TSG-RAN Working Group 3 meeting #6   **TSGR3#6(99)A36**

Sophia-Antipolis, France, 23 - 27 August 1999

Agenda Item: 26

Source: TSG RAN WG3

Title: Liaison on UTRAN Frame Synchronisation model

To: TSG RAN WG1, TSG RAN WG4, TSG RAN WG2

_____

R3 plans to include a stage-2-like specification of the UMTS RAN frame synchronisation in 25.401. This description should specify the frame-synchronisation related relations between SRNC, CRNC, node-B and UE.

It is clear that R3 can not make this description without the support of the other RAN WG's. Therefore this liaison would like to clarify the current frame synchronisation model used in R3 and the assumptions on which it is based. In addition the relation between different synchronisation related parameters will be described.

R1, R2 and R4 are kindly requested to study the described model, assumptions and parameter relations and comment regarding any incorrections/improvements. Ofcourse any other input aimed at completing the frame-synchronisation specification is highly appreciated.

Note: Since the text was created during the R3 meeting, R3 would like to apologise for any editorial imperfections that may be present.

Frame Synchronisation in the UMTS RAN

The UE-UTRAN synchronisation consists of two different aspects: a L2 (or transport channel synchronisation) and a L1 synchronisation.

1. Layer 2 Synchronisation

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

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

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

A L1-MAC primitive is defined to allow the L1 to indicate to L2 the necessity to adjust the timing of the DL transmission, in order to control and minimise the transmission delay. The primitive is carried in the user plane by Frame Protocol procedures within the UTRAN. This transport channel synchronisation mechanism is valid for all the transport channels, in FDD and TDD modes.

The CFN used by the transport channel synchronisation mechanism may be extended to form a larger L2 counter (HFN, Hyper frame number), to be used for example for ciphering. The initialisation of this counter is done at RRC level and the parameter is not visible at lower layers.

The parameters related to L2 synchronisation are described in the following paragraphs.

1.1. CFN

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

Since the CFN is mapped into one SFN and defines a specific frame for the transmission on the air interface, some L1-MAC primitives are defined to minimise the buffering time for the transmission on the air interface (i.e. to ensure that the TBS does not arrive too much in advance respect to the transmission time), and, in general, to control the delays in the transport channel.

The duration of the CFN cycle shall be longer than the maximum allowed transport delay between MAC and L1 (in UTRAN side, between SRNC and Node B, because the L1 functions that handle the transport channel synchronisation are in the Node B). Furthermore the CFN shall be shorter, or at most equal to the SFN. Currently the SFN is 12 bits long, and the proposal is to adopt 8 bits (2.56 seconds) for the CFN.

The range of CFN is 0…255 (integer value).

> Note: WG3 is still studying the possibility to extend the CFN for the PCH to 12 bits, for long sleepmode paging.

1.2. Frame_offset

Frame_offset is a radio link specific L1 parameter used to map the CFN, used in the transport channel, into the cell SFN transmitted between UE and UTRAN at L1.

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

$$SFN = CFN - Frame\_offset \quad \text{(from L2 to L1)} \tag{1.1}$$

$$CFN = SFN + Frame\_offset \quad \text{(from L1 to L2)} \tag{1.2}$$

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

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

1.3. SFN

Each cell has a Cell System Frame Number. This SFN is broadcasted on the BCH. The current WG3 assumption is that the SFN has a length of 12 bits.

2. Layer 1 synchronisation

As shown above, the transport channel synchronisation mechanism defines the radio frame in which the TBS transmission shall be started. From this reference point, other parameters are used to define the exact timing of the radio frame transmission. Those parameters are the time slot for TDD and the Chip Offset for FDD.

The parameters related to L1 synchronisation are described in the following paragraphs.

2.1. Chip Offset (FDD)

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

The Chip_offset parameter is calculated by the SRNC and provided to the node-B. The details concerning rounding the Chip_offset value to Td are FFS.

2.2. Time-slot (TDD)

The time-slot parameter indicates in which time-slot within the frame the transmission shall take place.

3. Synchronisation parameters from/to the UE

In order to obtain L1 and L2 synchronisation with the UTRAN, the UE reports and receives several parameters.

> Note: Currently WG3 is assuming that the UE may report 2 separate parameters (Tm and OFF) when adding a RL. WG2 liaison "Response to LS on UE requirement to report OFF" (TSGR3#6(99)842) discussed in R3#6, indicated that WG2 has not yet taken a final decision if 1 or 2 separate parameters will be reported by the UE. If WG2 decides to only report 1 (combined) parameter, the description below will have to be change but no major consequences are foreseen.

3.1. OFF

The reported OFF parameter has a resolution of 1 frame and a range of 0 to 255. OFF shall only be sent when the UTRAN has requested the UE to send this parameter. In the neighbouring cell list, the UTRAN indicates for each cell if the Frame_offset is already known by the UTRAN or shall be measured and reported but the UE.

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

1) The UE changes from common channel state to dedicated channel state: 1 RL
   In this case OFF will be zero (is it even reported ?).

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

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

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

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

3.2. Tm

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

Again five cases are discerned are discerned related to the determination of the OFF value by the UE:

1) The UE changes from common channel state to dedicated channel state: 1 RL
   In this case the Tm will be zero (is it even reported ?).

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

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

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

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

3.3. DOFF

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

The DOFF parameter has a resolution of 512 chips and a range of 0 to 599 (<80ms). The maximum value is chosen in accordance with the largest interleaving period supported on Uu.

The DOFF value sent to the UE is determined by the SRNC based on certain (load distributing) algorithms.

4. Calculations performed in the UTRAN

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

4.1. UE in common channel state.

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

4.2. UE changes state from common CH state to dedicated CH state: 1 RL

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

$$\text{Frame\_offset} * 38400 + \text{Chip\_offset} = \text{DOFF} * 512 \tag{4.1}$$

4.3. UE changes state from common CH state to dedicated CH state: several RL's

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

$$\text{Frame\_offset} * 38400 + \text{Chip\_offset} = \text{DOFF} * 512 + \text{OFF} * 38400 + \text{Tm} \tag{4.2}$$

Note [1]: note that formula (2) is covering formula (1) since in case 1, OFF and Tm are both equal to zero.

4.4. UE requests to add a new RL in dedicated CH state

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

$$\text{Frame\_offset} * 38400 + \text{Chip\_offset} = \text{OFF} * 38400 + \text{Tm} \tag{4.3}$$

4.5. Handover from other RAN to UMTS

Based on the definitions for OFF and Tm provided in chapter 3.1. and 3.2., formula (4.1) can also be used when the UE enters the UTRAN from another CN and establishes 1 dedicated RL. The same is true for formula (4.2) when establishing 1 or more dedicated RL's.

5. Calculations performed in the UE

5.1. First RL

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

$$\text{CFN} = ((\text{SFN} * 38400 + \text{DOFF} * 512) \text{ div } 38400) \bmod 256 \tag{5.1}$$

Note: in case the UE is coming from another RAN, the SFN is not the SFN from the camping cell but the SFN from the reference cell.

In this case the OFF is set to 0.

5.2. Additional RL's

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

However every time the UE enters a new cell the OFF value, which might have to be reported to the UTRAN, will have to be recalculated. The Frame_offset for the new cell can be computed with the following formula:

$$OFF[new] = (CFN - SFN[new]) \bmod 256 \qquad\qquad (5.2)$$

The difference (SFN[old] - SFN[new]) is calculated as the integer number of frames, with approximation to the lower integer number (*the exact definition of the difference is TBD*).