH state may perform uplink DTCH transmission. It is not possible for the network to control these requests. With the increase of the smartphone traffic, the increase of networks and UEs supporting seamless transition to CELL_FACH state from CELL_PCH state and with the increase of users in CELL FACH state because of the introduction in Rel-11 of longer DRX cycles, the amount of DTCH transmissions from CELL_FACH state is expected to increase considerably.

5.1.2.2.4 CELL_DCH state

5.1.2.2.4.1 DSAC update issue in CELL_DCH state

Currently the DSAC information is only sent in SIB3, so a UE in CELL_DCH state cannot determine if the DSAC information has been changed. Here are two basic scenarios for this issue.

Scenario 1: Network load status changes without UE mobility behaviour:

As shown in Figure 5.1.2.2-1, at T1, the UE is informed via DSAC that its Access Class is barred for PS.
Later, a CS call is established and the UE is switched to CELL_DCH state.

At T2, the network congestion for PS domain is relieved and SIB3 is updated in order to allow all the UE's accessing on PS domain (i.e. PS becomes unbarred in DSAC information). However, the UE in CELL_DCH state does not re-acquire the updated SIB3, and thus it is not able to send an Initial Direct Transfer for PS. At T3, the UE is switched to a state other than CELL_DCH state, it re-acquires SIB3 and updates the DSAC info. PS becomes now unbarred.
The PS traffic in this case is delayed for a duration equal to T3 minus T2.

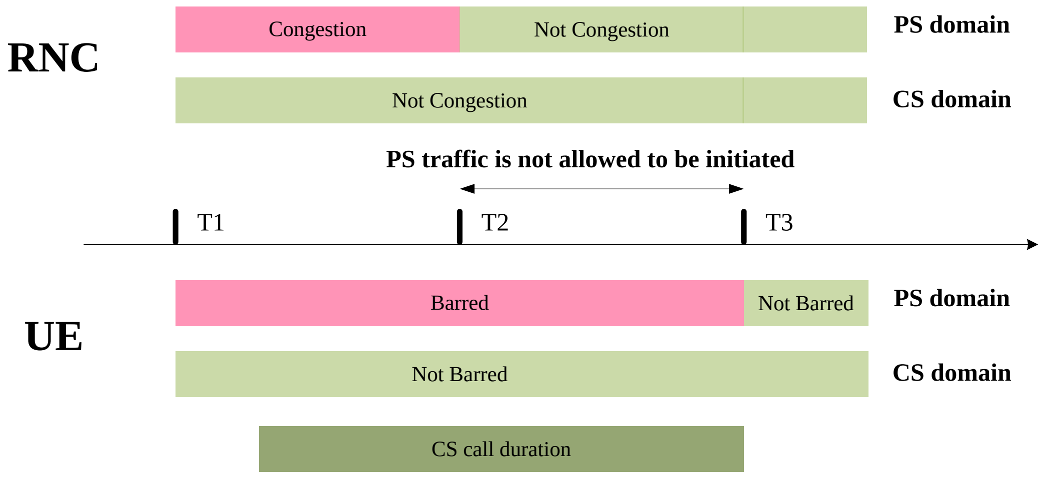


Figure 5.1.2.2-1: DSAC update issue in CELL_DCH (1)

In addition, if the network status changes from "Not Congestion" to "Congestion" (see Figure 5.1.2.2-2), users with out-of-date DSAC information will generate more IDT's than expected, worsening the network congestion.

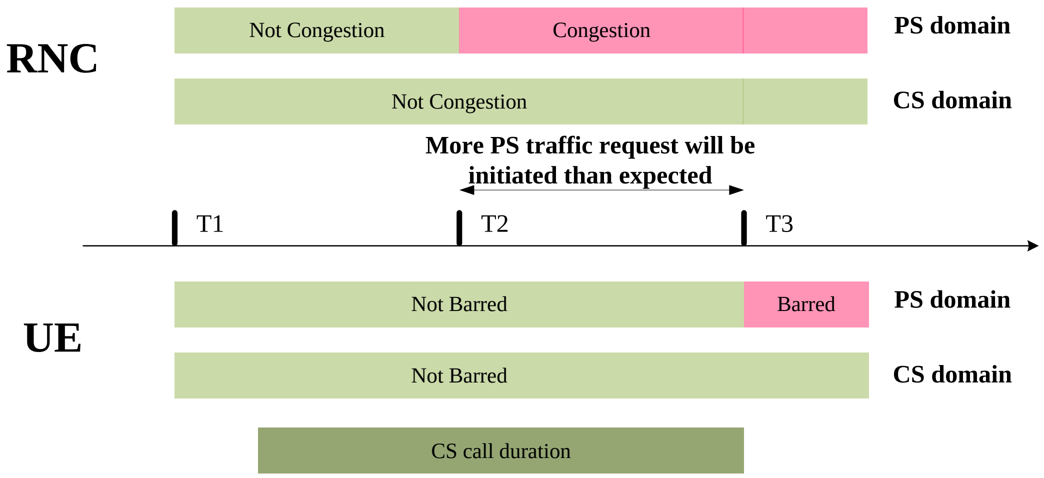


Figure 5.1.2.2-2: DSAC update issue in CELL_DCH (2)

Similar considerations may apply for the PPAC update in CELL_DCH state

Scenario 2: Network load status changes with UE mobility behaviour:

Similar issues may also happen if a UE has performed mobility procedures to a new cell, e.g. a cell change from other cells/Node Bs/RNCs, inter-RAT handover from E-UTRAN to UTRAN or from GSM to UTRAN. In these cases, the UE may have no DSAC information of the target cell, or the stored DSAC information for the target cell is out-of-date.

Similar considerations may apply for the PPAC update in CELL_DCH state.

5.1.3 Solutions

5.1.3.1 SIB3 reading

Regarding the scenarios described in 5.1.2.1.1 and 5.1.2.2.1, a possible improvement is to force the UE to re-acquire the SIB3 after state transition from CELL_DCH state, or after re-entering service area, or cell reselection procedure, regardless of the value tag. The solution does not have impacts on ASN.1.

Regarding the solution, considering that the congestion time may be short from a system point of view, to always force the UE to re-acquire SIB3 may lead to additional UE power consumption. It could be further studied how the feature is controlled /activated (e.g. network indicator and examples of how it can be done). The feature may also have an impact on latency.

5.1.3.2 Wait Time enhancements

Regarding the scenario described in 5.1.2.1.2, the introduction of mechanisms to differentiate the wait time per CN domain is a possible approach to enhance the Wait Time. The network can control the UE requests by configuring PS Wait Time without impacting CS calls (and vice versa). The enhancement of "Per CN Domain Wait Time" could be introduced in RRC CONNECTION REJECT message and RRC CONNECTION RELEASE message.

In addition, a possible improvement is to consider extending the value range of wait time. Possible alternatives to consider, with regards to the handling of paging requests received by a UE whilst the (extended value) wait time timer is running, are:

a) UE doesn't respond to received paging request from the network
b) UE response to paging request from the network is differentiated on a per paging cause basis.

The Wait Time differentiation, if needed, could be based on the mechanisms described in alternative 2 and alternative 3 of 5.1.3.3.

Wait Time enhancements, if needed, could also be applied to CELL UPDATE CONFIRM message.

5.1.3.3 Control of DTCH transmission based on priorities

As observed in clause 5.1.2.2.3.1, the amount of users in CELL_FACH state, or users that can seamlessly transit to CELL_FACH state, is expected to increase; this will bring an increase in the DTCH transmissions from CELL_FACH, which would therefore represent a significant portion of the overall traffic from UE's in common states.

The uplink DTCH traffic, or part of it, may be seen as lower priority than for instance DCCH traffic and therefore needs to be controlled separately. The network should be able to apply some control policy among the DTCH transmissions in order to differentiate between traffic relevant to prioritised and non-prioritised logical channels or users.

One solution in which these needs can be addressed is by introducing the concept of "Access Groups" for UE's in CELL_FACH state or CELL_PCH state with seamless transition to CELL_FACH state, aimed at controlling the way the UE's access the system for the DTCH transmissions.

The Access Groups may be composed of a UE related part and/or a Radio Bearer related part. The UE related part of the Access Group may be based for instance on the UE capabilities (e.g. whether the UE supports Rel-11 FACH enhancements) or user priorities. The Radio Bearer related part of the Access Group may be based for instance on logical channel/radio bearer identities or priorities. Every UE would belong to zero one or more Access Groups.

The Access Groups, assigned by the network and signalled to the UE during e.g. RRC setup, can be updated as a result of e.g. RAB Establishment. For each Access Group the network can indicate in the System Information the wanted UE action (e.g. block the access, delay the access)

The policy used to control the access can be per UE, (e.g. based on UE priority or UE capability), per radio bearer, (e.g. based on Radio Bearer Id and/or priority) or on a combination of UE and radio bearer type. The UE priority and/or the radio bearer priority could, for example, be based on the priorities used in the network to schedule HS-DSCH and E-DCH data.

The following clauses provide alternatives and examples on Access Group control based on UE priorities, Radio Bearer priorities and a combination of UE and Radio Bearer priorities.

Alternative 1: UE priority based control

The network may associate different users to different Access Groups so as to control the DTCH transmissions on the basis of UE priorities.

In the following example UE A, UE B and UE C receive the access control information in dedicated signaling, e.g. via a RRC Connection Setup or Radio Bearer Setup message. UE A is assigned AG0, UE B is assigned AG1 and UE C is assigned AG2.

Table 5.1.3.3-1: user based AG

UE A	UE B	UE C
AG0	AG1	AG2

Different handling priorities have been indicated with different colours in Table 5.1.3.3-1 (green for high priority, orange for medium priority, red for low priority)

When in CELL_FACH state or in CELL_PCH state with seamless transition, and before accessing the RACH or common E-DCH, the UE's will read the SIB's (or use the stored information blocks) in order to determine the status of the AG's and the action associated to each of them. The System Info may for instance indicate that UE's belonging to AG0 are allowed to access immediately, UE's belonging to AG1 are temporarily blocked, UE's belonging to AG2 are delayed according to a specific timer

Alternative 2: Radio Bearer priority based control

The UE's receive the access control information in dedicated signaling, e.g. via a RRC Connection Setup or Radio Bearer Reconfiguration message, containing an association between AG's and RB's.

Table 5.1.3.3-2 below shows an example of Access Groups assigned to a UE for different RB's: RB7 is associated to AG1, RB9 to AG2 and RB10 to AG3.

Table 5.1.3.3-2: traffic based AG

RB7	AG1
RB9	AG2
RB10	AG3

Different handling priorities have been indicated with different colours in Table 5.1.3.3-1 (green for high priority, orange for medium priority, red for low priority).

When in CELL_FACH state or in CELL_PCH state with seamless transition, and before accessing the RACH or common E-DCH, the UE will read the SIB's (or use the stored information blocks) in order to determine the status of the AG's and the action associated with each of them. The System Info may for instance indicate that AG2 is allowed to access immediately; AG3 is delayed according to a specific timer; AG1 is temporarily blocked.

Alternative 3: Combination of UE and Radio Bearer priority based control

UE A and UE B receive the access control information in dedicated signaling, e.g. via a RRC Connection Setup or Radio Bearer Setup message, containing an association between AG's and RB's.

Table 5.1.3.3-3 below shows an example of Access Groups assigned to UE A and UE B for different RB's: for UE A RB5 is associated to AG0, RB7 to AG1 and RB9 to AG2; for UE B RB5 is associated to AG0 and RB7 to AG5.

Table 5.1.3.3-3: user and traffic based AG

	UE A	UE B
RB5	AG0	AG0
RB7	AG1	AG5
RB9	AG2	

Different handling priorities have been indicated with different colours in Table 5.1.3.3-3 (green for high priority, orange for medium priority, red for low priority).

In this example the differentiation is achieved

- per Radio Bearer: different RB's associated to different AG's, for the same user
- per user: the same RB7 has higher access priority for UE B than for UE A (reflecting a user priority)

When in CELL_FACH state or in CELL_PCH state with seamless transition, and before accessing the RACH or common E-DCH, the UEs will read the SIB's (or use the stored information blocks) in order to determine the status of the AG's and the action associated with each of them. The System Info may for instance indicate that AG0 is allowed to access immediately; AG5 and AG2 are delayed according to a specific timer; AG1 is temporarily blocked.

Applicability of Access Group based control to Signalling Radio Bearers

If needed, Alternative 2 and Alternative 3 described above could also be extended to CCCH and DCCH transmission, i.e. RB0-4 by simply associating these Radio Bearers to Access Groups.

5.1.3.4 CELL_PCH/URA_PCH state without seamless transition

The network can indicate in the SIB that UE are not allowed to send CELL UPDATE message with cause "uplink data transmission" and Establishment cause not included.

5.1.3.5 DSAC update in CELL_DCH

Regarding the scenario described in 5.1.2.2.4.1, a possible improvement is that the network could send the DSAC information to a UE in CELL_DCH state.

Similar improvements may be considered for PPAC update in CELL_DCH state.

5.1.3.6 MAC back-off timer based on priorities

The Access Group concept described in 5.1.3.3 can also be applicable for the MAC back-off timer, i.e. different MAC back-off timers can be defined for different Access Groups (long timer for low priority, short timer for high priority).

5.1.4 Conclusions

Several scenarios were analysed and solutions have been identified for certain agreed scenarios aimed at improving UTRAN access control mechanisms in case of uplink overload.

The proposed solutions target the following improvements

- handling of access control parameters in idle and connected mode (including CELL_DCH state) in case of change of System Info
- differentiation of access delays or access restrictions per CN domain (so as prioritise for instance CS accesses over PS in case of congestion) for both idle and connected mode
- differentiation of access delays or access restrictions according to priorities for UE's in connected mode

The Wait Time improvement allows the network to differentiate, after a rejection or a release, the subsequent RRC Connection Request attempts on the basis of the CN domain identity. In case of uplink congestion it can allow a prioritisation of, for instance, CS accesses over PS accesses from idle mode, as a complementary mechanism to DSAC. Extension of the value range of the wait time would allow spreading the attempts for the non-prioritised CN domain over a longer time window.

For controlling DTCH transmissions one proposed solution allows the network to apply priority based access control policies for transmissions from CELL_FACH state or from CELL_PCH state with seamless transition. In case of UTRAN uplink overload, the network can choose to prioritise certain users, UE types or radio bearers over the others. In this way congestion mitigation can be obtained, creating more access opportunities for prioritised transmissions. Similar consideration can be drawn for the MAC back-off timer enhancements.

The control of DTCH transmissions in case of Cell Update message with cause "uplink data transmission" and Establishment cause not included allows the network to block PS, creating more access opportunities for CS data and signalling transmissions.

Additional mechanisms considered to be beneficial for the system include:

- The SIB3 reading solution providing, for certain scenarios, an improved handling of the access control parameters broadcasted in the System Info. In some scenarios it can help the network to steer in a more accurate way the UE accesses in case of network overload and hence frequent System Info updates.
- DSAC/PPAC updates in CELL_DCH state allowing a more accurate handling of Domain Specific Access Control and Paging Permission with Access Control parameters to be used in multi RAB scenarios. In some scenarios it can help the network to better control the traffic and the UL interference due to multi RAB traffic.

5.2 UL data compression

5.2.1 Background and motivation

HTTP [1] is the protocol used for retrieving webpages. A visit to a webpage typically consists of the web browser sending multiple, tens of HTTP GET/POST requests. Each GET request is made to obtain an object such as an HTML document, image, video, javascript or CSS file. These objects constitute various aspects of the website, and are processed by the browser to display the final webpage.

The following is a GET request made during a visit to www.amazon.com:

```
GET / HTTP/1.1
Host: www.amazon.com
User-Agent: Mozilla/5.0 (Windows NT 6.1; WOW64; rv:17.0) Gecko/20100101 Firefox/17.0
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Language: en-US,en;q=0.5
Accept-Encoding: gzip, deflate
Connection: keep-alive
Cookie: x-wl-uid=1nm5D3WRA2mfidzfIEB+fgNN3svOpy/jEBIHq+h8CEk1kt1Cc2DgpNSAnsFxLQwL5hgfY+3MipSY=;
session-id-time=2082787201l; session-id=184-2472291-4052047; csm-hit=535.90|; ubid-main=183-3799177-9039917;
session-
token=N9MiwGi+ROWIfFDs0xTrsA51G5cgeauxP0guon1LbsyU6THBQWb7XrrnNAR9wH6whoEYhZHJq5wRt8CTvuMl+ey
IEVmpA3heAV8ijMKMW2mn7S29jSZhknM9/iOsuq0AH1FO63UFXvvbDEf9n6z1taIQ9lNHwpkbaKwWmwTx20hF68aX7a
c/qYxHVzWfbMloQx0S1lfHKqVpIqAdZX6eX5MsbEp8haGEfK+FI5p6EczKicv1iYtf9PRTcLdDd4QO8ZWmzp+sudM=
Cache-Control: max-age=0
```

This GET is requesting the main HTML document for www.amazon.com. The request consists of various HTTP headers such as Host, User-Agent, Accept, Accept-Language, Cookie and others. Some of these HTTP headers, such as User-Agent, Accept-Language and Accept-Encoding would not change over time; and hence carry the same value in subsequent GET requests. The Cookie header, which is often the longest, is used by servers to identify the user over time and hence it is not uncommon for it to appear with the same value across several GET requests. The Host header identifies the location from which an object is requested, and this may also stay the same across GET requests for sites that host all or a majority of objects in one place.

It is expected that when comparing the stream of GET requests made in the course of downloading a webpage, there is significant redundancy across the GET packets. There are several other HTTP request methods, such as PUT and HEAD which also exhibit a similar behaviour since they follow the same format for HTTP headers.

By performing UL data compression, the number of bits needed to be sent over the air in order to convey the same amount of information is reduced. This results in a more efficient use of cellular resources by either increasing the application data rate or reducing the Rise-over-Thermal for the system.

Another possible advantage of compression is that it may enable more of the packets to be transmitted in the Cell FACH state, since the traffic volume threshold for transition to Cell DCH will be exceeded less often. The system benefits of this are reduced time holding dedicated resources in Cell DCH state resulting in reduced Rise-over-Thermal and reduced signalling load due to fewer RRC state transitions. User benefit of this is increased battery lifetime due to less time spent in the power demanding DCH state.

5.2.2 Analysis

Current mechanisms for compression include the header compression algorithms IPHC and RoHC. These algorithms operate on the TCP, UDP, IP headers of data packets. The payload of these data packets is left untouched by these algorithms; hence they cannot be used for compressing the HTTP requests.

IPHC [4] and RoHC [5] are well-studied mechanisms used to compress the TCP/IP headers of data packets. Generally, header compression may provide a compression factor of 5x (i.e. TCP/IP header is reduced by a factor of 5). The performance of current header compression algorithms is captured in clause 5.2.3.2.

5.2.3 Solutions

5.2.3.1 RAN-level compression

Figure 5.2.3.1-1 shows the architecture for a RAN-level compression solution. The transmission entity compresses a SDU received from upper layers (e.g. IP) to create a PDU. The receiver entity performs the reverse function to re-create the original SDU from the PDU it has received.

Here, compression is performed only on the payload of the TCP, UDP, IPv4/v6 packets. Hence, the compression and decompression layers need to parse the TCP, UDP and IPv4/v6 headers to identify the start and end of the payload.

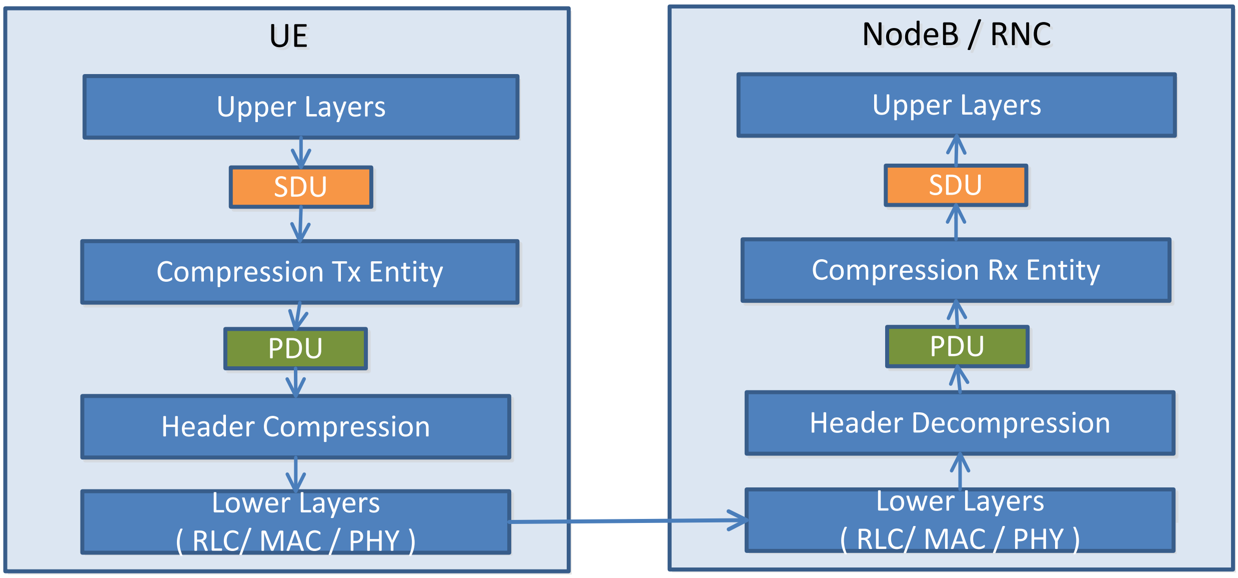


Figure 5.2.3.1-1: Architecture

5.2.3.1.1 Bytes to be (de-)compressed by RAN-level compression

There are well defined standards that perform the function of compressing UDP/TCP/IPv4/IPv6 headers. Hence, the approach taken is to extract the payload part of the data packet and to perform data compression on it alone. The various cases are illustrated below.

TCP/UDP-over-IP packet: The payload of the TCP/UDP packet is compressed/de-compressed.

Non-TCP/UDP-over-IP packet: The payload of the IP packet is compressed/de-compressed.

Non-IP packet: These packets are not processed. i.e., they pass through compression without any modifications.

5.2.3.1.2 Operations on TCP, UDP and IP headers

The RAN-level compression transmitting and receiving entities may change the payload of IP, TCP and UDP packets. This could cause the length and checksum fields in these headers to be incorrect, and hence they need to be updated.

5.2.3.1.3 Details of RAN-level compression methods

5.2.3.1.3.1 Existing compression methods

Gzip is a popular tool used for compressing data. The format of the file generated by Gzip is provided in [15]. It, in turn, uses the DEFLATE compressed data format specified in [14]. The DEFLATE data format supports compression of data by two mechanisms. One mechanism, which can be thought of as pattern-matching, is by identifying repeated string of bytes in data and replacing such occurrences with pointers to previous instances. The other mechanism is entropy coding of symbols using Huffman algorithm. It is worth noting that the DEFLATE format limits the pattern-match, to point to instances at most 32K bytes in the past and match length to be of at most 258 bytes. When applied to data packets, the algorithm faces the limitation that the pattern-match pointers can only point to instances within the packet. Due to this it fails to make use of redundancy across packets.

LZMA (Lempel–Ziv–Markov chain algorithm) is another compression mechanism, which is widely adopted in a number of operating systems and environments. This algorithm uses a dictionary compression scheme similar to the LZ77 algorithm with a variable compression-dictionary size. When compared to the gzip/bzip2 algorithms, it features a possibility to detect non-compressible data, where upon it avoids a situation when "compressed" data becomes larger than the original one.

5.2.3.1.3.2 IPDC

In this clause we describe the details of one particular instantiation of a RAN-level compression algorithm, namely IPDC.

The proposed algorithm is similar to Gzip and DEFLATE [14]. It uses the key ideas of pattern-matching (LZ77 algorithm) and entropy coding (Huffman). The main difference when compared to Gzip/DEFLATE is that the algorithm maintains a fixed amount of memory at the compressor and de-compressor so that it may keep track of the contents of past data packets. This memory enables the pattern-matching algorithm to reference instances of repeat bytes across packets.

<u>**IPDC Tx Entity**</u>

This clause describes how the transmission entity compresses the input bytes.

As the Tx Entity reads the input bytes, it tries to locate strings of bytes that have already occurred at a previous location in the input, or at some location in memory. If no match is found, bytes are written to an *Intermediate_Code_Representation* array as literal codes, (i.e. decimal value of the bytes is captured). If a match is found, a length code and distance code are inserted in the *Intermediate_Code_Representation*. Tables provided in clause 3.2.5 of [14] are used to determine the codes to be inserted for a particular length value and distance value.

Note that since the literal codes span 0 to 255, and length codes span 257 to 285, they can be thought of as representing one code space. Since the distance code occurs only after a length code, the distance codes can be considered as representing another independent code space. Next, dynamic Huffman encoding is performed on each of these code spaces (i.e. the literal+length space, and the distance space). The encoding provides the bitstrings to be used to represent each code in each of the two code spaces. Using this, *Intermediate_Code_Representation* is converted to *Intermediate_Bitstring_Representation*. Note that since several length values were represented by a single code and similarly several distance values were represented by a single code, extra bits (as captured in the tables provided in clause 3.2.5 of [14]) are inserted to identify which value is actually intended.

Finally, the Huffman tree is encoded as described in clause 3.2.7 of [14] to obtain an *Encoded_Huffman_Tree*. The final output consists of a concatenation of the *Encoded_Huffman_Tree* and the *Intermediate_Bitstring_Representation*.

The uncompressed version of the input bytes is pushed into the memory in FIFO fashion. This is done so that the data from the latest packet that is processed, is captured in memory.

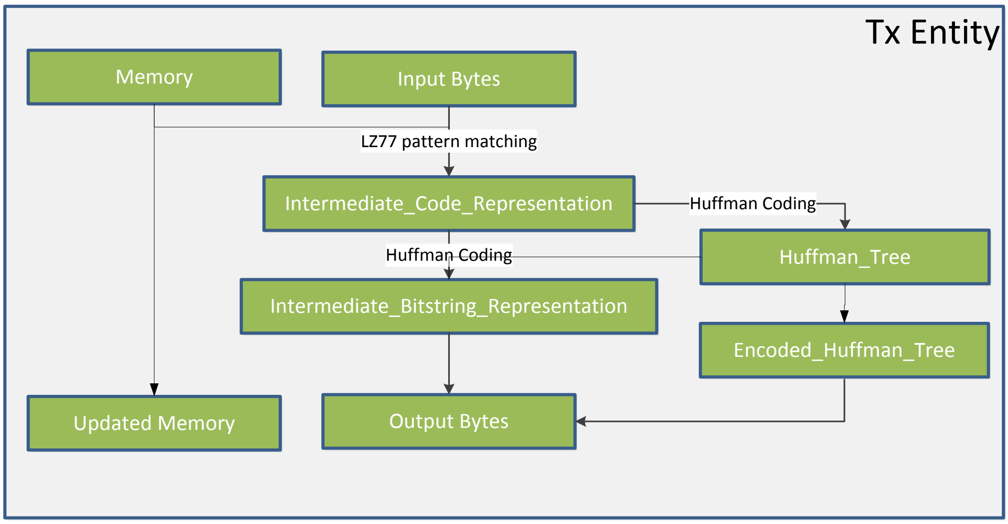


Figure 5.2.3.1.3.2-1: IPDC Tx Entity compression operation.
After compression, a copy of the input bytes is pushed into memory in FIFO fashion

Example: Tx Entity Compression Operation

Figure 5.2.3.1.3.2-3 shows the intermediate steps in the compression operation using input bytes set to '0102030A0B0C0D' in hex, and initial memory set to '0A0B0C0D' in hex. As shown in Figure 5.2.3.1.3.2-2, since the string '0A0B0C0D' is available in memory, it can be replaced by a length, distance value of 4, 7.
The length value of 4 maps to a code of 258. The distance value of 7 maps to a code of 5 and carries an extra bit '0'. Hence, in the *Intermediate_code_representation*, we have the following codes 1) length+literal: 1, 2, 3, 258 and 2) distance: 5. Separate Huffman trees are generated for these code spaces (as shown in Figure 5.2.3.1.3.2-3).
The *Intermediate_bitstring_representation* is derived using the *Intermediate_code_representation* and the Huffman trees generated. The Huffman tree is encoded as described in clause 3.2.7 of [14] to obtain *Encoded_Huffman_Tree*. The final output consists of a concatenation of the *Encoded_Huffman_Tree* and the *Intermediate_Bitstring_Representation*

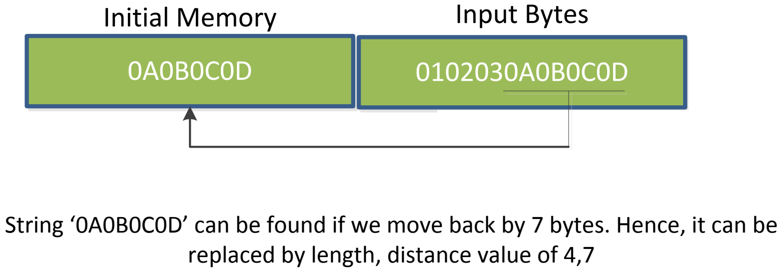


Figure 5.2.3.1.3.2-2: Referencing matching string

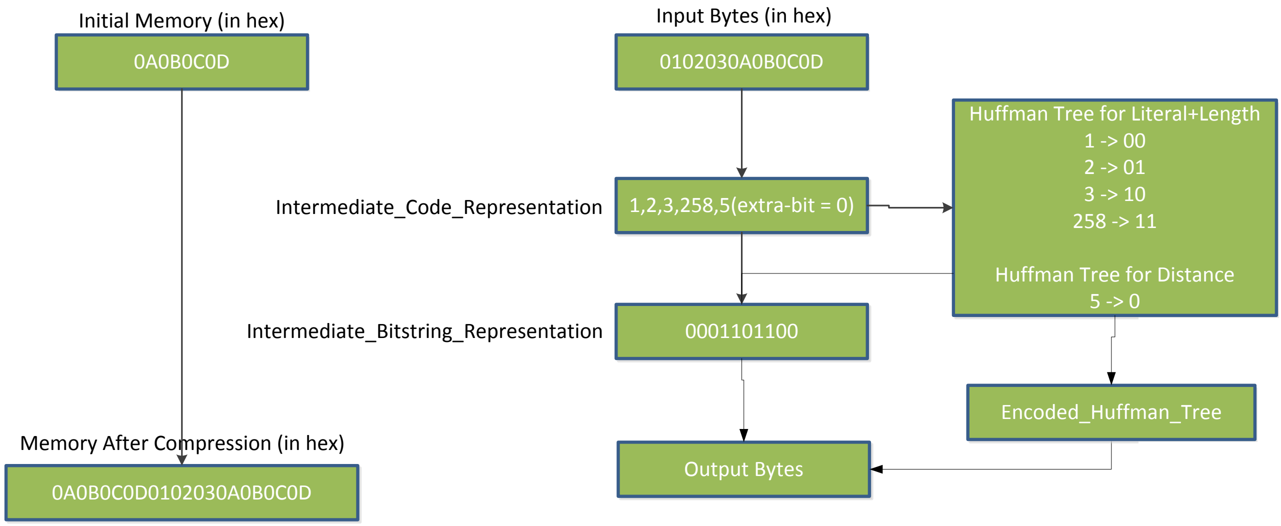


Figure 5.2.3.1.3.2-3: Example compression operation

IPDC Rx Entity

In this clause, we describe how the receiving entity decompresses the input bytes.

The input is parsed to obtain the *Encoded_Huffman_Tree* and the *Intermediate_Bitstring_Representation*. The Huffman tree is obtained by decoding the *Encoded_Huffman_Tree*, and is used to convert the *Intermediate_Bitstring_Representation* in to *Intermediate_Code_Representation*. The *Intermediate_Code_Representation* is parsed to provide an output byte stream in the following way: If the code represents a literal byte (i.e. the code is in the range of 0 to 255), the byte is output as is. If the code encountered represents a length code, the subsequent code is parsed as well since it represents the corresponding distance code. The length and distance value obtained is used to identify the string of bytes which need to be copied over. Depending on the distance value, they may refer to a previous location in the output stream, or to a location in memory.

The final output, which represents uncompressed data, is pushed into the memory in FIFO fashion. This is done so that the data from the latest packet that is processed, is captured in memory.

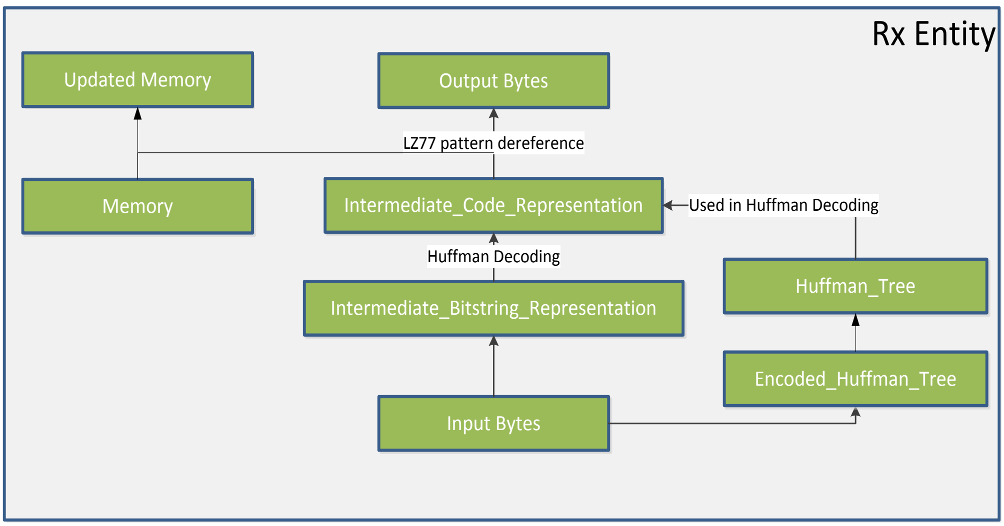


Figure 5.2.3.1.3.2-4: IPDC Rx Entity decompression operation.
After decompression, a copy of the final output bytes is pushed into the memory in FIFO fashion

5.2.3.2 Evaluation of solution

5.2.3.2.1 General aspects of RAN-level compression

The compression of data will be carried out at the UE. The following nodes are candidates for the placement of the decompression entity: SGSN/GGSN, RNC, Node B. Any compression mechanism that is supported should operate over the RLC layer so that the compression mechanism can avoid dealing with sequence errors and re-transmission issues. Hence the UE – Node B approach should be ruled out. If the UE – SGSN/GGSN approach is adopted, middle-boxes that look in to packet payload, such as proxy caches, deployed at the RNC will not be able to function properly since they will encounter compressed packets. This approach also means that the computational resource requirement, for decompression, will be much higher since a lot more data passes through the SGSN/GGSN than the RNC.

It should be noted that compressing ciphered data or certain pre-compressed data such as image/video/audio is not expected to provide much gains. If the payload data is ciphered or pre-compressed, the compression gain will come only from compressing IP/UDP/TCP/HTTP headers. In this scenario, the overall performance might not show significant savings compared to the case where no compression is performed.

A competing scheme to RAN-level compression could be to perform compression and decompression at a higher layer, such as IP or application layers. In such a design, the compression would occur at the UE and decompression at each IP address it communicates with. For instance, if a website visit triggers the web browser to load text from ip-address-1, images from ip-address-2 and advertisements from ip-address-3, the compression algorithm would not be able to take advantage of redundancy between data going to the different IP addresses. Another point to note in such an approach is that due to the end-to-end nature, any middle-boxes – such as proxy caches – may not be able to function as they do today since they will not be able to decode the compressed data. These problems do not arise in RAN-level compression.

5.2.3.2.2 Evaluation of compression algorithms

5.2.3.2.2.1 Evaluation setup

The various algorithms described above were evaluated using two evaluation setups described below.

Evaluation Setup 1: The algorithms were run on tcpdump logs collected for mobile devices within a corporate network. It was ensured that only traffic going to the internet was collected. Table 5.2.3.2.2.1-1 lists the assumptions associated with the performance evaluation. Under this setup a 5x compression of the TCP/IP headers was assumed for evaluation of header compression schemes.

Table 5.2.3.2.2.1-1: Table of assumptions

Gzip compression level setting (Setting captures tradeoff between speed and compression. It lies between 0 and 9, both inclusive. Higher values provide better compression.)	6 (This is the default setting)
IPDC memory size	32KB
Number of UEs logged	813
Duration of time logged	30mins
Type of UEs	Mobile devices
Type of traffic logged	Unencrypted

The distribution of packet sizes observed in the logs under this setup is captured in Figure 5.2.3.2.2.1-1.

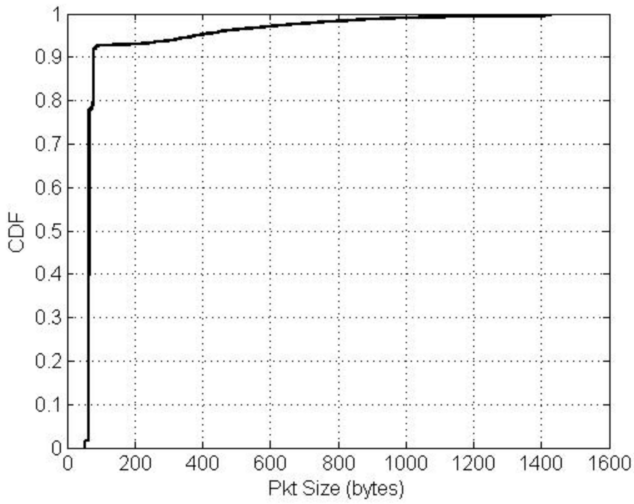


Figure 5.2.3.2.2.1-1: Packet size distribution under Evaluation Setup 1

Evaluation Setup 2: The algorithms were run on data taken directly from the IuPS interface, i.e., the one connecting RNC further to the core network. Since the IuPS interface does not only carry the user plane data, but also the core network signalling information, all the non-GTP packets were filtered out. Furthermore, since the GTP protocol itself can carry control information, only the so-called T-PDUs were considered, Every T-PDU was processed further in such a way that the transport layer and the IP/UDP/GTP headers were removed, thus leaving the user plane IP packet. Every decoded IP packet was written into a separate file, which could then be individually analysed, compressed, from which it was possible to remove IP/TCP headers etc.

Under this setup, the header compression mechanism emulates functioning of the Robust Header Compression algorithm, as defined in [5]. The considered RoHC profile handles not only 40 bytes IP/TCP packets, which are compressed on average to 5 bytes, but also so-called 52 bytes IP/TCP packets with "options", which are compressed on average to 8 bytes.

The distribution of packet sizes observed in the data collected under this setup is captured in Figure 5.2.3.2.2.1-2.

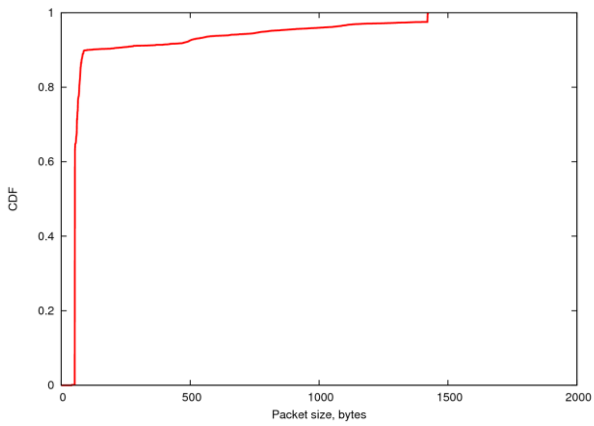


Figure 5.2.3.2.2.1-2: Packet size distribution under Evaluation Setup 2

5.2.3.2.2.2 Evaluation results

Table 5.2.3.2.2.2-1 compares compression statistics for the payload part of TCP/IP packets between Gzip and IPDC.

The metric 'Compression Level' is defined as (compressed_size / original_size)*100%.

Table 5.2.3.2.2.2-1: Compression statistics for the payload part of TCP/IP packets

Scenario (Evaluation Setup)	Compression level of Data Transmission for UL Payload only (Avg_UL_payload_size_compressed / Avg_UL_payload_size_original)*100
IPDC (1)	14.7%
Gzip (1)	71.4%

The above statistics indicate that UL data compression that takes advantage of redundancy across packets (IPDC) performs significantly better than per-packet compression (gzip).

Table 5.2.3.2.2.2-2 lists the compression statistics computed over entire IP packets (i.e. IP header + IP payload) on the uplink. Here, one can see that header compression alone can provide up to 53%-68% reduction of net data transmission on UL (depending on the evaluation setup). This is because a large percentage of the bytes on uplink, in the analyzed logs, are from TCP/IP headers. Enabling payload compression can provide gains both with and without header compression. This provides the motivation for enabling header compression in addition to data compression of the payload.

Table 5.2.3.2.2.2-2: Compression statistics computed over entire IP packets (i.e. IP header + IP payload) on the uplink

Scenario (Evaluation Setup)	Compression level of Data Transmission for UL (Avg_UL_packet_size_compressed / Avg_UL_packet_size_original)*100
IPDC w Header Compression (1)	17.9%
Gzip w Header Compression (1)	41.7%
LZMA w Header Compression (2)	48.0%
Header Compression (1)	52.6%
Header Compression (2)	67.8%
IPDC w/o Header Compression (1)	66.7%
Gzip w/o Header Compression (1)	90.9%
LZMA w/o Header Compression (2)	80.19%

Table 5.2.3.2.2.2-3 shows some further statistics for IPDC, collected by visiting individual websites (as opposed to from the entire log). For these results, the other assumptions are the same as described in evaluation setup 1:

Table 5.2.3.2.2.2-3: Compression statistics for the proposed algorithm

Scenario (Evaluation Setup)	Compression level of Data Transmission for UL Payload only (Avg_UL_payload_size_compressed / Avg_UL_payload_size_original)*100
Browsing to NYTimes.com (1)	16.9%
Browsing to PBS.org (1)	14.9%
Browsing to Whitehouse.gov (1)	20.8%
Browsing to Akamai.com (1)	17.9%
Browsing to Amazon.com (1)	23.8%

5.2.4 Conclusions

From the data provided, we notice that payload compression provides gains for compressible data. We can also draw the conclusion that compression that takes in to account redundancy across packets provides higher gains when compared to the individual packet compression. Since there is a noticeable amount of small packets in the UL direction, the header compression alone also provides gains. The highest amount of compression is achieved when both header and payload compression are enabled. Also, ciphered data or certain pre-compressed data such as image/video/audio may not be compressed. Finally, compression between UE and RNC does not require changes to the operation of middle boxes (such as proxy caches).

5.3 Improvements to EUL coverage

5.3.1 Background and motivation

In current 3G networks, there is still a substantial amount of large macro cells where supporting 2ms in the entire cell may be a challenge. In such environments, it may be necessary to fall back to the 10ms TTI when a user approaches the cell boundary. The switch to the 10ms TTI, however, should be made as late as possible in order to retain the advantage of the 2ms TTI and to avoid back-and-forth reconfigurations.

An efficient 2ms to 10msTTI switch is directly related to the accuracy of the coverage measurement and to the speed and robustness of the switching procedure. In case of non-optimal measurement triggers and slow switching procedures, some conservative safety margins have to be taken into account (e.g. long activation time for the switching procedure, leading to an early switch), resulting in further loss of 2ms coverage.

5.3.2 Analysis

5.3.2.1 Improvements to UPH measurements

The switch from 2ms to 10ms TTI is typically triggered by UL coverage measurements. Common methods for measuring the UL coverage are based on Measurement Report event 6A or 6D and UPH.

Event 6A and 6D, when configured, are triggered respectively when the UE Tx power becomes larger than an absolute threshold and when the UE Tx power reaches its maximum value. As for other measurements configured by L3, event 6A and 6D have the advantage of making use of filtering, hysteresis, time-to-trigger etc. which improve stability and avoid fluctuations of the measurements.

On the other hand the tuning of these measurements may be challenging due to the necessity of avoiding too early triggers (i.e. when the UE is still under a good 2ms TTI coverage) or too late triggers (i.e. the UE has already lost the 2ms TTI coverage and the measurement report cannot be received by the network).

An example of an event triggered too early is when UE Tx power increase is due to a high rate transmission when the UE is still under a good 2ms TTI coverage. An example of an event triggered too late is when the UE is moving out of 2ms TTI coverage when not transmitting data and the UL DPCCH power is still below the reporting threshold. When eventually the DPCCH power triggers the event, the UE will not have enough power to transmit the Measurement Report.

The UPH, UE power headroom, indicates the ratio of the maximum UE transmission power and the DPCCH code power, averaged over a 100 ms period. The UPH is sent as part of the MAC Scheduling Information. Compared to the event 6A and 6D, UPH provides a better coverage indication since it is based not only on the maximum UE Tx power but also on the UL DPCCH power. However this measurement does not make use of filtering, time to trigger and hysteresis, hence it is subject to fluctuation. In addition, existing UPH measurements as defined in 25.215 and 25.133 (e.g. the measurement period and accuracy) are not considered optimal for the network to make a TTI switching decision.

One more issue is that the UPH does not have its own triggers but it is sent only when the SI is triggered. Even though the SI can be configured periodically, in CELL_DCH state it cannot be sent if the TEBS (Total E DCH Buffer Status) is equal to zero, i.e. it cannot be sent if there is no data to send.

5.3.2.2 Reconfiguration enhancements

The switching procedure needs to be synchronized in order for the UE and the network to know exactly when the switch takes place. As a synchronized procedure, there is some risk associated with each execution, especially in situations where coverage may be an issue. Furthermore, the activation time is usually set rather conservatively to guard against occasional loss of the reconfiguration message or its acknowledgement. The consequence of an activation time not sufficiently long might be that the Node B and the UE do not switch at the same time, remaining misaligned for one or more CFN cycles.

Figure 5.3.2.2-1 gives an example of misalignment of E-DCH TTI lengths in the UE and in the network in case of retransmissions of the reconfiguration message.

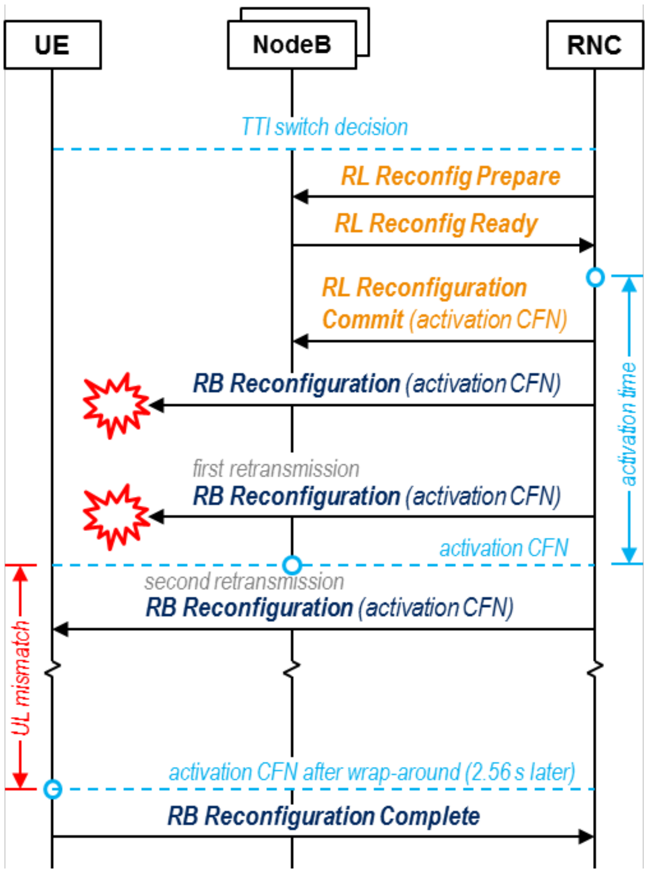


Figure 5.3.2.2-1: Example of misalignment of E-DCH TTI lengths in the UE and in the network

The network sends a reconfiguration message with an activation CFN taking into account at most one retransmission. Both the transmission and the first retransmission of the reconfiguration message are not received by the UE, whereas the Node B has correctly received the reconfiguration order (including the activation CFN). At activation time, the Node B switches to 10ms TTI, whereas the UE still has not received the reconfiguration message and continues operating at 2ms TTI for one more CFN cycle. Data transmitted in the meanwhile will be lost. If SRB2/SRB3/SRB4 are transmitted, the loss of the data will lead to an RLC unrecoverable error.

The case outlined herein describes some limitations related to the switching procedure, resulting in substantial loss of 2ms TTI coverage. Improvements aimed at reducing the switching procedure lead time and at increasing the procedure robustness would on the other hand allow gaining 2ms TTI coverage.

5.3.2.3 Initial TTI selection

Currently, the UE may include Measured results on RACH in uplink RRC messages if the network indicates to do so in SIBs, and either RSCP or Ec/No of the serving cell is allowed to be included (but not both). Ec/No is critical for the RNC in order for initial parameter configuration or admission control, and RSCP can reflect UE's position or the coverage area, for example, the coverage of 2ms E-DCH TTI or 10ms E-DCH TTI. Both RSCP and Ec/No may be needed for admission control and initial TTI selection.

5.3.3 Solutions

5.3.3.1 UPH measurements

As described above, UPH measurements do not rely on any filtering, apart from being averaged over a fixed 100 ms period. A possible improvement would be introducing additional and configurable (via RRC signaling) measurement windows or filter conditions, as for current L3 measurements. Similarly, other L3 mechanisms, such as triggering thresholds, hysteresis margins, time-to-trigger, number of repetitions after trigger, etc. may be introduced.

Regarding the signalling aspect, the UPH measurements may be sent to the network via the MAC protocol, using an 18-bit PDU having the same format as the SI. It should be possible that the filtered UPH can be transmitted even though the TEBS is zero. It should be possible to distinguish the filtered UPH report from the legacy UPH. It is FFS whether the UPH can also be sent using a RRC message.

5.3.3.2 E-DCH TTI switching

The speed and robustness of the switching procedure may be improved by introducing a lower layer (MAC or L1) synchronized reconfiguration with dynamic activation time determination between UE and Node B allowing the network not to determine beforehand the activation time (i.e. the activation time would be "now"), but guaranteeing at the same time that both Node B and UE are synchronized. The fast TTI switching mechanisms may rely on the network pre-configuration in the UE of 2ms and 10ms TTI, and the Node B's sending the final switching order via HS-SCCH order.

Either the Node B or the RNC takes the decision for TTI switching.

Figure 5.3.3.2-1 below shows an example of a 2ms to 10ms Node B-initiated switching procedure (where the TTI switch decision is taken by the serving Node B) relying on MAC UPH reports and 10ms TTI pre-configuration.

The UE sends an 18-bit UPH report to the Node B when the triggering criteria are met. The serving Node B initiates a synchronized reconfiguration with the UE to order the switch to a 10ms TTI. The synchronized reconfiguration may be achieved by using a HS-SCCH order followed by a L1 ACK (not shown in the figure). Optionally, if the reconfiguration fails, the UE will re-transmit the UPH report according to a configurable repetition pattern]. Both UE and the network will switch to 10ms TTI a predefined number of TTIs after the completion of the synchronized reconfiguration.

In case of Soft Handover, in order to ensure that both serving and non-serving Node B's switch TTI simultaneously, the UE may send a L1 or MAC indication after receiving the HS-SCCH order and before the actual switch. Alternatively, the serving Node B will inform the RNC of the TTI length update and the RNC will forward the information to all the Node B's in order to guarantee the alignment among serving and non-serving Node B's. In case L1 or MAC indication is used, the mechanism should ensure increased decoding possibility of the indication at the non-serving Node B's. This could entail, for example, transmitting the indication at higher power or re-transmitting till an acknowledgement is received from the non-serving Node B's.

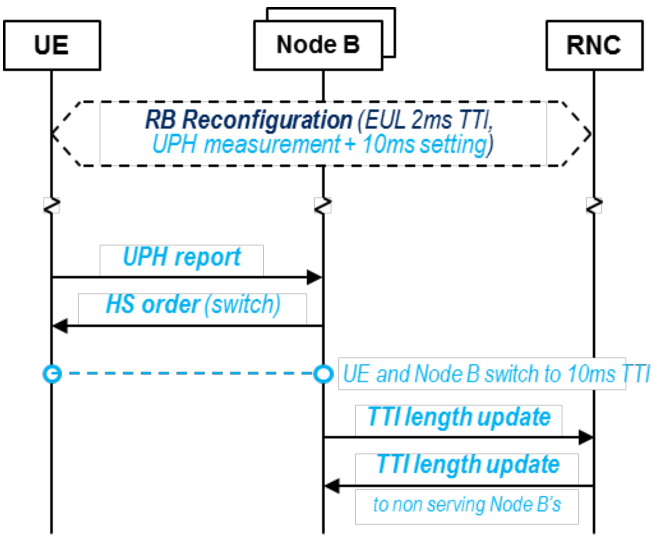


Figure 5.3.3.2-1: Node B-initiated E-DCH TTI switching procedure

In case the RNC takes the decision, either the Node B informs the RNC about the triggering criteria being met and the RNC responds with a "proceed" message or alternatively the RNC sends directly the reconfiguration message to the Node B. The RNC will inform all non-serving Node B's of the TTI length change.

5.3.3.3 Initial TTI selection enhancements

The network can configure, via system information, the UE to report both Ec/No and RSCP values e.g. during RRC Connection establishment procedure. In this case, the network will have additional information in order to make decision on initial E-DCH TTI selection for the UE.

In Rel-11 Further Enhancements to CELL_FACH state feature, if Concurrent deployment of 2ms and 10ms TTI is supported, the selected common E-DCH TTI type can be used for initial TTI configuration.

5.3.4 Conclusions

Three main improvement areas have been identified and solutions for these areas have been proposed.

The enhanced UPH measurements allow for a more accurate UL coverage evaluation. The new triggers can be used to determine the switch between 2 ms and 10 ms TTI. As a result, a better utilisation of the 2ms coverage area is expected.

The TTI switch enhancements allow for a fast and robust reconfiguration of the TTI type, contributing to an increase of the usable 2ms TTI coverage area. Two main design options are possible regarding which node (Node B or RNC) takes the switching decision.

The Node B based approach is faster as the Node B can make a decision and send immediately the activation command to a UE, whereas the RNC should first receive all the measurement information before making a decision. At the same time, if the Node B determines when the criteria for TTI switch are met, sends an indication to the RNC and waits for the "proceed" command from the RNC, then this approach is the same when compared to a case when the RNC makes a decision and sends the corresponding reconfiguration command to the Node B.

For the RNC based approach, if the RNC receives the enhanced UPH measurement (or an indication of it from the Node B), it might have more information with regards to deciding when to perform the UL TTI switch. As per the legacy behaviour, the RNC can already configure and receive a number of various RRC reports, such as 6x events and path loss measurements, which facilitate the RNC with a decision making process. That can be also complemented with additional information, such as established RABs, their QoS requirements, etc.

With the Node B based approach, in case of Soft Handover, if no additional messages are exchanged between the RNC and the Node B once the latter makes a decision, then an additional mechanism (e.g. a L1 or MAC indication) is needed to ensure that non-serving Node B's are updated with a new UL TTI length. Further evaluation may be needed on the reliability aspect of this mechanism.

Regarding the initial TTI selection enhancement, this allows the network to better estimate the initial coverage area of UE's requesting RRC connection from idle mode state, so as to allocate more efficiently the appropriate TTI.

5.4 Enabling high bit rates

5.4.1 Background and motivation

In a WCDMA system all users share the same uplink radio resources and can access the system at the same time. The separation of different users is achieved by using different scrambling codes. Due to the non-orthogonality of the codes, significant interference is still experienced. The interference increases with the increase of the transmitted bitrates. High bitrates introduce high interference to other users, and those users must increase their transmit power to overcome the interference and maintain their required signal to interference ratio at the receiver, affecting the cell both in terms of capacity and coverage. As a consequence the high bitrates supported by the 3GPP specifications are not sufficiently used in real network and mixed traffic environments.

It is well known that the most efficient way for a very high bitrate user to transmit in the uplink in a cell is when that user is alone, and can both achieve the required high signal to interference ratio, and avoid affecting other users in the cell. To enable ubiquitous high bitrate operation in a real-network environment, it makes sense to consider ways to isolate high-bitrates transmissions from users that are vulnerable to the high interference created and vice versa.

A natural way to accomplish this within the current WCDMA technology is to make use of a dedicated carrier, e.g. having a first "regular" carrier providing the basic services and a second carrier dedicated exclusively to high-bitrate transmissions.

One method of implementing this idea is to make use of the Inter-Frequency Handover (IFHO) procedure. Users are admitted on the regular carrier where user bitrates are limited to a certain maximum value. When there is a need for higher rates, the UE is reconfigured to a dedicated high-bitrate carrier using the IFHO procedure. When the need for high rates disappears, the UE is reconfigured back to a "regular" carrier.

This procedure has some major drawbacks when we consider real bursty network traffic, in that it entails continuous re-allocation of system resources and increased RRC signalling (with associated delays). Furthermore the method doesn't seem to be efficient in case of MRAB (e.g. in case a speech call is initiated while the UE is configured on a dedicated carrier)

An improved method is to make use of the Rel-9 DC-HSUPA feature. A UE can transmit simultaneously on two carriers, a primary carrier and a secondary carrier. The traffic can be split among the two carriers based on the respective serving grants. The primary carrier can be configured as a regular carrier and the secondary as dedicated high-bitrate carrier where only one user is allowed to transmit at a time. When there is no high-bitrate need, the UE is scheduled to transmit data only on the primary carrier. When there is the need, the UE can be scheduled to transmit on the secondary carrier in addition to the primary carrier or on the secondary carrier only, and subject to the availability of the secondary carrier.

This DC-HSUPA method is an obvious improvement for real bursty traffic compared to the IFHO method above. However it still has a number of drawbacks. For example it requires continuous activation and de-activation of the secondary carrier, with evident costs in terms of delays. As an alternative, maintaining the secondary uplink carrier active would imply frequent transmission of the UL DPCCH with increased interference and UE power consumption.

In order to overcome the issues described above, an approach is proposed based on a cost efficient clean carrier concept, i.e., a "Lean Carrier" approach that addresses the following:

1. Signalling and delays
2. Battery consumption for the UE
3. Impact of uplink interference on DPCCH of inactive users
4. Impact of DPCCH of inactive users on network capacity

On top of these high level goals, the Lean Carrier operations have to allow the co-existence of legacy users and Rel-12 users.

5.4.2 CPC and power control

5.4.2.1 Analysis

A Lean carrier capable UE may transmit on a primary and a secondary carrier simultaneously. The primary carrier may be configured to a regular carrier (with low to medium RoT) and is responsible for the UE's normal operations such as maintaining radio-link quality, maintaining mobility, transmitting RRC signalling and user data at a moderately low rate. The secondary carrier may be configured to a Lean Carrier, a carrier similar to a Rel-9 DC-HSUPA secondary carrier, which is better capable of efficient high bitrate/high RoT transmissions for multiple users. The Lean carrier is preferably used as a dedicated high bitrate data carrier.

For more efficient utilization of the Lean carrier it is desired that UEs can transmit on the Lean carrier with very low latency. One way of minimizing latency is to avoid delays involved with activating and deactivating UEs on the secondary carrier. UEs on the Lean carrier are therefore always activated, even for longer periods when data is not transmitted. UEs which are active on a regular Rel-9 DC-HSUPA secondary carrier, but not transmitting any data, will at least transmit periodic DPCCH bursts. Transmitting DPCCH bursts for channel sounding when no data is transmitted works well as long as the interference environment for a UE remains fairly stable in time. However this is not the case in an environment with bursty high data rate smartphone users. In these typical scenarios the interference can change quickly within a very short time. For the UE that is granted to transmit on the Lean carrier, the intra-cell interference it experiences is rather low. For the UEs that are not transmitting, the experienced interference can be extremely high when there is another high data rate UE transmitting on the carrier. This extreme environment has serious implications on transmitting DPCCH bursts while other high data rate transmissions are on-going, for example:

- *Increased DPCCH cost*
  A high SIR is needed for high data rate transmission. Since the UE keeps the same SIR target when it is not transmitting, the cost of stand-alone DPCCH transmission is rather expensive.

- *Inaccurate power for initial transmissions*
  Due to the high interference on the Lean carrier, potential stand-alone DPCCHs of UEs not transmitting data needs to have a fairly high power to maintain the required SIR. When it is a user's turn to transmit, the high interference disappears and the SIR can easily jump up. The highly increased UE transmission power may decrease the maximum bitrate as the UE can easily become power limited. On the other hand, if there has not been any data transmission on the Lean carrier, the UE would have lowered the DPCCH SIR due to stand-alone DPCCH transmission and the DPCCH power may be too low when the UE starts transmitting data.

- *Difficulty in following fading*
  Due to the large difference in interference when there is or is not data activity on the Lean carrier, there is a severe risk that inner-loop power control may react to the scheduling rather than the actual variation in channel fading if stand-alone DPCCHs are transmitted.

- *Too low DPCCH power after data transmissions*
  The problems with the difference in required DPCCH SIR between a UE transmitting and a UE not transmitting data can become even more severe in some situations, for example when the UE finishes its Lean carrier transmission at the top of the fading pattern and the channel starts deteriorating.

5.4.2.2 Solutions

There are several potential options to enhance power control and reduce DPCCH overhead.

Option 1: Control DPCCH SNR instead of SINR

This method can be seen a Node B implementation method. Instead of SINR target, Node B controls a SNR target for uplink Inner Loop Power Control. In this way, DPCCH power will not vary too much with the change of interference conditions.

Option 2: Disable the transmission of uplink DPCCH when no uplink data transmission occurs. That is, no DPCCH burst are transmitted between the uplink transmissions

Due to typical bursty high data rate traffic expected on a Lean carrier the power setting for the uplink channels is crucial for initial transmissions, regardless if DPCCH bursts are transmitted or not as explained in the analysis clause. For power control purpose the following two scenarios can be distinguished:

1. *The time between two transmissions on the Lean carrier is large*
   This is similar to the Rel-9 DC-HSUPA situation when the secondary carrier has been deactivated and activation is needed before data can be transmitted. There, the initial DPCCH power for the secondary carrier is determined from that of the primary carrier plus a configurable offset to account for the difference in fast fading between the two carriers. A similar approach can be used for the Lean carrier:

   PDPCCH,2 = PDPCCH,1 + Large_Gap_Margin,

   where PDPCCH,1 and PDPCCH,2 are the DPCCH power of the primary and secondary carriers.

2. *The time between two transmissions is relatively short*
   For example on the order of a typical CPC DTX cycle. In an environment without bursty high data rate traffic the DPCCH bursts, post-ambles and preambles can often handle the fast fading. In bursty high data rate traffic scenario this is not the case. To account for the possible need to increase the power after a transmission gap on a Lean carrier, an extra "small gap" margin can be added to the DPCCH power, instead of tracking the channel, when transmissions are recovered. This margin may be fixed or dependent on the size of the gap.

Option 3: DPCCH is only transmitted with E-DCH or as preamble during several TTIs/slots before E-DCH transmission. DPCCH is not transmitted periodically when there is no E-DCH transmitted as in CPC case.

DPCCH preamble is expected to benefit path search, power control and setting of uplink grant. After preamble stage, path search performance is expected to be reliable, DPCCH power is expected to be controlled at an appropriate value and uplink grant sent by Node B is expected to be efficient. How to set the length of DPCCH preamble may need further study.

5.4.2.3 Evaluations on link level results

A compendium of the main link simulation results are included in Appendix B.1.2, where the performance of the CPC baseline and the Lean Carrier proposal are evaluated for several scenarios. The most relevant findings for each of the evaluated scenarios are listed below:

- **Impact of DPCCH bursts on data transmission:** At very high bitrate, the simulation results have shown that data transmissions are sensitive to even small amount of interferences created by the DPCCH bursts from CPC. The transmissions can become unstable when interfered by more than just a couple of DPCCH bursts from other users. For this reason, the Lean carrier has a substantial gain over the baseline CPC at 10 Mbps. The gain, however, decreases at lower bitrates such as 5 and 2 Mbps, as can be seen from the results in Sec. B.1.2.2 below.
  The gain also decreases when longer DTX cycles and smaller DPCCH bursts are used.
  It should, however, be reminded that the current specification do not allow different CPC settings to be used for the primary and the secondary carrier for the same UE.
  The results in B.1.2.2 also show that when it is possible to use SNR power control and a lower operating SIR, e.g., -19 dB (corresponding to a system-level SIR of 5 dB), the gain of Lean from this aspect is further reduced and may become negligible in some scenario.

- **Impact of interference on DPCCH bursts:** Next the impact of data transmissions on the DPCCH bursts was studied. The results show that this has a significant impact on the performance. The impact increases when there are more DPCCH bursts between two data transmissions. More importantly, the gain of the Lean carrier over the baseline CPC remains quite substantial even in the case of the most extreme CPC setting.

5.4.2.4 Evaluations on system level results

System-level evaluation of Lean carrier performance is given in B.1.3 below. Simulation results for two traffic scenarios are provided:

- Full-buffer users with a fixed transmission pattern

- Dynamic traffic with lognormal-distributed file sizes and exponentially distributed reading times.

The results show quite good gains of 1 to 2 dB in noise rise when a static transmission pattern is used. With dynamic traffic, the gain is even larger, close to a 4dB gain even for the most extreme CPC pattern with the smallest burst size and the longest DTX cycle. There is also an improvement in the average cell throughput for the dynamic-traffic case.

5.4.3 Grant handling

5.4.3.1 Analysis

The motivation for introducing a grant handling enhancement is to avoid the drawbacks with operating a bursty high data rate traffic using legacy E-AGCH channel. The main drawbacks are:

- The need for signalling two E-AGCH's, one for starting and one for stopping data transmissions, which is explained in detail below.
- Serious consequences for missed detection of the terminating grant.
- Flexibility, e.g. ability to operate without TTI gaps between users.

The TDM scheduling can be realized in the currently working system, however the signalling overhead is significant. To begin the TDM operation all but one UE in a cell have to receive the ZERO-grant command. It is assumed that in the TDM mode the Node B has to nominate one UE which will transmit for the next period, while the UE transmitting in the previous period has to be informed that it has to stop the transmission. For that 2 commands have to be issued:

1 E-AGCH with either ZERO, INACTIVE

2 E-AGCH with Absolute Grant Value for a UE nominated to transmit in the next period.

The signalling message flow required to perform the TDM operation is presented in Figure 5.4.3.1-1.

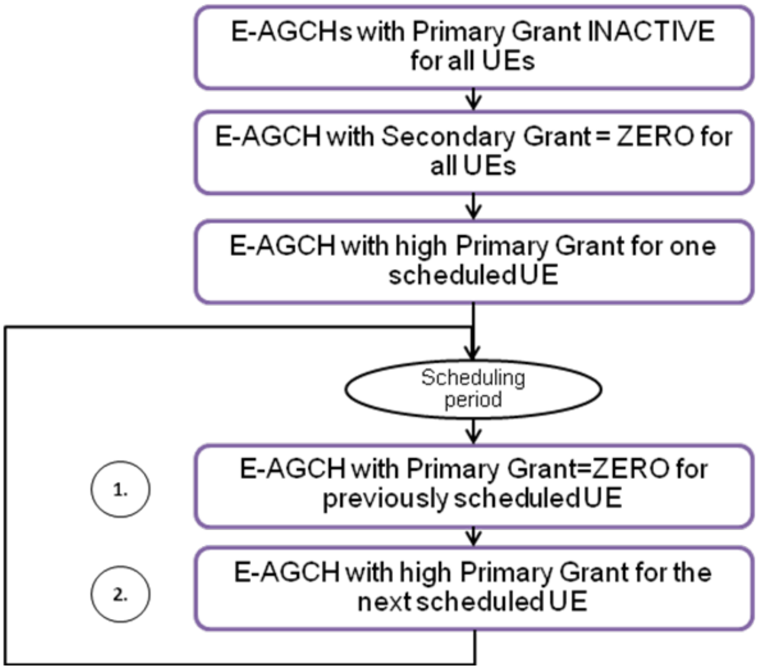


Figure 5.4.3.1-1: Legacy grant signalling for the TDM operation

The main disadvantage of this approach is that after sending the ZERO-grant to currently transmitting UE one TTI is lost (no UE transmitting with a high bitrate in the next TTI) before the next UE receives and applies new absolute grant. This reduces gains coming from the TDM scheduling. Reversing steps 1 and 2 would lead to a situation where two UEs transmit simultaneously with high grants for at least one TTI before one of them receives and applies the ZERO-grant. This would cause very high interference for both transmissions and also to the neighbouring cells.

5.4.3.2 Solutions

To avoid the drawbacks with the legacy Absolute Grant signalling following alternatives could be considered:

- Time limited grants: A new E-AGCH-like grant channel, for enabling time limited grants
- Grant detection: A new grant signalled to one UE to implicitly, by means of detecting a message with incorrect CRC on the grant channel, be interpreted as a stop-command for the other UE(s) currently actively transmitting.
- Fast scheduling grants: A new E-RGCH-like for separating scheduling from link adaptation.
- New E-AGCH timing for deactivation: A new timing for E-AGCH based grant deactivation enable the granted UE to be switched without a gap in transmission by using only one E-AGCH channel.

In addition, considering more than one UE may need to be scheduled at a given time to be able to fill the available RoT headroom in power/buffer limited situations and to be able to benefit from IC receivers, design options should consider to support more than one UE scheduled at a given time.

5.4.3.2.1 Time-Limited Grant (TG)

A Time-Limited Grant (TG) is similar to an Absolute Grant (AG) but with an additional field indicating the number of TTI for which the grant is valid. The main purpose is to avoid the scheduling gap mentioned above for the baseline Absolute Grant.

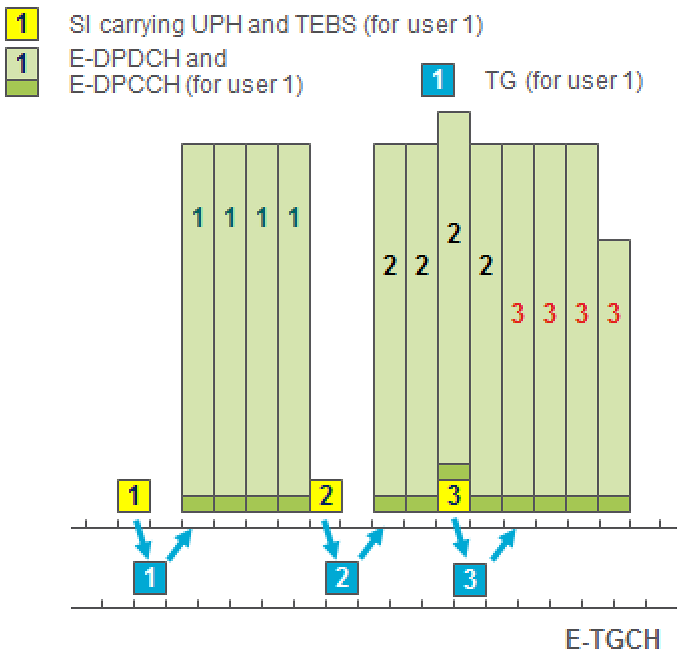


Figure 5.4.3.2.1-1: An example illustrating the use of TG for allocating transmission occasions in TDM operation

Figure 5.4.3.2.1-1 shows a simplified example of how a 4-TTI TG works. The network listens to the SI sent by the UEs when data transmission begins to decide which UE should be given a TG. TGs are then sent on the new grant channel, labelled as E-TGCH. For UE 1 in the figure, the TG is not renewed by the network, possibly due to a low buffer status. The TG of UE 2 is also not renewed because UE 3 has arrived and it needs to be prioritized in the scheduling. Note that some or all of the UEs may be given a TG of a longer or shorter duration depending on the need.

Unintended or unexpected transmissions or retransmissions in TDM operation can lead to collisions that are not resolved until HARQ failures occur for the UEs. When regular AGs are used, unexpected transmissions can result from missed detection of a transmission-terminating AG (e.g., the ZERO_GRANT) Unexpected retransmissions can be due to missed ACKs on the E-HICH or missed detection of a prior E-DCH transmission or re-transmission. For these reasons, in addition to the use of TGs for first transmissions, HARQ retransmissions are proposed to be granted using a TG.

The grant handling for retransmission can be more complicated than the example given in Figure 5.4.3.2.1-1. When switching between two UEs, as it is the case between UE 2 and 3 above, the network cannot grant a particular TTI to a new UE until it is sure that the previous UE will not perform a HARQ retransmission. The network can either prioritize a retransmission by granting the new user one TTI at a time or it can delay a retransmission until the next occasion. In the case that the UE does not receive a grant for a retransmission, to simplify the handling, the UE considers the retransmission executed, i.e., increment the RSN by 1 and keep the data in the HARQ buffer according to the baseline. Figure 5.4.3.2.1-2 shows the timing relation of the baseline E-AGCH with respect to the E-DCH. The same timing relation is proposed for the new grant channel.

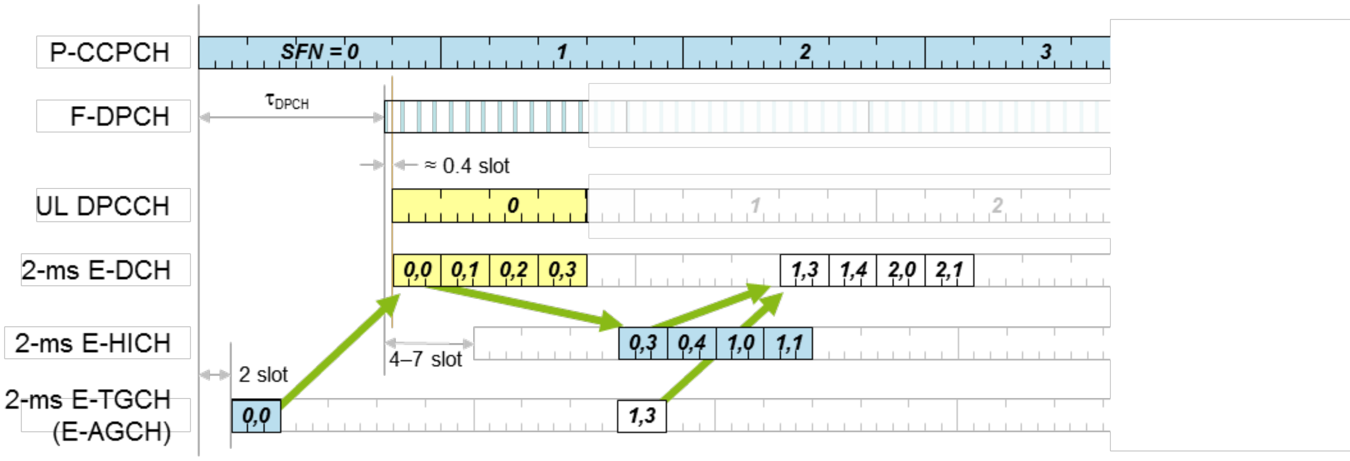


Figure 5.4.3.2.1-2: Timing of the E-AGCH and the new grant channel with respect to the E-DCH and related channels

In Figure 5.4.3.2.1-2 a TG is transmitted at (SFN, subframe) = (0, 0), which triggered 4 TTIs of data transmissions from (0, 0) to (0, 3) on the E-DCH. If not ACK'ed, the data will have to be retransmitted, in (1,3) to (2,1). Note that the HARQ feedback for the previous data transmission for a HARQ process and the grant for the next transmission for the same HARQ process have the same timing so that it is possible for the network to decide whether to grant a retransmission or a new transmission for another UE.

As mentioned, the design of the new grant channel follows that of the E-AGCH with the same channel structure and the same timing relations. Since the TDM operation is often intended for higher rates, fewer bits are needed to signal the grant value. The saved bits can then be used for signalling the grant duration. Thus the only change required is the re-interpretation of the bits sent on the E-AGCH.

5.4.3.2.2 Grant detection

In HSUPA all active UEs monitor the E-AGCH channel. When a transmission occurs each UE tries to decode the grant message by performing a CRC check with its E-RNTI. If a UE successfully decodes the grant it starts the grant update procedure. It is proposed that all other TDM UEs who receive an E-AGCH transmission which is not intended for them (the CRC check fails) automatically set their Serving Grants to zero. This way a single E-AGCH command would provide an absolute grant for one UE and at the same time “silence” other UEs in the cell. The mentioned E-AGCH channel for TDM UEs could be transmitted using dedicated OVSF code. This would ensure that grant signalling to legacy UEs would not interfere with the described approach.

The proposed solution saves signalling overhead as only one signalling message is needed every scheduling period. It also solves the problem of lost TTI between steps 1 and 2 in the Figure 5.4.3.1-1. The solution doesn't require new signalling channel design. Instead, the legacy E-AGCH channel can be used.

This raises a question whether a reliable detection of the E-AGCH transmission dedicated to another UE is possible without knowing the E-RNTI of that UE. Two errors that might occur are false alarm (UE detects the E-AGCH which is not present) and missed detection (UE doesn't detect the valid E-AGCH transmission). A simple link level simulation has been performed and is shown in Annex B.1.1.1. The simulations prove that the E-AGCH presence can be detected with high probability by other means than the CRC check.

One potential disadvantage of Grant Detection is scheduling only one UE at the time. In some cases a single UE may not be capable of utilizing whole RoT budget. That would lead to underutilization of resources unless another UE is scheduled at the same time to fill the remaining RoT margin. Scheduling of more than one UE can also help to utilize the capability of the successive interference cancelling receivers. One solution to this problem is to use the legacy E-AGCH to schedule additional UE(s). As mentioned before, the TDM operating UEs could use the E-AGCH channel transmitted on a dedicated OVSF code to allow coexistence with the legacy scheduling. It means that new UEs could monitor both new and legacy E-AGCHs and use also the legacy one to receive additional grants. The legacy E-AGCH cannot operate in the Grant Detection mode but it would be used only to provide additional flexibility to the Grant Detection scheme. A simplified illustration for this operation is presented below.

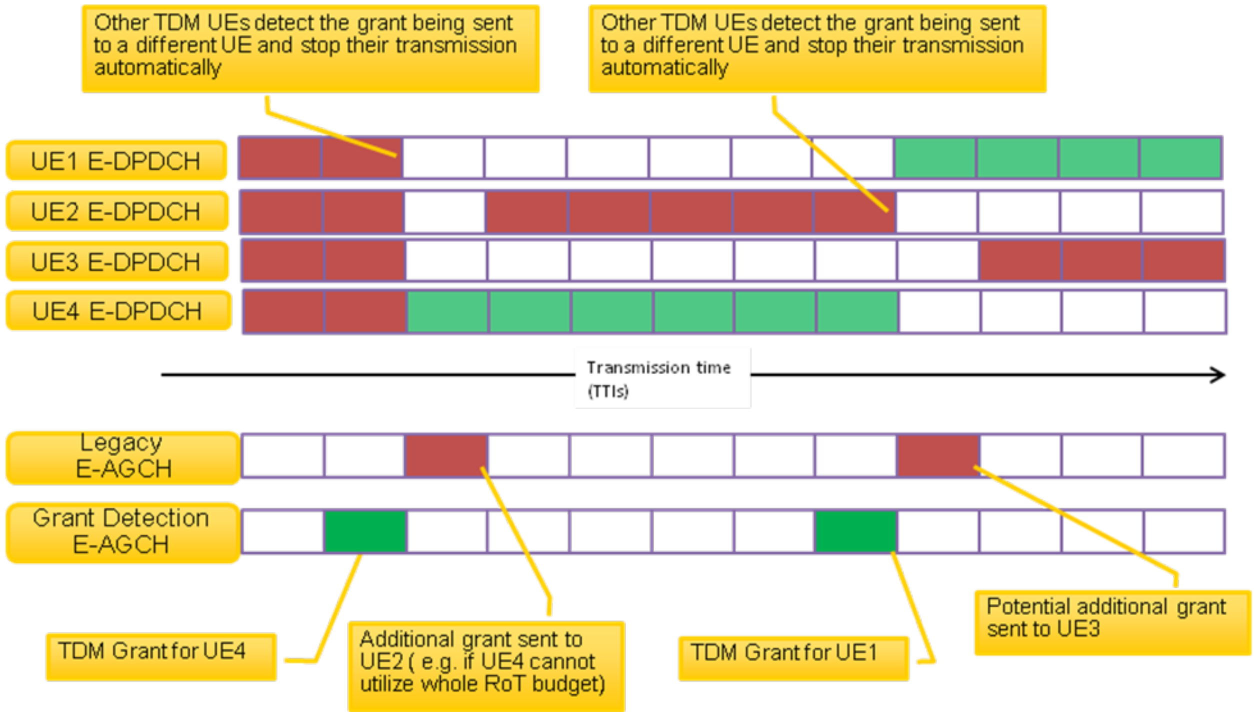


Figure 5.4.3.2.2-1: Scheduling multiple UEs using Grant Detection and legacy E-AGCH

Figure 5.4.3.2.2-1 presents example operation of a cell with 4 TDM UEs. When UE4 receives an Absolute Grant sent using the E-AGCH on a dedicated OVSF code it uses the grant value to update its Serving Grant and starts the transmission with the updated power level. Simultaneously other UEs detect this message being sent without decoding it and automatically stop their transmissions. Additionally, UE2 is scheduled using the legacy E-AGCH scheduling. This grant is sent using the legacy E-AGCH so it doesn't stop the transmission of UE4. When the Node B scheduler decides to schedule next UE it uses the Grant Detection channel again. This approach saves signalling overhead as there is no need to prolong the Absolute Grant in every TTI in which a UE is supposed to transmit. The grant is sent only once per scheduling period per UE so the longer the scheduling period the more overhead is saved. Another advantage of this solution is that the scheduler doesn't have to know the scheduling period when assigning a grant to a UE. The Node B can decide very dynamically on switching UEs taking into account instantaneous buffer and interference situation.

5.4.3.2.3 Fast Scheduling Grant

An alternative proposal for TDM scheduling signalling is separating the link adaptation from the scheduling information. The link adaptation which corresponds to granted transmission power can still be signalled using legacy methods utilizing E-AGCH or E-RGCH but new signalling method is required to signal the allocation of subframes for specific UEs. From this on we call such signalling Fast Scheduling Grant (FSG). When fast scheduling grant is used the UE follows the serving grant value signalled using legacy methods but transmits data only when it has received FSG showing that the UE has permission to transmit in the particular TTI. The FSG does not necessarily have to signal scheduling grant only for one TTI at a time but it can actually be combined with the other proposals on improved grant handling.

FSG can be signalled e.g. by re-using either E-AGCH or E-RGCH. Re-using E-RGCH as illustrated in Figure 5.4.3.2.3-1 seems more favourable. In this method a new signature should be reserved for the FSG for each UE. This signature could be in the same code channel as the legacy E-RGCH. Benefits of this signalling are obvious, it does not require UE to receive a new code channel and it does not require transmitting E-AGCH any more often as in legacy system. Also there is no unnecessary data to be transmitted; signatures for UEs that are not actively allocated are not transmitted.

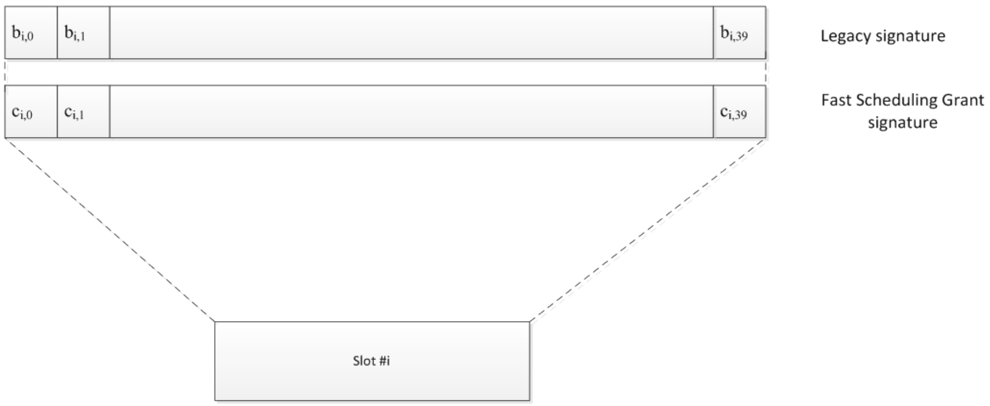


Figure 5.4.3.2.3-1. Re-using E-RGCH for fast scheduling grant

Simplest form of FSG is such that if a UE is scheduled, the FSG signature is transmitted mapped to symbol "1". If a UE is not scheduled, the FSG signature is transmitted mapped to symbol "DTX". Upon detecting the FSG symbol equal to "1" the UE can then start transmitting TTIs. In the most dynamic case each TTI is scheduled separately but alternative approach can be used for less dynamic scheduling where grant is applicable to a UE for a pre-determined time. However, since the E-RGCH signature only carries one information bit the duration would need to be configured by higher layers.

Another possible approach is switching grant on and off by still using the same FSG signalling. This can also be easily obtained by using ternary signalling structure in the legacy E-RGCH. Interpretation of the transmitted signal can be e.g.:

- "1" scheduling grant given to UE
- "-1" scheduling grant cancelled
- "DTX" no change in grant

A benefit with this scheme is that supporting more than one scheduled UE at the time does not require any extra channelization code allocation. Different operating point, i.e. missed detection target, compared to E-RGCH may be desirable for the efficient system operation and it can be achieved as shown by the evaluation in the Annex B.1.1.2.

5.4.3.2.4 New E-AGCH timing for deactivation

Shown in Figure 5.4.3.2.4-1, AG for UE1 deactivation will take effect in E-DCH TTI1. AG for UE2 activation will take effect in E-DCH TTI2. Therefore, a gap in E-DCH TTI1 is introduced.

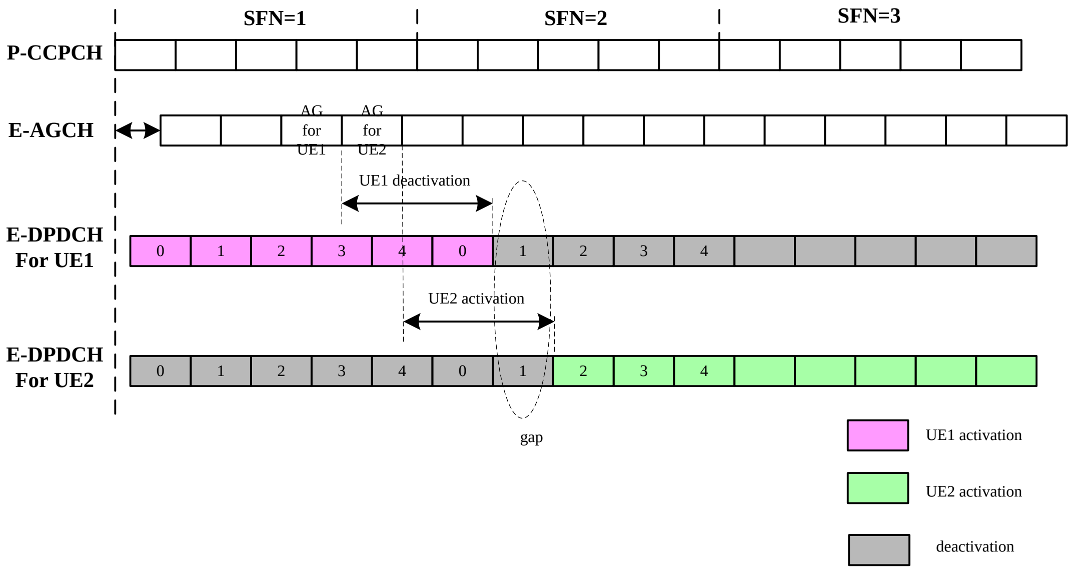


Figure 5.4.3.2.4-1: gap description using legacy E-AGCH

In order to solve the time gap problem described above, we redefine the E-AGCH taking effect time when it is used for deactivation. E-AGCH used for deactivation UE takes effect one TTI earlier than its legacy time. As shown in Figure 5.4.3.2.4-2, AG for UE2 activation takes effect in E-DCH TTI1, the same timing with legacy. AG used for UE1 deactivation takes effect in E-DCH TTI1 too, one TTI earlier than its legacy time TTI2. By using this new timing, there is no gap between users when switching happens.

In addition, deactivation requires no data preparation (such as E-TFC selection, transport channel processing etc.) in UE side, thus the proposed scheme has very little influence on the UE process capability.

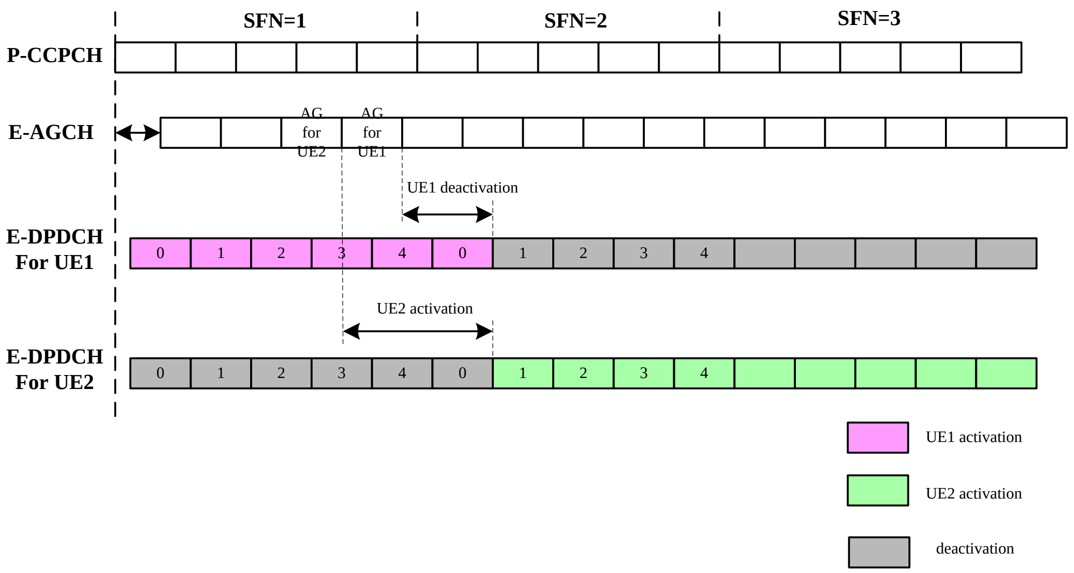


Figure 5.4.3.2.4-2: new E-AGCH timing for deactivation

Due to this scheme the timing specified in TS 25.214 [20] will be changed.

Currently one UE can only be configured by one E-AGCH channel. However, Node B can configure more than one E-AGCH channels to support more than one UE. If only one new UE is activated in one TTI and other activated UEs still remain activated, only one E-AGCH is needed to support multiuser scheduling. Moreover, when more than one new UE are activated at the same time, more E-AGCH channels are needed to support multiuser scheduling. This is a simple method to support multiuser in TDM scheduling.

The TDM scheduling is supported when Multi- E-AGCHs are used and meanwhile new E-AGCH timing is used.

5.4.4 Deployment scenarios for Lean carrier

5.4.4.1 Analysis

The benefit of deploying Lean carriers depends on the nature of the traffic and the available spectrum in the network. The following scenarios have been identified:

- Data-heavy networks: This is the main scenario where Lean carriers are most beneficial.
- Speech-heavy networks: Depending on the available spectrum, Lean carrier deployment may or may not be beneficial during busy hours. During off-hours, when more spectrum is available for data services, Lean carrier is a possibility.
- Spare spectrum during off-hours: In addition to the normal Lean carrier gain, this scenario also provides energy saving opportunity for the network by using DL DTX when there is temporarily no traffic in a cell.
- Under-utilized Lean carrier: A hybrid version that supports both legacy and Lean carrier operations may be used instead of an under-utilized Lean carrier. Under-utilization is then reduced, but the gain from Lean carrier operations is also impacted. An increased number of inter-frequency handovers between the Lean carrier and the primary "regular" carrier, for legacy UEs not supporting DC-HSUPA, may also have an impact on latency and reliability.

The main scenario which should be primarily considered is of course the first scenario of Data-heavy networks. Data traffic volume is much higher than speech volume in most networks and ratio of data traffic is growing with time.

5.4.5 Mobility

5.4.5.1 Analysis

In Rel-9 DC-HSUPA mobility the UE performs mobility measurements even when the secondary carrier is deactivated, if measurements are configured.

5.4.5.2 Solutions

Depending on the network, mobility measurements may not be configured on the Lean carrier. Mobility can still be maintained using the primary carrier and secondary active sets and serving cells can be maintained by mirroring those on the primary carrier. The primary option is that only the serving cell is kept on the secondary carrier. One other alternative could be that when the UE is transmitting on the secondary carrier the network has the option to instruct the UE to listen, or not to listen, to non-serving cells for RGs and TPC commands.

5.4.6 Conclusions

Under the sub-topic “enabling higher bit rates” of this study item improvements for increasing the system performance on uplink single and multi-carriers have been studied. A Lean carrier concept and different TDM scheduling schemes have been proposed. Simulations have been performed for evaluating the potential gains of the Lean carrier and the specific schemes enabling improved TDM scheduling.

5.4.6.1 Conclusions on grant handling

It was recognized that the time division multiplexing (TDM) operation can bring significant gains in HSUPA system. The existing Serving Grant signalling procedure is limited in a way that it cannot facilitate efficient TDM operation. In the Table 5.4.6.1-1 below results for solutions improving grant signalling were obtained and compared with the legacy TDM and CDM procedures.

Table 5.4.6.1-1: Average UE throughput [kbps] results for Ped A 3km/h, Rot 15dB - summary

	Scheduling period	UEs per sector	0.0175	0.25	1	4	10
CDM			9974	7838	3284	456	110
TDM	1 TTI	Legacy	9982	7353	2987	609	226
		Improved TDM scheduling schemes	9982	7586	3211	676	242
		Improved TDM scheduling gain	0.0%	3.2%	7.5%	10.9%	6.7%
		TDM gain over CDM	0.1%	-3.2%	-2.2%	48.3%	118.9%
TDM	5 TTIs	Legacy	9982	7675	3383	699	224
		Improved TDM scheduling schemes	9984	7692	3421	721	230
		Improved TDM scheduling gain	0.0%	0.2%	1.1%	3.1%	2.9%
		TDM gain over CDM	0.1%	-1.9%	4.2%	58.3%	108.7%
TDM	10 TTIs	Legacy	9984	7737	3504	768	229
		Improved TDM scheduling schemes	9982	7855	3527	769	229
		Improved TDM scheduling gain	0.0%	1.5%	0.7%	0.2%	-0.1%
		TDM gain over CDM	0.1%	0.2%	7.4%	68.8%	107.1%

Different grant handling mechanisms have been studied for improved TDM scheduling. The Grant detection approach saves signalling overhead compared to other schemes which might need repetitive granting. In order to schedule multiple users simultaneously an additional grant channel introduction was presented as one of possible solution. This also requires the UE to listen to multiple E-AGCH and a need for an E-AGCH DTX detection mechanism in the UE. It was proven by the LLS evaluation there is no risk of false detection of the E-AGCH DTX.

A benefit of the FSG (Fast Scheduling Grant) scheme can be that it is possible to schedule multiple UE's in the same TTI with a single channelization code allocation. Although other schemes can handle multiple UE's transmitting simultaneously, the scheduling cannot be done in the same TTI without allocating multiple E-AGCH channelization codes and requiring UE's to monitor them. With FSG switching scheduling grant off arbitrarily using signalling is slightly more complicated, an additional FSG needs to be signalled separately but due to low overhead that is not a problem. There is also a considerable risk for false detections of RGCH's which cause the transmissions from UE's to collide with each other, compared to the consequence of false detection of legacy RGCH which will just step the grant up or down one step. An implicit assumption for FSG is that the grant value is not changed frequently. In situations where a new grant value is needed for each user, this scheme has an additional overhead in the RG.

Another scheme which improves TDM scheduling is the time limited grants idea, where the legacy E-AGCH is used but the bits sent on the E-AGCH are re-interpreted. Since TDM scheduling is mainly intended for high data-rates, one proposal is to restrict grant signalling to a reduced set of grant values using fewer bits. The remaining bits can then be used for signalling the grant duration. If a UE wants to end his transmission before that granted time an additional terminating grant needs to be transmitted. The benefit of the solution with new E-AGCH timing for deactivation is also the simplicity. However the consequences of changing the deactivation timing of the E-AGCH have not been studied. Also an additional deactivation needs to be signalled, the overhead of deactivation signalling can be substantial when many small bursts scheduled.

Summary of grant handling schemes is shown in Table 5.4.6.1-2. The E-AGCH based grant schemes could require more frequent E-AGCH transmission increasing power consumption of the E-AGCH channel; however this might not be an issue in TDM scheduling scenarios.

Table 5.4.6.1-2: Summary of grant handling schemes

Schemes	Legacy scheme (CDM scheduling or HARQ process based TDM scheduling)	Time limited grant (E-AGCH based)	Grant detection (E-AGCH based)	Fast Scheduling Grant (E-RGCH based)	New E-AGCH timing for deactivation (E-AGCH based)
Scheduling method	Persistent grants	Time limited grants	Persistent grants, but grant is terminated by detection of AG with wrong CRC.	E-AGCH for grant value updates and E-RGCH for granting TX occasion	Persistent grants
AGCH	1 code channel	1 code channel	1 code channel	1 code channel	1 code channel
Additional AGCH	No	No	1 legacy channel added for legacy users or when multiple Rel-12 UEs are required to transmit data simultaneously	No	No
Additional RGCH	No	No	No	1 code channel one RGCH/HICH signature for each user Supports 13 UEs (1 RGCH, 1 HICH, 1 FSG per UE)	No

An improved grant handling mechanism is an essential part of the Lean carrier concept.
Though standalone grant handling schemes for improved TDM scheduling on a single carrier can be envisioned.

5.4.6.2 Conclusions on Lean carrier

The Lean secondary carrier provides a solution where the DPCCH bursts from CPC operation are eliminated when the UE is not transmitting any data on the secondary uplink carrier. Simulation results have been provided for studying the impact of the interference created by the CPC bursts on data transmissions and the impact of the interference from data transmissions on the DPCCH bursts. The Lean carrier operation is not compatible with legacy users. In case of a hybrid scenario supporting both Lean carrier capable UEs and legacy UEs, a loss can be expected in legacy UEs performance, e.g. broadcast channels are still needed, scheduling delay is increased for high-bitrate transmissions and SI transmission delay may be increased

The link level simulation results have shown link level gains of Lean carrier over legacy CPC in these high rate bursty traffic scenarios when DPCCH SIR based ILPC was used. ILPC target at received DPCCH SNR instead of SINR was investigated. Limited gain for Lean carrier over CPC was observed in these simulations and in case of two interfering CPC bursts and DPCCH SNR target equal to -19dB the difference in performance was negligible.

The simulations results on Lean carrier presented in Appendix B.1.1.2 and B.1.1.3 compare the Lean carrier performance with a baseline using CPC. The link-level results show that the interference created by DPCCH bursts is important when transmissions are scheduled at medium and higher data-rates. An impact on performance is observed when the DPCCH bursts are interfered by data transmissions. This impact increases with the number of DPCCH bursts between data transmissions.

Different CPC settings result in different interference levels created by the DPCCH bursts. For one evaluated setting, 100 users activated on a secondary carrier amount to an average of just 1.25 continuous DPCCH. The performance between Lean and CPC is very similar in this case for large and frequent data transmissions. When applied to bursty small data transmissions, the performance deteriorates. It should also be noted that the current specifications do not allow different CPC patterns to be used for the primary and the secondary carrier for the same UE, but it is possible to deactivate the secondary uplink carrier with HS-SCCH order. The extreme CPC setting, however, does not seem to have much effect on the performance loss due to high-bitrate data transmissions interfering with the DPCCH bursts.

These system simulation results show that with dynamic traffic, the difference in average RoT between Lean carrier and the CPC cases are more pronounced than with a fixed transmission pattern. At a very high load of 100 user/cell, a 4dB lower RoT can be achieved even when compared to the most extreme CPC case with the shortest possible burst size and the longest possible cycle length. Improvement in average cell throughput is also seen. The simulation was conducted without RoT control, and the active user was always scheduled with 5 Mbps instantaneous data rate.

Considering the traffic model used, the system reaches 100% TTI utilization at around 25 users with user data rates close to 160 kbps on average, and with 100 users the UE throughout degrades to 40 kbps on average. Below the 25 users/cell loading point a small reduction in observed RoT was seen for the same average cell throughput for Lean carrier over CPC.

The reduced transmission of DPCCH on the secondary carrier results in less overall Noise Rise in the system (reduced UL control channel overhead).Lean carrier may not be operable in SHO region due to TDM operation assumed. Due to mobility, before a UE can resume Lean carrier operation in a new cell its radio link timing needs to be reconfigured, which may lead to flushing of UL HARQ buffers.

5.4.6.2.1 Specifications and implementation impacts for Lean carrier operation

Table 5.4.6.2.1-1: Impacts on RAN1 specifications

TS 25.211	Clause 5.3.2 Dedicated downlink physical channels or Clause 5.3.3 Common downlink physical channels	A new grant channel may be defined. Impact on clause 5.3.2 or 5.3.3 depends on the design of the new grant channel.
	Clause 5.3.1 Downlink transmit diversity	Further define whether the new grant channel supports the transmit diversity or not.
	Clause 7 Timing relationship between physical channels	Timing relationship may be defined for the new grant channel or new timing may be defined for existing grant channels.
TS 25.212	4.10.1A.1 Information field mapping of the Absolute Grant Value	New mapping of Absolute grant and time limit value may be defined.
	Clause 4.6C Coding for HS-SCCH orders	HS-SCCH orders may be defined, if activation and deactivation of Lean carrier by HS-SCCH order are needed.
	A new clause for mapping for E-RGCH relative grant may be Clause 4.11A	A new clause, Clause 4.11A may be used for new E-RGCH mapping.
TS 25.213	Clause 5.2 Code generation and allocation	Spreading factor to be used for the new grant channel may be defined.
TS 25.214	Clause 6B E-DCH related procedures	New grant detection procedures may be defined. New E-DCH control timing may be defined for the new grant scheme.
	A new clause for general Lean carrier operation, could be Clause 6D	Referring to clause 6C, Lean carrier concept could be described in this clause.
	Clause 5.1 Uplink power control	Changes in uplink power control may be introduced for Lean carrier operation.
	Clause 5.2 Downlink power control	Changes in downlink power control may be introduced for Lean carrier operation.

Impacts on implementation

1 Transmitter at UE side
DPCCH is only transmitted together with data transmissions with/without preamble. For the case of long data transmission gap, the initial DPCCH Tx power of Lean carrier may be calculated via the initial DPCCH power of the primary carrier plus a configurable power margin, similar to the activation of legacy secondary carrier at each E-DCH transmission.
Some traffic will be moved to the primary carrier, e.g. SI, SRB, since only PS traffics are allowed on the secondary carrier in Lean carrier operation. In addition, PRACH is not allowed to be used, since UE is not allowed to anchor on the cell supporting Lean carrier, resulting that only one carrier can be anchored in the network deployment.

2 Transmitter at UTRAN side
New grant procedures may be introduced for improved TDM scheduling, e.g. new grant channel, new grant detection procedures, two grant channels or new grant timing (smaller gap of deactivation).

5.5 Reduced UL control channel overhead

5.5.1 Background and motivation

This part of the report is concerned with identifying the scenarios where it could be beneficial to reduce the uplink control channel overhead. Increased data capacity could either allow increased rates or increased number of users in the cell. In Rel-7, DPCCH discontinuous transmission was introduced to reduce the uplink control channel overhead in case of low uplink data transmission activity (e.g. web browsing). When there is temporarily no E-DCH transmission, DPCCH transmits discontinuously according to a pattern. This is a way to limit the control channel overhead during UE inactivity periods. To further improve cell capacity and coverage it is also worth studying reduced UL control channel overhead in the cases when uplink data transmission is on-going. Therefore, various approaches on control channel overhead optimization are investigated in Release 12. These approaches may include:

- Reducing the power or DTX of E-DPCCH
- Reducing the power or DTX of HS-DPCCH
- optimizing the DTX mechanisms of DPCCH

5.5.2 Analysis

The CQI is the key indicator for HSDPA downlink (DL) channel quality and its frequent reporting is essential to maintain a good DL efficiency. The UE estimates the channel from the CPICH, and computes the channel quality information. This information along with HARQ ACK/NAK is reported to Node-B using HS-DPCCH and its periodicity is configured by RRC signalling. The structure of HS-DPCCH for a single carrier, when the UE is configured in non MIMO mode, is shown in Figure 5.5.2-1.

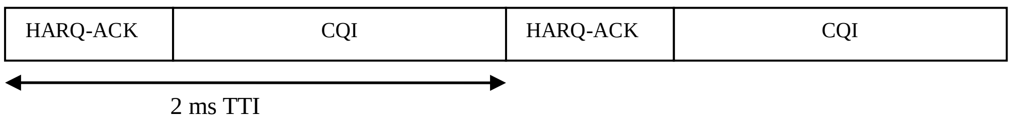


Figure 5.5.2-1: Frame structure for uplink HS-DPCCH

Node-B receives the CQI and allocates the required channelization codes, modulation and transport block size, pre-coding channel index (in MIMO mode), to the UE. This information is conveyed to the UE by HS-SCCH. Once the UE detects the HS-SCCH, downlink transmission starts. The reporting period impacts the downlink performance as well as the UE power consumption. If the reporting period is small the CQI quality is good, however the frequent signalling consumes UE power. On the other hand, if the reporting period is fixed to a large value, the CQI is outdated and the downlink throughput may be reduced.

The E-DPCCH carries the E-TFCI, RSN and Happy bit, and is always transmitted along with E-DPDCH. If the E-DPCCH could be transmitted at a reduced power or be totally avoided in certain time periods, the overall UL control channel overhead could be reduced. The reduction of E-DPCCH transmission is not considered when E-DPCCH boosting is used.

5.5.3 Solutions

5.5.3.1 Description of CQI cycle adaptive solution

Currently a single CQI reporting pattern is defined for HSDPA in multi-RAB scenario (HSPA coexistence with R99 channel, e.g., the UE receives downlink data (PS data) traffic and simultaneously has an active speech connection (CS data) established). In order to reduce HS-DPCCH channel overhead, the second CQI reporting pattern is defined additionally. Normally, the UE reports CQI using the first reporting pattern, i.e., transmits a CQI report once every C1 ms. If the UE has not been scheduled for a certain (configurable) period T, the UE switches to a second CQI reporting pattern, i.e., reports CQI every C2 ms, where C2>C1.

Note that the CQI reporting patterns as a special case may include switching off the reporting completely (basically setting C2 to infinity). One possibility to implement this is to (re)start one DL activity timer in the UE every time HS-DSCH data, an HS-SCCH order or any other signalling indication is received. If the activity timer expires, the UE switches from pattern1 to pattern2. The DL activity timer detects when it would be appropriate to reduce or completely stop the CQI transmission in the UL by monitoring the DL activity. The Node B may use a corresponding activity timer mechanism (one per UE) to determine whether to expect pattern1 or pattern2.

In order not to impact on HSDPA transmission, Node B could activate UE to report CQI at any time by physical signalling, e.g., by HS-SCCH order. Once the activation order is received by the UE, the UE would then immediately transmit CQI and (re)start the activity timer. UE reports CQI according to pattern1 when the activity timer is running, and UE reports CQI according to pattern2 when the activity timer expires.

To implement the above mechanism, RNC needs to configure the CQI reporting intervals C1, C2 and DL activity period for both UE and Node B

5.5.3.2 Evaluation of CQI cycle adaptive solution

From the UE perspective, the transmission of the CQI on HS-DPCCH consumes valuable power headroom which can be better utilized by DPDCH or E-DPDCH for increasing performance in power limited scenarios. From the network perspective, reducing the CQI reports would reduce uplink interference as well as improve cell capacity.

Baseline: When E-DCH and DPDCH are scheduled for transmission (Multi-RABs), CPC does not work in this scenario.

Timer_1: Time_1 is the pre-defined time interval. Timer_1 is 8ms, 16ms, or 32ms.

System simulation results are provided in Figure 5.5.3.2-1 and Figure 5.5.3.2-2 using the cycle adaptive solution, assuming that the CQI report is not activated by HS-SCCH order before data transmission. Figure 5.5.3.2-1 shows the average burst rate in Mbps and Figure 5.5.3.2-2 shows the percentage of average burst rate gain. In UL, it can be seen that there are about 36% to 43% gains in average burst rate for the cycle adaptive solution. Gains in UE throughput are from 12% to 13%. The UL performance gains are mainly due to the uplink power saving if the UE switches to a different CQI cycle in case of no downlink transmission. In DL, there are about 6% to 9% losses, which might be caused by the relatively poor CQI accuracy since Node B has to rely on long cycle CQI reporting for the first TTIs of DL scheduling before UE switches to short cycle CQI reporting.

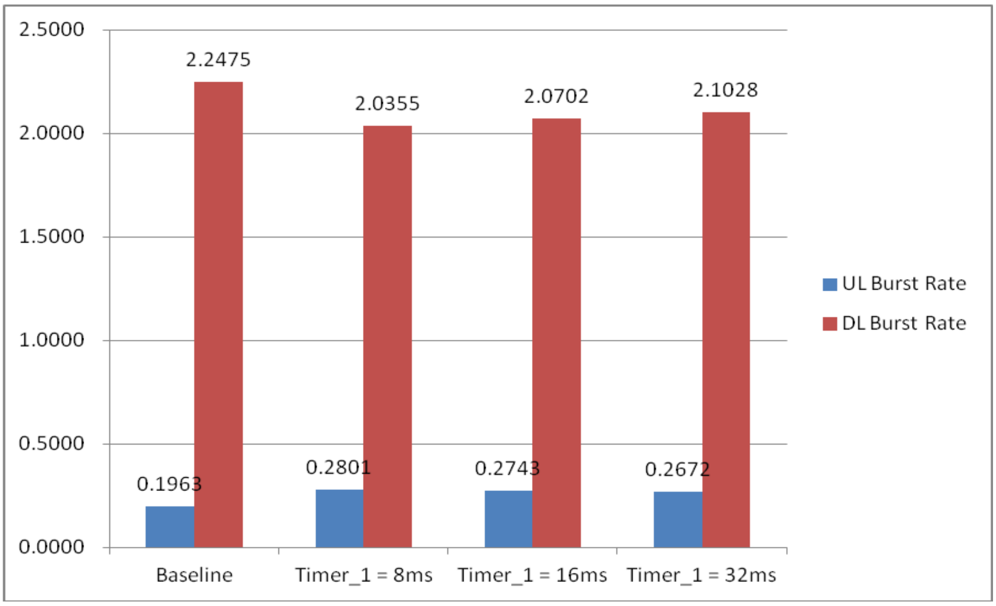


Figure 5.5.3.2-1: UL average burst rate and DL average burst rate in Mbps using cycle adaptive solution

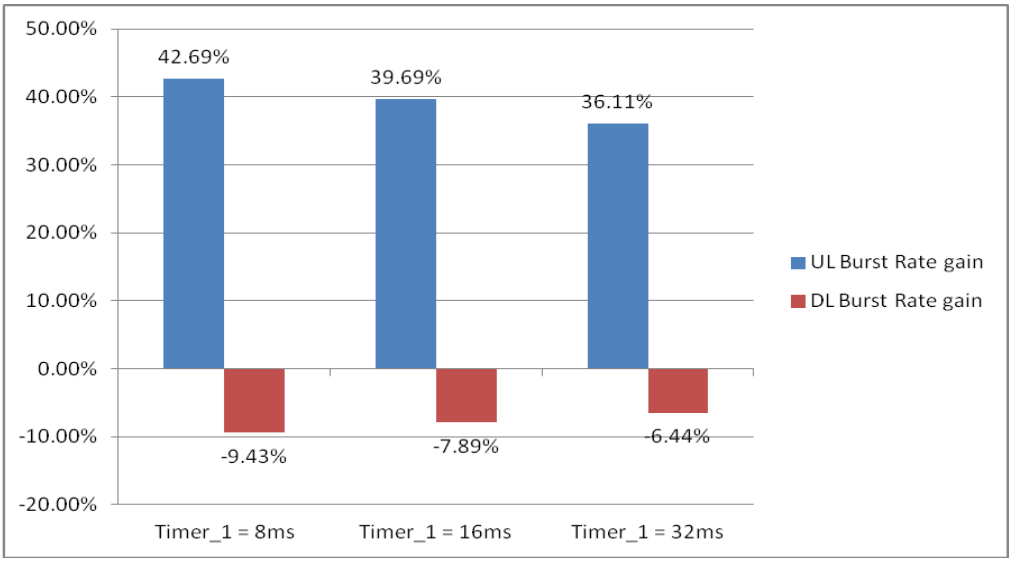


Figure 5.5.3.2-2: Performance gain of Cycle adaptive solution using cycle adaptive solution

5.5.3.3 Description of CQI report reduction for multi-RABs with speech solution

CQI reports are signalled also when a UE is configured for Multi-RAB, where it receives downlink data (PS data) traffic and simultaneously has an active speech connection (CS data) established. In a power-limited scenario, the UE may not have sufficient uplink transmit power to keep a desired level of uplink services. If a power-limited UE in Multi-RAB has stopped receiving downlink data (PS data) traffic, for example because of empty downlink data buffers, the CQI reports transmitted on the HS-DPCCH become a liability since they are taking power away from the DPCCH and the speech (CS data) and/or SRB traffic on the DPDCH. Avoiding or reducing the HS-DPCCH transmission in these scenarios would result in increased power for DCH channels and in turn improved coverage. It would therefore be desirable to avoid unnecessary CQIs under these power-limited scenarios. One solution is to stop CQI reporting after a certain period of DL data inactivity. Another solution could be to keep some reduced level of CQI reporting.

One method to detect when it would be appropriate to reduce or completely stop the CQI transmission in UL, and when it is appropriate to have 'normal' CQI transmission, is to introduce a DL inactivity timer. The DL inactivity timer shall monitor the DL data inactivity and after a certain period of DL inactivity trigger reduced CQI reporting. At least one parameter need to be introduced for this feature, the Time for the inactivity timer (Time values). Recovered DL activity will trigger normal CQI reporting.

A solution using variable CQI reporting period, if a certain level of CQI reports still are desired, can be achieve by introducing a parameter for reduced CQI reporting cycle. This parameter will signal values for reduced reporting cycle, e.g., x/2, x/4, etc. One of the included values can be 0, corresponding to no reporting.

One option can be to reduce the CQI reporting period when there is no DL transmission, even if the UE is not power limited. This can for example be controlled by a parameter which decides if CQI report reduction should be initiated depending on UE power headroom condition or not.

5.5.3.4 Evaluation of CQI report reduction for multi-RABs with speech solution

Currently HS-DPCCH is a liability when a UE configured for Multi-RAB is power-limited and is not receiving any downlink data (PS data) traffic. The HS-DPCCH is taking power away from the DPCCH and the speech (CS data) and/or SRB traffic on the DPDCH. Reducing the CQI reports in the mentioned scenarios would enhance coverage. This solution is in general similar to the CQI cycle adaptive solution except that it only focuses on the CQI reduction in power limited Multi-RAB scenarios for improving speech coverage.

5.5.3.5 Description of Serving Grant based E-DPCCH less solution

The E-DPCCH transmission could be avoided (E-DPCCH less mode) if the following criteria are satisfied by the UE:

1 The E-DPDCH transmission is not HARQ retransmission

2 The UE is neither buffer limited nor power limited

In order to allow Node B to distinguish E-DPCCH less transmission from no E-DCH data, UE should not enter E-DPCCH less mode until the ACK for the first E-DPDCH transmission is received during a certain period. When the UE buffer is empty, SI=0 is triggered which informs Node B that the UE has no data for transmission, and the UE exits the E-DPCCH less mode.

When E-DPCCH is not transmitted, Node B can deduce the TB size of E-DPDCH transmission according to the Serving Grant allocated to the UE.

The above operation is illustrated in Figure 5.5.3.5-1.

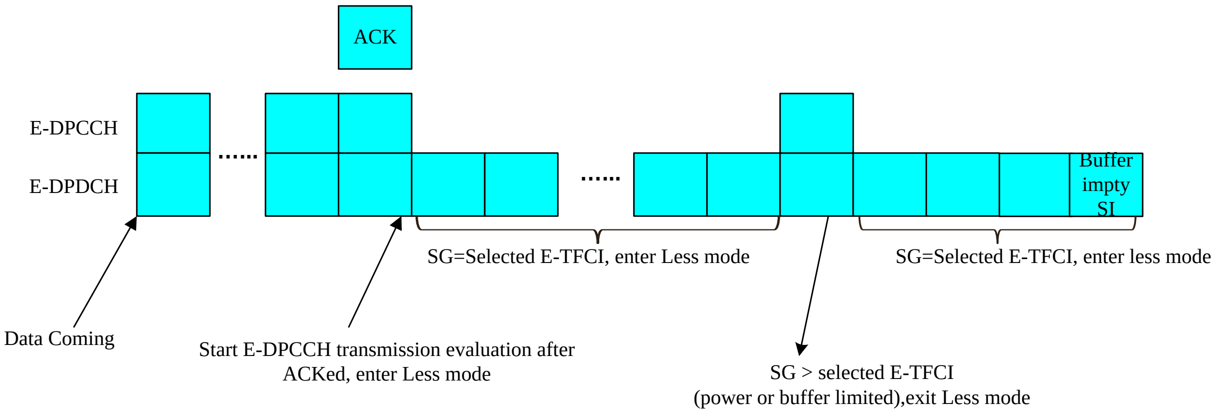


Figure 5.5.3.5-1: Serving Grant based E-DPCCH less

5.5.3.6 Evaluation of Serving Grant based E-DPCCH less solution

Most of the time E-DPCCH transmission could be avoided, since HARQ retransmissions does not always happen and Node B could always allocate an appropriate Serving Grant to the UE based on the SI report to avoid the buffer limitation and power limitation.

In case E-DPCCH less is enabled, both the average UE throughput and sector throughput are improved. The increase of UE throughput rate is mainly because more power can be allocated to E-DPDCH transmission due to the E-DPCCH transmission decrease. In case of a high load scenario, the increase of UE throughput can be translated into sector throughput gain.

E-DPCCH will not be avoided in case of E-DPCCH boosting. However, considering that the gain for E-DPCCH less operation is expected in the scenario of a large number of users continuously are transmitting at relatively low data rates, the E-DPCCH boosting will not impact the gain for E-DPCCH less operation evidently.

In soft handover the E-DPCCH may need to be transmitted always as neither the serving nor the non-serving Node B would be able to rely on knowing what the UE's maximum grant is.

The loss of happy-bits could cause some delays in the Node B scheduler operation, or alternatively the UE could transmit E-DPCCH if it is unhappy or if the status of the happy bit is changed.

Errors in grant signalling could lead to mismatch between the UE's and Node B's understanding of the maximum grant, and lead to loss of multiple initial transmission attempts until the Node B is able to detect the issue and send the UE a new absolute grant resolving the mismatch. This can lead to a lot of HARQ failures and RLC re-transmissions.

Baseband implementation complexity can also be expected with this scheme, so the potential increased complexity must be taken into account when evaluating gains.

System simulation results for E-DPCCH less operation with 2,6,10 users per cell are presented in Table 5.5.3.6-1 to Table 5.5.3.6-3. The corresponding UE throughput and RoT CDFs are given in Annex B.2.1 The simulation assumptions are listed in Table A.2.2-1 in Annex A.2.2

Simulation results in Tables 5.5.3.6-1-3 show that gains from 6% to 17% in UE burst rate are achieved when the number of UEs increases from 6 to 10. The gain in burst rate is mainly because more power can be allocated to E-DPDCH transmission due to the reduced E-DPCCH transmission. However, when the number of UEs is 2, there is a small loss of -0.3% in UE burst rate. One explanation is that with a small number of users, it is more likely that the UEs are transmitting at higher rates and therefore boosting is used. If boosting is used, E-DPCCH less operation is not enabled. The average RoT is close to the RoT target, which means that the simulated scenario can be regarded as high load scenario where the increase in UE burst rate can be translated into sector throughput gain.

Table 5.5.3.6-1: Simulation results for 2 UEs per cell

Case	E-DPCCH Less not enabled(Baseline)	E-DPCCH Less enabled	Gain
RoT(dB)	1.3381	1.2061	\
UE Throughput (Mbps)	0.20702	0.211	2.0%
Burst Rate (Mbps)	3.1314	3.122	-0.3%
UE Total Tx Power(dBm)	-3.4485	-3.9373	\

Table 5.5.3.6-2: Simulation results for 6 UEs per cell

Case	E-DPCCH Less not enabled(Baseline)	E-DPCCH Less enabled	Gain
RoT(dB)	4.2303	4.0159	\
UE Throughput (Mbps)	0.1674	0.1766	5.21%
Burst Rate (Mbps)	1.1145	1.1874	6.54%
UE Total Tx Power(dBm)	-2.3977	-2.9253	\

Table 5.5.3.6-3: Simulation results for 10 UEs per cell

Case	E-DPCCH Less not enabled(Baseline)	E-DPCCH Less enabled	Gain
RoT(dB)	6.036	5.902	\
UE Throughput (Mbps)	0.113	0.116	2.53%
Burst Rate (Mbps)	0.265	0.311	17.53%
UE Total Tx Power(dBm)	-2.873	-3.014	\

5.5.3.7 Description of blind E-DPDCH detection solution

Normally, small packet over HSPA (for example, VOIP or CS over HSPA) is transmitted with fixed formats or predefined transport format(s), then the E-DPDCH could be sent without E-DPCCH, and Node B could decode the E-DPDCH blindly. In order to make Node B distinguish original transmissions from re-transmission, the original transmissions can be sent without the E-DPCCH, while for the HARQ processes with retransmissions the E-DPCCH is present.

Another solution is that the transport format is fixed or consisting of a subset of the possible TBs, where the requirement for the subset is that the Node B needs to be able to blindly detect what is being sent. Then for that service with predefined transport format(s), the E-DPCCH is not transmitted for the first HARQ attempt. For the HARQ processes with retransmissions the E-DPCCH is transmitted so that Node B is aware that it is a retransmission.

5.5.3.8 Evaluation of blind E-DPDCH detection solution

The solution would mostly benefit scenarios where a large number of users are transmitting with a small set of recurring transport formats, such as VoIP, and in extending the coverage of the minimum data rate when used to eliminate E-DPCCH from the smallest TB size(s) only and enabling the UE to use the saved power headroom on E-DPDCH. The E-DPCCH could for example be eliminated from the minimum set E-TFC. Notably, when the E-TFCs that need to be blindly detected are known a priori, the solution is applicable in soft handover as well. The blind detection of the E-DPDCH will result in some additional computational complexity in the Node B.

The loss of happy bits would not cause problems in either of the abovementioned use cases, as with VoIP the UE would not have any need to indicate it is unhappy if the service was not configured as non-scheduled, and when the UE is power limited it could not indicate unhappiness with the current grant.

5.5.3.9 Description of reduced E-TFCI solution

An alternative solution is to reduce the E-TFCI information which is currently carried using 7 bits. This has been already considered in Rel-7 when it was identified that the E-TFCI constitutes a significant overhead that can be optimized. It was proposed to reduce the E-TFCI information from 7 to 4 bits for operation with low data rates where "E-TFCI" info does not vary dynamically over time but rather shows constant or within restricted range. In that case a new coding of E-DPCCH, e.g. Reed-Muller code RM(30,7) as proposed in [6], would have to be used. This has been taken further in [8] where it is proposed to completely remove the E-TFCI information for small packets and use blind detection of E-TFCI by the Node B. The RM(30,3) coding of the E-DPCCH channel is proposed to be used in this case. The figures below illustrate the overall coding chain for the E-DPCCH for two of embodiments of the Reed–Muller code, RM(30,10) which is currently used and RM(30,3).

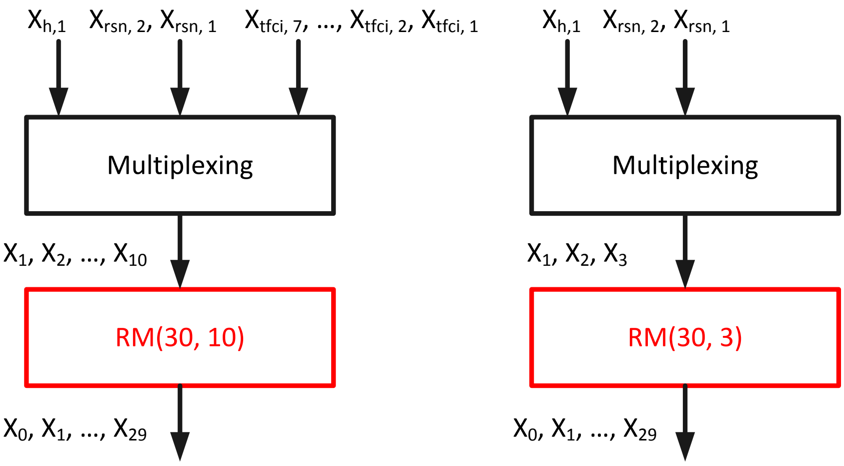


Figure 5.5.3.9-1: Legacy and modified coding chain for the E-DPCCH channel. Reed-Muller code RM(30,10) and RM(30,3).

5.5.3.10 Evaluation of reduced E-TFCI solution

The main benefits of RM(30,3) over full elimination of E-DPCCH are the following:

- The Node B implementation basing its E-DCH presence detection at least in part on E-DPCCH can be reused
- The Happy-bit is always available for the Node B scheduler
- Reduced E-DPCCH can also be used with retransmissions

The additional problem for the Node B implementation is that it needs to be able to blindly detect whether the E-DPCCH is using RM(30,3) or RM(30,10). The blind detection of the E-DPDCH will result in some additional computational complexity in the Node B.

5.5.4 Conclusions

Different schemes of optimizing uplink control channel overhead were investigated. As listed in Table 5.5.4-1, system level results for the high UE densities investigated show that the UE throughput gains were from 12% to 13% for CQI reduction and from 2% to 7% for E-DPCCH reduction. The results were obtained assuming an equal RoT CDM scheduler. A different UL scheduling algorithm may result in different results for E-DPCCH reduction.

Table 5.5.4-1: Gains with control channel overhead reduction

	UEs per cell	UE throughput gains	UE burst rate gains
HS-DPCCH reduction	10	12% to 13%	36% to 43%
E-DPCCH reduction	6 to 10	2% to 7%	6% to 17%

HS-DPCCH overhead reduction was considered in context of Multi-RAB, and the evaluation was done for Multi-RAB. The used baseline CQI feedback rate was 2 ms, and the gains would scale down proportionally if a longer CQI feedback rate was considered as a baseline. In case of lower UE densities control channel power constitutes relatively lower overhead and the gains of proposed improvements are significantly reduced. It should be noted that HS-DPCCH overhead reduction has a negative impact on the Downlink performance since the CQI accuracy is reduced. However, the uplink performance gain for the investigated scenario, a high density of UEs transmitting at low data rates, is considerably higher than the downlink degradation.

The proposed CQI reduction scheme for power limited Multi-RAB scenarios can be beneficial for improving speech coverage.

5.6 Low-complexity uplink load balancing

5.6.1 Background and motivation

Load balancing techniques are employed in cellular systems to overcome the problems of some cells being congested while others having free resources. With the load balancing technique applied to the uplink direction, the network can benefit from multiple cells and distribute UEs between them to equalize the load. This will facilitate better performance of UEs, and especially of those ones that do not support multi-carrier in uplink and thus cannot be assigned dynamically resources over several carriers. At the same time, the load balancing can be logically extended to a scenario with a UE supporting two uplink carriers and the network deploying more than two frequencies.

5.6.2 Analysis

As per the legacy HSPA behaviour, the uplink "anchor" carrier is linked logically to the corresponding downlink serving cell. It is the responsibility and the decision of RNC to choose which cell is the serving one for a particular UE. As a result, some form of the load balancing is already feasible with the legacy HSPA system by means of switching the serving cell to a different frequency. This approach, however, involves RNC and thus cannot perform fast and/or frequent switching between different cells without compromising application level performance. Thus, a different approach must be taken that would either avoid interaction with RNC, or minimize it in terms of reconfiguration process delays.

5.6.3 Solutions

5.6.3.1 Load balancing as extended enhanced serving cell change

One approach for implementing the uplink load balancing is to speed up the serving cell change procedure from one carrier to another, i.e. to speed up the reconfiguration process that currently involves a number of RRC messages exchanged between the RNC, and the UE. One way to achieve this is to extend the Enhanced Serving Cell Change procedure of Release 8. The eSCC pre-configuration information for potential target cell has all the major HSDPA/HSUPA features, and thus the same information container can used for fast inter-frequency serving cell change eliminating RRC message exchange at the time of switching, similarly to how the eSCC feature works between cells within the active set.

The limitation of eSCC is that the corresponding pre-configuration data is linked to the active set radio links, and it is not possible to provide pre-configuration for a cell that resides on another frequency. This limitation can be overcome by introducing the corresponding parameter that would indicate a frequency where a UE should move. Another difference compared to eSCC is that an order to switch to a new configuration would be coming from the serving HS-DSCH cell, as opposed to the target cell identified by the UE in its measurement report.

Uplink load balancing as an extension to enhanced serving change has the benefit of re-using as many existing components as possible, with marginal incremental changes. From the UE implementation perspective, the procedure is a normal inter-frequency serving cell change, where a new configuration is pre-configured in advance as in eSCC. All the functional aspects remain unchanged.

5.6.3.2 Load balancing as extended DC-HSUPA functionality

Another approach for implementing uplink load balancing is to rely upon the DC-HSUPA functionality. If a UE has the capability to transmit over two UL carriers simultaneously, then the two carriers are continuously in-synch and the Node B scheduler can distribute the load and/or to maximize the overall performance.

The only limitation of the current DC-HSUPA feature is that it is defined only for 2ms TTI, which was originally motivated by the fact that it was designed as a high-speed UL feature, not as the UL balancing approach. Thus, for the cell edge operation, it might be beneficial to consider introducing a new UE capability that would allow a combination of DC-HSUPA with 10ms TTI. Such an extension to DC-HSUPA would be very small.

5.6.3.3 Combination of extended eSCC and DC-HSUPA approaches

The approaches based on eSCC and DC-HSUPA can be viewed as complementing each other. As an example, if DC-HSUPA is extended with a support for 10ms TTI, then the fast re-configuration mechanism can facilitate fast re-configuration between 2 and 10ms TTIs as a UE moves from a cell edge to cell centre, and vice versa. Similarly, if an operator has more than two carriers, then the fast re-configuration mechanism can also ensure fast switching of the on-going DC-HSUPA operation to another pair of carriers, or switching DC-HSUPA to the single-carrier mode on another frequency.

5.6.4 Conclusions

During the study, it has been identified that the load balancing as extended enhanced serving cell change solution may be beneficial. The identified enhancements, presented in the earlier clauses, would require further studies to evaluate the benefits compared to existing methods (e.g. timing-maintained inter-frequency hard handover and DC-HSUPA), the network impact and the overall applicability of the new methods.

5.7 Rate adaptation

5.7.1 Background and motivation

In the current system we observe post receiver SINR saturation in the high SINR region due to inter-symbol and inter-stream interference. This causes inefficiency and instability which can be counter with Rate adaptation. Additional parameters (i.e. SD parameter) present in the proposed solutions takes into account post receiver SINR and Rx power disproportionality to adjust the TBS, enabling more stable operation.

As HSUPA system development is planned in the next versions of the 3GPP specifications (Release 12 and beyond), introduction of a mechanism for independent power control and scheduling is seen as one of natural approaches to boost the system performance. The main ideas of the concept, initial link-level and system level simulation results have already been presented in 3GPP [6], [7], [8], [9], [10], [11], [12] and [13].

5.7.2 Analysis

The power-based scheduling method is referred to the traditional HSUPA scheduling and E-TFC selection mechanism. For that approach the serving grant SG simultaneously defines the transmission power level and the E-TFC. The SG value is selected relative to the current DPCCH power level based on the available RoT budget. The proportionality of the E-DPDCH post-receiver SINR to the transmit power level is assumed by the method, where deviations are compensated by the outer loop power control (OLPC) with increasing or decreasing the DPCCH SIR target for the internal loop power control (ILPC) tracking.

As demonstrated by multiple studies [8], [9], [10], [11], [13] the power-based scheduling becomes inefficient when the post-receiver noise is dominated by the inter-symbol or inter-stream (in case of CLTD and MIMO transmission) interference but not the thermal noise.

It should also be mentioned that the WCDMA/HSUPA power control and scheduling are different from the corresponding procedures in other cellular systems (like LTE, WiMAX and even HSDPA), where power control and scheduling are done independently allowing for more flexibility and system efficiency.

5.7.3 Solutions

5.7.3.1 Description of novel Rate adaptation mechanisms

In power-based scheduling mode the purpose of OLPC is to compensate the deviations from the proportionality of SINR increase to TX power increase and to ensure the necessary BLER performance. For the latter, in SINR-based scheduling mode, the marginal control loop is introduced in the node B to adjust the *SD* parameter based on outcomes of the previous transmissions (similar principle to the legacy OLPC operation) prior to signaling the parameter to the UE. The inner and outer loop power control in current implementation is depicted on Figure 5.7.3.1-1 below:

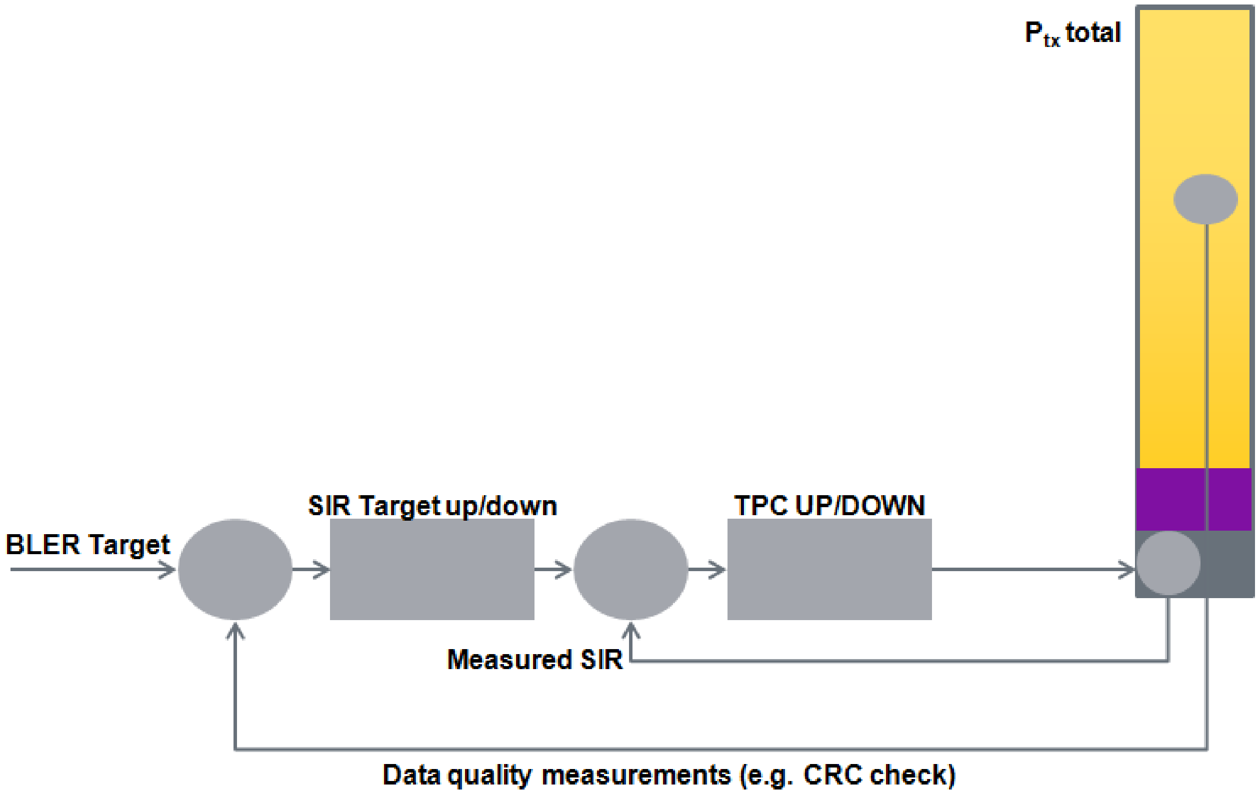


Figure 5.7.3.1-1: Inner and outer loop power control in power based approach

By introducing SINR based scheduling method we would like to decouple the power control and E-TFC selection procedure and by that changing current power based scheduling approach.

In order to implement these principles, the operation of the SINR-based scheduling and the associated modified power control procedures for the SIMO and CLTD modes is defined as follows:

The serving grant *SG* and SINR difference *SD* parameters are calculated and signaled by the Node B to the UE for each TTI. The *SG* parameter defines the E-DPDCH power relative to the DPCCH as for the legacy power-based approach. An illustration of the transmit power level and the *SG* and *SD* parameters for the SINR-based scheduling of a SIMO or CLTD transmission is given in Figure 5.7.3.1-2.

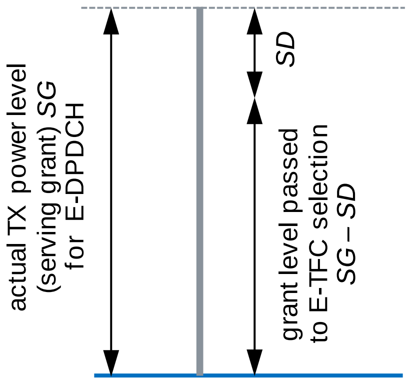


Figure 5.7.3.1-2: SINR-based scheduling using SG and SD parameters for the SIMO and CLTD transmission modes

E-TFC selection is done using the legacy procedure, but the *SD* parameter is applied to decrease the *SG* grant prior to passing it to the E-TFC. However, the actual transmit power is not affected by *SD*. The *SD* is selected so that the combination of the *SG* and *SD* allows the UE to estimate the post-receiver SINR level at the Node B and select the E-TFC that would provide the maximum throughput at the required BLER performance. The mechanism considering 2-loop scheme is illustrated on the Figure 5.7.3.1-3 below:

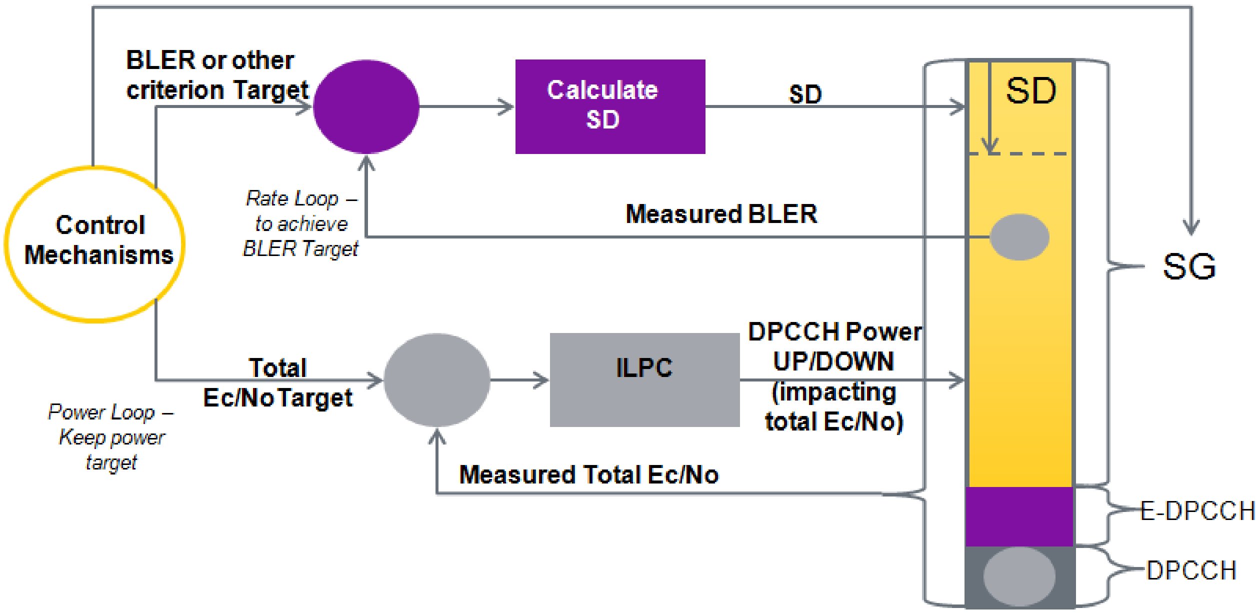


Figure 5.7.3.1-3: 2 loop scheme with rate and power loops

Compared to the power-based scheduling, the ILPC is affected by two changes:

- The subject of tracking is not the DPCCH SIR (Signal-to-Interference ratio) [8], but the DPCCH (or the total) received power. This change is motivated by the fact that the proportionality of SINR andTX power increase is no longer assumed. The power of all other physical channels relative to the DPCCH is fully defined by the SG parameter and is set the same as for the legacy operation.

- The power up/down threshold is no longer the SIR value set by OLPC (which is therefore disabled in SINR-based scheduling mode), but by the allowed RX Ec/No budget

Rate adaptation can also be enhanced by a modified 2-loop solution (illustrated in the Figure 5.7.3.1-3a below) with minor changes compared to legacy power-based scheduling as:

- The subject of tracking is not the DPCCH SIR (Signal-to-Interference ratio) [8], but the DPCCH (or the total) received power.

The modified 2-loop scheme could provide gains in terms of RoT stability by means of controlling DPCCH or the total received power, and E-TFC selection by means of signalling T2P dynamically (E-AGCH/E-RGCH) to meet the instantaneous channel conditions.

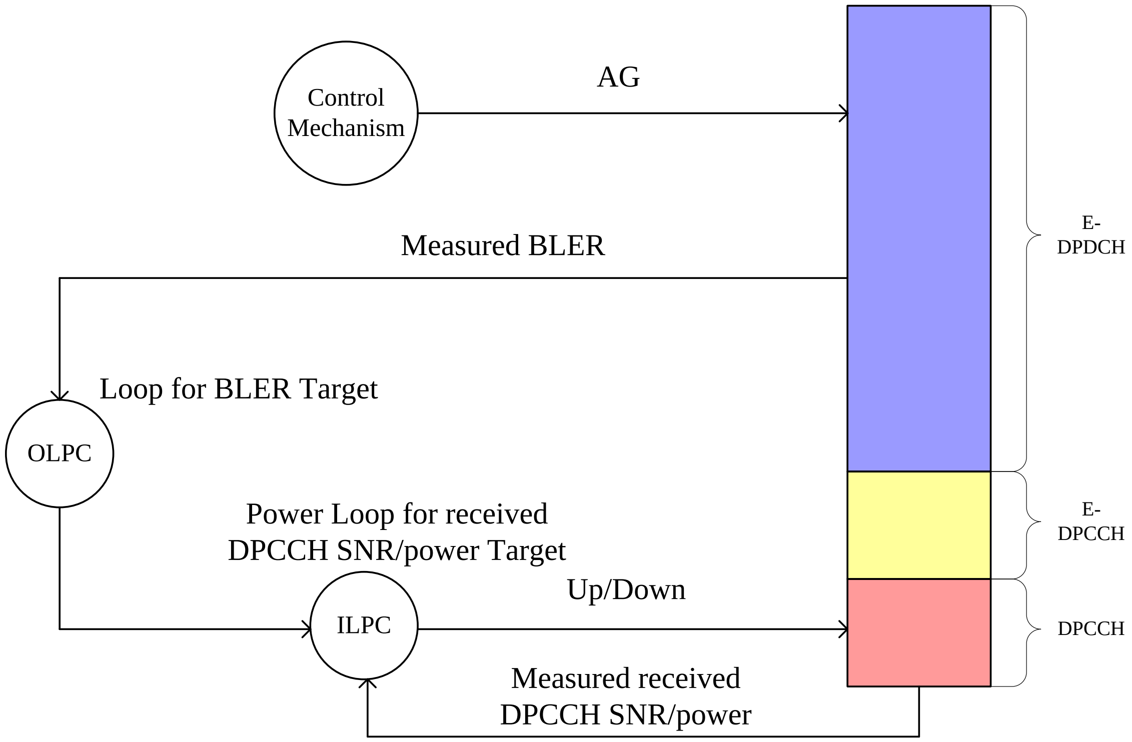


Figure 5.7.3.1-3a: A modified 2 loop scheme with modified ILPC and OLPC

It has been proposed that an alternative rate adaptation scheme with 3 loops could provide additional gains in system performance by the means of having independent control over the SIR on the control channels. To achieve rate adaptation with constant received power, data BLER control and DPCCH SINR control the following measures, incorporating 3 control loops, can be taken:

- Keep the existing DPCCH SINR-based power control loop.
- Add a second loop controlling the total received power.
- Since the SINR for traffic data now will vary due to channel conditions (ISI) and it will be changes in the fraction of power allocated to overhead channels, a back-off value applied to the granted rate can be used for controlling the transmission rate and keeping a desirable HARQ retransmission rate. This value can be signalled from Node B to UE through a third control loop.

As shown in Figure 5.7.3.1-5, two fast power control loops are used. The first power control command is used for increasing/decreasing the DPCCH power. The second power control command is used for increasing/decreasing the total power.

Assume that the UE has received commands to change the DPCCH power with a factor ΔP_c and that the total power shall change with a factor ΔP_s. Assuming at slot "t" we have the squared beta factors β^2_c, β^2_{ec}, $\Sigma\beta^2_{ed}(t)$, corresponding to the relative power of DPCCH, E-DPCCH and E-DPDCH respectively. One way to model the effect of the power commands is according to

$$\Delta P_c\, P(t)(\beta^2_c + \beta^2_{ec} + \Sigma\beta^2_{ed}(t+1)) = \Delta P_s P(t)(\beta^2_c + \beta^2_{ec} + \Sigma\beta^2_{ed}(t)) \quad (1)$$

Where P(t) in Equation 1 can be viewed as the power used by DPCCH at time t.

If $\beta^2_c = 1$ and we denote $\beta^2_{sum} = (\beta^2_c + \beta^2_{ec} + \Sigma\beta^2_{ed}(t))$ Equation 1 can be written as

$$\Sigma\beta^2_{ed}(t+1) = \beta^2_{sum}\, \Delta P_s/\Delta P_c - 1 - \beta^2_{ec} \quad (2)$$

Equation 2 then describes how β_{ed} values are dynamically updated to take the two power control loop commands into consideration. This is also illustrated in Figure 5.7.3.1-4.

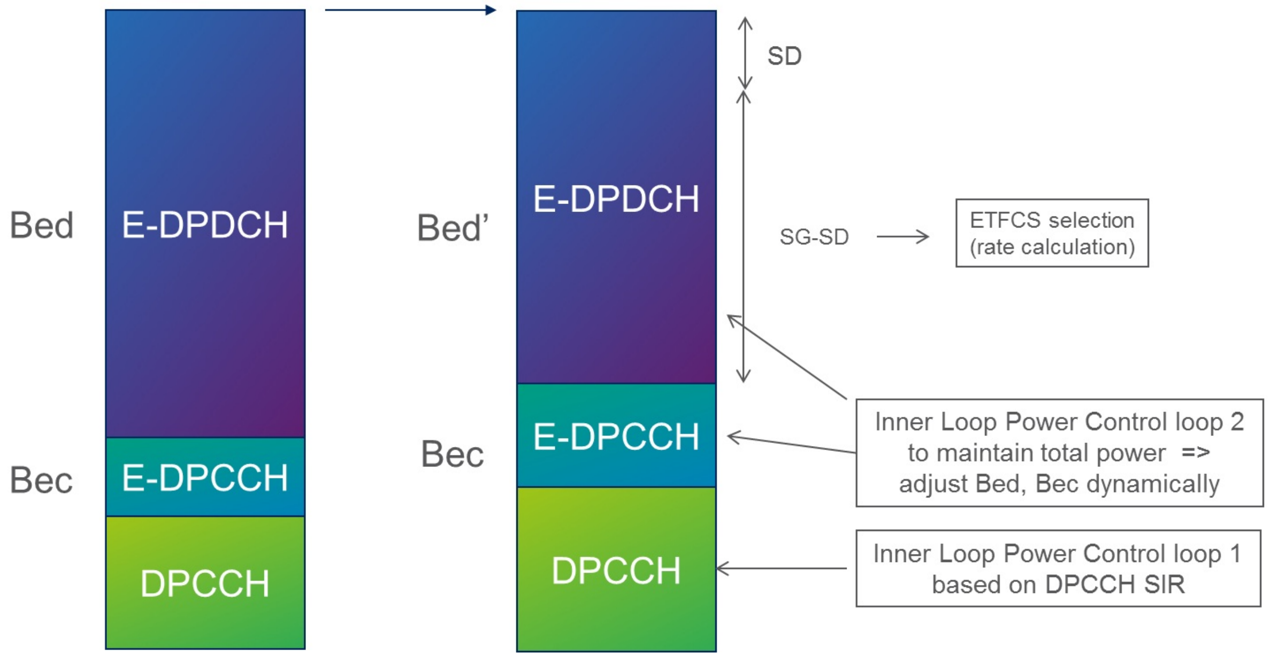


Figure 5.7.3.1-4: Power relations in the 3-loop scheme

The equations can be extended to also capture E-DPCCH boosting and additional channels as HS-DPCCH.

The rate offset (SD) calculation shown in Figure 5.7.3.1-5 can be done by the Node B, based on BLER statistics or SINR measurements. For the BLER controlled rate offset calculation, if BLER is higher than the desired target then the offset is lowered, otherwise it is increased. The UE then lowers/increases the rate but maintains the relative power of data versus control channels.

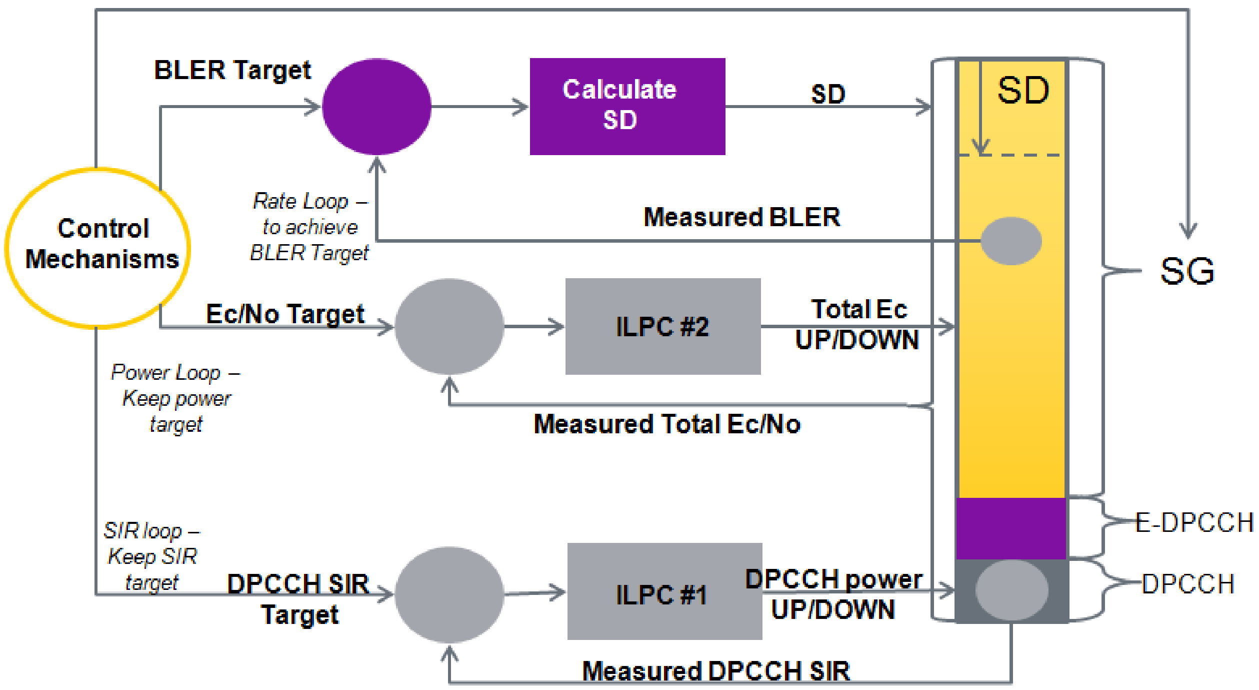


Figure 5.7.3.1-5: 3 loop scheme with rate, power and SIR loops

DL signalling requirements of different methods in case of single stream UL transmission are listed below:

1. Power-based scheduling:

   - TPC commands to control UL DPCCH Tx power (controlled by DPCCH SIR and impacting total Ec/No)

- Serving grant to control the data/DPCCH power ratio

2. 2-loop Rate adaptation:
   - TPC commands to control UL DPCCH Tx power (controlled by Ec/No)
   - Serving grant to control the data/DPCCH power ratio
   - SD offset for E-TFC selection in the UE
3. 3-loop Rate adaptation:
   - TPC commands to control UL DPCCH Tx power. Controlled by DPCCH SIR (e.g. a fixed value or a rate dependent value). ILPC#1 in Figure 5.7.3.1-5.
   - Power control commands to control total Tx power. Controlled by the Ec/No target level. ILPC#2 in Figure 5.7.3.1-5.
   - Serving grant to control the data/DPCCH power ratio
   - SD offset for E-TFC selection in the UE
4. Modified 2-loop Rate adaptation:
   - TPC commands to control UL DPCCH Tx power (controlled by Ec/No)
   - Serving grant to control the data/DPCCH power ratio

5.7.3.2 Soft handover operation with Rate adaptation

Using Soft Handover (SHO) with uplink signal reception assisted by the non-serving Nodes B may be beneficial for transmissions with improved rate adaptation based on the SINR-based scheduling as it is for the legacy operation and the power-based scheduling.

In general, different approaches can be envisioned to defining the SHO operation for the improved rate adaptation. On one side, this is due to some aspects remaining undefined to the SINR-based scheduling approach itself (irrespectively of SHO operation). Such important aspect is the power control scheme (2-loop, 3-loop, modified 2-loop). To address this, the SHO design aspects specific to a particular power control scheme are treated separately in the next subclauses along with the corresponding simulation results.

On the other side, multiple design aspects are to be defined specifically for the SHO with improved rate adaptation and include:

- *Ability of non-serving Nodes B to decode the data transmitted by SHO UEs*. Reception of data from SHO UEs by Non-serving Nodes B should be allowed from the general SHO point of view. However, some options may be envisioned where SHO operation for the improved rate adaptation will be limited to coordinated scheduling and power control only (when disabled see results 1a and 1b);
- Implementation of the rate adaptation procedure at the serving Node B only or in a collaborative way by Nodes B from the active set at the RNC.
  - In the first case, the E-TFC control mechanism operates only at the serving Node B similarly to the case of the disabled SHO. Non-serving Nodes B tries to decode the received TBs but provide only the ACK/NACK feedback without any impact on the data rate to be scheduled. The marginal loop defining the *SD* parameter resides in the serving Node B (in results 2a and 2b).
  - In the second (alternative) case, the marginal loop gets TB reception outcomes at the RNC from all Nodes B in the active set thus taking into account the combined reception probability. The marginal loop operation for the latter option is similar to the OLPC operation in the legacy system up to replacement of the target DPCCH SIR parameter by the E-DPDCH post-receiver SINR margin (*SD* parameter) (in results 3a and 3b).

Some SHO design parameters are specific to the power control approach and are considered in the corresponding subclauses below.

5.7.3.2.1 Soft Handover for 2-loop Rate Adaptation

The block diagram of the 2-loop power control approach (2-loop rate adaptation) is shown in Figure 5.7.3.1-3.

The considered aspect of the SHO procedure specific to the 2-loop power control approach is the extension of the SHO power control mechanisms. Three approaches for generation of the ILPC commands from non-serving Node B have been considered:

- *TPC commands are only sent from the serving Node B*. The commands from non-serving Nodes B are either not sent or ignored by the UE (all results "a").
- *TPC commands from non-serving Nodes B operating like overload indicators*. Non-serving Nodes B uses TPC DOWN commands to indicate that the interference level from the UE is too high and should be decreased. Otherwise, the UP commands are sent. The commands from non-serving Nodes B are applied to the DPCCH power level keeping the legacy procedure of combining TPC commands from the active set with no modifications (the UE is applying the DOWN command if any of the commands is DOWN) (all results "b").
- *TPC commands used for equal target RX DPCCH power control at all Nodes B in the active set*. This option is very close to the legacy SHO operation, where all cells in the active set transmit TPC commands to the UE. The difference compared to legacy is that instead of a SIR target, a DPCCH power target is distributed from RNC to all cells in the active set.

5.7.3.2.2 Soft handover for 3-loop Rate adaptation

The ILPC1 depicted in the lower part of Figure 5.7.3.1-5 adapts DPCCH SIR on a slot basis using legacy TPC UP/DOWN commands. The ILPC2 in Figure 5.7.3.1-5 adapts the total received power from the UE using total power UP/DOWN commands. The total received power measurements in Node B can be done by first measuring the power of the DPCCH. If the Node B is the only cell in the active set, then by using knowledge of the power commands transmitted to the UE and the TPC loop delay, the Node B can compute the power offset of the E-DPCCH and E-DPDCH channels and compute the total received power. This of course requires that the exact procedure for how the UE recalculates the power of DPCCH/E-DPCCH/E-DPDCH based on power control commands is well defined.

In the case of soft handover, the UE combines the power control commands (SIR control and Total received power control) from many Node B's. Therefore, in soft handover, the Node B does not know what power commands the UE actually has used to derive the new DPCCH/E-DPCCH/E-DPDCH power offsets. In practice this means that the Node B, instead of relying on knowledge of power offsets, needs to measure the power of E-DPCCH and E-DPDCH directly.

The following SHO options are proposed for 3-loop scheme:

SHO option 1. ILPC#1 operates (almost) as in legacy scheme, i.e. RNC determines a target DPCCH SIR value, which is distributed to all cells in the active set. However, the SIR target is not based on E-DPDCH decoding performance, but rather the requirement on reliable control channel detection in the serving cell. The UE combines ILPC#1 commands form all cells as in legacy operation. ILPC#2 is in the non-serving cells restricted to only transmit DOWN commands and DTX. This is proposed since the non-serving cell can no longer control its load by sending relative grants. The rate offset calculation can in this simplest option be made in the serving Node B only.

SHO option 2. Same as SHO option 1 but where the rate offset calculation is done in RNC based on decoding performance in all cells.

5.7.4 Conclusions

The Rate adaptation technique is considered as significant improvement to the HSUPA operation. Three different approaches i.e. 2-loop, 3-loop and modified 2-loop were studied and were shown to have better performance in comparison with the legacy system i.e. a power based scheduling approach, where the Serving Grant defines both Tx power level and E-TFCI selection.

Gains in terms of averaged UE throughput observed in evaluation were significant for higher UE densities and for higher RoT values. With 15 dB RoT target and for 10 users per cell, gains up to 25% over legacy scheduling were observed with modified 2-loop approach which does not require any standard changes. The 2-loop and 3-loop schemes were shown to provide additional gains from decoupling power control and scheduling. Gains up to 31% for 3-loop and up to 40% for 2-loop approach respectively, over legacy scheduling were observed. It should be noted that in evaluated scenarios efficient operation of the modified 2-loop scheme may provide similar gains as the 2-loop and 3-loop schemes.

Each presented approach of Rate Adaptation provides better RoT management which has a direct impact on system stability. The 3-loop approach provides independent control over DPCCH SIR due to introduction of an additional standardised control loop. However, the 2-loop and modified 2-loop approaches can also control DPCCH SIR with network side proprietary solutions. No proprietary solutions were used during the studies of Rate adaptation; instead the DPCCH Ec/No target was derived to be sufficient for high RoT target, and used in all simulated scenarios.

6 Impact on RAN WGs

The following clauses provide a high level description of the specification impact for different Working Groups due to the introduction of the features described in this Technical Report.

6.1 Impact on RAN1 specifications

25.211

E-DPCCH reduction in case of DTX (UL control channel overhead reduction), potential new grant channels (Enabling high bitrates, Rate adaptation), physical layer timing (Enabling high bitrates)

25.212

Change coding chain for the E-DPCCH for the "Reduced E-TFCI solution"

25.214

- Synchronisation, power control and DTX aspects for reduced transmission of uplink DPCCH in Lean carrier.
- DTX of E-DPCCH, introduction of a secondary CQI reporting pattern for UL control channel overhead reduction
- Rate adaptation procedure
- Use of HS-SCCH orders for fast TTI switch
- Use of HS-SCCH orders for fast TTI switch

6.2 Impact on RAN2 specifications

25.304

Access Control updates

25.306

UE capabilities related to the support of the new features

25.308

Functional description of the DL related aspects relevant to the Lean carrier would be needed (e.g. on CPC)

25.319

Functional description of

- TTI switching procedure enhancements
- Lean carrier
- Low complexity load balancing

25.321

- Potential impact of back-off timers in Control of RACH transmissions (alternatively it may be covered in the RRC specification)
- Evolved Scheduling Information and its triggers, coding of UPH
- E-TFCI selection procedure for Rate Adaptation and Lean carrier

25.331

- Signaling enhancement for all the new features
- Access Control enhancements (including SIB3 reading improvements)
- Configuration of UL data compression
- Enhanced UPH report (configuration and reporting)
- Enhanced reconfiguration procedures (for TTI switch as well as load balancing)
- Configuration of overhead reduction

6.3 Impact on RAN3 specifications

RAN3 specifications, e.g. TS 25.433, 25.423, 25.425, 25.435 may be impacted to introduce the signalling enhancements needed for the support of the chosen improvements (e.g. for TTI switching procedure enhancements).

6.4 Impact on RAN4 specifications

25.101

Potential impact on requirements related to modifications of the inner loop power control and initial power setting (Rate adaptation), new grant channel (Rate adaptation, Enabling high bitrates), power reference used for E-TFC selection (Rate adaptation).

25.104

Potential impact on the E-DPCCH performance due to changes in coding rate (UL control channel overhead reduction).

25.133

Update of UPH measurements. RRM requirements (e.g. initial synchronization) for fast hard handover between two carriers (low complexity uplink load balancing)

Annex A: Simulation assumptions

A.1 Enabling high bit rates

A.1.1 Link level simulation assumptions for Lean carrier

The link simulations assumptions for Lean carrier are shown in Table A.1.1-1.

Table A.1.1-1: Link level simulation assumptions

Parameter	Value
Transmission modes	SIMO
Physical channels	DPCCH, E-DPCCH and E-DPDCH
ΔT2TP [dB]	10
E-DCH TTI [ms]	2
Modulation	QPSK/16-QAM
TBS [bits]	4422, 10134 or 20268 (simulations are not limited to these TBSs)
Fixed SIR Targets [dB]	range depending on TBS, with 1 dB step-size
H-ARQ approach	Incremental redundancy
Channel encoder	3GPP Release 6 Turbo Encoder
Turbo decoder	Max log MAP
Number of iterations for turbo decoder	8
Node B Receiver Type	LMMSE (2 RX antennas)
DPCCH slot format	1 (8 Pilot + 2 TPC)
Path Searcher	Ideal
Channel estimation	Realistic
TPC feedback error rate	No errors (ideal feedback)
TPC feedback delay [slots]	2
TPC period [slots]	1
OLPC	OFF
ILPC	ON
Propagation channel	PA3, TU3, VA30
Correlation of channel realizations between different RX antennas	0

Simulations for evaluating achievable gains with the Lean carrier concept are performed on a single carrier, representing the Lean carrier or a baseline secondary carrier. The simulations are performed modeling one or more UE's transmitting bursty traffic using either the Lean carrier concept or using a baseline based on DC-HSUPA and CPC.

- Lean carrier - Transmissions in these simulation assumptions are scheduled periodically with a predefined transmission length and a predefined transmission periodicity. For an "ideal" Lean Carrier user DPCCH is only transmitted during data transmission meaning that no preambles/post-ambles or DPCCH bursts are transmitted.

- Baseline - Transmissions are scheduled according to the same pattern (transmission length and transmission periodicity) as the Lean carrier user(s).

A.1.1.1 Data traffic pattern

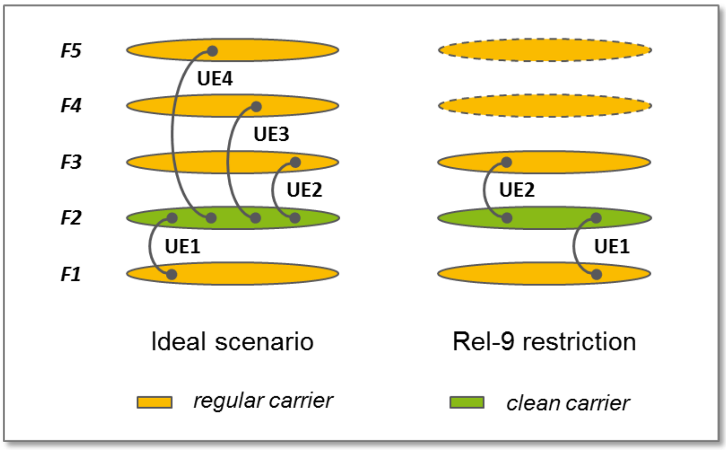
One traffic pattern to study is 10TTI data transmission in every 160TTIs. Studying other traffic patterns is optional.

A.1.1.2 Interference modelling on data transmissions

Simulations are performed in such a way that it's possible to draw conclusions on the effect from the number of activated users for different traffic management strategies (e.g. including different CPC burst patterns). Simulation results shall be provided for various numbers of users interfering with data transmissions. E.g. 2, 1, 0.5, 0.33 or 0.25 users. Fractional interfering users can be interpreted as they interfere only part of the time, e.g. 0.5 means that users only interfere with the data transmissions 50% of the time.

When results are presented the assumed number of activated users on the secondary carrier and the assumed traffic management strategy can be explained. They configurations can then be mapped to different selected interfering users, as mentioned above.

Different frequency pairing scenarios for a Lean carrier can be envisioned. See Figure A.1.1.2-1. In an ideal scenario, when there aren't any restrictions on the pairing of primary and secondary carriers, the number of UEs that a Lean carrier can support may be very large. Considering the Rel-9 DC-HSUPA restriction, a Lean carrier can only be paired with an adjacent carrier. Even with the Rel-9 restriction, the number of UEs supported on a Lean carrier may still be quite substantial since two primary carriers can be paired with one Lean carrier.



NOTE: F1 to F5 are consecutive adjacent carriers.
In the ideal scenario, a clean carrier can be paired with any other carrier to form a primary-secondary pair.
With the Rel-9 restriction, a clean carrier can only be paired with an adjacent carrier.

Figure A.1.1.2-1: Frequency pairing scenarios for a clean carrier

Keeping as many users as possible active on a Lean carrier gives the advantage of providing good latency for the users that have data to send once they need to send it.

If the Rel-9 restriction on adjacent carriers is lifted, even more users can be supported on the Lean carrier. In real smartphone heavy networks of today, in for example urban environments, it would be possible to support more than 50 users per primary carrier. So supporting 100 users on a Lean carrier could be possible if the primary carriers are capable to serve that many Lean carrier UEs.

The CPC configuration used for comparison is 1 TTI for DPCCH burst, 20TTI for CPC cycle 1 and 160TTI for CPC cycle 2. The parameters are chosen for achieving as low DPCCH overhead as possible using current standard. These settings results in lower DPCCH overhead. It is assumed that for UEs with data transmission the CPC cycle is 20 TTI and for background UEs which are supposed to be dominant the CPC cycle is 160 TTI, i.e. totally 2 TTIs (6 slots) of DPCCH per burst cycle of 160 TTIs are transmitted taking into account the pre and post-ambles transmitted with the DPCCH burst. The average number of DPCCH interferers per TTI can be summarized in Table A.1.1.2-1 and Table A.1.1.2-2.

Table A.1.1.2-1: Mapping of number of users on the clean carrier to number of interfering DPCCH's per TTI in Scenario A

Scenario A	Number of users per primary/Lean carrier									
	10/10	20/20	30/30	40/40	50/50	60/60	70/70	80/80	90/90	100/100
Average Number of DPCCH Interferers per TTI on the Lean carrier TTI in Cycle 1	1	2	3	4	5	6	7	8	9	10
Average Number of DPCCH Interferers per TTI on the Lean carrier TTI in Cycle 2	0.125	0.25	0.375	0.5	0.625	0.750	0.875	1.0	1.125	1.25
NOTE: Lean carrier is configured as Lean carrier is paired with one primary carrier where the primary carrier is frequency adjacent to the Lean carrier. Contributions from Cycle 1 and Cycle 2 are given separately.										

Table A.1.1.2-2: Mapping of number of users on the clean carrier to number of interfering DPCCH's per TTI in Scenario B, where the Lean carrier is configured as Lean carrier is paired with two primary carriers where each primary carrier is frequency adjacent to the Lean carrier. Contributions from Cycle 1 and Cycle 2 are given separately.

Scenario B	Number of users per primary/Lean carrier									
	10/20	20/40	30/60	40/80	50/100	60/120	70/140	80/160	90/180	100/200
Average Number of DPCCH Interferers per TTI on the Lean carrier TTI in Cycle 1	2	4	6	8	10	12	14	16	18	20
Average Number of DPCCH Interferers per TTI on the Lean carrier TTI in Cycle 2	0,25	0,5	0,75	1	1,25	1,5	1,75	2	2,25	2,5
NOTE: Lean carrier is configured as Lean carrier is paired with two primary carriers where each primary carrier is frequency adjacent to the Lean carrier. Contributions from Cycle 1 and Cycle 2 are given separately.										

The total amount of DPCCH interference per TTI will be the sum of DPCCH interference from users using cycle 1 and those using cycle 2, considering the ratio of users using cycle 1 and users using cycle2.

A.1.1.3 Link performance metrics

- Throughput or BLER at different received Ec/No

A.1.2 System simulation assumptions

The system simulation assumptions for Lean carrier are shown in Table A.1.2-1 and Table A.1.2-2.
The traffic model in Table 2 is to be seen as a guideline and other traffic models may be used as well.

Table A.1.2-1: System Simulation Parameters for Lean Carrier Evaluation

Parameters	Values and comments
Cell Layout	21 cell hexagonal (7 Node B, 3 sectors per Node B with wrap-around) 57 cell hexagonal (19 Node B, 3 sectors per Node B with wrap-around)
Inter-site distance	500 m
Carrier Frequency	2000 MHz
Carrier bandwidth	5MHz
Path Loss	L=128.1 + 37.6log10(R), R in kilometres
Log Normal Fading	Mean= 0 Standard Deviation: 8dB Inter-Node B Correlation: 0.5 Intra-Node B Correlation :1.0 Correlation Distance: 50m
Antenna pattern	"Combining method in 3D antenna pattern" in Table A.2.1.1-2 [16]
Channel Model	PA3, TU3, VA30
Penetration loss	20dB
Maximum UE EIRP	24dBm
Maximum Tx Power of BS	43dBm
Max BS Antenna Gain	14dBi
Max UE Antenna Gain	0dBi
Node B Noise Figure	5 dB
UE Noise Figure	9 dB
Thermal noise density	-174dBm/Hz
Number of HARQ processes	8
Node B Receiver	2-Rx LMMS
Soft Handover Parameters	R1a (reporting range constant) = 3dB R1b (reporting range constant) = 6dB
Max active set size	3
Power control	10% BLER after the 1st transmission
Target RoT	6dB, 12dB, 18dB for Lean carrier 6dB for legacy carrier
Traffic Model	Bursty traffic
UE_DTX_cycle_1	20 TTIs, other values are optional
UE_DTX_cycle_2	160 TTIs, other values are optional
Inactivity_Threshold_for_UE_DTX_cycle_2	8 TTIs
UE_DPCCH_burst_1	1 TTI, other values are optional
UE_DPCCH_burst_2	1 TTI, other values are optional
CPC preamble length	2, 4 or 15 slots
DPCCH preamble for Lean carrier capable UE	0, 2, 4 or 15 slots

Table A.1.2-2: Uplink Bursty Traffic Model for Lean Carrier Evaluation

	Component	Distribution	Parameters	PDF
UL traffic model	File size (S)	Truncated Lognormal	Mean = 0.125 Mbytes Std. Dev. = 0.045 Mbytes Maximum = 0.3125 Mbytes	$f_X = \frac{1}{\sqrt{2\pi}\sigma x}\exp\left[\frac{-(\ln x-\mu)^2}{2\sigma^2}\right], x \ge 0$ $\sigma = 0.35, \mu = 11.675$
	Inter-burst time	Exponential	Mean = 5 sec	$f_X = \lambda e^{-\lambda x}, x \ge 0$ $\lambda = 0.2$

A.1.2.1 System performance evaluation metrics

For bursty traffic, the following performance measures are used for evaluation:

Average burst rate:

- The burst rate is defined as the ratio between the data burst size in bits and the total time the burst spent in the system.
- The total time the burst spent in the system is the time difference measured between the instant the data burst arrives and the instant when the transfer of the burst over the air interface is completed.
- The total time the burst spent in the system is equal to the sum of the transmission time over the air and the queuing delay.

Total system throughput

UE throughput: average, 50%, and 5%

Average and CDF of RoT for UL

The baseline should be TDM operation with CPC. It should be emphasized that Lean and legacy operations are by nature not compatible. The main purpose of the hybrid carrier scheme is to reduce under-utilization. The gain from Lean operations is impacted in hybrid scenarios and is expected not to offer gains compared to that of a scenarios with 100% penetration of Lean carrier users. A loss can be expected in legacy UEs performance, e.g. broadcast channels are still needed, scheduling delay is increased for high-bitrate transmissions and SI transmission delay may be increased.

A.2 Overhead channel reduction

A.2.1 System simulation assumptions for HS-DPCCH reduction

Table A.2.1-1 lists the system simulation assumptions for HS-DPCCH reduction evaluation.
Table A.2.1-2 provides the traffic model for HS-DPCCH reduction evaluation.

Table A.2.1-1: System simulation assumptions

Parameters	Values and comments
Cell Layout	21 cell hexagonal (7 Node B, 3 sectors per Node B with wrap-around)
Inter-site distance	500 m
Carrier Frequency	2000 MHz
Carrier bandwidth	5MHz
Path Loss	L=128.1 + 37.6log10(R), R in kilometres
Log Normal Fading	Mean= 0 Standard Deviation: 8dB Inter-Node B Correlation: 0.5 Intra-Node B Correlation :1.0 Correlation Distance: 50m
Antenna pattern	3GPP ant (2D ant): $A(\theta) = -\min\left[12\left(\frac{\theta}{\theta_{3dB}}\right)^2, A_m\right]$ θ_{3dB} = 70 degrees, Am = 20 dB LPN: 2D Antenna, Omni-directional
Channel Model	PA3
Penetration loss	20dB
Maximum UE EIRP	24dBm
Maximum Tx Power of BS	43dBm
Max BS Antenna Gain	14dBi
Max UE Antenna Gain	0dBi
Node B Noise Figure	3 dB
UE Noise Figure	9 dB
Thermal noise density	-174dBm/Hz
Number of HARQ processes	8
Node B Receiver	Rake
UE Receiver	LMMSE
Soft Handover Parameters	R1a (reporting range constant) = 3dB R1b (reporting range constant) = 6dB
Max active set size	3
Power control	UL: 10% BLER after the initial transmission DL: 10% BLER after the initial transmission
Target RoT	6dB
Traffic Model	burst
Number of UEs per cell	HS-DPCCH evaluation: 10 E-DPCCH evaluation: 20
CQI Feedback Cycle	For Cycle adaptive solution, Cycle 1 is 2ms TTI, and Cycle 2 is 40ms TTI; Other CQI feedback cycles can be considered.
DPCCH SIR target	-19dB
HS-DPCCH gain factor for non-SHO	0dB
HS-DPCCH gain factor for SHO	4dB

Table A.2.1-2: Traffic model for HS-DPCCH evaluation

	Component	Distribution	Parameters	PDF
UL traffic model	File size (S)	Truncated Lognormal	Mean = 0.125 Mbytes Std. Dev. = 0.045 Mbytes Maximum = 0.3125 Mbytes	$f_x = \frac{1}{\sqrt{2\pi}\sigma x}\exp\left[\frac{-(\ln x-\mu)^2}{2\sigma^2}\right], x \ge 0$ $\sigma = 0.35, \mu = 11.675$
	Inter-burst time	Exponential	Mean = 5 sec	$f_x = \lambda e^{-\lambda x}, x \ge 0$ $\lambda = 0.2$
DL traffic model	File size (S)	Truncated Lognormal	Mean = 0.5 Mbytes Std. Dev. = 0.1805 Mbytes Maximum = 1.25 Mbytes	$f_x = \frac{1}{\sqrt{2\pi}\sigma x}\exp\left[\frac{-(\ln x-\mu)^2}{2\sigma^2}\right], x \ge 0$ $\sigma = 0.35, \mu = 13.061$
	Inter-burst time	Exponential	Mean = 5 sec	$f_x = \lambda e^{-\lambda x}, x \ge 0$ $\lambda = 0.2$

Performance metrics:

- UL average burst rate
- DL average burst rate

A.2.2 System simulation assumptions for E-DPCCH reduction

Table A.2.2-1 lists the system simulation assumptions for E-DPCCH overhead reduction evaluation. Table A.2.2-2 provides the traffic model for E-DPCCH reduction evaluation.

Table A.2.2-1: System Simulation Parameters for E-DPCCH Overhead Reduction Evaluation

Parameters	Values and comments
Cell Layout	21 cell hexagonal (7 Node B, 3 sectors per Node B with wrap-around) 57 cell hexagonal (optional)
Inter-site distance	500 m
Carrier Frequency	2000 MHz
Carrier bandwidth	5MHz
Path Loss	L=128.1 + 37.6log10(R), R in kilometres
Log Normal Fading	Mean= 0 Standard Deviation: 8dB Inter-Node B Correlation: 0.5 Intra-Node B Correlation :1.0 Correlation Distance: 50m
Antenna pattern	3GPP ant (2D ant): $A(\theta) = -\min\left[12\left(\frac{\theta}{\theta_{3dB}}\right)^2, A_m\right]$ θ_{3dB} = 70 degrees, Am = 20 dB LPN: 2D Antenna, Omni-directional
Channel Model	PA3
Penetration loss	20dB
Maximum UE EIRP	24dBm
Maximum Tx Power of BS	43dBm
Max BS Antenna Gain	14dBi
Max UE Antenna Gain	0dBi
Node B Noise Figure	3 dB
UE Noise Figure	9 dB
Thermal noise density	-174dBm/Hz
Number of HARQ processes	8
Node B Receiver	Rake
UE Receiver	LMMSE
Soft Handover Parameters	R1a (reporting range constant) = 3dB R1b (reporting range constant) = 6dB
Max active set size	3
Power control	UL: 10% BLER after the initial transmission
Target RoT	6dB
Traffic Model	Burst, full buffer (optional)
Number of UEs per cell	2, 4, 6, 8, 10
DPCCH SIR target	-19dB
E-DPCCH gain factor(β_{ec})	0dB; -1.94dB for the case of RM(30,3) coding
E-DPDCH rate threshold for applying E-DPCCH boosting	1 Mbps

Table A.2.2-2: Traffic model for E-DPCCH evaluation

	Component	Distribution	Parameters	PDF
UL traffic model	File size (S)	Truncated Lognormal	Mean = 0.125 Mbytes Std. Dev. = 0.045 Mbytes Maximum = 0.3125 Mbytes	$f_X = \frac{1}{\sqrt{2\pi}\sigma x}\exp\left[\frac{-(\ln x-\mu)^2}{2\sigma^2}\right], x \geq 0$ $\sigma = 0.35, \mu = 11.675$
	Inter-burst time	Exponential	Mean = 5 sec	$f_X = \lambda e^{-\lambda x}, x \geq 0$ $\lambda = 0.2$

Performance metrics:

- UE Throughput CDF
- Burst rate CDF
- RoT, UE throughput, burst rate and UE totalTX power (with and without E-DPCCH transmission)
- DPCCH SIR

A.3 Rate adaptation

A.3.1 Link Simulation assumptions

The link simulations assumptions for uplink rate adaptation are shown in Table A.3.1-1 and Table A.3.1-2.

Table A.3.1-1: Link level simulation assumptions

Parameter	Value
Transmission modes	SIMO
Physical channels	DPCCH, E-DPCCH, E-DPDCH
ΔT2TP [dB]	10
E-DCH TTI [ms]	2
Modulation	QPSK, 16-QAM
TBS [bits]	Variable: 120 – 22995 bits
H-ARQ operating point	10% BLER after the 1st transmission attempt
H-ARQ approach	Incremental redundancy
Channel encoder	3GPP Release 6 Turbo Encoder
Turbo decoder	Max Log MAP
Number of iterations for turbo decoder	8
Node B Receiver Type	LMMSE, 2 RX antennas
DPCCH slot format	1 (8 Pilot, 2 TPC)
Power control measurements	Ideal, realistic
Searcher (finger placement)	Ideal, realistic
Channel estimation	Ideal, realistic (E-DPCCH assisted)
E-DPCCH decoding	Ideal, realistic (optional)
Target RoT [dB]	5, 7.5, 10, 12.5, 15, 17.5, 20
Propagation channel	PA3, VA3, VA30
Correlation of channel realizations between different RX antennas	0
Number of H-ARQ Processes	8
Maximum number of H-ARQ Transmissions	4
ILPC and OLPC	*see Table A.2.1-2*
ILPC 1 Update Rate [slots]	1*
ILPC 1 Step Size [dB]	±1*
ILPC 1 delay [slots]	2*
ILPC 2 Update Rate [slots]	1*
ILPC 2 Step Size [dB]	±1*
ILPC 2 delay [slots]	2*
SD Update Rate [TTI]	1*
SD delay [TTI]	5*
SD update based on	SINR difference or BLER
Feedback error rate on control loops	*optional*
NOTE: *indicates initial simulation parameter values, other values can be provided for evaluating the rate adaptation schemes.	

For the baseline SG is calculated based on the available RX Ec/No (RoT) budget. E-FTCs to be used for the data transmission are selected according to the existing specification. The beta factor set is designed taking into account the requirement for reliable E-DPCCH decoding (minimum DPCCH SIR power).

For the 2-loop, 3-loop and modified 2-loop rate adaptation schemes other mechanisms are used for controlling the total received power and/or data transmission rates. A summary of used control loops are shown in Table A.3.1-2.

Table A.3.1-2: Overview of power control and scheduling schemes

Power control and scheduling (E-TFCI selection) scheme	DPCCH SIR control loop (ILPC 1)	Total RX power control loop (ILPC 2)	Rate adaptation (SD) control loop	OLPC for BLER control	Scheduling grant calculation
Baseline	Yes	No	No	Yes	Every 2ms
2-loop scheme	No	Yes	Yes	N/A	Only initially (in link simulations)
3-loop scheme	Yes	Yes	Yes	N/A	Only initially (in link simulations)
Modified 2-loop scheme	No	Yes	No	Yes	Every 2ms

A.3.1.1 Evaluation metrics

- Throughput values at different RoT targets
- RX and TX power levels
- DPCCH SIR levels
- RoT levels
- Statistics on loop parameters

A.3.2 System simulation assumptions

The system simulations assumptions for uplink rate adaptation are shown in Table A.3.2-1 and Table A.3.2-2.

Table A.3.2-1: Deployment model simulation assumptions

Parameter	Value
Deployment scenario	3GPP Macrocell
Cell layout	Wrap-around hexagonal grid, 19 sites with 3 sectors per site
Inter-site distance [km]	0.5 1.0 (optional)
Path loss and shadow fading models	As in [4]
Node B antenna pattern	"Combining method in 3D antenna pattern" in Table A.2.1.1-2 [16]
Node B antenna tilt angle, θ_{etilt}	10º 8º (optional)
UE antenna pattern	Omnidirectional
UE antenna gain [dBi]	0
Penetration loss [dB]	10
Maximum UETX power [dBm]	23
Node B noise figure [dB]	3
Thermal noise PSD [dBm/Hz]	-174
Minimum distance between UT and serving cell [m]	25
Carrier frequency [GHz]	2.0
Channel model profile	PA3, VA3, VA30
Correlation between the antennas	0
User mobility model	Doppler spectrum
User distribution	Randomly and uniformly distributed over the area
Interference modeling	Explicitly modeled interference, given percentage of the strong interferes are modeled with taking into account their temporal and spatial correlation properties, less powerful interferers are modeled by equivalent AWGN noise. (The simplified interference modeling is optional)
Traffic model	Full buffer

Table A.3.2-2: System operation assumptions

Parameter	Value
Transmission modes	SIMO
Link-to-system mapping interface	Effective SINR based
E-DCH TTI [ms]	2
Modulation	QPSK, 16-QAM
ΔT2TP [dB]	10
Channel estimation	Ideal, realistic
Pilot SIR estimation	Ideal, realistic
E-DPCCH decoding	Ideal, realistic (optional)
Node B receiver	LMMSE with RX diversity
Number of TX antennas	1
Number of RX antennas	2
Soft handover	Disabled**
Softer handover	Enabled
OLPC delay [TTI]	8
Target BLER	10% after the 1st transmission attempt
H-ARQ approach	Incremental redundancy
Target RoT [dB]	6; 15
ILPC and OLPC	*see Table A.3.1-2*
ILPC 1 Update Rate [slots]	1*
ILPC 1 Step Size [dB]	±1*
ILPC 1 delay [slots]	2*
ILPC 2 Update Rate [slots]	1*
ILPC 2 Step Size [dB]	±1*
ILPC 2 delay [slots]	2*
SD Update Rate [TTI]	1*
SD delay [TTI]	5*
SD update based on	SINR difference or BLER

NOTE 1: * indicates initial simulation parameter values, other values can be provided for evaluating the rate adaptation schemes.
NOTE 2: ** indicates Soft and softer handover are in the initial simulation assumptions disabled. If a soft handover handling mechanism for rate adaptation is agreed to be included in the study item, these assumptions can be updated accordingly.

The following scheduler types shall be considered in the system simulations:

- CDM legacy
- TDM legacy
- TDM rate adaptation
- CDM rate adaptation (optional)

A.3.2.1 Evaluation metrics

- Average UE throughput versus average sector throughput curves
  - UE densities: 0.0175, 0.25, 1, 4 and 10 UEs per sector
- Statistics on relative throughput gains
- Average BLER statistics
- RoT distribution (CDF)

Annex B: Simulation results

B.1 Enabling high bit rates

B.1.1 Grant handling simulation results

B.1.1.1 Grant detection

The approach used to detect the grant transmission is described below:

- Decode the E-AGCH irrespectively of its actual presence in the received signal
- Without passing the CRC check and irrespectively of E-AGCH decoding success perform E-AGCH coding and mapping on decoded signal
- Calculate cross-correlation between the obtained signal and the received signal.
- The detection threshold is selected to provide fixed, admissible false alarm probability of 1%.
- The missed detection probability is measured as a function of the RX Ec/No

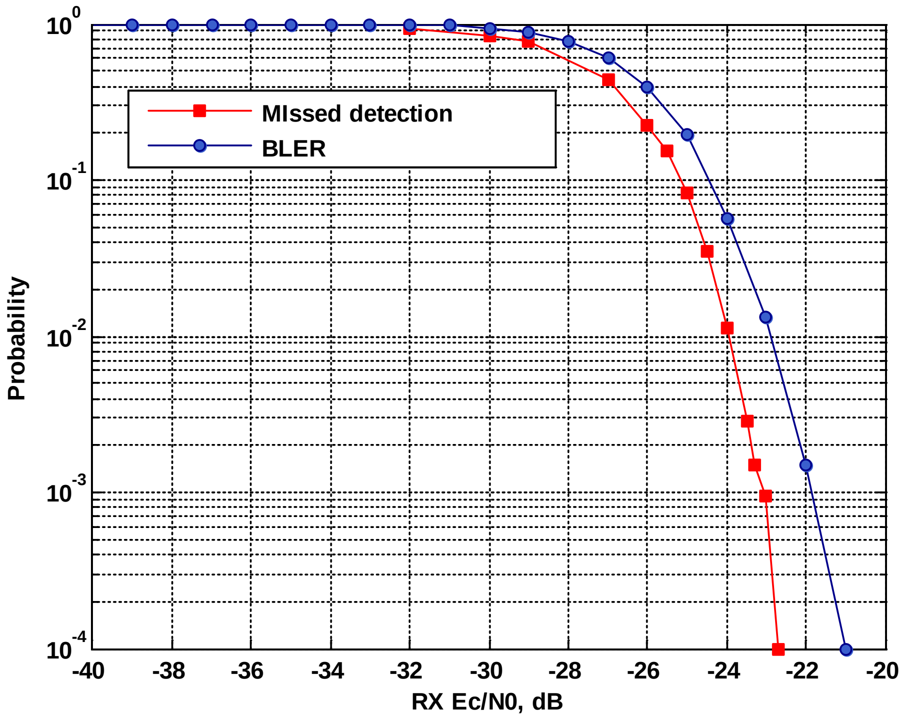


Figure B.1.1.1-1: E-AGCH BLER and missed detection presented as a function of RX Ec/No in AWGN channel

Figure B.1.1.1-1 depicts the missed detection probability and BLER of E-AGCH channel as a function of Rx Ec/No for the false alarm probability of 1%. Assuming that the E-AGCH power is high enough to be decoded by all UEs in the sector with the BLER of 1%, corresponding to -23dB RX Ec/No, the missed detection probability will be below 0.1%. In this range of RX Ec/No the missed detection probability is 10 times lower than the probability of not decoding E-

AGCH correctly. Thus, it can be concluded that presented TDM operation improvement can work with very high reliability.

B.1.1.2 Fast Scheduling Grant

Example of performance evaluation of E-AGCH and E-RGCH in the FSG perspective is shown in Figure B.1.1.2-1. The evaluation assume 2ms E-DCH TTI and only one radio link, i.e. E-RGCH is assumed to be transmitted from serving cell and hence corresponding E-RGCH coding is used. 2ms TTI is assumed to be the most interesting case for TDM scheduling.

Performance requirements in 25.101 [21] for 2ms serving E-RGCH are assuming quite low operation point and hence required error rate for missed hold is 10% and missed up/down 5%. However, simulations show that 1% error rate for both can be obtained by using very low Ec/Ior values and thus low overhead. It must be noted that when E-RGCH is re-used for FSG signalling typically only one or two UEs are scheduled at the same time and number of simultaneously transmitted FSG signatures is low. There is no need to transmit signatures used to transmit FSG to the UEs that are not scheduled. Assumptions have been different when HSUPA downlink channel performance requirements have been specified and hence lower overhead is desirable there.

As can be seen Ec/Ior required to obtain 1% error probability is 4-5 dBs lower for E-RGCH than E-AGCH. If FSG is signalled separately for each TTI then it means re-using E-RGCH would be beneficial compared to E-AGCH scheme if transmission of packet requires in average less than three TTIs. However, if FSG on/off signalling scheme is used then the E-RGCH solution becomes more efficient despite the fact that also the FSG off needs to be transmitted. Aforementioned applies only to separate FSG signalling and does not take changing power grant into account.

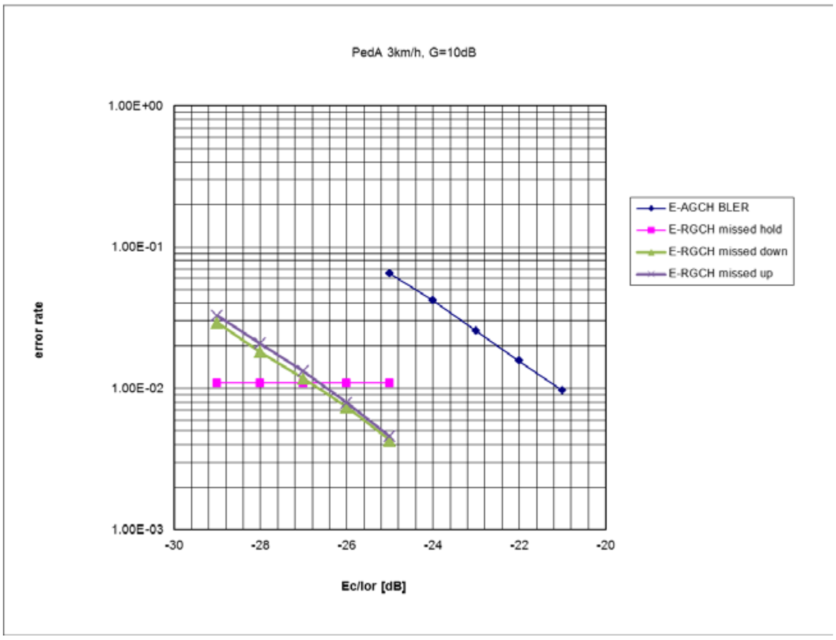


Figure B.1.1.2-1: Performance of E-AGCH and E-RGCH in Ped A channel.

B.1.2 Link Level Simulations Results for Lean carrier

It was agreed in [17] to simplify the evaluation by performing simulations on a single carrier that represents the dedicated secondary carrier. Bursty traffic on the dedicated secondary carrier is modeled using periodic transmissions from one or more UEs. Comparisons are then made between the Lean carrier proposal and the baseline CPC solution.

Lean carrier transmissions are scheduled periodically with a predefined transmission length and a predefined transmission periodicity. Two versions of the Lean Carrier are considered:

- Lean0: The basic Lean Carrier where user DPCCH is transmitted only during data transmission, with no preambles/post-ambles or DPCCH bursts transmitted.

- Lean+: Lean carrier with preambles and post-ambles immediately before and after each burst of data transmission.

Baseline CPC transmissions are scheduled according to the same pattern as the Lean carrier users. DPCCH gating is used to reduce the control channel overhead. This means DPCCH preambles, post-ambles and periodic DPCCH bursts are transmitted, creating extra interference on the dedicated secondary carrier. Baseline CPC users configured on the dedicated secondary carrier can, therefore, interfere with each other even when they are not transmitting data.

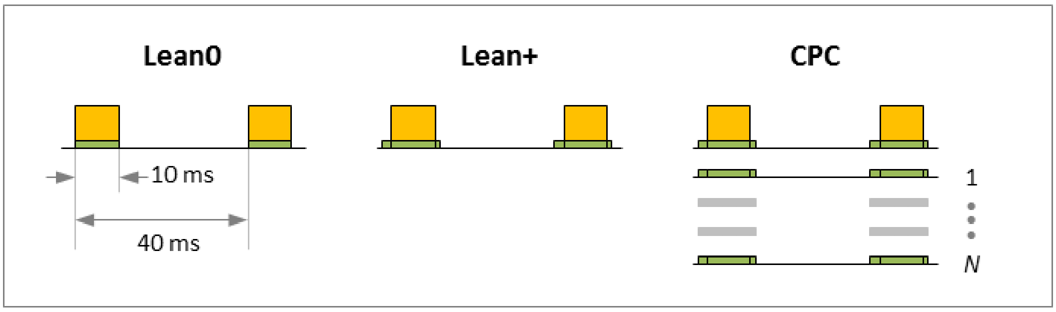
B.1.2.1 Simulation scenarios and results

This clause contains a comprehensive summary of the different scenarios that have been evaluated, and presents the main results and observations that were captured from the simulations. Most of the simulations were performed by using the PA 3km/h channel model, but results for the TU 3km/h and VA 30km/h channel models have been included in a complementary way aiming at further extending this study.

B.1.2.2 Impact of DPCCH bursts on data transmission

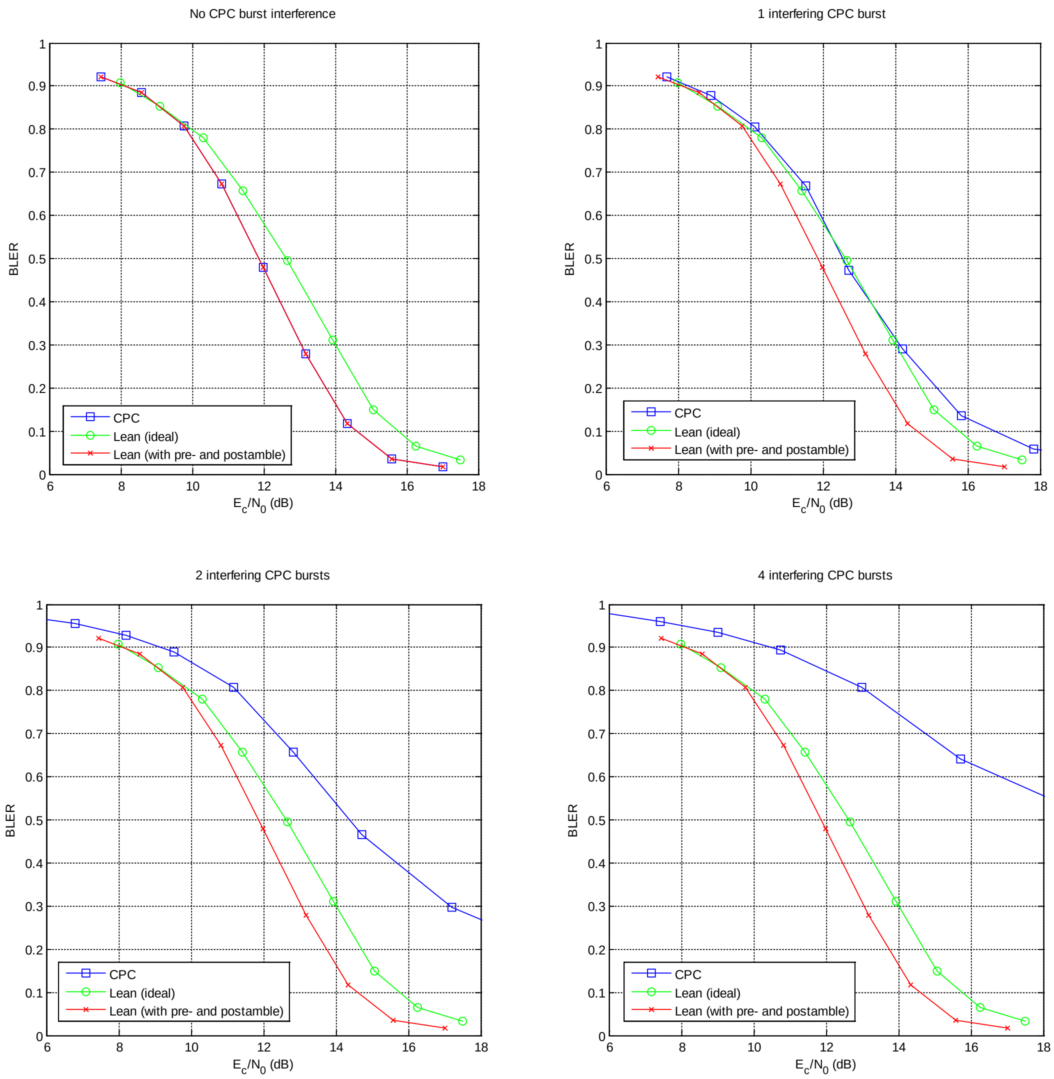
B.1.2.2.1 Scenario A: 10Mbps transmissions in a PA3 environment

High bitrate transmission requires operation in a high RoT environment. When operating close to the pole capacity, the system can easily become unstable. The interference from the CPC bursts of non-scheduled users, although small in absolute term, can have a significant impact on the data rate of the transmitting user. The simulation results for 10 Mbps transmissions have been presented in [18]. The transmission patterns for the Lean and the CPC cases are given in Figure B.1.2.2.1-1.



NOTE: All cases have a 10ms data burst and a 40ms repetition cycle.
For the CPC case, the data transmissions are interfered by a number of DPCCH bursts.
For the Lean cases, there is no interferer.

Figure B.1.2.2.1-1: Transmission patterns for the results shown in Figure B.1.2.2.1-2



NOTE: From left to right and top to bottom: Results of BLER vs Ec/No for 0, 1, 2, and 4 interfering DPCCH bursts.

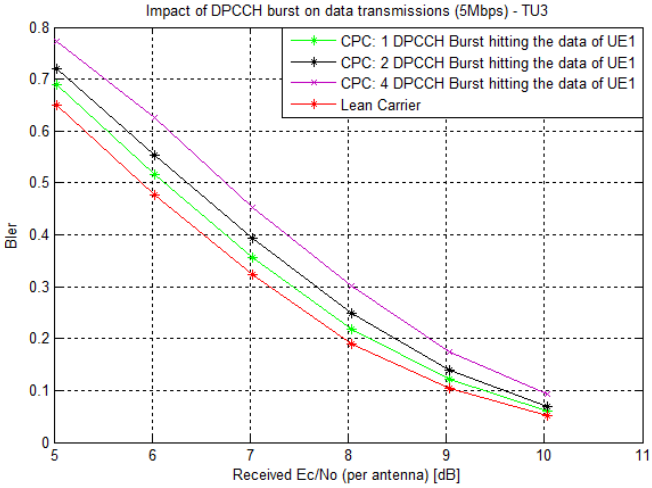
Figure B.1.2.2.1-2: Impact of DPCCH bursts on data transmission at 10 Mbps

The results are reproduced here in Figure B.1.2.2.1-2. It can be seen that the Lean+ case in general performs slightly better than the Lean0 case. This is due to the extra preambles, which provides more opportunity (especially for small burst sizes) for power control to adapt to fast fading. Furthermore, the preambles are not being interfered. Adding interference on the preamble will narrow the gap between Lean0 and Lean+. When there is no interferer, the CPC case is by definition identical to the Lean+. When the number of interferers increases, the CPC performance decreases quite quickly and start to become unstable when there are more than two interferers. This confirms the basic premise that the performance of high bitrate transmissions is very susceptible to interference and it needs to operate in a clean environment.

To summarize, at a high bitrate such as 10 Mbps, data transmissions are rather sensitive to small interferences and can become unstable when interfered by more than a couple of DPCCH bursts.

B.1.1.2.2 Scenario B: Lower bitrates for the TU3 and VA30 environments

The performance for Lean Carrier and CPC in the case of the TU3 channel model is shown in Figure B.1.1.2.2-1.

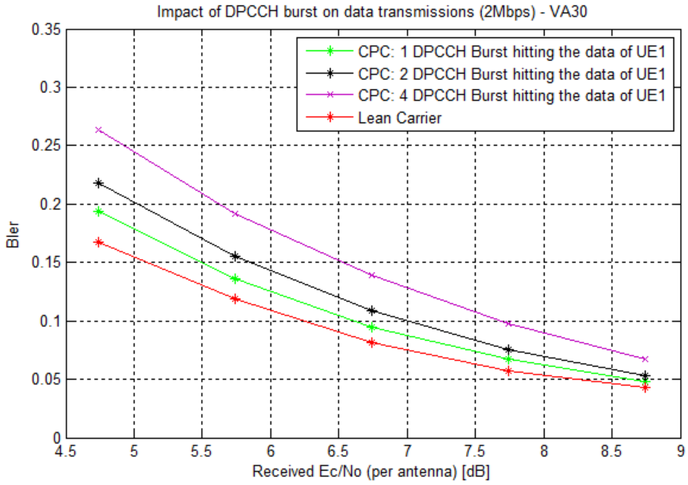


NOTE: Results of BLER vs Ec/No for 1, 2 and 4 interfering DPCCH bursts.

Figure B.1.1.2.2-1: Impact of DPCCH bursts on data transmission at 5 Mbps by using the TU3 channel model

Compared to the PA channel, the TU channel model is more dispersive (it is composed by 20 taps, while its maximum delay spread is 2.140µs) and it is more challenging to achieve high date rates. As a consequence 5Mbps is used in the simulations. Although less severe given that the data rate was reduced, in general from Figure B.1.1.2.2-1 it can be seen that the trend that was observed before in Figure B.1.2.2.1-2 for case of 10Mbps also prevails here. That is, it can be noticed that even when the DPCCH bursts are tiny in terms of power, they lead to some performance degradation for CPC.

The VA30 channel was also taken into consideration. It is slightly more dispersive (maximum delay spread = 2.510 µs) than the TU channel, and in addition to that, its higher speed will add more complexity to the scenario since in this case the channel is changing much more rapidly (shorter coherence time) compared to the speed of the previously studied channels. The results are shown in Figure B.1.1.2.2-2.



NOTE: Results of BLER vs Ec/No for 1, 2 and 4 interfering DPCCH bursts.

Figure B.1.1.2.2-2: Impact of DPCCH bursts on data transmission at 2 Mbps by using the VA30 channel model

From the above figure it can be noticed that the trend among Lean Carrier and CPC is also consistent for the VA30 channel even when the data rate was deliberately decreased up to 2Mbps aiming at managing in a better way the dispersivity and fading rapidity given by the nature of this channel.

To summarize, when more dispersive channel models, as it is the case of the TU and VA are used for evaluating the impact of the DPCCH burst on data transmission, it can be observed that the CPC performance deteriorates even if the data rate is reduced aiming at overcoming the adverse effects of this type of channels. However, it is also observed that the extent of the deterioration decreases as the transmission rate goes down.

B.1.2.2.3 Scenario C: 5Mbps transmission in a PA3 environment

By following the same idea of the scenario shown in Figure B.1.2.2.1-1, the Lean carrier proposal and CPC were evaluated by considering 10TTIs data transmission in every 160 TTIs with a DTX cycle of 20TTIs, and a DPCCH burst size equal to 1 subframe (i.e., an extreme CPC setting).

Two DPCCH ILPC methods, i.e. control target at DPCCH SINR and DPCCH SNR were considered. The simulation results are depicted in Figure B.1.2.2.3-1 and Figure B.1.2.2.3-2 assuming DPCCH target equals to -14dB.

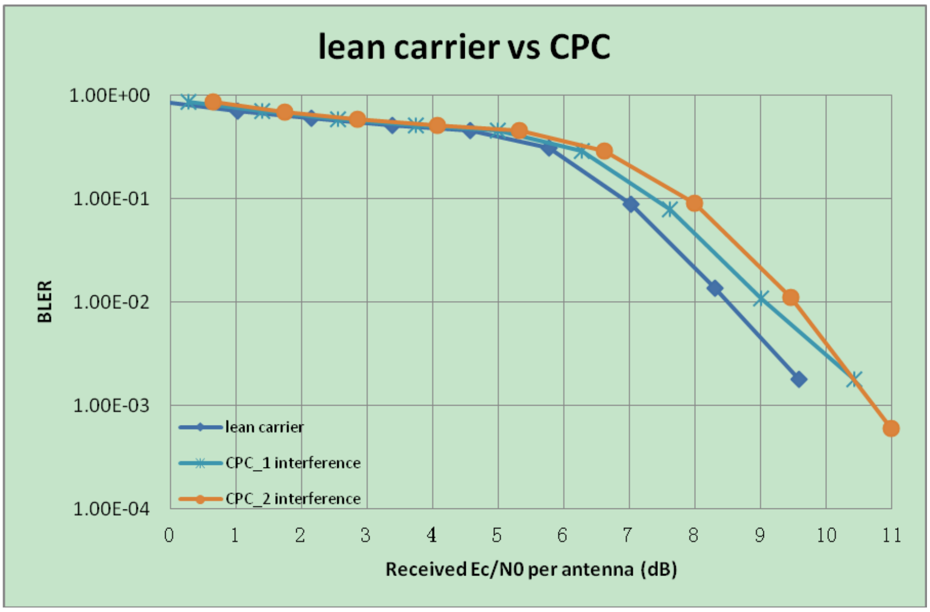


Figure B.1.2.2.3-1: Simulation Results of 1 and 2 Interferences (DPCCH SINR target -14dB)

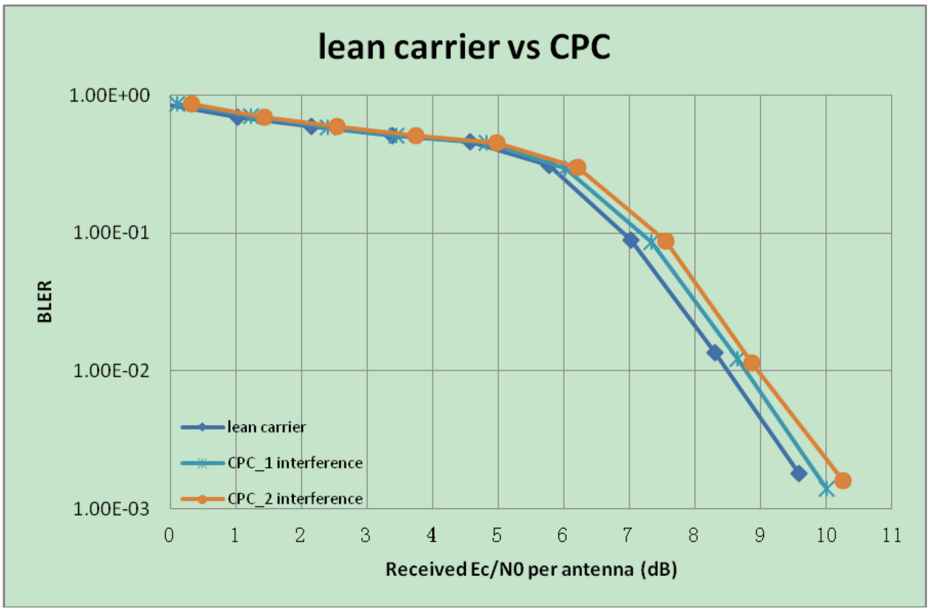


Figure B.1.2.2.3-2: Simulation Results of 1 and 2 Interferences (DPCCH SNR target -14dB)

In case of ILPC target of SINR used (Figure B.1.2.2.3-1), the impact of interference on DPCCH burst for other users results in about 1dB performance loss at maximum. In case of ILPC target of SNR used (Figure B.1.2.2.3-2), the impact of interference on DPCCH burst for other users is reduced to about 0.5dB performance loss at maximum.

The BLER results are provided in Figure B.1.2.2.3-3 and Figure B.1.2.2.3-4 assuming DPCCH target equals to -19dB.

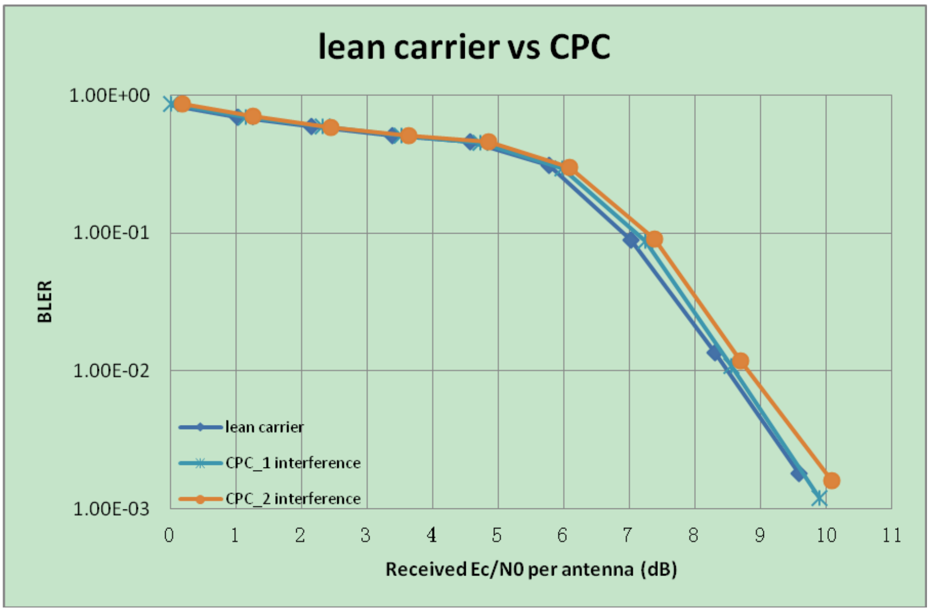


Figure B.1.2.2.3-3: Simulation Results of 1 and 2 Interferences (DPCCH SINR target, -19dB)

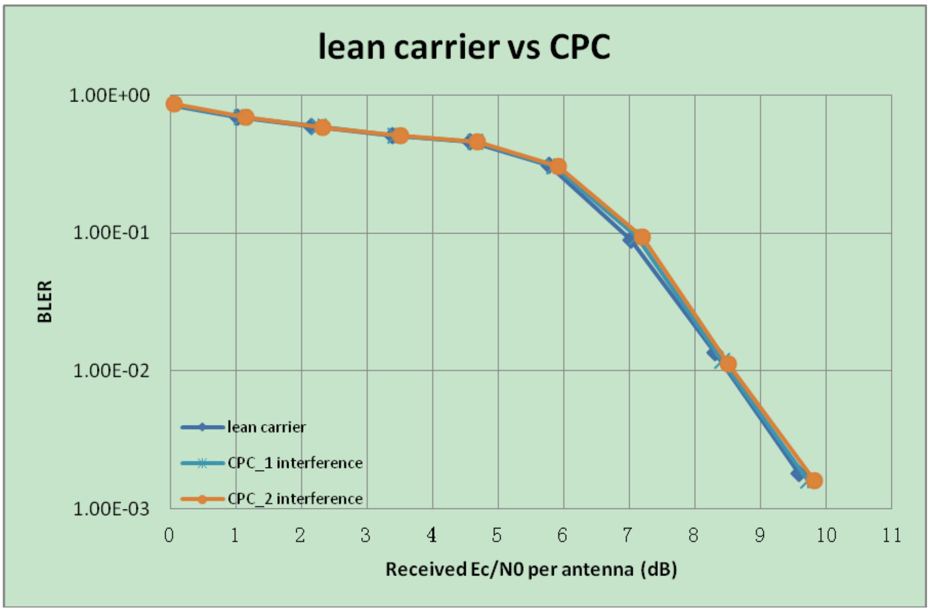


Figure B.1.2.2.3-4: Simulation Results of 1 and 2 Interferences (DPCCH SNR target -19dB)

It can be observed that the impact of DPCCH burst on data for other users is reduced to 0.4dB at maximum in case of ILPC target at DPCCH SINR and almost no impact in case of ILPC target at DPCCH SNR.

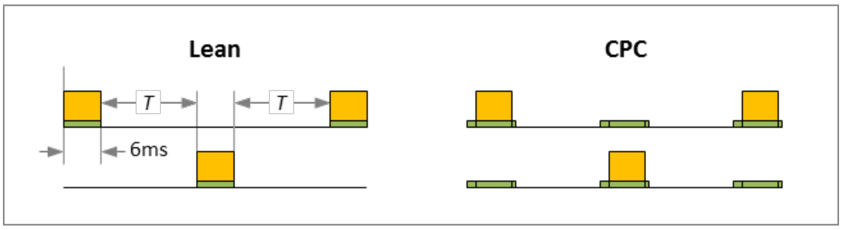
In conclusion, at 5Mbps, and for the PA3 channel model it is observed that the performance gain of Lean carrier is lower in case of DPCCH control target at SNR than in case of DPCCH SINR. The performance gain of Lean carrier will be further reduced, if we lower the DPCCH target value from -14dB to -19dB. It should be noted that there is no performance gain of Lean carrier in case of DPCCH SNR target equal to -19dB.

B.1.2.3 Impact of interference on DPCCH bursts

It has been noted in [19] that the large fluctuation in interference in a "clean" environment may make it difficult for the DPCCH bursts used in CPC to fulfill their role in tracking fast fading and providing the right power level at the starts of data transmissions. This clause presents simulations results concerning this issue.

B.1.2.3.1 Alternating data and DPCCH bursts

The scenario used in this clause is depicted in Figure B.1.2.3.1-1.



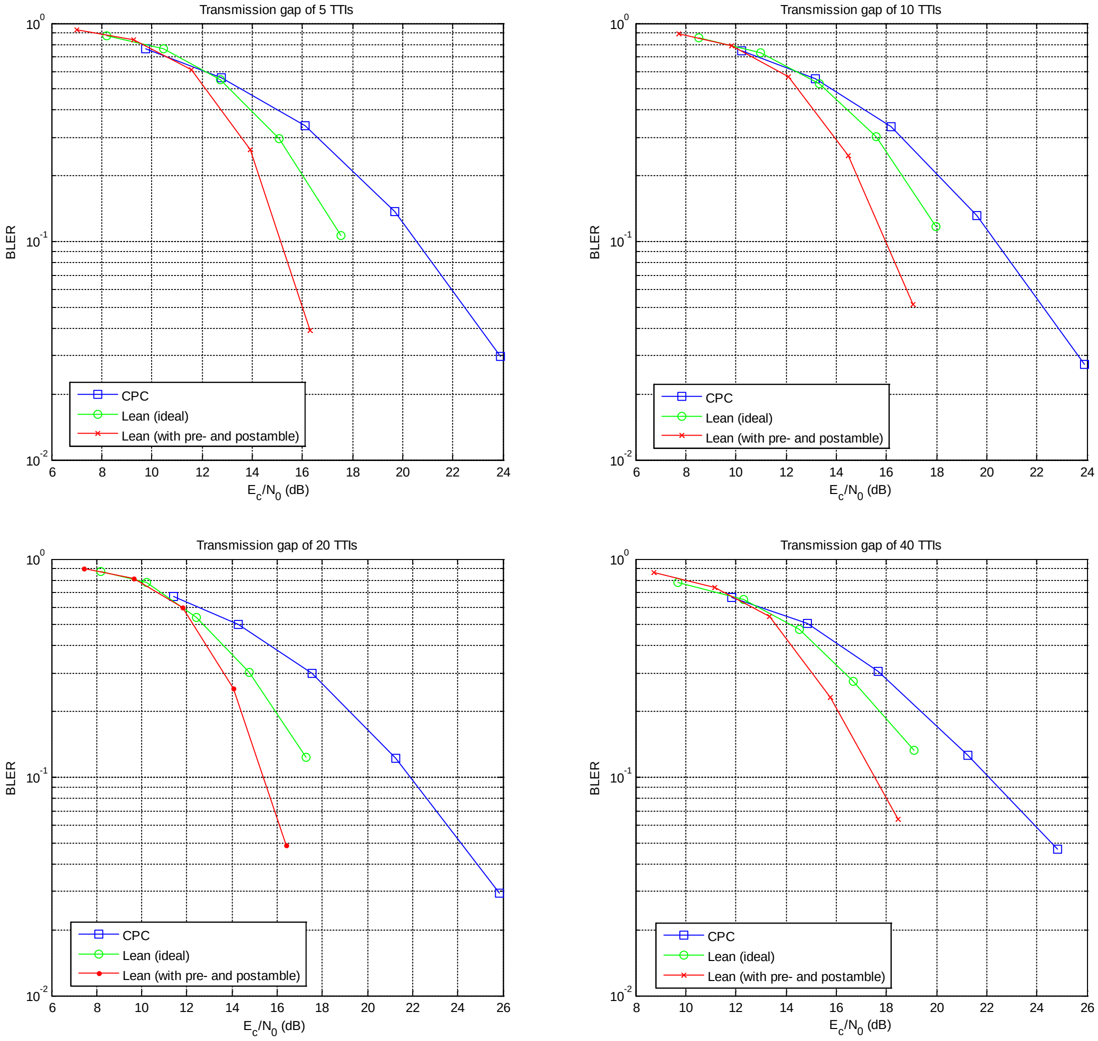
NOTE 1: Two users with identical transmission pattern but transmitting 180° out of phase were simulated. The pattern consists of alternating data and DPCCH bursts separated by a gap of length T. All cases have a 6ms data burst. The gap T is varied between 10 and 80 ms giving repetition periods of 32 to 172 ms (repetition period = 2(T+6ms)).

NOTE 2: The Lean case (representing both Lean0 and Lean+), the interfering data burst is shown for illustrative purpose only, it has no effect on the other user.

Figure B.1.2.3.1-1: Transmission pattern A for studying the impact of interference on DPCCH bursts

The result of the simulations is shown in Figure B.1.2.3.1-2. These simulations show the impact on link performance for closely spaced transmissions (up to 172 ms apart) with one DPCCH burst in between. The degradation due to the presence of the DPCCH burst is significant in all cases: a 2 to 4 dB increase in Ec/No at 10% BLER compared to the Lean0 case. The variation in the amount of degradation between the different cases seems to be related to correlation of the transmissions with the fast fading cycle.

Observation: Intervening DPCCH bursts have a significant impact on the performance of short and closely spaced data bursts.



NOTE: From left to right and top to bottom:
Results of BLER vs Ec/No for transmission gaps *T* = 10, 20, 40, and 80 ms.
The time between the starts of two data bursts by the same UE are 32, 52, 92, and 172 ms.

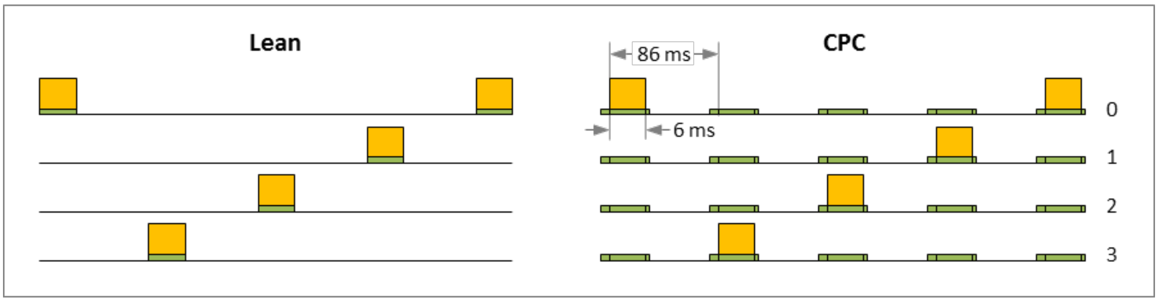
Figure B.1.2.3.1-2: Impact of interference on DPCCH bursts case 1: Alternating data and DPCCH bursts for 10 Mbps data transmissions (pattern A)

B.1.2.3.2 Multiple DPCCH bursts between data transmissions

Another property of smart-phone traffic is the unpredictable nature of when the next activity burst will come. As a result, there may be none or many intervening DPCCH bursts between two data transmissions. Figure B.1.2.3.2-1 shows the transmission pattern for the case where there are 3 intervening DPCCH bursts.

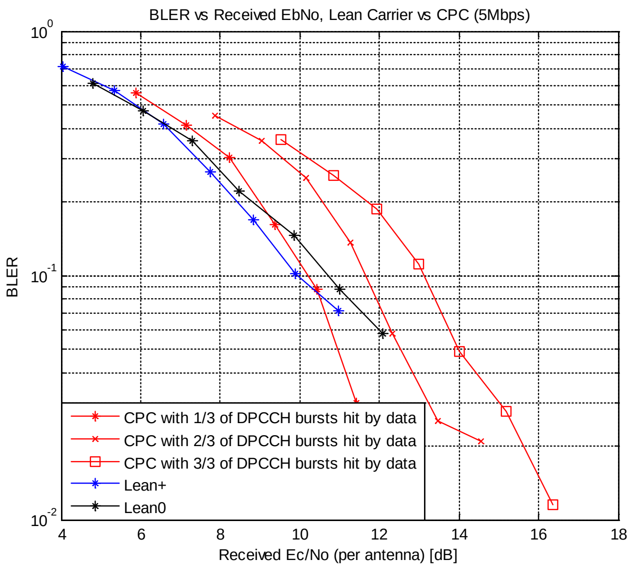
Figure B.1.2.3.2-2 shows the performance impact when one or more of the DPCCH bursts of one user are interfered by data transmissions from other users. A clear trend of performance degradation can be seen as more and more of the DPCCH bursts are interfered with.

Observation: The performance degradation due to DPCCH burst being interfered by data transmissions has a cumulative effect. The more the number of DPCCH bursts being interfered with the larger is the impact on the efficiency of the subsequent transmissions.



NOTE: For each CPC user, a DPCCH burst of 6ms is transmitted every 86 ms and a 6ms data burst is transmitted every 4 DPCCH burst (344 ms).
One, two, or all three of the standalone DPCCH bursts may be interfered by data transmissions.
The simulated CPC scenarios are: 0+1, 0+1+2, and 0+1+2+3.
Users 1, 2, and 3 for the Lean case are included for illustrative purpose only.
They do not interfere with user 0 or with each other.

Figure B.1.2.3.2-1: Transmission pattern B for studying the impact of interference on DPCCH bursts



NOTE: The different curves show the case where 1, 2, and 3 of the 3 DPCCH bursts are interfered by data transmissions and the comparison with the Lean carrier cases.

Figure B.1.2.3.2-2: Impact of interference on DPCCH bursts case 2: Alternating 1 data and 3 DPCCH bursts for 5 Mbps data transmissions.

In order to know the implications of dealing with some other channel models for this type of scenarios, the TU3 and VA30 channels were studied as well. So, by following the same idea, the scenario depicted in Figure B.1.2.3.2-1, was firstly evaluated for the TU3 channel model, which results are shown in Figure B.1.2.3.2-3.

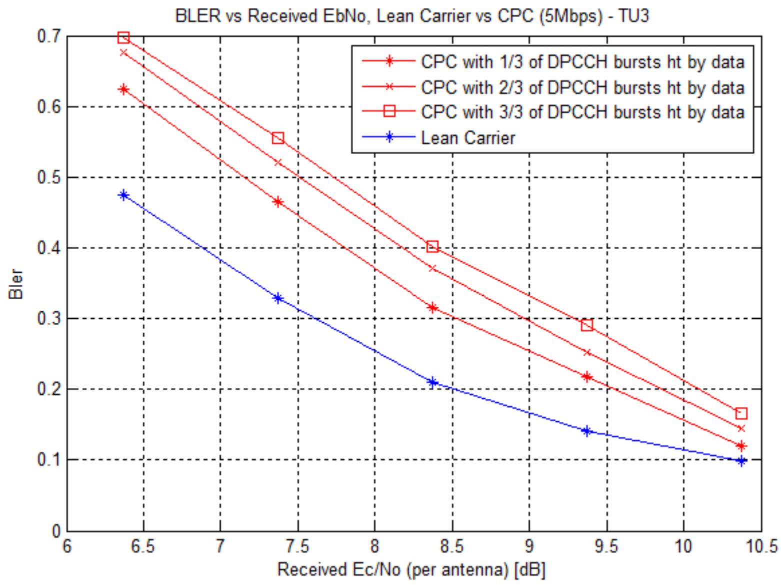


Figure B.1.2.3.2-3: Impact of interference on DPCCH bursts case 2 for the TU3 channel model: Alternating 1 data and 3 DPCCH bursts for 5Mbps data transmissions.

By performing an inspection of the curve shown above, it can be noticed that the performance of a CPC user is degraded by the interference undergone by the DPCCH bursts. Moreover, cumulative effect takes place as more DPCCH bursts get hit by data of other users.

Continuing with the analysis, the same scenario was evaluated for the VA30 channel, with its results shown in Figure B.1.2.3.2-4.

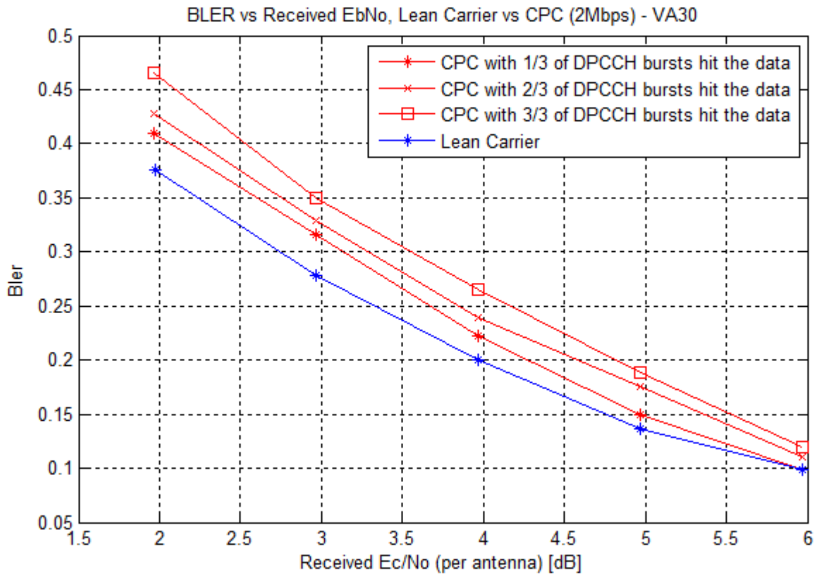


Figure B.1.2.3.2-4: Impact of interference on DPCCH bursts case 2 for the VA30 channel model: Alternating 1 data and 3 DPCCH bursts for 2Mbps data transmissions.

When the same scenario is evaluated under the VA30 channel conditions, in general the performance for Lean Carrier and CPC with 1/3 of the DPCCH bursts hit by data at the10% BLER operating point is quite similar (To remember that VA30 was evaluated at 2Mbps aiming at being consistent with what is described at the end of the subclause B.1.2.4.1; where it is stated that the data rate was decreased aiming at overcoming the adverse effects of this channel), however a bias in the performance starts to become distinguishable when 2/3 and 3/3 of the DPCCH bursts are hit by data.

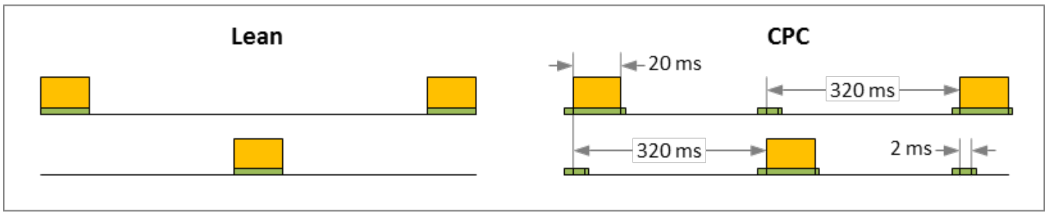
In conclusion, the cumulative effect observed for the PA3 channel also prevails for the TU3 and VA30 channels. The performance of CPC gradually gets biased as more DPCCH bursts are hit by data, highlighting that although it was less evident for VA30 since it was evaluated at 2Mbps, the cumulative effect also occurred.

B.1.2.4 Extreme CPC settings

One proposal to reduce the impact from the DPCCH bursts is to reduce the average DPCCH load due to unscheduled users. The DPCCH load can be reduced by reducing the burst size and increasing the DTX cycle. This clause looks at the performance of some scenarios with extreme CPC settings, in particular, those with the longest DTX cycle (320 ms) and the smallest DPCCH burst (1 subframe + preambles and post-ambles) currently allowed by 3GPP.

B.1.2.4.1 Alternating data and DPCCH bursts with 20ms data bursts

The transmission pattern for this case is shown in Figure B.1.2.4.1-1. It has the extreme CPC setting mentioned above and a 20ms data burst.



NOTE: The Lean case (representing both Lean0 and Lean+) are also shown for comparison.

Figure B.1.2.4.1-1: Transmission pattern for extreme CPC setting with alternating 20ms data and 2ms DPCCH bursts.

The simulation result is shown in Figure B.1.2.4.1-2 below. The performance of CPC and the Lean cases are rather close. This result is not entirely unexpected.

Normally, the use of a very small DPCCH burst and a very long DTX gap could easily lead to power control instability due to the inability to track fast fading. When factoring in a typical 2− 3 slot TPC delay, the problem becomes even worse. In the current scenario, however, the large 30-slot data burst is able to correct any power control error. Had it not been the alternating arrangement of the data and DPCCH bursts, the power control error would have accumulated over time and led to instability. We will see some indication of this in the results that follow.

Note also that a 20ms burst at 5 Mbps will deliver 12.5 kB of data. This is a rather large packet compared to many examples of delay-sensitive traffic such as HTTP request and SIP signaling.

In conclusion, for the specific scenario of an extreme CPC setting with a constant supply of 10-TTI data bursts every other DPCCH burst, the performance of CPC and the Lean carrier case are quite similar.

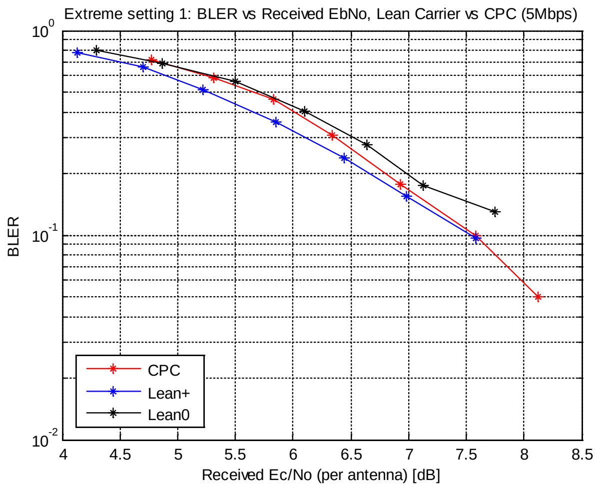


Figure B.1.2.4.1-2: Impact of interference on DPCCH bursts for extreme CPC setting, case 1: Alternating data and DPCCH bursts at 5Mbps transmissions.

The transmission pattern for the extreme CPC setting was also evaluated for the TU3 and VA30 channel models as it is shown in Figure B.1.2.4.1-3 and Figure B.1.2.4.1-4 respectively

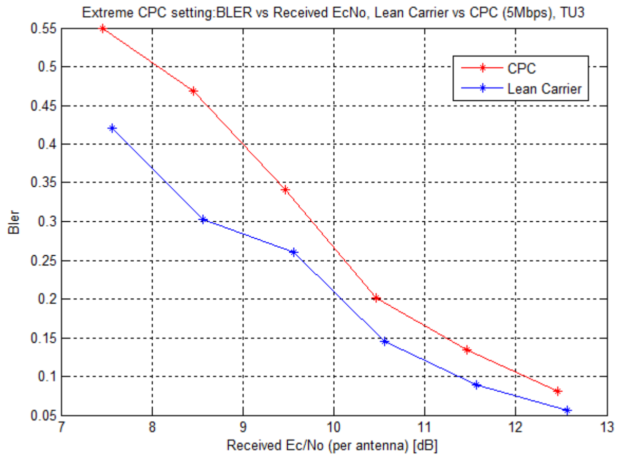


Figure B.1.2.4.1-3: Impact of interference on DPCCH bursts for extreme CPC setting under the TU3 channel model: Alternating data and DPCCH bursts at 5Mbps transmissions.

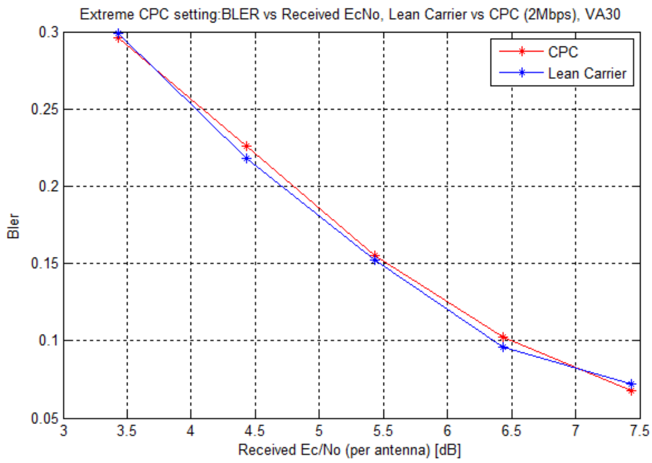
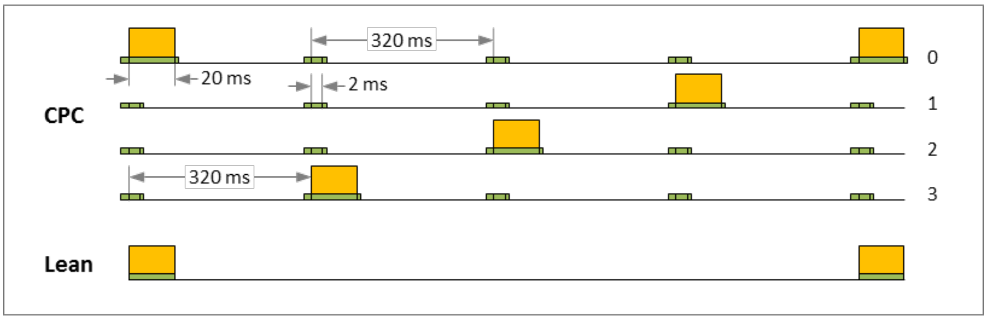


Figure B.1.2.4.1-4: Impact of interference on DPCCH bursts for extreme CPC setting under the VA30 channel model: Alternating data and DPCCH bursts at 5Mbps transmissions.

In conclusion, when there is a multipath diversity gain given by more dispersive channels than the PA3 channel model, it is observable that the specific scenario of considering an extreme CPC setting gets degraded for a CPC user around 0.5dB compared to Lean carrier when the TU3 channel is in use, and that when the VA30 channel model enters into consideration then the Lean carrier case and CPC perform quite similar. However, as it was highlighted in [17], the fact of having a 10-TTI data burst doesn't fit the behaviour of a smart phone traffic which is characterized by having only a couple of data bursts every time a user transmits, and which according to [17] deteriorates the performance of the so called extreme CPC setting.

B.1.2.4.2 Multiple DPCCH bursts between 20ms data bursts

To further study the case with extreme CPC setting, the previous scenario is extended with 3 standalone DPCCH bursts between transmissions. Details of the transmission patterns are given in Figure B.1.2.4.2-1. The resulting performance is shown in Figure B.1.2.4.2-2.

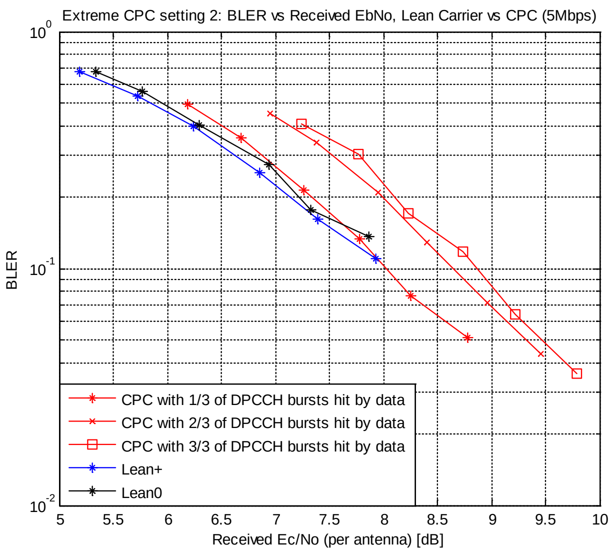


NOTE: One, two, or all three of the DPCCH bursts may be interfered by data transmissions, i.e., the simulated scenarios are: 0+1, 0+1+2, and 0+1+2+3.
The Lean case (representing both Lean0 and Lean+) are also shown for comparison.

Figure B.1.2.4.2-1. Transmission pattern for extreme CPC setting with three 2ms DPCCH bursts between two data transmissions

Similar to the less extreme case shown in clause B.1.2.4.1, the performance of CPC can be seen to deteriorate when more and more of the DPCCH bursts are interfered with. The performance when only one out of 3 of the DPCCH bursts are hit is close to those of the Lean carrier cases, but when two or more of the bursts are hit, the performance is significantly worse.

In conclusion, despite the use of the smallest DPCCH burst of 2ms and a rather long data burst of 20ms, the trend that the performance deteriorates when more and more of the DPCCH bursts are interfered by data transmissions remains.



NOTE: The different CPC curves show the case when 1, 2, and 3 of the 3 DPCCH bursts are interfered by data transmissions.
Comparison with the Lean carrier cases is also shown.

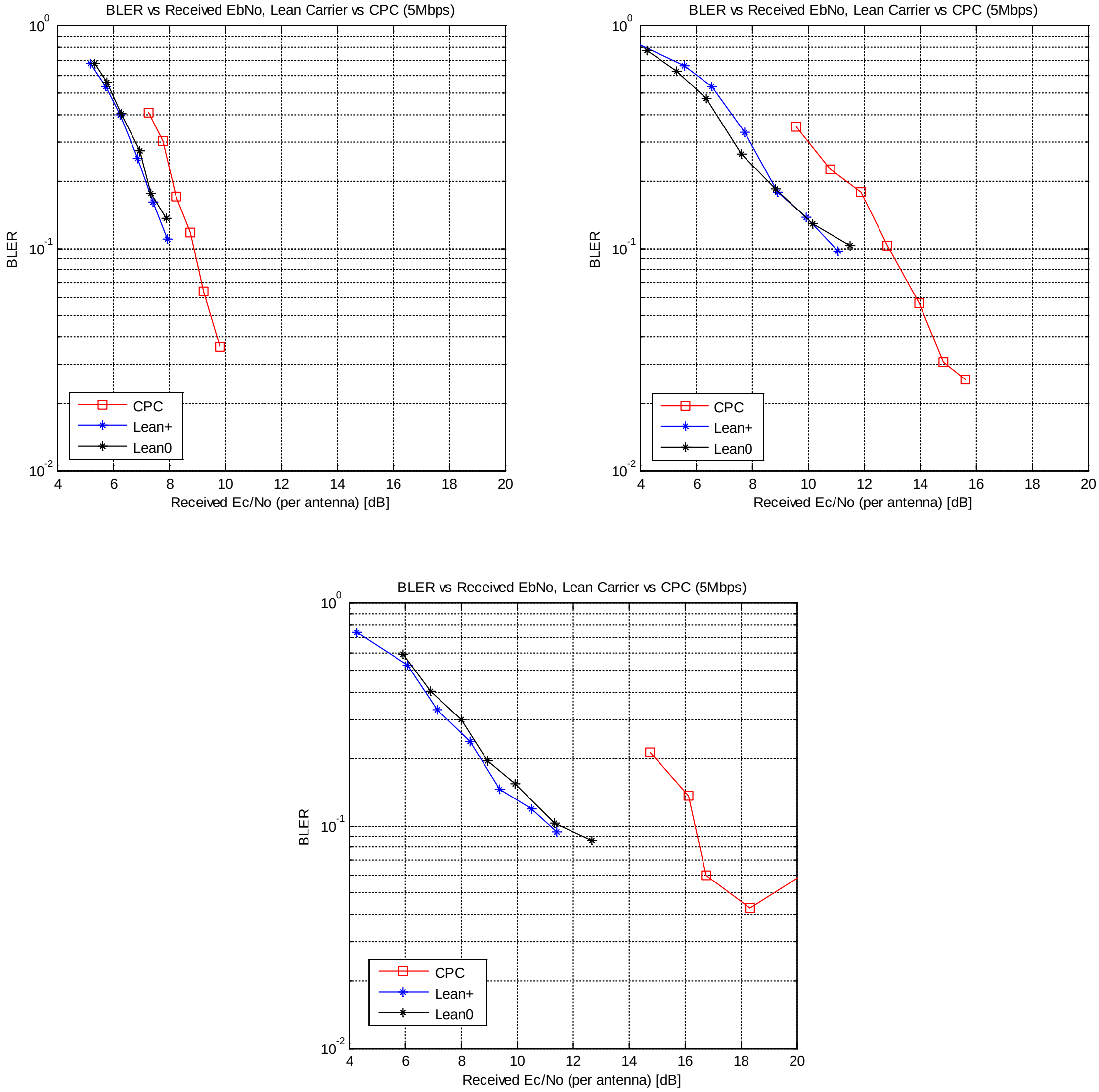
Figure B.1.2.4.2-2. Impact of interference on DPCCH bursts for the extreme CPC setting, case 2: Alternating 1 data and 3 DPCCH burst at 5 Mbps transmissions.

B.1.2.4.3 Different data-burst lengths

The length of the data burst is varied in order to understand the impact it has on the overall performance, data-burst lengths of 6, 10, and 20 ms have been investigated. The transmission pattern is identical to the one given in Figure B.1.2.4.2-1, where all 3 DPCCH are hit by interference, except for the length of the data bursts which take on the above values for both the CPC and Lean carrier cases. The resulting performance is given in Figure B.1.2.4.3-1.

As the length of the data burst decreases, the performance with extreme CPC setting can be seen to deteriorate much more quickly than that of the Lean carrier cases. The CPC case with a 6ms (3 TTI) data bursts seems to be close to becoming unstable.

In conclusions, the extreme CPC setting has quite poor performance for data bursts shorter than 20 ms when compared to the Lean carrier cases. This shows that the extreme CPC setting will have trouble supporting smaller data bursts typical of delay-sensitive traffic such as HTTP requests or SIP signaling.



Note: From left to right and top to bottom: Data burst length = 20, 10, and 6 ms

Figure B.1.2.4.3-1: Performance of different data burst length for max DTX cycle and min burst length scenario..

B.1.3 System level simulation results for Lean carrier

B.1.3.1 Full-buffer users with a fixed transmission pattern

The results described in this clause use a network of 9 cells. Full-buffer users are used and each user has a periodic data transmission pattern with 4 TTI of data followed by a gap of 80 TTI. The transmission start for each user is offset from the previous by 4 TTI so that there is no gap between the transmissions and at most one user transmitting at any one time. Retransmissions are given absolute priority over new data transmissions. This means a retransmission would always steal the transmission slot for the users that follow.

This arrangement allows a maximum of 21 users to transmit in a cell. When there are more than 21 users in a cell, irrespective of whether that is due to a higher amount of offered traffic or normal traffic fluctuations, the extra users are not scheduled. As with link system simulations, three scenarios, Lean0, Lean+, and CPC, are distinguished. In the CPC case, a DPCCH burst of 2 TTI is transmitted in the gap between two data transmissions. This is illustrated in Figure B.1.3.1-1 below.

Outer-loop power control is used to control the HARQ BLER at a 10% level for both Lean carrier and CPC users. Simulations are performed for both the Ped A 3 km/h and TU 3 km/h channel models. The results are given in separate clauses below.

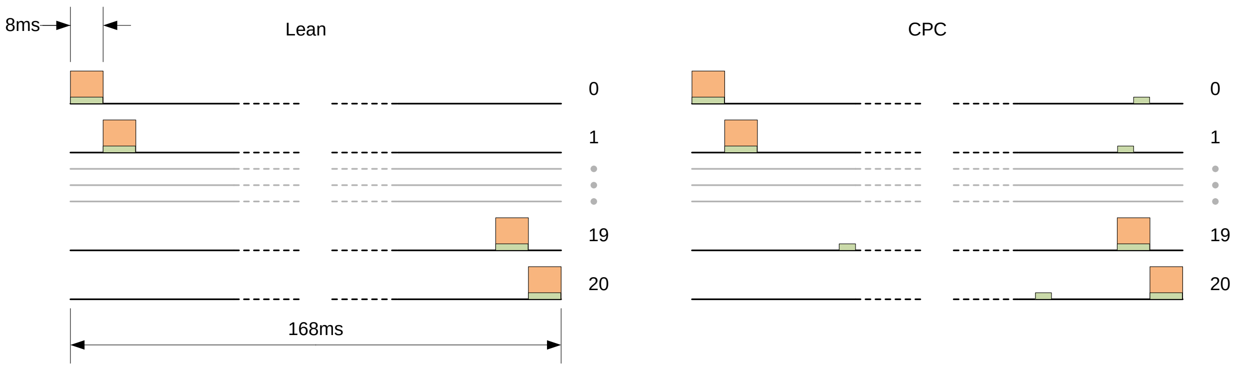


Figure B.1.3.1-1: Transmission pattern used by full-buffer users

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B.1.3.1.1 TU3 simulation results

Simulations were performed for the Lean0 and CPC case with the TU3 channel. The results are shown in Figure B.1.3.1.1-1.

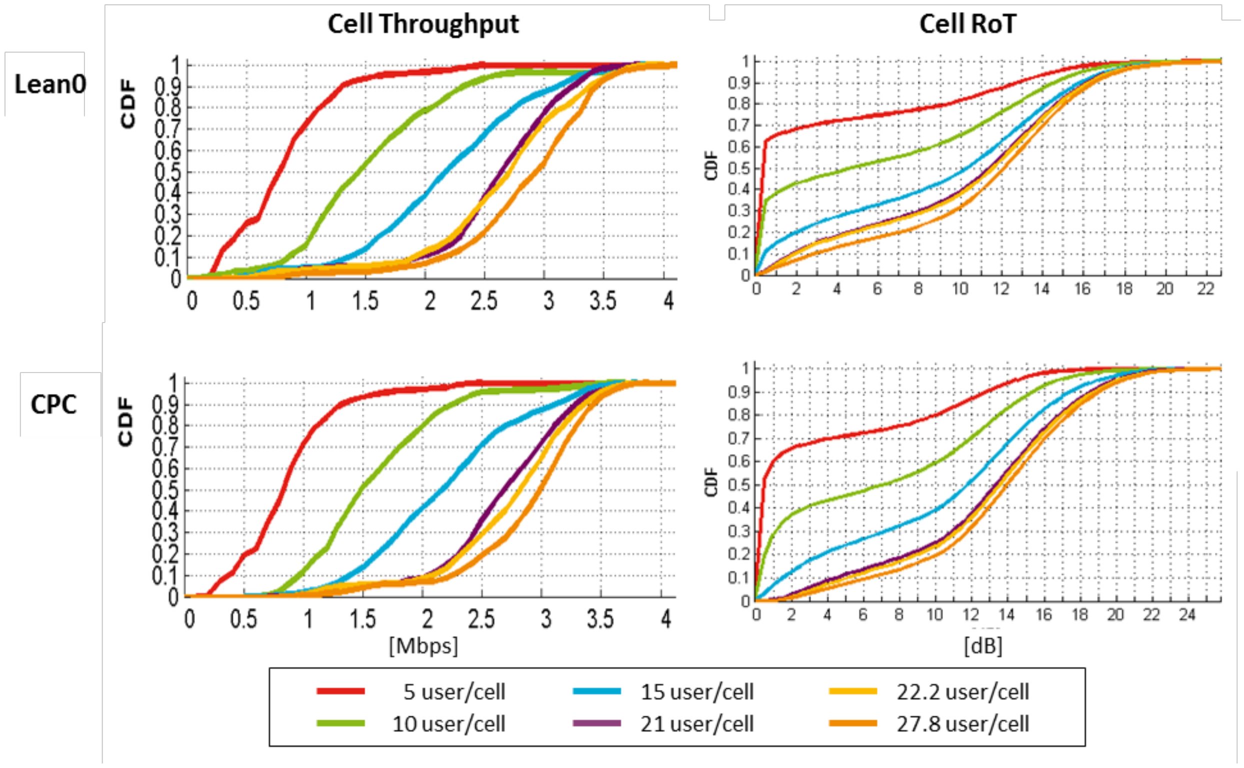


Figure B.1.3.1.1-1: Simulation results for fixed transmission pattern with the TU3 channel

The average cell throughputs between the Lean and CPC cases are very similar. This is expected since there is the same amount of offered traffic in each case and the HARQ BLER is control at 10% for all users. The difference between the two cases is in the average interference in the cells. Starting at 10 user/cell, the Lean0 case can be seen to have roughly a 2dB lower RoT than the CPC case at the 50 percentile.

B.1.3.1.2 PA3 simulation results

For the PA3 channel, an extra case with Lean+ was added. The results are shown in Figure B.1.3.1.2-1. As before, the uplink cell throughputs for the three cases are very similar. A similar trend for the average RoT as in the TU3 case is observed a gain of 1 to 2 dB for the Lean cases over the CPC case.

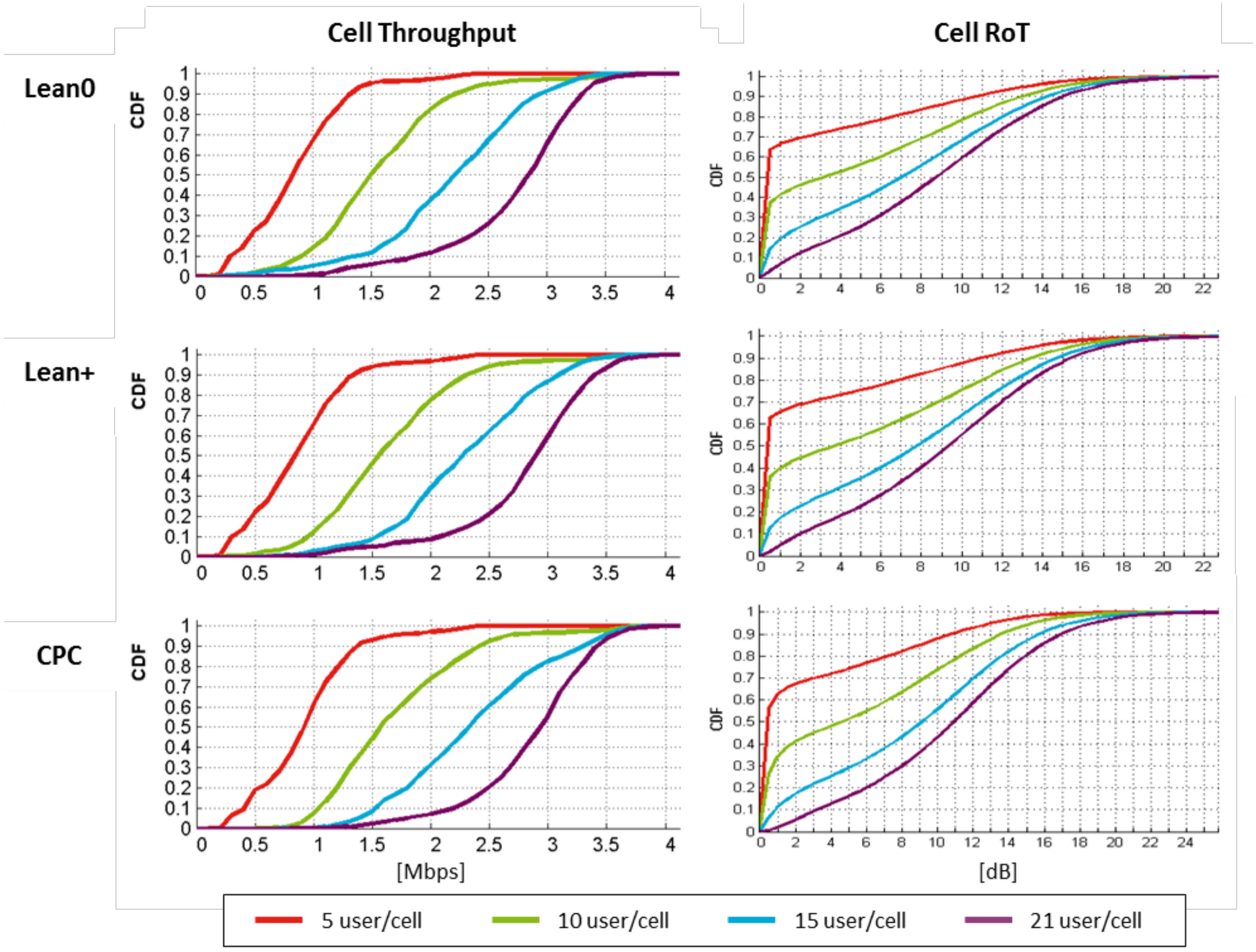


Figure B.1.2.1.3-1: Simulation results for fixed transmission pattern with the PA3 channel

B.1.3.1.3 Summary for the fixed transmission pattern scenario

Average cell throughput and average RoT has been studied for the 3 scenarios of Lean0, Lean+ and CPC using a fixed transmission pattern and different numbers of full-buffer users per cell. Due to the fixed offered load in each scenario and the same HARQ BLER target, very similar cell throughputs are seen in all case. The main difference lies in the average RoT, with the Lean0 and Lean+ cases having a gain of 1 to 2 dB over the CPC case in medium to high load scenarios.

B.1.3.2 Dynamic traffic with round-robin scheduling

This clause describes simulation results performed using dynamic traffic and a round robin scheduling. The traffic is given by a truncated lognormal distribution for file sizes (125 ± 45 kB) and an exponential distribution for reading times (5s average), as they are specified in the system simulation assumption clause above.

For the round-robin scheduling, each user is given transmission priority for a fixed number of TTIs. If the user runs out of data to send or if the number of prioritized TTIs is reached, the transmission priority goes immediately to the next user. As in the fixed pattern case, retransmissions have absolute priority over new transmissions and a user can lose some of their transmission slots due to retransmissions from previously transmitted users.

Simulations are performed with the PA3 channel for the Lean+ case and two CPC cases with different settings:

(DPCCH burst size) / (DTX cycle length) = 4ms / 160ms and 2ms / 320ms,

where the same cycle length is used for both cycle 1 and cycle 2, and the preambles and post-amble are not included in the burst sizes. The results are given in Figure B.1.3.2-1.

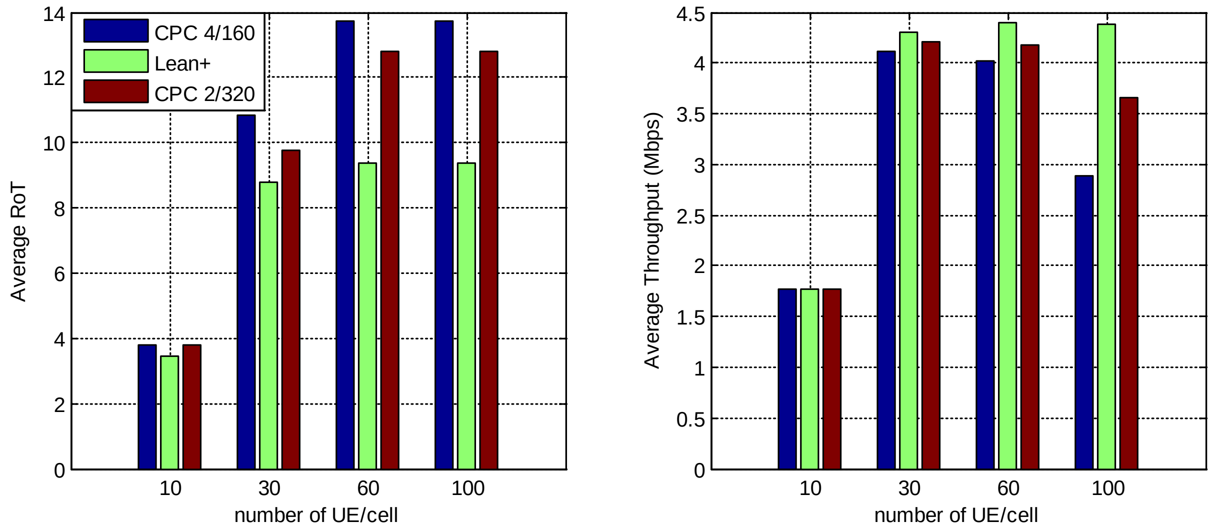


Figure B.1.3.2-1: Comparison of average RoT (left) and average cell throughput (right) between Lean and two CPC cases with different burst sizes (4ms, 2ms) and DTX cycle lengths (160ms, 320ms).

These results show that with dynamic traffic, the difference in average RoT between Lean carrier and the CPC cases are more pronounced than with a fixed transmission pattern. At a full load of 100 user/cell, a 4dB lower RoT can be achieved even when compared to the most extreme CPC case with the shortest possible burst size and the longest possible cycle length. Improvement in average cell throughput is also seen.

In the case of CPC, the variations observed in the cell throughput and RoT are connected to the fact that an increased amount of DPCCH bursts in the system leads to power control inaccuracies due to collisions of DPCCH bursts with data and vice versa. This in turn results in more HARQ retransmissions for the CPC case in comparison to the Lean carrier proposal. The simulation was conducted without RoT control, and the active user was always scheduled with 5 Mbps instantaneous data rate. Considering the traffic model used, the system reaches 100% TTI utilization at around 25 users with user data rates close to 160 kbps on average, and with 100 users the UE throughout is 40 kbps on average.

B.2 Overhead channel reduction

B.2.1 E-DPCCH reduction simulation results

B.2.1.1 2 UEs per cell

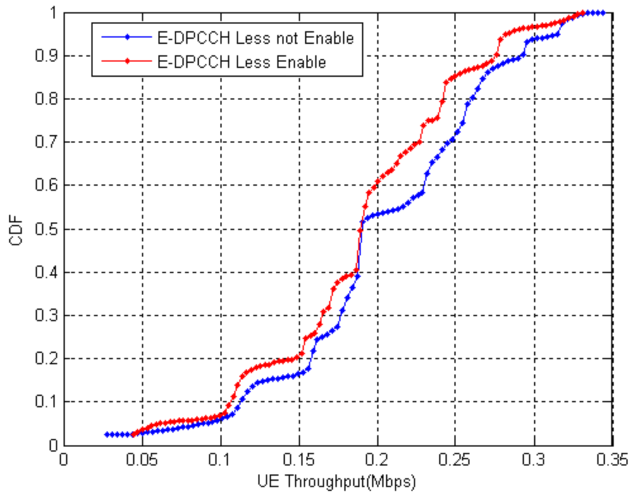


Figure B.2.1.1-1: UE Throughput CDF

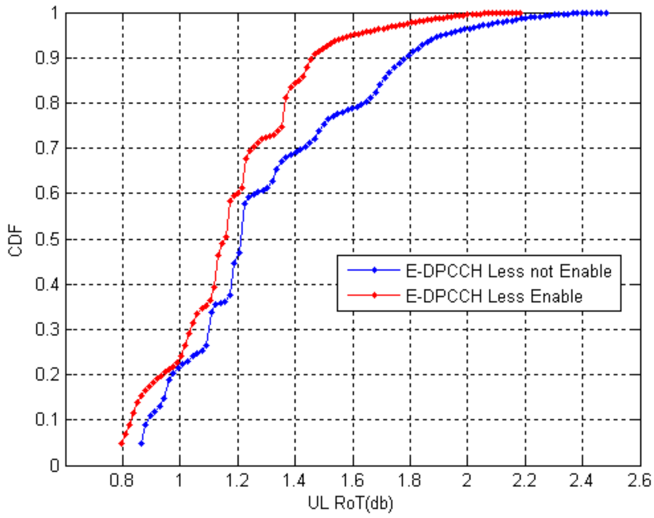


Figure B.2.1.1-2: RoT CDF

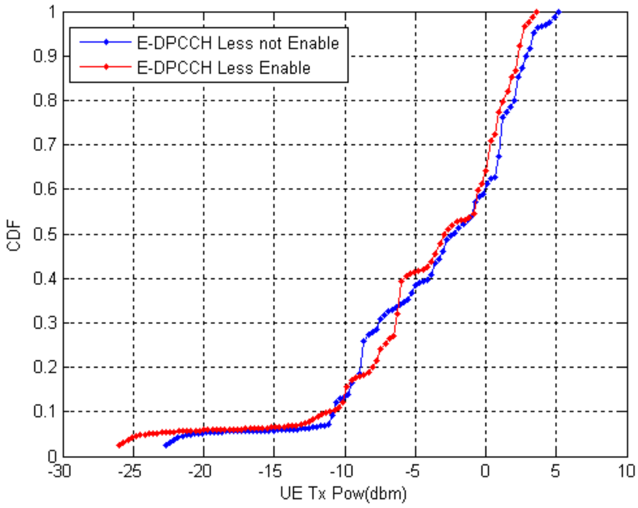


Figure B.2.1.1-3: UE Tx Power CDF

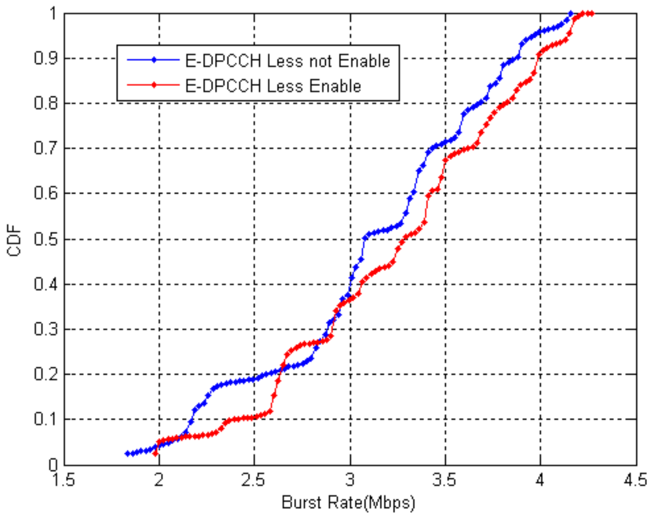


Figure B.2.1.1-4: Burst Rate（Mbps）

B.2.1.2 6 UEs per cell

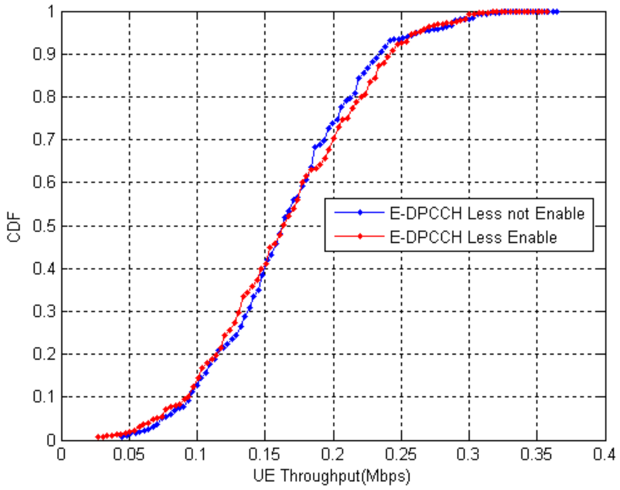


Figure B.2.1.2-1: UE Throughput CDF

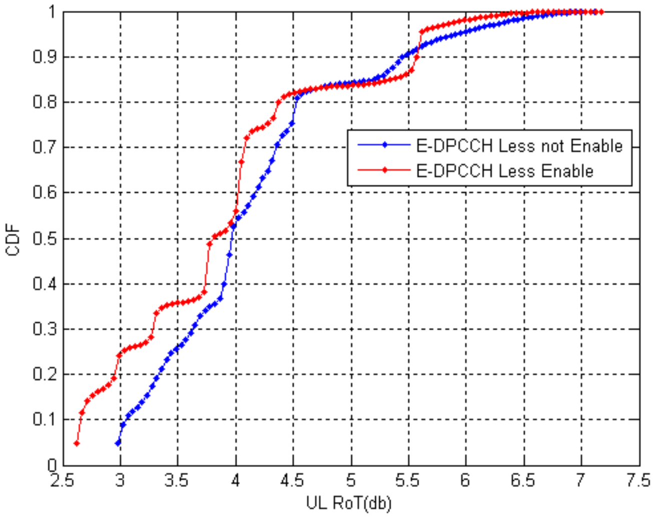


Figure B.2.1.2-2: RoT CDF

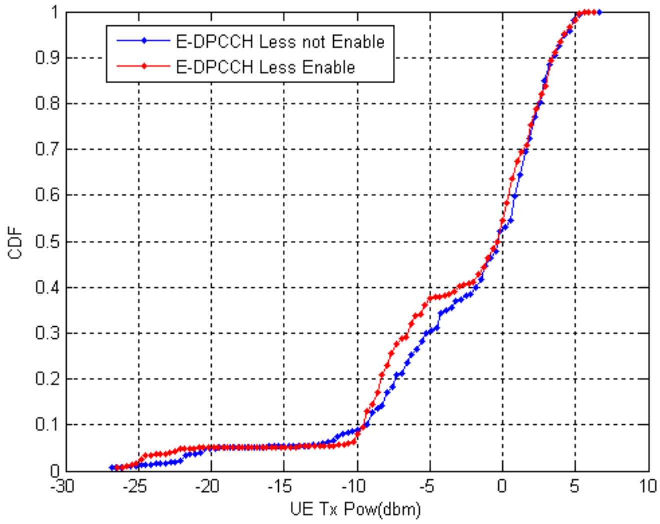


Figure B.2.1.2-3: UE Tx Power CDF

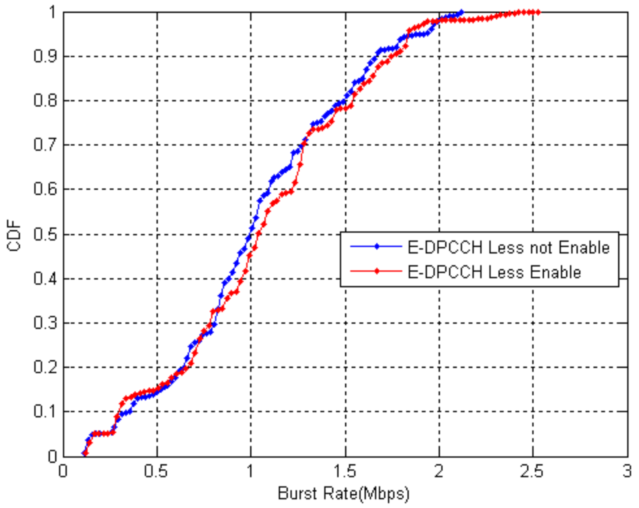


Figure B.2.1.2-4: Burst Rate（Mbps）

B.2.1.3 10 UEs per cell

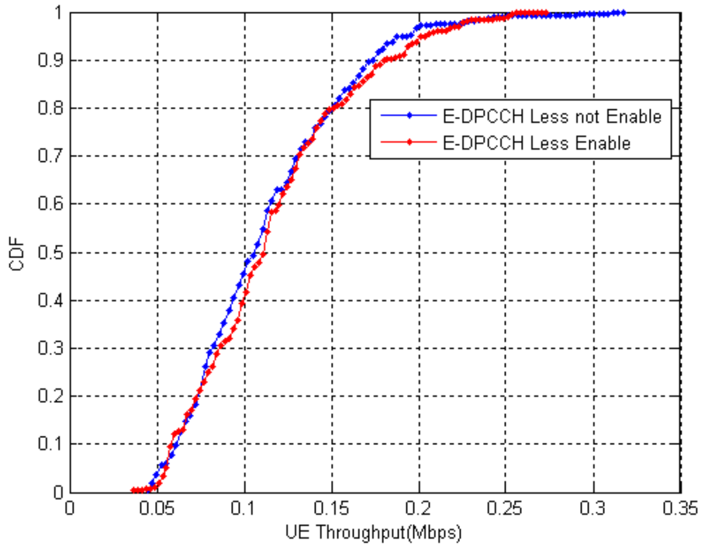


Figure B.2.1.3-1: UE Throughput CDF

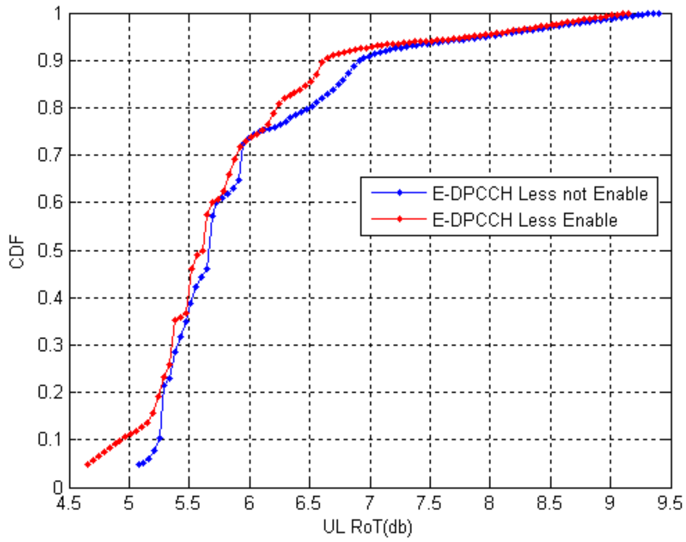


Figure B.2.1.3-2: RoT CDF

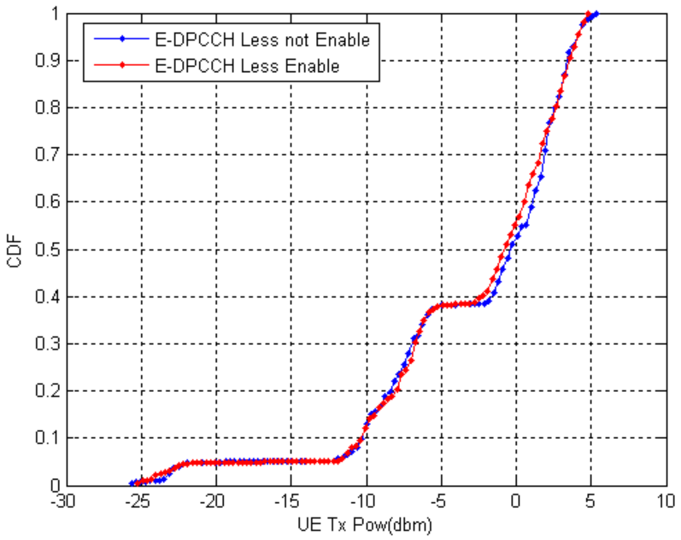


Figure B.2.1.3-3: UE Tx Power CDF

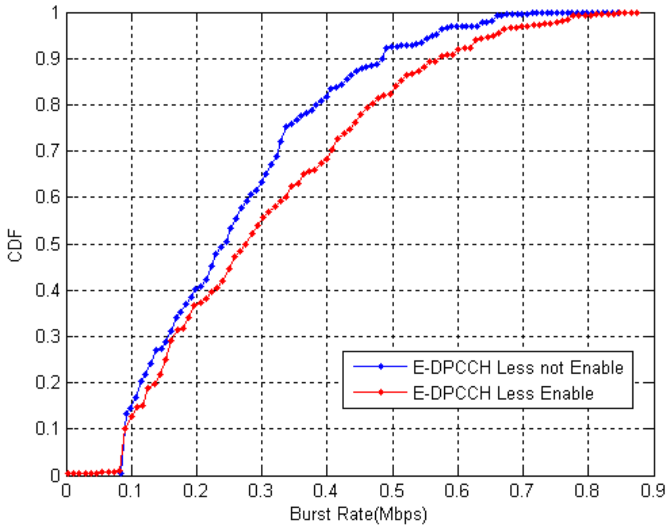


Figure B.2.1.3-4: Burst Rate（Mbps）

B.3 Rate adaptation

B.3.1 Link simulation results for Rate adaptation

B.3.1.1 Simulation set 1

B.3.1.1.1 Additional assumptions

The results are simulated for realistic channel estimation, power control measurements, finger placement and E-DPCCH decoding in order to more fairly account for the DPCCH reception reliability impact on the system performance as well as the DPCCH overhead.

Additional simulations have been completed to optimize the DPCCH settings for each of the scheduling schemes. The parameters being optimized and the results obtained for each of the schemes are as follows:

1 For the power-based scheduling and the modified 2-loop approach, the parameter being optimized is the target pre-receiver DPCCH SIR used for the E-DPDCH gain factors design. According to the simulations the value of -16 dB is taken.

2 For the 2-loop scheme, the DPCCH pre-receiver RX Ec/No is optimized and the selected value is -12 dB.

3 For the 3-loop scheme, the DPCCH target post-receiver SIR controlled by the third loop is the optimization parameter. The value of 10 dB is taken.

It should be noted that DPCCH level over thermal noise is constant in the 2-loop approach and was optimized for Rx Ec/No target equals to 20dB. Motivation behind that was to achieve reliable DPCCH reception in all scenarios.

B.3.1.1.2 Throughput vs. RX Ec/No

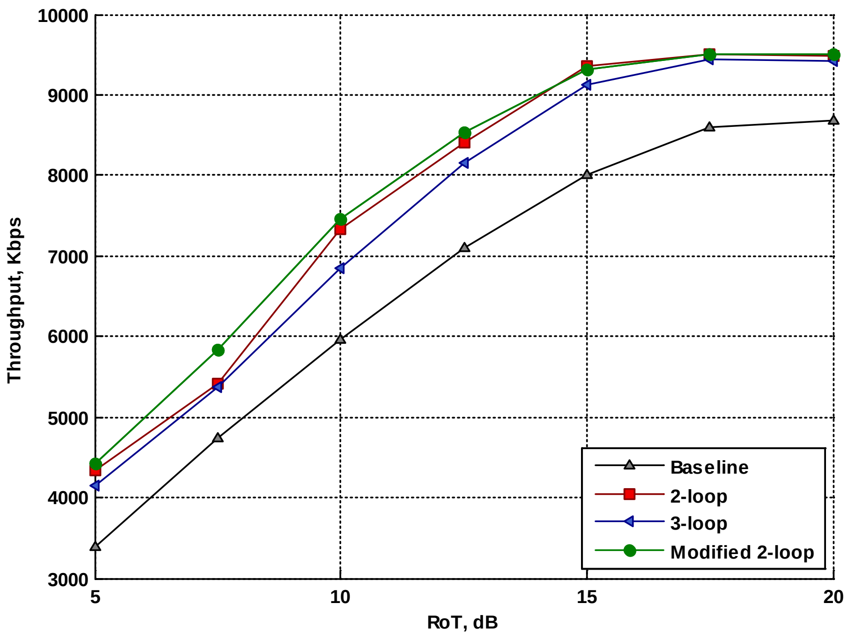


Figure B.3.1.1.2-1. Average throughput as a function of the average RX Ec/No for different scheduler options for the Ped A, 3 km/h channel model

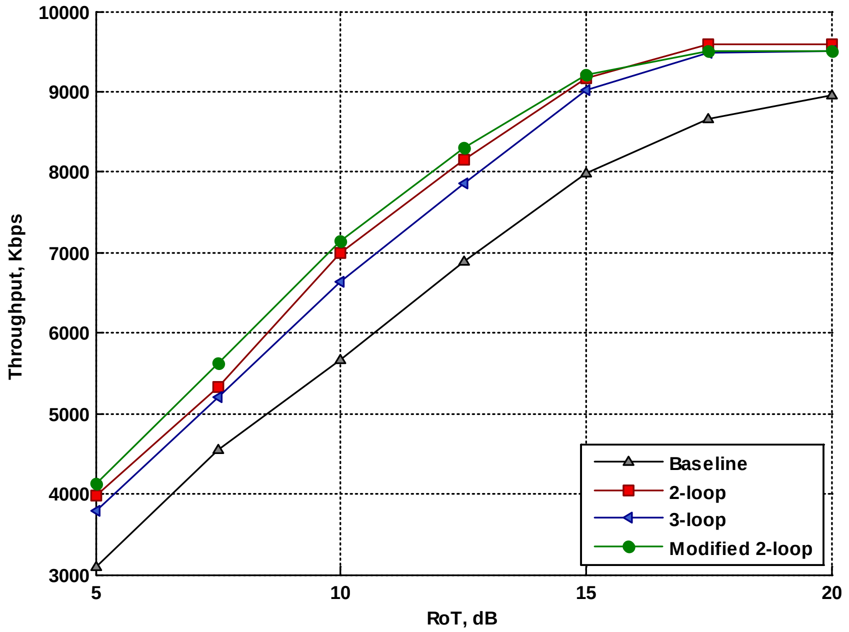


Figure B.3.1.1.2-2. Average throughput as a function of the average RX Ec/No for different scheduler options for the Veh A, 3 km/h channel model

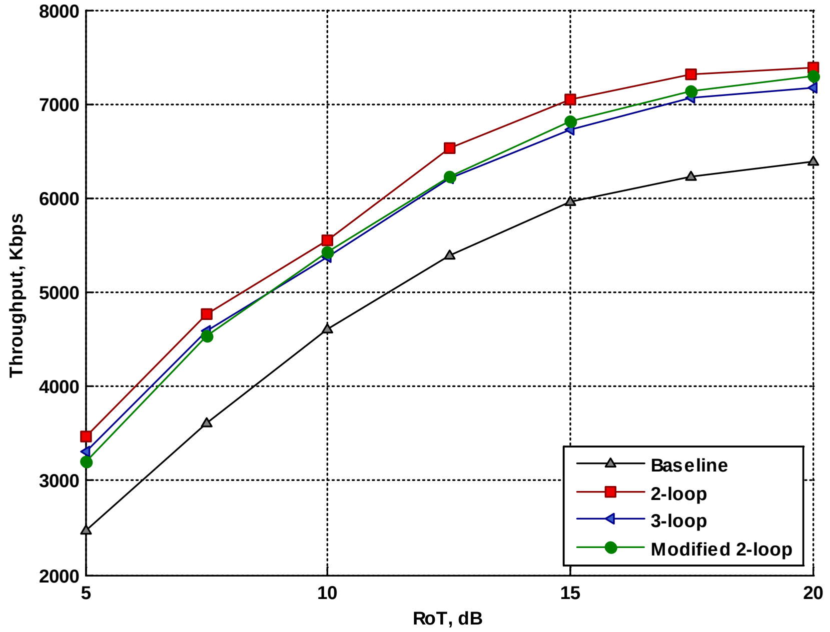
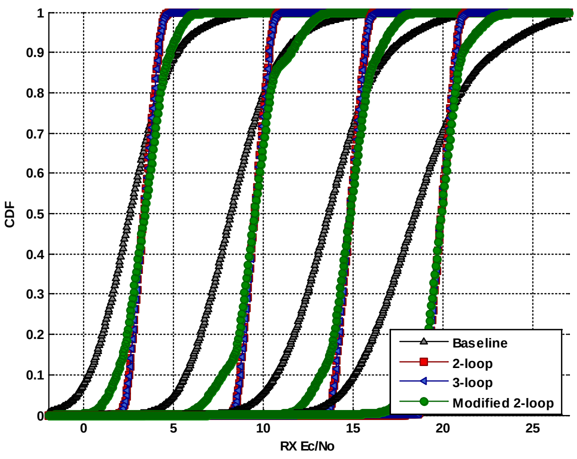


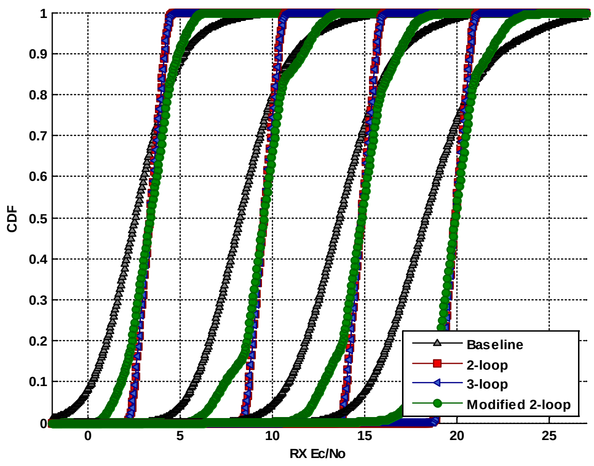
Figure B.3.1.1.2-3. Average throughput as a function of the average RX Ec/No for different scheduler options for the Veh A, 30 km/h channel model

It can be seen that according to the presented link-level simulation results the modified 2-loop approach provides equivalent and even slightly better performance than other evaluated schemes except for the Veh A, 30 km/h channel where the 2-loop scheme demonstrates a small gain over the modified 2-loop approach. The gains of the SINR-based scheduling options relative to the power-based scheduling are up to 10-13%.

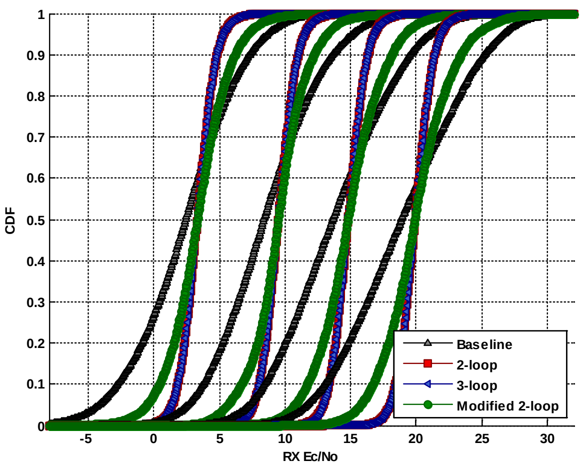
B.3.1.1.3 RX Ec/No Distributions



(a)



(b)



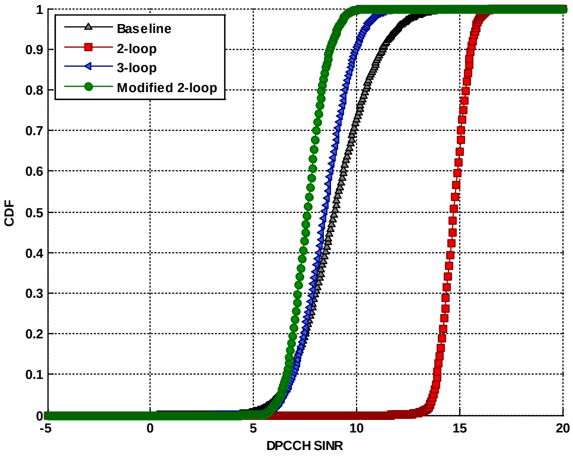
(c)

Figure B.3.1.1.3-1. CDFs of RX Ec/No for different target RX Ec/No values and for different scheduler options: power-based scheduling, 2-loop SINR-based scheduling, and 3-loop SINR-based scheduling for the Ped A 3km/h (a), Veh A, 3 km/h (b), and Veh A 30 km/h (c) channel models

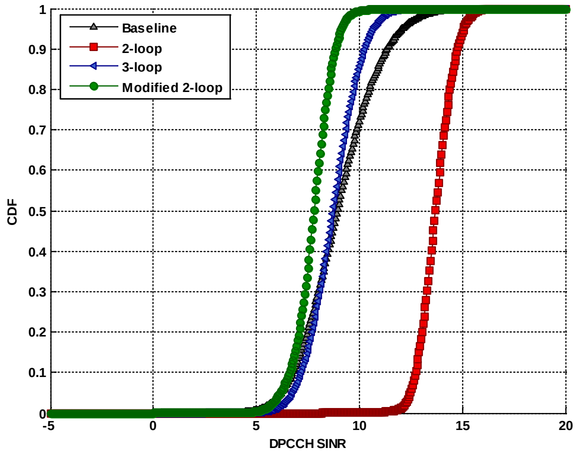
As we can see from the provided link-level results, the RX Ec/No distributions of the 2-loop and 3-loop approaches of the SINR-based scheduling algorithm demonstrate much more accurate RoT control than for the power-based scheme. The modified 2-loop performance in terms of the RoT control accuracy is in between the 2/3-loop SINR-based scheduling and the power-based scheduling. That behavior is considered to be the expected one since the approaches using more direct procedures for the RX power level control provides more stable RoT distributions.

It should be also noted that while a lower RX power stability of the modified 2-loop approach relative to the 2-loop and 3-loop schemes does not impact negatively the performance at the link level, at the system level it may be a reason for an additional system performance loss in for the case of multiple UEs per sector. A possible mechanism for this loss is a stronger variation of the interference level in the system.

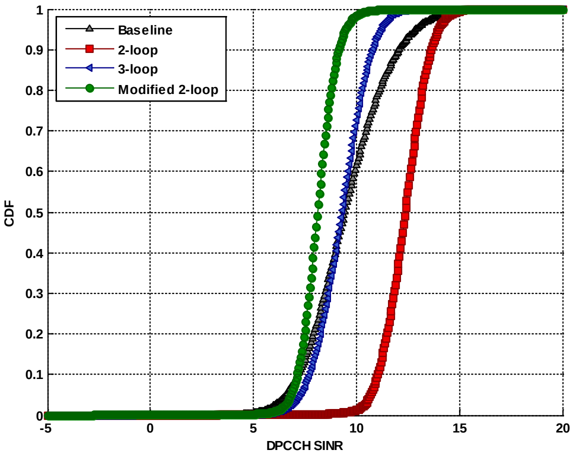
B.3.1.1.4 DPCCH SIR Distributions



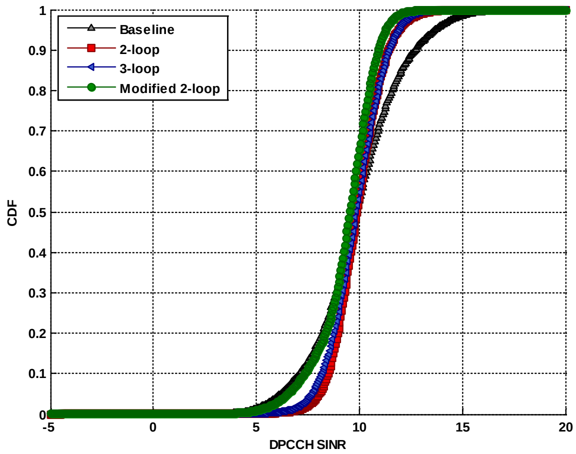
(a) RX Ec/No target = 5 dB



(b) RX Ec/No target = 10 dB

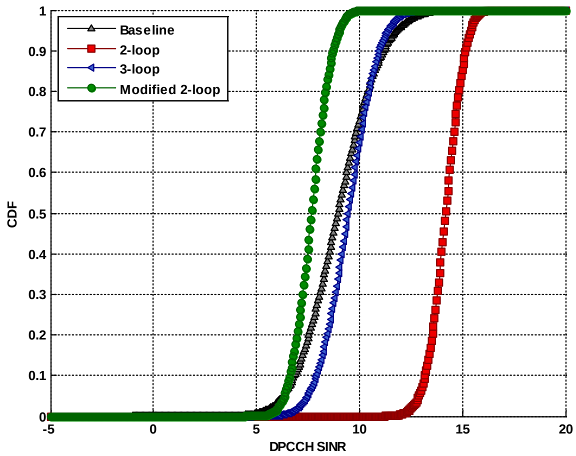


(c) RX Ec/No target = 15 dB

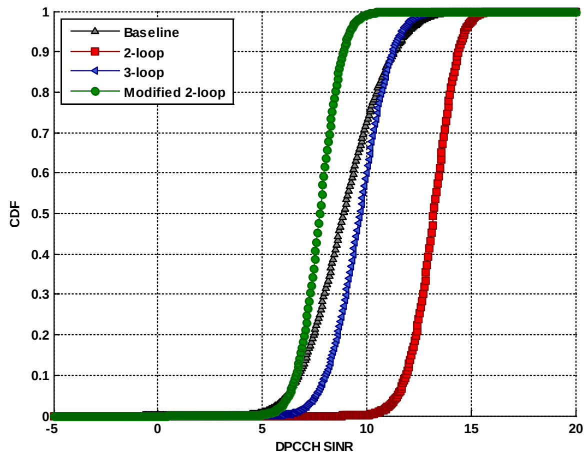


(d) RX Ec/No target = 20 dB

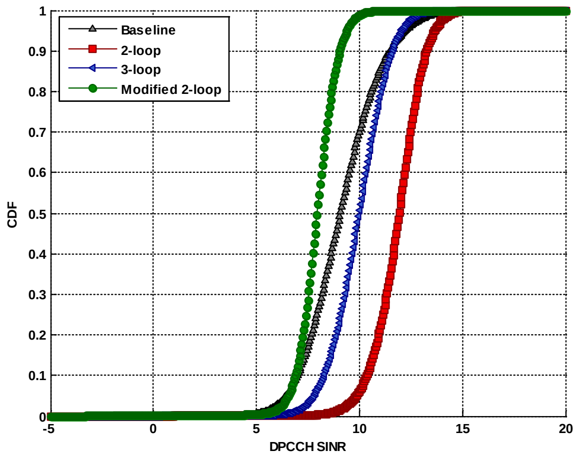
Figure B.3.1.1.4-1. CDFs of DPCCH SINR for different target RX Ec/No values of 5 dB (a), 10 dB (b), 15 dB (c), and 20 dB (d) and different scheduler options: power-based scheduling, 2-loop SINR-based scheduling, and 3-loop SINR-based scheduling for the Ped A 3km/h channel models



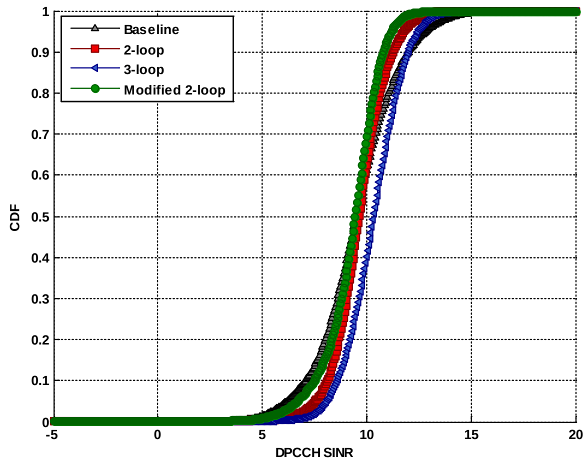
(a) RX Ec/No target = 5 dB



(b) RX Ec/No target = 10 dB

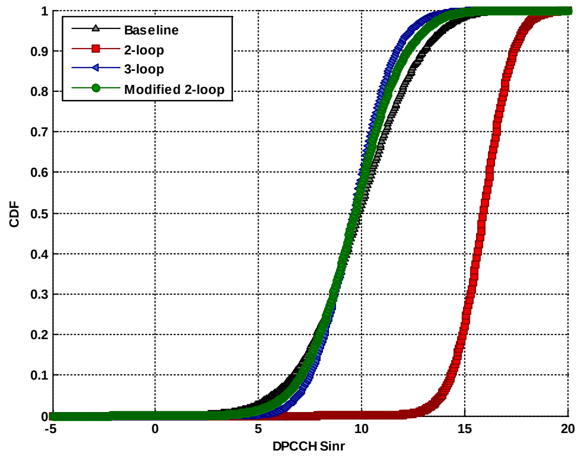


(c) RX Ec/No target = 15 dB

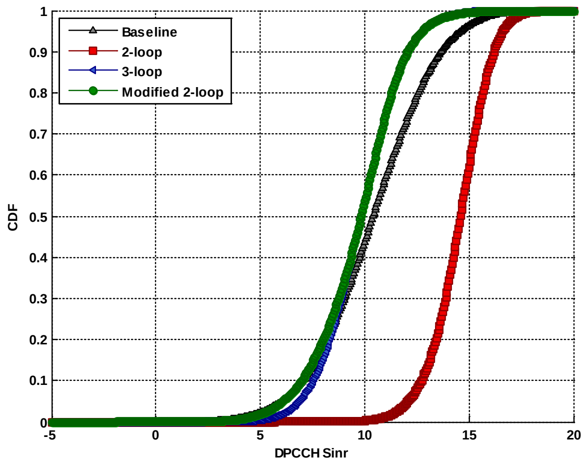


(d) RX Ec/No target = 20 dB

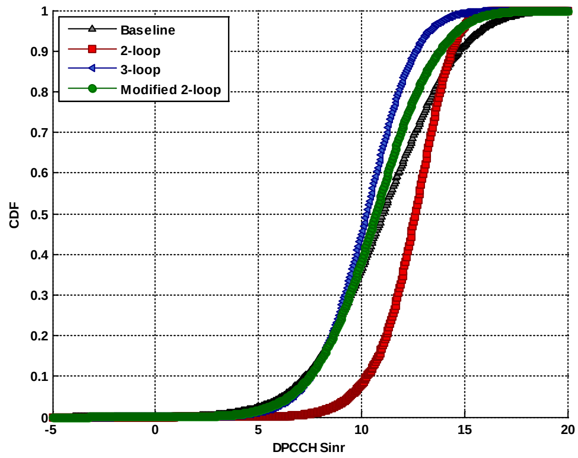
Figure B.3.1.1.4-2. CDFs of DPCCH SINR for different target RX Ec/No values of 5 dB (a), 10 dB (b), 15 dB (c), and 20 dB (d) and different scheduler options: power-based scheduling, 2-loop SINR-based scheduling, and 3-loop SINR-based scheduling for the Veh A 3km/h channel models



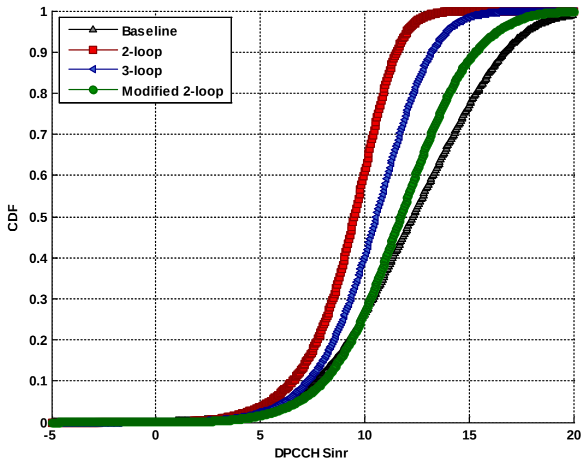
(a) RX Ec/No target = 5 dB



(b) RX Ec/No target = 10 dB



(c) RX Ec/No target = 15 dB



(d) RX Ec/No target = 20 dB

Figure B.3.1.1.4-3. CDFs of DPCCH SINR for different target RX Ec/No values of 5 dB (a), 10 dB (b), 15 dB (c), and 20 dB (d) and different scheduler options: power-based scheduling, 2-loop SINR-based scheduling, and 3-loop SINR-based scheduling for the Veh A 30 km/h channel models

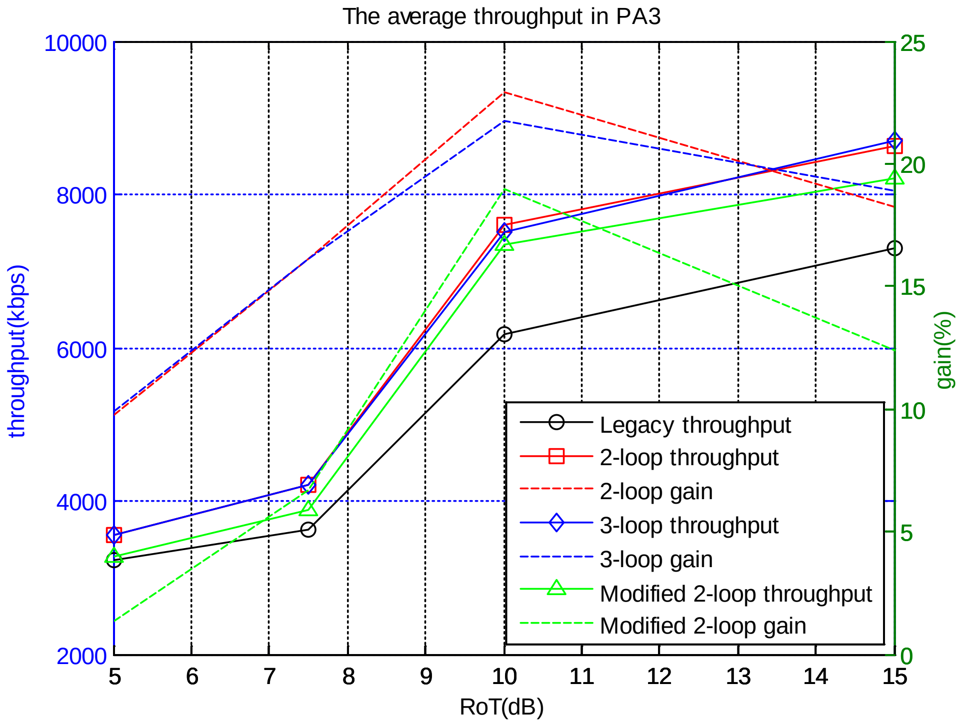
The modified 2-loop approach provides very close DPCCH SINRs to the power-based scheme due to the same E-DPDCH beta-factor set used in the simulations.

According to the presented results, it can be seen that despite different principles involved in the DPCCH SINR and power level control, all the scheduling algorithms provide similar distributions of the DPCCH SINR. The average DPCCH SINR level is approximately equal to 10 dB that is sufficient to guarantee reliable Node B synchronization, power estimation and E-DPCCH decoding procedures.

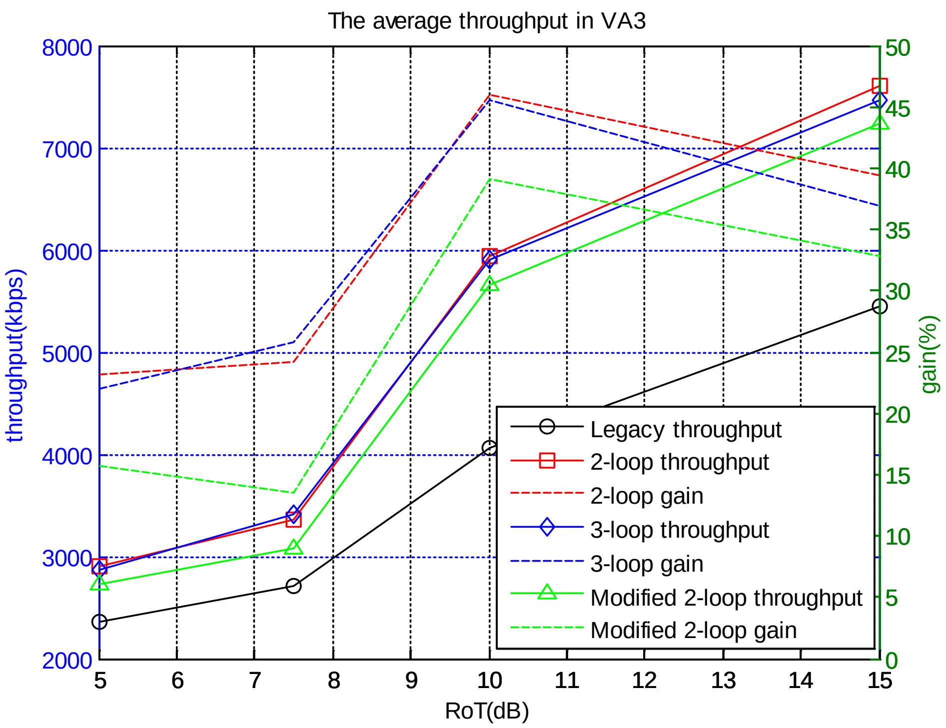
As can be observed from the figures above DPCCH SIR level in case of 2-loop scheme and low Rx Ec/No is higher compared to other schemes. It is caused by the fact that in case of this scheme we do not assume a dynamic control over DPCCH power. That is why constant DPCCH level over thermal noise has been selected via additional Link Level simulations. This level has been optimized for 20dB Rx Ec/No in order to ensure reliable DPCCH reception regardless of the scenario. That is why the DPCCH level for low Rx Ec/No values is too high and decreases with increasing Rx Ec/No (thus increasing gain factor). This DPCCH power overhead visible in case of 2-loop scheme and low Rx Ec/No can be optimized by the propriety solutions but it was not the part of this evaluation. It can be observed that the 3-loop scheme provides stable control of the DPCCH SIR at the given SIR target of 10dB in all simulations which gives a built in protection of DPCCH and control channel performance. Thus the benefit of the third loop is specifying a method for maintaining the DPCCH Rx power at the desired level regardless of varying levels of interference, while other rate adaptation schemes require proprietary solutions for ensuring an adequate DPCCH Rx power level.

B.3.1.2 Simulation set 2

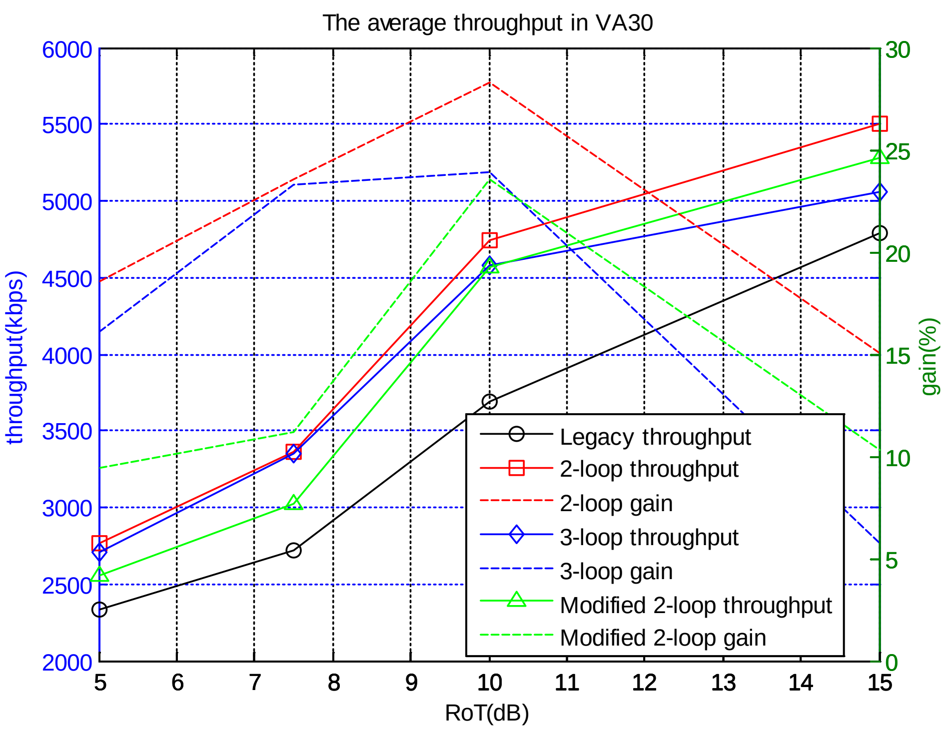
B.3.1.2.1 Throughput



(a) PA3 channel model



(b) VA3 channel model

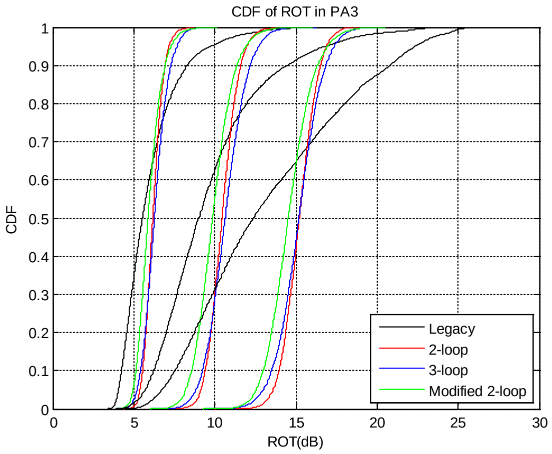


(c) VA30 channel model

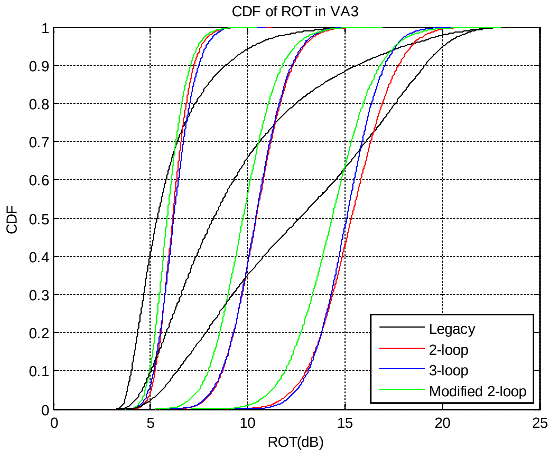
Figure B.3.1.2.1-1: The average throughput for different target RoT values

The average throughput of 2-loop, 3-loop and modified 2-loop schemes is higher than legacy scheme, with the gain of 24%, 22% and 16% respectively.

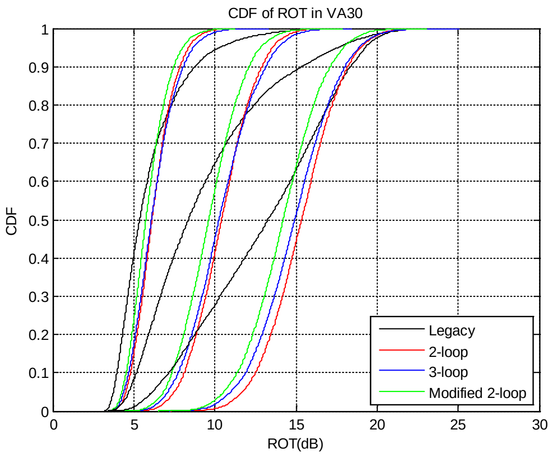
B.3.1.2.2 RoT CDF



(a) PA3 channel model



(b) VA3 channel model

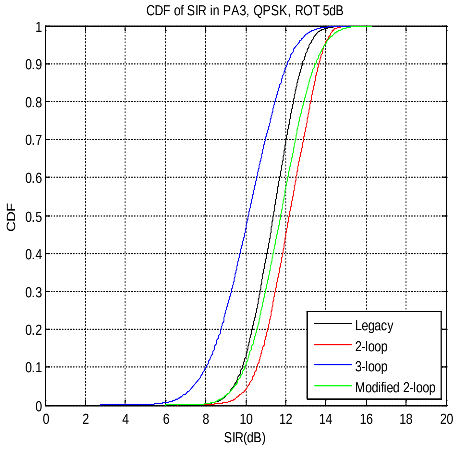


(c) VA30 channel model

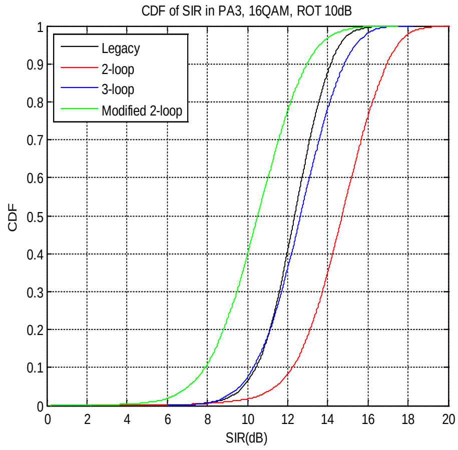
Figure B.3.1.2.2-1: CDF of ROT for different target RoT values (5, 10, 15 dB)

The 2-loop, 3-loop and modified 2-loop schemes improve the stable of DPCCH SIR control compared with the legacy scheme. The stability of modified 2-loop scheme is slightly less than the 2-loop and 3-loop scheme.

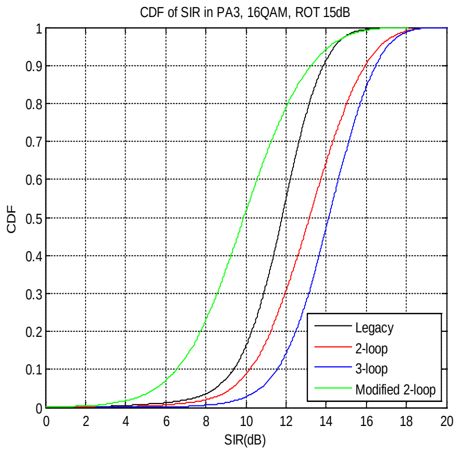
B.3.1.2.3 DPCCH SIR



(a) Target RoT = 5 dB

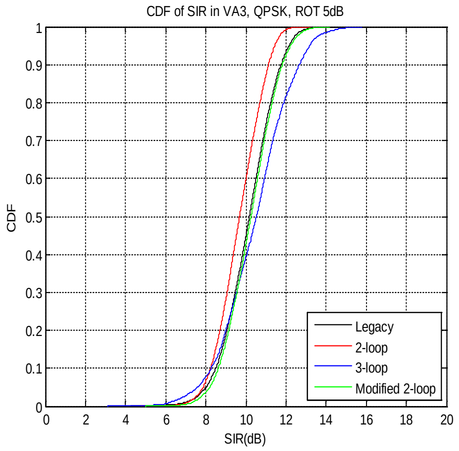


(b) Target RoT = 10 dB

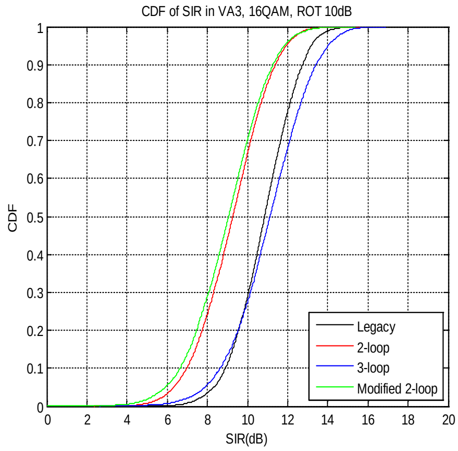


(c) Target RoT = 15 dB

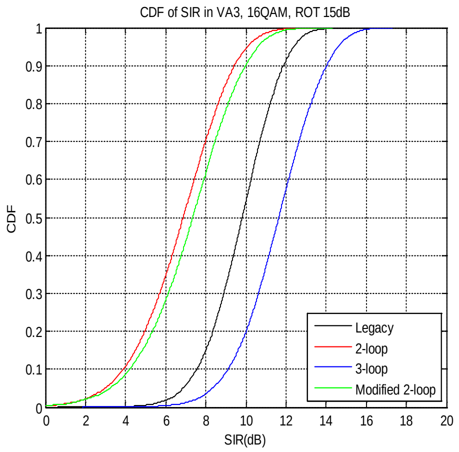
Figure B.3.1.2.3-1: DPCCH SIR CDF, PA3 channel model



(a) Target RoT = 5 dB

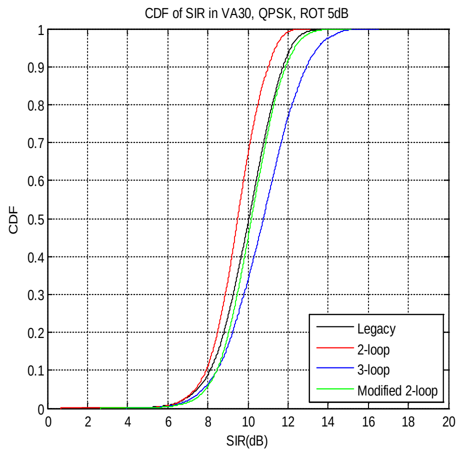


(b) Target RoT = 10 dB

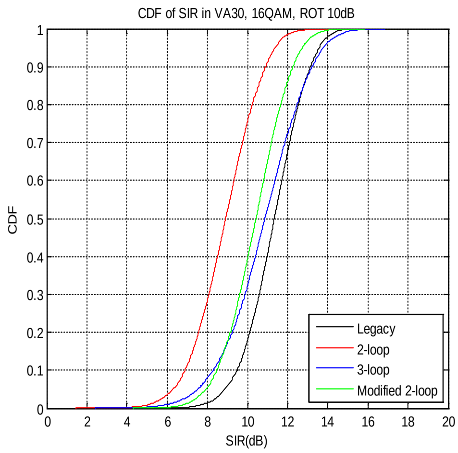


(c) Target RoT = 15 dB

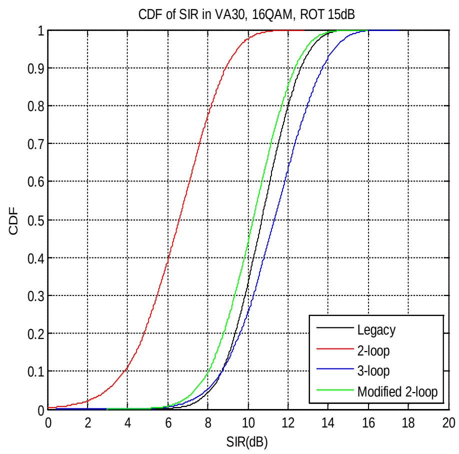
Figure B.3.1.2.3-2: DPCCH SIR CDF, VA3 channel model



(a) Target RoT = 5 dB



(b) Target RoT = 10 dB



(c) Target RoT = 15 dB

Figure B.3.1.2.3-3: DPCCH SIR CDF, VA30 channel model

Without the SIR control loop, the 2-loop and modified 2-loop scheme do not control SIR and it can be observed that the SIR range with 2-loop and modified 2-loop schemes varies in different channel models. In the 3-loop scheme, when the SIR target control is based on the BER of the control channel, the demodulation error of control channel will result in the rising of SIR. So in some cases a large SIR is observed for the 3-loop scheme.

B.3.2 System simulation results for Rate adaptation

B.3.2.1 Simulation set 1

B.3.2.1.1 Additional assumptions

All system level simulations for the baseline (power-based) scheduling and the 2-loop, modified 2-loop and 3-loop schemes are performed in assumption of the TDM scheduling. In particular, only a single UE in each sector in the same TTI is selected for the data transmission and transmits the DPCCH, E-DPCCH and E-DPDCH channels. All other UEs transmit only the DPCCH channel every TTI. A UE scheduled for the data transmission is randomly re-selected among all associated UEs once per the scheduling period of 10 TTIs. I.e., all associated UEs occupy equal time-domain and RX power resources on average. The UE re-selections are performed in different sectors asynchronously.
The OLPC or marginal loops are frozen while a UE is not scheduled.

A short summary of the power control and scheduling operations for different schemes is presented in Table B.3.2.1.1-1.

Table B.3.2.1.1-1: Summary of evaluated scheduler schemes

Power control and scheduling (E-TFCI selection) scheme	Serving grant control loop (absolute or relative grants)	Total RX power control loop	Rate adaptation (SD) control loop	DPCCH SIR control loop	DPCCH SIR target control
Baseline	Every 2 ms	No	No	Every 0.67 ms	OLPC-driven
2-loop scheme	Only initially	Every 0.67 ms	Every 2 ms	No	N/A
Modified 2-loop scheme	Every 2 ms	Every 0.67 ms	No	No	N/A
3-loop scheme	Only initially	Every 0.67 ms	Every 2 ms	Every 0.67 ms	Fixed

For the 2-loop and modified 2-loop schemes, scheduled UEs in the TDM mode have the same (equal) RX power targets. The equal targets are also used for the RX power of non-scheduled UEs (for DPPCH reception). For the 3-loop scheduling scheme, for non-scheduled UEs only one ILPC loop driven by the DPCCH SINR is active (similar to the legacy scheduling scheme) to adjust the DPCCH power level.

The DPCCH power setting for all scheduling schemes is performed to provide (on average) a required DPCCH post-receiver SINR level of ~10 dB when 20 dB RoT target is used. The SLS parameters impacting the DPCCH power setting are the DPCCH SIR used for E-DPDCH gain factors design for the baseline and modified 2-loop schemes, the DPCCH Ec/No for the 2-loop scheme and the target DPCCH SINR for the 3-loop scheme. The selected values for the mentioned parameters are listed in Clause A.3.2.

B.3.2.1.2 Average Throughputs and Gains

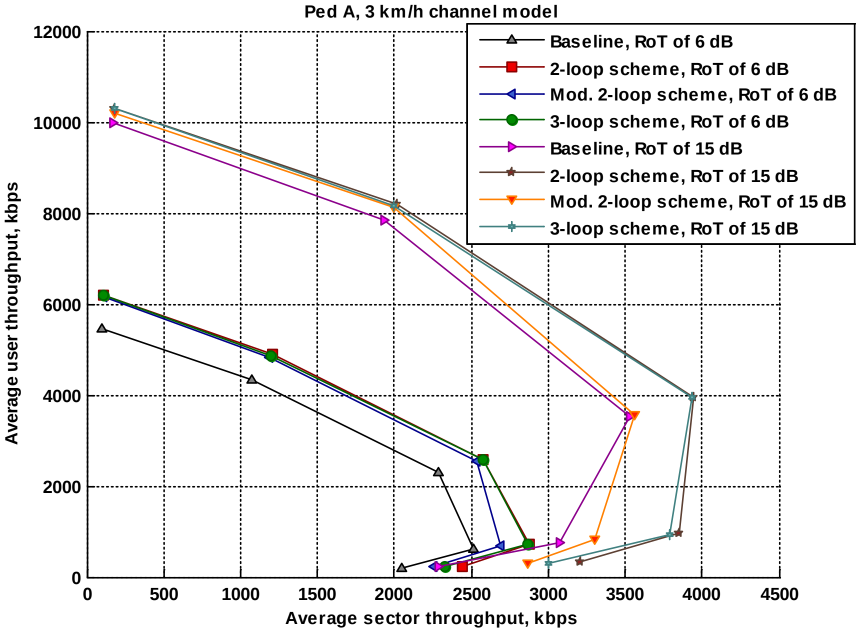


Figure B.3.2.1.2-1: Average UE throughput versus average sector throughput for different rate adaptation schemes for 0.0175, 0.25, 1, 4 and 10 UEs per sector, the RoT of 6 dB and 15 dB and the Ped A, 3 km/h channel

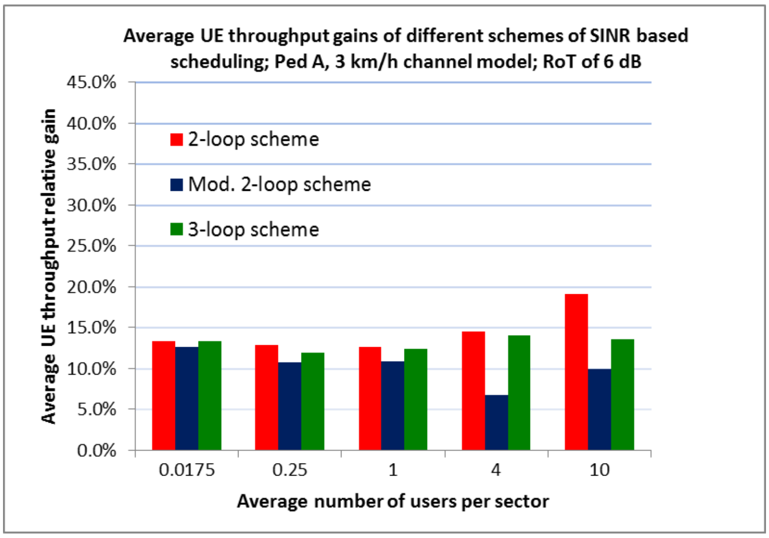


Figure B.3.2.1.2-2: Average UE throughput gains for the 2-loop, modified 2-loop and 3-loop schemes over the baseline, the RoT of 6 dB, the Ped A, 3 km/h channel

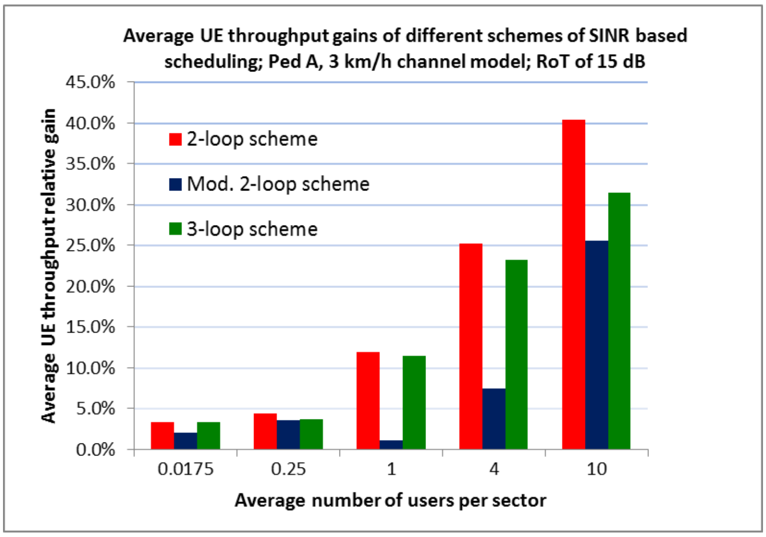


Figure B.3.2.1.2-3: Average UE throughput gains for the 2-loop, modified 2-loop and 3-loop schemes over the baseline, the RoT of 15 dB, the Ped A, 3 km/h channel

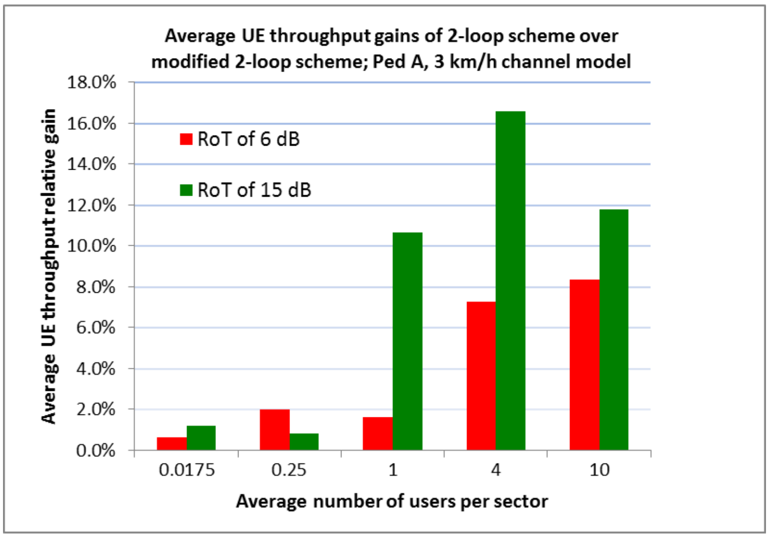


Figure B.3.2.1.2-4: Average UE throughput gains for the 2-loop scheme over the modified 2-loop scheme, the RoT of 6 dB and 15 dB, the Ped A, 3 km/h channel

Table B.3.2.1.2-1: Average UE throughputs for the baseline, 2-loop, modified 2-loop and 3-loop schemes and throughput gains over the baseline for the RoT of 6 dB and 15 dB, the Ped A, 3 km/h channel

RoT	UEs per sector		0.0175	0.25	1	4	10
6 dB	Average UE t-put, kbps	Baseline	5463	4348	2289	629	205
		2-loop scheme	6191	4910	2579	720	244
		Mod. 2-loop scheme	6151	4814	2538	672	226
		3-loop scheme	6191	4865	2572	717	233
	Average UE t-put gain	2-loop scheme	13.3%	12.9%	12.7%	14.5%	19.1%
		Mod. 2-loop scheme	12.6%	10.7%	10.9%	6.8%	9.9%
		3-loop scheme	13.3%	11.9%	12.4%	14.1%	13.6%
15 dB	Average UE t-put, kbps	Baseline	9982	7855	3527	769	229
		2-loop scheme	10311	8199	3946	963	321
		Mod. 2-loop scheme	10190	8132	3566	826	287
		3-loop scheme	10314	8141	3933	947	300
	Average UE t-put gain	2-loop scheme	3.3%	4.4%	11.9%	25.3%	40.4%
		Mod. 2-loop scheme	2.1%	3.5%	1.1%	7.4%	25.6%
		3-loop scheme	3.3%	3.6%	11.5%	23.2%	31.5%

The provided simulation results demonstrate that the 2-loop and 3-loop approaches have very close performance with a marginal benefit of the 2-loop scheme. Both schemes provide the significant gain over the legacy power-based scheduling (baseline) of about 20-40% in terms of the average UE throughput. The gains are higher for higher UE densities and for higher target RoT values.

The modified 2-loop approach performs similarly to the 2-loop approach (Figure B.3.2.1.2-4) for low UE densities (0.25 UEs per sector and below) which is additionally confirmed by the link level simulation results (Clause B.3.1). However, for higher UE densities (1-10 UEs per sector) the performance of the modified 2-loop scheme is situated between the performance for the power-based scheduling and the 2-loop scheme. The gains of the modified 2-loop approach over the baseline are up to 10-25% which is lower than for other proposed rate adaptation schemes. The gains of the 2-loop approach over the modified 2-loop approach for high UE densities (1-10 UEs per sector) reach 8% for the RoT of 6 dB and 16% for the RoT of 15 dB.

The main reason for a lower performance of the modified 2-loop approach in comparison with the 2-loop and 3-loop schemes consists in non-complete decoupling of the power-control and rate adaptation procedures. The remaining interaction of those two mechanisms is in a variation of the E-DPDCH beta-factors together with variations of the data rate (E-TFC) according to the legacy UE procedure. This leads to stronger variations ofTX and RX powers in the system (lower stability) as well as to the necessity of readjustment of the power via ILPC after each E-TFC change which limits the power control and rate adaptation accuracy.

The described behavior of the results is also identical for the Veh A, 3 and Veh A, 30 km/h channel models.

B.3.2.1.3 CDFs of RoT

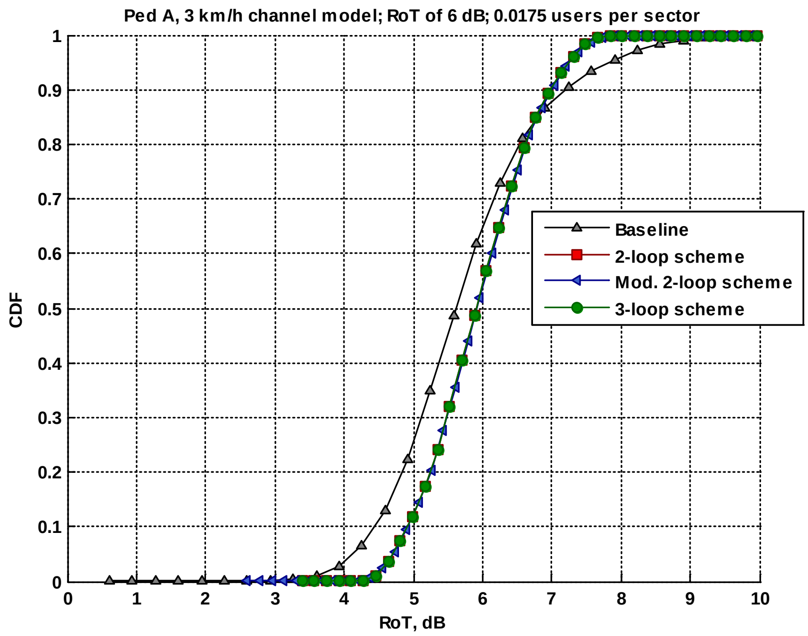


Figure B.3.2.1.3-1: CDF of RoT for 0.0175 users per sector and for the baseline, 2-loop, modified 2-loop and 3-loop schemes, the RoT of 6 dB, the Ped A, 3 km/h channel

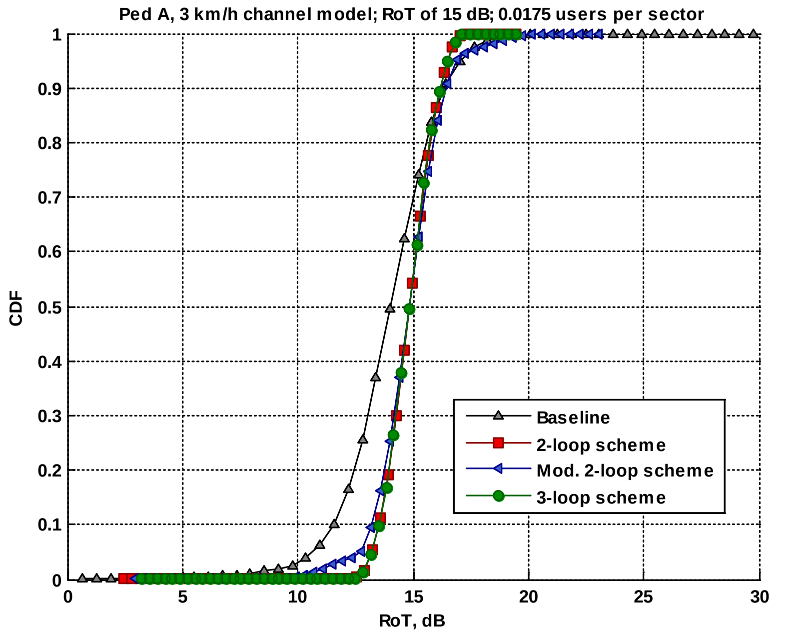


Figure B.3.2.1.3-2: CDF of RoT for 0.0175 users per sector and for the baseline, 2-loop, modified 2-loop and 3-loop schemes, the RoT of 15 dB, the Ped A, 3 km/h channel

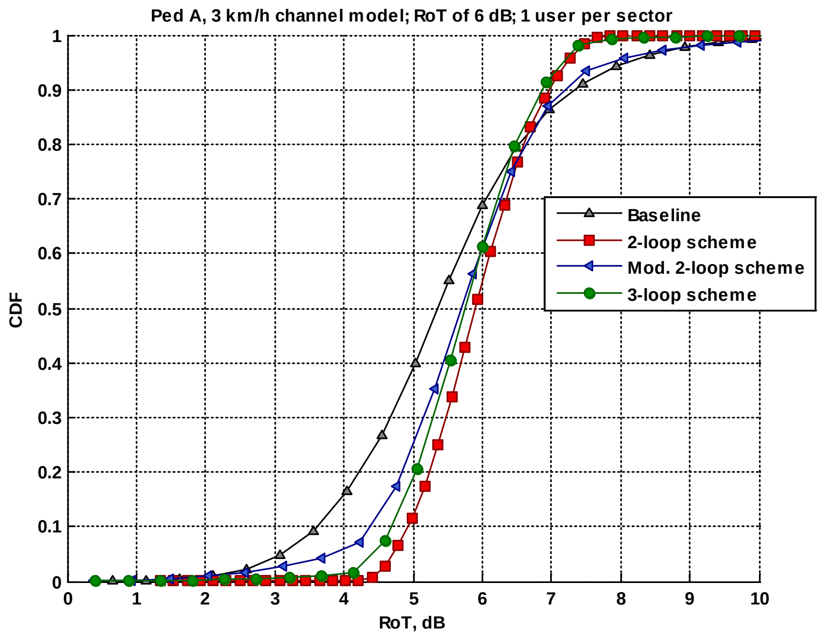


Figure B.3.2.1.3-3: CDF of RoT for 1 user per sector and for the baseline, 2-loop, modified 2-loop and 3-loop schemes, the RoT of 6 dB, the Ped A, 3 km/h channel

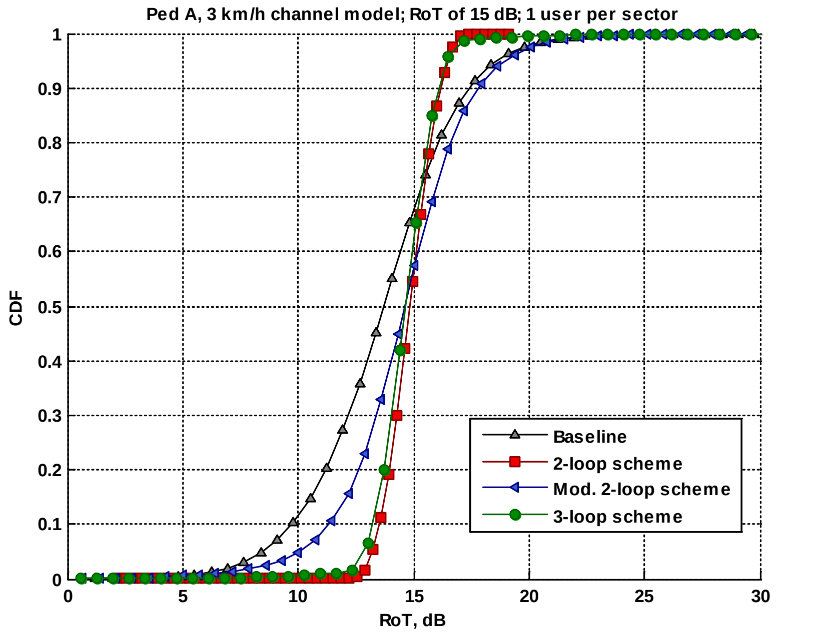


Figure B.3.2.1.3-4: CDF of RoT for 1 user per sector and for the baseline, 2-loop, modified 2-loop and 3-loop schemes, the RoT of 15 dB, the Ped A, 3 km/h channel

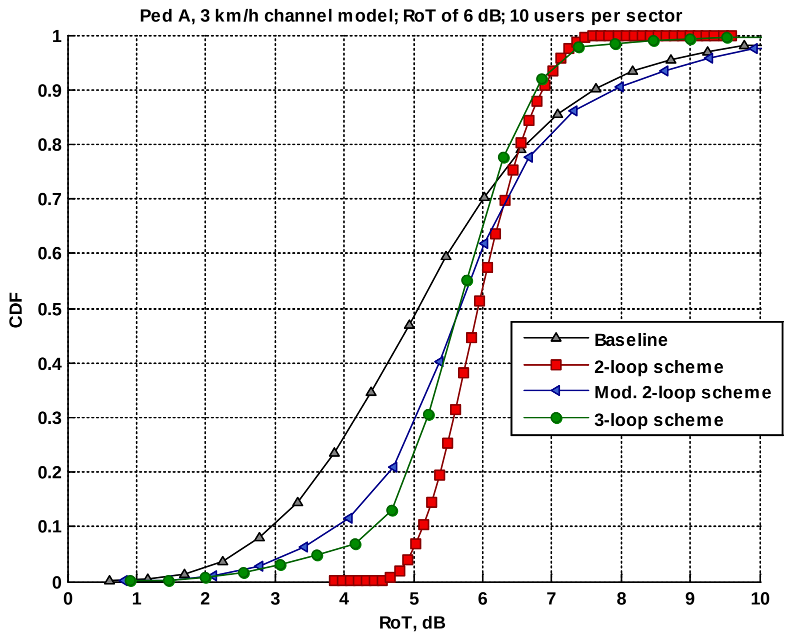


Figure B.3.2.1.3-5: CDF of RoT for 10 users per sector and for the baseline, 2-loop, modified 2-loop and 3-loop schemes, the RoT of 6 dB, the Ped A, 3 km/h channel

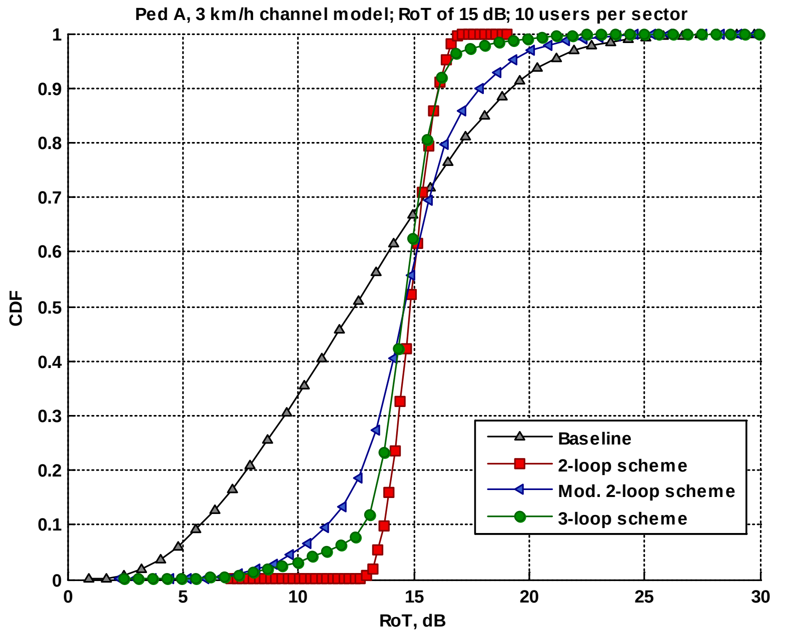


Figure B.3.2.1.3-6: CDF of RoT for 10 users per sector and for the baseline, 2-loop, modified 2-loop and 3-loop schemes, the RoT of 15 dB, the Ped A, 3 km/h channel

The provided RoT distributions demonstrate that all the proposed schemes of improved rate adaptation have steeper CDFs (higher level of RoT stability) in comparison with the power-based scheduling (baseline). The 2-loop approach has the most straight and robust mechanism of the RoT control that is confirmed by the most accurate performance observed from the presented graphs. The curves for the modified 2-loop approach and the 3-loop approach are less steep because of additional procedures involved into the power control when compared to the 2-loop approach. For the modified 2-loop approach a stronger power spread (relative to the 3-loop) is caused by additional TX power variations occurring at E-TFC change. For the 3-loop approach, stronger power variations are caused by interaction of two ILPC loops. It was also observed that for high UE densities slightly higher RoT was observed for the 2-loop solution than other rate adaptation schemes. The higher RoT overshoot of the modified 2-loop compared to 2-loop may be explained by the rate adaptation frequency of 1 TTI; every time the OLPC sees BLER target deviate from the target a new grant is issued leading to a transient in experienced RoT, until ILPC converges back to the RoT target. If the modified 2-loop is operated differently is may be possible that the overshoot is mitigated.

B.3.2.1.4 CDFs of DPCCH SINR

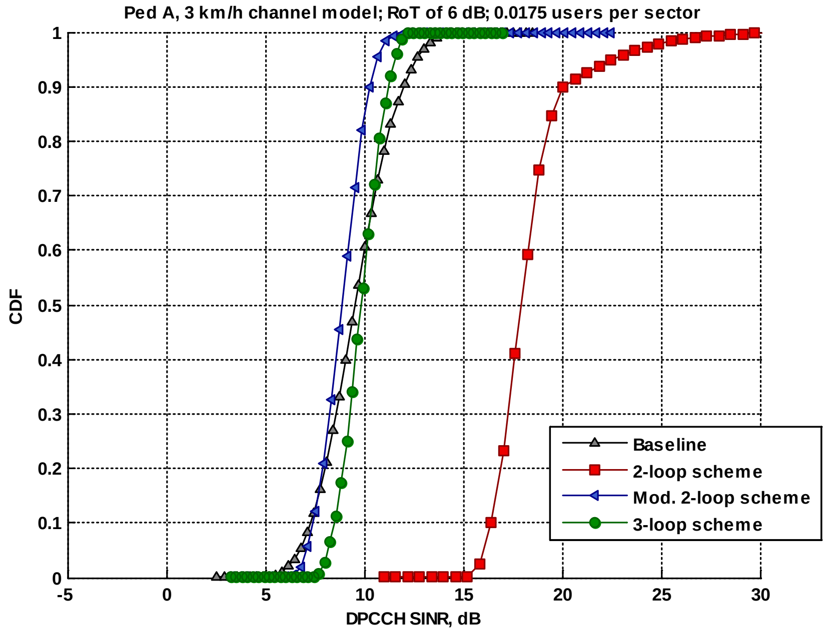


Figure B.3.2.1.4-1: CDF of DPCCH SINR for 0.0175 users per sector and for the baseline, 2-loop, modified 2-loop and 3-loop schemes, the RoT of 6 dB, the Ped A, 3 km/h channel

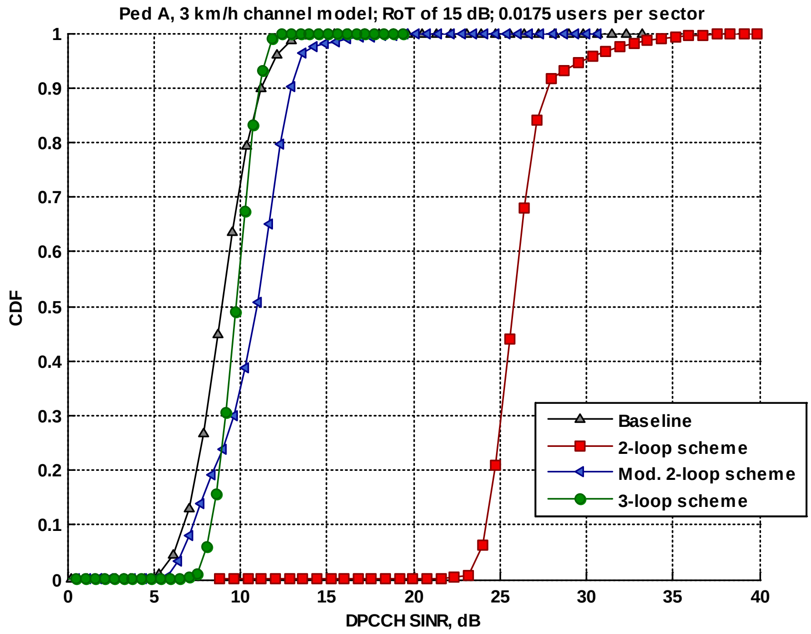


Figure B.3.2.1.4-2: CDF of DPCCH SINR for 0.0175 users per sector and for the baseline, 2-loop, modified 2-loop and 3-loop schemes, the RoT of 15 dB, the Ped A, 3 km/h channel

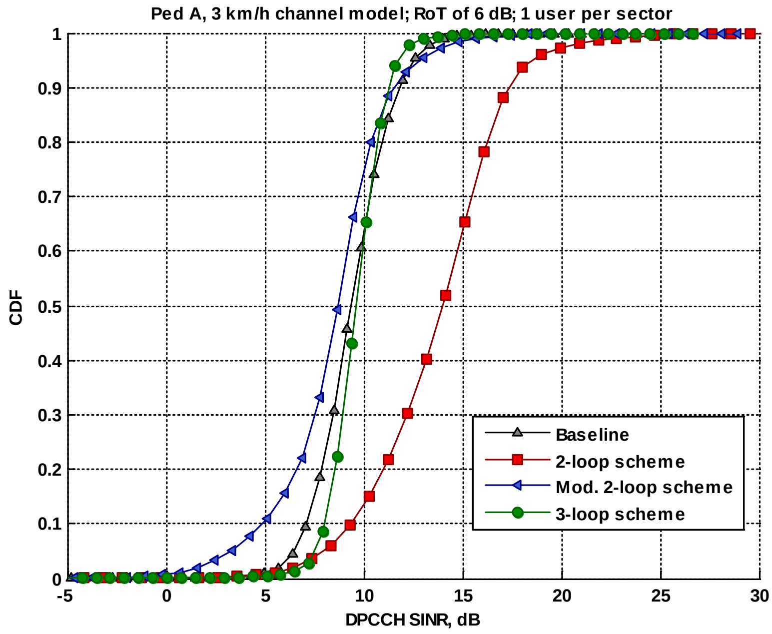


Figure B.3.2.1.4-3: CDF of DPCCH SINR for 1 user per sector and for the baseline, 2-loop, modified 2-loop and 3-loop schemes, the RoT of 6 dB, the Ped A, 3 km/h channel

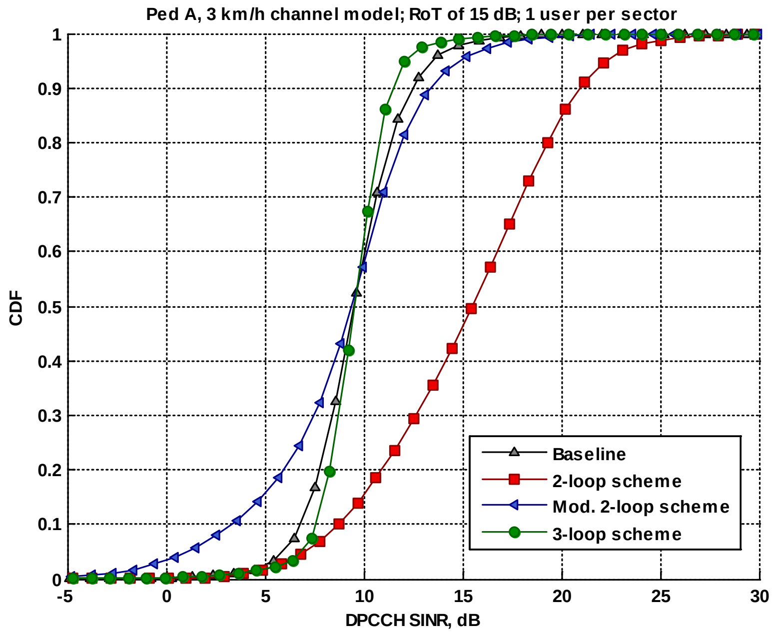


Figure B.3.2.1.4-4: CDF of DPCCH SINR for 1 user per sector and for the baseline, 2-loop, modified 2-loop and 3-loop schemes, the RoT of 15 dB, the Ped A, 3 km/h channel

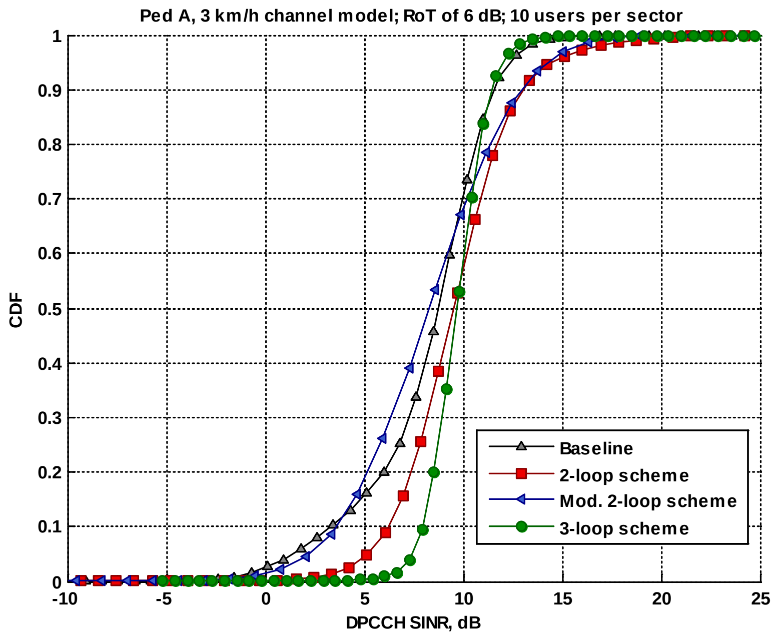


Figure B.3.2.1.4-5: CDF of DPCCH SINR for 10 users per sector and for the baseline, 2-loop, modified 2-loop and 3-loop schemes, the RoT of 6 dB, the Ped A, 3 km/h channel

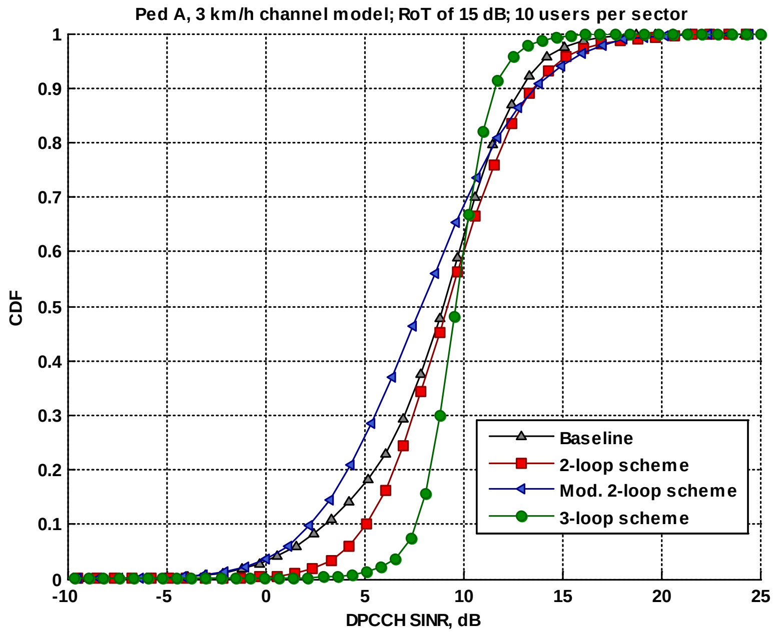


Figure B.3.2.1.4-6: CDF of DPCCH SINR for 10 users per sector and for the baseline, 2-loop, modified 2-loop and 3-loop schemes, the RoT of 15 dB, the Ped A, 3 km/h channel

A proper selection of the DPCCH RX Ec/No should be done for the 2-loop and modified 2-loop schemes to reach the required level of DPCCH SINR, while for other approaches (3-loop and power-based) that DPCCH SINR is controlled directly. However, the DPCCH SINR distributions demonstrate that the required SINR minimum average level of 10 dB is in most cases achieved on for all evaluated scheduling schemes. For higher UE densities (e.g. 10 users per sector) the 3-loop scheme is observed to provide a more stable control of the DPCCH SIR compared to other schemes.

B.3.2.2 Simulation set 2

B.3.2.2.1 Target ROT of 6dB

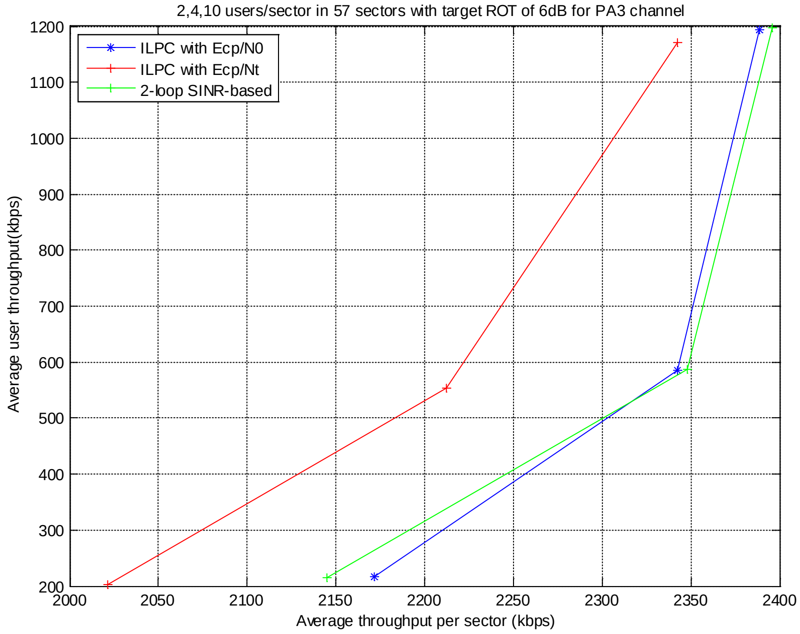


Figure B.3.2.2.1-1: The comparison of the average throughputs for 2, 4 and 10 users per sector

Table B.3.2.2.1-1: The average UE throughputs and relative gains for 2, 4 and 10 user per sector

UEs per sector		**2**	**4**	**10**
Average UE throughput (kbps)	**Ecp/Nt**	1171.2	553.04	202.12
	Ecp/N0	1194.2	585.6	217.2
	SINR-based	1197.8	587.0	214.5
Average UE throughput relative gain (%)	**Ecp/N0**	1.96%	5.88%	7.45%
	SINR-based	2.27%	6.13%	6.13%

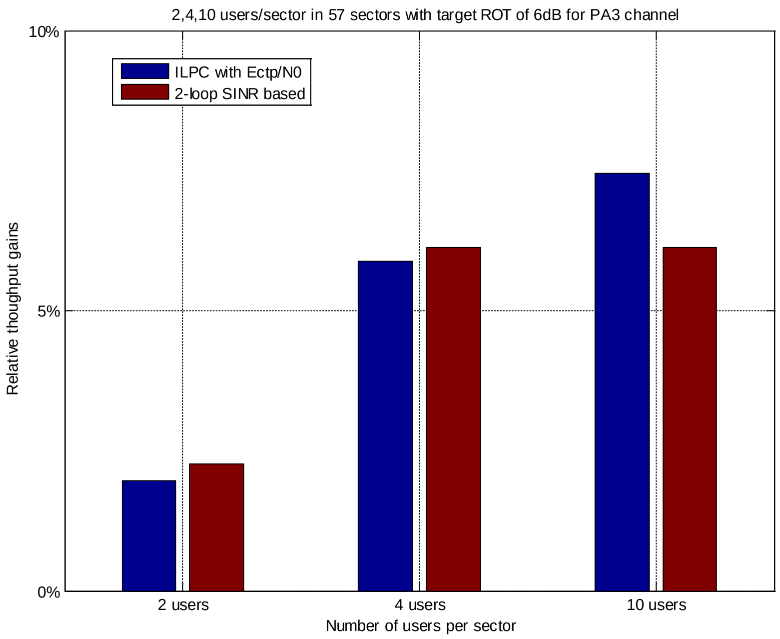


Figure B.3.2.2.1-2: The relative throughput gains for 2, 4 and 10 user per sector

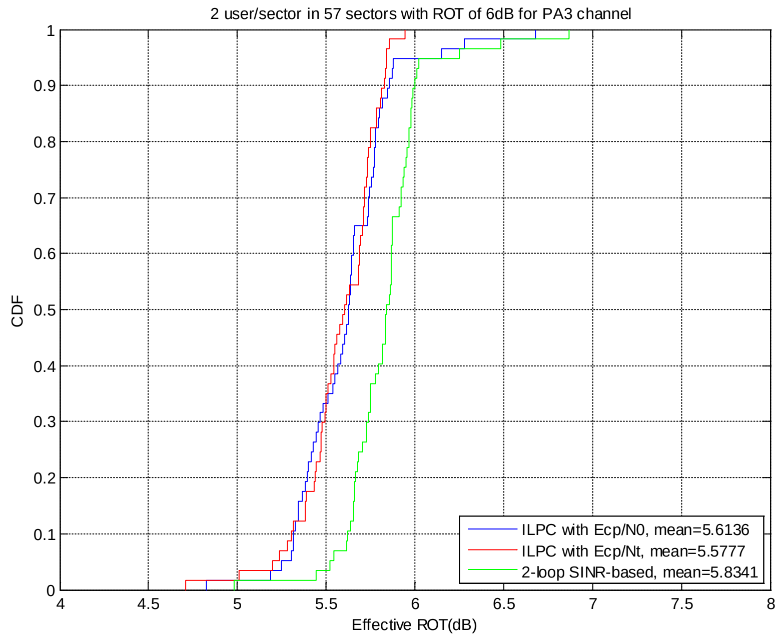


Figure B.3.2.2.1-3: The comparison of the ROT distribution for 2 users per sector

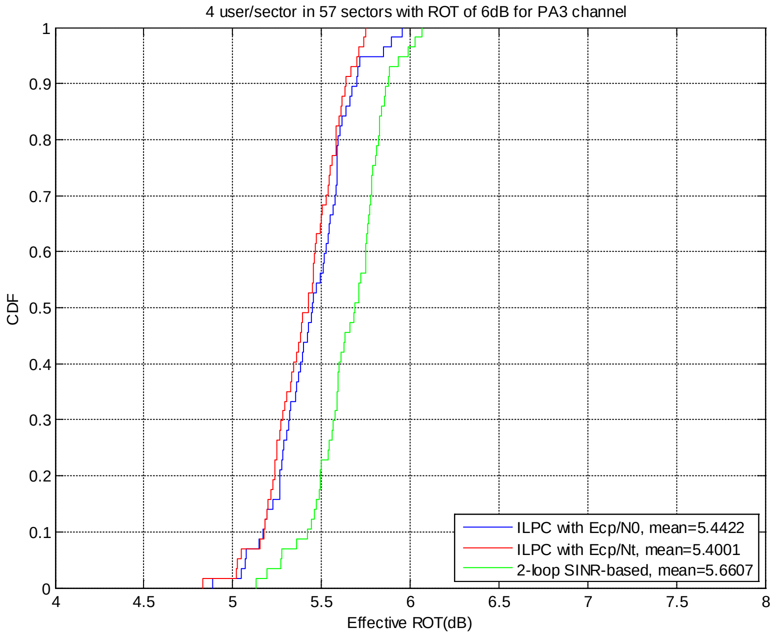


Figure B.3.2.2.1-4: The comparison of the ROT distribution for 4 users per sector

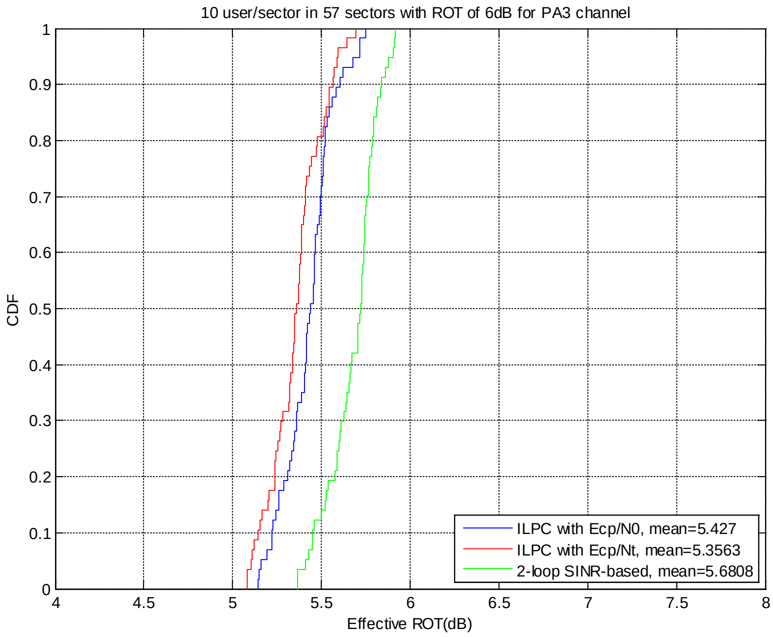


Figure B.3.2.2.1-5: The comparison of the ROT distribution for 10 users per sector

B.3.2.2.2 Target ROT of 15dB

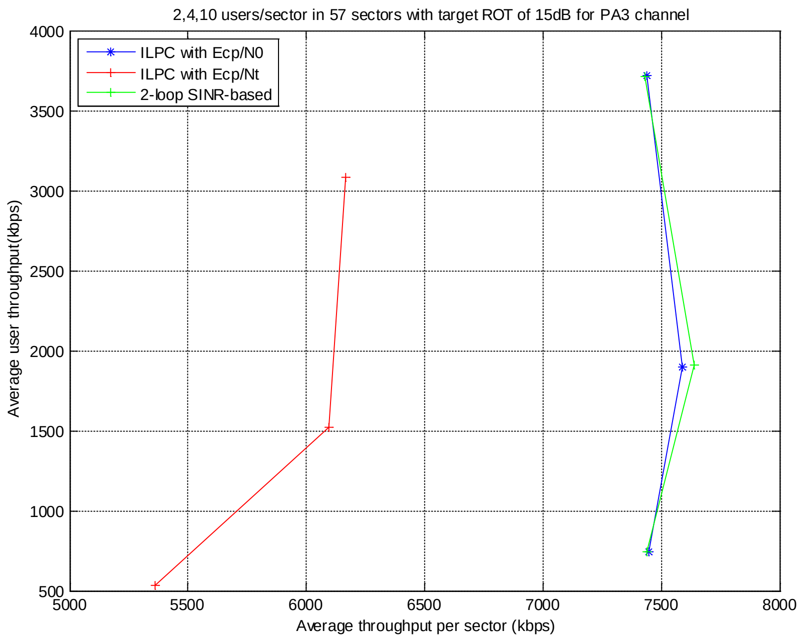


Figure B.3.2.2.2-1: The comparison of the average throughputs for 2, 4 and 10 users per sector

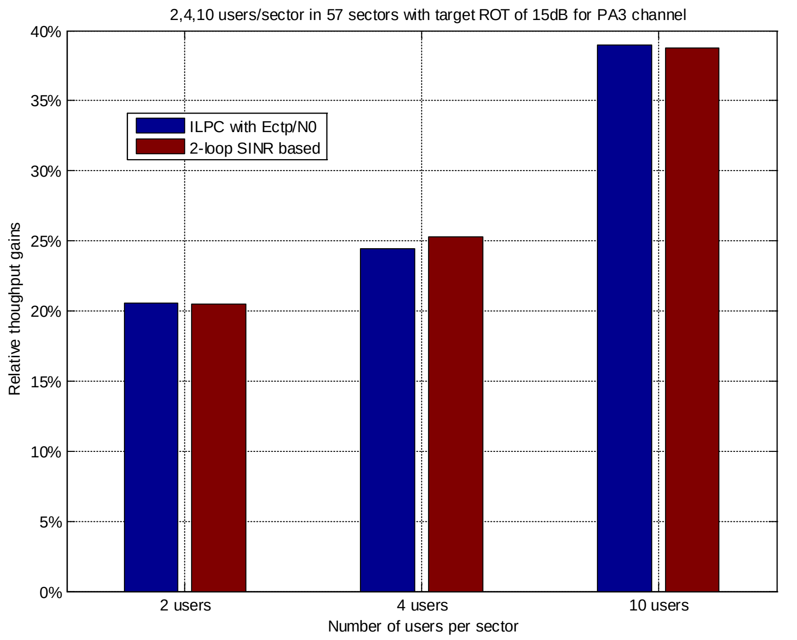


Figure B.3.2.2.2-2: The relative throughput gains for 2, 4 and 10 user per sector

Table B.3.2.2.2-1: The average UE throughputs and relative gains for 2, 4 and 10 user per sector

UEs per sector		2	4	10
Average UE throughput (kbps)	Ecp/Nt	3084.1	1524.1	536.04
	Ecp/N0	3718.8	1897.1	744.9
	SINR-based	3715.1	1909.3	743.7
Average UE throughput relative gain (%)	Ecp/N0	20.6%	24.5%	38.9%
	SINR-based	20.5%	25.3%	38.7%

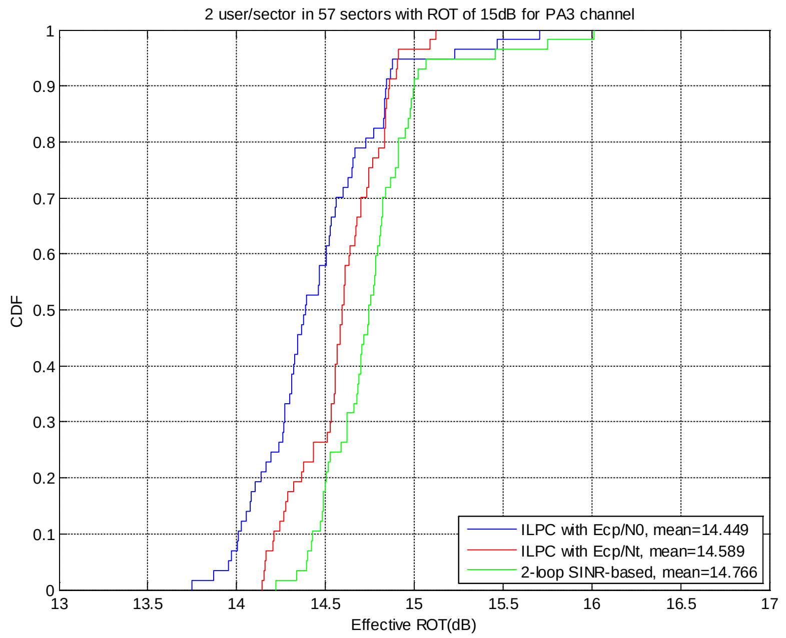


Figure B.3.2.2.2-3: The comparison of the ROT distribution for 2 users per sector

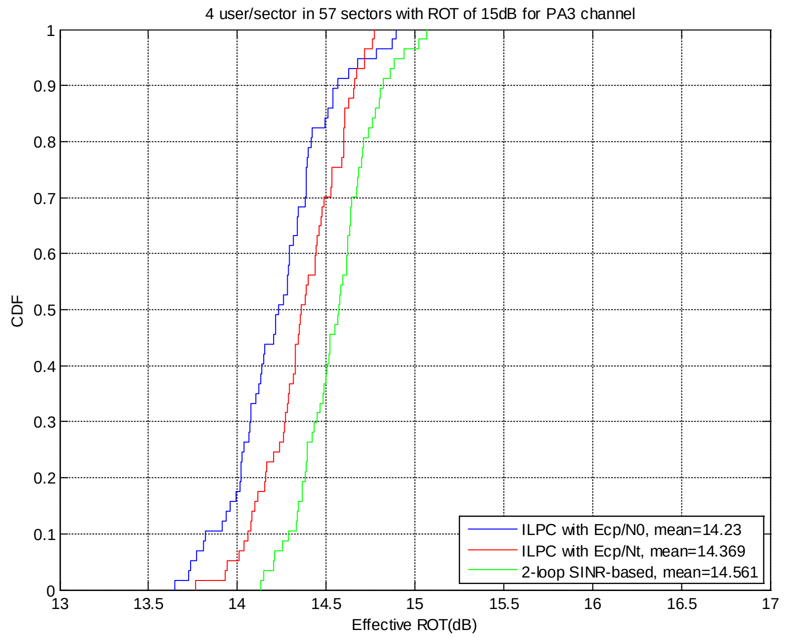


Figure B.3.2.2.2-4: The comparison of the ROT distribution for 4 users per sector

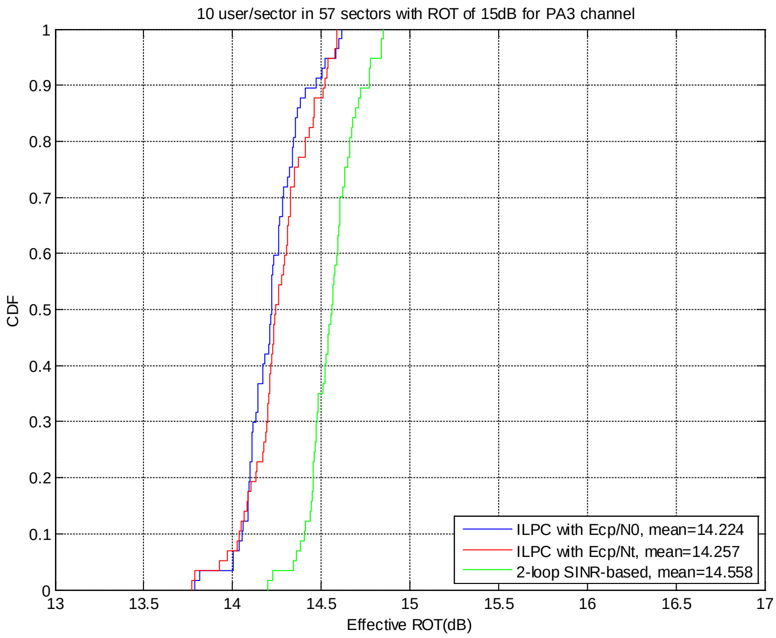


Figure B.3.2.2.2-5: The comparison of the ROT distribution for 10 users per sector

B.3.2.3 Simulation set 3

B.3.2.3.1 Throughput gains

Table B.3.2.3.1-1 summarises the average UE throughputs and throughput gains for baseline, 2-loop scheme and modified 2-loop scheme with ROT of 6dB and 15dB. The results show that SINR-based scheduling (including both 2-loop and modified 2-loop schemes) has gain over legacy scheduling, and the gain is from 6% to about 48% due to different conditions. Moreover, the gain for modified 2-loop scheme is similar gain with 2-loop scheme in almost all scenarios.

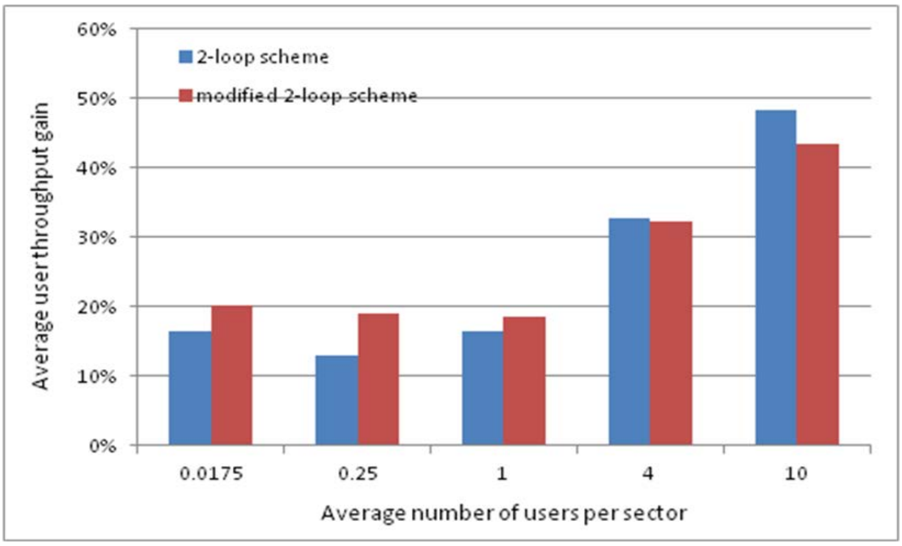


Figure B.3.2.3.1-1. Average UE throughput gains for the 2-loop and modified 2-loop over the baseline, PA3 channel, RoT= 6 dB

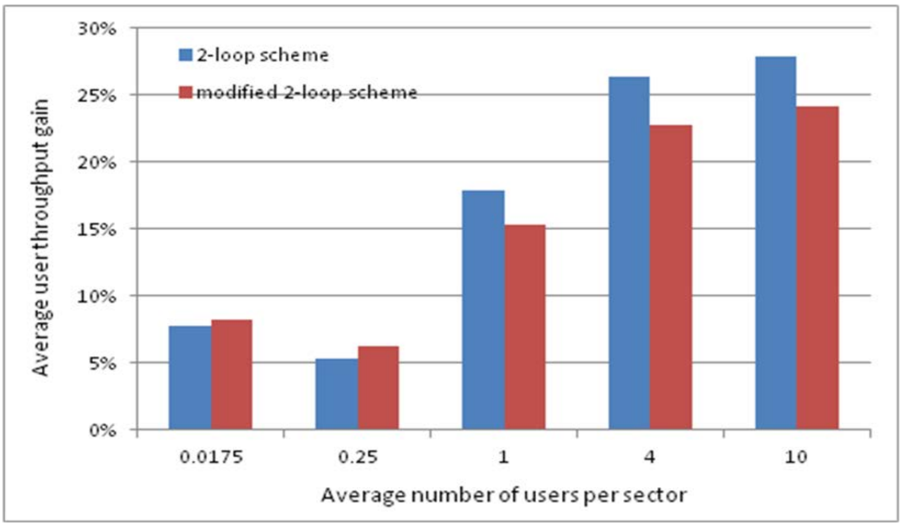


Figure B.3.2.3.1-2. Average UE throughput gains for the 2-loop and modified 2-loop over the baseline, PA3 channel, RoT= 15 dB

Table B.3.2.3.1-1: Average UE throughput gains for the baseline, 2-loop and modified 2-loop with RoT of 6 dB and 15 dB

RoT	UEs per sector		0.0175	0.25	1	4	10
6 dB	Average UE throughput, [kbps]	Baseline	4823	4202	2461	426	145
		2-loop scheme	5614	4745	2864	565	215
		Modified 2-loop scheme	5801	5000	2918	563	208
	Average UE throughput gain [%]	2-loop scheme	16.4	12.9	16.4	32.8	48.2
		Modified 2-loop scheme	20.3	18.9	18.6	32.2	43.3
15 dB	Average UE throughput, [kbps]	Baseline	9511	8188	3739	589	233
		2-loop scheme	10253	8622	4408	744	298
		Modified 2-loop scheme	10292	8696	4311	723	290
	Average UE throughput gain [%]	2-loop scheme	7.8	5.3	17.9	26.2	27.9
		Modified 2-loop scheme	8.2	6.2	15.3	22.7	24.3

B.3.2.3.2 CDFs of ROT

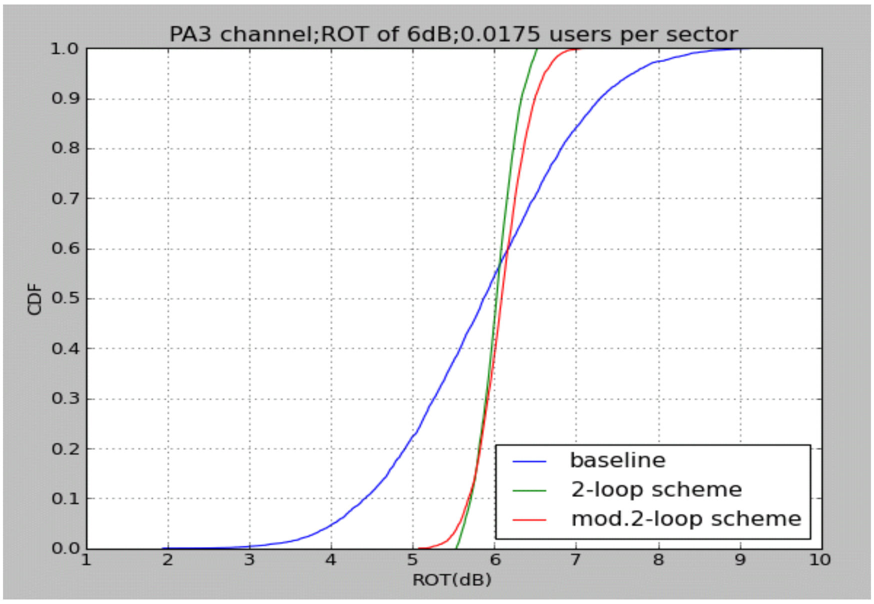


Figure B.3.2.3.2-1: The CDF of RoT for 0.0175 users per sector, PA3 channel, RoT = 6 dB

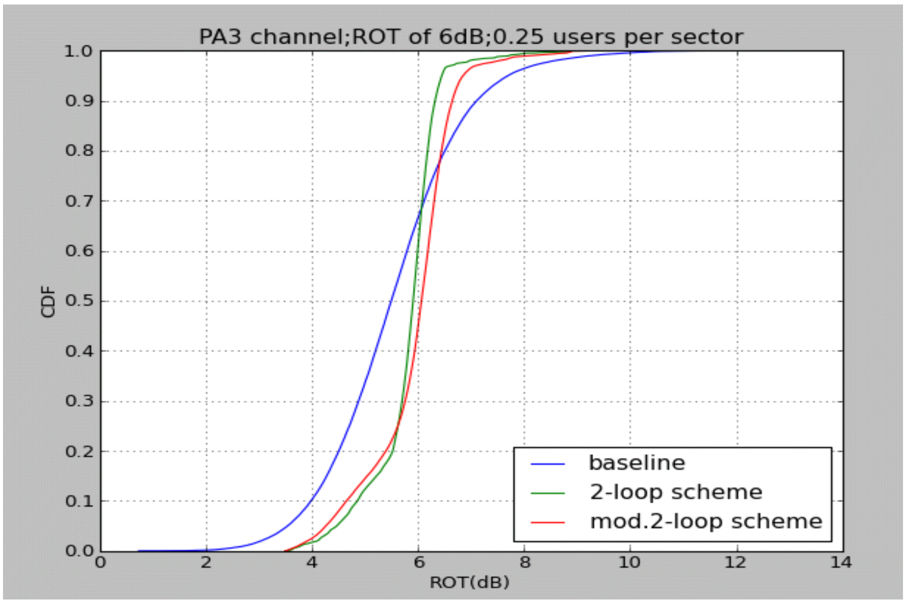


Figure B.3.2.3.2-2: The CDF of RoT for 0.25 users per sector, PA3 channel, RoT = 6 dB

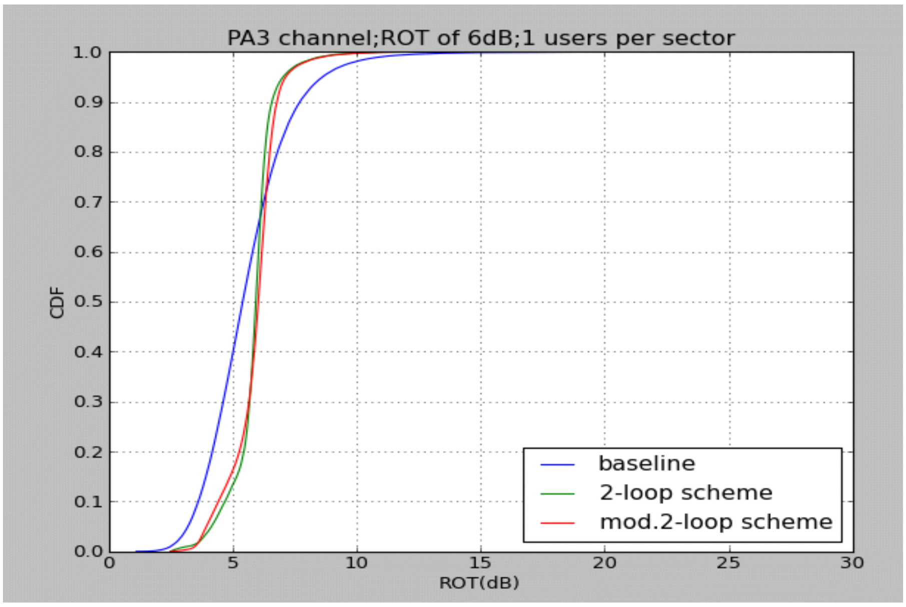


Figure B.3.2.3.2-3: The CDF of RoT for 1 users per sector, PA3 channel, RoT = 6 dB

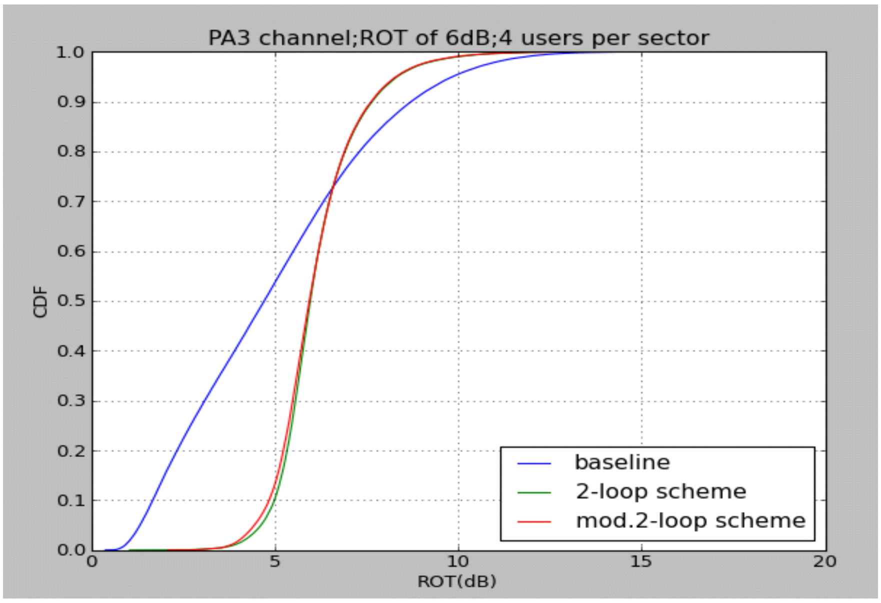


Figure B.3.2.3.2-4: The CDF of RoT for 4 users per sector, PA3 channel, RoT = 6 dB

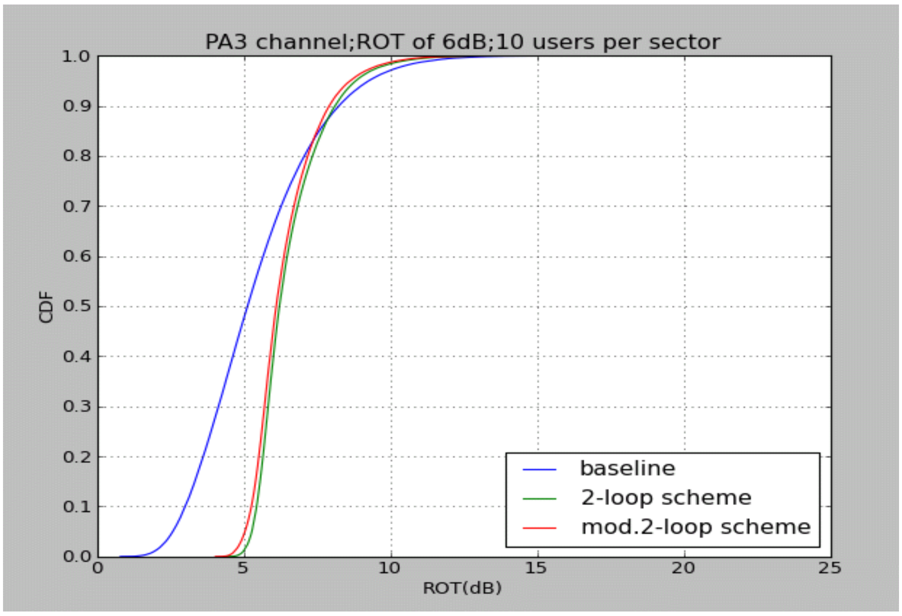


Figure B.3.2.3.2-5: The CDF of RoT for 10 users per sector, PA3 channel, RoT = 6 dB

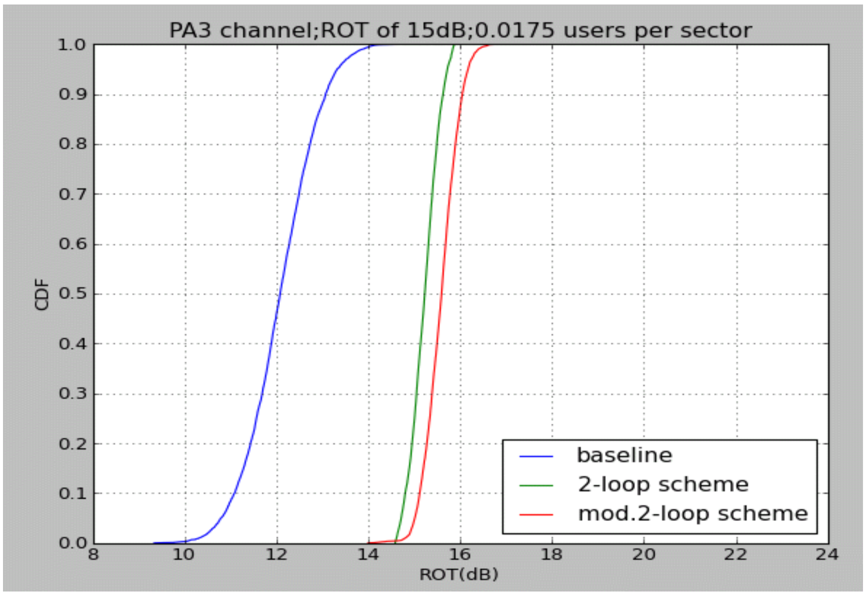


Figure B.3.2.3.2-6: The CDF of RoT for 0.0175 users per sector, PA3 channel, RoT = 15 dB

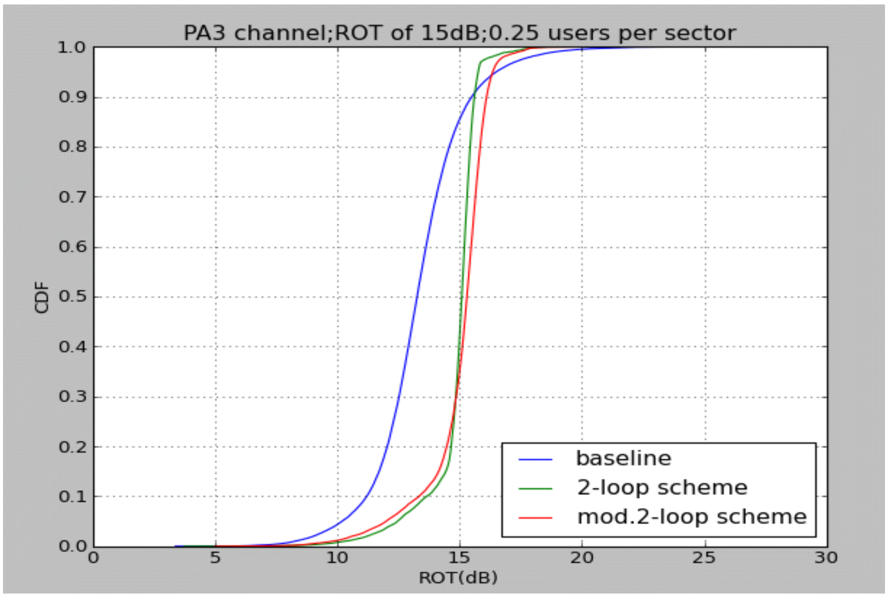


Figure B.3.2.3.2-7: The CDF of RoT for 0.25 users per sector, PA3 channel, RoT = 15 dB

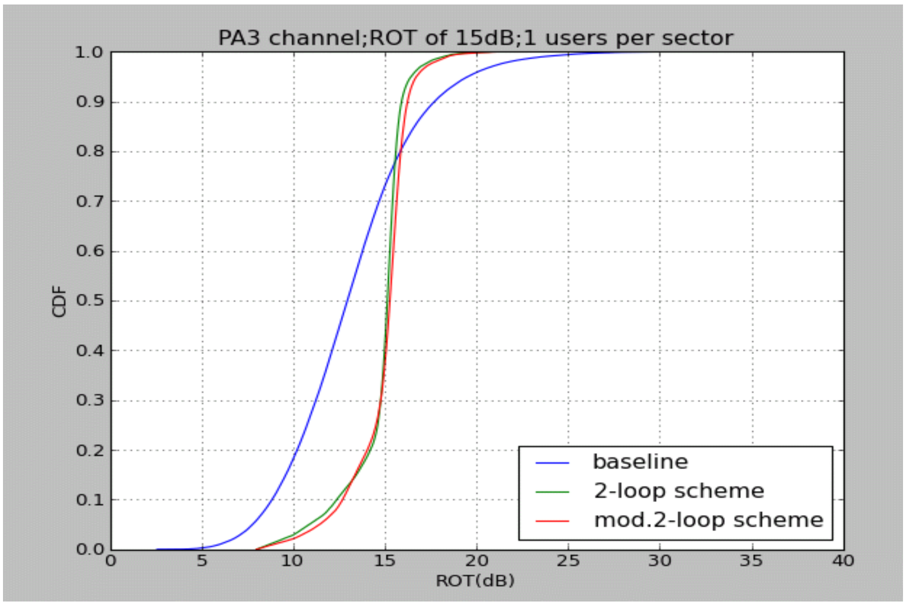


Figure B.3.2.3.2-8: The CDF of RoT for 1 users per sector, PA3 channel, RoT = 15 dB

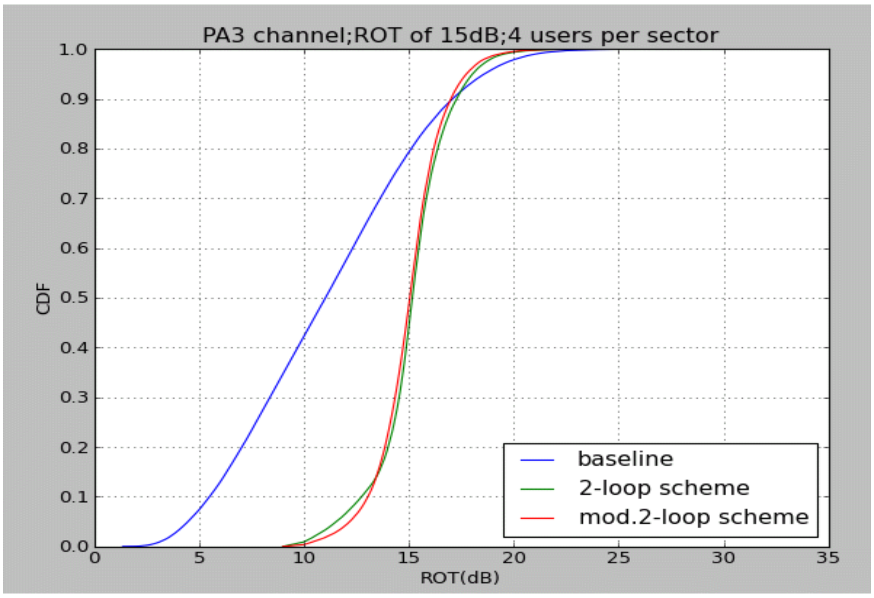


Figure B.3.2.3.2-9: The CDF of RoT for 4 users per sector, PA3 channel, RoT = 15 dB

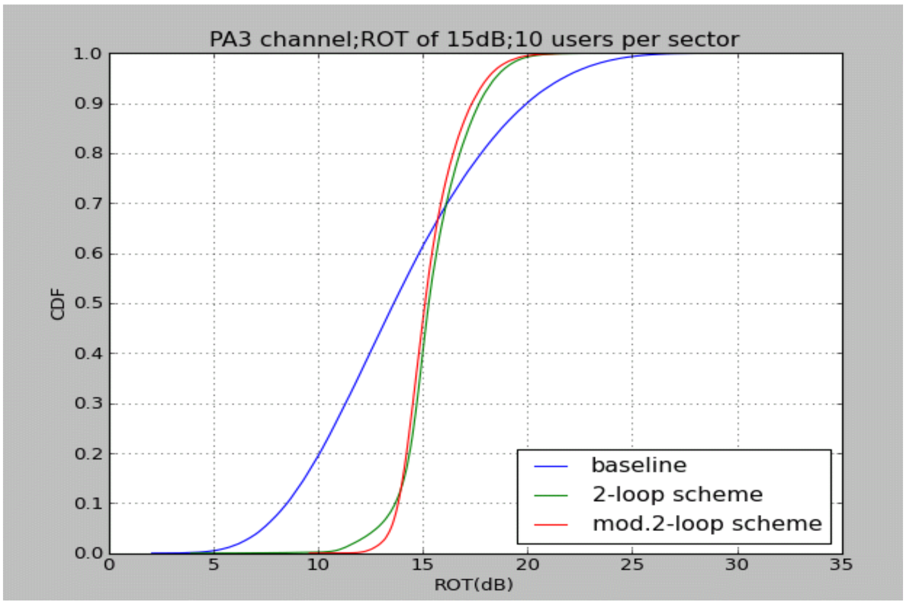


Figure B.3.2.3.2-10: The CDF of RoT for 10 users per sector, PA3 channel, RoT = 15 dB

The provided RoT distributions also demonstrate that both 2-loop and modified 2-loop schemes have gain to the baseline. All CDFs show that SINR-based scheduling have steeper curve than legacy scheduling since SINR-based scheduling has better controlling of ROT.

B.3.2.4 Soft handover simulation results for 2-loop Rate adaptation

The following six SHO options have been considered and simulated for the 2-loop rate adaptation:

1a. (baseline option). SHO is disabled, TPC commands are sent only from the serving Node B and the rate adaptation procedure is performed at the serving Node B;

1b. SHO is disabled, TPC commands are sent from all Nodes B in the active set (TPC commands from non-serving Nodes B operating like overload indicators), and the rate adaptation procedure is performed at the serving Node B only;

2a. SHO is enabled, TPC commands are sent only from the serving Node B, the rate adaptation procedure is performed at the serving Node B only;

2b. SHO is enabled, TPC commands are sent from all Nodes B in the active set (TPC commands from non-serving Nodes B operating like overload indicators), the rate adaptation procedure is performed at the serving Node B only;

3a. SHO is enabled, TPC commands are sent only from the serving Node B, the rate adaptation procedure is performed in a collaborative way by Nodes B from the active set at the RNC;

3b. SHO is enabled, TPC commands are sent from all Nodes B in the active set (TPC commands from non-serving Nodes B operating like overload indicators), the rate adaptation procedure is performed in a collaborative way by Nodes B from the active set at the RNC.

The lists of system level simulation assumptions for the deployment model and assumptions of the system operation are provided in simulation assumptions, and additional parameters are provided in Table B.3.2.4-1.

Table B.3.2.4-1: Additional system simulation parameters related to SHO operation

SHO R1a parameter [dB]	4
SHO R1b parameter [dB]	6

Ped A, 3 km/h Channel Model

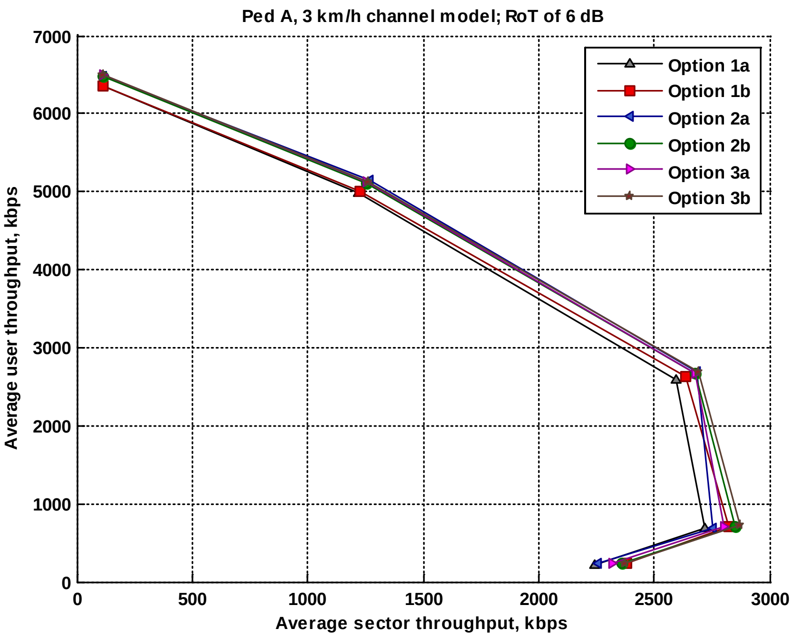


Figure B.3.2.4-1: Average UE throughput versus average sector throughput for different UE densities (0.0175, 0.25, 1, 4 and 10 UEs per sector), Ped A, 3 km/h channel model, the RoT of 6 dB

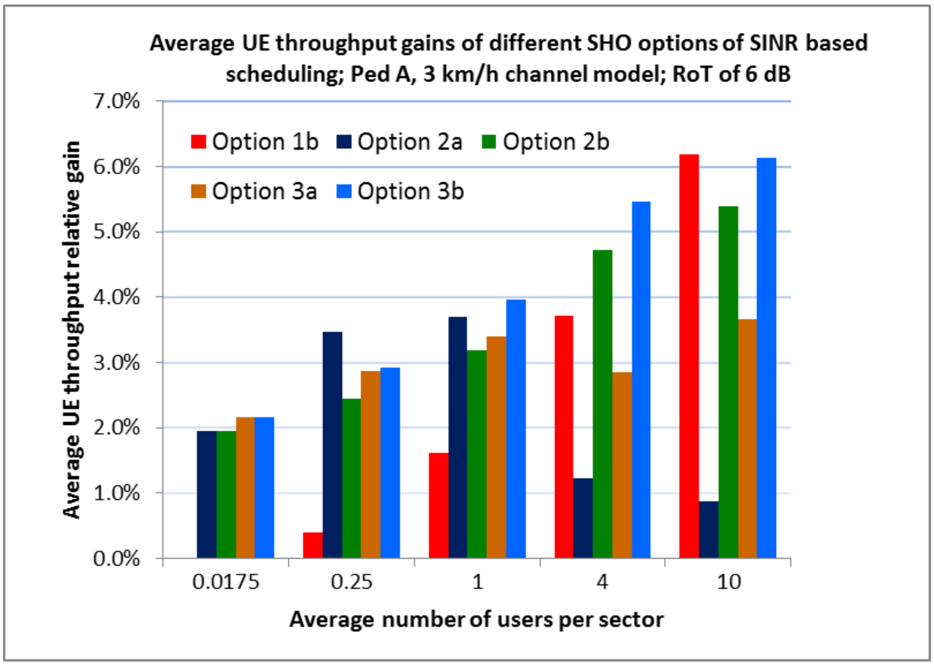


Figure B.3.2.4-2: Relative gains of the average throughput for different SHO options over option 1a, Ped A, 3 km/h channel model, the RoT of 6 dB

Table B.3.2.4-2: Average UE throughputs for different SHO options and relative throughput gains of different options over option 1a, Ped A, 3 km/h channel model, the RoT of 6 dB

Option	UEs per sector	0.0175	0.25	1	4	10
1a	Average t-put	6360	4978	2593	681	224
1b	Average t-put	6360	4998	2635	706	238
	SHO gain	0.0%	0.4%	1.6%	3.7%	6.2%
2a	Average t-put	6484	5150	2688	689	226
	SHO gain	2.0%	3.5%	3.7%	1.2%	0.9%
2b	Average t-put	6484	5099	2675	713	236
	SHO gain	2.0%	2.4%	3.2%	4.7%	5.4%
3a	Average t-put	6498	5120	2681	700	232
	SHO gain	2.2%	2.9%	3.4%	2.8%	3.7%
3b	Average t-put	6498	5123	2696	718	238
	SHO gain	2.2%	2.9%	4.0%	5.5%	6.1%

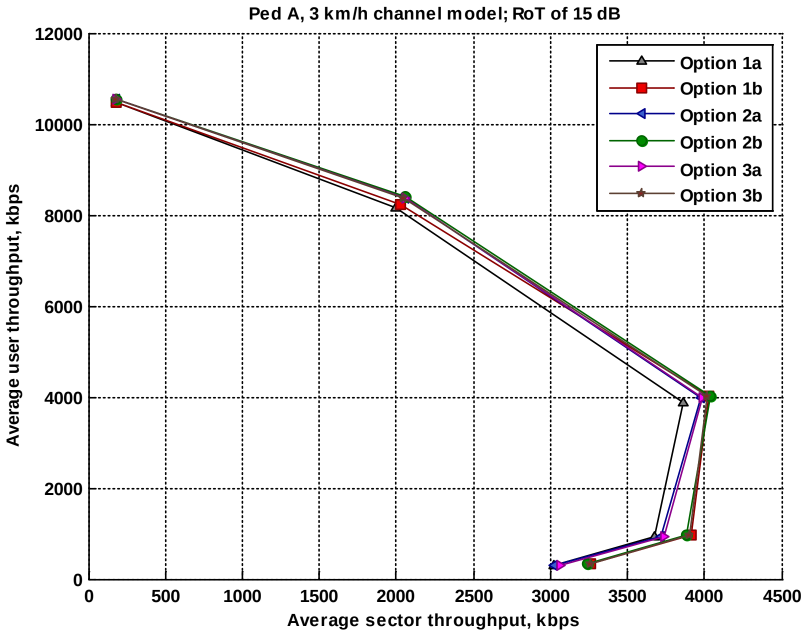


Figure B.3.2.4-3: Average UE throughput versus average sector throughput for different UE densities (0.0175, 0.25, 1, 4 and 10 UEs per sector), Ped A, 3 km/h channel model, the RoT of 15 dB

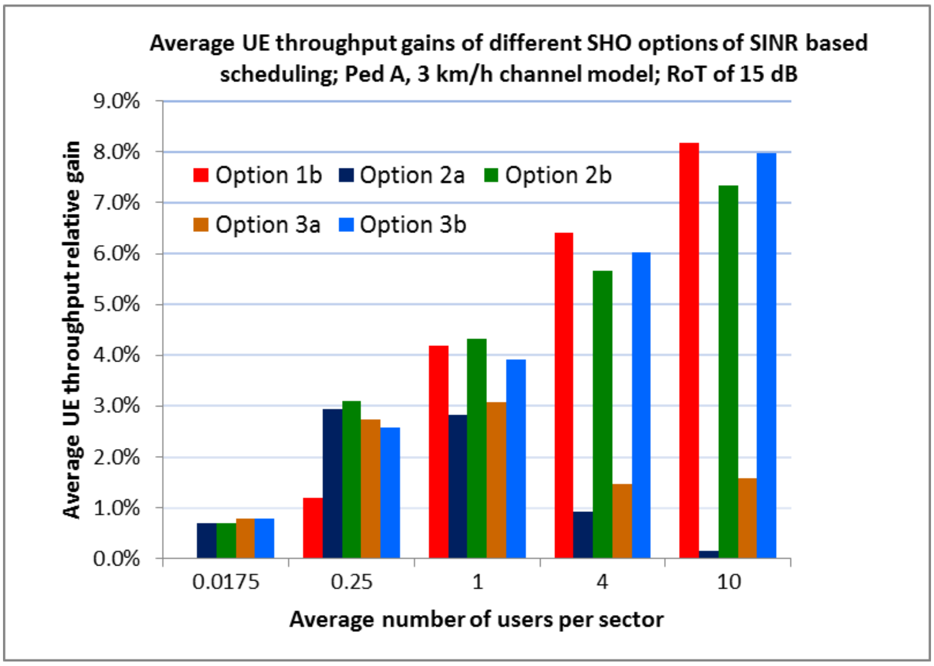


Figure B.3.2.4-4: Relative gains of the average throughput for different SHO options over option 1a, Ped A, 3 km/h channel model, the RoT of 15 dB

Table B.3.2.4-3: Average UE throughputs for different SHO options and relative throughput gains of different options over option 1a, Ped A, 3 km/h channel model, the RoT of 15 dB

Option	UEs per sector	0.0175	0.25	1	4	10
1a	Average t-put	10477	8142	3867	920	302
1b	Average t-put	10477	8240	4029	979	326
	SHO gain	0.0%	1.2%	4.2%	6.4%	8.2%
2a	Average t-put	10550	8380	3976	928	302
	SHO gain	0.7%	2.9%	2.8%	0.9%	0.1%
2b	Average t-put	10550	8394	4034	972	324
	SHO gain	0.7%	3.1%	4.3%	5.7%	7.4%
3a	Average t-put	10558	8365	3986	933	307
	SHO gain	0.8%	2.7%	3.1%	1.5%	1.6%
3b	Average t-put	10558	8352	4019	975	326
	SHO gain	0.8%	2.6%	3.9%	6.0%	8.0%

Veh A, 3 km/h Channel Model

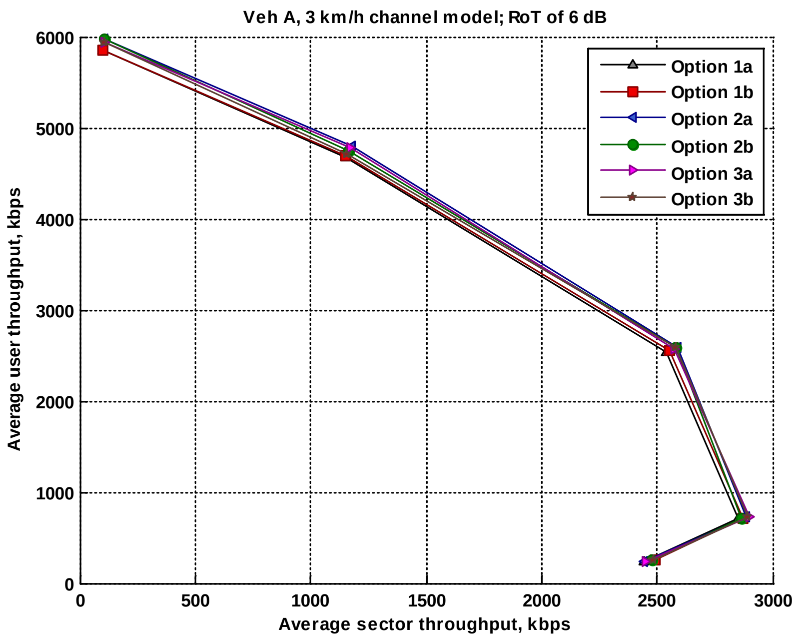


Figure B.3.2.4-5: Average UE throughput versus average sector throughput for different UE densities (0.0175, 0.25, 1, 4 and 10 UEs per sector), Veh A, 3 km/h channel model, the RoT of 6 dB

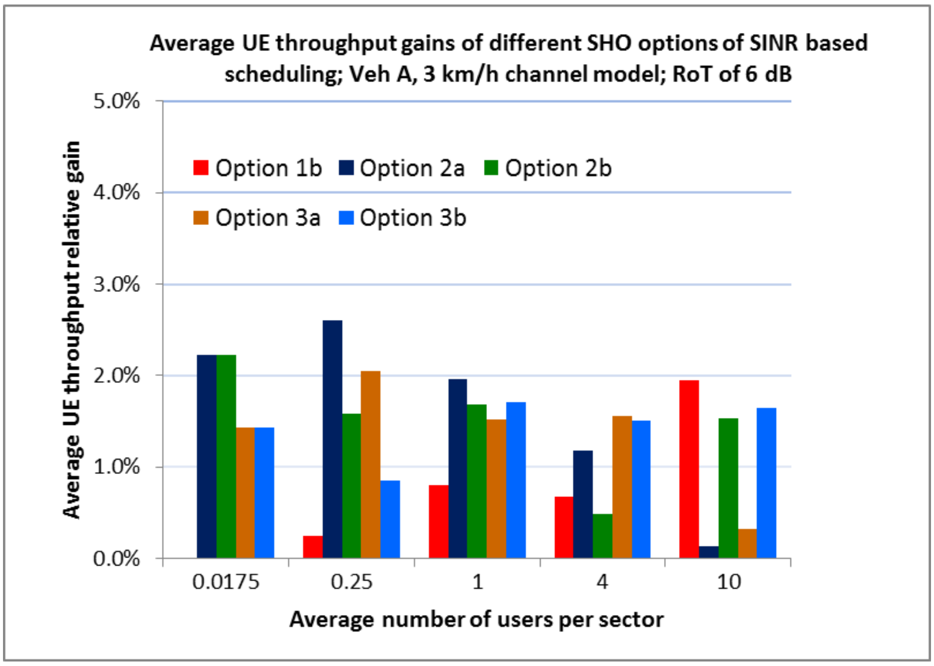


Figure B.3.2.4-6: Relative gains of the average throughput for different SHO options over option 1a, Veh A, 3 km/h channel model, the RoT of 6 dB

Table B.3.2.4-4: Average UE throughputs for different SHO options and relative throughput gains of different options over option 1a, Veh A, 3 km/h channel model, the RoT of 6 dB

Option	UEs per sector	0.0175	0.25	1	4	10
1a	Average t-put	5848	4677	2537	713	244
1b	Average t-put	5848	4689	2557	718	249
	SHO gain	0.0%	0.3%	0.8%	0.7%	1.9%
2a	Average t-put	5979	4799	2587	722	245
	SHO gain	2.2%	2.6%	2.0%	1.2%	0.1%
2b	Average t-put	5979	4751	2580	717	248
	SHO gain	2.2%	1.6%	1.7%	0.5%	1.5%
3a	Average t-put	5932	4773	2576	724	245
	SHO gain	1.4%	2.1%	1.5%	1.6%	0.3%
3b	Average t-put	5932	4717	2580	724	248
	SHO gain	1.4%	0.8%	1.7%	1.5%	1.6%

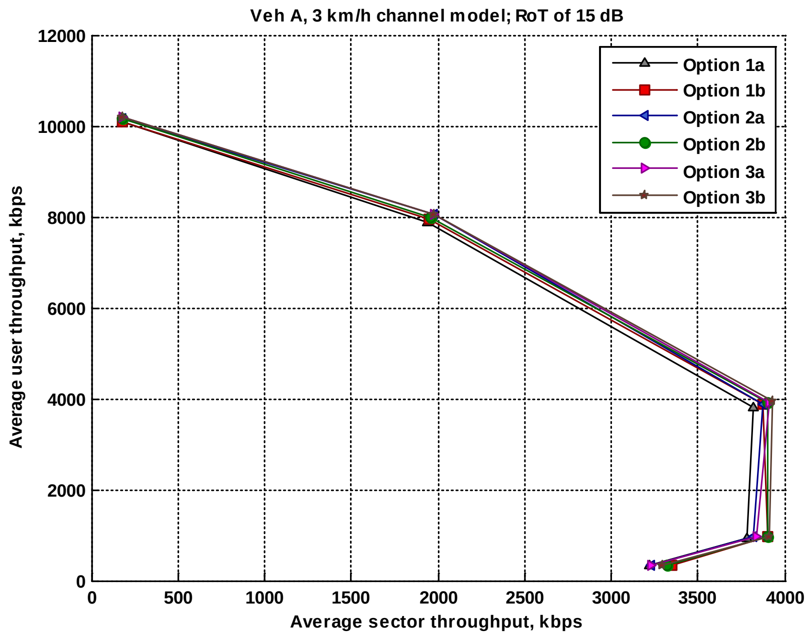


Figure B.3.2.4-7: Average UE throughput versus average sector throughput for different UE densities (0.0175, 0.25, 1, 4 and 10 UEs per sector), Veh A, 3 km/h channel model, the RoT of 15 dB

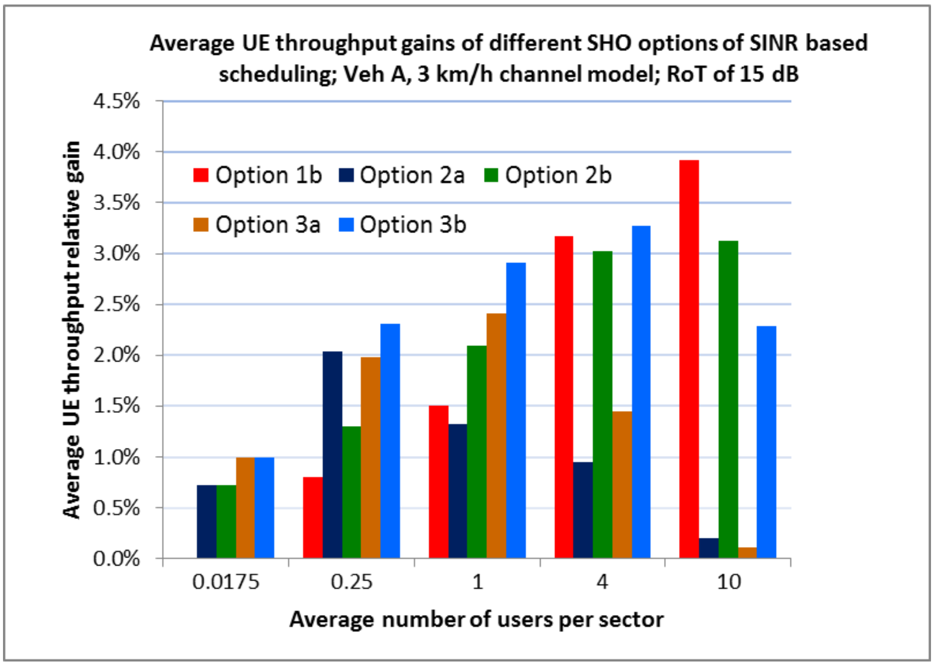


Figure B.3.2.4-8: Relative gains of the average throughput for different SHO options over option 1a, Veh A, 3 km/h channel model, the RoT of 15 dB

Table B.3.2.4-5: Average UE throughputs for different SHO options and relative throughput gains of different options over option 1a, Veh A, 3 km/h channel model, the RoT of 15 dB

Option	UEs per sector	0.0175	0.25	1	4	10
1a	Average t-put	10094	7882	3822	947	322
1b	Average t-put	10094	7945	3879	977	335
	SHO gain	0.0%	0.8%	1.5%	3.2%	3.9%
2a	Average t-put	10167	8043	3873	956	323
	SHO gain	0.7%	2.0%	1.3%	0.9%	0.2%
2b	Average t-put	10167	7984	3902	975	332
	SHO gain	0.7%	1.3%	2.1%	3.0%	3.1%
3a	Average t-put	10194	8038	3914	960	323
	SHO gain	1.0%	2.0%	2.4%	1.4%	0.1%
3b	Average t-put	10194	8064	3933	978	330
	SHO gain	1.0%	2.3%	2.9%	3.3%	2.3%

The presented results demonstrate that the SHO gains with novel rate adaptation differ depending on UE densities and RoT target. Enabling SHO for novel rate adaptation can bring up to 9% average UE throughput gain depending on the channel model used. The final choice of SHO approach should also consider aspects other than throughput gains i.e. complexity, signalling overhead etc.

Annex C: Change history

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
2013-01	R2#81	R2-130442	-	-	Initial Draft	-	0.0.1
2013-05	R2#82	R2-131626	-	-	Updated draft to capture some initial agreements made at RAN2#81bis	0.0.1	0.0.2
2013-05	R2#82	R2-132150	-	-	Clean version (Editorial updates)	0.0.2	0.1.0
2013-05	R2#82	R2-132167	-	-	Version collecting agreements of RAN2#82 in email discussion [82#07]	0.1.0	0.1.1
2013-05	R2#82	R2-132179	-	-	RAN2 agreed version following email discussion [82#07]	0.1.1	0.2.0
2013-08	R2#83	R2-132954	-	-	Version collecting agreements of RAN2#83	0.2.0	0.2.1
2013-08	R2#83	R2-132976	-	-	RAN2 agreed version following RAN2#83	0.2.1	0.3.0
2013-10	R2#83bis	R2-133667	-	-	Version collecting agreements of RAN2#83 in email [83#15] and of RAN1#74 in email [74#31]	0.3.0	0.3.1
2013-10	R2#83bis	R2-133676	-	-	Editorial updates	0.3.1	0.3.2
2013-10	R2#83bis	R2-133677	-	-	Clean version (Editorial updates)	0.3.2	0.4.0
2013-10	R2#83bis	R2-133684	-	-	Version collecting agreements of RAN2#83bis	0.4.0	0.4.1
2013-10	R2#83bis	R2-133731	-	-	Version collecting further agreements of RAN2#83bis in email discussion [82bis#05]	0.4.1	0.4.2
2013-10	R2#83bis	R2-133734	-	-	TR v0.5.0 as agreed by email discussion [83bis#05]	0.4.2	0.5.0
2013-11	R2#84	R2-134541	-	-	Version collecting agreements of RAN2#84	0.5.0	0.5.1
2013-11	R2#84	R2-134542	-	-	RAN2 agreed version	0.5.1	0.6.0
2013-12	RP-62	RP-131708	-	-	Editorial clean up to submit TR for approval to RAN #62	0.6.0	1.0.0
2013-12	RP-62	RP-132011	-	-	MCC clean-up	1.0.0	1.0.1
2013-12	RP-62	-	-	-	TR approved as v12.0.0 at RAN #62	1.0.1	12.0.0