3GPP TR 25.868 V5.0.1 (2002-03)

Technical Report

3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
Node B Synchronisation for 1.28 Mcps TDD;
(Release 5)

Keywords

<UMTS, radio, synchronization >

3GPP

Postal address

3GPP support office address

650 Route des Lucioles - Sophia Antipolis
Valbonne - FRANCE
Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Internet

http://www.3gpp.org

Contents

Foreword

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

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- x the first digit:
  - 1 presented to TSG for information;
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  - 3 or greater indicates TSG approved document under change control.
- 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.

1 Scope

The present document describes the solution recommended to enable the synchronisation of Node Bs over the air in 1.28Mcps TDD for Rel-5.

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] R1-01-0839: "Simulation results for NodeB synchronisation over the air for 1.28 Mcps TDD".

3 Definitions, symbols and abbreviations

3.1 Definitions

3.2 Symbols

3.3 Abbreviations

4 Background and Introduction

NodeB synchronisation for 1.28Mcps TDD is a Rel-5 work item that was agreed in RAN#11 plenary meeting. This work item involves the introduction of functionality to enable nodeBs to be synchronised.

This report identifies the required modifications within the UTRA layers 1/2/3.The method described is in addition to the Rel-4 feature of the synchronisation port contained in TS 25.402.

5 Motivation

Cell synchronisation is planned for 1.28Mcps TDD in order to fully exploit the system capacity. There are several factors that have an impact on the system capacity. The most important ones are:

- Inter-slot interference: without frame synchronisation there could be leakage from an UL timeslot into a DL timeslot, especially crucial for the UE due to the potentially close distance between UEs and the near-far effect.
- neighbouring cell monitoring: In TDD mode, certain measurements have to be performed in certain parts of certain timeslots of neighbouring cells. Without cell synchronisation, the UE would have to synchronise itself before being able to perform the measurements.

- Handover: The 1.28Mcps TDD mode may use timing advance and synchronisation in order to align receptions from all UEs at the cell's receiver. After a handover, the UE has to start transmission in the new cell with a timing advance value as good as possible. With the assumption, that the TDD cells are synchronised to each other, the handover performance can be optimised.

6 Accuracy Requirements

The minimum requirement for cell synchronisation accuracy determined by WG4 is 3us. Cell synchronization accuracy is defined as the maximum deviation in frame start times between any pair of cells on the same frequency that have overlapping coverage areas.

The minimum requirement for the synchronisation is set quite loose and in order not to impact the system capacity and the performance. However, the accuracy can be enhanced to allow the support of other purposes, such as LCS or improvement of handover procedure.

7 Concept of Node B Synchronisation

7.1 General

In addition to proprietary means there are two ways to achieve cell synchronisation in a TDD system:

- Synchronisation of nodes Bs to an external reference via the synchronisation port standardised for Rel-4
- Synchronisation of cells or Node Bs via the air interface described in this report for Rel-5

The solution described in this report allows a mixture of both schemes, i. e. some cells may be synchronised over the air, some via the synchronisation port. In general, at least one time reference (e. g. GPS) is needed for each island of cells having connectivity to each other.

The RNC shall be the master of the synchronisation process, since the measurements performed by a cell, shall be ordered, signalled to and processed by the RNC.

7.2 Node B on air synchronisation procedure by the DwPCH

The methods described in this section make use of the DwPCH to achieve Node B synchronisation over the air. Two options are investigated in the following sub-clauses:

- the centric option, which defers to the RNC all timing computations
- the distributed option, which leaves the maintenance of the synchronised status to the Node B by performing the timing adjustment

7.2.1 DwPCH centric solution

This section describes an example of how the RNC may implement a Node B and Cell synchronization procedure using over the air measurements including the measurement of one cell's DwPCH transmissions by other cells.

The synchronization procedure is based on making use of the transmissions of the DwPCH from neighboring NodeBs based on an RNC schedule. The timing offset measurements are reported back to the RNC for processing. The RNC generates cell timing updates that are transmitted to the Node Bs and cells for implementation. The synchronization procedure has three phases, the frequency acquisition phase, the initial phase and the steady-state phase. For Node Bs and cells with high accuracy frequency references, the frequency acquisition phas e may be omitted. The procedure for late entrant cells is slightly different and is described separately.

Frequency Acquisition Phase

The procedure for frequency acquisition is used to bring cells of an RNS area to within frequency limits prior to initial synchronisation. This phase would allow cells to use low cost reference oscillators with accuracies in the order of several ppm. No traffic is supported during this phase:

1 The cell(s) identified as master time reference (e.g. containing the GPS receiver or connected to an external time reference) shall transmit the SYNC_DL on DwPCH continuously

2 Initially all other cells shall be considered as unlocked (i.e. not in frequency lock).

3 While being in this state, a cell shall not transmit, but shall listen for transmissions from other cells. The cell shall perform frequency locking to any transmission received.

4 When a cell has detected that it has locked its frequency to within 50 ppb of the received signal it shall signal completion of frequency acquisition to the RNC and begin transmitting the own SYNC_DL.

5 When the RNC has received completion of frequency acquisition signals from all cells the frequency acquisition phase is completed.

Initial Synchronisation

For Initial Phase, where no traffic is supported, the following procedure for initial synchronisation may be used to bring cells of an RNS area into synchronisation at network start up.

1. The RNC sends a request over the relevant Iub to the cell(s) with a timing reference (e.g.GPS) for a timing signal. The RNC adjusts its clock appropriately, compensating for the known round trip Iub delay.

2. The RNC sends timing updates over the Iub to all the cells, apart from the one containing the GPS, instructing them to adjust their clocks towards its own timing. Each of the timing offsets is again adjusted.

3. At this point, none of the cells is supporting traffic. All cells are instructed to transmit their own SYNC_DL and listen to specific SYNC_DL from neighboring cells based on RNC schedule for initial synchronisation.

4. The cells those listen for transmissions and successfully detect other cells' DwPTSs shall report their timing and received S/(N+I) to the RNC over the relevant Iub. Knowing the schedule, the RNC is able to determine the cells which made the transmission and place a measurement entry in the relevant place in its measurement matrix. After all cells have made their transmissions, the RNC computes the set of updates, which will bring the cells nominally into synchronization.

5. Steps 3 and 4 are repeated several times (typically 10). This serves two purposes:

   - The rapid updates allow the correction of the clock frequencies as well as the clock timings to be adjusted in a short space of time. This rapidly brings the network into tight synchronization.

   - The S/(N+I) values are averaged over this period. This provides more accurate measurements (averaging over noise and fading), which can be used in the automatic generation of a measurement plan.

6. The S/(N+I) values are used, automatically, to plan a measurement pattern. This is performed as follows:

   - A matrix of minimal connectivity is computed on the basis of designating pairs of cells are minimal neighbours if either their estimated average S/(N+I) exceeds a threshold or if they have mutual neighbours.

   - The set of cells is divided into partitions of cells. Each partition must satisfy the requirement that no pairs of cells within that partition are minimally connected.

Steady-State Phase

The steady-state phase is used to maintain the required synchronisation accuracy. With the start of the steady-state phase, traffic is supported in a cell. A procedure that may be used for the steady-state phase make use of the DwPCH transmissions.

7. All of the cells are arranged to transmit its own predetermined SYNC_DL and receive specific other SYNC_DL from neighboring cells according to the above procedure. All cells report the reception timing for the specific SYNC_DLs back to the RNC.

8. At the end of each cycle, the RNC collates the information. In general there should always exist a path of bi-directional valid measurements that link every cell either directly or indirectly to the cell with UTC capability.

However, the model is arranged such that only those cells which have such a path will be updated on any given occasion.

9. The process of transmissions/measurements and updating then continues indefinitely.

Late entrant Node Bs

A procedure that may be used for introducing new cells into an already synchronised RNS is as follows:

The scheme for introducing new node Bs into a synchronized RNS is as follows:

1. The late entrant Node B cells are instructed to listen to specific SYNC_DL from neighboring cells based on RNC schedule for its initial synchronisation..
2. After this time the late entrant Node B can measure the timings of DwPTS transmissions received from specific Node Bs from neighboring cells and report these to the RNC. In turn, the RNC specify a SYNC_DL and can give the late entrant Node B its own schedules for SYNC_DL measurements of neighboring NodeBs.

7.2.2 DwPCH distributed solution

This section describes an example of how the RNC may implement a Node B and Cell synchronization procedure using over the air measurements including the measurement of one cell's DwPCH transmissions by other cells. This method intends to reduce the necessarily required high blanking rate of the method in 7.2.1.

The synchronization procedure is based on making use of the transmissions of the DwPCH from neighboring NodeBs based on an RNC schedule. The timing offset measurements are used in the NodeB, to adjust the timing to a neighbouring NodeB, depending on the configuration by the RNC. The RNC generates schedules, which define the blanking rate and time for the DwPCH of a Node B. The synchronization procedure has two phases, the initial phase and the steady-state phase. The procedure for late entrant cells is slightly different and is described separately.

Initial Synchronisation

For Initial Phase, where no traffic is supported, the following procedure for initial synchronisation may be used to bring cells of an RNS area into synchronisation at network start up.

1. The RNC sends a request over the relevant Iub to the cell(s) with a timing reference (e.g.GPS) for a timing signal. The RNC adjusts its clock appropriately, compensating for the known round trip Iub delay.
2. The RNC sends timing updates over the Iub to all the cells, apart from the one containing the GPS, instructing them to adjust their clocks towards its own timing. Each of the timing offsets is again adjusted
3. At this point, none of the cells is supporting traffic. All cells are instructed to transmit their own SYNC_DL and listen to specific SYNC_DL from neighbouring cells based on RNC schedule for initial synchronisation.
4. The cells those listen for transmissions and successfully detect other cells' DwPCHs shall report their timing and received SNIR to the RNC over the relevant Iub. .
5. Steps 3 and 4 are repeated several times (typically 10). This allows more accurate timing measurements to be performed. It also allows the SNIRs to be averaged over any fading to produce reasonably accurate entries for the path loss matrix.
6. The NodeBs adjust their timings according to adjustment commands received from the RNC based on the measurements above.The RNC forms a path gain matrix from the average of measurements reported to it from the various NodeBs. This is used for setting up the schedules for the steady state phase
7. The RNC also generates a table of path delays between NodeBs which can hear one another. The relevant entries of this table are communicated to the NodeBs so that they can compensate for path delays when adjusting their clocks during the steady state phase

Steady-State Phase

The steady-state phase is used to maintain the required synchronisation accuracy. With the start of the steady-state phase, traffic is supported in a cell. A procedure that may be used for the steady-state phase make use of the DwPCH transmissions.

1. All of the cells are arranged to transmit its own predetermined SYNC_DL and measure a specific other SYNC_DL sequence from a neighbouring cell according to the above procedure.

2. The NodeB compares the observed time difference, considering the known propagation delay and corrects its own timing.

3. The process of transmissions/measurements and updating then continues indefinitely.

Late entrant Node Bs

A procedure that may be used for introducing new cells into an already synchronised RNS is as follows:

The scheme for introducing new node Bs into a synchronized RNS is as follows:

1. The late entrant Node B cells are instructed to listen to SYNC_DL sequences from neighboring cells.

2. After this time the late entrant Node B can measure the timings of DwPCH transmissions received from specific Node Bs from neighboring cells and reports these to the RNC. In turn, the RNC specify a SYNC_DL and can signal the late entrant Node B its schedule for SYNC_DL measurements of a neighboring NodeB.

7.2.2.1 Some seen drawbacks by the opponents

1. Possible loss of control and supervision over network synchronisation operations. What happens if a Node B doesn't synchronise properly?

2. Steady state phase relies on a radio environment snapshot that has been captured during the initial phase and may quickly not be valid any more.

3. Iterative synchronisation of several slave Node B's in reference to a single master Node B.

7.3 Node B on air synchronisation procedure by extended synchronisation sequences

The method described in this section makes use of new synchronisation sequences, with respect to the ones currently defined by the standard. Actually, two alternative sequences are proposed of 128 or 192 chip length respectively; both sequences extend the DwPTS transmissions over the guard period and also the UpPTS (7.3.1).

Due to the longer duration, both sequences increase the processing gain with respect to what can be achieved with the DwPCH; therefore a reduction of the blanking rate with respect to the method described in section 7.2.1 is expected, though how much blanking rate can be reduced is still to be investigated.

Furthermore, the extension over the guard interval and the UpPTS (7.3.1), requires detailed investigations about possible impacts to the system performance.

In particular, some seen drawbacks by the opponents are:

- make use of GP by transmissions (frame structure)
- blanking of UpPCH accesses (lost RACH capacity),
- claimed gain is seen questionable, because UEs would try to access the system (no signalling on "forbidden" timeslots is possible)
- possible problems in HO, because UpPCH can not be received
- unclear, what this means to UE – positioning, because with DwPCH it was possible to reuse the blanking for IPDLs for UE Positioning (method in 7.3.1)

7.3.1 CEC sequences

This method is based on using both DwPTS and UpPTS time slots to transmit dedicated sequences for Node B synchronisation. The transmitted sequences are 192 chips long CEC (Concatenated Extended Complementary) sequences. In addition to the 3 dB extra processing gain brought by their higher length, they present a 32 chips wide perfect correlation window around the main peak and allow 2 Node B's to transmit their sequences simultaneously in steady state phase without interfering to each other in the tracking phase.

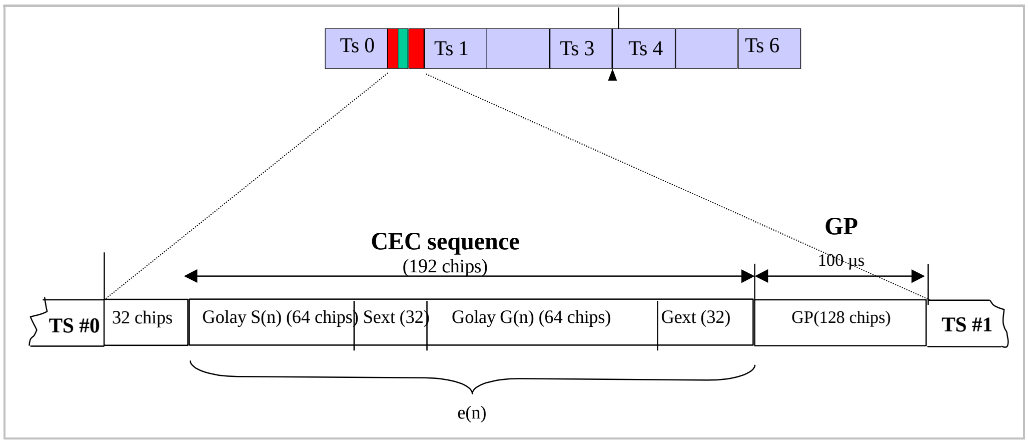

Figure 1: Structure of the combination of the CEC implementation for Node B synchronisation

At first, the sequence detecting performance for the Node B synchronization can be improved due to the 3dB extra processing gain brought by the CEC sequences in regards of SYNC_DL sequences. Then a second gain comes from the possibility for dual Node B transmission. By properly selecting the Node B for the transmission of the second sequence, the need for first interferer blanking is avoided and even replaced by a second measurement. It then appears that the number of blanked sub-frames due to Node B synchronization can be reduced. In addition, signalling amount over Iub is expected to be reduced since there is no need for signalling to the Node B which sequence to correlate with.

The DL / UL separation is shifted at the end of the CEC sequence but not reduced. The impacts to the system performance due to the blocking of RACH procedure should be investigated further by simulation. The expected extra performance gain due to the perfect correlation window must be investigated as well.

7.3.2 Extended SYNC_DL sequence using Gold sequence

This method is based on using an extended SYNC_DL sequences with the length of 128 chips which consists of first 64 chips, being the original SYNC_DL sequences and the second 64 chips is the modified Gold sequence.

The procedure based on extended SYNC_DL sequence is similar to the procedure based on DwPCH centric solution described in 7.2.1.. The extended sequence will be transmitted in DwPTS and the first 64 chips of the GP after the DwPTS during Node B synchronization.

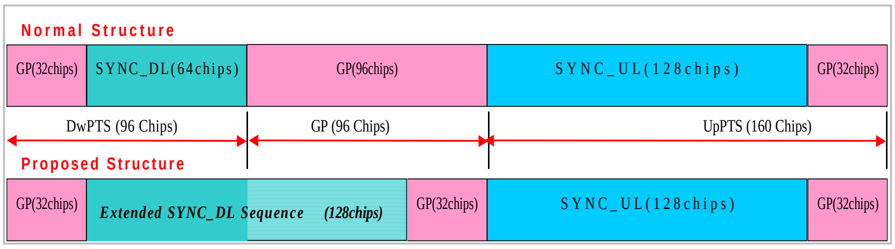

Figure 2: Structures of DwPTS and GP and UpPTS

Since the extended SYNC_DL sequences have the double length of the original SYNC_DL sequences, their processing gain is increased by 3dB, compared with the method based on DwPCH. The detecting performance of sequence for the Node B synchronization can be improved due to the increase of the processing gain. This will appear that the required transmission power of sequence for Node B synchronization can be decreased, which results in the number of the blanked sub-frames due to Node B Synchronization can also be reduced. In addition, no more signaling for extended sequences is needed since it gives the one-to-one mapping between SYNC-DL sequence and extended sequence.

Due to the longer sequence, the length of GP is changed from 96 chips to 32 chips, the impacts to the system performance due to the blocking of RACH procedure should be investigated further by simulation.

7.4 Potential Improvements for Handover

For handover the UE may be provided with information about the synchronization accuracy of the new cell so that it can apply the proper handover procedure to new cell and proper timing advance value in the new cell:

1. In cells with low sync accuracy (e.g. > 0.5us), HO will be done similar to random access procedure by sending UpPCH to the target cell to reach accurate uplink synchronization (the UpPCH may be sent with the calculated TA to the target cell to assure not to interfere with other time slots). The new value of TA is calculated by the UE after receiving the FPACH acknowledging the respective UEs UpPCH.

2. In cells with high sync accuracy (e.g. +- 0.1us) autonomous calculated TA in the UE will be used to synchronize to the target cell during HO. The maximum timing inaccuracy will be 0.4us.

The necessity to transmit the UpPCH for handover or not is indicated by higher layers signaling.

7.5 DwPCH for UE positioning

7.5.1 UE positioning enhancement with IPDL

To support time difference measurements for location services, idle period can be created in the downlink (hence the name IPDL) during which time the transmission of a NodeB is temporarily switched off. During the idle periods, the visibility of neighbour cells from the UE is improved. The idle periods are arranged in a determined pattern according to high layer signalling.

As discussed in NodeB synchronisation procedure, the NodeB switches off its DwPCH transmission and listens to the neighbour cells according to the schedule of RNC. Since timing difference measurement can be performed on any channel, so the blanking of the DwPCH (IPDL) can also be used for the UE.

7.5.2 UE positioning without IPDL

If the UE has the capability of an advanced technique such as interference cancellation, UE positioning without IPDL can be considered as an alternative solution. In case of UE positioning without IPDL, the UE complexity increase needs to be considered. Further study needs to be done to investigate the performance and the complexity issue.

8 Impact on Interfaces

More information on the RAN3 interface aspects can be found in Annex A.

8.1 Uu Interface

There is an impact on the receiving cell.

The receiving cell has to blank its own transmission of DwPCH on certain times and listen to the neighbouring cell. The UE may be informed about the blank of DwPCH, e.g., it can use such blanking period as IPDL for the measurements supporting LCS.

The cell sync codes to be used are SYNC-DL sequence, which have been described in detail in TS 25.223.

For handover the UE may be provided with information about the synchronisation accuracy so that it can apply the proper timing advance value and procedure in the new cell as described in section 7.3.

8.2 Iub Interface

The messages between a NodeB and the RNC were elaborated in detail in RAN3.

Procedures necessary are:

to instruct the transmitting Node B to transmit its normal SYNC_DL sequence in the DwPTS and

to blank the DwPCH of the neighbouring Node Bs and

to request measurements from the individual cells.

In general, the procedures listed above are similar to those already present for 3.84Mcps TDD. For this reason, a reuse of existing Iub procedures has been done wherever possible. Below is a list of differences between the two TDD options, which resulted in changes to existing Iub procedures:

- In 1.28Mcps TDD, SYNC_DL sequence is used to transmit over DwPCH to get to Cell Synchronisation, while Cell Sync burst is used to transmit over PRACH in 3.84Mcps TDD.
- Cell synchronisation procedure is based on radio subframe in 1.28Mcps TDD while Cell synchronisation procedure is based on radio frame in 3.84Mcps TDD. So one new IE 'Sub-frame LCR' is defined for 1.28Mcps TDD to indicate which subframe during the radio frame is used to achieve Cell synchronisation.

For the reason described above, some new IEs and IE groups are defined for 1.28Mcps TDD compared to 3.84Mcps TDD. Corresponding changes apply to TS25.433.

To give on overview on the mechanism of the synchronisation over the air interface, a new section for 1.28Mcps TDD is added to TS25.402.

8.3 Iur Interface

Each RNC area is synchronised individually to at least one reference clock (e. g. GPS). This automatically ensures synchronisation between RNC areas. Therefore, no communication over Iur is necessary for cell synchronisation between RNC areas.

9 Impact on network elements

9.1 UE

The UE shall have the capability to take into account the blanking of DwPCH and shall support the synchronisation accuracy signalling mechanism and have the capability to correct its TA value for handover.

The blanking interval of the DwPCH has to be chosen in such way, that this blanking is transparent for the initial cell search procedure also to the Rel-4 UEs.

9.2 Node B

The transmitting Node B would send its normal SYNC_DL sequence in the DwPTS. The neighbouring Node Bs measure this sequence in their DwPTS, therefore the DwPTS has to be blanked in the neighbouring cells for certain sub-frames to allow the measurements of the transmitting Node B.

The cells shall support the reception of the DwPCH from the neighbouring cells as well as measure the reception time. At least one external reference clock (e.g. GPS receiver) has to be added per connectivity area.

Furthermore, the cells shall have to provide means for adjusting their timing and optionally the clock rate on command. The changes in the NBAP protocol have to be supported.

9.3 RNC

The RNC has the control of the whole algorithm. It shall initialise, establish and maintain a connectivity plan. It shall order and collect measurements and compute adjustment commands as well as support the necessary NBAP signalling. It may estimate the synchronisation accuracy between cells and signal the relevant information to the UEs for handover.

10 Performance Analysis

10.1 Blanking of the DwPCH

Simulation assumptions:

- 6 immediate neighbours
- all of the NodeBs at the same range
- frequency reuse = 1

→ the only variable is the lognormally distributed shadowing effect (assuming that the NodeBs are on a regular grid).

Description:

For each deployment, the signal to interference ratio was computed for the signal from every neighbour. Then, the strongest N interferers to that signal were blanked, where N ranged from 1 to 4. Cumulative density functions were plotted for these cases. In the simulation, shadowing is considered, using a typical figure of 8 dB.

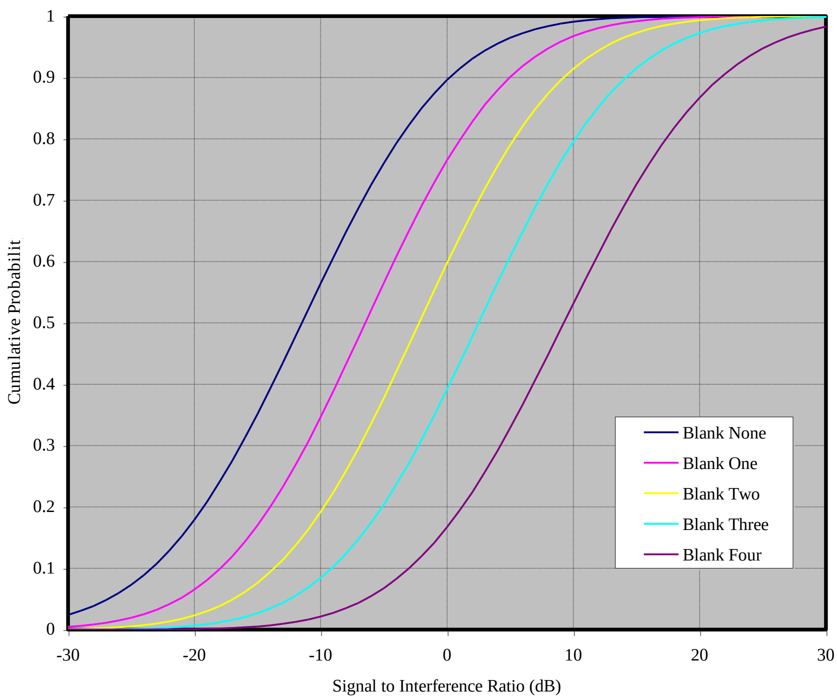

Figure 3: Signal to Interference Ratio Distribution with 8 dB Lognormal Shadowing

The simulation shows:

- the median performance with blanking improves
- there are gains from selecting the strongest interferers to blank
- choice of the sequences for blanking and the number of blanked sequences must carefully be chosen by the RNC
- The more neighbours are blanked, the higher the SIR (in median performance) for a given SYNC-DL sequence
- These simulations show, that blanking is essential for the operation of the Node B synchronisation method, using the DwPCH for a single frequency re-use deployment.

Conclusion:

Blanking of the DwPCH is necessary in order to reduce the interference in the DwPTS and allow for node B synchronisation over the air. Blanking of strong neighbours allows for monitoring more distant and therefore weaker other neighbours. The performance can further be improved by Network planning and averaging of different measurements.

10.2 Usage of receive beamforming

Simulation assumptions:

- 6 immediate neighbours
- all of the NodeBs at the same range
- frequency reuse = 1
- receive beamforming

Description:

Figure 4 present the results for the cumulative density function of signal to interference ratio for blanking up to 4 interferers for the case, that receive beamforming is applied.

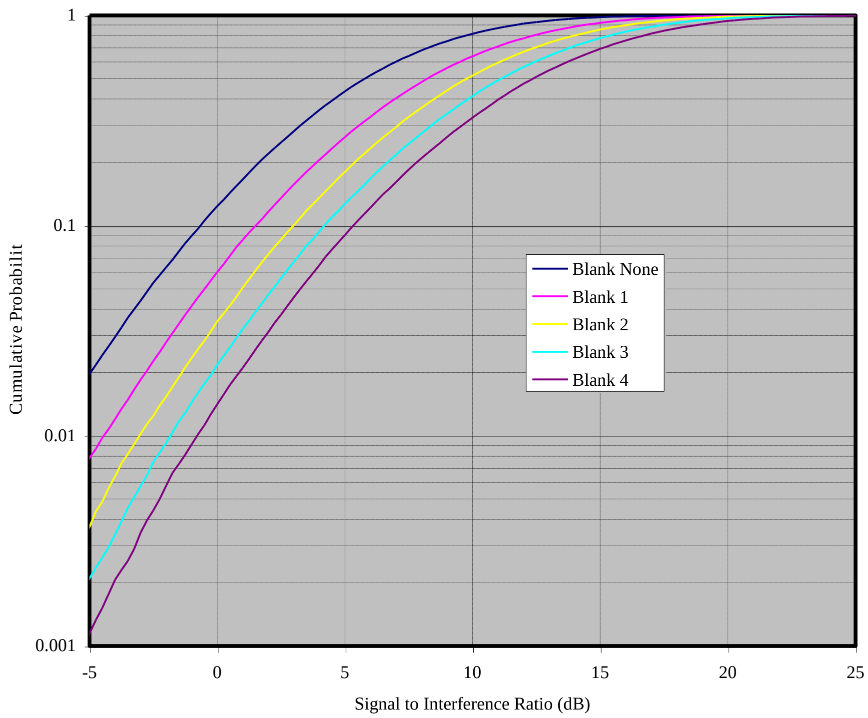

Figure 4: Cumulative Probability of SIR for Antenna Diameter 1.25 Times Wavelength - Partially Correlated Shadowing

The simulation shows:

- receive beamforming increases the signal to interference ratios of the SYNC-DL sequences
- the number of blanked neighbours is no longer the dominant criterion for the achieved performance of the synchronisation method
- fewer neighbouring interferers cause interference to a specific node B

- with receive beamforming the number of interferers (SYNC-DL sequences), that have to be blanked to achieve the required performance, can be reduced

Conclusion:

The use of smart antennas further increases the performance of this node B synchronisation method which could reduce the number of neighbours, which have to be blanked (only DwPCH).

11 Backward Compatibility

UTRAN: The synchronization over the air in Rel-5 can be used in addition to and in combination with the synchronization via the sync port in Rel-4. Therefore backward compatibility is ensured for the UTRAN.

UE: The Rel-4 UEs cannot receive the DwPCH when it is blanked based on the RNC schedule. However, the UE algorithms involved in detecting and processing the DwPCH for initial cell search have to cope with failed detection of one or more DwPCH(s), e.g. due to fading. Therefore, backward compatibility is satisfied for the Rel-4 UE if the DwPCH of Rel-5 or later BS is blanked at an acceptably low rate. The determination of the required blanking rate in order to meet the required Node B synchronization accuracy remains to be done, and then the impact of this rate on initial cell search must be verified to be minor.

Annex A:
RAN3 Aspects

3GPP TR R3.004 V1.0.0 (2002-02)

(Proposed Technical Report)

3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
Node B synchronisation for 1.28 Mcps TDD;
(Iub/Iur aspects)

(Release 5)

Keywords

<keyword[, keyword]>

3GPP

Postal address

3GPP support office address

650 Route des Lucioles - Sophia Antipolis
Valbonne - FRANCE
Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Internet

http://www.3gpp.org

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[1] 3GPP TS 25.433: "UTRAN Iub Interface NBAP Signalling".

[2] 3GPP TS 25.402: "Synchronisation in UTRAN, Stage 2".

[3] 3GPP TR 25.838: "Node B Synchronisation for TDD (Iub/Iur aspects) ".

[4] 3GPP TS 25.435: "UTRAN Iub Interface user plane protocols for CCH data streams".

[5] R1-01-1348 TR 25.868 V1.1.0: "Node B Synchronization OTA for 1.28 Mcps TDD"

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply.

Neighbour cell for synchronisation: A cell is a “direct neighbour cell” of another cell, if these two cells can safely receive the signals sent out for intercell-synchronisation (e.g. the SYNC_DL in the DwPTS) of each other.

Minimal neighbours: A cell C(1) and a cell C(2) are called “minimal neighbours” if they are either direct neighbours, or there exists an intermediate cell C(3) such that C(1) and C(2) are both direct neighbours to C(3).

Indirect neighbours: A cell C(1) is an indirect neighbour to a cell C(N) if there exists a chain of intermediate cells C(2), C(3), …, C(N-1) such that C(1) is direct neighbour of C(2), C(2) is direct neighbour of C(3) etc, and C(N-1) is direct neighbour of C(N).

Connectivity Area : the Connectivity Area is an island covered by a set of cells which are all direct or indirect neighbours to each other.

Master cell: A cell which has local access to a reference clock which allows for frame and multiframe (SFN period) synchronisation to that reference clock independent of over-the-air synchronisation.

3.2 Abbreviations

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

DwPCH Downlink Pilot Channel
DwPTS Downlink Pilot Timeslot
GPS Global Positioning System

NBAP	NodeB Application Part
RFN	RNC Frame Number
RNC	Radio Network Controller
RNS	Radio Network Subsystem
SFN	Cell System Frame Number (counter)
SIR	Signal to Interference Ratio
TDD	Time Division Duplex
UE	User Equipment

4 Background and Introduction

Node B synchronisation for 1.28Mcps TDD is a release 5 work item that was agreed in RAN#11 meeting. This work item enables the 1.28 Mcps TDD Inter Node B Node Synchronisation via the air interface. This includes the synchronisation of cells among each other belonging to the same Node B or to neighbouring Node B.

This document will identify the changes that are required to WG3 documents to enable the adoption of the accepted methods into the 3GPP standards.

5 Requirements

For support of the Node B Synchronization for 1.28 Mcps TDD the following functionalities have to be provided:

- Synchronisation of the radio frame clock and multiframe clock (SFN period, 4096 frames) between neighbouring cells.
- Possibility to synchronise cells without external reference at each Node B.
- Possibility to synchronise the 1.28 Mcps TDD cells belonging to the same or different Node B to an external clock (e.g. GPS) provided at a sync port of one or more "master cells".
- Combining Iub interface signalling for "course synchronisation" with over-the-air synchronisation for "fine tuning".
- Simultaneous, initial synchronisation of a group of cells in an RNS to each other and to a master cell before taking the cells into active service.
- Maintaining steady state synchronisation of a group of cells in an RNS during ongoing service.
- Synchronisation of "late entrant" cells being added to a set of active cells without service interruption of the active cells.
- Support of a range of synchronisation algorithms as described in [5], where the choice of the algorithm is left to the CRNC.

6 Study Areas

6.1 General

This section contains some basic information about Node B synchronization over the air for 1.28Mcps TDD.

6.1.1 DwPCH for Node B Synchronization

The DwPCH is normally used for synchronization of UEs in UTRA 1.28Mcps TDD mode to the respective UTRAN cells. In 1.28Mcps TDD there exist 32 cell groups, each using a unique SYNC_DL code, which is transmitted on the DwPCH in the DwPTS timeslot. The DwPTS consists of a Guard Period and a 64 chip long sequence, the SYNC_DL sequence (cf. Figure 5).

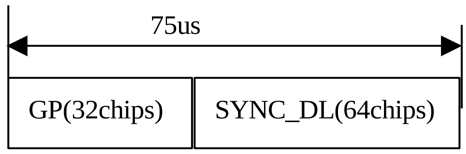


Figure 5: Structure of DwPTS

The DwPCH can – in addition to that original purpose of UE synchronisation – be used for maintaining a group of cells in a “connectivity area” synchronised to each other. For this purpose, a cell must be instructed not only to transmit the DwPCH signal, but also to receive this signal from neighbouring cells. This may result in a scheme as outlined below for the Steady-State synchronisation phase.

A cell transmits its normal SYNC_DL sequence in the DwPCH. However, in certain selected subframes, a cell shall “blank” the DwPCH transmission, i.e. it shall suspend transmission, and shall receive (measure) the DwPCH bursts from neighbouring cells instead. The cells will be transmitting more often than they will be making measurements. Scheduling information is used to inform a cell when to listen to its neighbours, at which time it must blank its own DwPCH. The scheduling of the listening/blanking sequence for each of the cells is controlled by the RNC.

During the sync schedules, only a few cells will transmit their SYNC_DL bursts. The listening cell shall make a measurement of one of these neighbours (nearer to a master than itself) Since in 1.28 Mcps TDD, neighbouring cells will typically transmit on different frequency bands, a cell which shall measure the DwPCH bursts of its neighbours must be able to receive bursts of different frequency bands. The cell will be scheduled to listen to the required frequency bands, in order to obtain the required measurements.

6.1.2 Over the Air Cell Synchronization mechanism

For cell synchronization over the air interface three different synchronisation stages are distinguished:

- Initial synchronisation,
  The initial synchronisation is used when a TDD network is newly established and has to be synchronised. It is assumed that none of the cells is supporting traffic at this time. The initial synchronization consists of two phases: the preliminary phase and the initial phase

- Steady-State phase,
  In the steady state phase the synchronisation mechanism during normal operation applies.

- Late-Entrant cells,
  Synchronisation mechanism for cells to be added to a synchronous network or cells recovering from loss of radio interface synchronisation.

This results in the following phase structure:

1. Initial Synchronisation

1.1 Preliminary Phase

1.2 Initial Phase

2. Steady State Phase

3. Late Entrant Synchronisation

6.1.3 Synchronization Procedures

The Node B synchronization procedure for 1.28Mcps TDD is an optional procedure based on the usage of the transmissions of the DwPCH according to an RNC schedule. The timing offset measurements are reported back to the RNC for processing. The RNC generates cell timing updates that are transmitted to the Node Bs and cells for implementation. Alternatively, the Node B can also be instructed by the RNC to apply autonomous timing adjustments in specific cells, and to report the cumulated adjustments back to the RNC for surveillance purposes.

The initial synchronization procedure has two phases to bring a network into a synchronized operation, the preliminary phase and the initial phase.

Once the network is in synchronisation, the steady-state phase serves for maintaining synchronisation.

In addition there is the procedure for late entrant cells for cells to be added to a synchronised network.

6.1.3.1 Initial synchronisation

Preliminary Phase

1) There should be at least one “master cell” in each RNS connectivity area. This is a cell that is synchronised by an external reference (e.g. GPS). This cell should determine the local time modulo SFN period (4096 radio frames).

2) At the beginning of the Preliminary Phase, the RNC has to be informed which cells are “master cells”, i.e. at which of the cells an external reference is connected.

3) The RNC retrieves the reference timing signal from these master cells. When receiving the response about the timing, the RNC adjusts its internal clock RFN (RNC Frame Number), compensating for the Iub transmission delay by subtracting half of the estimated round trip Iub delay.

4) Now the RNC proceeds by updating the timing of all the remaining cells in the RNC, instructing them to adjust their clocks. Each of the timing offsets is adjusted by the half the Iub round trip delay for that Node B.

Required Iub interface procedures:

- Procedure for retrieving the SFN from the cells and for measuring the Iub interface roundtrip delay. – This can be done via existing Frame Protocol procedures.

- Procedure for cell timing (SFN and Frame boundaries) adjustment.

Result: The RFN in the RNC and the SFNs in all the cells are in “coarse synchronisation” with the “master cells”. The remaining timing uncertainty is due to the Iub interface transmission delay and is typically not more than a few radio frames. (It is up to the RNC to calculate the range of uncertainty after the Preliminary Phase and to take this into account in the following synchronisation steps.)

Initial Phase

The Initial Phase can start once the cells are in “course synchronisation” with respect to their SFNs.

1) At this point, none of the cells is supporting traffic. All cells are instructed to transmit the SYNC_DL one-at-a-time and for the others to listen to that SYNC_DL signal based on RNC schedule for initial synchronisation. The SYNC_DL sequence is transmitted continuously throughout each radio frame period. Note: timeslots are not supported during the initial phase.

2) The cells that listen to transmissions and successfully detect other cells SYNC_DLs report their timing and received S/(N+I) to the RNC over the relevant Iub. Knowing the schedule, the RNC is able to determine the cells which made the transmission and place a measurement entry in the relevant place in its measurement matrix.

3) After all cells have made their transmissions, the RNC computes both the estimated signal propagation delay between each two neighbouring cells, and the set of updates which will bring the cells nominally into synchronization. The RNC commands the respective cells to perform that timing update.

4)Steps 1 to 3 are repeated several times (typically 10). This serves two purposes:

- The rapid updates allow the correction of the clock frequencies as well as the clock timings to be adjusted in a short space of time. This rapidly brings the network into tight synchronization.

- The S/(N+I) values are averaged over this period. This provides more accurate measurements (averaging over noise and fading) which can be used in the automatic generation of a measurement plan for the Steady-State Phase to follow.

5) The S/(N+I) values are used by the RNC, automatically, to plan a measurement pattern for the Steady-State phase. This may be performed as follows:

- A matrix of minimal connectivity is computed which indicates for each pair of cells whether they are minimal neighbours. A pair of cell is designated minimal neighbours if either their estimated average S/(N+I) exceeds a threshold (so they are direct neighbours) or if they have mutual direct neighbours.

- The set of cells is divided into partitions of cells. Each partition must satisfy the requirement that no pairs of cells with the same SYNC_DL on the same frequency within that partition are minimally connected. If this split into partitions succeeds, it means that all cells in a partition can send their SYNC_DL signals simultaneously without causing ambiguity for the receiving cells, because any receiving cell can distinguish the transmitting cells from the SYNC_DL code and the frequency band. – It is advantageous to minimise the number of partitions by suitable assignment of SYNC_DL codes to the cells.

Required Iub interface procedures:

- RNC to command Node B to send in a specific cell a specific SYNC_DL code with specified transmit power throughout a specific radio frame SFN, and to repeat that transmission with a certain repetition pattern within each SFN period for indefinite time.
- RNC to command Node B to receive in a specific cell a set of specific SYNC_DL codes in specified frequency bands, whenever this cell is not transmitting its own SYNC_DL code, and to report the measured times of arrival of these SYNC_DL codes, and the associated S/(N+I) values, to the RNC.
- Node B to report measurements of SYNC_DL codes, with associated timing and S/(N+I), to the RNC.
- RNC to command a cell (in a Node B) to adjust its timing. The range of timing adjustment can exceed one radio frame in this phase but its step size should be sufficiently small to achieve the required target synchronisation accuracy required to enter the Steady State phase.

Result: The RNC knows the "visibility" between each pair of cells, i.e. the path attenuation and S/(N+I) values for SYNC_DL signals; so it can determine a SYNC_DL transmit and receive schedule for the Steady State phase. It also knows the propagation delay between neighbouring cells. – At the end of this Initial Phase, the cells are in synchronisation, due to the timing update commands received from the RNC.

6.1.3.2 Steady-State Phase

The steady-state phase allows the system to reach/or maintain the required synchronization accuracy. Several schemes may be possible in that Steady-State phase. We first present the “basic” scheme, and then present some recommended extensions, which may be used under adverse circumstances, to achieve reliable measurements of SYNC_DL codes from neighbour cells, and to achieve immediate, fast timing corrections while reducing the Iub interface signalling load.

6.1.3.2.1 Basic method

1) Each of the cells transmits its own predetermined SYNC_DL on the DwPCH and receives the specific SYNC_DL of neighbouring cells according to a SYNC_DL burst transmit and receive schedule which defines a synchronisation cycle that is periodically applied by the cell. All cells report the reception timing for each specific SYNC_DL back to the RNC. Note: timeslots are now supported and the DwPCH is carried in the DwPTS only.
2) At the end of each cycle, the RNC collates the information and sends timing correction commands to the respective cells. – Note: In general there should always exist a path of bi-directional valid measurements that link every cell either directly or indirectly to the master cell with reference clock. However, the timing correction may be arranged such that only those cells which have such a path will be updated on any given occasion.
3) The process of transmissions/measurements and updating then continues indefinitely.

Required Iub interface procedures:

- RNC to command the cells to apply a “synchronisation schedule” consisting of “synchronisation cycles”; to send their normal SYNC_DL in the DwPTS time slots with the required transmit power; to “blank” the DwPTS at certain periodic times within the SFN period, and to perform measurements of SYNC_DL codes of neighbouring cells, and to report the measured timing and S/(N+I) to the RNC
- Node B to report the measurements according a specified reporting characteristics: immediately, or after each synchronisation cycle, or after an SFN period.
- RNC to send a timing adjustment command.

Result: The cells remain in accurate synchronisation to each other and to the master cells.

6.1.3.2.2 Extended method

The following extensions of the basic scheme could be supported, for improved performance:

1) **Averaging of measurements:** For increasing the S/(N+I) values of measured SYNC_DL bursts, it shall be possible for a cell to apply an averaging of SYNC_DL bursts received from the same neighbouring cell, before deriving the receive timing from the correlation result. – During the averaging period, the timing in the neighbouring cells transmitting the SYNC_DL bursts should be "frozen" in order to avoid "blurring" of the averaged measurements. – **Proposed solution**: This optional averaging should be supported by subdividing the Synchronisation Cycles into a number of "Subcycles" where in each Subcycle, a full set of SYNC_DL samples is received, and by averaging over the subcycles, such that at the end of a Synchronisation Cycle a full set of timing deviation measurements with improved S/(N+I) is available. The number of subcycles should be configured by the CRNC; if there is just one subcycle per Sync Cycle, no averaging is performed.

2) **Self-adjustment of the radio interface timing**: It shall be possible for the RNC to allow the Node B to perform a timing correction based on its own measurements autonomously without requiring the RNC to calculate the amount of timing correction. This reduces the amount of Iub interface signalling while allowing for fast corrections of timing deviations. - However, the RNC shall specify the frame numbers when these timing adjustments shall be applied. So the RNC can make sure that in the rest of the time, and in particular during neighbouring cell measurement averaging periods, the timing of cells being measured remains unchanged. - After each timing adjustment, or after a series of adjustments, the Node Bs shall report their (accumulated) adjustments to the RNC for surveillance purposes. – Proposed solution: This SRNC should indicate the possibility of self-adjustment, by inclduing a *Propagation Delay Compensation* IE into the CELL SYNCHRONISATION RECONFIGURATION message, in addition to the SYNC_DL code to measure. Whenever this optional IE is present, the Node B should use the respective SYNC_DL measurement (after potential averaging) to perform the self-adjustment at the end of a Synchronisation Cycle. – Whenever this IE is not present, no self-adjustment shall be performed.

Required Iub interface procedures:

- The synchronisation burst receive plan which the RNC sends to Node B, shall be extended to include, for each synchronisation cycle, the number of subcycles. If this number is larger than unity, averaging shall be performed over a Sync Cycle period.
- The synchronisation burst receive plan shall also include an optional Propagation Delay Compensation IE as side information added to a SYNC_DL burst to measure. If this IE is present, the respective SYNC_DL burst measurements shall be used for timing self-adjustment.
- The measurement reports sent from Node B to RNC shall be extended to be able to report timings and S/(N+I) values derived from averaged measurements, and to report the cumulated adjustment, cumulated since the last report, in case self-adjustment has been applied.

6.1.3.3 Late-Entrant Cells

The scheme for introducing new cells into a synchronized RNS is as follows:

1) Late-entrant cells (new cells being added without GPS receiver) or cells recovering from unavailability shall first be roughly synchronised via Iub interface messages..
2) The RNC should tell the late-entrant which SYNC_DL codes and carrier frequencies to listen for, corresponding to its neighbour cells. After the late-entrant cell has achieved frequency lock it should be reported to the RNC.
3) The late entrant then continues to listen and then reports the timing of the sync bursts that it receives. The RNC knows the location of all cells and therefore should be able to compute a timing adjustment for the late-entrant that takes into account the expected propagation delays between the late-entrant and its neighbours. The RNC adjusts the cell and the cycle is repeated until the RNC is satisfied that the cell's timing is accurate enough for it to be allowed to enter the Steady State phase.
4) The RNC can then give the late-entrant cell its own schedule for sync burst transmission and reception and can also include it in the schedules given to its neighbouring cells..

6.2 Iub interface

Procedures are necessary

- to instruct the transmitting Node B to transmit its normal SYNC_DL sequence in the DwPTS and
- to blank the DwPCH of the listening Node Bs and
- to request measurements from the individual cells.
- to adjust its transmitted power for the SYNC_DL sequence in the DwPTS when performing cell synchronisation measurements
- to adjust the transmitted power of the SYNC_DL sequence in the DwPTS during NodeB sync transmission and reception operations.

The same procedures can be used as for Node B synchronization for 3.84Mcps TDD.

The same messages can be used as for Node B synchronization for 3.84Mcps TDD.

It is expected that there are impacts on the information elements, which are introduced for the Node B synchronization for 3.84Mcps TDD, but it can be solved in a backward compatible way. Additional Information Elements for the extended signalling approach for the steady state phase must be introduced.

6.3 Iur interface

It is expected that Node B Synchronization for 1.28 Mcps TDD (Iub/Iur aspects) affects the NBAP [1] specification and the Synchronization in UTRAN Stage 2 [2]. Since it is assumed that each RNC area is synchronized individually to at least one reference clock, this ensures automatically synchronization between RNC areas. Therefore no communication over Iur is necessary between RNC areas.

6.4 Node B

The transmitting Node B would send its normal SYNC_DL sequence in the DwPTS, possibly at modified transmitter power. The neighbouring Node Bs measure this sequence in their DwPTS, therefore the DwPTS has to be blanked in the listening cells for certain subframes to allow the measurements of the transmitting Node Bs. Blanking of the DwPTS in non listening cell may also be necessary to furnish adequate SINR in the listening cells. Furthermore at least one external reference clock (e.g. GPS receiver) has to be added per connectivity area.

6.5 RNC

The RNC has to control the whole algorithm, the initialisation and establishment of a connectivity plan, collection of measurements and computation of the adjustment commands as well as support the necessary NBAP signalling. It may estimate the synchronisation accuracy between cells and signal the relevant information to the UEs for handover. All algorithms involved in the computation of timing updates and schedules are proprietary.

6.6 Synchronisation Signalling aspects

6.6.1 Initial Synchronisation

This stage covers the "Preliminary Phase" where the Node B is roughly synchronised via Iub interface messages, and the "Initial Phase" where the radio interface timing of the cells is fine-tuned via radio for the first time.

6.6.1.1 Preliminary Phase

Iub signalling in the preliminary phase shall serve the following purposes:

- Reference cell identification: The RNC shall be informed at which of the cells the external reference clock (e.g. GPS receiver) is connected.
- Reference time retrieval: For the initial adjustment, the reference time of a cell where a GPS receiver is connected has to be requested.
- Initial Synchronisation adjustment: The reference time has to be provided to the cells without the GPS receiver.

The procedures and messages for 1.28 Mcps TDD are identical to those described for 3.84 Mcps TDD in [3] and appropriate amendments have already been incorporated into the NBAP specification [1].

Reference Cell Identification:

The information about the reference clock availability is included within the RESOURCE STATUS INDICATION message that is sent from the Node B to the RNC when a Local Cell becomes existing at the Node B.

Reference Time Retrieval:

For the reference time retrieval the DL Transport Channels Synchronization procedure or the Node Synchronisation procedure on the PCH frame protocol (see [4]) can be used. At this phase, a timing granularity of one radio frame is considered sufficient, which can be achieved by retrieval of the SFN which the cell has derived from the external reference clock.

Initial Synchronization Adjustment:

For the cells to adjust first the DL Transport Channels Synchronization procedure on the PCH frame protocol shall be performed in order to determine the deviation from the reference SFN.

By means of the CELL SYNCHRONISATION ADJUSTMENT REQUEST message, the Frame Adjustment value is then transmitted by the RNC to the cells without an external reference clock.

6.6.1.2 Initial Phase

In the initial phase the RNC will establish the "connectivity matrix", and in addition, the cells are for the first time brought into fine-synchronisation. During the initial phase any UE connections are disabled. The following procedures will have to be considered:

- Cell Sync Burst Instruction: Each cell is instructed to transmit a cell sync burst at a certain SFN number and to listen to other cells' sync bursts for the rest of the time.
- Cell Sync Bursts Measurement Report: The cells report on measured cell sync bursts.
- Synchronisation Adjustment: The RNC provides timing adjustments to the cells.

Cell Sync Burst Instruction

The RNC instructs each cell in turn to transmit a common SYNC_DL sequence in a specified SFN while all other cells listen. The CELL SYNCHRONISATION INITIATION REQUEST message is used to define the transmission and listening schedule.

Each cell uses the same carrier frequency and transmits just once in order to avoid any ambiguity in reception. The RNC will decide how many frames apart transmissions from successive cells shall be scheduled, taking into account the estimated errors in timing accuracy. In particular, initially there may have to be frames in which no transmission is scheduled.

Note: 1.28Mcps TDD timeslots are not supported during this phase.

Cell Sync Bursts Measurement Report

The cells report timing and SIR measurements via the CELL SYNCHRONISATION REPORT message.

The resolution of the arrival time measurement shall be about 75ns.

Cell Sync Adjustment

Whenever a cell reports the reception of a sync burst, the RNC can deduce unambiguously from the timing which cell made the transmission and therefore calculate the apparent time difference between transmission and reception. Part of the difference will be due to the distance between the cells and part due to the difference in their clocks. In principle, if each pair of cells hears each other's transmission then both factors can be deduced. However, to determine how much timing correction to apportion to each cell is more complicated.

When all cells have transmitted, the RNC computes the set of timing updates and communicates them to each cell via the CELL SYNCHRONISATION ADJUSTMENT REQUEST message.

The cell can deduce a frequency correction from the timing adjustment and the elapsed time since the previous update. It sends a CELL SYNCHRONISATION ADJUSTMENT RESPONSE message to the RNC after implementing the adjustment.

Several iterations of the steps of the Initial Phase are required to achieve the necessary timing and frequency accuracy. A timing accuracy of a few µsec is needed, not least to ensure that in future a received SYNC_DL sequence cannot invade much of the guard period at the end of timeslot 0 i.e. immediately preceding the DwPCH. The RNC could define a new transmission/measurement schedule for each iteration as timing accuracy improves, in order to accelerate the process.

6.6.2 Steady-State Phase

For the Steady State phase, two versions have been proposed: (1) The Centralised Control approach, and (2) the Flexible Signalling approach. These are described in the two subchapters below.

In addition, it is possible to include some elements of the Flexible Signalling approach into the Centralised Control as an extension, in order to increase the performance of the Centralised Control approach without introducing new NBAP messages. This has been done below in the chapter for Centralised Control, under the lable "Extended flexibility". The extended flexibility could be supported by additional Information Elements in the existing NBAP messages used for TDD Node B synchronisation.

6.6.2.1 Centralised Control

In the steady state phase each cell gets a cell sync burst plan that defines when cell sync bursts shall be transmitted and when cell sync bursts should be received. In this phase, the normal traffic is supported, i.e. the regular cell synchronisation monitoring and update is done in parallel to ongoing UE connections.

The cells now transmit their own pre-defined SYNC_DL sequence, rather than using a common code, on the frequency specified by the RNC. The plan should aim to minimise the blanking i.e. to maximise the number of sub-frames in which a cell transmits its SYNC_DL sequence.

As in the Initial Phase, the following procedures have to be considered:

- Cell Sync Burst Instruction
- Cell Sync Bursts Measurement Report
- Synchronisation Adjustment

Cell Sync Burst Instruction

Defining the schedule consists of defining the transmission parameters and defining the receiving parameters i.e. it is defined at which radio frames the cell shall transmit a sync burst and at which radio frames the cell shall measure specific sync bursts. This is achieved via the CELL SYNCHRONISATION RECONFIGURATION REQUEST message.

The SFNs when to send or receive are not indicated explicitly but they are derived by the fact that the whole SFN period (4096 frames) is subdivided into several 'synchronisation cycles' of equal length, and each "synchronisation cycle" is itself divided into several "repetition periods" of equal length. The first radio frame in each repetition period is available for either transmitting or receiving synchronisation bursts. The measurement results can be reported to the RNC as configured in the measurement reporting characteristics, which can be after each measurement (i.e. once per repetiton period), or after each "synchronisation cycle", or after each SFN period, or event driven.

Note: 1.28Mcps timeslots are now supported from this phase onwards.

Extended flexibility: Averaging: It may be required to increase the S/(N+I) values of the received SYNC_DL bursts in order to provide high quality "Time of Arrival" estimations which are then reported to the RNC or otherwise processed. For this purpose, it has been proposed in [5] to apply "averaging" over a set of received SYNC_DL bursts. – This can be supported by extending the synchronisation schedule (transmit and receive plan) as follows: Each "Synchronisation Cycle" is subdivided into a number of "Sybcycles", where within each subcycle, a full set of "repetitions" (SYNC_DL transmissions or receptions) is performed. The data received during a subcycle are stored in a buffer for averaging. At the end of the Synchronisation Cycle, the result of averaging over the subcycle is the basis for deriving timing measurements and S/(N+I) indications, where the S/(N+I) has been improved by averaging, and henve the timing measurement is more reliable. The averaging buffer is reset at the beginning of a new Synchronisation Cycle.

The is an extension of the normal Centralised Approach: If the number of subcycles is set to unity, the extension falls back into the normal centralised procedure.

Extended flexibility: Self-adjustment. Another extensions proposed in [5] is the possibility of self-adjustment of the timing by the cells themselves, based on SYNC_DL measurements. This shall be supported as follows: An optional Information Element "Propagation Delay Compensation" shall be added to each SYNC_DL burst to receive. If this IE is present, the cell shall use the measured timing for self-adjustment of its timing, i.e. whenever the measured "Time of Arrival" of a SYNC_DL burst does not match the value included in the Propagation Delay Compensation IE, the cell shall perform a timing adjustment, for reducing the timing deviation to that neighbouring cell. (Typically, that adjustment shall be less than half the deviation, to avoid instable adjustment cycles.) – This timing adjustment shall only be done at the end of a Synchronisation Cycle.

The RNC can prohibit that self-adjustment of the cells by omitting the Propagation Delay Compensation IE.

Cell Sync Bursts Measurement Report

The cell changes frequency if necessary to receive the specified SYNC_DL bursts. It decodes the specified SYNC_DL sequences from defined neighbouring cells and reports received code, signal time and power indicator to the RNC via the CELL SYNCHRONISATION REPORT message.

Extended flexibility: Accumulated Adjustment Reporting. The Cell Synch Burst Measurement Report should be extended to include the Accumulated Adjustment IE, provided the cells in the Node B had been enabled to perform self-adjustment. This adjustment reporting should be done in the same messsage as the measurement reporting, and shall always report the sum of timing adjustments performed since the last measurement report. This shall also include the timing adjustments performed by explicit adjustment command from the RNC, if this adjustment occurred after the last measurement report.

Synchronisation Adjustment

The RNC analyses the measurement reports continuously. A CELL SYNCHRONISATION ADJUSTMENT REQUEST message is sent to a cell when the analysis concludes that a correction is necessary.

The steps of the Steady-State phase are repeated indefinitely.

Based on the above extensions, the Centralised Control approach already provides the following features proposed for the "Flexible Signalling" approach in [5]:

- Averaging of a sequence of sync burst correlation results, for increased reliability of measurements
- Self-adjustment of the timing
- Reporting of accumulated timing adjustment

6.6.2.2 Flexible Signalling

Master / Slave Control

In the de-centralized approach, the roles of the NodeB and RNC with respect to NodeB synchronization could be characterized as client / server. In these roles the RNC provides each NodeB with enough information to operate its OTA synchronization essentially autonomously. Even in the centralized approach, the schedules for transmission and reception and the applicable codes were downloaded once and then applied autonomously by the NodeB. Whilst this is attractive in reducing the amount of Iub traffic from the RNC to the NodeBs it is very inflexible. It results in highly specialized, complex and relatively large Iub messages.

In the proposed alternative the NodeB is essentially a "dumb slave". The NodeB is unaware of schedules for transmission or reception other than in terms of a generic clock structure. The NodeB is instructed directly to transmit DwPTS at given power, or to blank, or to search for a particular code. This instruction must be sent every time the operation is required. Therefore every 8th or 16th subframe or more seldom, if the schedule allows for less blanking. Although this approach leads to increased Iub traffic from the RNC to the NodeBs, the amount of this traffic is minimal since the applicable message fields can be very small.

There would be basically 6 RNC to NodeB Iub message types ('Do nothing unusual' would not require a message at all)

1. Change Power to X - For power controlled transmissions of DwPTS
2. Blank the DwPCH transmission for a subframe
3. Correlate against code N and report the measurement.
   (If the RNC wanted the Node B to correlate against more than one code simultaneously then it would repeat this message with the other value(s) of N.)
4. Correlate against code N and log measurement into your averager
5. Adjust your clock by Y (goes with message 3)
6. Adjust your clock according to your local measurement using Z as the estimate of propagation delay (goes with message 4). Reset your averager

Note: We could remove messages 4 and 6 and absorb the de-centralized approach into the centralized.

However, this is unattractive because, the amount of data that goes into the averager is large. To implement the approach centrally would probably require that the averaging was performed at the RNC. This would lead to quite large amounts of data in the uplink Iub messages.

The timing of the response to these messages would be implicit i.e. the messages would be acted on the next time the SFN modulo 32 was zero (if we wanted more flexibility for signaling faster, we could reduce this, e.g. to SFN modulo 16 (or 8).

Since these message are mutually exclusive, the message itself would be trivial - 3 bits to identify the message type and a maximum of 8 bits for either X, Y, Z or N. Say two bytes in total.

The NodeB to RNC Iub messages would typically contain similar or more amounts of data.

Note: The messages 3. and 4. can be combined into one message and if the RNC wanted the Node B to correlate against more than one code simultaneously then this message would contain all codes.

Also messages 5. and 6. can be combined into one procedure.

Reduced Signalling Master Slave Control

Whilst the above approach would be ideal, it has the disadvantage of greatly increasing the volume of traffic in the RNC to NodeB direction for the Iub. It is understood that the traffic requirement could be between 5 and 10 times too large for an RNC serving 100 NodeBs. Thus we require a means for reducing the level of traffic. The following option is offered for consideration:

Node B Cycling Message Memory

Here the Node B has a memory of the messages relating to *N* schedules, where *N* is the number of schedules in the repeat cycle. If no messages are received in a subsequent schedule whose ordinal number is equal to *i* modulo *N* then the stored message for schedule *i* is re-applied. If such a message is received then this will replace the message previously stored for schedule *i*.

A possible refinement would be for every message sent to contain a bit representing a 'store' flag. If the bit is set to '1' then the corresponding stored message is overwritten. If the bit is set to '0' then the corresponding stored message is not overwritten. This bit would give the option of introducing messages requesting occasional departures from normal operation without losing the regular pattern, which has been laid down.

A further bit could control a 'suspend' function. If this bit was true then the associated message could be stored into a reserve buffer and not acted on immediately. Rather, the previously stored message would still be acted on. A broadcast message could be sent to all Node Bs, saying: 'update'. All Node Bs would then overwrite the contents of their message buffer with the contents of the reserve buffer. This would allow messages to be transferred in a staggered (therefore reduced traffic volume) fashion but implemented, if desired, in a synchronous way.

The cycle time for each schedule is (currently) 32 sub frames or 160 ms. If there are 4 schedules in a repeat cycle then it would take 640 ms to send messages for all schedules. In the pure master slave approach it would be possible to change the structure every repeat cycle. With the approach described above we could, for example, signal to 10% of the Node Bs over 640 ms in suspend mode. In the next 640 ms we would signal to the next 10% and so on until, after 6.4 seconds, all Node Bs had been updated. At this point the RNC would broadcast an 'update' message and the new schedules would instantly be taken up by all Node Bs in the RNS.

Thus we could alter the schedules completely in less than 7 seconds. For RNSs with fewer Node Bs the update period would shrink proportionately. If we wish to affect the operation of only a small part of the RNS this can be done immediately.

The above approach would provide a compromise between the extreme flexibility provided by pure master slave control and the very high signaling overhead required.

Mechanisms for RNC Verification of Node Bs

It is desirable that the RNC has the capability of providing confidence that individual Node Bs are synchronizing correctly.

Each NodeB has a clock with an absolute accuracy of ±50 ppb, equivalent to 50 ns/second. One possible method of verifying the operation of sync is to ascertain whether the cumulative updates over a period of time are consistent with this clock accuracy. According to simulations of synchronization, a variation of around ±1 µs could arise. Thus cumulative adjustments greater than this must be observed in order to reflect and underlying trend. If we take a threshold of 3 µs, as specified, then we see that, at least 2 µs of this should only arise as a result of clock inaccuracy. A clock on the edge of its error range would accumulate a drift of 2 µs in 40 seconds. Thus, if the accumulated adjustments over 40 seconds exceeded 3 µs we could reasonably conclude that either the synchronization scheme was failing or the clock was not operating within its specified limits.

Thus, the Node B could perform measurements and, if indication was given, send a respective message to the RNC. Parameters could be associated with the message such as, by how far the threshold was exceeded after 40 seconds. This would provide considerable flexibility.

Alternatively, the RNC may wish to interrogate the NodeB in a more master-slave fashion. One approach would be for the RNC to send a ACCUMULATED CLOCK UPDATE REQUEST message to a Node B at a certain time. At a late time the RNC would send a ACCUMULATED CLOCK UPDATE RESPONSE message to that Node B, whereupon it would send back a message containing the total of all clock updates generated over the period between the two messages. This would provide considerable flexibility.

Enhanced De-Centralised Control

Various concerns have been raised about the reliability of de-centralized Node B sync at WG1#22 in Jeju cf. [5]. Specifically, the issues raised have been:

1. Possible loss of control and supervision over network synchronization operations. What happens if a Node B does not "synchronize properly"?
2. Steady state phase relies on a radio environment snapshot that has been captured during the initial phase and may quickly not be valid any more
3. Iterative synchronization of several slave Node B's in reference to a single master Node B.

These issues can readily be addressed by the more flexible signaling approach. In the proposed de-centralized scheme there are basically 3 schedules for synchronization. It was further proposed to include a 4^{th} schedule which would accommodate late entrants without the need to re-plan the whole set of schedules whenever a new late entrant was introduced to the system.

With the new flexible signalling approach this 4^{th} schedule can be used for more than one purpose. In addition to supporting late entrants, it can be used for a long cycle ongoing set of measurements to maintain an up to date path loss matrix at the RNC. Using this matrix the RNC can re-compute the set of schedules at any time without the need, suddenly, to send large amounts of data over the Iub to all of the Node Bs. In principle, with this approach, it would be possible, if desired, to re-plan the sync schedules for the entire network, or parts of it, to accommodate every late entrant. This could happen transparently.

With the flexible approach, the RNC can establish special arrangements to provide signals necessary to provide synchronization to late entrants. In addition to the above, the ongoing long cycle of measurements can be used to check that each Node B is correctly synchronized. Thus if Node B *B* synchronizes to Node B *A* (which may, for example, be a master) then from time to time Node B *A* can listen to Node B *B* and can confirm that it is appropriately synchronized.

The above options fully satisfy the concerns raised above. Specifically:

1. A Node B that does not "synchronize properly" will be detected.
2. The radio environment snapshot that was captured during the initial phase will be updated on an ongoing basis.
3. Iterative synchronization of several slave Node Bs in reference to a single master Node B may create some cumulative error. Simulations have shown this, nevertheless, to lead to acceptable errors. The network is planned so that there are never more than 3 hops to a master (except perhaps temporarily for some late entrants). The ongoing measurements will allow the actual timing errors of all Node Bs to be determined.

Disclaimer: The flexible signalling approach will only be introduced if RAN1 deems necessary.

6.6.3 Late-Entrant Cells

Late-entrant cells (new cells being added without GPS receiver) or cells recovering from unavailability shall first be roughly synchronised via Iub interface messages. The initial synchronisation adjustment shall be performed as in the Preliminary Phase.

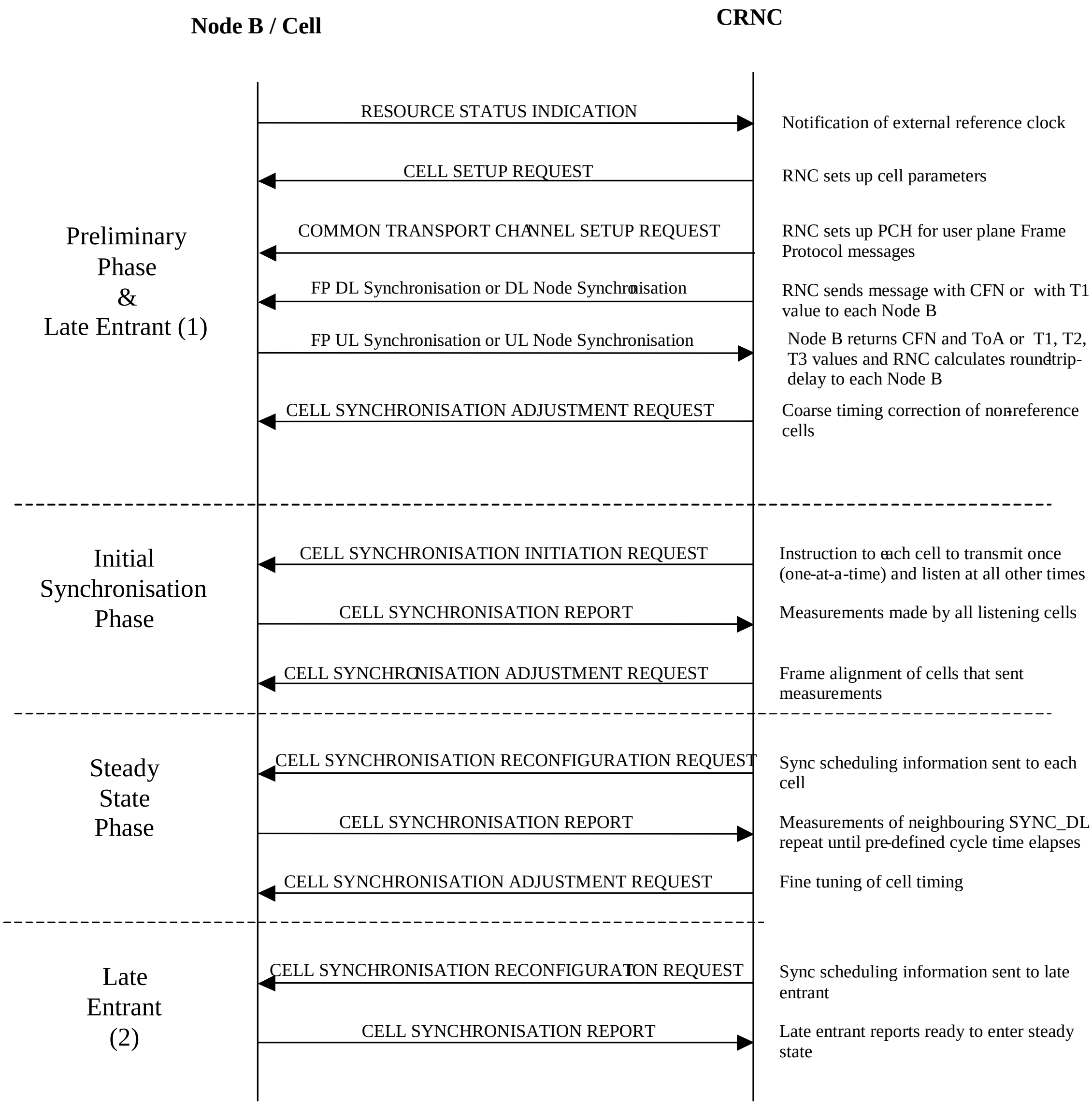
The RNC uses the CELL SYNCHRONISATION RECONFIGURATION REQUEST message to tell the late-entrant which SYNC_DL codes and carrier frequencies to listen for, corresponding to its neighbour cells. The late-entrant cell to listen so that it can adjust its frame timing.

The late-entrant cell has now obtained system time subject to an unknown propagation delay between it and its neighbours. This should be good enough for it to be allowed to enter the Steady State phase so at this point it sends a CELL SYNCHRONISATION REPORT to the RNC.

The RNC can then give the late-entrant cell (via a CELL SYNCHRONISATION RECONFIGURATION REQUEST message) its own schedule for sync burst transmission and reception and can also include it in the schedules given to its neighbouring cells.

6.6.4 Synchronisation Sequence

The following flow chart indicates the sequence of messages over the Iub between the CRNC and the Node Bs, in order to bring the 1.28 Mcps TDD system into synchronisation. For clarity, the flow chart does not include response messages.



6.7 Synchronisation Instructions

6.7.1 Instruction definitions

According to the signalling aspects for cell synchronisation (see Ref. [2]), procedures are necessary to instruct the LCR cells to transmit the SYNC_DL sequence and to request measurements from the individual cells when a SYNC_DL sequence was received.

In order to avoid a high number of signalling messages to start the SYNC_DL transmission and then to start the common measurements on SYNC_DL sequences, a combined procedure is proposed by which:

- the cells are instructed to transmit the SYNC_DL
- measurements on SYNC_DL sequences are started.

Further procedures are necessary for measurement reports, to terminate the started SYNC_DL transmission, to change the power, to blank the DwPCH, to correlate against codes and to cover the failure cases.

For the state transition phase from the Initial Phase to the Steady State Phase it is proposed to have a SYNC_DL "reconfiguration" procedure in order to avoid a SYNC_DL termination procedure and a further procedure to restart the SYNC_DL transmission and SYNC_DL measurements.

In the case of a late-entrant cell that is not a reference cell, it shall be given information regarding the SYNC_DL transmissions of neighbouring cells and shall acquire frequency lock on these transmissions. There shall be no special instruction for the late entrant cell to inform the RNC when it has acquired lock, but it shall immediately begin to make measurements on the SYNC_DL sequences of the neighbouring cells and then report when it is ready to enter the steady state phase.

6.7.2 Information elements

Within the Cell Sync burst instruction definitions the transmission of SYNC_DL sequences during the different phases have to be initiated and measurements are started in parallel. The following table summarises the information elements required within the individual synchronisation phases.

The *Synchronisation Report Characteristics* IE defines when measurements shall be reported to the CRNC and is set to different values for the different phases of synchronisation.

Table 1: Information elements for Initial Phase

	Initial Phase
Cell Synchronisation Initiation Request	
Cell sync burst transmission initiation LCR	UARFCN
	SYNC_DL Code ID
	SFN
	Sub-Frame LCR
	DwPCH Power
	Synchronisation Report Type
Cell sync burst measurement initiation LCR	SYNC_DL Code ID
	Synchronisation Report Type
	Report Characteristics

In the steady-state phase the synchronisation schedule defines a number of cells each transmitting a SYNC_DL sequence at the same time, which shall be measured by another number of cells. The individual SYNC_DL sequences are distinguished by different SYNC_DL codes.

To define the SFN where to receive, the SFN period is divided into cycles that have the same schedule. Within a cycle each cell is given an individual set of parameters for the SYNC_DL sequences to receive.

The cell will always transmit the SYNC_DL sequence using the information given in the transmission information parameters, in every subframe when it is not requested to make measurements of the SYNC_DL sequences of neighbouring cells.

Table 2: Information elements for Steady-State Phase

	Steady-State Phase
Cell Synchronisation Reconfiguration Request	
Cell sync burst schedule	Number of cycles per SFN period
	Number of subcycles per cycle
	Number of repetitions per subcycle
Cell sync burst transmission reconfiguration	UARFCN
	SYNC_DL Code ID
	DwPCH Power
Cell sync burst measurement reconfiguration (For each cell to receive from)	SFN per cycle to receive
	Sub-Frame LCR
	UARFCN
	SYNC_DL Code ID
	Propagation Delay Compensation (opt.)
	Synchronisation Report Type
	Report characteristics

Table 3: Information elements for Cell Synchronisation reports

	Initial Phase	Steady-State Phase	Late-Entrant Cells	Frequency Acquisition
Cell Synchronisation Report	SFN where SYNC_DL has been received	SFN where SYNC_DL has been received	NULL (indicates ready to enter steady state)	NULL (indicates lock achieved)
	Sub-Frame LCR	Sub-Frame LCR		
		Accumulated Clock Update Value		
	Cell Sync Burst Timing	(For all simultaneous receptions)		
	Cell Sync Burst SIR	Cell Sync Burst Timing		
		Cell Sync Burst SIR		

For late entrant cells no report is sent to indicate that frequency acquisition is complete, but reports are sent giving details of measurements made on the SYNC_DL sequences of specified neighbouring cells.

For the Master / Slave Control the following messages and IEs for the steady-state phase should be introduced:

Table 4: Messages and Information elements for Master/Slave Control

DwPCH Power	C-ID
	DWPCH Power
Blank	C-ID
Correlation	SYNC_DL Code ID
	Log/Send

For the mechanisms for RNC Verification of Node Bs the following procedure and IEs for the steady-state phase should be introduced:

Table 5: Messages and Information elements for Master/Slave Control

Accumulated Clock Update	
Accumulated Clock Update Request	
Accumulated Clock Update Response	Accumulated Clock Update Value

6.8 Synchronisation Adjustment

6.8.1 Adjustment procedure definitions

The purpose of Synchronisation Adjustment procedure is to allow the CRNC to adjust the timing of the radio transmission of a cell within a Node B for time alignment. In the steady state phase, the adjustment that can be made each radio frame is limited by a maximum adjustment step size.

6.8.2 Adjustment elements

Synchronisation adjustment will be handled differently during the individual synchronisation phases. The following table indicates the required information elements.

Table 6: Information elements for Synchronisation Adjustment procedure

	Initial Phase	**Steady-State Phase**	**Late-Entrant Cells**
Synchronisation Adjustment	Frame Adjustment value	Timing Adjustment value	Timing Adjustment value
	Timing Adjustment value	Timing Adjustment Step Size	SFN, indicates starting frame number when Timing Adjustment value shall apply
		DwPCH Power (adjustment)	Sub-Frame LCR
		SFN, indicates starting frame number when Timing Adjustment value shall apply	
		Sub-Frame LCR	

6.9 Synchronisation alarming

For Node B synchronisation only the Cell Synchronisation procedures and the Synchronisation Adjustment procedures are necessary. Calculating the timing adjustment between neighbouring cells is to be performed within the CRNC. The Node B is only informed about SYNC_DL sequences to transmit and about measurements to be performed. For SYNC_DL measurements thresholds may be defined to inform the RNC about synchronisation deviations. Thus, a specific alarming procedure is not necessary. – This also holds in case the autonomous self-adjustment of the timing (clock update) based on local measurements has been enables by the CRNC. In the measurement reports, the CRNC is informed about the measured timing deviations, and the accumulated clock updates. So the CRNC can detect whenever a synchronisation problem would occur at any Node B, and can e.g. switch off the autonomous self-adjustment, by sending another SYNCHRONISATION RECONFIGURATION REQUEST message to the Node B.

6.10 Backward compatibility/Coexistence synchronisation methods

In REL-4 Node Bs are synchronised via the synchronisation port only (see [2]). This synchronisation port signal provides a 256 frames multiframe clock which allows for synchronisation of the last 8 bits of the Cell System Frame Number (SFN) of the cells of the Node B.

In REL-5 the Node Bs may be synchronised either via the synchronisation port or via the air interface. Synchronisation via the air interface requires an extension of the synchronisation port that all 12 bits of the SFN are provided. Based on this basic functions following application cases exist:

Table 7: Synchronisation coexistence cases

	NODE B SYNCHRONISATION	Node B	RNC	
1.	Sync port (SFN mod 256=0)	REL-4	REL-4	Synchronisation method via sync port as defined for REL-4
			REL-5	Synchronisation method via sync port as defined for REL-4
2.	Sync port (SFN mod 4096=0)	REL-5	REL-4 REL-5	No procedures within the RNC are provided. The synchronisation is therefore only based on synchronisation via the sync port. Since the Synchronisation via the air interface may be cell based, the reference clock has to be provided to all cells within the Node B, same as for REL-4 Node B Synchronisation via air interface applies

7 Agreements and associated contributions

This section shows the changes to NBAP messages that need to be made in order to support the synchronisation procedures of 1.28 Mcps TDD.

7.1 NBAP Elementary Procedures used in Synchronisation

The following Class 1 procedures shall be used for synchronisation purposes:

Table 8

Elementary Procedure	Message	Successful Outcome	Unsuccessful Outcome
		Response message	**Response message**
Cell Synchronisation Initiation [TDD]	CELL SYNCHRONISATION INITIATION REQUEST	CELL SYNCHRONISATION INITIATION RESPONSE	CELL SYNCHRONISATION INITIATION FAILURE
Cell Synchronisation Reconfiguration [TDD]	CELL SYNCHRONISATION RECONFIGURATION REQUEST	CELL SYNCHRONISATION RECONFIGURATION RESPONSE	CELL SYNCHRONISATION RECONFIGURATION FAILURE
Cell Synchronisation Adjustment [TDD]	CELL SYNCHRONISATION ADJUSTMENT REQUEST	CELL SYNCHRONISATION ADJUSTMENT RESPONSE	CELL SYNCHRONISATION ADJUSTMENT FAILURE

The following Class 2 procedures shall be used for synchronisation purposes:

Table 9

Elementary Procedure	Message
Resource Status Indication	RESOURCE STATUS INDICATION
Cell Synchronisation Reporting [TDD]	CELL SYNCHRONISATION REPORT
Cell Synchronisation Termination [TDD]	CELL SYNCHRONISATION TERMINATION REQUEST
Cell Synchronisation Failure [TDD]	CELL SYNCHRONISATION FAILURE INDICATION

7.2 Synchronisation Instruction Procedures

7.2.1 Cell Synchronisation Initiation [TDD]

7.2.1.1 General

This procedure is used by a CRNC to request the transmission of cell sync bursts and/or to start measurements on cell sync bursts in a Node B.

7.2.1.2 Successful Operation

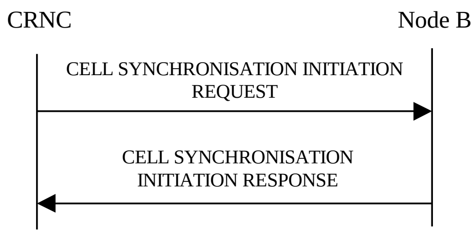


Figure 6: Cell Synchronisation Initiation procedure, Successful Operation

The procedure is initiated with a CELL SYNCHRONISATION INITIATION REQUEST message sent from the CRNC to the Node B using the Node B control port.

Upon reception, the Node B shall initiate the requested transmission according to the parameters given in the request and start the measurement on cell sync bursts if requested.

If the Node B was able to initiate the cell sync burst transmission and/or measurement requested by the CRNC it shall respond with the CELL SYNCHRONISATION INITIATION RESPONSE message sent over the Node B control port.

7.2.1.3 Unsuccessful Operation

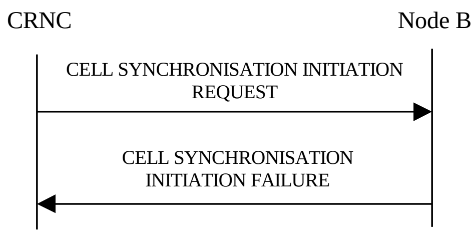


Figure 7: Cell Synchronisation Initiation procedure, Unsuccessful Operation

If the requested transmission or measurement on cell sync bursts cannot be initiated, the Node B shall send a CELL SYNCHRONISATION INITIATION FAILURE message over the Node B control port.

7.2.2 Cell Synchronisation Reconfiguration [TDD]

7.2.2.1 General

This procedure is used by a CRNC to reconfigure the transmission of cell sync bursts and/or to reconfigure measurements on cell sync bursts in a Node B.

7.2.2.2 Successful Operation

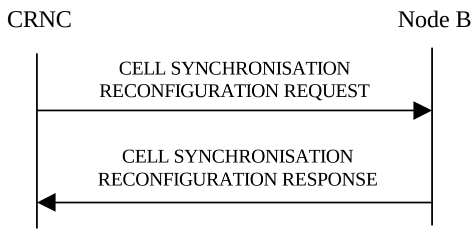


Figure 8: Cell Synchronisation Reconfiguration procedure, Successful Operation

The procedure is initiated with a CELL SYNCHRONISATION RECONFIGURATION REQUEST message sent from the CRNC to the Node B using the Node B control port.

Upon reception, the Node B shall reconfigure the cell sync burst transmission and/or measurements according to the parameters given in the request.

If the Node B was able to reconfigure the cell sync burst transmission and/or measurement requested by the CRNC it shall respond with the CELL SYNCHRONISATION RECONFIGURATION RESPONSE message sent over the Node B control port.

7.2.2.3 Unsuccessful Operation

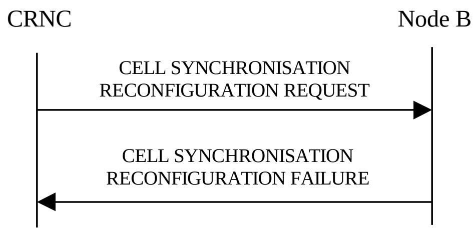


Figure 9: Cell Synchronisation Reconfiguration procedure, Unsuccessful Operation

If the Node B cannot reconfigure the requested transmission or measurement on cell sync burst, the CELL SYNCHRONISATION RECONFIGURATION FAILURE message shall be sent to the CRNC.

7.2.3 Cell Synchronisation Reporting [TDD]

7.2.3.1 General

This procedure is used by a Node B to report the result of cell sync burst measurements requested by the CRNC with the Cell Synchronisation Initiation or Cell Synchronisation Reconfiguration procedure.

7.2.3.2 Successful Operation

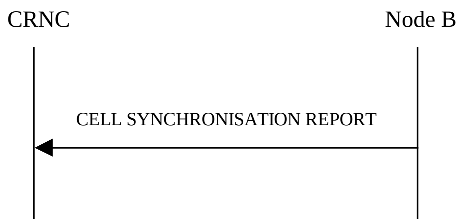


Figure 10: Cell Synchronisation Reporting procedure, Successful Operation

If the requested synchronisation measurement reporting criteria are met, the Node B shall initiate a Cell Synchronisation Reporting procedure. The CELL SYNCHRONISATION REPORT message shall use the Node B control port.

7.2.4 Cell Synchronisation Adjustment [TDD]

7.2.4.1 General

The purpose of Cell Synchronisation Adjustment procedure is to allow the CRNC to adjust the timing of the radio transmission of a cell within a Node B for time alignment.

7.2.4.2 Successful Operation

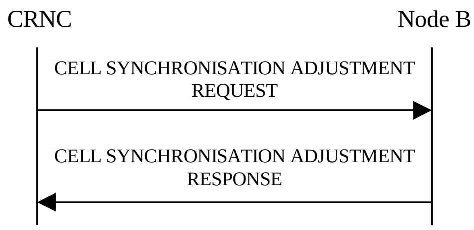


Figure 11: Cell Synchronisation Adjustment, Successful Operation

This procedure is initiated with a CELL SYNCHRONISATION ADJUSTMENT REQUEST message sent by the CRNC to the Node B using the Node B control port.

Upon reception, the Node B adjusts the timing of each of its identified cells according to the parameters given in the message.

When the cell synchronisation adjustment is successfully done by the Node B the Node B shall respond with a CELL SYNCHRONISATION ADJUSTMENT RESPONSE message.

7.2.4.3 Unsuccessful Operation

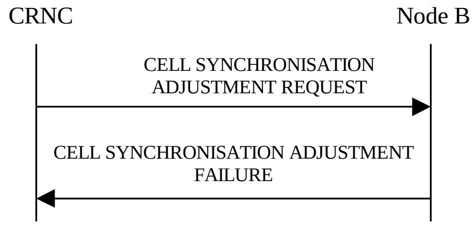


Figure 12: Cell Synchronisation Adjustment, Unsuccessful Operation

If the Node B cannot perform the indicated cell synchronisation adjustment due to hardware failure or other problem it shall send the CELL SYNCHRONISATION ADJUSTMENT FAILURE as a response.

7.2.5 Cell Synchronisation Termination [TDD]

7.2.5.1 General

This procedure is used by the CRNC to terminate a cell sync burst transmission or measurement previously requested by the Cell Synchronisation Initiation procedure or Cell Synchronisation Reconfiguration procedure.

7.2.5.2 Successful Operation

Figure 13: Cell Synchronisation Termination procedure, Successful Operation

This procedure is initiated with a CELL SYNCHRONISATION TERMINATION REQUEST message, sent from the CRNC to the Node B using the Node B control port.

Upon reception, the Node B shall terminate transmission of cell sync bursts or reporting of cell sync burst measurements corresponding to the CSB Transmission Id or CSB Measurement Id.

7.2.6 Cell Synchronisation Failure [TDD]

7.2.6.1 General

This procedure is used by the Node B to notify the CRNC that a synchronisation burst transmission or synchronisation measurement procedure can no longer be supported.

7.2.6.2 Successful Operation

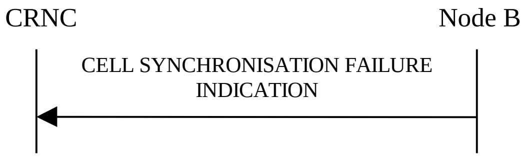


Figure 14: Cell Synchronisation Failure procedure, Successful Operation

This procedure is initiated with a CELL SYNCHRONISATION FAILURE INDICATION message, sent from the Node B to the CRNC using the Node B control port, to inform the CRNC that a previously requested transmission or measurement on cell sync bursts can no longer be supported.

7.3 Synchronisation Instruction Message Definitions

7.3.1 Cell Synchronisation Initiation [TDD]

7.3.1.1 CELL SYNCHRONISATION INITIATION REQUEST

IE/Group Name	Presence	Range	IE type and reference	Semantics description	Criticality	Assigned Criticality
Message Discriminator	M		9.2.1.45		–	
Message Type	M		9.2.1.46		YES	reject
Transaction ID	M		9.2.1.62		–	
C-ID	M		9.2.1.9		YES	reject
Cell Sync Burst Repetition Period	M		9.2.3.4J		YES	reject
Time Slot Information		0~~1~~..15		Mandatory For 3.84 Mcps TDD only	GLOBAL	reject
>Time Slot	M		9.2.3.23		–	
Cell Sync Burst		0..1		For 3.84	GLOBAL	reject

Transmission Initiation Information				Mcps TDD only		
>CSB Transmission ID	M		9.2.3.4N			
>SFN	M		9.2.1.53A		–	
>Cell Sync Burst Code	M		9.2.3.4G		–	
>Cell Sync Burst Code shift	M		9.2.3.4H			
>Initial DL transmission Power	M		DL Power 9.2.1.21		–	
Cell Sync Burst Measurement Initiation Information		0..1		For 3.84 Mcps TDD only	GLOBAL	reject
>CSB Measurement ID	M		9.2.3.4I			
>Cell Sync Burst Code	M		9.2.3.4G		–	
>Cell Sync Burst Code shift	M		9.2.3.4H			
>Synchronisation Report Type	M		9.2.3.18E		–	
>SFN	O		9.2.1.53A		–	
>Synchronisation Report Characteristics	M		9.2.3.18D		–	
Cell Sync Burst Transmission Initiation Information LCR		0..1		For 1.28Mcps TDD only	GLOBAL	reject
>CSB Transmission ID	M		9.2.3.4N		–	
>SFN	M		9.2.1.53A		–	
>UARFCN	M		9.2.1.65		–	
>Sub-Frame LCR	O				–	
>SYNC_DL Code ID	M		9.2.3.18B		–	
>DwPCH Power	M		9.2.3.5B		–	
>Synchronisation Report Type	O		9.2.3.18E	Used to indicate Frequency Acquisition Phase	–	
Cell Sync Burst Measurement Initiation Information LCR		0..1		For 1.28Mcps TDD only	GLOBAL	reject
>CSB Measurement ID	M		9.2.3.41		–	
>UARFCN	M		9.2.1.65		–	
>SFN	O		9.2.1.53A		–	
>Sub-Frame LCR	O				–	
>SYNC_DL Code ID	M		9.2.3.18B		–	
>Synchronisation Report Type	M		9.2.3.18E		–	
>Synchronisation Report Characteristics	M		9.2.3.18D		–	

7.3.1.2 CELL SYNCHRONISATION INITIATION RESPONSE

IE/Group Name	Presence	Range	IE Type and Reference	Semantics Description	Criticality	Assigned Criticality
Message Discriminator	M		9.2.1.45		–	
Message Type	M		9.2.1.46		YES	reject
Transaction ID	M		9.2.1.62		–	
Criticality Diagnostics	O		9.2.1.17		YES	ignore

7.3.1.3 CELL SYNCHRONISATION INITIATION FAILURE

IE/Group Name	Presence	Range	IE Type and Reference	Semantics Description	Criticality	Assigned Criticality
Message Discriminator	M		9.2.1.45		–	
Message Type	M		9.2.1.46		YES	reject
Transaction ID	M		9.2.1.62		–	
Cause	M		9.2.1.6		YES	Ignore
Criticality Diagnostics	O		9.2.1.17		YES	Ignore

7.3.2 Cell Synchronisation Reconfiguration [TDD]

7.3.2.1 CELL SYNCHRONISATION RECONFIGURATION REQUEST

IE/Group Name	Presence	Range	IE type and reference	Semantics description	Criticality	Assigned Criticality
Message Discriminator	M		9.2.1.45		–	
Message Type	M		9.2.1.46		YES	reject
Transaction ID	M		9.2.1.62		–	
C-ID	M		9.2.1.9		YES	reject
Time Slot	M		9.2.3.23	Note 1	-	
Number of cycles per SFN period	M		9.2.3.7B		YES	reject
Number of subcycles per cycle period	M		9.2.3.s		YES	reject
Number of repetitions per subcycle period	M		Number of repetitions per cycle period 9.2.3.7C		YES	reject
Cell Sync Burst Transmission Reconfiguration Information		0 .. < maxnoofCellSyncBursts >		For 3.84Mcps TDD only	Global	reject
>CSB Transmission ID	M		9.2.3.4N		–	
>Sync Frame number to transmit	M		Sync Frame number 9.2.3.18C		–	
>Cell Sync Burst Code	O		9.2.3.4G		–	
>Cell Sync Burst Code shift	O		9.2.3.4H		–	
>DL transmission Power	O		DL Power 9.2.1.21		–	
Cell Sync Burst Measurement Reconfiguration Information		0..1		For 3.84Mcps TDD only	YES	reject
>Cell Sync Burst Measurement Information		1 .. <maxnoofCellSyncBursts>			GLOBAL	reject
>>Sync Frame number to receive	M		Sync Frame number 9.2.3.18C		–	
>>Cell Sync Burst Information		1..< maxnoofreceptionspe			–	

		rSyncFrame>				
>>>CSB Measurement ID	M		9.2.3.4I		–	
>>>Cell Sync Burst Code	M		9.2.3.4G		–	
>>>Cell Sync Burst Code shift	M		9.2.3.4H		–	
>Synchronisation Report Type	O		9.2.3.18E		YES	reject
>Synchronisation Report Characteristics	O		9.2.3.18D		YES	reject
Cell Sync Burst Transmission Reconfiguration Information LCR		0..1		For 1.28Mcps TDD only	GLOBAL	reject
>CSB Transmission ID	M		9.2.3.4N			
>UARFCN	O		9.2.1.65			
>SYNC_DL Code ID	M		9.2.3.18B			
>DwPCH Power	M		9.2.3.5B			
Cell Sync Burst Measurement Reconfiguration Information LCR		0..1		For 1.28Mcps TDD only	YES	reject
>Cell Sync Burst Measurement Information LCR		1 .. <maxnoofCellSyncBurstsLCR>			GLOBAL	reject
>>Sync Frame number to receive	M		Sync Frame number 9.2.3.18C		–	
>>Sub-Frame LCR	M					
>>UARFCN	M		9.2.1.65			
>>Cell Sync Burst Information LCR		1..<maxnoofreceptionsperSyncFrameLCR>			–	
>>>CSB Measurement ID	M		9.2.3.4I		–	
>>>SYNC_DL Code ID	M		9.2.3.18B		–	
>>>Propagation Delay Compensation	M		Timing Adjustment value 9.2.3.22a		–	
>Synchronisation Report Type	O		9.2.3.18E		YES	reject
>Synchronisation Report Characteristics	O		9.2.3.18D		YES	reject

Range bound	Explanation
maxnoofCellSyncBursts	Maximum number of cell sync bursts per repetition period for 3.84Mcps TDD
maxnoofreceptionsperSyncFrame	Maximum number of cell sync burst receptions per Sync Frame for 3.84Mcps TDD
maxnoofCellSyncBurstsLCR	Maximum number of cell sync bursts per repetition period for 1.28Mcps TDD
maxnoofreceptionsperSyncFrameLCR	Maximum number of cell sync burst receptions per Sync Frame for 1.28Mcps TDD

Note 1: [1.28Mcps TDD - There is no Time Slot indication needed for 1.28Mcps TDD, the CRNC should indicate Time Slot 0 and the Node B shall ignore it.]

7.3.2.2 CELL SYNCHRONISATION RECONFIGURATION RESPONSE

IE/Group Name	Presence	Range	IE Type and Reference	Semantics Description	Criticality	Assigned Criticality
Message Discriminator	M		9.2.1.45		–	
Message Type	M		9.2.1.46		YES	reject
Transaction ID	M		9.2.1.62		–	
Criticality Diagnostics	O		9.2.1.17		YES	ignore

7.3.2.3 CELL SYNCHRONISATION RECONFIGURATION FAILURE

IE/Group Name	Presence	Range	IE Type and Reference	Semantics Description	Criticality	Assigned Criticality
Message Discriminator	M		9.2.1.45		–	
Message Type	M		9.2.1.46		YES	reject
Transaction ID	M		9.2.1.62		–	
Cause	M		9.2.1.6		YES	Ignore
Criticality Diagnostics	O		9.2.1.17		YES	Ignore

7.3.3 Cell Synchronisation Reporting [TDD]

7.3.3.1 CELL SYNCHRONISATION REPORT

IE/Group Name	Presence	Range	IE type and reference	Semantics description	Criticality	Assigned Criticality
Message Discriminator	M		9.2.1.45		–	
Message Type	M		9.2.1.46		YES	ignore
Transaction ID	M		9.2.1.62		–	
Cell Synchronisation Information		*1..* <maxCellinNodeB >			EACH	ignore
>C-ID	M		9.2.1.9		YES	ignore
>CHOICE *Synchronisation Report Type*					YES	ignore
>>*Initial Phase* or *Steady-State Phase*					–	
>>>Cell Sync Burst Measured Information		1 .. <maxnoofCellSyncBursts>			–	
>>>>SFN	M		9.2.1.53A		–	
>>>>Cell Sync Burst Information		1..<maxnoofreceptionsperSyncFrame>			–	
>>>>>CHOICE *Cell Sync Burst Availability Indicator*	M				–	
>>>>>>Cell Sync Burst Available					–	
>>>>>>>Cell Sync Burst Timing	M		9.2.3.4L		–	
>>>>>>>Cell	M		9.2.3.4K		–	

Sync Burst SIR						
>>>>>>*Cell Sync Burst not Available*			NULL		–	
>>>>Sub-Frame LCR	O		9.2.3.17B	For 1.28Mcps TDD only	–	
>>>Accumulated clock update	O		Timing Adjustment Step Size 9.2.3.22a	For 1.28Mcps TDD only	–	
>>*Late-Entrant Cell*			NULL		–	
>>*Frequency Acquisition*			NULL		–	

Range bound	Explanation
maxCellinNodeB	Maximum number of Cells in a Node B
maxnoofCellSyncBursts	Maximum number of cell sync bursts per repetition period for 3.84Mcps TDD
maxnoofreceptionsperSyncFrame	Maximum number of cell sync burst receptions per Sync Frame for 3.84Mcps TDD

7.3.4 Cell Synchronisation Adjustment [TDD]

7.3.4.1 CELL SYNCHRONISATION ADJUSTMENT REQUEST

IE/Group Name	Presence	Range	IE type and reference	Semantics description	Criticality	Assigned Criticality
Message Discriminator	M		9.2.1.45		–	
Message Type	M		9.2.1.46		YES	ignore
Transaction ID	M		9.2.1.62		–	
Cell Adjustment Information		1..<maxCellinNodeB>			EACH	ignore
>C-ID	M		9.2.1.9		–	
>Frame Adjustment value	O		9.2.3.5C		–	
>Timing Adjustment value	O		9.2.3.22a		–	
>DL Transmission Power	O		9.2.1.21	For 3.84 Mcps TDD only	–	
>SFN	O		9.2.1.53A		–	
>Timing Adjustment Step Size	C - Timing Adjustment Value		9.2.3.22b		--	
>Sub-Frame LCR	O			For 1.28Mcps TDD only	–	
>DwPCH Power	O		9.2.3.5B	For 1.28Mcps TDD only	–	

Condition	Explanation
Timing Adjustment value	The IE shall be included if the *Timing Adjustment value* IE is present.

Range bound	Explanation
MaxCellinNodeB	Maximum number of Cells in a Node B

7.3.4.2 CELL SYNCHRONISATION ADJUSTMENT RESPONSE

IE/Group Name	Presence	Range	IE type and reference	Semantics description	Criticality	Assigned Criticality
Message Discriminator	M		9.2.1.45		–	
Message Type	M		9.2.1.46		YES	ignore
Transaction ID	M		9.2.1.62		–	
Criticality Diagnostics	O		9.2.1.17		YES	Ignore

7.3.4.3 CELL SYNCHRONISATION ADJUSTMENT FAILURE

IE/Group Name	Presence	Range	IE type and reference	Semantics description	Criticality	Assigned Criticality
Message Discriminator	M		9.2.1.45		–	
Message Type	M		9.2.1.46		YES	ignore
Transaction ID	M		9.2.1.62		–	
CHOICE *cause level*	M				YES	ignore
>General					–	
>>Cause	M		9.2.1.6		–	
>Cell specific					–	
>>Unsuccessful Cell Information Response		1..<maxCellinNodeB>			EACH	ignore
>>>C-ID	M		9.2.1.9		–	
>>>Cause	M		9.2.1.6		–	
Criticality Diagnostics	O		9.2.1.17		YES	Ignore

Range bound	Explanation
MaxCellinNodeB	Maximum number of Cells in a Node B

7.3.5 Cell Synchronisation Termination [TDD]

7.3.5.1 CELL SYNCHRONISATION TERMINATION REQUEST

IE/Group Name	Presence	Range	IE Type and Reference	Semantics Description	Criticality	Assigned Criticality
Message Discriminator	M		9.2.1.45		–	
Message Type	M		9.2.1.46		YES	ignore
Transaction ID	M		9.2.1.62		–	
C-ID	M		9.2.1.9		YES	ignore
CSB Transmission ID	O		9.2.3.4N		YES	ignore
CSB Measurement ID	O		9.2.3.4I		YES	ignore

7.3.6 Cell Synchronisation Failure [TDD]

7.3.6.1 CELL SYNCHRONISATION FAILURE INDICATION

IE/Group Name	Presence	Range	IE Type and Reference	Semantics Description	Criticality	Assigned Criticality
Message Discriminator	M		9.2.1.45		–	
Message Type	M		9.2.1.46		YES	ignore
Transaction ID	M		9.2.1.62		–	
C-ID	M		9.2.1.9		YES	ignore
CSB Transmission ID	O		9.2.3.4N		YES	ignore
CSB Measurement ID	O		9.2.3.4I		YES	ignore
Cause	M		9.2.1.6		YES	ignore

7.4 Information Elements

The following is a list of additional and/or changed Information Elements that may be required in Node B synchronisation for 1.28Mcps TDD.

7.4.1 Sub-Frame LCR

The *Sub-Frame LCR* IE indicates the 5ms sub-frame to which the given parameters are relevant. Choices are: 0 = Sub-Frame #1, 1 = Sub-Frame #2, or 2 = Both.

IE/Group Name	Presence	Range	IE type and reference	Semantics description	~~Criticality~~	~~Assigned Criticality~~
Sub-Frame LCR			INTEGER (0..2)			

7.4.2 Synchronisation Report Characteristics

The *Synchronisation Report Characteristics* IE defines how the reporting on measured cell sync bursts shall be performed

Different methods shall apply for the measured cell sync burst reports. In the frequency acquisition phase the measurement report shall be sent when the frequency locking is completed. In the initial phase and for the measurement on late-entrant cells an immediate report after the measured frame is expected.

In the steady-state phase measurement reports may be given after every measured frame, after every SFN period, after every cycle length or only when the requested threshold is exceeded.

IE/Group Name	Presence	Range	IE type and reference	Semantics description
Synchronisation Report characteristics type	M		ENUMERATED (Frame related, SFN period related, Cycle length related, Threshold exceeding, Frequency Acquisition completed, ...)	
Threshold exceeding	C-			Applies only to the Steady

	Threshold exceeding			State Phase
>Cell Sync Burst Threshold Information		0~~1~~.. <maxnoofCellSyncBursts>		For 3.84Mcps TDD only
>>Sync Frame number to receive	M		Sync Frame number 9.2.3.18C	
>>Cell Sync Burst Information		1..<maxnoofreceptionsperSyncFrame>		
>>>Cell Sync Burst Code	M		9.2.3.4G	
>>>Cell Sync Burst Code shift	M		9.2.3.4H	
>>>Cell Sync Burst Arrival Time	O		Cell Sync Burst Timing 9.2.3.4L	
>>>Cell Sync Burst Timing Threshold	O		9.2.3.4M	
>Cell Sync Burst Threshold Information LCR		0 .. <maxnoofCellSyncBurstsLCR>		For 1.28Mcps TDD only
>>Sync Frame number to receive	M		Sync Frame number 9.2.3.18C	
>>Sub-Frame LCR	M		9.2.3.17B	
>>Cell Sync Burst Information LCR		1..<maxnoofreceptionsperSyncFrameLCR>		
>>>SYNC_DL Code ID	M		9.2.3.18B	
>>>Cell Sync Burst Arrival Time	O		Cell Sync Burst Timing 9.2.3.4L	
>>>Cell Sync Burst Timing Threshold	O		9.2.3.4M	

Range bound	Explanation
maxnoofCellSyncBursts	Maximum number of cell sync burst per repetition period for 3.84Mcps TDD
maxnoofreceptionsperSyncFrame	Maximum number of cell sync burst receptions per Sync Frame for 3.84Mcps TDD
maxnoofCellSyncBurstsLCR	Maximum number of SYNC_DL bursts per repetition period for 1.28Mcps TDD
maxnoofreceptionsperSyncFrameLCR	Maximum number of cell sync burst receptions per Sync Frame for 1.28Mcps TDD

7.4.3 Timing Adjustment Step Size

The *Timing Adjustment Step Size* IE indicates the maximum timing adjustment (in $1/8^{th}$ chips) that can be made within a radio frame during the steady-state phase.

IE/Group Name	Presence	Range	IE type and reference	Semantics description
Timing Adjustment Step Size			INTEGER (1..16)	

7.4.4 Number of subcycles per cycle period

The *Number of subcycles per cycle period* IE indicates the number of Synchronisation Subcycles per Cycle Length where the synchronisation burst reception results shall be averaged over all the subcycles in a Synchronisation Cycle.

IE/Group Name	Presence	Range	IE type and reference	Semantics description
Number of subcycles per cycle period			INTEGER (1..15)	

8 Specification Impact and associated Change Requests

It is expected that Node B Synchronisation for LCR TDD (Iub/Iur aspects) affects the NBAP [2] specification and the Synchronisation in UTRAN Stage 2 [3]. Since it is assumed that each RNC area is synchronised individually to at least one reference clock, this ensures automatically synchronisation between RNC areas. Therefore, no communication over Iur is necessary.

8.1 Impact on TS 25.402

The mechanism of the synchronisation over the air interface will be introduced in a new section for 1.28Mcps TDD based on the information in section 6.

CR 032: Node B Synchronisation for 1.28Mcps TDD

8.2 Impact on TS 25.433

In 1.28Mcps TDD, SYNC_DL sequence is used to transmit over DwPCH to get to Cell Synchronisation, while Cell Sync burst is used to transmit over PRACH in 3.84Mcps TDD.

Cell synchronisation procedure is based on radio subframe in 1.28Mcps TDD while Cell synchronisation procedure is based on radio frame in 3.84Mcps TDD. So one new IE 'Sub-frame LCR' is defined for 1.28Mcps TDD to indicate which subframe during the radio frame is used to achieve Cell synchronisation.

For the reason described above, some new IEs and IE groups need to be defined for 1.28Mcps TDD compared to 3.84Mcps TDD.

For details see chapter 7, or the corresponding CRs.

CR 608: Node B synchronisation for 1.28Mcps TDD

9 Backward Compatibility

For all impacted specifications, backward compatible changes to Rel. 99 and Rel. 4 are expected.

History

Document history		
Date	**Version**	**Comment**
May 2001	0.0.1	First proposal
May 2001	0.1.0	Approved by WG3 #21
August 2001	0.1.1	Includes some input chapters approved by WG3 #22

Document history		
Date	**Version**	**Comment**
August 2001	0.2.0	Approved by WG3 #23
August 2001	0.2.1	Includes some input chapters approved by WG3 #23
October 2001	0.3.0	Approved by WG3#24
October 2001	0.3.1	Includes some input chapters approved by WG3 #24
November 2001	0.4.0	Approved by RAN WG3 #25
January 2002	0.4.1	Includes some input chapters approved by WG3 #26
February 2002	0.5.0	Approved by RAN WG3 #27
February 2002	0.5.1	Includes some text changes approved by RAN WG3 #27
February 2002	1.0.0	Final status after RAN WG3 #27
Rapporteur for R3.004 is:		
Mr Xu Chuan, CATT Tel. : +86 10 62304422 EXT 206 Fax : +86 10 62303127 Email : xuc@catt.ac.cn		
This document is written in Microsoft Word version.		

Annex B: Change history

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
08/03/02	RAN_15	RP-020251			Approved at TSG RAN #15 and placed under Change Control	-	5.0.0
05/04/02	-	-			Small editorial corrections done by the secretary.	5.0.0	5.0.1