3GPP TR 25.872 V11.0.0 (2011-09)

Technical Report

3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
High Speed Packet Access (HSDPA) multipoint transmission
(Release 11)

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Keywords
UMTS, radio

3GPP

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Contents

Foreword

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

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

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where:

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

Introduction

This TR collects the work done under the HSDPA Multipoint Transmission Study Item [2]

1 Scope

HSPA based mobile internet offerings are becoming very popular and data usage is increasing rapidly. Consequently, HSPA has begun to be deployed on more than one transmit antenna or more than one carrier. As an example, the single cell downlink MIMO (MIMO-Physical layer) feature was introduced in Release 7. This feature allowed a NodeB to transmit two transport blocks to a single UE from the same cell on a pair of transmit antennas thus improving data rates at high geometries and providing a beamforming advantage to the UE in low geometry conditions. Subsequently, in Release-8 and Release-9, the dual cell HSDPA (DC-HSDPA) and dual band DC-HSDPA features were introduced. Both these features allow the NodeB to serve one or more users by simultaneous operation of HSDPA on two different carrier frequencies in two geographically overlapping cells, thus improving the user experience across the entire cell coverage area. In Release 10 these concepts were extended so that simultaneous transmissions to a single UE could occur from four cells (4C-HSDPA).

When a UE falls into the softer or soft handover coverage region of two cells on the same carrier frequency, it would be beneficial for the non-serving cell to be able to schedule packets to this UE and thereby improving this particular user's experience, especially when the non-serving cell is partially loaded. MultiPoint HSDPA allows two cells to transmit packets to the same UE, providing improved user experience and system load balancing. MultiPoint HSDPA can operate on one or two frequencies.

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-101439, “Study Item Description for HSDPA Multipoint Transmission”

[3] R1-110126, “DL Scheduling, RLC and Flow Control assumption for Inter-NodeB Multi-Point Transmissions”, Qualcomm Inc., 3GPP RAN1 #63

[4] R1-106335, “System Performance Evaluation of DF-DC”, Qualcomm Inc., 3GPP RAN1#63.

[5] R1-112880, “Simulation result summary for HSDPA Multipoint Transmission”, InterDigital Communications, LLC., Alcatel-Lucent, Alcatel-Lucent Shanghai-Bell, Ericsson, HiSilicon, Huawei, Nokia, Nokia Siemens Networks, Qualcomm Inc., Renesas Mobile Europe Ltd., ST-Ericsson, 3GPP RAN1#66

3 Definitions, symbols and abbreviations

Delete from the above heading those words which are not applicable.

Clause numbering depends on applicability and should be renumbered accordingly.

3.1 Definitions

For the purposes of the present document, the terms and definitions given in TR 21.905 [x] 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 [x].

Definition format (Normal)

***<defined term>:** <definition>.*

example: text used to clarify abstract rules by applying them literally.

3.2 Symbols

For the purposes of the present document, the following symbols apply:

Symbol format (EW)

<symbol>	<Explanation>

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [x] 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 [x].

Abbreviation format (EW)

<ACRONYM>	<Explanation>

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4 Objectives of the HSDPA Multipoint Transmission Study

The study on HSDPA multipoint transmission should fulfill the following objectives:

- Identify the potential HSDPA multipoint transmission methods and evaluate their system performance and user experience benefits for the following scenarios:
  a. Simultaneous HSDPA transmission from a pair of cells operating on the same carrier frequency in any given TTI to a particular user.
  b. Single HSDPA transmission from any one of the two cells operating on the same carrier frequency in any given TTI to a particular user.
  c. In addition to a single carrier operation, consideration shall also be given to the operation of the HSDPA multipoint transmission method in combination with Release 10 functionality, e.g. MC-HSDPA+MIMO x 2 sectors.
  d. Functionality currently defined in DC-HSDPA and/or 4C-HSDPA for e.g. channel coding of CQI reports and CQI reporting measurement procedures should be reused where possible
  e. Any impact to legacy terminals from any of the proposed methods should be clarified as part of the study.
- Identify potential standardization impact for HSDPA multipoint transmission operation:
- Identify impact to implementation that are relevant to the following for both Intra-NodeB and Inter-NodeB same frequency cell aggregation and cell switching:
  a. ME
  b. RAN

5 Descriptions of the HSDPA Multipoint Transmission Concepts

5.1 Single point data transmission

5.1.1 HS-DDTx

In this scheme:

- One out of two cells operating in the same frequency can schedule a transport block on the HS-DSCH in to the UE, while the other cell does not send anything on HS-DSCH on the corresponding TTI
    - The two cells belong to the same NodeB (Intra-NodeB aggregation)
    - The choice of cell that schedules the transport block can be based on the CQI feedback (i.e. cell that has the stronger CQI)
- The HS timing between the two cells may not be asynchronous
- The UE monitors HS-SCCH on both cells
- The ACK/NACK and CQI information for each cell are transmitted jointly per TTI
- The UE may have a single Rx antenna only and is LMMSE capable

The reference case for this scheme should be single carrier HSDPA.

5.1.2 SF-DC Switching

In this scheme:

- One out of two cells can schedule a transport block on the HS-DSCH in to the UE in the same frequency
    - The two cells belong to the same NodeB (Intra-NodeB aggregation)
    - The choice of cell that schedules the transport block can be based on the CQI feedback (i.e. cell that has the stronger CQI)
- The HS timing between the two cells may be asynchronous
- The UE monitors HS-SCCH on both cells
- The ACK/NACK and CQI information for each cell are transmitted jointly per TTI
- The H-ARQ retransmission in a particular TTI to a UE can be scheduled on either cell
- The UE has a single Rx antenna and is capable of LMMSE per cell

The reference case for this scheme should be single carrier HSDPA

5.1.3 DF-4C Switching

This is an extension of SF-DC switching.

In this scheme:

- The UE is configured on a pair of frequencies (f1, f2)
- On each frequency, one out of two cells can schedule a transport block on the HS-DSCH in to the UE in the same frequency.

    - The pair of cells belong to the same NodeB (Intra-NodeB aggregation)
    - The choice of cell between the two cells that schedules the transport block can be based on the CQI feedback (i.e. cell that has the stronger CQI)
    - A maximum of two transport blocks can be scheduled to the UE during a TTI.
- The HS timing between the two cells may be asynchronous
- The ACK/NACK and CQI information for each of the four cells are transmitted jointly per TTI.
- The UE has a single Rx antenna and is capable of LMMSE per cell

The reference case for this scheme should be DC-HSDPA as in Rel-8.

5.2 Multiflow data transmission

5.2.1 SF-DC Aggregation

In this scheme:

- Each of a pair of cells can simultaneously schedule a transport block on the HS-DSCH to the UE in the same frequency
    - The two cells can
        - belong to the same NodeB (Intra-NodeB aggregation) or
        - belong to non-colocated NodeBs (Inter-NodeB aggregation)
- The HS timing between the two cells may be asynchronous
- The UE monitors HS-SCCH on both cells
- The ACK/NACK and CQI information for each cell are transmitted jointly per TTI
    - In the Inter-NodeB case, both cells decode the HS-DPCCH
- The UE is capable of a Type 3i receiver per cell.

The reference case for this scheme should be single carrier HSDPA

5.2.2 DF-DC Aggregation

In this scheme:

- The UE is configured on a pair of frequencies (f1, f2)
- Each of a pair of cells can simultaneously schedule a transport block on the HS-DSCH to the UE.
- The two cells can
    - be on the same frequency (f1 or f2) or on
    - a different frequency
        - one cell on f1
        - other cell on f2
    - belong to the same NodeB (Intra-NodeB aggregation) or
    - belong to non-colocated NodeBs (Inter-NodeB aggregation)

- The HS timing between the two cells may be asynchronous
- The UE monitors HS-SCCH on both cells
- The ACK/NACK and CQI information for each cell are transmitted jointly per TTI on a single frequency
- The UE has a single Rx antenna and is capable of LMMSE per cell.

The reference case for this scheme should be DC-HSDPA as in Rel-8. In particular, the baseline scheme(s) correspond to a hotspot scenario where one sector transmits on two frequencies (f1,f2) and the neighboring sector transmits on a single frequency as described in [4]. Performance should be evaluated for the UEs that have both SC and DC sectors in the active set, and whose strongest cells on two carriers are different (as shown in Figure 2 of [4]).

5.2.3 DF-4C Aggregation

This scheme is an extension of SF-DC aggregation.

In this scheme:

- The UE is configured on a pair of frequencies (f1, f2)
- On each frequency, each of a pair of cells can simultaneously schedule a transport block on the HS-DSCH to the UE.
    - The pair of cells can belong to the same NodeB (Intra-NodeB aggregation)
    - The pair of cells can belong to different NodeBs (Inter-NodeB aggregation)
    - A maximum of four transport blocks can be scheduled to the UE during a TTI.
- The HS timing between the two cells may be asynchronous
- The ACK/NACK and CQI information for each of the four cells are transmitted jointly per TTI.
- The UE is capable of a Type 3i receiver per cell.

The reference case for this scheme should be DC-HSDPA as in Rel-8.

5.3 Single Frequency Network data transmission

5.3.1 HS-SFN

In this scheme:

- Each of a pair of cells synchronously transmits the bit-exactly same transmission on the same HS-PDSCH codes using the same scrambling code and the same frequency to the UE so that the signals ‘SFN-combine’ over the air and the UE receiver sees just one multipath signal
    - The two cells belong to the same NodeB (Intra-NodeB aggregation)
- The HS timing between the two cells is synchronous
- The transmit phase of each cell may be adjusted (multipoint MIMO)
- The power delay profile of each cell may be adjusted
- The UE monitors HS-SCCH on the serving cell only
- The UE may have a single Rx antenna only and is LMMSE capable

The reference case for this scheme should be single carrier HSDPA

6 Evaluation Methodology

6.1 System Simulation Assumptions

Table 6.1: System Simulation Assumptions for MP-HSDPA

Parameters	Comments
Cell Layout	(1) Hexagonal grid, 19 Node B, 3 sectors per Node B with wrap-around (2) Deployment with Remote Radio heads (Figure 6.2) (3) Hexagonal grid, 19 Node B, 6 sectors per Node B with wrap-around (optional)
Inter-site distance	1000 m
Carrier Frequency	2000 MHz
Path Loss	L=128.1 + 37.6log10(R), R in kilometers
Penetration loss	10 dB
Log Normal Fading	Standard Deviation : 8dB Inter-Node B Correlation:0.5 Intra-Node B Correlation :1.0
Max BS Antenna Gain	14 dBi for 3-sector deployment 17 dBi for 6-sector deployment

Parameters	Comments
Antenna pattern	Mandatory – 3-sector deployment: $A(\theta) = -\min\left[12\left(\frac{\theta}{\theta_{3dB}}\right)^2, A_m\right]$ θ_{3dB} = 70 degrees, Am = 20 dB Optional – 3-sector deployment: (3D ant) Kathrein Antenna Pattern with 7 deg downtilt (1) (3D ant) Based on 36.814, table A.2.1.1.2 (*) $A_H(\varphi) = -\min\left[12\left(\frac{\varphi}{\varphi_{3dB}}\right)^2, A_m\right]$ φ_{3dB} == 70 degrees, A_m = 25 dB $A_V(\theta) = -\min\left[12\left(\frac{\theta - \theta_{etilt}}{\theta_{3dB}}\right)^2, SLA_V\right]$ θ_{3dB} = 10, SLA_v = 20 dB $A(\varphi,\theta) = -\min\{-[A_H(\varphi) + A_V(\theta)], A_m\}$ The parameter θ_{etilt} is the electrical antenna downtilt. Antenna height at the base station is set to 32m. Antenna height at the UE is set to 1.5 m. Optional – 6-sector deployment: $A(\theta) = -\min\left[12\left(\frac{\theta}{\theta_{3dB}}\right)^2, A_m\right]$ θ_{3dB} = 35 degrees, Am = 23 dB
Number of UEs/cell	1, 2, 4, 8, 16, 32 UEs dropped uniformly across the system
Channel Model	PA3, VA3, PB3 (optional) Fading across all pairs of antennas is completely uncorrelated.
CPICH Ec/Io	-10 dB
Total Overhead power	30%
UE Antenna Gain	0 dBi
UE noise figure	9 dB
Thermal noise density	-174 dBm/Hz
Maximum Sector Transmit Power	43 dBm

Parameters	Comments
Soft Handover Parameters	R_{1a} (reporting range constant) = 6 dB, R_{1b} (reporting range constant) = 6 dB CIO = 3dB (DF-DC schemes, for 1-carrier to 2-carrier boundary cells, favouring the 2-carrier sites)
HS-DSCH	Up to 15 SF 16 codes per carrier for HS-PDSCH -Total available power for HS-PDSCH and HS-SCCH is 70% of Node B Tx power, with HS-SCCH transmit power being driven by 1% HS-SCCH BLER, or HS-PDSCH HARQ: Both chase combining and IR based can be used. Maximum of 4 transmissions with 10% target BLER after the first transmission. Retransmissions are of highest priority.
HS-DPCCH	9 slot CQI delay CQI estimation noise may be added
Number of H-ARQ processes	6
Maximum active set size	3
Traffic	Bursty Traffic Source Model File Size: Truncated Lognormal, $\mu = 11.736$ $\sigma = 0.0$, Mean = 0.125 Mbytes, Maximum = 1.25 Mbytes Optional: File Size: Truncated Lognormal, $\mu = 13.061$ $\sigma = 0.35$, Mean = 0.5 Mbytes, STD = 0.1805 Mbytes, Maximum = 1.25 Mbytes Inter-arrival time: Exponential, Mean = 5 seconds
OCNS	OCNS=0, namely all sectors transmit at full power only when they have data.
Candidate Schemes	Multiflow schemes: (1) SF-DC Aggregation (2) SF-DC Switching (3) DF-DC Aggregation (4) DF-4C Aggregation (optional) (5) DF-4C Switching (optional) See Section 5 for more details HS-SFN schemes: (1) HS-SFN with DDTx (2) HS-SFN with feedback

Parameters	Comments
DL Scheduling	The companies should describe the scheduling used. One example scheduling approach is described below • For Intra-NodeB aggregation, a single scheduler is assumed. • For Inter-NodeB aggregation, the scheduler at each cell is independent without any information exchange. • For a UE i, served by cell k, either as the primary or secondary serving cell, its priority is the classic PF metric: $R_{req,\, i,k}/(\alpha_{i,k} R_{served,i,k})$ where $R_{req,\, i,k}$ is the requested data rate based on CQI, $R_{served,i,k}$ is the average served rate and $\alpha_{i,k}$ is a scaling factor. • For each cell, two classes of UEs are defined during scheduling, o Class A: UEs that have this cell as serving (via strongest link). o Class B: UEs that do NOT have this cell as serving (via weaker link). • The used prioritisation mechanism between Class A and Class B UEs shall be described.
Number of MAC-ehs entities	• For Intra-NB schemes, there is only one MAC-ehs entity at the UE. • For Inter-NB schemes, there are two MAC-ehs entities at the UE, one for each cell
RLC layer modeling	(1) Ideal (2) Realistic (optional) – Approach used should be described. (Note 1)
Iub Flow control modeling	(1) Ideal (2) Realistic (optional) – Approach used should be described. (Note 1)
HS-DPCCH Decoding	(1) Ideal (2) Realistic (optional) – Approach used should be described.
MP-HSDPA UE capabilities	All MP-HSDPA UEs are capable of 15 SF 16 codes and 64QAM for each cell Percentage of MP-HSDPA capable UEs : 100% and 30% Note : In the baseline when MP-HSDPA UEs are replaced with non-MP-HSDPA UEs, the receiver type remains the same. Eg : In the baseline when 30% SF-DC-HSDPA UEs are replaced with non SF-DC-HSDPA UEs, these UEs are still capable of Type 3i receiver.
Legacy UE capabilities	(1) Single Rx LMMSE (Type 2)
UE distribution	UEs uniformly distributed within the system (mandatory) Loading ratio between heavily loaded and lightly loaded cells: 3:1 (optional) • The heavily loaded cells are (0,1,8)
Secondary serving cell	The secondary strongest cell in the UE active set, based on path loss and shadowing, is the secondary serving cell. For Intra-NB schemes, secondary serving HS-DSCH cell is further restricted to be at the same Node B as the primary serving cell
CQI Estimation (HS-SFN schems)	(1) Ideal (2) Realistic: CQI estimation model in HS-SFN receiver should be described
CQI Impact **(HS-SFN schemes)**	Realistic: How CQI impact in non HS-SFN users is modeled should be described

Note 1: One example of “realistic” RLC modeling and realistic Iub Flow control modeling was presented in [3].

Table 6.2: Assumptions specific to candidate MP-HSDPA schemes

Scheme	UE receiver
SF-DC Aggregation	Type 3i
SF-DC Switching	Type 2 or Type 3
DF-DC Aggregation	Type 2 or Type 3
DF-4C Aggregation	Type 3i
DF-4C Switching	Type 2 or Type 3
HS-DDTx	Type 2 or Type 3
HS-SFN	Type 2 or Type 3

The 6-sector site is illustrated in Figure 6.1 matching to the more typically used 3-sector 19-site layout. The overall simulation area and site locations are exactly the same as in the 3-sector case.

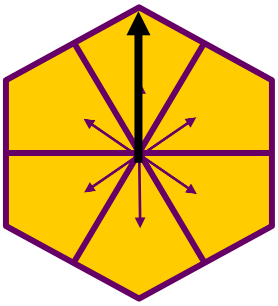

Figure 6.1 A cell-site with 6-sector antennae.

One example of a 6-cell RRH layout is illustrated in Figure 6.2 where the same colored cells correspond to a set of cells controlled by a single Node B. There are 3 RRH clusters in the system. When non-uniform loading is simulated, the heavily loaded cells are (0,1,8). Note that other RRH layouts, e.g. consisting of more RRH clusters can also be studied.

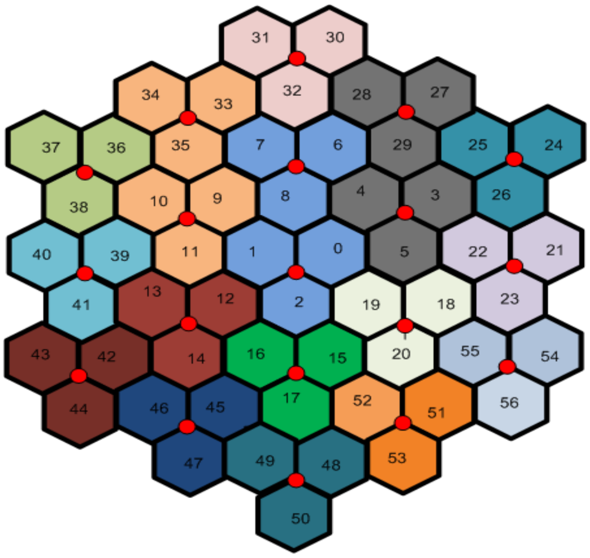

Figure 6.2 A network of 6-cell RRH.

6.2 System Performance Evaluation Metrics

6.2.1 Metrics without modeling RLC or Iub flow control

The following performance metrics should be compared between the reference case and the MP-HSDPA schemes:

- Sector throughput at different number of users (N)
- Normalized and un-normalized user burst rate distribution (CDF)
- User burst rate gain at different user burst rate percentiles or geometries: This would be the user throughput improvements as a function of the user-quantile (relative improvement of average per-user burst rate over user-quantile, e.g. by how much did the burst rate of the worst 10% of users improve). This metric can demonstrate any cell edge user performance enhancement
- User burst rate gain for UEs in softer and soft handover
- CDF of user burst rates for UEs in softer and soft handover
- PER after all the HARQ retransmissions
- Error rate of HS-DPCCH decoding
- Fraction of UEs in softer and soft handover
- In addition to the burst rate gain for all UEs in the system user burst rate gain for those UEs in the 3 heaviest loaded cells should also be reported in the case of non-uniform loading
- In addition to the CDF of the user burst rate gain for all UEs in the system the CDF of user burst rate gain for those UEs in the 3 heaviest loaded cells should also be reported in the case of non-uniform loading

For the MP-HSDPA schemes, the performance metrics should be evaluated separately for the MP-HSDPA capable UEs and the non MP-HSDPA capable UEs.

In the case where a RRH deployment scenario is considered the presented performance measures should only be reported for the UEs which have a cell belonging to a RRH cluster as its serving HS-DSCH cell.

6.2.2 Additional metrics with RLC or Iub flow control modeled

The following performance metrics are helpful to evaluate the impact from the out-of-order MAC reception at the UE:

- RLC retransmission rate
- RLC layer throughput
- PDF of RLC packet delay: the delay is calculated as the time between when the RLC packet is constructed at the RNC until it is delivered by UE RLC receiver to upper layers; RLC packets discarded after maximum number of retransmissions should be counted separately

7 Evaluation Results

Detailed evaluation results can be found in the attached Excel sheet [5].

8 Impact on Implementation

In an HSPA system, slot boundaries for any two cells do not coincide. Moreover, clocks at different cells could have different sources and thereby can drift relative to each other, particularly across Node-Bs. Hence, the HS-DPCCH timeline on the Uplink needs to be defined for MP-HSDPA capable UEs.

ACK timelines are well-defined in 3GPP TS 25.211. The UE transmits ACK 7.5 slots after receiving the HS-PDSCH sub-frame. When MP-HSDPA is deployed and the UE reports ACKs from serving and secondary serving cells using the Rel-8 format, timelines need to be compressed either at the UE (for ACK generation) or at the Node-B (for ACK decoding), or both at the UE and Node-B.

Figure 8.1 shows an example, where the timeline of HS-DPCCH at the UE and Node-B can both be changed so as to distribute the burden of early ACK generation and decoding between the UE and Node-B. In this example, ACK is generated 6.5 slots after the reception of subframe 0 of secondary serving cell, thereby compressing ACK timeline at UE for secondary serving cell. For the serving cell however, the timeline is compressed at the cell site for decoding ACK.

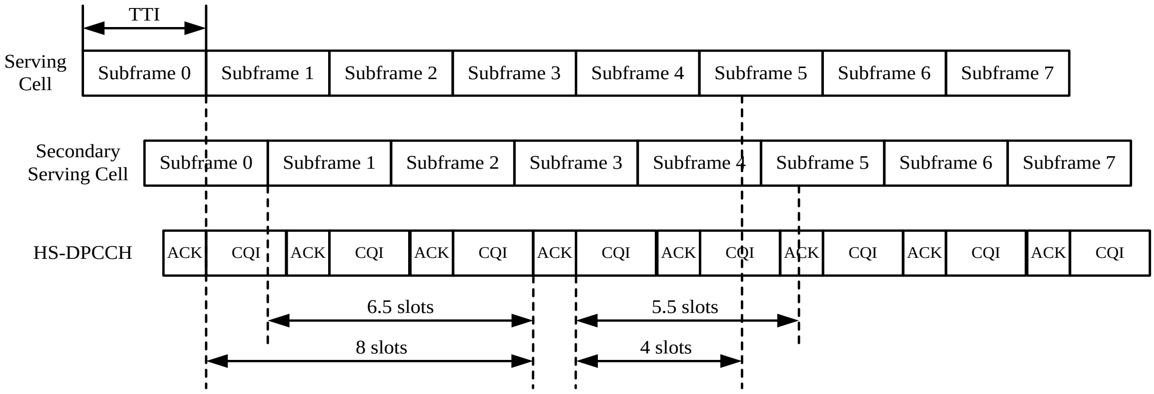

Figure 8.1: ACK Timeline burden shared by both UE and Node-B

8.1 Impact on Infrastructure Implementation

The following additions are required in the signaling from RNC to the UE and from RNC to both the serving and secondary serving cells to support time alignment between the serving and secondary serving HS-DSCH cells .

- Depending upon the compressability of the timelines at the UE and Node-B, the RNC will inform the UE of the subframe pairing and HS-DPCCH timing through an RRC message.
- Through an NBAP message, the RNC will inform the serving and secondary serving cell of the timeline for ACK, so that the serving and secondary serving cells can decode and associate the received ACK to the appropriate subframe transmitted.

Upon receiving a measurement report from the UE (subframe misalignment), the RNC will inform the UE of the timeline and updated subframe pairing it needs to use for the ACK on the uplink. The RNC will also inform the serving and secondary serving HS-DSCH cells of the updated ACK timeline they need to use.

8.2 Impact on UE Implementation

8.2.1 Impact on UE implementation due to asynchronous cell timings

The following changes are required in the UE implementation to support time alignment between the serving HS-DSCH cell and the secondary serving HS-DSCH cell:

- Based on the received RRC message, UE will pair subframes for serving and secondary serving HS-DSCH cells for transmitting ACK in the Release 8 format.
- Whenever sub-frame time difference exceeds a threshold, the UE sends a measurement report to the UTRAN. For this purpose, new events similar to Events 6F/6G may need to be defined.

8.2.2 Impact on UE Implementation due to SF-DC switching

Figures 8.2 and 8.3 show the block diagrams of the RF/Front end and baseband processing of a SF-DC switching UE that has a single Rx antenna and is capable of LMMSE receiver (Type 1) per HS-DSCH cell.

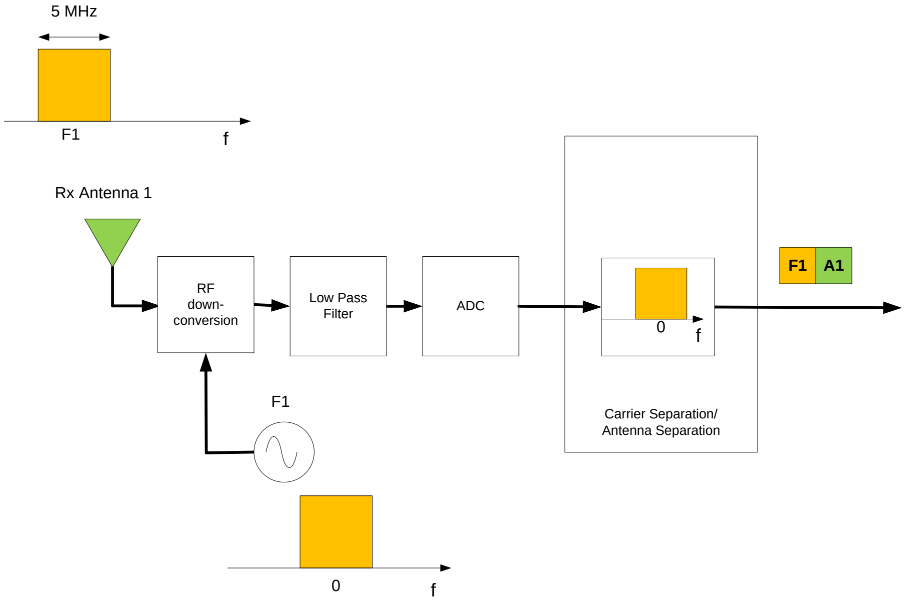

Figure 8.2: Single Rx Antenna, SF-DC-HSDPA switching receiver: RF/Front End

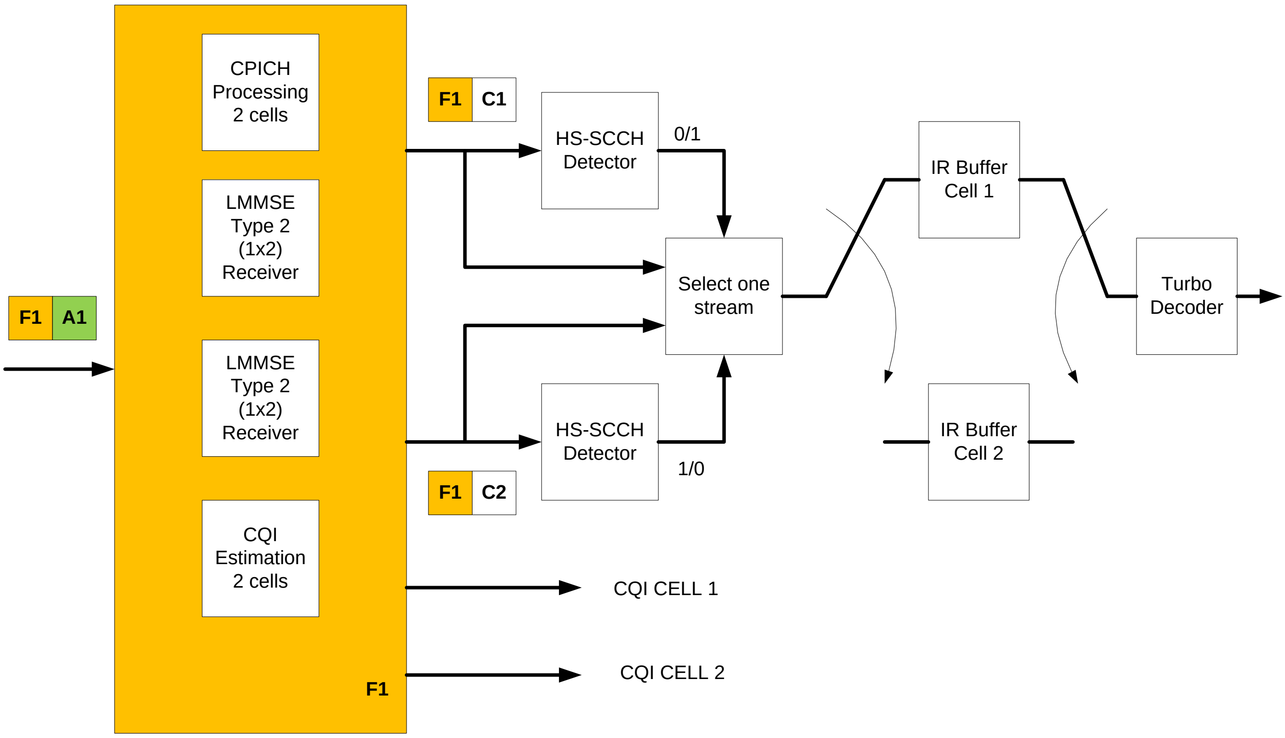

Figure 8.3: Single Rx Antenna, SF-DC-HSDPA switching receiver: Baseband processing

8.2.3 Impact on UE Implementation due to SF-DC and DF-DC aggregation

Figure 8.4 illustrates a high level block diagram of a Rel-8 DC-HSDPA UE (adjacent carriers) with Rx diversity enabled, while Figure 8.5 illustrates a block diagram of it's RF/Front end. Note that the same receiver can be reused for the purpose of DF-DC aggregation.

Figures 8.6 and 8.7 illustrate the case when SF-DC aggregation is enabled in the UE. As seen in Figures 8.6 and 8.7, the modifications needed to support SF-DC aggregation relative to a Rel-8 DC-HSDPA receiver are quite trivial. In fact the RF/Front end is identical to a SC-HSDPA UE. As shown in Figure 8.5, the major change relative to a DC-HSDPA UE is to connect the SC-HSDPA RF/Front end output to both the base-band receiver chains and rely on single carrier functions in the base-band of one of the receiver chains to control the RF/Front end.

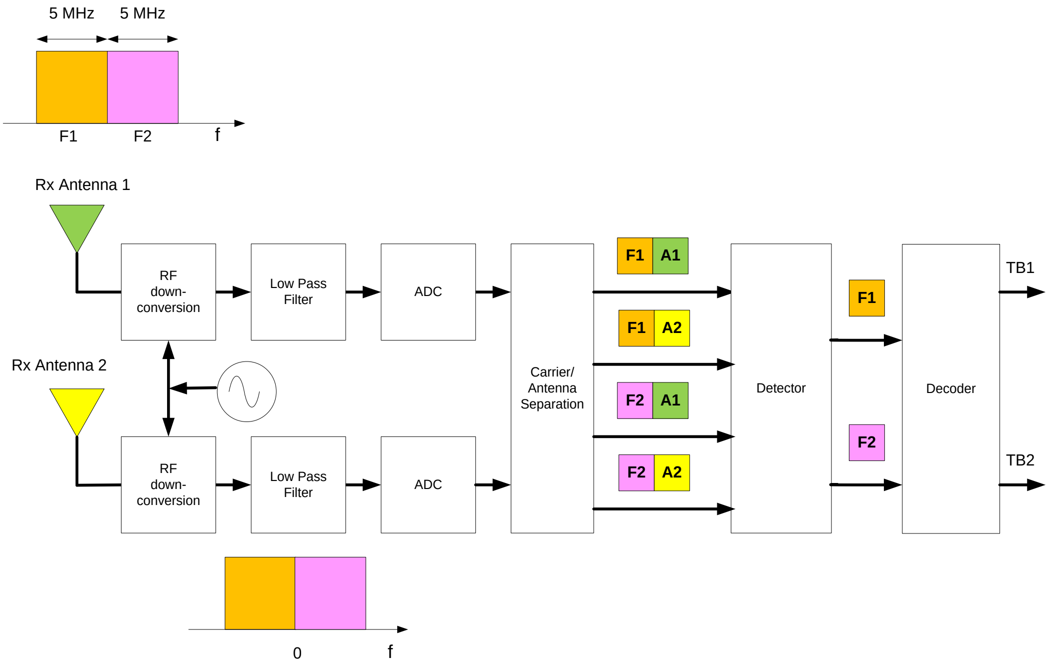

Figure 8.4: DC-HSDPA UE Receiver: High Level Block Diagram

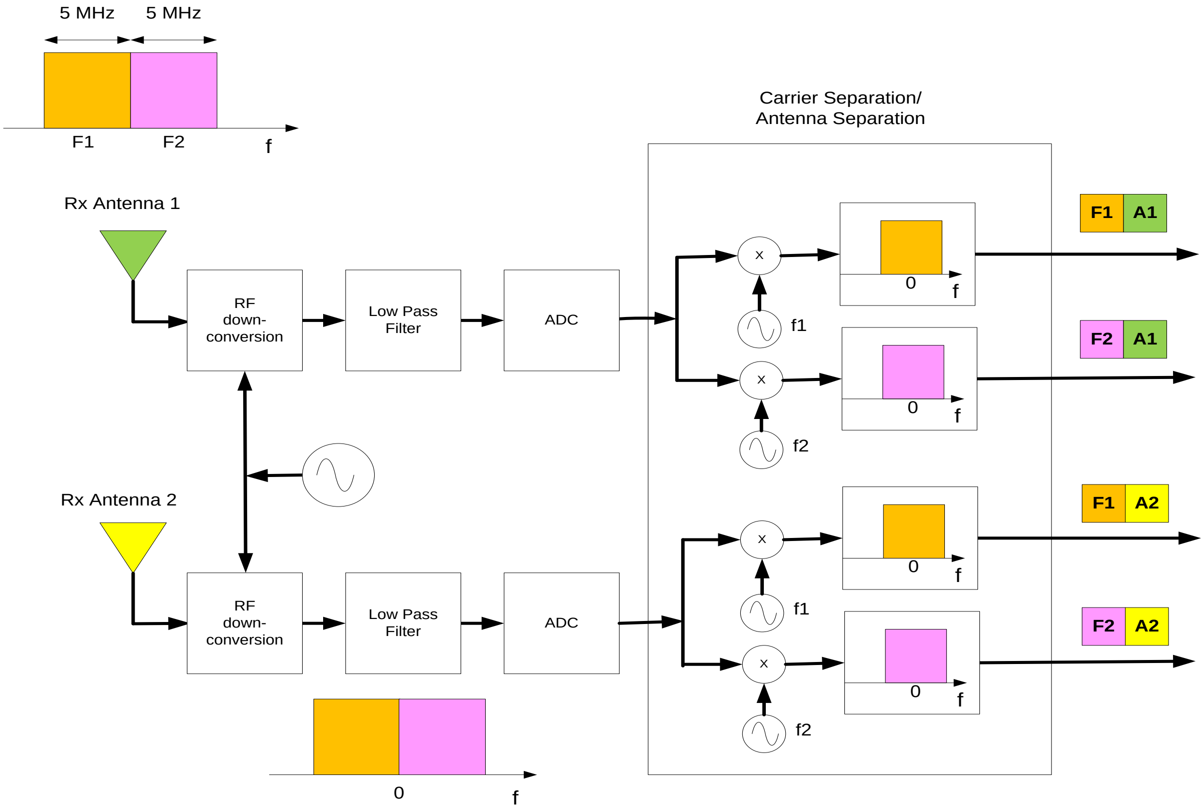

Figure 8.5: DC-HSDPA Receiver: RF/Front End Block Diagram

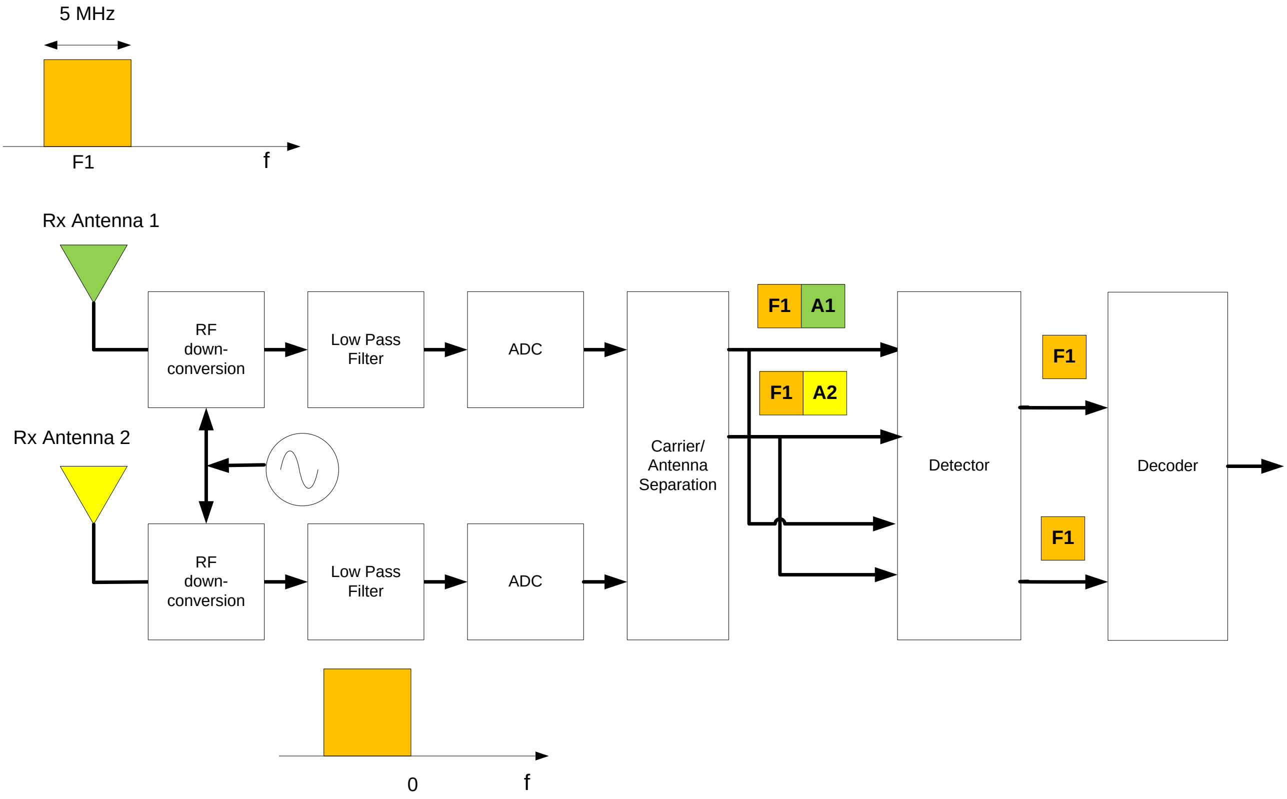

Figure 8.6: SF-DC-HSDPA aggregation receiver: High Level Block Diagram

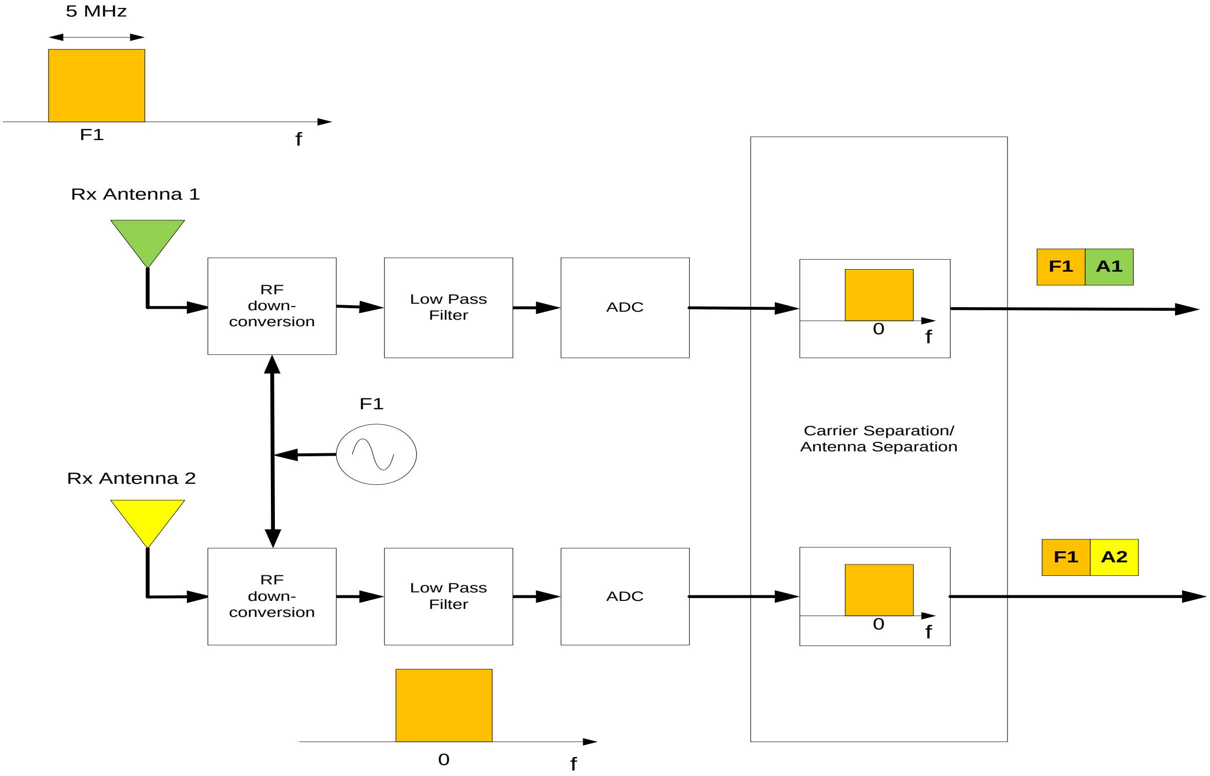

Figure 8.7: SF-DC-HSDPA aggregation receiver: RF/Front End Block Diagram

8.2.4 Impact to synchronization function of the secondary serving HS-DSCH cell

One key difference relative to DC-HSDPA is that the timing of the secondary serving HS-DSCH cell may be asynchronous to the serving HS-DSCH cell. This may be due to either of the following:

- In order to avoid having overlapping SCHs in different cells belonging to the same NodeB, a timing delay denoted by T_{cell} is introduced in each cell of a NodeB to delay the start of SCH, CPICH and the DL Scrambling Code(s) in that cell.
- In the case of transmissions from different NodeBs to a single UE, since the NodeBs are asynchronous with respect to each other, the timing difference on the HS-PDSCH between 2 different NodeBs can be offset to within a 2ms sub-frame

While the above may affect the synchronization function as implemented today in a DC-HSDPA UE implementation, it should be noted that since Rel-99, UE is capable of demodulating DCH transmissions from asynchronous cells in soft handover. Hence, the synchronization function from such an implementation can be reused for the purpose of demodulating the secondary serving HS-DSCH cell.

8.2.5 Summary of Impact on UE Implementation

Table 8.1: RF/Front End Complexity Comparison

	Baseline DC-HSDPA or DF-DC aggregation	SF-DC-HSDPA switching	SF-DC-HSDPA aggregation

Number of configured downlink frequencies	2	1	1
Number of configured serving HS-DSCH cells	2	2	2
Number of physical Rx antennas	2	1	2
Number of RF local oscillators	1	1	1
Number of RF down conversion units	2	1	2
Number of Analog LPFs	2	1	2
Analog LPF bandwidth [MHz]	10, 10	5	5, 5
Normalized ADC Sampling Rate	1.0, 1.0	0.5	0.5, 0.5
Number of digital oscillators	4	0	0
Number of digital phase rotators	4	0	0
Number of digital FIR filters	4	1	2

Table 8.2: Baseband Complexity

	Baseline DC-HSDPA or DF-DC aggregation	**SF-DC-HSDPA switching**	**SF-DC-HSDPA aggregation**
Receiver Type per cell	Type 3	Type 1	Type 3i
Number of cells in which HS-PDSCH is simultaneously received	2	1	2
Synchronization function in Secondary Serving HS-DSCH cell	Does not rely on presence of SCH in secondary serving HS-DSCH cell	Two options: 1. Rely on presence of SCH in secondary serving HS-DSCH cell or 2. Signal timing difference between P-CCPCH radio frames of the two serving HS-DSCH cells	Two options: 1. Rely on presence of SCH in secondary serving HS-DSCH cell or 2. Signal timing difference between P-CCPCH radio frames of the two serving HS-DSCH cells
Generation of ACK in secondary serving HS-DSCH cell	7.5 slots	4.5 to 7.5 slots	4.5 to 7.5 slots
Peak data rate [Mbps]	43.2	21.6	43.2

9 Higher layer impact

9.1 Overview

One of the multi-point schemes, called HS-SFN, assumes that exactly the same data on the same scrambling code is scheduled from different cells to a UE. Since the transmitted data is exactly the same, limited or no changes to the higher layer protocols, in particular RLC and PDCP, are expected. Other schemes, such as SF-DC aggregation and DF-DC aggregation, which hence will be collectively referred to as “Multiflow” schemes, assume that the application level data is split in the access network thus scheduling different content from different cells. Obviously it requires changes in the MAC and higher layers to sustain such architecture. Within HSPA RAN at least three potential data split options can be identified, which hence will be referred to as MAC-ehs, RLC, and PDCP splits. In turn, data split options depend heavily on whether the participating set belongs to the same site or different sites, i.e., whether intra- or inter-site transmission takes place. For the obvious reasons the RNC based options (PDCP and RLC splits) are better suited for inter-site scenarios, while the MAC-ehs split is in practice limited to intra-site operation. For the sake of further clarity, we will consider them separately based on whether it is intra- or inter-site Multiflow.

9.2 Intra-site Multiflow data split

Since data transmission in the intra-site Multiflow scheme takes places from cells belonging to the same site, it is possible to implement data split at the MAC-ehs layer, which would be almost identical to the DC-HSDPA architecture and, therefore, would require relatively small modifications, if any. The UE MAC-ehs can be shared and different data can be transmitted over different cells on their respective HARQ processes. Furthermore, data split in MAC-ehs would enable joint scheduling leading to higher scheduling gains. Unlike inter-site specific data split options, which are considered below, the fact that RLC PDUs may arrive in a different order over different HARQ processes is handled by the MAC-ehs TSN numbering. Thus, RLC PDUs are delivered to the RLC receiver in sequence.

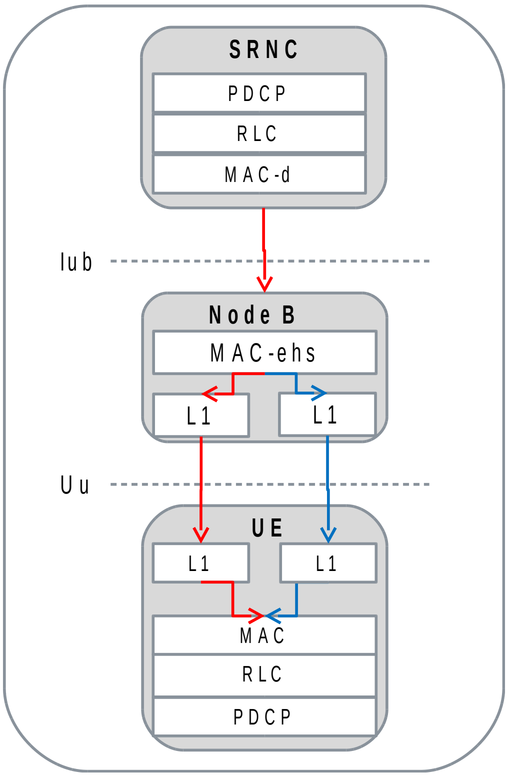

Figure 9.1 MAC-ehs traffic split solution

However, the MAC-ehs option is not available for inter-Node B multipoint operation, mainly due to the fact that there is no interface between the Node Bs. Furthermore, even if there were such an interface, MAC-ehs splitting would only be possible and beneficial if that interface did not suffer from any delays. Therefore, we can conclude that MAC-ehs splitting is not an option that should be considered for inter-Node B Multiflow scheme.

9.3 Inter-site Multiflow data split

In this subsection we consider a few data split options which are applicable to inter-site scenario. In particular, the RLC level and the PDCP level solutions are presented. Both schemes aim at addressing the concern that upper layer packets may be delivered out-of-order.

9.3.1 RLC split

As follows from its name, the RLC level data split suggests that higher layer data, after forming one stream of RLC PDUs, is split into multiple streams each destined to a correspondent cell. So, similar to the existent architecture, there is a single RLC entity per UE.

The advantage of this scheme is that the RNC is more flexible in optimizing how large SDUs are segmented to RLC PDUs depending on each link status. As an example, a large SDU can be segmented into (at least) two pieces, where each of them is scheduled over a different link. In addition, subsequent RLC re-transmissions can take place over either link in the participating set thus possibly benefiting from instantaneously better and/or less loaded cell. The extent of the gain may need to be further evaluated since the RNC does not have the real-time information from each cell and majority of the re-transmissions are handled by HARQ. Also the traffic pattern and link throughput imbalance has large impact on how beneficial it is to use RLC segmentation for the packet delay optimization.

Since there is a single RLC stream, which is transmitted from cells belonging to different sites, RLC PDUs are likely to arrive to a UE in a different order. In general, this issue is similar to the situation with DC-HSDPA and L1 HARQ retransmissions. However, in DC-HSDPA, the T1 timer used for re-ordering ensures that enough time is given to the UE to receive a packet that can be potentially delayed due to HARQ retransmissions. With multi-point transmissions we can no longer rely on the MAC-ehs to account for any potential delays as the data from different Node Bs will be reordered in different MAC-ehs entities or reordering queues. As a solution to avoid unnecessary NACKs, an appropriate value for the status prohibit timer can be set. However, having a relatively small status prohibit timer optimized for DC-HSDPA operation may result in sending a NACK too early in the Multiflow scenario thus reducing the overall performance. Indeed, one can expect considerably larger delays due to different Iub load and completely independent scheduling. Setting the status prohibit timer to a large value and waiting for a RLC PDU may lead to unnecessary performance degradation as an RLC PDU may indeed have been lost.

In R2-112849, a network mechanism is proposed that aims at avoiding unnecessary retransmissions. In this scheme, the UE Status PDU reporting mechanisms remain unchanged. This scheme relies upon an algorithm at the RNC side that keeps track of a cell, over which a RLC PDU is transmitted for the first time. Based on the Status PDU from the UE, RNC distinguishes whether a sequence number gap is due to genuine loss or out-of-order.. RNC utilizes this information to delay, up to a timer value, on retransmitting the data in the sequence number gap identified as out-of-order. As seen in R1-111542, the impact of this retransmission delay timer is minimal. In particular, the RLC PDU delays are improved due to higher MAC throughput and no delay in the retransmission of the genuinely lost RLC PDUs is incurred. At the same time, there are concerns that the retransmission delay timer may cause outage for the TCP layer and the TCP performance may suffer due to longer RTT. It will furthermore take longer time duration to pass the TCP slow start phase and consequently user perception may degrade.

In R2-113299, another mechanism is proposed which relies on the UE starting a timer in the RLC whenever a missing RLC PDU sequence number is detected. If the timer expires and the RLC PDU(s) within the gap have not been received, the UE determines that the data has been genuinely lost and may report the STATUS report to the transmitting entity. This mechanism has the advantage that RLC Status reporting is prohibited until the UE is sure that the data is genuinely lost. On the one hand, this solution does not introduce any complexity to the network, on the other hand, it introduces some RLC protocol modifications to the UE. Additionally, when compared to the network based algorithm, this mechanism does not require the UE to send very frequent periodic status report, but can rely on missing RLC PDU status reporting. However, one disadvantage of this scheme is that the UE cannot immediately distinguish between genuine loss and out-of-order due to skew, thus the recovery for genuine lost RLC PDUs may be delayed by this timer.

In R2-112050, it was identified that due to the common RLC sequence numbering space, a stalled data transmission at one Node B can block the overall data transmission due to the limited window for outstanding packets. Although this issue is not specific to RLC split based schemes, it is believed that it can be mitigated with a properly chosen retransmission delay timer and tighter Iub flow control.

In addition, a solution with one RLC entity has clearly an advantage of ensuring the SDU in-sequence delivery. Indeed, since there is one RLC receiver buffer with a single numbering space, no additional mechanisms are needed. Yet another advantage is that whenever a link changes or is removed from the participating set, the RLC level ACK/NACKs will ensure the retransmission of RLC PDUs dropped from Node B buffers as a result of link removal.

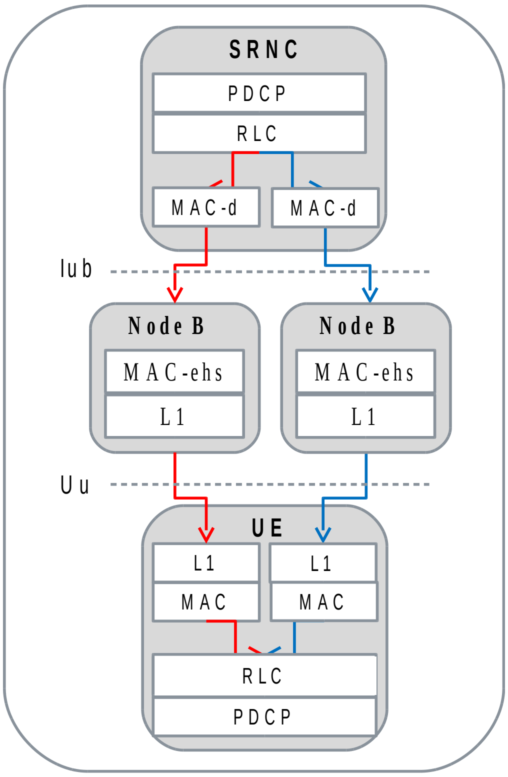

Figure 9.2 RLC level traffic split solution

9.3.2 PDCP split

Another option for splitting data in the inter-site scenario is the PDCP layer. Its benefit is that it allows for keeping the lower protocol layers untouched and parallelising of RLC processes in RNC. As follows from the figure, RNC keeps several (at least two) RLC state machines for a single PDCP entity per UE. As a result, there is no need for a bookkeeping scheme to track over which cell a particular PDU is transmitted, and a UE can send safely ACK/NACKs for a correspondent RLC stream. One drawback of this scheme is that RLC PDU re-transmissions must be performed over the same RLC stream as the initial transmission. Another limitation is that the PDCP layer lacks segmentation support, which may lead to higher packet delays if the radio link qualities are unequal and the number of PDUs in PDCP buffer is very low.

When compared to the RLC split, another important difference is that the SDU in-sequence delivery must be ensured at the PDCP layer based on SDUs received from both RLC entities. For this purpose, it is necessary to mandate the usage of the PDCP SN field. This additional overhead is small because the SN field will take only two bytes per SDU. One can argue that having an additional re-ordering buffer at the PDCP layer will cause increased memory consumption. Indeed, depending on the memory allocation strategy – either static or dynamic – the overall memory consumption will be either larger or comparably the same when compared to the RLC split.

Another important issue of the PDCP split is the absence of ACK/NACK mechanism. However, it bears mentioning that the each RLC stream provides a guaranteed delivery thus ensuring that at the end all the SDUs will be delivered to the PDCP reordering buffer. Otherwise, if RLC runs out of retransmission attempts, either an RLC Reset procedure or an RLC unrecoverable error is triggered and the whole bearer will need to be re-established. If under this or similar circumstances a particular SDU is missing in the PDCP re-ordering buffer and is not delivered by the network, then the data forwarding process may stall at the UE side. As a result, the UE may resort to implementing the additional PDCP level timer that will advance automatically the re-ordering buffer upon timer expiry. Somewhat similar to the RLC split retransmission delay timer, it must be started for every gap seen in the PDCP re-ordering buffer. This timer value must obviously account for the maximum number of attempts the network can do so as not to wait more than the maximum number of RLC retransmissions can take. Any holes seen at the PDCP level at the expiry of this timer would then need to be recovered through TCP retransmissions.

Similar to the RLC split, the PDCP level solution may suffer when one of the radio links is removed thus potentially causing RLC PDU drops from the Node B buffer. However, unlike the RLC split, there is no intrinsic mechanism that can send ACK/NACKs for SDUs. As an example, if a UE has two cells in its active set and is served by both primary serving cell and secondary serving cell, and event 1B is triggered to remove the secondary serving cell from its active set, there can be remaining data at the Node B buffer at secondary serving cell. Possible solutions are the network side intelligent re-buffering and re-transmission schemes, as well as "flexible mapping" approach proposed in R2-112849. In a few words, two logical channels are always maintained for the same data flow, even after event 1B. In steady state, each RLC is transmitted over one particular cell. During mobility events, such as event 1B, RLC PDUs which were mapped to the affected cell can be transmitted or retransmitted over the other cell.

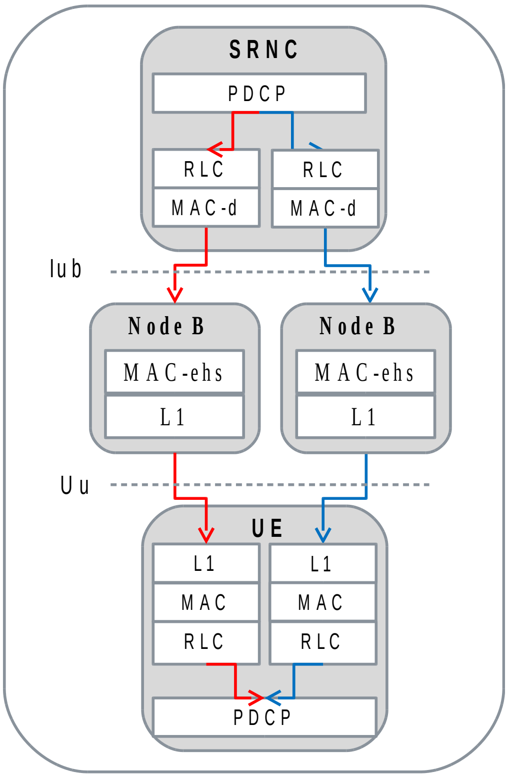

Figure 9.3 PDCP level traffic split solution

10 Impact on performance of legacy UEs

It is essential to ensure that introduction of any new feature does not degrade performance for existing users.

Multiflow schemes schedule terminals from multiple cells, and thus has the potential to generate a larger amount of interference in the system than is the case when Multiflow schemes are not present. Such interference could impact in particular users that do not have interference mitigating receivers. Furthermore, scheduling Multiflow users in secondary serving cell(s) might reduce the amount of resources available for non Multiflow users in those cells. On the other hand, improved throughput due to Multiflow can reduce the amount of time for which Multiflow users are scheduled, which would have the opposite effect.

It is possible to mitigate any loss of scheduling opportunities for non Multiflow users by either giving absolute priority to scheduling users for whom the scheduling cell is their primary serving cell in the Node B scheduler, or through higher layer load sharing techniques such as Iub flow control, or a combination of prioritization schemes in the Node B scheduler and Iub flow control..Note though that if no prioritization is present between non Multiflow users and Multiflow users some degradation on the non Multiflow users could be expected.

System performance results relating to Multiflow in which only 30% of UEs were Multiflow capable are captured in the attached spreadsheet (detailed in section 7). The remaining 70% of the UEs were not Multiflow capable and did not possess interference mitigating receivers. Simulations were carried out under the assumption of ideal flow control, but with Node B schedulers that gave absolute priority for users for whom the scheduling cell was their primary serving cell.

The results show that enabling Multiflow has a negligible impact on the performance of the legacy users if priority is given to users for whom the scheduling cell is their primary serving cell.

Other simulations on Multiflow with realistic RLC and flow control modelling also show the same conclusion.

Study of the impact of HS-SFN on legacy users follows the similar analysis to the multiflow schemes, and the system performance results relating to the HS-SFN scheme with partial penetration of HS-SFN capable users (30%) also show a negligible impact on the legacy users if the scheduling priority is given to the users for whom the scheduling cell is their primary serving cell.

The impact of HS-DDTx on legacy users was not studied. Some concerns were raised on the impact of HS-SFN to legacy UEs' reception of control and common channels as well as impact on CQI computation's accuracy.

11 Impact on specifications

The likely specification impacts of Multiflow (SF-DC, DF-DC, DF-4C) and single point switching (SF-DC, DF-4C) are outlined in the subsections below. The specification impacts of HS-DDTx and HS-SFN were not studied.

11.1 Impact on RAN1 specifications

25.211

Both Multiflow and switching operation can be introduced without major modifications to the physical channels

25.212

The coding and modulation of the data can be done per serving cell as today. For the HS-DPCCH channel, the joint structure defined in the MC-HSDPA features can be used for Multiflow. For switching; some optimisation of the HS-DPCCH may be possible for switching due to the reduced amount of ACK/NACK/DTX combinations.

25.213

No modifications are envisaged to be required

25.214

The signalling of the modulation and coding scheme can be done using the Type-1 HS-SCCH format available in Release 7 using one HS-SCCH on each serving cell.

An update to the timing relationship between HS-PDSCH reception and ACK/NACK will be required to take into account the difference in timing of the two serving cells.

Some signalling of the intra Node B cell timing offset parameter T_{cell} and / or some modification of the synchronisation procedure may be required; the need for which would need to be studied further during a WI.

11.2 Impact on RAN2 specifications

25.306

UE capabilities relating to supported Multiflow or switching options would be introduced.

25.319

A Stage 2 description of the Multiflow and/or switching operation would be needed.

25.321

No change is expected to the existing MAC-ehs protocol architecture. Since the single point data transmission schemes (SF-DC switching, DF-4C switching) apply to two cells in the same Node B, a single data flow is split at the MAC-ehs layer. If the Multiflow transmission schemes are applied to two cells in the same Node B, a single data flow is split at the MAC-ehs layer

For Inter-NodeB SF-DC aggregation cases, downlink data should be split to two serving cell (NodeBs). Currently there are two options, one is RLC based data split, and the other is PDCP based data split. Each option will introduce additional modifications to RLC layer (25.322) or PDCP layer (25.323).

25.331

Some signalling of the intra Node B cell timing offset parameter T_{cell} and / or some modification of the synchronisation procedure may be required; the need for which would need to be studied further during a WI.

RRC Messages and associated procedure s containing physical layer & MAC configuration would need to be added.

A UE capability would need to be indicated either in RRC CONNECTION REQUEST or RRC CONNECTION SETUP COMPLETE message.

11.3 Impact on RAN3 specifications

Configuration in RAN3, NBAP or RNSAP signallings would be extended to indicate configuration, e.g. the Radio Link Setup procedure.

The Radio Link Reconfiguration procedure could be used to setup and/or change a secondary serving HS-DSCH.

11.4 Impact on RAN4 specifications

25.101

Existing Tx and Rx core RF requirements as specified for single frequency devices apply to SF-DC UE. Existing Tx and Rx core RF requirements as specified for DC-HSDPA devices apply to DF-4C UEs

New demodulation requirements may be needed for HS-DPCCH for switching if the HS-DPCCH is optimised

TS 25.104, Rel-10:

There is a potential need to introduce a relative frequency error and/or a relative time alignment error between serving HS-DSCH cell and secondary serving HS-DSCH cell that belong to the same NodeB on a configured downlink frequency.

12 Conclusion

HSDPA Multipoint Transmission schemes, in particular, the Multiflow schemes, provide promising gain in user throughput, especially for users in the handover region.

In case that ideal RLC and Iub flow control are assumed, the gain under uniform loading is seen mostly in the light to medium loading scenarios. For example, under medium to light loading, the Intra-NodeB Multiflow scheme can provide up to around 30% to 50% average throughput gain for users in softer handover, and around 3 to 5% for all the users; the Inter-NodeB Multiflow scheme can, in addition provide around 20% to 30% average throughput gain for users in soft handover, and around 3% to 10% for all the users. The Inter-NodeB Multiflow schemes provide much larger gain in overall user throughput than the Intra-NodeB only schemes, since many more users can benefit from Multiflow scheduling. It was also shown that similar gains can be obtained in the light to medium loading for certain realistic RLC and Iub flow control algorithms.

When the load across cells is not uniform, the Multiflow gain is much more significant for UEs in the heavily loaded cells with lightly loaded neighboring cells. For example, in the heavily loaded cells, the Intra-NodeB Multiflow scheme can provide over 50% throughput gain for users in the softer handover region and gains well over 100% were observed in some scenarios; the Inter-NodeB Multiflow scheme can, in addition, provide similar gains for users in the soft handover region.

Furthermore, using appropriate prioritization schemes, the gains from Multiflow can be obtained with minimal or no degradation to legacy UEs. It is worth noting that Inter-NodeB Multiflow schemes, by allowing data to be sent over multiple Iub links, can also provide higher gains when the Iub capacity is the limiting factor.

Both Intra-NodeB and Inter-NodeB Multiflow schemes require certain modification to the physical layer to support asynchronous cells. In addition, the Inter-NodeB Multiflow schemes require certain enhancements to the upper layers

(RLC or PDCP). Overall, the impact of the Multiflow schemes on the network and UE implementations is fairly modest.

From a complexity versus performance analysis perspective, at this stage the *Multiflow Data Transmission* family of multipoint concepts appears to be the most attractive for work item considerations. The different design choice alternatives available for the inter-site operation option could be further investigated in the possible WI phase.

Annex A: Change history

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
2011-02	R1#64	R1-111049			Initial Draft		0.1.0
2011-02	R1#64	R1-111166			Updated with R1-111050, R1-111051		0.1.1
2011-02	R1#64	R1-111206			Editorial corrections		0.1.2
2011-03	R1#64	R1-111116			Updates after email review		0.1.3
2011-05	R1#65	R1-111843			Restructured according to R1-111487, updated with R1-111546 and R1-111547, converted to a new TR template		0.1.4
2011-05	R1#65				Added a TR number, included evaluation results in R1-111847		0.1.5
2011-05	R1#65	R1-111867			For information to RAN#52 as v1.0.0. Included updated evaluation results in R1-111866		1.0.0
2011-08	R1#66	R1-112636			Updated with R2-113617	1.0.0	1.0.1
2011-09	R1#66				Small update to section 8 timing example and inclusion of sections 10, 11 and 12 according to post-RAN1#66 meeting email review	1.0.1	1.0.2
2011-09	R1#66	R1-112734			Updated after email review	1.0.2	1.0.3
2011-09	R1#66	R1-112879			Endorsed as v2.0.0 and submitted to RAN#53 for approval	1.0.3	2.0.0
2011-09	RAN#53	RP-111207	-	-	Go under change control as version 11.0.0 according to plenary decision	2.0.0	11.0.0