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Title: Text proposal for TR 25.854: Study report for USTS (Section 4.1 Timing control)

Document for: Approval

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1. Introduction

In this Las Vegas meeting, we presented and discussed "Considerations on timing alignment bit (TAB) for USTS" [1]. According to decision of WG1 in this meeting, we propose text proposal for the TR 25.854 in this document.

2. Text proposal for TR 25.854

========================== text proposal ==========================

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4.1 Timing control

In USTS mode, time alignment is required to preserve orthogonality between channelisation codes from different UEs and also to properly despread the cell-specific long scrambling code. The transmission time at UE is adjusted in two steps. The first step is Initial synchronization and the second is tracking process.

1) Initial synchronisation: Adjust transmission time according to the initial timing control information given by higher layer through FACH.

2) Tracking process (Closed Loop Timing control): Adjust the transmission time according to the Time Alignment Bit (TAB) over DPCCH.

In Figure 4.2, before adjustment, DPCH message is expected to arrive at point A, where $?_{DPCH,n}$ is a multiple of 256 chips offset and T_0 is constant. After adjustment according to T_{INIT_SYNC}, the arrival at Node B is scheduled to occur at point B, $?_{DPCH,n} + T_0 + T_{ref}$ later from the beginning of each P-CCPCH frame in the Node B. There may be variation around point B due to movement of UE and this can be overcome by Tracking process using TAB commands. And accordingly, it keeps the uplink DPCCH/DPDCH frame of a UE arriving at Node B at the same point. In return, the UL/DL relative timing is not fixed but is to vary in the range with a width of 2?. The width and the range are closely related to the reference time T_{ref}.

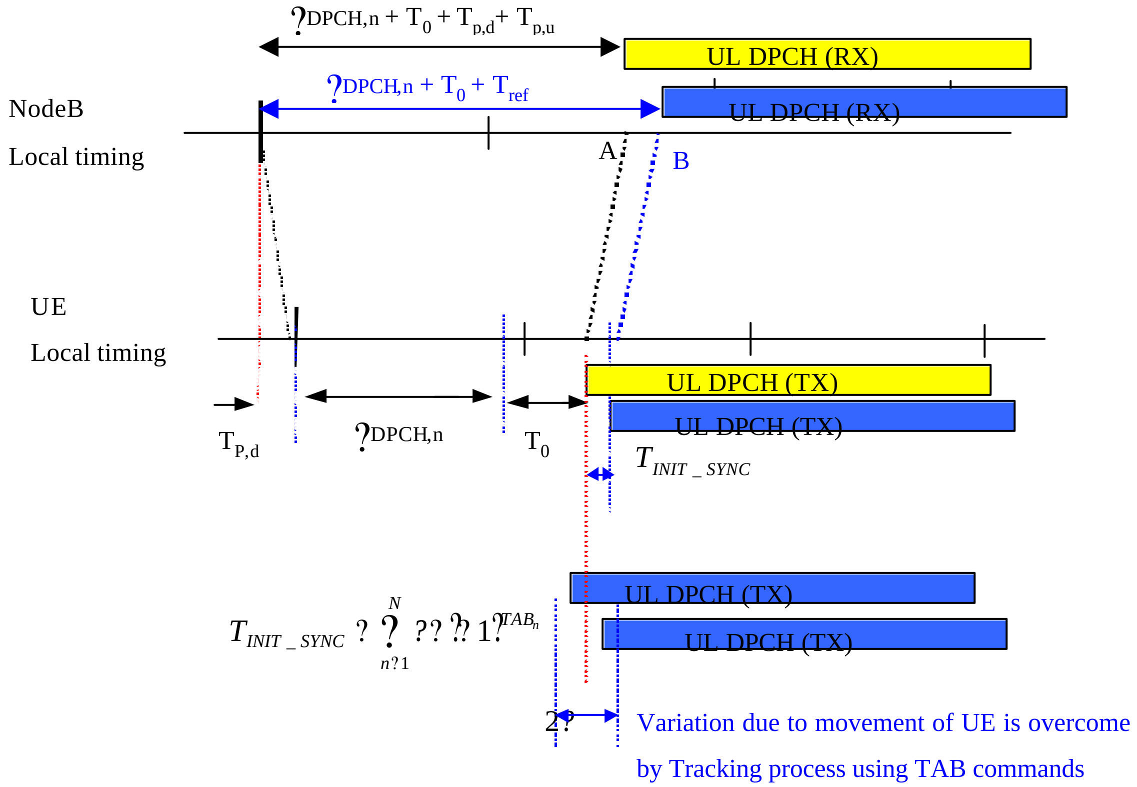

Figure 4.2 Initial synchronisation and Tracking process for DPDCH/DPCCH (Yellow: before adjustment, Blue: After adjustment).

4.1.1.The reference time

T_{ref} is given to RNC as initial loading data and the desired arrival time becomes $?_{DPCH,n}$? T_0 ? T_{ref} in the Node B. Since $?_{DPCH,n} = T_n$? 256 chip, T_n ? {0, 1, …, 149}, the desired arrival time may exist every 256 chips according to $?_{DPCH,n}$. Different UE arrives at the cell at one of the desired arrival times according to $?_{DPCH,n}$ and the orthogonality among channelisation codes can be preserved. The proposed value for T_{ref} is the maximum one-way propagation delay and for example, it comes to 128 chips for a cell radius of 10 km and a chip rate of 3.84 Mcps.

4.1.2.Initial synchronization

First, UTRAN obtains the round trip propagation delay (RTPD) by doubling the value of PRACH Propagation Delay measured in TS 25.215 and sets the amount of adjustment for initial synchronisation T_{INIT_SYNC} to compensate the difference between the RTPD and T_{ref}. UE adjusts its transmission time according to T_{INIT_SYNC} delivered from

UTRAN through FACH. Since T_0 is a constant (1024 chips) and T_{ref} is a given value and same for all UEs in a cell, after initial synchronisation, the arrival in the Node B can be controlled to occur within $[?_{DPCH,n} ? T_0 ? T_{ref} ? 1.5chips, ?_{DPCH,n} ? T_0 ? T_{ref} ? 1.5chips]$ due to 3 chip resolution for reporting PRACH Propagation delay.

4.1.3.Tracking process

4.1.3.1. Time Alignment Bit (TAB)

In case of USTS, a proper timing control rate needs to be determined by considering the synchronisation performance of timing control and the impact on closed loop power control performance. One proposal is that the TPC bits are replaced by Time Alignment Bits (TABs) every two frames (20 msec timing control interval).

4.1.3.1.1 TAB bit pattern

We can consider TAB bit pattern is independent or dependent. Independent TAB bit pattern means that every TAB bit is determined independently in Node B, and dependent TAB bit pattern expresses that 10 TABs are encoded by certain coding scheme such as bi-orthogonal coding. Intuitively, independent TAB bit pattern is proper to fast channel variations during the timing update interval such as 200ms. Meanwhile, dependent TAB bit pattern seems to be fit for the situation in which there is no variation and thus only one TAB symbol is enough to send in Node B during the timing update interval. In TAB bit pattern, the repeated TABs improve the reliability. Figure 4.3 shows one example of dependent TAB bit pattern which employs bi-orthogonal coding.

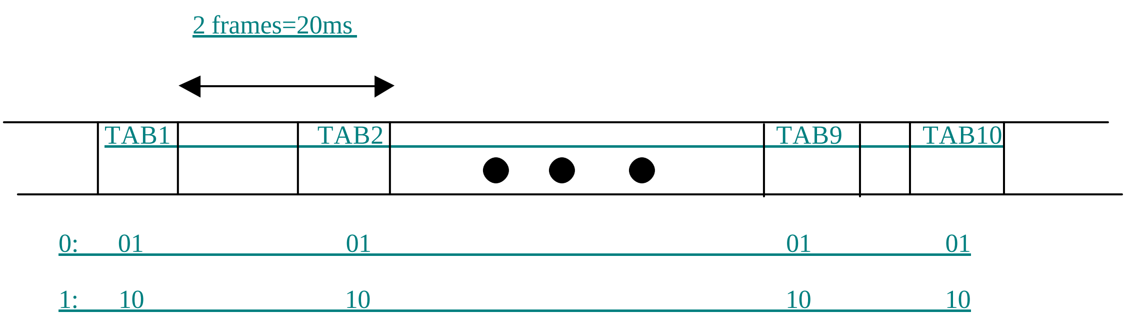

Figure 4.3 one example of dependent TAB bit pattern using bi-orthogonal coding.

4.1.3.1.2 TAB transmission in Node B

By combining of 10 TABs somehow it is possible to make more reliable decision of timing updates in UE. However, it is needed to check the intervals of TAB transmission on Node B because TABs are punctured into TPC fields in DPCCH. We have proposed several intervals such as 40ms / 50ms / 100ms, including 20ms. According to each interval, 5 / 4 / 2 TABs are transmitted respectively. To determine the appropriate interval, simulation results are required in the standardization phase. As well, we can consider the flexibility of TAB as fixed or variable transmission interval. In the variable case, the intervals can be adaptively determined according to channel environments and the required reliability. The impacts on WG2 / 3 should also be considered to clarify the operation of this scheme.

4.1.3.2. Closed loop timing control

The proposed procedure is as follows;

- Node B compares the received arrival time with the desired arrival time from UE every 200 msec (according to WG4 UE transmit timing assumptions [1]).
- When the received arrival time is earlier than the desired arrival time at a Node B, Time Alignment Bit (TAB) is set to "0". When this is later than the desired arrival time, TAB = "1".
- TAB replaces the TPC bit in slot #14 in frames with CFN mod 2 = 0.
- At the UE, a number of Time Alignment Bits are combined over a 200 ms interval, which increases the reliability of the time alignment process.. When the combined time alignment command is judged as "0", the transmission time shall be delayed by ?T, whereas if it is judged as "1", the transmission time shall be advanced by ?T. ?T is the timing control step size, whose minimum value depends on the oversampling rate.

4.1.3.3. Proposed adaptive tracking scheme after Initial synchronization

< The step size in this section is just a proposal. The step size in normal tracking process is denoted as ?T in subsection 4.1.3.2 and this value can be constant in the range between maximum and minimum values or it can be adaptively changed in that range. What value is optimal in view of synchronisation performance and how to adaptively change the step size if needed is FFS>

The adaptive tracking scheme after initial synchronisation changes the TAB command period and timing control step size to reduce the impact of coarse initial synchronisation due to 3 chip resolution at initial synchronisation phase. In other words, when a UE enters USTS mode it can adjusts its uplink transmission time with the timing control step bigger in size than that of the normal tracking process and the TAB command period shorter than that of the normal tracking process during initial several frames.

- The timing control step size is 3* ?T for the first TAB period and the timing control step size is 1/4 for the other TAB periods
- A TAB command is transmitted to UE once every frame during the first three frames and is transmitted once every 2 frames (20ms) after three frames are transmitted.

4.2. Code usage for USTS

4.2.1. Scrambling code

The long scrambling code described in Section 4.3.2.2. of TS 25.213 is used. However, this long scrambling code is not UE specific but is common to a number of UEs, and the initial loading value of PN generator is determined by the network. The spreading and modulation scheme for USTS is same as in Section 4 of TS 25.213.

In USTS mode, a number of UEs share a common scrambling code and the different and orthogonal channelisation codes needs to be allocated to each UE. To preserve orthogonality among channelisation codes, the UEs need to start to generate the common scrambling code at the same reference time (e.g., P-CCPCH frame time). Figure 4.3 shows a simple example with two UEs. Different UE uses different orthogonal codes to discriminate UE (exactly speaking, discriminate channel) and the UEs use a same scrambling code. Channelisation codes repeat at least every 256 chips but a scrambling code repeats every 10 msec (38400 chips). To obtain the orthogonal property in USTS mode, the scrambling code has to be aligned at chip level as described in the Figure 4.~~3~~4. Accordingly, two UEs are modulated with a same scrambling chip value if they are at the same time point.

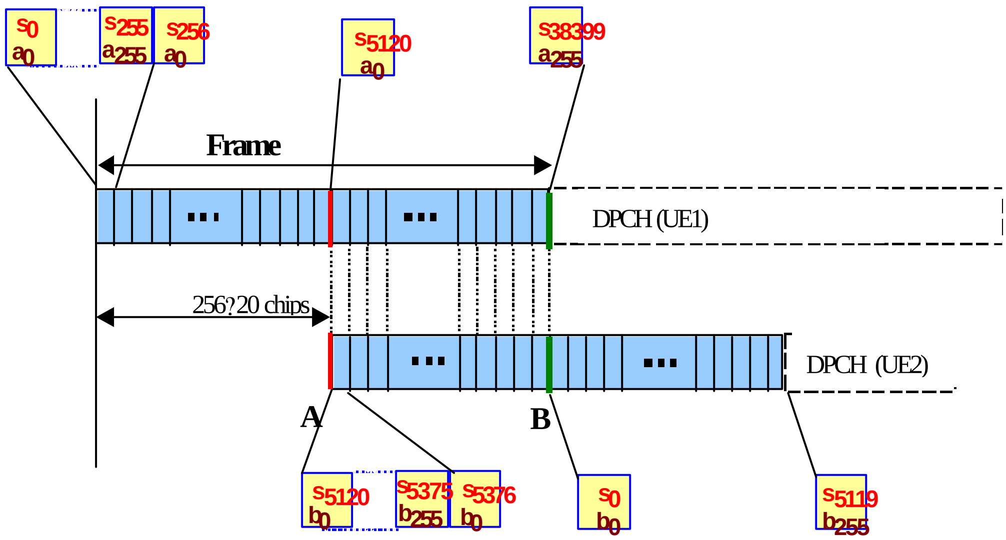

Figure 4.34 Timing at Node B and usage of scrambling and orthogonal codes in case of two UEs (a,b : channelisation codes, s : scrambling code, SF = 256)

In order to prevent channelisation code shortage problem, more than one scrambling codes can be used. In this case, since the USTS gain can be obtained among the UEs sharing a same scrambling code, a careful scrambling code assignment is needed to maximise the USTS gain. For example, in case of two scrambling codes for USTS, if the channelisation codes of a scrambling code are used up, channelisation codes of an additional scrambling code can be used.

4.2.2.Channelisation code allocation

Since UEs in USTS mode may share a common scrambling code, the UE discrimination is done by channelisation codes. At least two codes are needed to each UE: one for DPCCH and the other for DPDCH. In case of USTS, the channelisation codes for DPDCH(s) and DPCCH in a UE are chosen among unoccupied OVSF codes by other UEs from either upper half part or lower half part of OVSF code tree of a common scrambling code. The spreading factor and node number of channelisation code are delivered from network to each UE.

Reference: 3GPP TSG R1-99-581, “Channelisation code assignment for RSTS”, ETRI.

4.2.2.1 Proposed OVSF code allocation rule for USTS

<This is one proposed way of doing code allocation>

The performance gain of USTS improves as more UEs share the same scrambling code. If OVSF codes are allocated inefficiently, fewer UEs can share the scrambling code. Since the SF of OVSF code for DPCCH is always 256 while the SF of OVSF code for DPDCH can be between 4 and 256, a special OVSF code allocation rule can be introduced to allocate OVSF codes to more UEs.

Mapping Rule of Channelisation Code between DPDCH and DPCCH is as follows:

- The sub-trees below the nodes $C_{ch,8,3}$ and $C_{ch,8,7}$ are reserved for DPCCH.
- ***In the upper half code tree***, for the channelisation code for the DPDCH, the index k of $C_{ch,SF,k}$ shall be chosen from the following range.

$$k \in \begin{cases} 0,1,\ldots,(3\cdot SF/8 - 1) & \text{if } SF \le 64 \\ 0,2,\ldots,46 & \text{if } SF = 128 \\ 0,4,\ldots,92 & \text{if } SF = 256 \end{cases}$$

And, the channelisation code for the associated DPCCH shall be $C_{ch,256,127-n}$, where

$$n = 64 \cdot k / SF$$

- ***In the lower half code tree***, for the channelisation code for the DPDCH, the index k of $C_{ch,SF,k}$ shall be chosen from the following range.

$$k = \begin{cases} \lceil 4 \cdot SF/8 \rceil, (\lceil 4 \cdot SF/8 \rceil + 1), \ldots, (\lceil 7 \cdot SF/8 \rceil - 1) & \text{if } SF \leq 64 \\ 64, 66, \ldots, 110 & \text{if } SF = 128 \\ 128, 132, \ldots, 220 & \text{if } SF = 256 \end{cases}$$

- And, the channelisation code for the associated DPCCH shall be $C_{ch,256,255-n}$, where

$$n = 64 \cdot k / SF.$$

If more than one channelisation codes for DPDCHs are allocated to a UE, then the channelisation code for DPCCH corresponding to the first allocated channelisation code for DPDCH will be used as the channelisation code for the DPCCH.

4.3. Soft handover in USTS mode

<This section is describing only sample candidates which is restricted to USTS Study report and not universal description of soft handover procedure>

For seamless communication, soft handover needs to be considered for USTS, where the different code usage of scrambling and channelisation codes, and the transmission timing control should be taken into account.

The radio link can be in one of the following three modes:

- Normal mode : No timing control, UE discrimination by Scr code
- USTS mode : Timing control, UE discrimination by both Scr and Ch codes
- Non-USTS mode : No timing control, UE discrimination by both Scr and Ch codes

The difference between Normal mode and Non-USTS mode is as follows. If one of the radio links to the cell sites in Active set is in USTS mode, it is discriminated by both scrambling code and channelisation codes assigned for USTS mode in all cells in Active set. Therefore, the other links should be in non-USTS mode. This is because the UE has only a single transmitter and there can be more than one UEs who enter the SHO region from the same original cell and accordingly, they use the common scrambling code and the discrimination can be done only by channelisation codes. In normal mode, the UEs in SHO region use their own unique scrambling codes.

Four candidates for supporting soft handover have been proposed in USTS mode. Table 4.1 summarises these candidates. In this section, only two-way soft handover is considered for easy understanding. In Candidate 1, when the UE enters SHO region, it abandons the USTS mode and operates in normal mode with both cell sites. For this, a reconfiguration process is first required to assign new scrambling codes and channelisation codes for the radio link with the original cell and then, the normal soft handover procedure is followed. When the UE moves further into the target cell and leaves out of SHO region, it continues to be in normal mode with stronger radio link. If it leaves out of SHO region back into the original cell, it resumes the USTS mode and accordingly, for normal to USTS mode transition, reconfiguration process is required to assign new scrambling code and channelisation codes, and timing adjustment is necessary. Candidate 2 is different from Candidate 1 only in that the soft handover happens in the reverse direction.

In Candidates 3 and 4, the UE continues to be in USTS mode with either of two cell sites in SHO region, which may provide better performance. In Candidate 3, the UE keeps the radio link with the original cell site being in USTS mode until it moves out of the coverage of the original cell. When the UE drops the radio link with the original cell, it changes the mode of the radio link with the target cell to USTS mode. At this point, reconfiguration of scrambling and channelisation codes and also the timing control are required for non-USTS to USTS mode transition. If the UE returns to the original cell, just dropping the weaker radio link is the only thing the UE has to do.

In Candidate 4, the radio link modes of both links are changed in the middle of soft handover, which may improve the performance by providing USTS mode to a better radio link compared to Candidate 3. When the change point is at the cell boundary, Candidate 4 is the same as Candidate 3. And therefore, Candidate 3 can be seen as a special case of

Candidate 4. If the change point is anywhere inside the SHO region, the optimum point and how to detect it need to be elaborated further.

Table 4.1 Four soft handover candidates for USTS (A simple example in case of two-way soft handover).

	The mode of UE		
Movement of UE	In original cell	In SHO region	In target cell
Candidate 1	USTS	Normal(O)+Normal(T)	Normal
Candidate 2	Normal	Normal(O)+Normal(T)	USTS
Candidate 3	USTS	USTS(O)+Non-USTS(T)	USTS
Candidate 4	USTS	USTS(O)+Non-USTS(T) ✍ Non-USTS(O)+USTS(T)	USTS

<Note> (O) : the mode with the **original** cell (T) : the mode with the **target** cell

If the new cell does not support USTS, only candidate 1 is applicable. And Candidate 2 is appicable when the original cell does not support USTS. R5 Node B means that it has the following two capabilities:

(1) timing control.

(2) discrimination of different UEs with both scrambling code and channelisation code(s).

R99/R4 Node B does not have either of two capabilities.

Figure 4.~~4~~5 shows handover procedure for candidate 3 in more details. Both cells are in USTS mode, and UE2 and UE3 are in USTS mode with Node B1 and Node B2, respectively. When UE1 is in USTS mode, Node B1 assigns Scr1 and Ch3 to UE1. During soft handover, UE1 continues to use these codes and continues to be in USTS mode with Node B1. However, while UE1 is in SHO but it is in non-USTS mode with Node B2 because Tx timing of UE is controlled only to Node B1. When the UE1 moves out of SHO region, reconfiguration is required to assign new Scr and Ch codes and to inform the amount of timing adjustment for non-USTS to USTS transition. The amount of timing adjustment can be calculated with Round trip time measured in TS 25.215 (accordingly, RTPD) and T_{ref} . At this point, abrupt timing control may be required, which results in transmission gap at UE1. The same procedure is also required for normal to USTS mode transition.

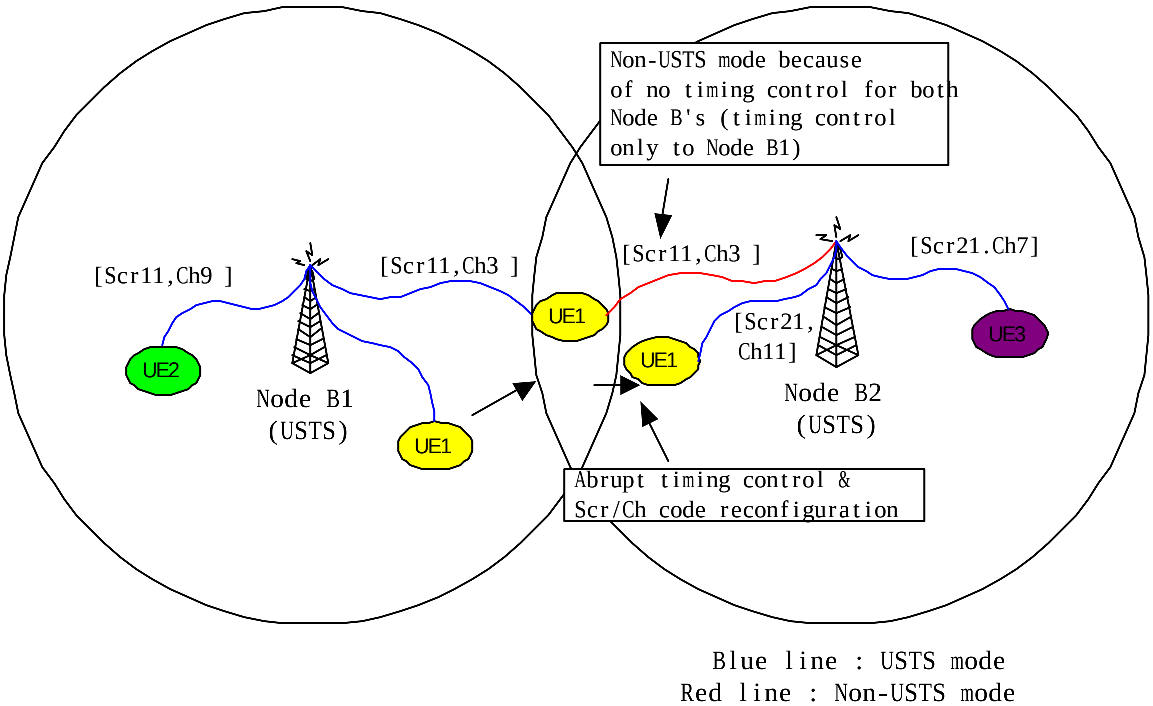

Figure 4.~~4~~5 Two-way soft handover procedure for Candidate 3.

Figure 4.~~5~~6 shows the handover candidate 4 in two-cell layout. Both Node Bs are operated in USTS. UE1 and UE2 are operated in USTS with Node B #1 and Node B #2, respectively. Let us focus on UE0 with interest. When UE0 is operated in USTS with Node B #1, UE0 gets scrambling code (Scr11) and channelisation code (Ch3) from Node B #1. When UE0 enters into the handover process, the radio link in non-USTS mode with Node B #2 is set up. Note that only Node B #1 controls the transmit timing of UE0, which uses the same codes and is operated in USTS with Node B #1. While UE0 exists in the soft handover region, the reconfiguration process is required to assign new scrambling code (Scr21), channelisation code (Ch11) and timing adjustment for non-USTS to USTS transition in Node B #2. Also USTS to non-USTS transition in Node B #1 is required to preserve the reliability from soft handover. The required timing adjustment for new USTS link can be obtained by RTPD and Tref in the same manner with candidate 3. Timing of non-USTS link in Node B #1 is acquired by the new USTS time adjustment and the time difference between Node B #1 and Node B #2. Finally, UE0 releases the radio link with Node B #1 when the UE0 does not need soft handover and soft handover process is completed.

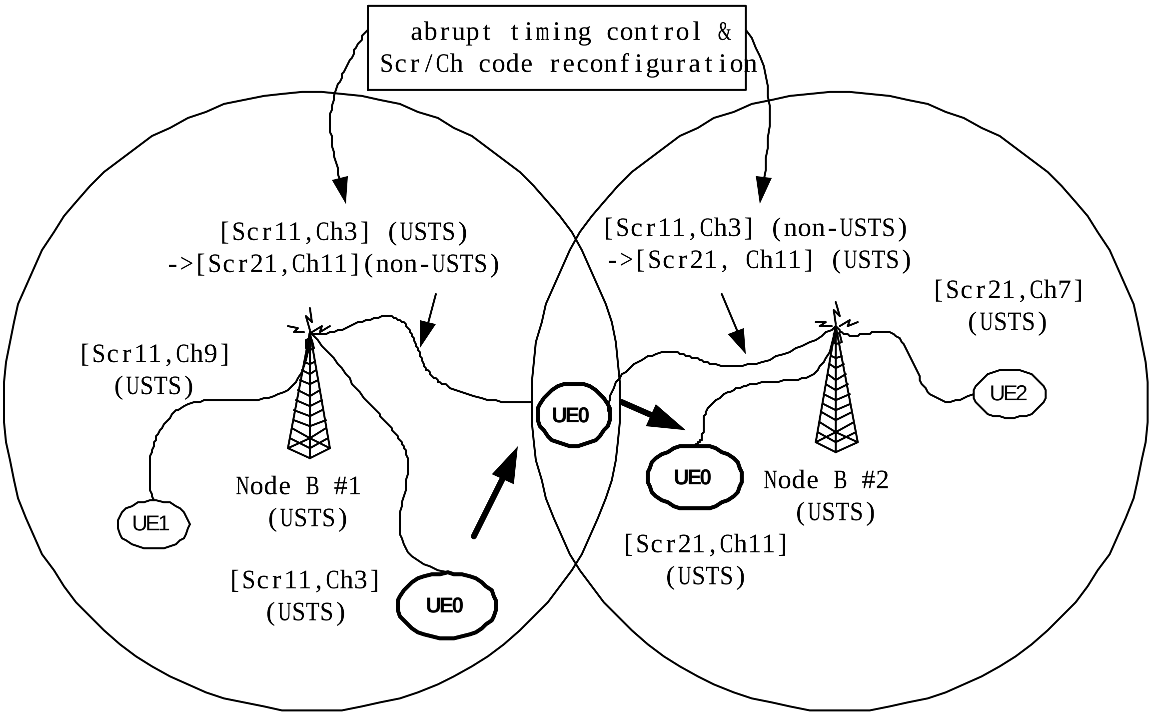

Figure 4.~~5~~6. **Two-way soft handover procedure for candidate 4.**

Figure 4.~~6~~7 describes the arrival timing at Node B1 and Node B2. The arrival times from UEs in the Node B1 are controlled to be $?_{DPCH,1i} ? T_0 ? T_{ref}$ from the beginning of P-CCPCH1. Since $?_{DPCH,1i}$ is a multiple of 256 chips, the possible arrival point at Node B1 repeats every 256 chips. During soft handover, UE3 is in USTS mode with Node B1 and therefore, its arrival time at Node B1 is kept at $?_{DPCH,13} ? T_0 ? T_{ref}$. However, even though the UE3 is in SHO with Node B2, it is in non-USTS mode because the arrival time at Node B2 is not controlled to guarantee synchronized reception with UE4 & UE5. When UE3 moves further into Node B2 area and drops the old link, then in order to be in USTS mode with Node B2, the arrival time at Node B2 needs to be controlled. Point a or point b can be chosen for USTS and their difference is 256 chips. To prevent abrupt timing advance at UE side, point b is always selected and therefore, transmission gap may result, which is less than 256 chips, i.e., the transmission at UE needs to be stopped for less than 256 chips and resumes after the gap. For this, $?_{DPCH,23}$ needs to be reassigned when selecting point b.

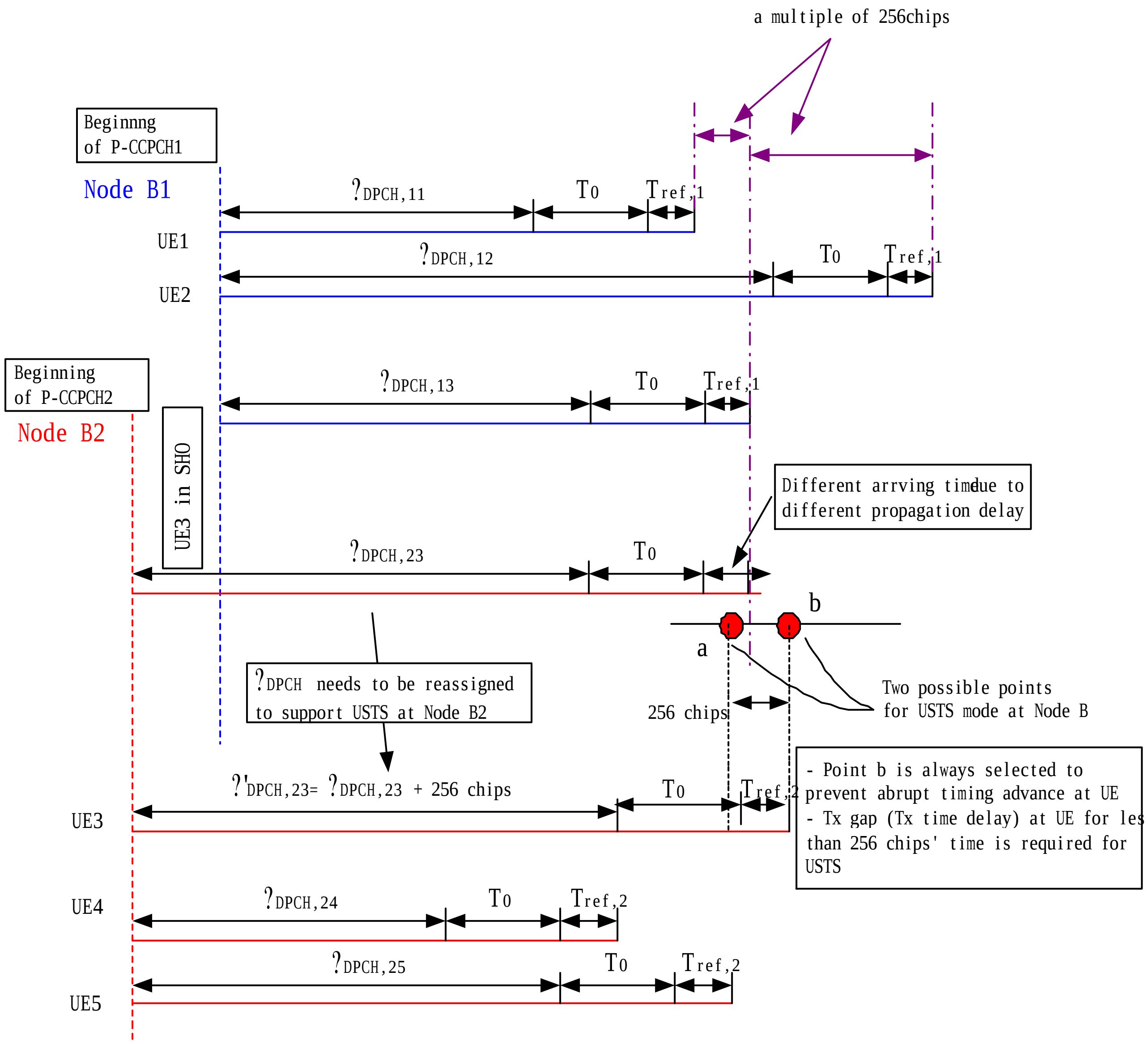

Figure 4.57 Arrival timing at Node B1 and Node B2

Reference

[1] R1-01-0061, “Comparison of soft handover for USTS”, LGE

[2] R1-01-0245, “Considerations on Timing Alignment Bits (TAB) for USTS”, LGE

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3. Reference

[1] TSG R1-01-0245, Considerations on timing alignment bits for USTS, LG Electronics.