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Agenda Item: Synchronisation ad-hoc, 4

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Title: Model and parameters for UE-UTRAN frame synchronisation

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1 Introduction

This paper presents the UE-UTRAN synchronisation model as developed until now in RAN Working groups. It clarifies the synchronisation concept, the parameters and the layers of the air interface where they are defined. The paper deals only with air interface aspects.

2 Discussion

The synchronisation, as discussed until now in WG3 and other RAN working group, can be grouped into two different aspects: a L2 (or transport channel synchronisation) and a L1 synchronisation.

2.1 Transport Channel 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 other side associated with the same TBS.

The CFN is not transmitted in air interface, but mapped by L1 to the Cell SFN of the first radio frame used for the transmission of the TBS (the Cell SFN is broadcast at L1 in the BCH). The parameter used for the mapping (OFF) is either defined by the UE-L1 and passed to UTRAN-L1 at the initialisation of the radio link (in case of DCH), or it has a default value (=0) in case of common radio link (RACH/FACH).

If the UE is using more than one RL (soft handover), OFFs of the two radio links are selected in order to have timed transmission of the diversity branches in the air interface.

A L1-MAC primitive is defined to allow the L1 to indicate to MAC the necessity to adjust the timing of the DL transmission, in order to control and minimise the transmission delay. The primitive in UTRAN side is carried in the user plane by Frame Protocol procedures.

Transport channel synchronisation mechanism is valid for all the transport channels, in FDD and TDD modes.

Note that the CFN counter of the transport channel synchronisation mechanism, is extended in some cases by a 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 layer.

2.2 L1 synchronisation

As shown above, the transport channel synchronisation mechanism defines the first radio frames where the TBS shall be transmitted. From this reference point, other parameters are used to define the exact timing of the radio frame transmission. Those parameters are the time slot, in case of TDD, and the DOFF / Td in case

of FDD (FDD parameters are defined with different names in WG1, WG2 and WG3, and a common definition of the parameters is proposed below, to be used in all TSG RAN documents).

The L1 parameters are defined/measured by the UE L1 but also assigned/modified by RRC for RRM reason.

If the UE is using more than one RL (soft handover), the L1 parameters of the two radio link are selected in order to have timed transmission in the diversity branches.

Note that L1 parameters are defined independently of the OFF parameters used for the transport channel synchronisation (those are used for different functions at different layers of the protocol stack).

2.3 Clarification on some synchronisation parameters

2.3.1 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 time instance for the transmission in air interface, some L1-MAC primitives are defined to minimise the buffering time for the transmission in 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.

In UTRAN side, those primitives are carried by the User plane Frame Protocol procedures in Iub/Iur interfaces. The procedures defined in the FP and internal algorithms in the SRNC are used to determine the optimum transmission time of the DL frames from the SRNC.

The duration of the CFN cycle shall be longer that 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 Cell SFN. Currently the Cell SFN is 12 bits long, and the proposal is to adopt 8 bits (2.56 seconds) for the CFN. Thus the range of CFN is 0…255 (integer value).

2.3.2 OFF

OFF 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:

Cell SFN = CFN - OFF (from L2 to L1)

CFN = Cell SFN + OFF (from L1 to L2)

OFF and CFN have same range (8 bits, 0…255) and only the 8 least significant bits of the Cell SFN are used. The subtractions above are modulo 256, i.e. 256 is added if the result is negative and subtracted if the result is above 255.

In case the UE has a dedicated transport channel, OFF of the radio links is selected by the UE-L1 and communicated to the UTRAN L1 via RRC +Iub/Iur L3 signalling when the radio link is setup. In case of an additional RL, UE selects the OFF in order to have synchronised transmission among all the branches. Also in case of hard handover, the OFF of the target cell is selected with the same criteria, in order to avoid discontinuity in the CFN cycle.

OFF for one RL is defined as follows:

- RL in the cell is a common resource (UE RACH and FACH):

  OFF = 0 default parameter (not signalled).

  Note: This is necessary in order to ensure that same OFF is used by all the UE using the same common channel (because OFF is unique in the transport channel).

- The RL in the cell is a UE dedicated resource (at least one DCH is setup in this cell), and this is the first radio link of the UE:

  OFF = 0 (or random number selected by the UE, if OFF is zero it is in any case signalled to SRNC, to be confirmed by WG2)

- The RL in the cell is a UE dedicated resource (at least one DPCCH is setup in this cell), and the UE has already one 'dedicated' RL in another cell (ex: an additional RL in soft handover or new radio link in hard handover):

  OFFtarget = (Cell SFNsource - Cell SFNtarget) + OFFsource

  Cell SFNsource and OFFsource are selected by one of the RL in the initial active set, and the difference is calculated as the integer number of frames, with approximation to the lower integer number. The OFF values are rounded modulo 256 (length of OFF).

  OFF is either measured by the UE or calculated by UTRAN (in case the difference between the Cell SFN of the two cells is known). In the neighbouring cell list, UTRAN indicates for each cell is the OFF is known or shall be measured.

2.3.3 Measurement time difference to a cell (Tm)

Tm is measured by the UE and reported to UTRAN within the measurement report message: it gives the timing information of a target cell to be used by UTRAN to set the DOFF (see later) when the RL is configured in the target cell (FDD only).

It is currently defined in two documents:

From [25.331]:

> *The measured time difference to cell indicates the time difference which is measured by UE between CFN in the UE and the SFN of the target neighbouring cell. It is notified to SRNC by Measurement Report message or Measurement Information Element in other RRC messages.*

From [25.211]:

> ***T_m**: This value is measured by the UE and reported to the RNC prior to soft handover. The RNC can then notify this value to the target cell, which then knows how to set T_d to achieve proper reception and transmission frame timing of the dedicated physical channel.*
>
> *<Editors note: Descriptive text: Note that since the UE reports the value T_m as the time-difference between the received Primary CCPCH frame-timing from the target cell and the earliest received existing DPCH path, the propagation delay to the target cell is already compensated for in the setting of T_d at the target cell. The DPCH signal from the target cell will reach the UE at the same time as the earliest received existing DPCH path. The only remaining error, besides frequency-drift and UE mobility related errors, is due to a (known) rounding error at the target cell in order to maintain downlink orthogonality.>*

The definitions are consistent (even if there shall be no reference to the CFN in the definition), and the following changes to the last definition are proposed:

> **T_m**: It is the time-difference between the received Primary CCPCH frame-timing from the target cell and the earliest received existing DPCH path. This value is measured by the UE and reported to the RNC ~~prior to soft handover~~. The RNC ~~can then notify this value to the target cell, which~~ then knows how to set ~~T_d~~ DOFF to achieve proper reception and transmission frame timing of the dedicated physical channel.
>
> The range of Tm is from 0 to10 msec., with the accuracy of one chip (to be confirmed by WG1). Tm=X means that the beginning of the frame received in the existing DPCH is measured by the UE to be X chips after the beginning of the radio frame received in the Primary CCPCH of the target cell.

2.3.4 Default DPCH Offset Value (DOFF), Td and chip offset

DOFF is an offset set by UTRAN that defines the frame timing of a new RL. DOFF is used to evenly distribute the transmission periods of the DCH, in order to gain capacity in air interface and UTRAN terrestrial interfaces (FDD only).

Definition of DOFF from [25.331]

> *Indicates the default offset value within interleaving size at a resolution of 512chip (1/5 slot) to offset CFN in the UE. This is used to distribute discontinuous transmission periods in time and also to distribute NodeB-RNC transmission traffics in time. Even though the CFN is offset by DOFF, the start timing of the interleaving will be the timing that "CFN mod (interleaving size)"=0 (e.g. interleaving size: 2,4,8) in both UE and SRNC.*

Td defines the frame timing to be used in one additional soft handover branch, and it is calculated from the Tm reported by the Tm received from the UE.

Definition of Td from [25.211]

> ***T_d**: This timing offset is used for the frame timing of DPCHs and Secondary CCPCHs. It can be individually set up for each DPCH and Secondary CCPCH. The T_d values for the latter may be broadcast on the BCH, or known a-priori. The resolution is 256 chips in order to maintain downlink orthogonality and the range is TBD. <Editors note: Descriptive text: The purpose of T_d is:*
> *- In an originating/terminating cell, to distribute discontinuous transmission periods in time, and also to distribute Node B-RNC transmission traffic in time.*
> *- At soft handover, to synchronise downlink DPCHs to the same UE, in order to minimise the buffering requirements at the UE.>*

The definitions are not consistent, and furthermore WG3 uses another term, 'chip offset' (in RNSAP and NBAP specifications). It is proposed that the parameters are merged into the only DOFF, calculated by UTRAN based on the Tm and/or considering the existing DOFF in the cell.

In addition the definition shall clarify that the range of DOFF is from 0 to 80msec., with the the accuracy of 256 chips. Thus DOFF = X means that the beginning of the frame in the new DPCH shall be X*256 chips after the beginning of the radio frame received in the Primary CCPCH of the target cell.

3 Proposals

- To include the contents of chapter 2 in [25.401] (only the first paragraph of chapters 2.3.3 and 2.3.4 shall be included).
- To include the proposed parameters in the relevant RNSAP/NBAP messages (replacing the old ones).
- To send the present contribution to WG1 and WG2 the paper in order to allow the harmonisation of the parameters names and definitions in the RAN working Groups.

4 References

[25.401] TS 23.401, *UTRAN overall description*

[25.331] TS 25.331 RRC Protocol Specification

[25.211] TS 25.211 Physical Channels and Mapping of Transport Channels onto Physical Channels