TSG-RAN Working Group 2 (Radio layer 2 and Radio layer 3)
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Agenda Item: 7

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Title: Description of the Timing Advance Mechanism for TDD

Document for: Decision

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1. Introduction

Under some circumstances, e.g. large cells, it could be necessary for a UE operating in the UMTS-TDD system to receive and act upon timing advance instructions from the UTRAN, and for the UTRAN to detect that a timing advance is required and signal this to the UE. In other circumstances e.g. small cells timing advance signalling is not necessary.

This paper proposes functionality that supports timing advance and shows how MAC and RRC operate for this in an UMTS-TDD system.

2. Discussion

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

1. Measurement of the timing offset on the physical channels:
   (i) On PRACH transmissions,
   (ii) On DPCH transmissions,
   (iii) On PUSCH transmissions.
2. Assignment of correct timing advance value when establishing new channels:
   (i) At switch to DCH/DCH state,
   (ii) At switch to USCH/DSCH state.
3. Correction of timing advance value for channels in operation:
   (i) At least one uplink DCH in operation,
   (ii) Only USCH/DSCH in operation.
4. Setting of timing advance value for target cell at handover.

These points are discussed in the following sections.

2.1 Reporting of timing offset measurements to the RRC

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

PRACH: The UTRAN physical layer measures the timing accuracy of the RACH bursts transmitted by the UE. It measures the timing offset of the received signal and passes this together with the transport block to MAC-c. Direct reporting to RRC is not possible, because the physical layer has no UE specific context for the received data. From MAC-c, the measurement is signalled to RRC in different ways for CCCH data and DCCH/DTCH data.

For CCCH data, the MAC-c passes the measured timing offset together with the received data through a transparent mode RLC instance to the RRC.

For DCCH/DTCH data, the measured timing offset is passed from MAC-c to MAC-d, possibly over Iur interface. MAC-d is a user specific MAC instance, and can report the timing offset measurement to RRC with a CMAC_MEASUREMENT primitive.

PUSCH: The UTRAN physical layer measures the timing accuracy of the PUSCH bursts transmitted by the UE. It measures the timing offset of the received signal and passes this together with the transport block to MAC-sh. Direct reporting to RRC is not possible, because the physical layer has no UE specific context for the received data. From the MAC layer, the measurement is signalled to RRC by MAC measurement primitives.

DPCH: Since a DPCH channel is always dedicated to one UE, a user specific context is already known in the physical layer. The RRC can configure the physical layer measurements to report the measured timing offset directly to RRC. Some processing of the measurements in the physical layer is also possible, e.g. periodic or event triggered measurement reporting.

2.2.1 Switch to DCH/DCH state

It is suggested that timing correction for DCH/DCH state is handled by RRC. It is proposed that the transition to DCH/DCH state from USCH/DSCH state, RACH/FACH state or Idle Mode would operate in the following manner:-

(i) The UTRAN RRC checks, weather an up to date timing offset measurement is available. Such a measurement can be available from a recent RACH access (e.g. from initial access) or from a recent USCH transmission. If no up to date timing offset measurement is available, the RRC has to trigger an uplink transmission from the UE before it can assign a DCH.

(ii) RRC calculates the required timing advance value and saves it in the UE context for later use in dedicated or shared channel activation.

(iii) The UTRAN RRC attaches the timing advance value to the channel allocation message that it signals to the UE by way of MAC-c and the FACH.

(iv) When the UE MAC-c receives the channel allocation message it passes it to the UE RRC. Then the UE RRC forwards the timing advance value to the physical layer.

Consequently, it is suggested that timing advance for establishment of a DCH has only impact on the RRC layer. The RRC only has to ensure, that a recent timing offset measurement is available, and to include the required timing advance in the DCH setup message.

2.2.2 Switch to USCH/DSCH state

For uplink traffic using the USCH, short time allocations are sent to the UE regularly. Therefore switch to USCH is very similar to handling of timing advance updates during USCH operation as described in section 2.3.2. The UTRAN only has to check, weather an up to date timing offset measurement is available. Such a measurement can for example be available from a recent RACH access (e.g. from initial access). If no up to date timing offset measurement is available, the UTRAN has to trigger an uplink transmission from the UE before it can assign a DCH

2.3.1 UE in Traffic using at least one uplink DCH

An UE that is operating a dedicated channel (DCH/DCH state), has to update the timing advance from time to time to keep the received signal at the NodeB within the required time window. The frequency of timing advance updates depends on the movements of the UE. Only radial movements in the cell change the distance between the UE and the NodeB and therefore require correction of the timing advance.

An unrealistic worst case for the timing advance update frequency is one update every 2 seconds (for a UE moving with 500 km/h exactly radial to the cell, and midamble for 16 users). This is a quite unlikely scenario, because the midamble for 16 users is foreseen for environments with low delay spread, e.g. microcells. In these cells, UE speeds of more than 120 km/h are not expected. This reduces the worst case update frequency to 8 seconds under reasonable assumptions.

It is proposed that in case of at least one DCH the RRC should act as administrator of timing correction for the UE.

The UE reports the timing advance that is used for transmission as part of the measurement reporting to the UTRAN. The frequency of reporting can be controlled by the UTRAN.

It is proposed that the timing correction procedure would operate in the following manner:-

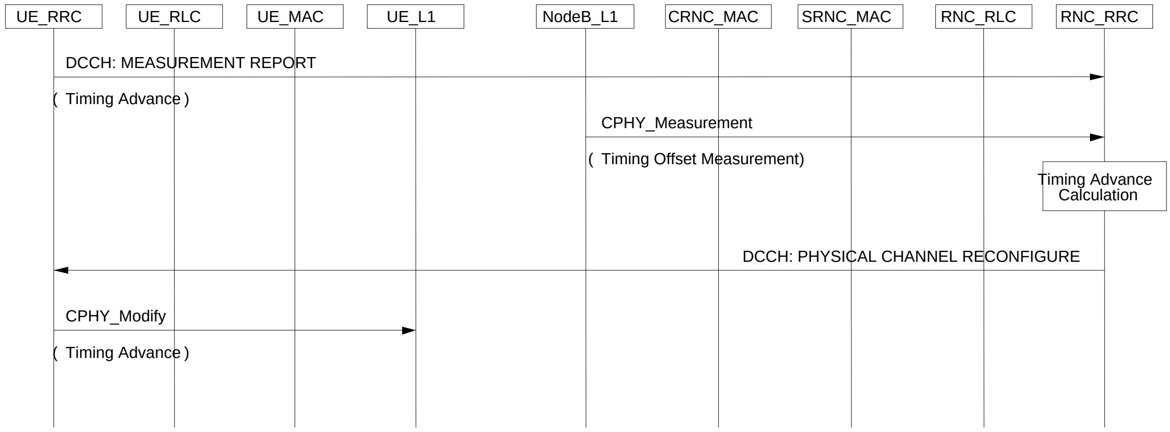
(i) The UTRAN physical layer monitors the timing accuracy of all uplink traffic from the UE. If the measured timing offset exceeds a predefined threshold, it passes the measured timing offset to the UTRAN RRC. The configuration and signalling of the measurements use the common measurement functions of the RRC.

(ii) RRC determines whether a new timing advance value has to be transmitted to the UE taking into account when the last correction was signalled. The criteria for determining when a new value has to be transmitted is an implementation option, but a simple timer started when the last correction was sent could be one option.

(iii) Timing advance corrections are signalled to the UE via RRC signalling. Timing advance can for example be changed with the Physical Channel Reconfiguration procedure.

(iv) When the UE RRC receives the a new timing advance value on FACH or DCCH then it informs the physical layer.

(v) It is suggested that there is no need for the UE to acknowledge the timing correction message in this case. The UTRAN periodically measures the UE timing accuracy, and the UE reports the received timing advance value as part of the measurement reporting. The UTRAN then is able to detect when a timing advance message has not been received and needs to be resent .



2.3.2 UE in Traffic using only USCH/DSCH

It is proposed that the timing correction procedure would operate in the following manner:-

(i) The UTRAN physical layer monitors the timing accuracy of all uplink traffic from the PUSCH. If the measured timing offset exceeds a predefined threshold, it passes the measured timing offset together with the received transport blocks to the UTRAN MAC-sh. The MAC-sh knows the identity of the transmitting UEs for all received transport blocks and signals the timing offset to the RRC with a measurement primitive.

(ii) RRC determines whether a new timing advance value has to be transmitted to the UE taking into account when the last correction was signalled. The criteria for determining when a new value has to be transmitted is an implementation option, but a simple timer started when the last correction was sent could be one option.

(iii) If a Timing Advance update is needed, the RRC includes a new timing advance value in the next USCH allocation message to the UE. No acknowledgement of the timing advance correction is needed, because it is transmitted together with the allocation signalling.

The USCH/DSCH case presents a more difficult scenario for the implementation of timing advance because, in principle, the UE may be out of communications with the UTRAN for periods of time that could result in a need for timing advance update before the UE transmits in an uplink resource unit. There are a number of ways in which this problem may be addressed. The following are identified here and should be supported:

(i) The scheduler periodically polls UE that are registered for USCH/DSCH traffic but which do not have a DCH established. The poll allocates a resource unit for acknowledgement. The UE responds with an RLC Status message. This allows the UTRAN RRC to detect when a timing advance update is needed and initiates its signalling (via the allocation message). It is suggested that the poll frequency could be such that no acknowledgement from the UE to the timing advance update is required. It is further suggested that the UTRAN RRC monitors the timing status and would not allocate resources for uplink and downlink data transfer to a UE that is out of synchronisation (i.e. no accurate poll response received for a time period).

(ii) There is no periodic polling or correction probe signalling. In this case the UTRAN would require confirmation that the UE has timing accuracy before it signals an allocation to the UE or signals the timing correction in the same FACH message as the allocation.

(a) where the data transfer is uplink after a longer idle period then the UE has to transmit a capacity request on the RACH. The UTRAN RRC is informed of any timing error of this RACH. The RRC can then include the required timing advance value within the allocation signalling.

(b) If a new allocation follows an USCH transmission, the timing error is already known to the UTRAN from measurements of the last uplink transmission. In this case, the RRC can determine wether a timing advance update is necessary, and include the required timing advance within the allocation signalling.

2.4 Handover

Handover between different cells in a TDD system requires the correct setting of the timing advance for the target cell, before uplink traffic transmissions are allowed. Since the UMTS-TDD system has synchronised base stations, a UE is able to measure the time offset between the two cells and, consequently, is able to correct its timing on handover without UTRAN assistance. It is proposed that the UE RRC would control physical layer measurement of the timing offset between the cells and the application of the resultant timing correction by the physical layer. To improve the accuracy for the calculated timing advance, the UTRAN can include the measured timing offset value in the handover command message.

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

Consequently, it is proposed that, to accommodate handover, timing advance correction functionality is required only in the UE RRC and UE physical layer.

3 Proposal

To introduce the concept of timing advance in the permanent RAN2 documents the following text should be added to **TS25.301**.

In Section 5.2.2 L1 functions:

- Support of timing advance on uplink channels

In Section 5.4.2 RRC functions:

- **Timing advance control.** The RRC controls the operation of timing advance.

In **TS25.331** the following text concerning timing advance should be added:

In section 7, Functions of RRC, the following text should be added:

- **Timing advance control.**

4 Conclusion

The timing advance concept was discussed. Under some circumstances e.g. large cells it could be necessary for a UE operating in the UMTS-TDD system to receive and act upon timing advance instructions from the UTRAN, and for the UTRAN to detect that a timing advance is required and signal this to the UE. Therefore it is proposed to incorporate the proposed text into TS25.301 and TS25.331.
Text proposals for the documents TS25.302, TS25.321 and TS 25.322 will be presented in separate papers.

5 References

[1] 3GPP TSG RAN TS25.224, V2.0.0 ,TDD Physical Layer Procedures
[2] ETSI UMTS 30.03, V3.2.0, Selection procedures for the choice of radio transmission technologies of the UMTS
[3] 3GPP TSG RAN WG2 Tdoc R2-99435, Timing Advance Mechanism for TDD, Source: Siemens
[4] 3GPP TSG RAN WG3 Tdoc R3-99604, Timing Advance for TDD, Source: Siemens
[5] 3GPP TSG RAN WG4 Tdoc R4-99337, Application Timing Advance (TA) in the TDD Mode , Source: Siemens
[6] 3GPP TSG RAN Tdoc RP-99357, Timing advance for TDD, Source: Siemens