TS 25.402 V2.0.0(<1999-09>)

Technical Specification

3rd Generation Partnership Project (3GPP);
Technical Specification Group (TSG) RAN;

Synchronisation in UTRAN, Stage 2

3GPP

Reference

<Workitem> (<Shortfilename>.PDF)

Keywords

<keyword[, keyword]>

3GPP

Postal address

Office address

Internet

secretariat@3gpp.org

Individual copies of this deliverable
can be downloaded from
http://www.3gpp.org

Contents

Intellectual Property Rights

Foreword

This Technical Specification has been produced by the 3rd Generation Partnership Project, Technical Specification Group RAN.

The contents of this TS may be subject to continuing work within the 3GPP and may change following formal TSG approval. Should the TSG modify the contents of this TR, it will be re-released with an identifying change of release date and an increase in version number as follows:

Version m.t.e

where:

m indicates [major version number]

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

y the third digit is incremented when editorial only changes have been incorporated into the specification.

1 Scope

The present document constitutes the stage 2 specification of different synchronisation mechanisms in UTRAN and on Uu.

2 References

[1] TS 25.401 "UTRAN Overall Description".

[2] TS 25.423 "UTRAN I_{ur} Interface RNSAP Signalling".

[3] TS 25.433 "UTRAN I_{ub} Interface NBAP Signalling".

[4] TS 25.435 "UTRAN I_{ub} Interface User Plane Protocols for Dedicated Transport Channel Data Streams".

[5] TS 25.427 "I_{ub}/I_{ur} Interface User Plane Protocol for DCH Data Streams".

[6] EIA 422-A-78 "Electrical characteristics of balanced voltage digital interface circuits".

3 Definitions, symbols and abbreviations

3.1 Definitions

3.2 Abbreviations

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

BFN	Node B Frame Number (counter)
CFN	Connection Frame Number (counter)
CH	Channel
CN	Core Network
CRNC	Controlling RNC
DL	Down Link
DCH	Dedicated Channel
DPCH	Dedicated Physical Channel
DPCCH	Dedicated Physical Control Channel
DSCH	Downlink Shared Channel
DRNC	Drift RNC
FACH	Forward Access Channel
FDD	Frequency Division Duplex
GPS	Global Positioning System
HO	Handover
LTOA	Latest Time of Arrival
L1	Layer 1
L2	Layer 2
LSB_x	Last x Significant Bits
MAC	Medium Access Control
MDC	Macro Diversity Combiner
PCCPCH	Primary Common Control Physical Channel
PCH	Paging Channel
PUSCH	Physical Uplink Shared Channel
RACH	Random Access Channel
RAN	Radio Access Network
RFN	RNC Frame Number (counter)
RL	Radio Link
RNC	Radio Network Controller
RNS	Radio Network Subsystem
RRC	Radio Resource Control
SFN	Cell System Frame Number (counter)
SRNC	Serving RNC
SRNS	Serving RNS
TBS	Transport Block Set
TDD	Time Division Duplex
TOA	Time of Arrival
TOAWE	Time of Arrival Window Endpoint
TOAWS	Time of Arrival Window Startpoint
TTI	Time Transmission Interval
UE	User Equipment
UL	Up Link
USCH	Uplink Shared Channel
UTRAN	UMTS Terrestrial Radio Access Network

4 Synchronisation Issues

4.1 General

This section identifies the different UTRAN synchronisation issues, i.e.:

- Network Synchronisation;
- Node Synchronisation;
- Transport Channel Synchronisation;
- Radio Interface Synchronisation;
- Time Alignment Handling.

The Nodes involved by the above mentioned synchronisation issues (with the exception of Network and Node Synchronisation) are shown by the Synchronisation Issues Model of Figure 1.

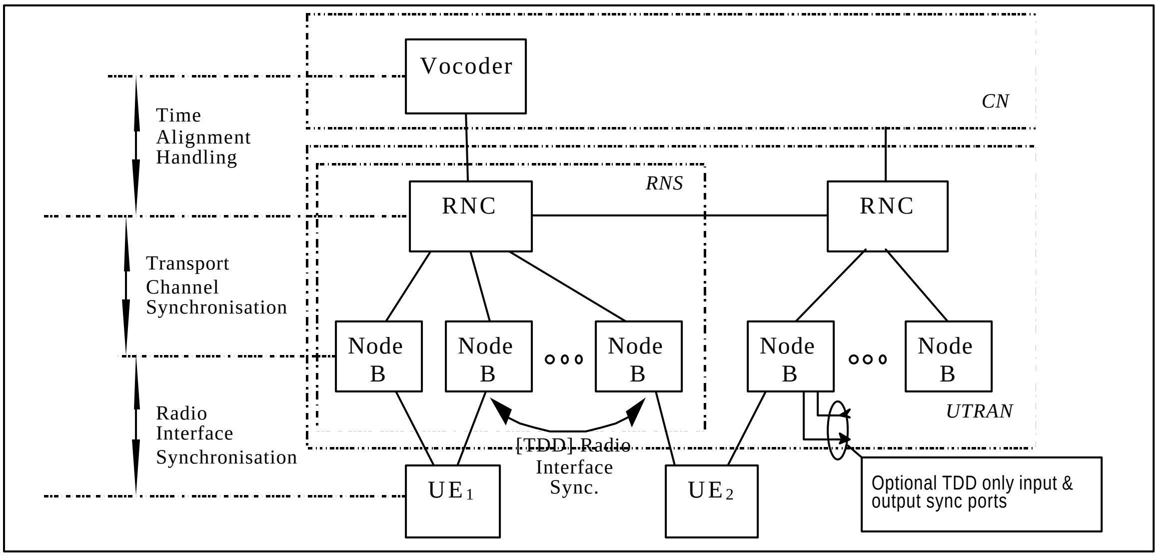


Figure 1: Synchronisation Issues Model

The UTRAN solutions for some of the identified items are described in sections 9-12. Additional information on UTRAN synchronisation issues and the detailed specification of UTRAN solutions can be found in the following Technical Specifications:

- Summary of UTRAN Synchronisation Issues:

  TS 25.401 “UTRAN Overall Description”, section 9.

- RNC-Node B Node Synchronisation:

  TS 25.427 “I$_{ub}$/I$_{ur}$ Interface User Plane Protocol for DCH Data Streams”, section 8.5;

  $_{ub}$ Interface User Plane Protocols for Dedicated Transport Channel Data Streams”, section 5.2.

- Transport Channel Synchronisation:

  TS 25.427 “I$_{ub}$/I$_{ur}$ Interface User Plane Protocol for DCH Data Streams”, sections 8.2 – 8.3;

  $_{ub}$ Interface User Plane Protocols for Dedicated Transport Channel Data Streams”, sections 5.3 – 5.4.

4.2 Network Synchronisation

The Network Synchronisation relates to the stability of the clocks in the UTRAN. The standard will specify the performance requirements on UTRAN internal interfaces.

4.3 Node Synchronisation

Node Synchronisation relates to the estimation and compensation of timing differences among UTRAN nodes. FDD and TDD modes have different requirements on the accuracy of the timing difference estimation and on the necessity to compensate for these differences.

Two types of Node Synchronisation can be identified, “RNC-Node B” and “Inter Node B” Node Synchronisation. Their usage differs and the requirements differ between the FDD and TDD modes.

“RNC-Node B” Node Synchronisation allows to get knowledge of the timing differences between RNC and its Node Bs.

“Inter Node B” Node Synchronisation is necessary in the TDD mode to compensate the timing differences among Node Bs in order to achieve a common timing reference. The purpose of having a common timing reference is to allow Radio Frame Synchronisation, which is used, within neighbouring cells to minimise cross-interference.

Positioning / Localisation functions may also set requirements on Node Synchronisation (FFS).

4.4 Transport Channel Synchronisation

The Transport Channel Synchronisation mechanism defines the radio frame in which the TBS transmission shall be started. In FDD from this reference point the Chip Offset is used to define the exact timing of the radio frame transmission (FDD Radio Interface Synchronisation).

4.5 Radio Interface Synchronisation

The Radio Interface Synchronisation relates to the timing of the radio frame transmission (either in downlink [FDD] or in both directions [TDD]). FDD and TDD have different mechanisms to determine the exact timing of the radio frame transmission and also different requirements on the accuracy of this timing.

In FDD Radio Interface Synchronisation is necessary to assure that the UE receives radio frames synchronously from different cells, in order to minimise UE buffers.

In TDD Radio Interface Synchronisation is necessary to synchronise radio frames within neighbouring cells (Radio Frame Synchronisation) in order to minimise cells cross-interference and between UE and UTRAN (Timing Advance) in order to minimise UE-cell interference.

4.6 Time Alignment Handling

Time Alignment handling relates to TTIs and is used to adapt to 10 ms framing (or to unit length e.g. 20 ms) i.e. to send and receive frames ‘just-in-time’ and thus minimising the delay. Time Alignment is an issue between e.g. Vocoders and the Macrodiversity Combiner (MDC) in RNC. Time Alignment could also be used for circuit switched services like data.

5 Synchronisation Counters and Parameters

This section defines counters and parameters used in the different UTRAN synchronisation procedures.

The parameters used only by FDD has been indicated with the notation [FDD – parameter].

BFN Node B Frame Number counter. This is the Node B common frame number counter. BFN is optionally frequency-locked to a Network sync reference.
Range: 0 to 4095 frames, 12 bits.

RFN RNC Frame Number counter. This is the RNC node common frame number counter. RFN is optionally frequency-locked to a Network sync reference.
Range: 0 to 4095 frames, 12 bits.

SFN Cell System Frame Number counter. SFN is sent on BCCH on Layer 1. SFN is used for paging groups and system information scheduling etc.
In FDD SFN = BFN adjusted with T_cell.
In TDD SFN is locked to the BFN (i.e. SFN=BFN).
Range: 0 to 4095 frames, 12 bits.

CFN Connection Frame Number (counter). CFN is the frame counter used for the L2/transport channel synchronisation between UE and UTRAN. A CFN value is associated to each TBS and it is passed together with it through the MAC-L1 SAP. CFN provides a common frame reference (at L2) to be used e.g. for synchronised transport channel reconfiguration.

The duration of the CFN cycle is longer than the maximum allowed transport delay between MAC and L1 (in UTRAN side, between SRNC and Node B, because the L1 functions that handle the transport channel synchronisation are in the Node B).
Range: 0 to 255 frames, 8 bits. When used for PCH the range is 0 to 4095 frames, 12 bits

Frame_offset Frame_offset is a radio link specific L1 parameter used to map the CFN, used in the transport channel, into the SFN that defines the specific radio frame for the transmission on the air interface.

At the L1/L2 interaction, the mapping is performed as:

$LSB_8(SFN) = CFN + Frame\_offset$ (from L2 to L1) (5.1)

$CFN = LSB_8(SFN) - Frame\_offset$ (from L1 to L2) (5.2)

The resolution of all three parameters is 1 frame. Frame_offset and CFN have the same range (8 bits, 0…255) and only the 8 least significant bits of the SFN are used. The operations above are modulo 256.

In the UTRAN, the Frame_offset parameter is calculated by the SRNC and provided to the node B.

OFF The parameter OFF is calculated by the UE and reported to the UTRAN only when the UTRAN has requested the UE to send this parameter. In the neighbouring cell list, the UTRAN indicates for each cell if the Frame_offset is already known by the UTRAN or shall be measured and reported by the UE.

OFF has a resolution of 1 frame and a range of 0 to 255.

Five different cases are discerned related to the determination of the OFF value by the UE:

1. The UE changes from common channel state to dedicated channel state: 1 RL
In this case OFF will is be zero.

2. The UE changes from common channel state to dedicated channel state: several RL's
OFF is in this case defined as being the difference between SFN of the camping cell and the SFN of the other candidate cells. Again the UE sets OFF to zero for the cell to which the UE sends an UL RRC message (cell #1). For cells #2 to n, the UE sets OFF to the difference

between the SFN of cell#2,n and the SFN of cell#1.
This could be seen as if a virtual dedicated physical channel (DPCH) already is aligned with cell #1.

3. The UE adds another RL in dedicated channel state (macro-diversity)
OFF is in this case defined as being the time difference between the CFN and the SFN of the cell in which the RL is to be added.

4. The UE is coming from another RAN and goes to dedicated channel state: 1 RL
This case is identical to case 1)

5. The UE is coming from another RAN or another frequency in the same RAN and goes to dedicated channel state: several RL's
This case is identical to case 2), with one exception: OFF will not be zero for the cell to which the UE sends an UL RRC message (the measurement information will be received via the CN in this case) but for a reference cell selected by the UE. All other reported OFF values will be relative to the SFN of this selected reference cell.

[FDD – DOFF] The DOFF (Downlink-Offset) is used to define Frame_offset and Chip_offset at first RL setup. The resolution should be good enough to spread out load over Iub and load in Node B (based on certain load distributing algorithms). In addition it is used to spread out the location of Pilot Symbol in order to reduce the peak DL power since Pilot symbol is always transmitting at the fixed location within a slot (the largest chips for one symbol is 512chips).

The SRNC sends a DOFF parameter to the UE when the new RL will make the UE change its state (from common channel state or other when coming from another RAN) to the dedicated channel state.

Resolution: 512 chips; Range :0 to 599 (<80ms).

[FDD – Chip Offset] The Chip_offset is used as offset for the DL DPCH relative to the PCCPCH timing. The Chip_offset parameter has a resolution of 1 chip and a range of 0 to 38399 (< 10ms).

The Chip_offset parameter is calculated by the SRNC and provided to the Node B.

Frame_offset + Chip_offset (sent via NBAP) are in Node B rounded together to closest 256 chip boundary. The 256 chip boundary is used regardless of the used spreading factor, also when the spreading factor is 512. The rounded value (which is calculated in Node B) controls the DL DPCH air-interface timing.

The "Frame_offset + Chip_offset" 256 chip boundary rounding rules for Node B to consider for each DL DPCH are:

1. IF (Frame_offset x 38 400 + Chip_offset) modulo 256 [chips] = {1..127} THEN round (Frame_offset x 38 400 + Chip_offset) modulo 256 frames down to closest 256 chip boundary.

2. IF (Frame_offset x 38 400 + Chip_offset) modulo 256 [chips] = {128..255} THEN round (Frame_offset x 38 400 + Chip_offset) modulo 256 frames up to closest 256 chip boundary.

3. IF (Frame_offset x 38 400 + Chip_offset) modulo 256 [chips] = 0 THEN "Frame_offset x 38 400 + Chip_offset" is already on a 256 chip boundary.

The reported Tm parameter has a resolution of 1 chip and a range of 0 to 38399. The Tm shall always be sent by the UE.

Five different cases are discerned related to the determination of the Tm value by the UE:

1. The UE changes from common channel state to dedicated channel state: 1 RL
In this case the Tm will be zero.

2. The UE is changes from common channel state to dedicated channel state: several RL's
Tm is in this case defined as being the time difference between the received PCCPCH path of the camping cell and the received PCCPCH paths of the other candidate cells. Again the UE

sets Tm to zero for the cell to which the UE sends an UL RRC message (cell #1). For cells #2 to n, the UE sets Tm to the time difference of the PCCPCH reception timing of cell#2,n from the PCCPCH reception timing of cell#1.

3. The UE adds another RL in dedicated channel state (macro-diversity)
   Tm is in this case defined as being the time difference between "$T_{UETX} – T_o$" and the earliest received PCCPCH path of the target cell. T_{UETX} is the time when the UE transmits an uplink DPCCH frame, hence "$T_{UETX} – T_o$" is the "optimum" arrival time for the first path of a received DPCH.

4. The UE is coming from another RAN and goes to dedicated channel state: 1 RL
   This case is identical to case 1.

5. The UE is coming from another RAN or another frequency in the same RAN and goes to dedicated channel state: several RL's
   This case is identical to case 2, with one exception: Tm will not be zero for the cell to which the UE sends an UL RRC message (the measurement information will be received via the CN in this case) but for a reference cell selected by the UE. All other reported Tm values will be relative to the timing of the PCCPCH in this cell.

[FDD – T_cell] T_cell represents the Timing delay used for defining the start of SCH, CPICH and the DL Scrambling Code(s) in a cell relative BFN. The main purpose is to avoid having overlapping SCHs in different cells belonging to the same Node B. A SCH burst is 256 chips long. SFN in a cell is delayed T_cell relative BFN.

Resolution: 256 chips. Range: 0 .. 9 x 256 chips.

t1 RNC specific frame number (RFN) that indicates the time when RNC sends the frame through the SAP to the transport layer.

t2 Node B specific frame number (BFN) that indicates the time when Node B receives the correspondent DL synchronisation frame through the SAP from the transport layer.

t3 Node B specific frame number (BFN) that indicates the time when Node B sends the frame through the SAP to the transport layer.

TOAWS TOAWS (Time of Arrival Window Startpoint) is the window startpoint. DL data frames are expected to be received after this window startpoint (see Figure 7). TOAWS is defined with a positive value relative Time of Arrival Window Endpoint (TOAWE). A data frame arriving before TOAWS gives a Timing Adjustment Control frame response.
The resolution is 1 ms, the range is: {0 .. CFN length/2 –1 ms}.

TOAWE TOAWE (Time of Arrival Window Endpoint) is the window endpoint. DL data frames are expected to be received before this window endpoint (see Figure 7). TOAWE is defined with a positive value relative Latest Time of Arrival (LTOA). A data frame arriving after TOAWS gives a Timing Adjustment Control frame response.
The resolution is 1 ms, the range is: {0 .. CFN length –1 ms}.

LTOA LTOA (Latest Time of Arrival) is the latest time instant a Node B can receive a data frame and still be able to process it. Data frames received after LTOA can not be processed (discarded). LTOA is defined internally in Node B to be a processing time before the data frame is sent in air-interface. The processing time (Tproc) could be vendor and service dependent.
LTOA is the reference for TOAWE (see Figure 7).

TOA TOA (Time of Arrival) is the time difference between the TOAWE and when a data frame is received (see Figure 7). A positive TOA means that data frames are received before TOAWE, a negative TOA means that data frames are received after TOAWE. Data frames that are received after TOAWE but before LTOA (TOA+TOAWE>=0) are processed by Node B.
When RNC measures data frame reception times to determine window position or to supervise data frame reception times, TOA could be added with TOAWE to make the measurements window position independent.
TOA has a resolution of 125 µs. TOA is positive when data frames are received before TOAWE.

The range is: {0 .. +CFN length/2 –125 µs}.
TOA is negative when data frames are received after TOAWE.
The range is: {–125 µs .. –CFN length/2}.

6 Node Synchronisation

6.1 General

By Node Synchronisation it's generally meant the achievement of a common timing reference among different nodes. In UTRAN although a common timing reference among all the nodes could be useful, it is not required.

In fact, in order to minimise the transmission delay and the buffering time for the transmission on the air interface, it can be useful to estimate the timing differences between RNC and Node Bs, without the need to compensate for the phase differences between RNC's and Node B's clocks.

On the other hand the achievement of a common timing reference among Node Bs is needed in TDD to allow Radio Frame Synchronisation, i.e. the phase differences among Node B's clocks shall be compensated.

For these reasons in UTRAN node synchronisation refers to the following two aspects:

- RNC-Node B Node Synchronisation;
- Inter Node B Node Synchronisation.

6.1.1 RNC-Node B Node Synchronisation

The Node Synchronisation between RNC and Node B can be used to find out the timing reference differences between the UTRAN nodes (RFN in RNC and BFN in Node B). The use is mainly for determining good DL and UL offset values for frame synchronisation between RNC and their Node Bs. Knowledge of timing relationships between these nodes is based on a measurement procedure called RNC-Node B Node Synchronisation Procedure. The procedure is defined in the user plane protocols for Iub (DCH, DSCH, and FACH/PCH) and Iur (DCH). The usage over the CCH channels, e.g. FACH, is for the actual RNC-Node B Node Synchronisation procedure.

When the procedure is used from SRNC over the DCH user plane, the usage is Round-trip-delay measurements. These could be used to determine offset values between RNCs and to find out the actual round-trip-delay a certain service has (as the Node Sync Control Frames are transferred the same way as the DCH frames).

The procedure may also be carried out over a high priority transport bearer (beneficial when used between CRNC and Node Bs for the RNC-Node B Synchronisation purpose). Measurements of node offsets can be made at start or restart as well as during normal operation to supervise the stability of the nodes.

If a good Network synchronisation reference is used, the drift between nodes will be low, but could occur. If a Network synchronisation reference isn't available or is poor (as is the case in some transport network types), the local node reference oscillator must be relied upon. Then the RNC-Node B Node Synchronisation procedure can be used as a background process to find out the frequency drift between nodes. Therefore, a system can be deployed without Network synchronisation references (to e.g. the Node B's).

In the RNC-Node B Node Synchronisation procedure, the RNC sends a DL Node Synchronisation control frame to Node B Containing the parameter T1. Upon reception of a DL Synchronisation control frame, the Node B shall respond with UL Synchronisation Control Frame, indicating t2 and t3, as well as t1 which was indicated in the initiating DL Node Synchronisation control frame.

6.1.2 Inter Node B Node Synchronisation

In the FDD mode Inter Node B Node Synchronisation could be reached via the RNC-Node B Node Synchronisation in order to determine inter Node B timing reference relations.

This could be used to determine Inter-cell relationships (via T_cell) which can be used in the neighbour cell lists in order to speed up and simplify cell search done by UE at handover.

In TDD Inter Node B Node Synchronisation is used to achieve a common timing reference among Node Bs.

TDD may have several solutions for Inter Node B Node Synchronisation:

- Synchronisation of Node B's to an external reference via a standardised synchronisation port (see section 6.1.2.1);
- Synchronisation of Node B's on the air-interface, e.g. through Node B's cross measurements.

Depending on the deployment scenario, either one of the different solutions or a combined one can be adopted.

6.1.2.1 TDD Node B Synchronisation Ports

This section defines the Node B input and an output synchronisation ports that can be used for Inter Node B Node Synchronisation. These synchronisation ports are optional.

The input synchronisation port (SYNC IN) allows the Node B to be synchronised to an external reference (e.g. GPS), while the output synchronisation port (SYNC OUT) allows the Node B to synchronise directly another Node B (see Figure 2).

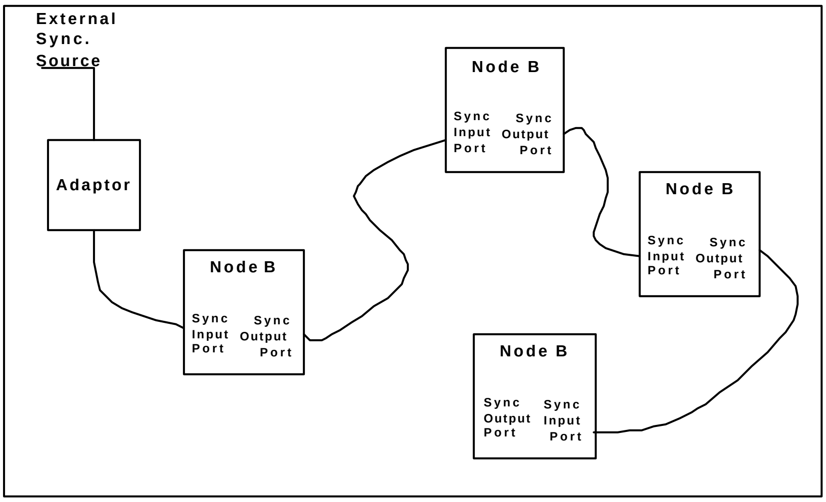


Figure 2: Usage of Synchronisation Ports

This allows to connect Node B's in a daisy chain configuration, so that a single external reference is enough and all remaining nodes B can be synchronised (e.g. in case of indoor operation).

The Node B starts the synchronisation to the external reference when a valid input synchronisation signal is detected at the input synchronisation port.

If a valid synchronisation signal is detected, the Node B regenerates that signal at its output synchronisation port. The propagation delay between the input and output synchronisation ports shall not exceed 500 ns.

The electrical characteristics of the synchronisation ports shall conform to RS422 [6] (output synchronisation port: section 4.1; input synchronisation port: section 4.2).

The synchronisation signal (illustrated in Figure 3) is a 100 Hz signal having positive pulses of width between 5 µs and 1 ms. This signal establishes the 10 ms frame interval. The start of a frame is defined by the falling edge of the pulse.

The synchronisation signal at the input port shall have a frequency accuracy better than the one of the Node B.

The relative phase difference of the synchronisation signals at the input port of two neighbouring Node B's shall not exceed 5 µs.

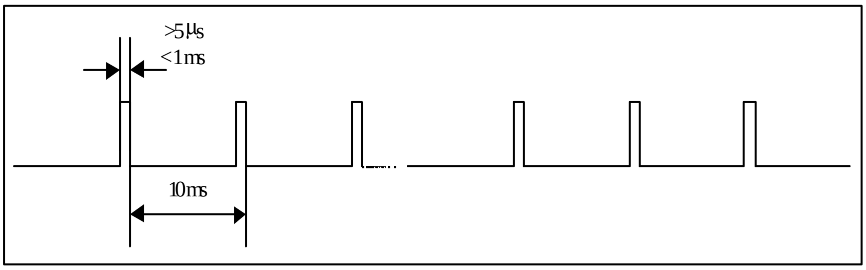


Figure 3: Synchronisation signal

Synchronisation by a GPS receiver

The signal transmitted by a Global Positioning System (GPS) satellite indicates the GPS time that provides an absolute time reference. This makes the GPS receiver suitable for Inter Node B Node Synchronisation.

Inter Node B Node Synchronisation is achieved by relating the synchronisation signal (at the input synchronisation port to the GPS signal. Since the duration of a UTRAN frame is 10 ms, this implies that every 100 frames the start of a UTRAN frame coincides with an integer GPS second.

6.1.2.2 TDD Inter Node B Node Synchronisation procedure

In TDD it is assumed that all the cells belonging to the same Node B are synchronised among each other. This means that as Inter Node B Node Synchronisation is achieved, also cells belonging to those Node B's are synchronised.

In order to achieve Inter Node B Node Synchronisation several solutions can be applied.

In the procedure described in this section it is assumed that Node Bs may be synchronised through an external reference (e.g. GPS) connected to the input synchronisation port defined in section 6.1.2.1. The other Node Bs may be synchronised through Node B's cross measurements on the air interface.

All the Node B's that are synchronised through the external source become Reference; all the other Node B's are synchronised via the air through a master-slave mechanism.

Note that in case of isolated area one of the Node B's could act as a free-running reference, i.e. as a reference not connected to an external source.

In order to get synchronised a Node B shall listen at an active cell belonging either to a reference Node B or to an already synchronised Node B (that acts as a master of the synchronisation process for the unsynchronised Node B, i.e. the slave Node B).

All the Node B's that cannot listen to cells belonging to other Node B's shall be synchronised through their synchronisation port (i.e. they are References as well).

Note that the propagation delay between a slave cell and its master cell can be determined through cells cross measurements. This allows the slave cell to take into account this propagation delay when synchronising to its master.

The Inter Node B Node Synchronisation procedure is shown in Figure 4.

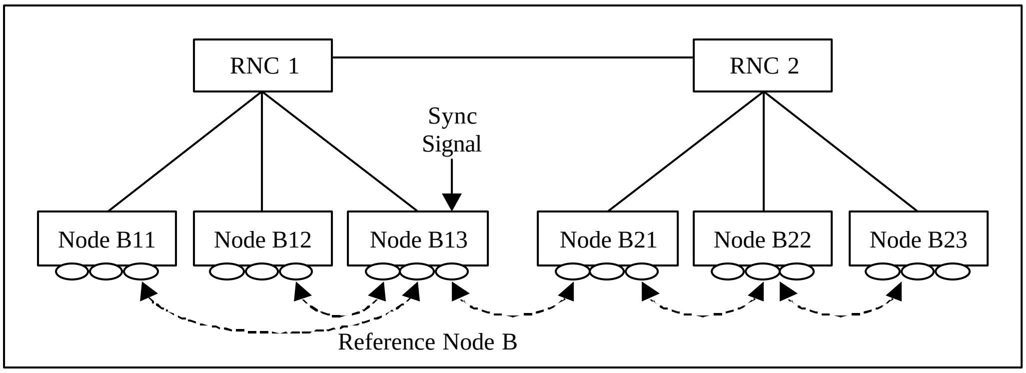


Figure 4: TDD Inter Node B Node Synchronisation

In the example of Figure 4 Node B13 is the only Reference, i.e. it is the only one that is synchronised through an external source. Node B11, Node B12 and Node B21 can listen at least to one cell of Node B13. This means that they can get synchronised over the air directly to the Reference Node B. On the contrary Node B22 can listen only to a cell belonging to Node B21. This means that it can get synchronised only to Node B21 that acts as a master for B22 (second hierarchical level of synchronisation), while Node B23 can get synchronised only to Node B22 that acts as a master for B23 (third hierarchical level of synchronisation).

The synchronisation hierarchy for the example of Figure 4 is shown in Figure 5.

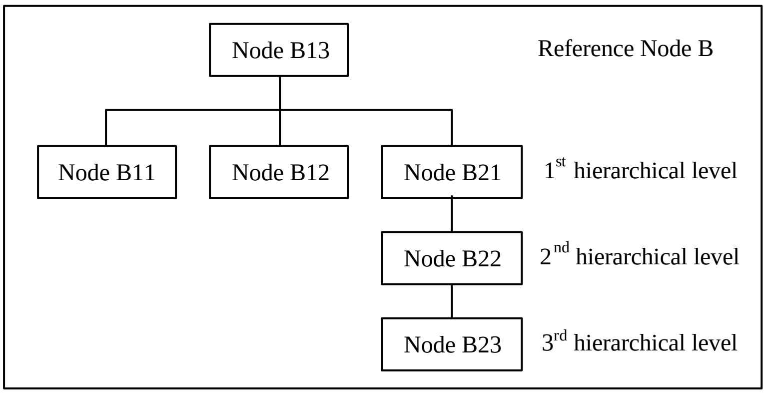


Figure 5: TDD Synchronisation Hierarchy

7 Transport Channel Synchronisation

7.1 General

The Transport Channel (or L2) synchronisation provides a L2 common frame numbering between UTRAN and UE (frame synchronisation between the L2 entities). This frame number is the Connection Frame Number (CFN), and it is associated at L2 to every TBS and passed to L1: the same CFN is received on the peer side associated with the same TBS.

The CFN is not transmitted in the air interface for each TBS, but is mapped by L1 to the SFN of the first radio frame used for the transmission of the TBS (the SFN is broadcast at L1 in the BCH). The mapping is performed via the Frame_offset parameter.

In case of soft handover, the Frame_offsets of the different radio links are selected in order to have a timed transmission of the diversity branches in the air interface.

A L1-MAC primitive is defined to allow the L1 to indicate to L2 the necessity to adjust the timing of the DL transmission, in order to control and minimise the transmission delay and the buffering time for the transmission on the air interface (i.e. to ensure that the TBS does not arrive too much in advance respect to the transmission time). The primitive is carried in the user plane by Frame Protocol procedures within the UTRAN. This transport channel synchronisation mechanism is valid for all the transport channels.

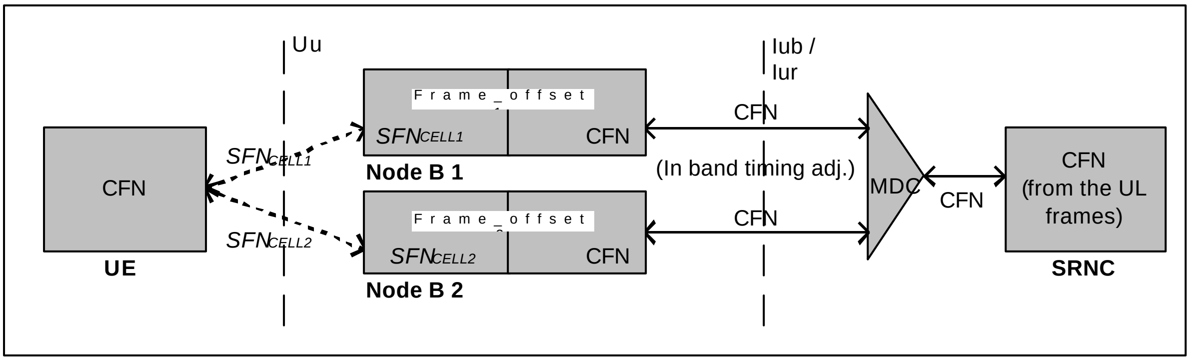


Figure 6: Transport Channel (Layer 2) Synchronisation

7.2 Timing adjustment on Iub/Iur interfaces

A receiving window is configured in Node B at Transport bearer Setup, Addition and Reconfiguration for DL frames (TOAWS and TOAWE). The purpose is to make it possible to supervise whether data frames are received in the window or not. When frames are received outside that window, a response is sent to RNC called Timing Adjustment Control frame. This response contains Time of Arrival information (TOA)(see Figure 7).

The window could be defined to have a margin before LTOA (TOAWE >0). This is to indicate to RNC that data frames are a bit late but they are still processed by Node B. In this case, data frames are received after TOAWE but before LTOA.

Offset values, used for sending data frames from RNC over Iub, could therefore be refined by using this window definition and supervising method.

DL Sync Control frames will always give TOA as response, even if the DL Sync Control frame is received within the window. The purpose of Sync Control frames is to measure when frames are received for a certain transport bearer

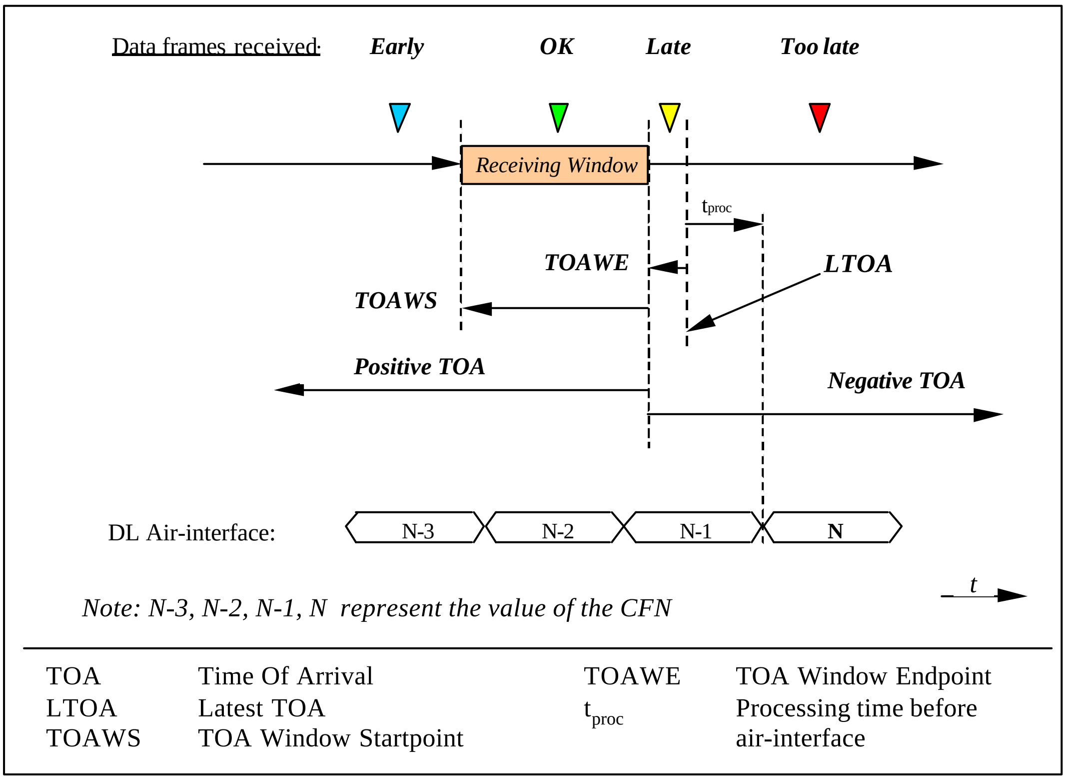


Figure 7: Illustration of TOAWS, TOAWE, LTOA and TOA

The window size and position can be chosen with respect to expected data frame delay variation and different macro-diversity leg delays.

8 Radio Interface Synchronisation

8.1 General

This section describes the Radio Interface Synchronisation for FDD and TDD.

8.2 FDD Radio Interface Synchronisation

8.2.1 General

FDD Radio Interface Synchronisation assures that UE gets the correct frames when received from several cells. The UE measures the Timing difference between its DPCH and SFN in the target cell when doing handover and reports it to SRNC. SRNC sends this Time difference value in two parameters Frame_offset and Chip_offset over Iub to Node B. Node B rounds this value to the closest 256 chip boundary in order to get DL orthogonality (regardless of used spreading factor). The rounded value is used in Node B for the DL DPCH.

DOFF is selected by the SRNC considering the interleaving period (e.g. 10, 20, 40 or 80ms) when entering in dedicated state from common channel state

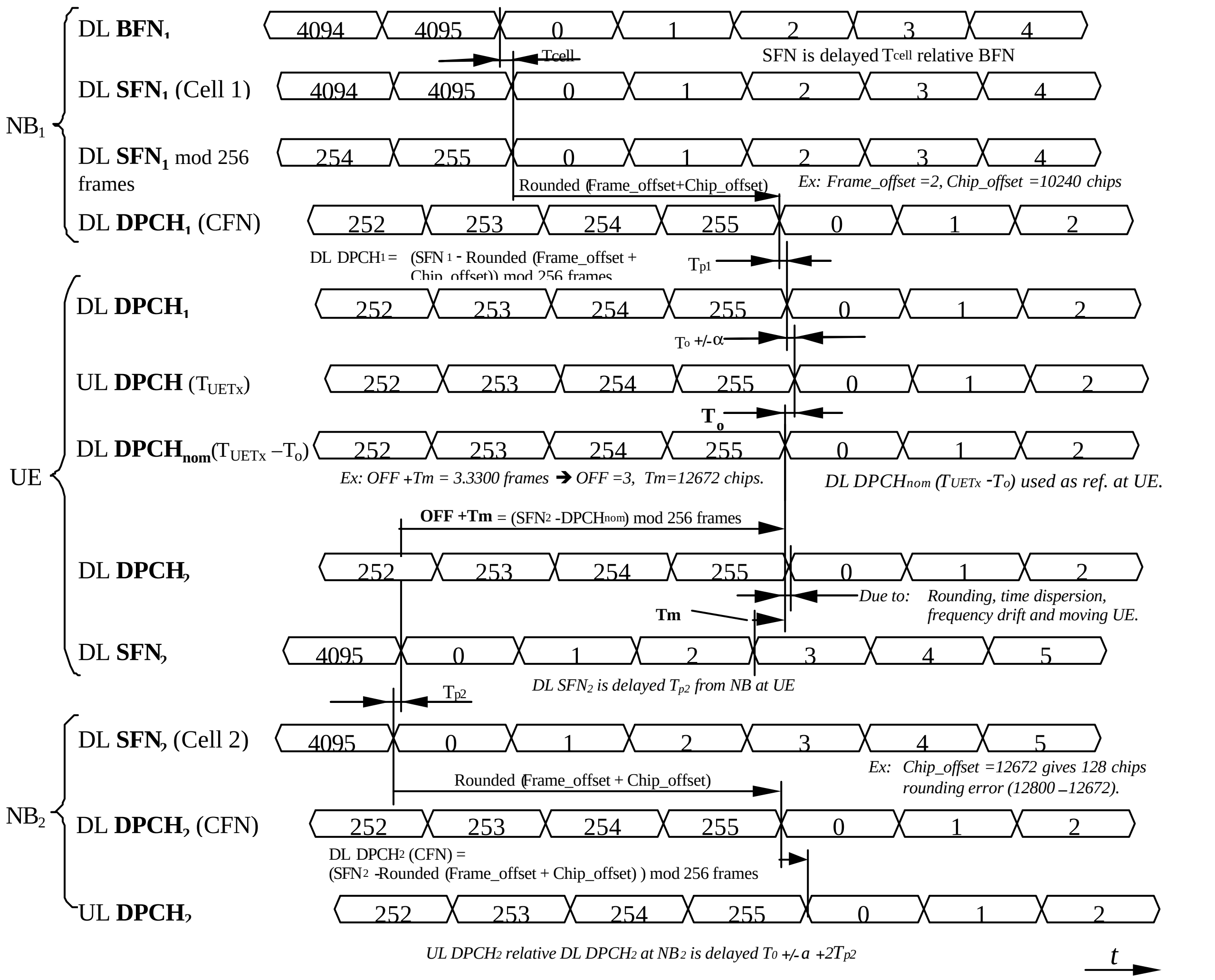
Services are scheduled by using DOFF in order to average out the Iub traffic load and the Node B processing load. DOFF is only used when setting up the first RL in order to initialise Frame_offset and Chip_offset and to tell UE when frames are expected.

UE uses the UL DPCH as it is a more defined time instant than the DL DPCH as the fingers of the Rake receiver move all the time due to time-dispersion.

The handover reference is the time instant T_{UETx} -To, which is called DL $DPCH_{nom}$ in the timing diagram.

T_{cell} is used to skew cells in the same Node B in order to not get colliding SCH bursts, one SCH burst is 1/10 of a slot time.

The timing diagram shows an example with two cells connected to one UE where handover is done from source cell (Cell 1) to target cell (Cell 2).



α	1st received DL DPCH finger relative DL DPCH nom	T cell	Specifies the SFN delay relative BFN
BFN	Node B Frame Number (counter)	T m	Measured by UE at HO, T m has a range from 0 to 38399 chips.
CFN	Connection Frame Number (DPCH related)		
DPCH	Dedicated Physical Channel (CFN related)	T o	Is a constant of 1024 chips, is the nominal difference between first received DPCH finger (DL DPCH nom) and T UETx at UE.
HO	Handover		
NBx	Node B (x: 1=source, 2=target)		
OFF	Offset with a range from 0 to 255 frames	T pX	Propagation delay (one way), UE to Cell X
RFN	RNC Frame Number (counter)	T UETx	The time when UE transmits an UL Dedicated Physical Channel.
RNC	Radio Network Controller		
SFN	System Frame Number (counter)		

Figure 8: FDD Radio Interface Synchronisation timing diagram

SFN_1 is found in Cell 1 at Node B_1 and SFN_2 at Cell 2 and Node B_2. SFN_1 is sent T_cell_1 after the Node B_1 reference BFN_1. CFN is the frame numbering that is related to each DL and UL Dedicated Physical Channel (DPCH). UL DPCH is sent from UE to both Cells (both Node B’s in this example). UL DPCH at Node B_2 is shown to indicate the difference to the DL $DPCH_2$ at Node B_2.

The new RL (DL $DPCH_2$) which is setup at the HO will face some deviation from nominal position due to the rounding of Frame_offset and Chip_offset to 256 chip boundary in Node B. Also Time dispersion, Node B-UE frequency drift and UE movement affects this phase deviation.

The nominal DL DPCH timing at UE is T_o before the T_{UETX} time instant, which could be expressed:

$$\text{DL } DPCH_{nom} = T_{UETX} - T_o \qquad (8.1)$$

In UE dedicated state, OFF and Tm are measured at UE according to the following equation:

$OFF + Tm = (SFN_{target} – DL\ DPCH_{nom})$ mod 256 frames [chips] (8.2)

Note: OFF has the unit Frames and Tm the unit Chips.

Example: assume that OFF + T_m equals “3.3300” frames (as given as an example in Figure 8).
Then OFF = 3 and T_m = “0.33” which corresponds to T_m = 12672 chips.

In other words (referring to the timing diagram in Figure 8):

- How to determine T_m at UE: Select a time instant 1) where frame N starts at DL SFN_2 e.g. frame number 3, the time from that time instant to the next frame border of DL $DPCH_{nom}$ 2) equals T_m
(if these are in phase with each other, T_m is zero).

How to determine OFF: The difference between the frame number selected for time instant 1) and the frame number starting at instant 2) mod 256 frames equals OFF.
Example: (3 –0) mod 256 = 3, another example is (1 –254) mod 256 = 3.

8.2.2 Neighbour cell list timing information

A cell can optionally broadcast a neighbouring cell list that indicates timing information for neighbouring cells. The list contains the inter cell timing difference to neighbour cells with associated estimated uncertainty. The inter cell timing uncertainty depends on what timing difference estimating means that are used in the system (No means at all, Node sync measurements, UE inter-cell measurements, Cells belonging to the same Node B or even GPS). The purpose with the neighbouring cell list timing information is to enable shorter cell search time for UE, to save UE battery and to potentially lower BCH Tx power for cells in a synchronised cluster.

8.3 TDD Radio Interface Synchronisation

8.3.1 General

The TDD Radio Interface Synchronisation relates to the following two aspects:

- Radio Frame Synchronisation;
- Timing Advance.

In TDD mode Radio Frame Synchronisation among Node B’s is achieved by means of the Inter Node B Node Synchronisation that allows to achieve a common timing reference among Node B’s. Radio Interface Synchronisation between UE and UTRAN is achieved by means of the Timing Advance mechanism.

8.3.2 Radio Frame Synchronisation

Radio Frame Synchronisation is necessary to ensure that the uplink/downlink switching points are positioned at the same time instant at least in adjacent cells (see Figure 9).

This requirement is necessary to avoid that a receiving UE can be saturated by a transmitting UE in a neighbouring cell.

In addition it automatically ensures that the slots of different cells are synchronised, i.e. they do not overlap at the UE.

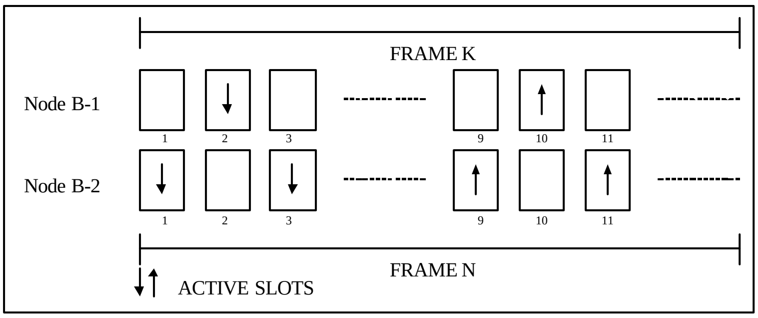


Figure 9: Radio Frame Synchronisation

8.3.3 Timing Advance

Timing Advance is used in uplink to align the uplink radio signals from the UE to the UTRAN both in case of uplink Dedicated Physical Channels (DPCH) and of Physical Uplink Shared Channels (PUSCH).

The handling of timing advance can be divided in four main categories: measurement, initial assignment, correction during operation, and setting on handover. For each category, a number of different cases can be distinguished.

1. Measurement of the timing offset on the physical channels:

    (i) On PRACH transmissions;

    (ii) On DPCH transmissions;

    (iii) On PUSCH transmissions.

2. Assignment of correct timing advance value when establishing new channels:

    (i) At switch to DCH/DCH state;

    (ii) At switch to USCH state.

3. Correction of timing advance value for channels in operation:

    (i) At least one uplink DCH in operation;

    (ii) Only USCH in operation.

4. Setting of timing advance value for target cell at handover.

8.3.3.1 Measurement of the timing offset on the physical channels

Timing offset measurements are always performed in the physical layer in Node B. These measurements have to be reported to the higher layers, where timing advance values are calculated and signalled to the UE. For this reporting, a number of different ways are foreseen, depending on the used channels.

PRACH: The Node B physical layer measures the timing accuracy of the RACH bursts transmitted by the UE. It measures the timing offset of the received signal (Rx Timing Deviation) and passes this together with the transport block to the CRNC (by means of the Iub RACH Frame Protocol). In case the PRACH supports a DCH, the measured timing offset may be passed from DRNC to the SRNC over Iur interface (by means of the Iur RACH Frame Protocol).

PUSCH: The Node B physical layer measures the timing accuracy of the PUSCH bursts transmitted by the UE. It measures the timing offset of the received signal (Rx Timing Deviation) and passes this together with the transport block to the CRNC (by means of the Iub USCH Frame Protocol).

DPCH: The Node B physical layer measures the timing accuracy of the DPCH bursts transmitted by the UE. It measures the timing offset of the received signal (Rx Timing Deviation) and passes this together with the transport block to the SRNC (by means of the Iub & Iur DCH Frame Protocols).

8.3.3.2 Assignment of correct timing advance value when establishing new channels

8.3.3.2.1 Switch to DCH/DCH state

The transition to DCH/DCH state from USCH/DSCH state, RACH/FACH state or Idle Mode operates in the following manner:

(i) The SRNC checks whether an up to date timing offset measurement is available. Such a measurement can be available from a recent RACH access (e.g. from initial access) or from a recent USCH transmission. If no up to date timing offset measurement is available, the SRNC has to trigger an uplink transmission from the UE before it can assign a DCH. The SRNC calculates the required timing advance value and saves it in the UE context for later use in dedicated or shared channel activation.

(ii) The SRNC attaches the timing advance value to the channel allocation message that it signals to the UE via FACH (RRC CONNECTION SETUP or RADIO BEARER SETUP).

(iii) When the UE receives the channel allocation message it configures its physical layer.

8.3.3.2.2 Switch to USCH state

For uplink traffic using the USCH, short time allocations are sent to the UE regularly. Therefore switch to USCH is very similar to handling of timing advance updates during USCH operation. The UTRAN only has to check, whether an up to date timing offset measurement is available. Such a measurement can be available from a recent RACH access (e.g. from initial access). If no up to date timing offset measurement is available, the UTRAN has to trigger an uplink transmission from the UE before it can assign an USCH.

8.3.3.3 Correction of timing advance value for channels in operation

8.3.3.3.1 UE in Traffic using at least one uplink DCH

An UE that is operating a dedicated channel (DCH/DCH state), has to update the timing advance from time to time to keep the received signal at the Node B within the required time window. Under reasonable assumptions the worst case update frequency is in the order of 8 seconds.

The timing correction procedure operates in the following manner:

(i) The SRNC determines whether a new timing advance value has to be transmitted to the UE taking into account when the last correction was signalled.

(ii) Timing advance corrections are signalled to the UE via RRC signalling on FACH or DCH (PHYSICAL CHANNEL RECONFIGURATION, TRANSPORT CHANNEL RECONFIGURATION or RADIO BEARER RECONFIGURATION).

(iii) When the UE receives the a new timing advance value, it configures its physical layer.

There is no need for the UE to acknowledge the timing correction message:the Node B periodically measures the UE timing accuracy, and the UE reports the received timing advance value as part of the measurement reporting. The SRNC is then able to detect when a timing advance message has not been received and needs to be resent .

8.3.3.3.2 UE in Traffic using only USCH

The timing correction procedure operates in the following manner:

(i) The CRNC determines whether a new timing advance value has to be transmitted to the UE taking into account when the last correction was signalled. Two cases are possible:

(a) if the data transfer is uplink after a longer idle period then the UE has to transmit a capacity request on the RACH. The CRNC is therefore informed of any timing error on this RACH.

(b) if a new allocation follows an USCH transmission, the timing error is already known to the CRNC from measurements of the last uplink transmission.

(ii) If a Timing Advance update is needed, the CRNC includes a new timing advance value in the next USCH allocation message to the UE (PHYSICAL SHARED CHANNEL ALLOCATION).

(iii) When the UE receives the a new timing advance value, it configures its physical layer.

8.3.3.4 Setting of timing advance value for target cell at handover

Handover between different cells requires the correct setting of the timing advance for the target cell, before uplink traffic transmission is allowed. Since the TDD system has synchronised base stations, a UE is able to measure the time offset between the two cells and, consequently, is able to correct its timing on handover without UTRAN assistance. However to improve the accuracy for the calculated timing advance, the SRNC can include the measured timing offset value in the HANDOVER COMMAND message.

After a successful handover, a HANDOVER COMPLETE message is transmitted in the new cell. In this message, the UE can report the calculated timing advance, which is used for access to the new cell. By this way, the SRNC is informed as fast as possible about the timing advance in the UE, and it can correct the timing advance if necessary.

9 Usage of Synchronisation Counters and Parameters to support Transport Channel and Radio Interface Synchronisation

9.1 General

This section describes how the different synchronisation parameters are computed and used in order to obtain Transport Channel (L2) and Radio Interface (L1) Synchronisation.

The parameter that need to be determined by the UE are CFN, OFF and Tm (FDD only).

The parameter that need to be determined by the UTRAN are DOFF (FDD only), Frame_offset and Chip_offset (FDD only).

Figure 10 summarises how these parameters are computed. A detailed description of the actions in each state is given in the following sub-sections.

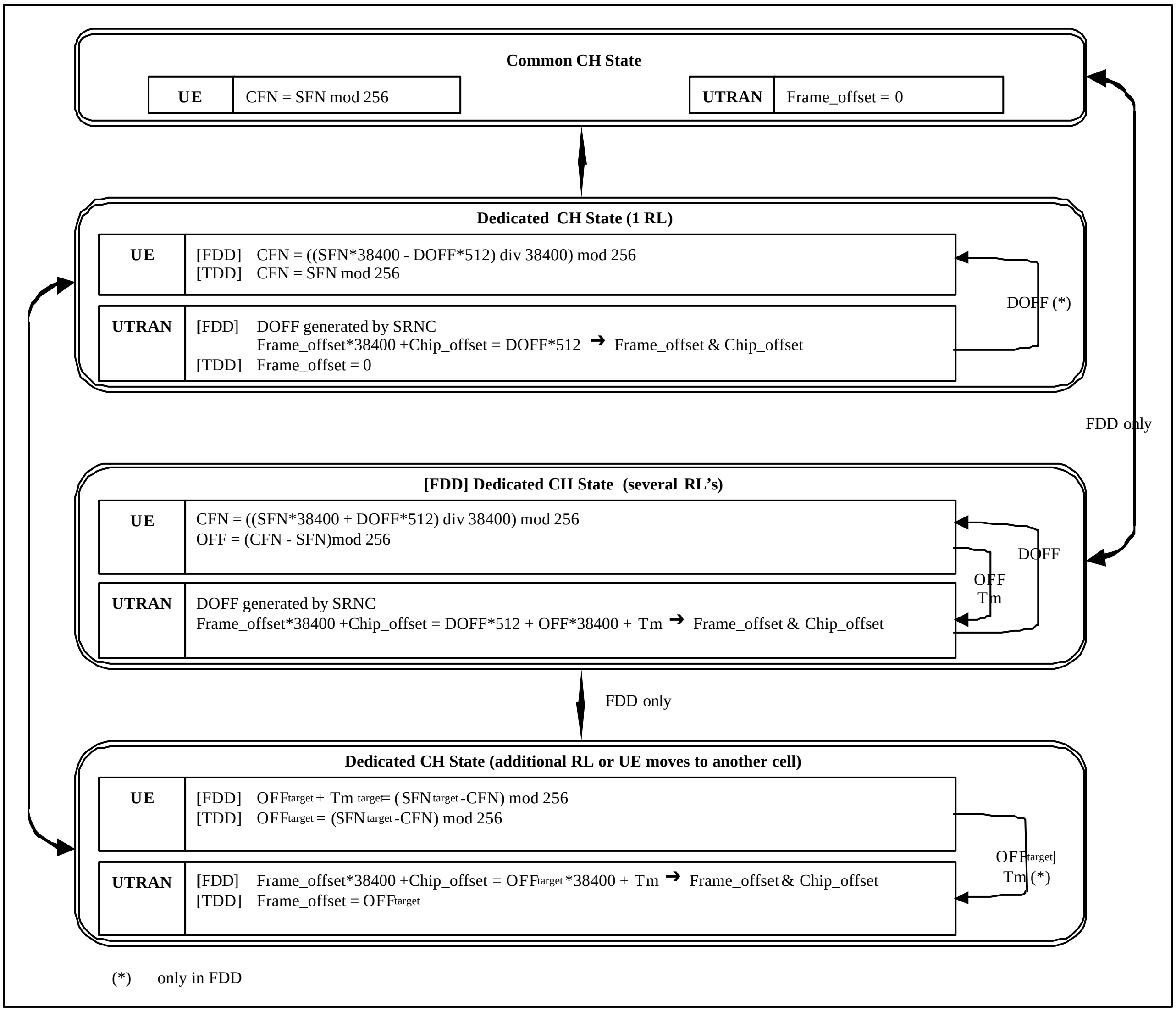


Figure 10: Calculations performed by UE and UTRAN

Figure 11 describes what offset parameters are signalled and used in the different nodes at Initial RL setup and at Handover (HO) in FDD. The rounding to closest 256 chip boundary is done in Node B. The rounded Frame_offset and

Chip_offset control the DL DPCH air-interface timing. The 256 chip boundary is to maintain DL orthogonality in the cell (the rounding to the closest 256 chip boundary is done in Node B to facilitate the initial UL chip synchronisation process in Node B).

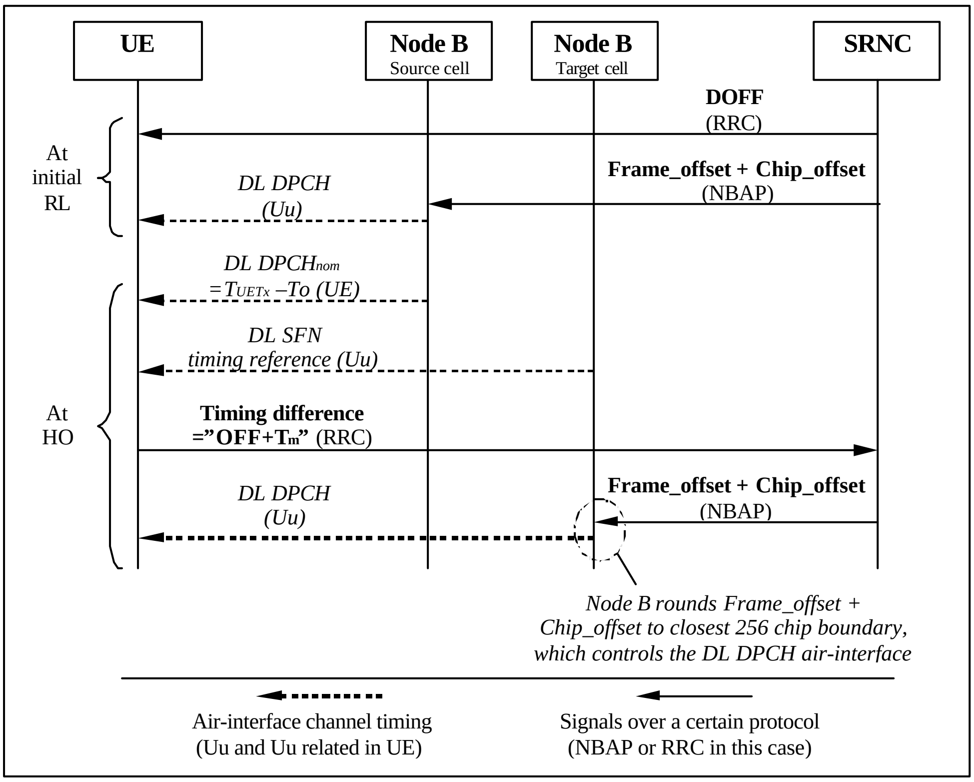


Figure 11: [FDD] Usage of Offset values at initial RL and at HO

Figure 12 describes what offset parameters are signalled and used in the different nodes at Initial RL setup and at Handover (HO) in TDD.

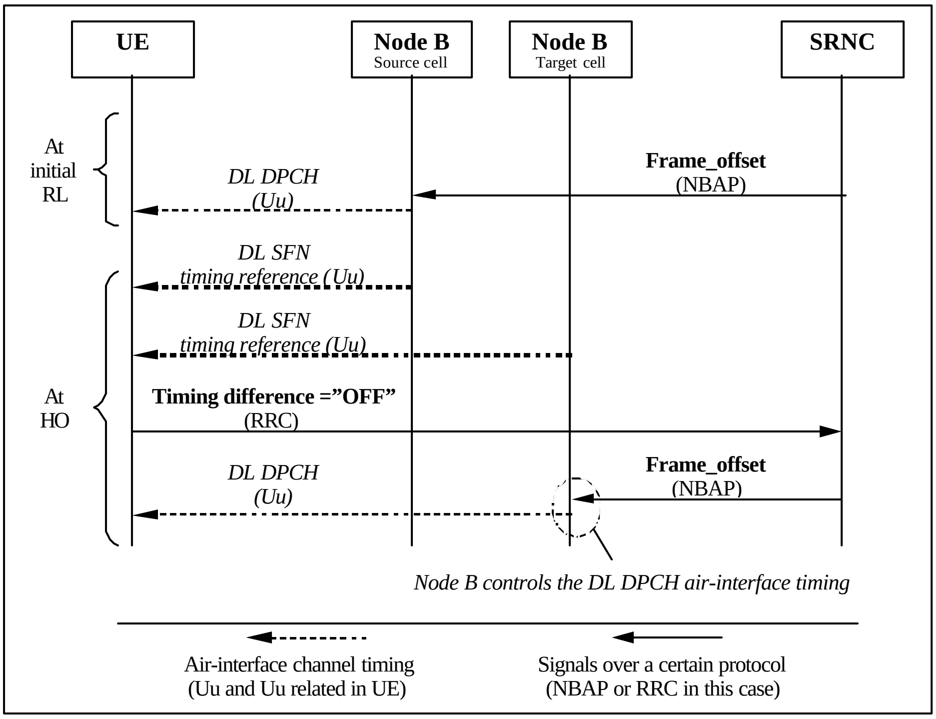


Figure 12: [TDD] Usage of Offset values at initial RL and at HO

9.2 Calculations performed in the UTRAN

This chapter describes how an SRNC can calculate the Frame_offset and Chip_offset based on the parameters received from the UE and available in the UTRAN.

9.2.1 UE in common channel state

In common channel state (UE on RACH/FACH), the Frame_offset is set to 0.

9.2.2 UE changes state from common CH state to dedicated CH state: 1 RL

In FDD, based on the received parameters from the UE and the DOFF value generated in the SRNC, the SRNC calculates the Frame_offset and the Chip_offset:

Frame_offset*38400 +Chip_offset = DOFF*512 (9.1)

In TDD Frame_offset = 0.

9.2.3 UE changes state from common CH state to dedicated CH state: several RL's (FDD only)

Based on the received parameters from the UE and the DOFF value generated in the SRNC, the SRNC calculates the Frame_offset and the Chip_offset. The Frame_offset and the Chip_offset are calculated from the following formula:

Frame_offset*38400 +Chip_offset = DOFF*512 + OFF*38400 + Tm (9.2)

Note that formula (9.2) is covering formula (9.1) since in case 1, OFF and Tm are both equal to zero.

9.2.4 UE in dedicated CH state requests to add a new RL or moves to another cell

In FDD, based on the received parameters from the UE, the SRNC calculates the Frame_offset and the Chip_offset with the following formula:

Frame_offset*38400 +Chip_offset = OFF*38400 + Tm (9.3)

In TDD Frame_offset = OFF.

9.2.5 Handover from other RAN to UMTS

In FDD, based on the definitions for OFF and Tm formula (9.1) can also be used when the UE enters the UTRAN from another CN and establishes 1 dedicated RL. The same is true for formula (9.2) when establishing 1 or more dedicated RL's.

In TDD when the UE enters the UTRAN from another CN and establishes 1 dedicated RL, OFF is 0.

9.3 Calculations performed in the UE

9.3.1 First RL

In FDD, based on the received DOFF and the SFN of the cell in which the UE is camping, the UE can calculate the CFN with the following formula:

CFN = ((SFN*38400 - DOFF*512) div 38400)mod 256 (9.4)

In TDD the CFN is initialised with the value:

$CFN = SFN \mod 256$ (9.5)

Note: in case the UE is coming from another RAN, the SFN is not the SFN from the campin g cell but the SFN from the reference cell. In this case the OFF is set to 0.

9.3.2 Additional RL's or UE moves into a new cell

As long as the UE has one or more RL's established, the CFN will be increased (mod 256) by 1 every frame. Normally no special corrections are needed when moving from one cell to the other.

However every time the UE enters a new cell (target cell), OFF might have to be reported.

In FDD Tm is always reported. The target cell OFF is calculated using the following formula:

$OFF_{target} + Tm_{target} = (SFN_{target} - CFN) \mod 256$ (9.6)

OFF is calculated as the integer number of frames, Tm is the Frame fractional part with the unit chips.

In TDD the target cell OFF is calculated using the following formula:

$OFF_{target} = (SFN_{target} - CFN) \mod 256$ (9.7)

9.4 Synchronisation of L1 configuration changes

When a synchronised L1 configuration change shall be made, the SRNC commands the related Node B's to prepare for the change. When preparations are completed and SRNC informed, serving RNC decides appropriate change time. SRNC tells the CFN for the change by a suitable RRC message. The Node B's are informed the CFN by RNSAP and NBAP Radio Link Reconfiguration procedures.

At indicated switch time UE and Node B's change the L1 configuration.

History

Document history		
v 0.0.1	1999-10	Content derived from TS 25.401 V1.4.1 section 9 and annex A. Revision marks highlight changes respect to TS 25.401 V 1.3.1.
v 0.0.2	1999-10	Structure of the document completely rearranged. Figure 2 added by the editor in order to clarify section 6.1.2.1. Figure 5 added by the editor in order to clarify section 6.1.2.2. Figure 11 added by the editor in order to clarify section 9. Section on TDD Multi Frame Synchronisation removed, according to decision during last WG1 meeting.
v 0.1.0	1999-11	Proposal of R3-99e02 added in section 8.2.1. Proposal of R3-99e03 added in section 7.3.
v 0.1.1	1999-11	Figure 1 added. Definition of DOFF expanded. Figure 6 modified (HFN removed). Definition of UFN, HFN and CSN removed since not used in this spec. Some text in section 7.3.3 added by the editor. Figure 13 added by the editor.
v 1.0.0	1999-12	Approved during RAN3#9 Iub/Iur SWG with minor changes.
v 1.0.1	1999-12	Section 7.2 modified according to R3-99i00. Other minor modifications.
v 2.0.0	1999-12	Approved during RAN3#9 for submission to RAN#6.
Editor for UMTS25.402 is:		
Flavio Piolini Siemens Information & Communication Networks S.p.A. Mobile Networks - System Engineering GSM and UMTS 20060 Cassina de' Pecchi (MI)- Italy S.S. 11 Padana Superiore Km. 158 Phone: (+39) 02 43886527 Fax: (+39) 02 43886550 Email: flavio.piolini@siemens-icn.it		
This document is written in Microsoft Word version 7/97.		