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Title: **Timing Advance Mechanism for TDD**

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Agenda Item: **8**

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1. Introduction

The aspect of time correction in the TDD operation mode was discussed during the TSG RAN WG2 and TSG RAN WG4. This mechanism is already covered in the RAN1 specification TS25.224 TDD Physical Layer Procedures [1]. In RAN2 it was decided to submit a paper to TSG RAN for clarification. In the following this timing advance mechanism in TDD is discussed.

2. The Need for Timing Advance in TDD

Due to the TDMA component of the UTRA TDD mode, the received signals of different users at the Node B have to be aligned within certain limits. Under certain circumstances, e.g. large cells, the use of timing advance for the transmissions from the UE is needed to keep the timing of the received signals at the Node B in the required range. Two different limits have been identified:

- Align in the BTS the channel estimation in the mid-amble window to allow a good channel estimation
- Avoid in the UE the overlapping between a received DL burst and an UL burst sent in the consecutive TS

Note that no collision may occur between an UL burst followed by a DL burst.

3. Overview

Depending on the size and the environment of a TDD cell, different requirements for timing advance can be identified:

1. For small cells (i.e. radius smaller than about 1.4km), no timing advance is required. The midamble window and the guard periods between the slots can accommodate the propagation delay and the delay spread for the entire cell.

2. For larger sized cells (i.e. radius between 1.4km and about 4km), timing advance is required to keep the timing of the received midamble at the Node B within the defined time window for channel estimation. The channel estimation degrades, if large parts of the channel impulse response are received outside this window. For this scenario, the guard periods between the bursts avoid overlapping of adjacent bursts, at the Node B as well as at the UE.

For very large cells (i.e. radius larger than about 4 km), the required timing advance results in the overlapping between a received DL burst and an UL burst sent in the consecutive TS. In this a percentage of the data may be interfered. No problems arises if UEs which are more than 4km from the Node B have no UL slots assigned immediately after DL slots.

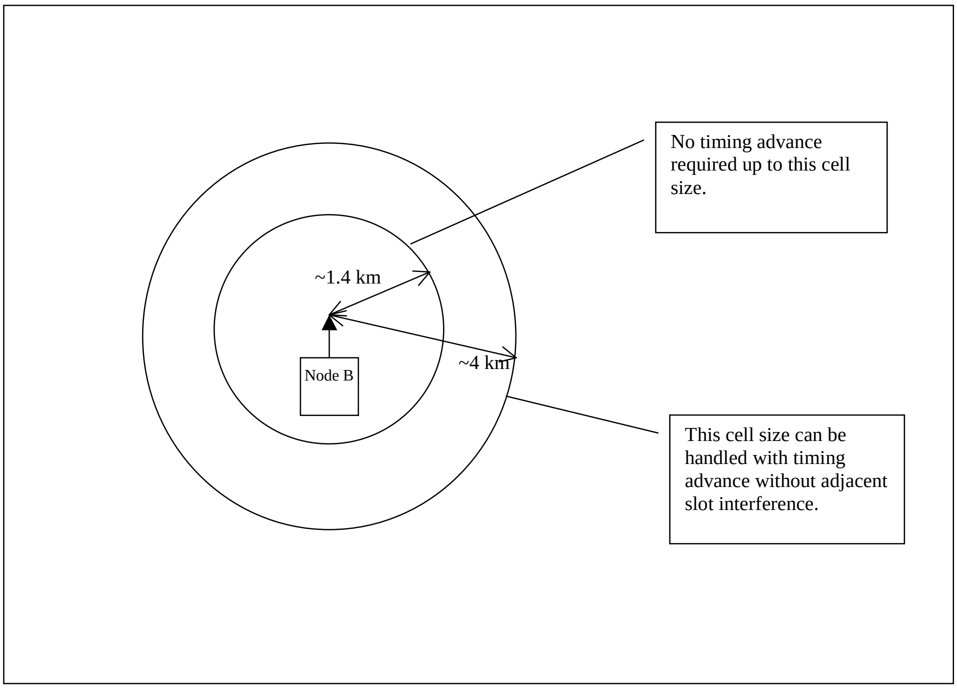

Figure 1 Relation between cell size and timing advance operation

4. Discussion

The following Table 1 and Figure 2 give an overview of the burst structure in TDD operation.

Chip number (CN)	Length of field in chips	Length of field in µs	Contents of field
0-975	976	238.3	Data symbols
976-1487	512	125.0	Midamble
1488-2463	976	238.3	Data symbols
2464-2559	96	23.4	Guard period

Table 1The contents of the burst type 1 fields

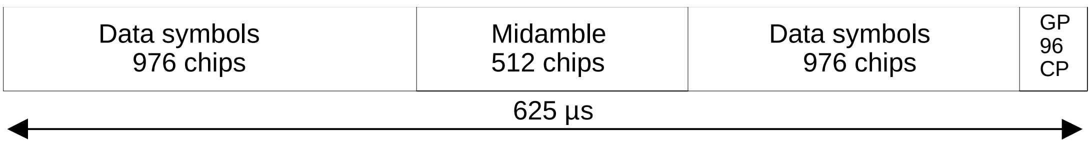

Figure 2 Burst structure of the burst type 1. GP denotes the guard period and CP the chip periods.

The midamble is used for channel estimation of 8 users. Each user has a measurement window of 57 chips (13.9 µs) for his channel impulse response in the joint channel estimation. Only the parts of the channel impulse response which are received during this window can be used for channel estimation. To protect neighbouring slots from collisions due to timing inaccuracies, a guard period of 96 chips (23.4 µs) is inserted between adjacent slots.

In the following calculations a delay spread of 4 µs is assumed as a worst case. All channel models from [2] except vehicular channel B fall under this limit. Even for radio channels with higher delay spread the performance is only slightly degraded, because most of the received signal energy is available in a period of 4µs of the channel impulse response.

Small Cells

- For small cells no timing advance is required. In this case, the window of the joint channel estimation is the limiting factor for the cell size. The window size of 13.9 µs has to accommodate the radio signal round trip delay and the delay spread of the radio channel. If a relatively large delay spread of 4 µs (Outdoor to Indoor Channel B [2]) is assumed, 9.9 µs are left for the radio round trip delay. This allows a cell radius of max. 1.4 km.

Larger Cells

- For larger cells, a timing advance is necessary and assumed in the following to be working. Now the guard period between adjacent slots becomes the limiting factor, the second scenario applies. If the timing advance value is chosen too high, the UE already starts transmission while it still has to receive data from the downlink direction. For the maximum allowable timing advance only a part of the full range of 23.4 µs guard period is available. The delay spread and the switching time in the UE have to be reserved from the guard period. With a delay spread of 4 µs (Outdoor to Indoor Channel B [3]), and switching time of 1 µs, there remain 18.4 µs for the timing advance to compensate radio round trip delay. which leads to a cell radius of 2.75 km .

- Additionally some shift of the channel impulse response in the received mid-amble window can be tolerated. If the delay spread (4 µs) is reserved, then9.9 µs of the mid-amble window may be tolerated for additional round trip delay. This allows an extension of the cell radius for additional 1.4 km Therefore cells with a radius up to 4.15 km can be supported by the TDD operation.

For very large cells, i.e. cells with a radius >4.15 km, the large radio round trip delay requires timing advance values that can not be accommodated in the guard period between two slots. In this case, the timeslot preceding the uplink transmission is interfered by the transmitted signal. For this case, special precautions have to be taken to avoid these interference. Possible solutions includes mechanisms to avoid adjacent slot interference by co-ordinated resource allocation, e.g.-

1) avoiding the assignment of an UL slot immediately after a DLslot
2) taking service distribution schemes into account to minimise probability of interference.

4.2 Relation of data rate and cell size

The maximum cell size for a given UE power class is dependent from the desired data rate. The following Table 2 and Figure 3 summarise the relation between data rate and cell radius.

Service	Cell radius
Speech	100%
LCD64	66.8%
LCD144	53.2%
LCD384	11.1%[1]

Table 2 Relation between data rate and cell radius

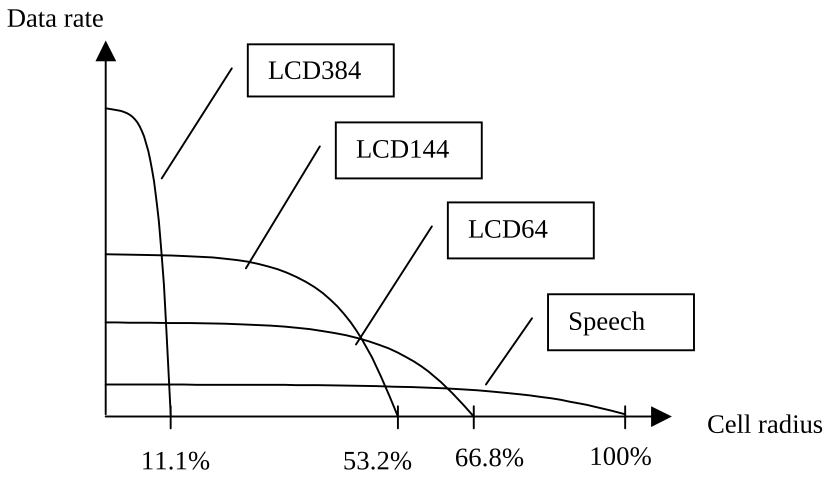

Figure 3 Schematic description of the relation between data rate and cell radius

[1] Note that for the ITU submission LCD 384 was simulated in Pedestrian environment only, while the other services where simulated in the vehicular environment.

Only low bit rate services can be supported at the border of large cells. These services occupy only one uplink time slot. This gives a high flexibility for assigning those services to timeslots, which even for large timing advance do not interfere with downlink traffic.

5. Aspects on Layer 2/3

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 correction is required and signal this to the UE. In other circumstances e.g. small cells timing advance signalling is not necessary. Consequently, it is proposed that it is signalled within the BCCH whether a cell is or is not operating timing correction.

5.1 Scenarios affected by Timing Advance

Four situations relating to timing advance are identified:-

(i) Initial Access,

(ii) Handover,

(iii) UE in traffic, where the UE operates with at least one DCH possibly in conjunction with use of the USCH/DSCH,

(iv) UE in traffic, using only the USCH/DSCH.

Each has different requirements for timing correction.

5.1.1. Initial Access

It is proposed that timing correction on initial access would operate in the following manner:-

The UTRAN physical layer measures the timing accuracy of the RACH burst transmitted by the UE. It calculates the timing advance that is required and pass this to the RNC RRC.

(i) RRC attaches the timing advance value to the response to the previous received message signalled to the UE using the the FACH.

(ii) When the UE RRC receives this response it passes the timing advance value to the physical layer.

5.1.2 Handover

It is proposed that no functionality, additional to that what is required for normal traffic operations, is required to accommodate handover. Because 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. 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.

5.1.3 UE in Traffic using at least one DCH

It is suggested that, where timing correction is required in a cell, then a UE may need to receive a timing advance message in a range of e.g. 10 seconds, this value cover speeds of movement up to 500km/h . It is assumed that whenever a UE has a DCH established there is any uplink traffic from the UE with a frequency that is less than these 10 seconds.

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 may report 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 need for a timing advance is detected it will be calculated and passed to the UTRAN RRC.

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

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

(iv) 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 .

5.1.4. UE in Traffic using only USCH/DSCH

This 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. In the following two of them are identified here and may be supported, details are for further study:

(i) The USCH/DSCH 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 its UTRAN to detect when a timing advance update is needed and initiates its signalling. 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 receives timing status reports from the physical layer 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. No acknowledgement of the timing advance correction is needed, because it is transmitted together with the allocation signalling.

  (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 is informed of any timing error of this RACH transmission by the physical layer. The UTRAN 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 UTRAN can determine if a timing advance update is necessary, and include the required timing advance within the allocation signalling.

6. Conclusion

The timing advance concept was discussed. It was shown that in TDD the system can operate in larger cells, if timing advance is supported. Therefore it is proposed to incorporate the support of timing advance in the relevant specifications of TSG RAN.

Detailed Change request will be presented if there is an agreement in supporting of the timing advance concept.

7. 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