TSG-RAN Working Group 1 Meeting #12 ***TSGR1#11(00)0471***
Seoul, Korea
April 10-13, 2000

Source: InterDigital Comm. Corp.

Title: Synchronization of TDD Cells

Document for: Discussion

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1 Introduction

This contribution proposes an approach for NodeB synchronization over the air using existing waveforms. This technique is a tool, proposed to support the requirement and it does not preclude the use of other techniques as well.

For convenience, this contribution includes, as attachments, two WG3 documents, which were introduced in 1999.

2 Use of Synchronization Channel (SCH)

The principal feature is based on each Node B occasionally monitoring a designated neighboring Node's Synchronization Channel (SCH), measuring the Time of Arrival (TOA), confirming the identity, and sending this information to the Controlling RNC. Then subtracting the known or derived propagation delay, the RNC process determines the difference in time of transmission. This is used as an input to a tracking algorithm and, as needed, the RNC may then send a time correction to either one of the Nodes.

The basic tools are

- A message from the RNC to the Node B to perform the measurement, specifiying which Node B to listen to.
- A message from a Node B to its controlling RNC providing the measured TOA.
- A message from the controlling RNC to a Node B telling it to correct its time base by a specified amount.

Note that the RNC tracking and Node B time base management process may be implemented in many different ways and should not be standardized. Either one of the Nodes can be assigned to be the time reference, with the other one receiving the correction. These roles are independent of which one transmitted and which one received.

This technique was originally introduced in TSG RAN WG3 #6 in August, 1999. Two references are attached for convenience. TSGR3#6(99)905, Synchronization of TDD Cells,InterDigital Comm. Corp, and TSGR3#6(99) 882, NBAP & RNSAP Procedure for TDD Synchronization(some additions/modifications to R3-99905), Italtel / Siemens. Shortly after these contributions were made, work on this topic was suspended, based on common agreement that Node B Synchronization should be a topic for R2000.

3 Other Techniques for Node Synchronization

The proposed approach is most suited for scenarios where there is sufficient link margin between neighboring Node Bs. It is most convenient to manage when Node Bs share the same controlling RNC, but with higher layer signalling this may not be a limitation.

Other techniques which can augment this proposal include:

- Hard wired connection to a precise time reference (the R99 solution)
- Increase the SCH power on occasions, to compensate for link limitations.
- Use UE measurements of Time Difference of Arrival between two cells.

The last technique is particularly well suited to pico cells, where, due to the very small cell radius, there is negligible error introduced by the unknown propagation delay.

4 Conclusion

We have introduced an approach to Node B Synchronization that requires no new Layer 1 formats. It uses several new messages between Node Bs and RNCs; these messages have already been introduced into WG3.

The performance of this approach will be documented in related contributions.

Attachment A
Reprint of *TSGR3#6(99)905*

TSG-RAN Working Group 3 Meeting #6 ***TSGR3#6(99)905***
Sophia Antipolis, France
August 23-27, 1999

Agenda Item: Sync Adhoc 4.5, 4.7

Source: InterDigital Comm. Corp.

Title: Synchronization of TDD Cells

Document for: Approval

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5 Introduction

TDD operation requires that base stations frames be in time synchronization with accuracy on the order of 1 microsecond. Reference, TSGR1#3(99) 165 identified an approach based on a new synchronization waveform, beacon transmission. This contribution suggests an approach that does not require a special air interface waveform, but does use new messages between the RNC and Node B.

This document identifies two candidate approaches to perform this synchronization. We may select either one, or a combination of the two.

6 Description of the candidates

6.1 Base stations synchronizes to absolute time

In this solution, there is no action required for the protocol standards. However, the BS performance document must specify that the base station start frame transmission on absolute time intervals, correct to within a specified limit; e.g. 1 microsecond (exact value to be determined).

6.2 Synchronization of Base Stations by the RNC

6.2.1 Basic Principle

In this solution, the RNC will occasionally tell the Node b cells to perform a simple cell search for a defined neighbor cell. It derives the time offset of the received signal with respect to its own reference. It sends a response to the RNC containing the measured Time offset (units: chips; signed number; could be negative).

In this concept, the RNC has all relevant information stored, including sync channel t_{offset} of the primary sync code, downlink scrambling code for the synchronization channel, etc., and passes the information to the Node B for this procedure.

For pairs of cells; e.g. Base Station A and Base Station B, the RNC compares two corresponding time delays. Assuming that the measurements have been obtained at nominally the same time,

TAB = Time delay from A as seen by B

TBA= Time delay from B as seen by A

Then, defining
deltaT = the time error to be estimated,
R = the distance between the Base Stations
c = speed of light
We obtain
TAB = deltaT +R/c
TBA =-deltaT +R/c
and
deltaT = (TAB-TBA)/2

Note that R is not needed for the actual calculation. However, noting that TAB+TBA=2*R/c, this could be used to optimize processing.

6.2.2 Effect of non-simultaneous measurements

Consider the effect induced because measurements are not necessarily taken at the same time. If the two base stations under consideration have no drift rate relative to one another, then there is no error introduced by non-simultaneous measurements.

If there is a significant drift, then the RNC must use some form of tracking algorithms, for instance a simple one could be periodic re-synchronization using the basic principle outlined above.

6.2.3 Connectivity issues

It is possible that there is not complete connectivity; i.e. islands of cells, not connected via the air to one another. It is proposed that each group of cells within an island (could be entire network if full connectivity exists), would have at least one cell with an external accurate timing reference. In reference TSGR1#3(99) 165, Siemens identified GPS and GNSS as possible absolute timing references, these or any others can be used as long as the cell can be synchronized to an absolute time reference to within 1 microsecond.

7 Proposals

The proposal is to allow the use of a combination of both the absolute timing reference and the air synchronization method to achieve the desired synchronization while giving a maximum flexibility to a vendor for the Node B hardware implementation. Any RNC to RNC coordination is outside the scope of this document.

7.1 Replace section 9.7 of UTRAN Overall description 25.401 with the following text.

9.7 TDD Frame Synchronization

In the UTRA TDD mode, the cells within the UTRAN are synchronized with respect to Radio Frame. This synchronization is achieved via a combination of absolute timing references such as GPS and/or GNSS, and simple adjustments commanded by the RNC's which are made by cells reading the synchronization channel of neighboring cells.

For time alignment of the uplink radio signals from the UE to the UTRAN, timing advance can be applied whenever necessary. Timing advance is based on uplink burst timing measurements performed by the Node B L1, and on Timing Advance commands sent downlink to the UE. The details are FFS.

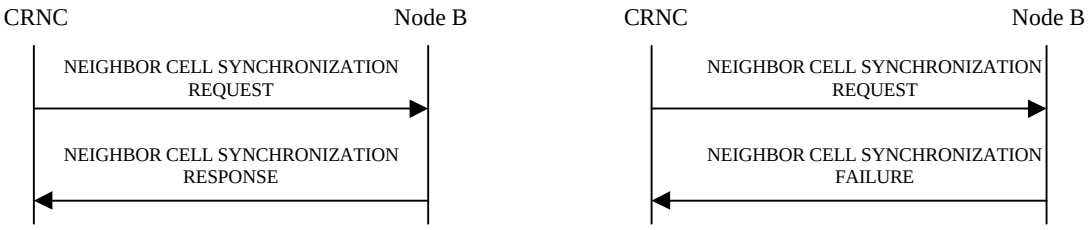
7.2 Add the following two procedures to the list of procedures in NBAP 25.433 (chapter 7)

- Neighbor Cell Synchronization (TDD only)
- Cell Synchronization adjustment (TDD only)

7.3 Add the following two sections to chapter 8 of NBAP 25.433 (sections 8.1.10, and 8.1.11)

8.1.10 Neighbor Cell Synchronization

The purpose of Neighbor Cell Synchronization is to have the selected cell read the synchronization channel of another cell allowing the timing alignment necessary for TDD. The Neighbor Cell Synchronization Procedure requires three message types, a Neighbor Cell Synchronization request, a Neighbor Cell Synchronization response in the successful case when a neighbor cell is received and a chip offset is determined, and a Neighbor Cell Synchronization failure in the unsuccessful case. The CRNC initiates this based on its knowledge of the cell configuration and the cells necessary to align timing. The request contains the cell id that is making the request along with the pertinent neighbor cell information to allow it to read the synchronization channel. The Node B responses back with the offset from its internal timing and the timing read from the neighbor's synch channel.



a) Successful case **b) Unsuccessful case**

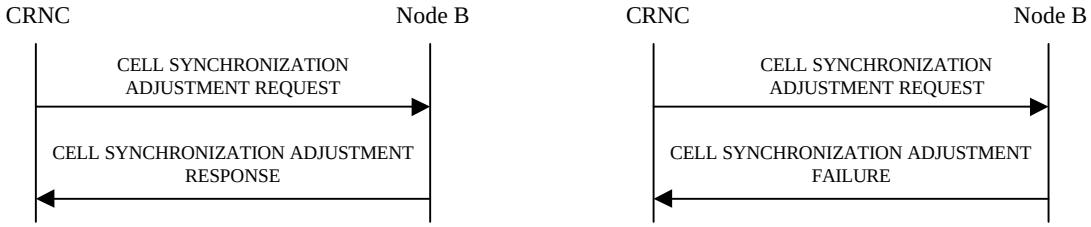
NEIGHBOR CELL SYNCHRONIZATION REQUEST message contains:
- Transaction ID
- Cell Id
- Neighbor Cell information

NEIGHBOR CELL SYNCHRONIZATION RESPONSE message contains:
- Transaction ID
- Cell Id
- Frame discrepancy

NEIGHBOR CELL SYNCHRONIZATION FAILURE message contains:
- Transaction ID
- Cell Id
- Failure reason

8.1.11 Cell Synchronization Adjustment

The purpose of Cell Synchronization Adjustment is to allow the CRNC to adjust the timing of a cell for time alignment in TDD. The Cell Synchronization Adjustment Procedure requires three message types, a Cell Synchronization adjustment request, a Cell Synchronization response in the successful case, and a Cell Synchronization Failure in the unsuccessful case. The CRNC initiates this based on its knowledge of the cell configuration and the cells necessary to align timing. The request contains the cell id that is being aligned along with the pertinent adjustment. The Node B responses back with a response in the successful case or a failure in the unsuccessful case.



a) Successful case **b) Unsuccessful case**

CELL SYNCHRONIZATION ADJUSTMENT REQUEST message contains:
- Transaction ID
- Cell Id
- Chip Offset

CELL SYNCHRONIZATION ADJUSTMENT RESPONSE message contains:
- Transaction ID
- Cell Id

CELL SYNCHRONIZATION ADJUSTMENT FAILURE message contains:
- Transaction ID
- Cell Id
- Cause

7.4 Add the following sections to chapter 9.1 of NBAP 25.433 (sections 9.1.38 – 9.1.43)

9.1.38 NEIGHBOR CELL SYNCHRONIZATION REQUEST

This message is sent from CRNC to Node B in order to check the synchronization of neighbor cells in TDD.

Information Element	**Reference**	**Type**
Message Discriminator		M
Message Type		M
Transaction ID		M
Cell ID		M
Neighbor Cell information		**M**

DL Scrambling Code		M
Toffset		M
Sync Midamble		M
PSCH TS id - K		M

9.1.39 NEIGHBOR CELL SYNCHRONIZATION RESPONSE

This message is sent from Node B to CRNC as response to the Neighbor Cell Synchronization Request message and returns the chip offset of the neighbors synchronization channel.

Information Element	**Reference**	**Type**
Message Discriminator		M
Message Type		M
Transaction ID		M
Cell Id		M
Measured Chip Offset		M

9.1.40 NEIGHBOR CELL SYNCHRONIZATION FAILURE

This message is sent from Node B to CRNC as response to the Neighbor Cell Synchronization Request message when the Neighbor cell could not be read.

Information Element	**Reference**	**Type**
Message Discriminator		M
Message Type		M
Transaction ID		M
Cell Id		M
Failure Cause		M

9.1.41 CELL SYNCHRONIZATION ADJUSTMENT REQUEST

This message is sent from CRNC to Node B in order to set the clocking of a cell in TDD.

Information Element	**Reference**	**Type**
Message Discriminator		M
Message Type		M
Transaction ID		M

Cell ID		M
Chip Offset Adjustment		M

9.1.42 CELL SYNCHRONIZATION ADJUSTMENT RESPONSE

This message is sent from Node B to CRNC as response to the Cell Synchronization Adjustment Request message and returns the chip offset of the neighbors synchronization channel.

Information Element	**Reference**	**Type**
Message Discriminator		M
Message Type		M
Transaction ID		M
Cell Id		M

9.1.43 CELL SYNCHRONIZATION ADJUSTMENT FAILURE

This message is sent from Node B to CRNC as response to the Cell Synchronization Adjustment Request message when the Neighbor cell could not be adjusted.

Information Element	**Reference**	**Type**
Message Discriminator		M
Message Type		M
Truncation ID		M
Cell Id		M
Failure Cause		M

7.5 Add the following sections to chapter 9.2 of NBAP 25.433 (sections 9.2.39 – 9.2.43)

9.2.39 Toffset

The offset of the primary synchronization code for a neighboring cell

9.2.40 Sync Midamble

Midamble used of the TDD synchronization channel for a neighboring cell

9.2.41 PSCH TS id K

The timeslot in TDD that contains the Synchronization channel.

9.2.42 Measured Chip Offset

Value of the measured offset of neighbor cell during synchronization process.

9.2.43 Chip Offset adjustment

The chip adjustment to be made in a cell to facilitate cell synchronization

Attachment B
Reprint of *TSGR3#6(99) 882*

TSG-RAN Working Group Sync Ad Hoc meeting ***TSGR3#6(99) 882***
August 23rd 1999
Sophia Antipolis, France

Title: **NBAP & RNSAP Procedure for TDD Synchronization (some additions/modifications to R3-99905)**

Source: **Italtel / Siemens**

Agenda Item: **4.7**

Document for: **Approval**

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8 Introduction

The different proposals to achieve synchronization in TDD can be grouped into two main classes:

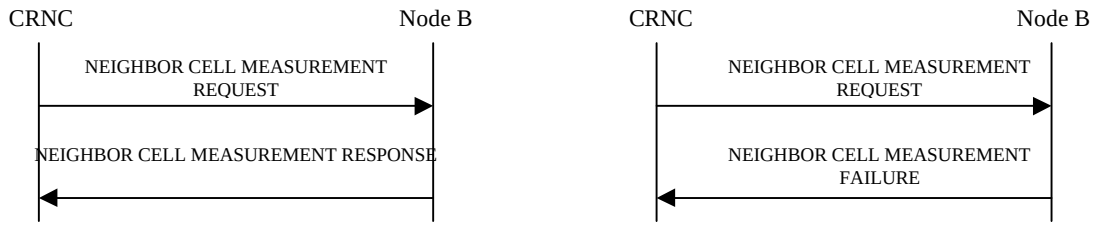
- Synchronization of nodes B to an external reference via a standardized synchronization port;
- Synchronization of nodes B on the air interface, e.g. through nodes B cross measurements or assisted by UEs.

Each of them has some advantages and some drawbacks, and it can be foreseen that a combined solution will be adopted.
It is however probable that whichever solution belonging to the second class is adopted, some new functionality will be needed on Iub.
In every solution the RNC shall be the master of the synchronization process, since the measurements either performed by one cell on another one, or by the UE on one cell, shall be received by the RNC (in the second case these measurements can be delivered only at RRC level, i.e. it's not reasonable to use a direct L1 signaling between the UE and the node B).
This means that at least a procedure from the RNC to the node B is needed to adjust the node B timing.
Other procedures are more solution dependent, since could not be needed in case of a UE assisted synchronization.
Some procedures have been introduced, for example, in R3-99905 (Interdigital).
This proposal is based on cross measurements of cell Physical Synchronization Channels (PSCHs) belonging to different nodes B, and requires a procedure from the RNC to the node B to request a measurement on a neighbor cell PSCH.
Even if some L1 issues still need to be clarified, it is recognized that it is useful to introduce at this time not only NBAP but also RNSAP relevant procedures to include the case in which the Node B performing the cell search for a cell which does not belong to the same RNC.
Furthermore we ask to issue a Liaison Statement to RAN WG1 and RAN WG4 in order to get an opinion about the feasibility of the proposal contained in R3-99905.

9 Revisions of R3-99905

8.1.10 Neighbor Cell Measurement

The purpose of Neighbor Cell Measurement is to have the selected cell (Measuring Cell) read the synchronization channel of another cell (Measured Cell) allowing the timing alignment necessary for TDD.
The Neighbor Cell Measurement Procedure requires three message types, a Neighbor Cell Measurement Request, a Neighbor Cell Measurement Response in the successful case when a neighbor cell is received and a chip offset is determined, and a Neighbor Cell Measurement Failure in the unsuccessful case. The CRNC initiates this based on its knowledge of the cell configuration and the cells necessary to align timing. The request contains the Measuring Cell Id that is making the request along with the pertinent Measured Cell information to allow it to read the synchronization channel. The Node B responses back with the offset from its internal timing and the timing read from the neighbor's synch channel.
In case the Measured Cell IE is missing, the Node B measures its relative frame timing in respect to the best cell it can detect (the ID of the detected cell is given in the Cell Measurement Response).



a) Successful case **b) Unsuccessful case**

NEIGHBOR CELL MEASUREMENT REQUEST message contains:
- Transaction ID
- Measuring Cell Id
- Measured Cell information

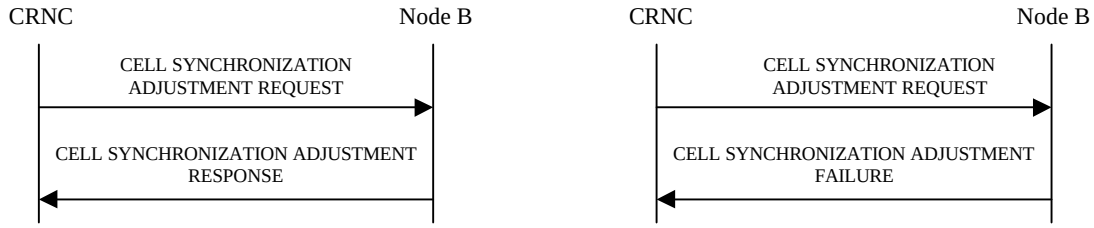
NEIGHBOR CELL MEASUREMENT RESPONSE message contains:
- Transaction ID
- Measured Cell Id
- Measured Chip Offset

NEIGHBOR CELL MEASUREMENT FAILURE message contains:
- Transaction ID
- Measured Cell Id
- Failure reason

8.1.11 Synchronization Adjustment

The purpose of Synchronization Adjustment is to allow the CRNC to adjust the timing of a Slave Node Bfor time alignment in TDD. The Synchronization Adjustment Procedure requires three message types, a Synchronization Adjustment request, a Synchronization Response in the successful case, and a Synchronization Failure in the unsuccessful case. The CRNC initiates this based on its knowledge of the cell configuration and the cells necessary to align timing. The request contains the Chip Offset Adjustment and the Master Cell ID, i.e. the ID of the cell that the Node B continue to monitor (when this IE is not present, then the Node B does not continue

to monitor its Master Cell). The Node B responses back with a response in the successful case or a failure in the unsuccessful case.



a) Successful case **b) Unsuccessful case**

CELL SYNCHRONIZATION ADJUSTMENT REQUEST message contains:
- Transaction ID
- Master Cell Id
- Chip Offset Adjustment

CELL SYNCHRONIZATION ADJUSTMENT RESPONSE message contains:
- Transaction ID

CELL SYNCHRONIZATION ADJUSTMENT FAILURE message contains:
- Transaction ID
- Cause

9.1 Add the following sections to chapter 9.1 of NBAP 25.433 (sections 9.1.38 – 9.1.43)

9.1.38 NEIGHBOR CELL MEASUREMENT REQUEST

This message is sent from CRNC to Node B in order to check the synchronization of neighbor cells in TDD.

Information Element	**Reference**	**Type**
Message Discriminator		M
Message Type		M
Transaction ID		M
Measuring Cell ID		M
Measured Cell information		**O**
Measured Cell ID		O
DL Scrambling Code		O
Toffset		M
Sync Midamble		O
PSCH TS id - K		O

9.1.39 NEIGHBOR CELL MEASUREMENT RESPONSE

This message is sent from Measuring Node B to CRNC as response to the Neighbor Cell Synchronization Request message and returns the chip offset of the neighbors synchronization channel.

Information Element	Reference	Type
Message Discriminator		M
Message Type		M
Transaction ID		M
Measured Cell Id		O
Measured Chip Offset		M

9.1.40 NEIGHBOR CELL MEASUREMENT FAILURE

This message is sent from Measuring Node B to CRNC as response to the Neighbor Cell Synchronization Request message when the Neighbor cell could not be read.

Information Element	Reference	Type
Message Discriminator		M
Message Type		M
Transaction ID		M
Measured Cell Id		O
Failure Cause		M

9.1.41 SYNCHRONIZATION ADJUSTMENT REQUEST

This message is sent from CRNC to Slave Node B in order to set the clocking of a cell in TDD.

Information Element	Reference	Type
Message Discriminator		M
Message Type		M
Transaction ID		M
Master Cell ID		O
Chip Offset Adjustment		M

9.1.42 SYNCHRONIZATION ADJUSTMENT RESPONSE

This message is sent from Slave Node B to CRNC as response to the Cell Synchronization Adjustment Request message.

Information Element	Reference	Type
Message Discriminator		M
Message Type		M
Transaction ID		M

9.1.43 SYNCHRONIZATION ADJUSTMENT FAILURE

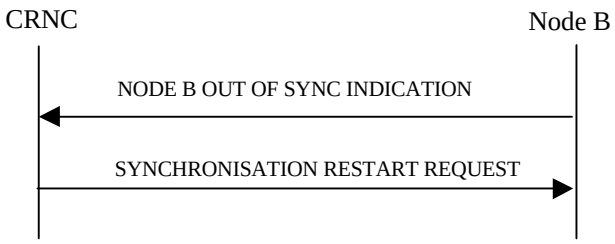
This message is sent from Slave Node B to CRNC as response to the Cell Synchronization Adjustment Request message when the Slave Node B could not be adjusted.

Information Element	Reference	Type
Message Discriminator		M
Message Type		M
Transaction ID		M
Failure Cause		M

11 Further additions to TS 25.433

SYNCHRONIZATION RECOVERY

This recovery procedure is used in case the locked slave Node B looses its Master Cell or the Master Cell becomes unreliable. When the CRNC is notified that the synchronization of the Node B to the master cell has been lost, it can decide whether to stop the Node B transmission (in this case the SYNCHRONISATION RESTART REQUEST is issued) or to proceed with different recovery actions.



NODE B OUT OF SYNC INDICATION message contains:

- Transaction ID

SYNCHRONIZATION RESTART REQUEST message contains:

- Transaction ID

NODE B OUT OF SYNC INDICATION

This message is sent from the slave Node B to the CRNC when the Master Cell is lost or becomes unreliable.

Information Element	**Reference**	**Type**
Message Discriminator		M
Message Type		M
Transaction ID		M

SYNCHRONIZATION RESTART REQUEST

This message is sent by the CRNC to the slave Node B in case the CRNC decides to stop Node B transmission and to restart the search for a Master Cell.

Information Element	**Reference**	**Type**
Message Discriminator		M
Message Type		M

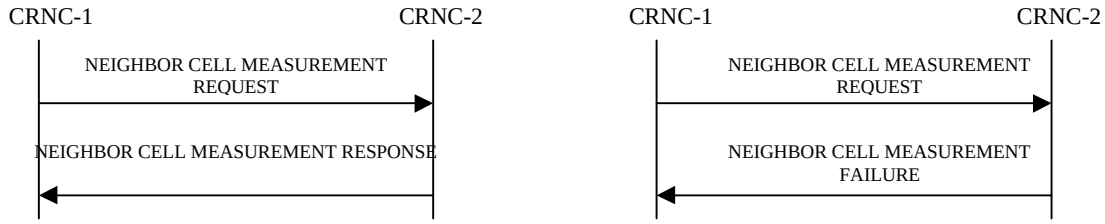
Transaction ID		M

12 Additions to TS 25.423

12.1 Add the following sections to chapter 8 of RNSAP 25.423

Neighbor Cell Measurement

The purpose of Neighbor Cell Measurement is to have the selected cell belonging to CRNC-2 (Measuring Cell) read the synchronization channel a cell belonging to CRNC-1 (Measured Cell). This allows the cross measurements of two cells belonging to different RNCs.
The Neighbor Cell Measurement Procedure requires three message types, a Neighbor Cell Measurement Request, a Neighbor Cell Measurement Response in the successful case when a neighbor cell is received and a chip offset is determined, and a Neighbor Cell Measurement Failure in the unsuccessful case. CRNC-1 initiates this based on its knowledge of the cell configuration and the cells necessary to align timing. The request contains the Measuring Cell Id along with the pertinent Measured Cell information to allow it to read the synchronization channel. CRNC-2 responses back with the offset from its internal timing and the timing read from the neighbor's synch channel.



a) Successful case **b) Unsuccessful case**

NEIGHBOR CELL MEASUREMENT REQUEST message contains:
- Transaction ID
- Measuring Cell Id
- Measured Cell Id

NEIGHBOR CELL MEASUREMENT RESPONSE message contains:
- Transaction ID
- Measured Cell Id
- Measured Chip Offset

NEIGHBOR CELL MEASUREMENT FAILURE message contains:
- Transaction ID
- Measured Cell Id
- Failure reason

12.2 Add the following sections to chapter 9.1 of RNSAP 25.423

NEIGHBOR CELL MEASUREMENT REQUEST

This message is sent from CRNC-1 to CRNC-2 in order to check the synchronization of one of its cells.

Information Element	**Reference**	**Type**
Message Discriminator		M
Message Type		M
Transaction ID		M
Measuring Cell ID		M
Master Cell ID		M

NEIGHBOR CELL MEASUREMENT RESPONSE

This message is sent from CRNC-2 to CRNC-1 as response to the Neighbor Cell Measurement Request message and returns the chip offset respect to the Measured Cell synchronization channel.

Information Element	**Reference**	**Type**
Message Discriminator		M
Message Type		M
Transaction ID		M
Measured Chip Offset		M

NEIGHBOR CELL MEASUREMENT FAILURE

This message is sent from CRNC-2 to CRNC-1 as response to the Neighbor Cell Measurement Request message when the Measured cell could not be read.

Information Element	**Reference**	**Type**
Message Discriminator		M
Message Type		M
Transaction ID		M

Failure Cause		M