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**Title:** **Study report for USTS**

**Document for:** **Discussion**

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# 1. Introduction

This study report has been written based on the following documents:

- R1-00-903 "Uplink synchronous transmission scheme (USTS)"
- R1-00-904 "Performance study of USTS"
- R1-00-1114 "Answer to questions and comments on USTS"
- R1-00-1263 "Feasibility study on USTS"

- R1-00-0873 "OVSF code allocation rule for USTS"
- R1-00-1075 "An adaptive tracking scheme for USTS"

# 3G TR 25.USTS V0.0.0.0 (2000-mm)

*Study Report*

**3rd Generation Partr**
**Technical Specification Group Radio Access Network;**
**Study Report for Uplink Synchronous Transmission Scheme (USTS)**
**(Release 5)**

Uplink Synchronous Transmission Scheme

<keyword[, keyword]>

***3GPP***

Postal address

3GPP support office address

650 Route des Lucioles - Sophia Antipolis
Valbonne - FRANCE
Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Internet

http://www.3gpp.org

# Contents

# Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

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Version x.y.z

where:

- x the first digit:
  - 1 presented to TSG for information;
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- y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.
- z the third digit is incremented when editorial only changes have been incorporated in the document.

# Introduction

At RAN#9 plenary meeting, a study report for "Uplink synchronous transmission scheme" was decided to be finished by March 2001. Uplink Synchronous Transmission Scheme (USTS) is an alternative technology applicable for low mobility terminals, especially in indoor and dense pedestrian environments. USTS can reduce uplink intra-cell interference by means of making a cell receive orthogonalized signals from UEs. This feature is intended to support uplink synchronous transmission with low overhead, good capacity characteristics, and minimal impact on hardware and software resources at the UE and in the UTRAN.

# 1 Scope

This study report describes the techniques behind the concept of uplink synchronous transmission scheme and how this concept should be integrated into the overall architecture of UTRA. It also deals with the feasibility of USTS, including performance and expected complexity.

# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

?? References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.

?? For a specific reference, subsequent revisions do not apply.

?? For a non-specific reference, the latest version applies.

[1]TS25.133 : Requirements for support of radio resource management (FDD)

[2]TS 25.211 : Physical channels and mapping of transport channels onto physical channels (FDD)

[3]TS 25.213 : Spreading and modulation (FDD)

[4]TS 25.214 : FDD : Physical layer procedures

[5]TS 25.302 : Services provided by the Physical Layer

[6]TS 25.331 : Radio Resource Control (RRC) Protocol Specification

[7]TS 25.423 : UTRAN Iur Interface RNSAP Signalling

[8]TS 25.433 : UTRAN Iub Interface NBAP Signalling

[9]TS 25.435 : UTRAN interface User Plane Protocol for Common Transport channel Data Streams

[10] TR 25.926 : UE Radio access capabilities definition

[11] TR 25.839 : Uplink Synchronous Transmission Scheme (USTS) (Iur/Iub aspects)

# 3. Definitions, symbols and abbreviations

## 3.1 Definitions

No specific definition is made in this document.

## 3.2 Symbols

$T_{ref}$ Reference time

$T_{INIT\_SYNC}$ Amount of adjustment for initial synchronisation

## 3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

CFN Connection frame number
DPCCH Dedicated physical control channel
DPDCH Dedicated physical data channel
RTD Round trip delay
RTPD Round trip propagation delay
TAB Time alignment bit
UE User equipment

USTS Uplink synchronous transmission scheme
UTRAN Universal terrestrial radio access network

# 4. Study Area for USTS

<Note> USTS is optional for both UE and UTRAN.

## 4.1. Timing control

In a 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 controlled by two steps. The first step is Initial synchronization and the second is tracking.

1) Initial synchronisation: Adjust transmission time through the initial timing control information given by higher layer
2) Tracking process (Closed Loop Timing control): Adjust the transmission time through the Time Alignment Bit (TAB) over DPCCH.

In Figure 4.1, 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 frame. 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 of each frame.

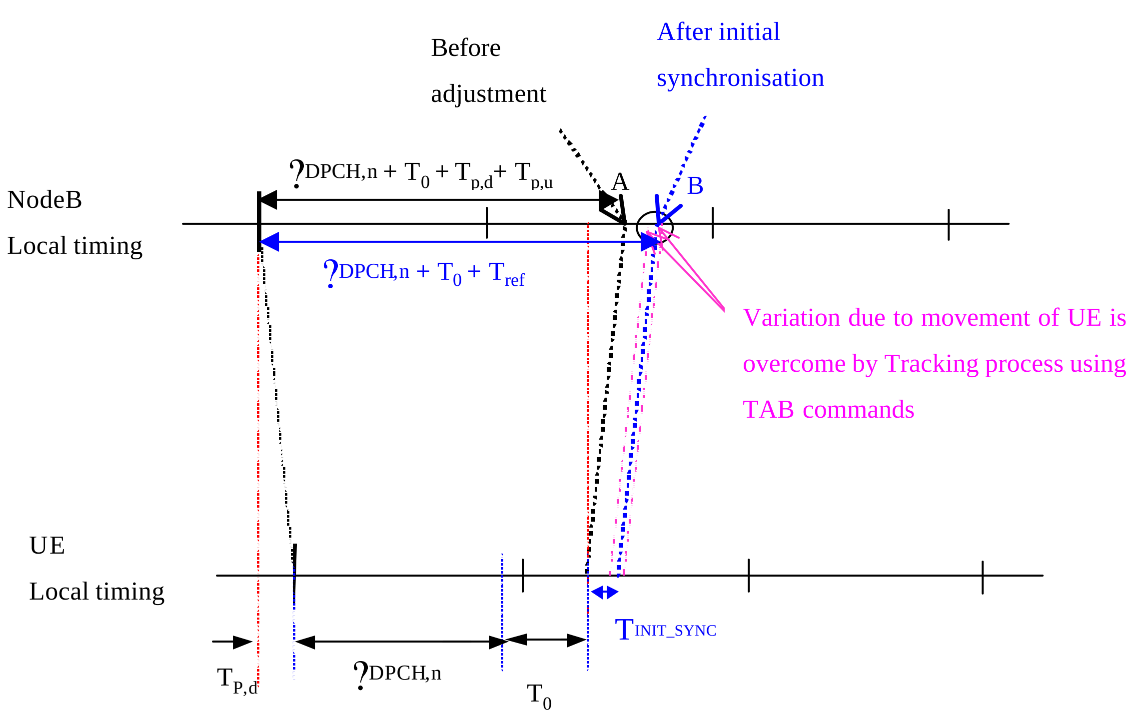

**Figure 4.1 Initial synchronisation and Tracking for DPDCH/DPCCH**

## 4.1.1 Reference time

The reference time $T_{ref}$ is given to RNC as initial loading data and the desired arrival time becomes $?_{DPCH,n}$ ? $T_0$ ? $T_{ref}$ . 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 time according to $?_{DPCH,n}$ and the orthogonality among channelisation codes can be preserved.

## 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. 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 can be controlled to occur at $[?_{DPCH,n}$ ? $T_0$ ? $T_{ref}$ ? $1.5 chips, ?_{DPCH,n}$ ? $T_0$ ? $T_{ref}$ ? $1.5 chips]$ 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, the TPC bits in slot #14 in frames with CFN mod 2 = 0 are replaced by Time Alignment Bits (TABs).

### 4.1.3.2. Closed loop timing control

The procedure is as follows;

- Node B compares the received arrival time with the desired arrival time from UE every 20msec.
- 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, hard decision on the TAB shall be performed. When it 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. Adaptive tracking scheme after Initial synchronization

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 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 4.2 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. Therefore, channelisation codes repeat every 256 chips when SF = 256 but a scrambling code repeats every 10 msec (38400 chips). To obtain the orthogonality property in USTS mode, the scrambling code has to be aligned at chip level as described in the Figure 4.2. Accordingly, two UEs are modulated with a same scrambling chip value if they are at the same time point.

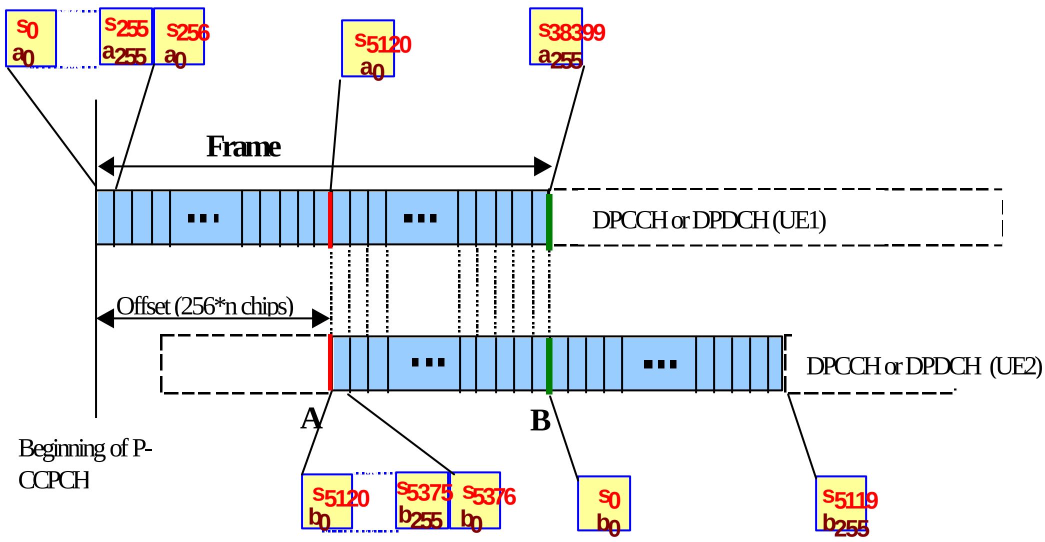


**Figure 4.2 Timing at Node B and usage of scrambling and orthogonal codes in case of two UEs (a,b : channelisation codes, s : scrambling code, SF = 256)**

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 there is no more channelisation codes to use for a scrambling code, 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.

### 4.2.2.1 OVSF code allocation rule for USTS

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.

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

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

$$n ? 64 ? k / \mathrm{SF}$$

- ***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.

$$k ? \begin{cases} ??4 ? \mathrm{SF}/8?,(?4 ? \mathrm{SF}/8?? 1),???,(?7 ? \mathrm{SF}/8?-1) & \text{if SF ? 64} \\ 64,66,???,110 & \text{if SF ? 128} \\ 128,132,???,220 & \text{if SF ? 256} \end{cases}$$

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

$$n ? 64 ? k / \mathrm{SF}.$$

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

Three candidates for supporting soft handover have been proposed in USTS mode. Table 4.1 summarises these candidates.

**Table 4.1 Three candidates for two -way soft handover in USTS mode**

| | 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 | USTS | USTS(O)+Non-USTS(T) | USTS |
| Candidate 3 | USTS | USTS(O)+Non-USTS(T) ✍<br>Non-USTS(O)+USTS(T) | USTS |

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

<Note> 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

<Note> In Candidate 3, 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 with more complexity compared to Candidate 2.

If the new cell does not support USTS, only candidate 1 is applicable. 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. During the transition from non-USTS mode to USTS mode in candidates 2 and 3, transmission (Tx) gap is required to support USTS. Figure 4.3 shows handover procedure for candidate 2 in more details.

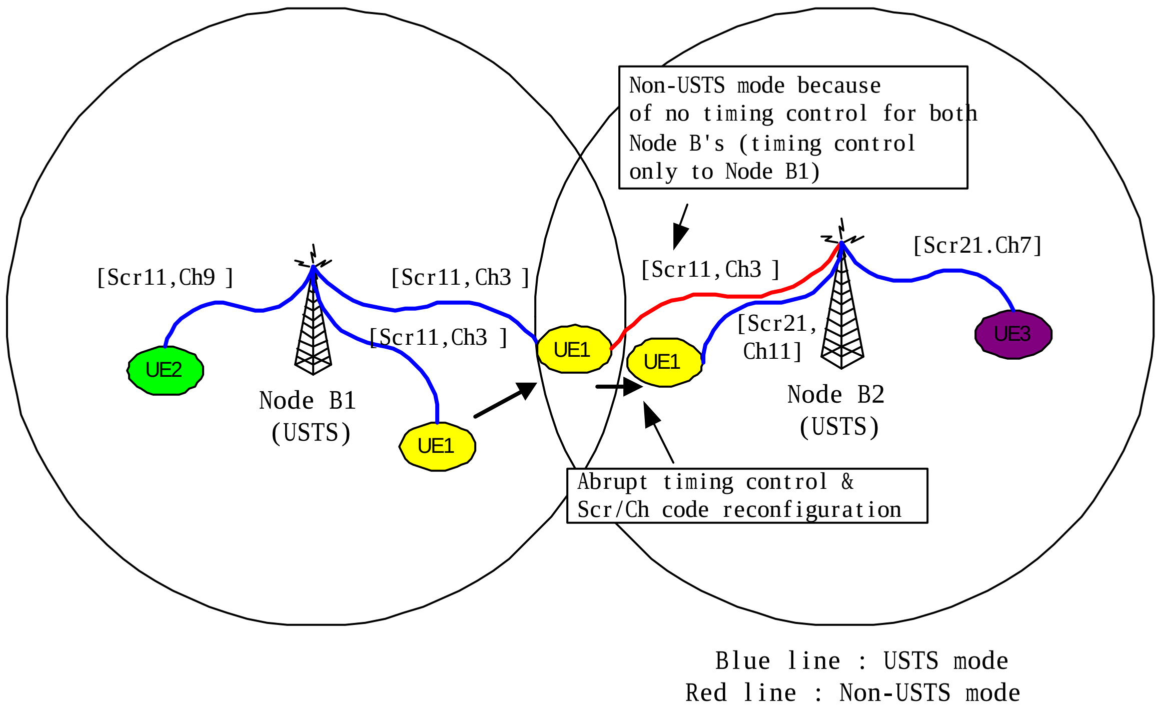


**Figure 4.3 Two-way soft handover procedure for Candidate 2.**

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 is required and this requires transmission gap at UE1.

To explain this in more detail, Figure 4.4 describes the arrival timing at Node B1 and Node B2. The arrival times of UEs in 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 arrival point at Node B1 repeats every 256 chips. During soft handover, UE3 is in USTS mode 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 not in USTS mode because the arrival time at Node B2 is not controlled to guarantee synchronized reception with UE4 & UE5. When UE3 further moves 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 is needed, 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. This kind of timing control is necessary for fast transition to USTS mode. $?_{DPCH,23}$ needs to be reassigned when selecting point b.

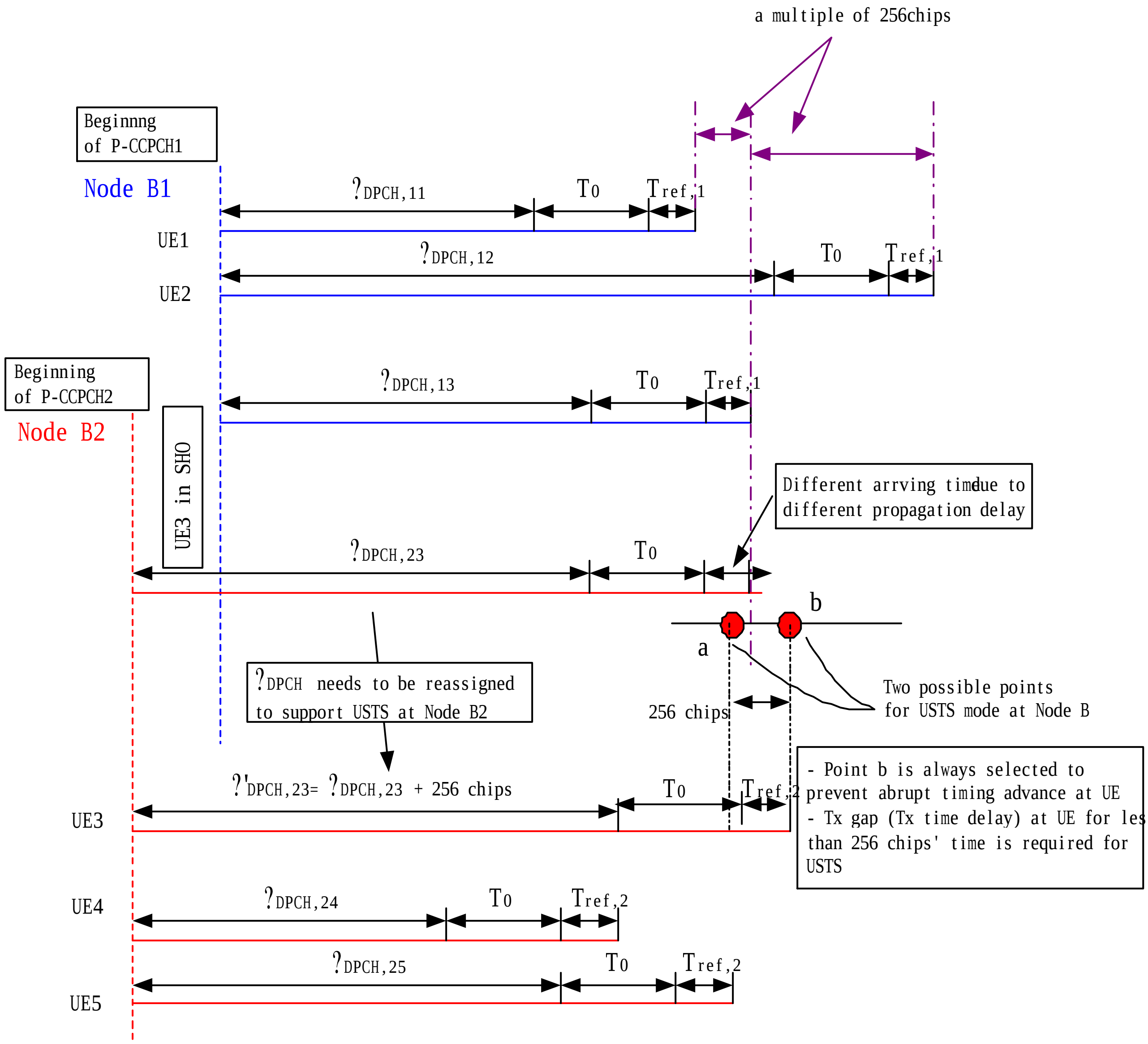


**Figure 4.4 Arrival timing at Node B1 and Node B2**

# 5. Performance

## 5.1. Simulation parameters

- The first detected paths (in time) of UEs are aligned
- Channel model : outdoor urban high-rise channel model (JTC)

  : ITU indoor and pedestrian models
- Number of Rake fingers = 1, 3
- Mobile speed : 3 km/h, 5.6 km/h, 20 km/h, 60 km/h
- SF : 128
- Single cell
- Closed power control : OFF
- Channel estimation : Ideal
- No channel coding
- Number of oversamples per chip : 4, 8
- Modulation/Spreading : QPSK/complex, BPSK
- Carrier frequency : 1.9 GHz, 2 GHz

## 5.2. Simulation results

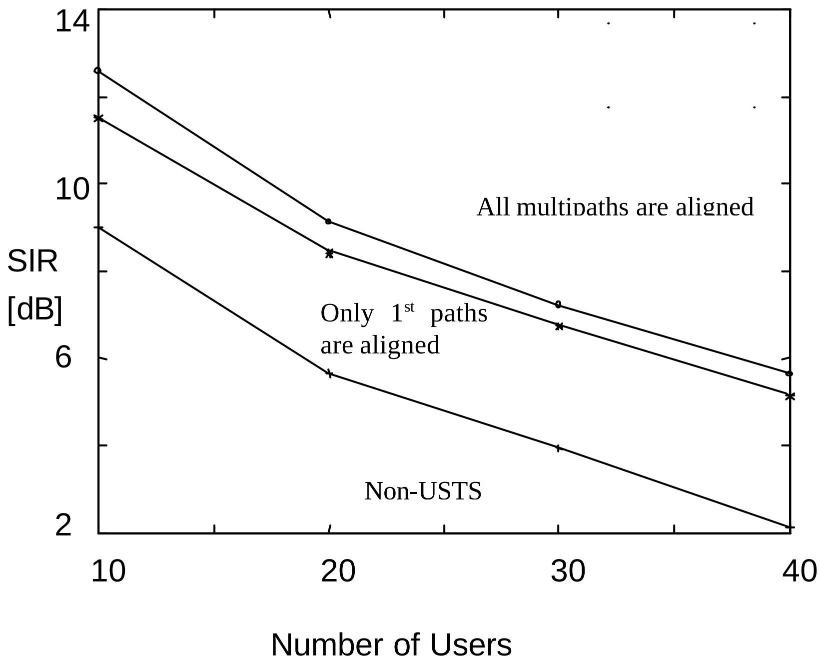


**Figure 5.1 SIR comparison for varying the number of users under JTC channel model**

- Channel model : outdoor urban high-rise channel model (JTC)
- Number of Rake fingers = 3
- Mobile speed : 5.6 km/h
- All UEs are either in USTS mode or in non-USTS mode
- Timing alignment precision : [-1/8 chip, +1/8 chip]
- Modulation/Spreading : BPSK
- Carrier frequency : 1.9 GHz

✍✍ About 3 dB gain in SIR can be achieved compared to non-USTS

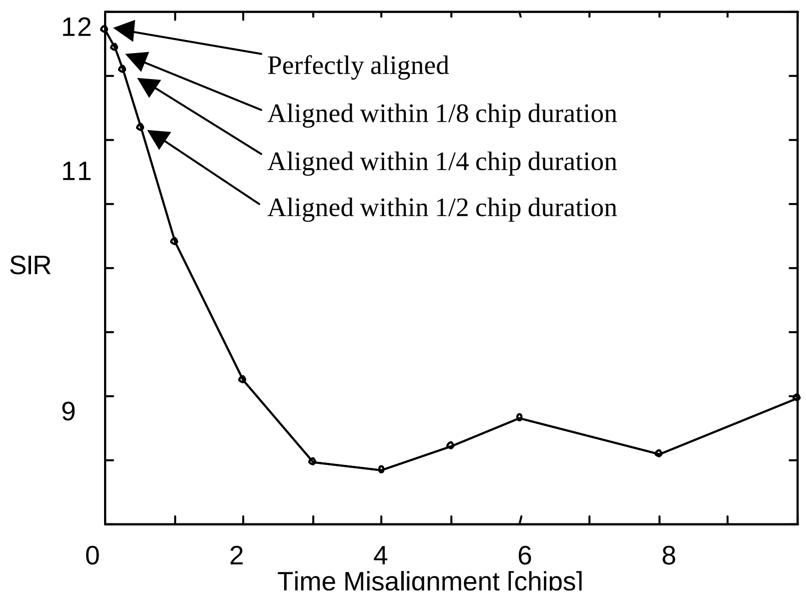


**Figure 5.2 Impact of timing control resolution.**

- Number of users = 10
- All UEs are in USTS mode
- Channel model : outdoor urban high-rise channel model (JTC)
- Number of Rake fingers = 3
- Mobile speed : 5.6 km/h
- Modulation/Spreading : BPSK
- Carrier frequency : 1.9 GHz

<Note> The amount of misalignment is randomly chosen in the range of [-x,+x] chips and therefore, the arrival times of UEs are randomly distributed around the desired arrival time.

<Note> If the amount of misalignment is larger than 3 chips, the obtainable SIR in USTS mode is the same as in non-USTS mode (refer to Fig. 5.1)

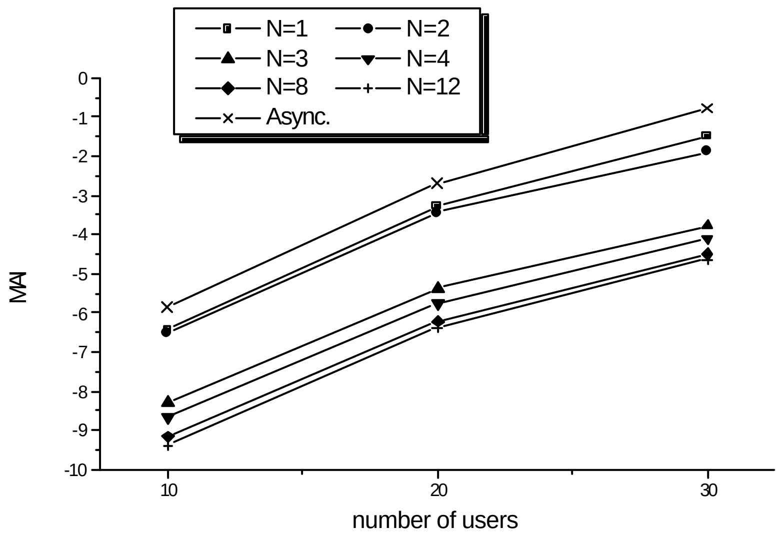


**Figure 5.3 Timing control rate versus channel variation rate**

- All UEs are in USTS mode
- Channel model : ITU-R Vehicular B model
- Number of Rake fingers = 3
- Mobile speed : 20 km/h
- Modulation/Spreading : BPSK
- Carrier frequency : 1.9 GHz
- Timing control step size = 1/4 chip
- N = the ratio of timing control rate to average channel variation rate
- The average channel variation interval = 100 msec
- Delay variation is randomly selected from [0,1] chip range

✍✍ For N > 3, the additional performance improvement is less than 1 dB.

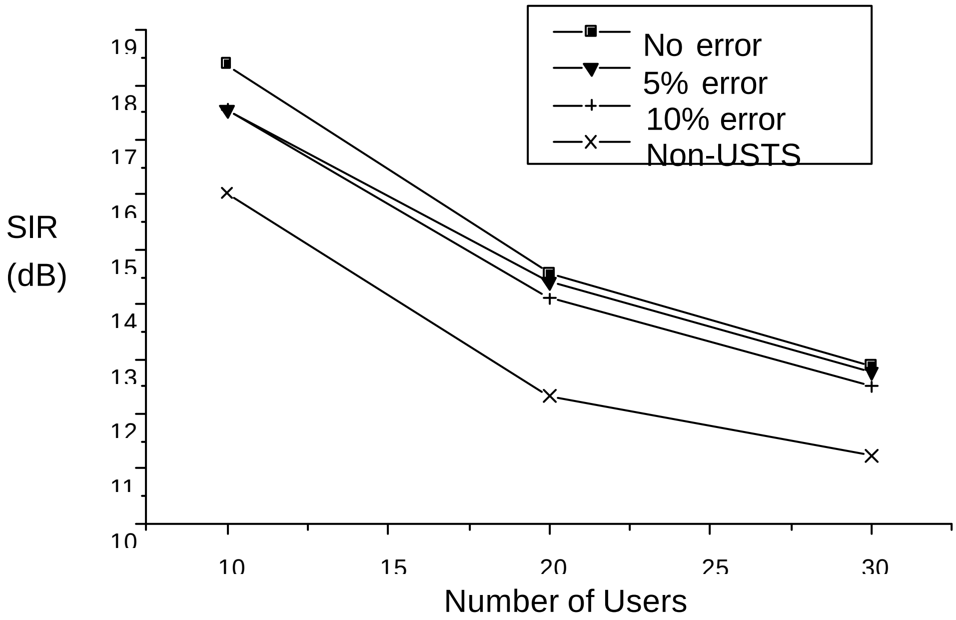


**Figure 5.4 Impact of TAB error**

- All UEs are in USTS mode
- Channel model : ITU-R Vehicular B model
- Number of Rake fingers = 3
- Mobile speed : 60 km/h
- Modulation/Spreading : BPSK
- Carrier frequency : 1.9 GHz
- Timing control step size = 1/4 chip
- Timing control interval = 25 msec
- The average channel variation interval = 100 msec
- Delay variation is randomly selected from [0,1] chip range

✍✍ For less than 10 % error in TAB, the performance degradation is less than 1 dB in SIR.

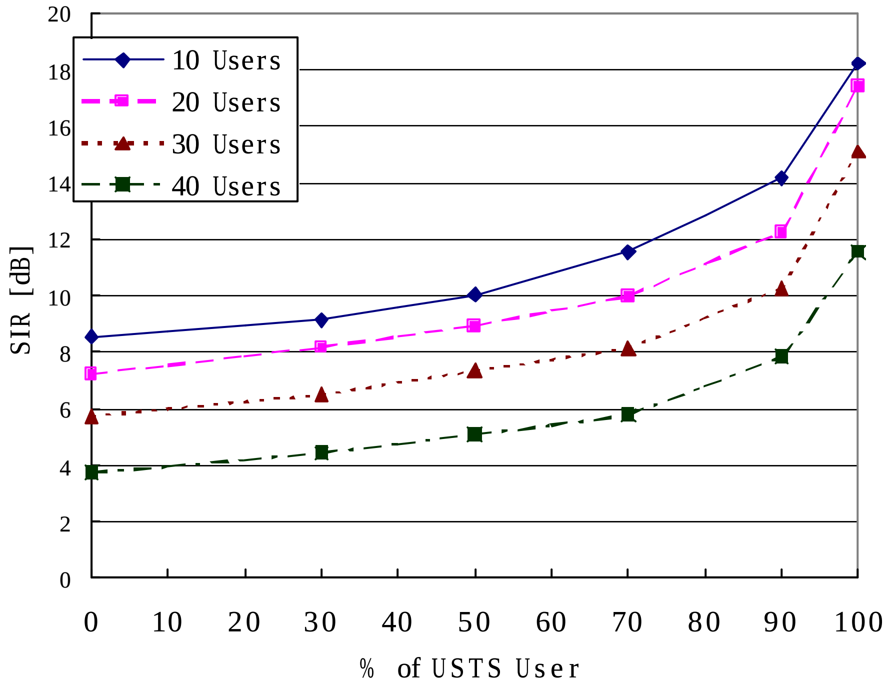


**Figure 5.5 Performance in a USTS/non-USTS mixed situation**

- Channel model : Pedestrian A (Speed : 3 km/h)
- Number of oversamples per chip : 4
- Carrier frequency : 2 GHz
- Number of fingers = 1
- Modulation/Spreading : QPSK/complex
- Chip rate : 3.84 Mcps

<Note 1> Under the above channel model, the first three paths are very close to each other so that they are within one chip duration and therefore, they are not discriminated. And the signal powers of the other paths are very small. Accordingly, choosing one Rake finger in the simulation is reasonable under this channel model.

<Note 2> The percentage of USTS users largely affects the performance gain. In case of Candidates 2 and 3, if all UEs support USTS, then 30 % of them are usually in SHO. If the multiple cell system is taken into account, no more than 85 % of UEs can be in USTS mode from the view point of the cell under consideration.

<Note 3> Compared to the single cell system, if multiple cell (other cell) and soft handover are taken into account, the performance gain of USTS is reduced. For example, if the other cell inteference factor f is 0.77 and half of the UEs in SHO are assumed to be in non-USTS mode, the gain is reduced by half approximately. However, the performance gain of USTS is still high, especially in indoor and dense pedestrian environments.

**Table 5.1 Average SIR comparison under various channel models (10 UEs).**

| Channel model | USTS (100 %) | Non-USTS (100 %) |
|---|---|---|
| Indoor A | 14.57 dB | 9.02 dB |
| Indoor B | 12.78 dB | 7.49 dB |
| Pedestrian A | 18.22 dB | 8.54 dB |
| Pedestrian B | 11.42 dB | 8.73 dB |

<Note> We also have simulation results in Indoor A and Pedestrian B channel models. As more strong multipaths exist, the performance gain of USTS decreases. However, since in most cases of indoor or pedestrian environment, the first detected path is relatively stronger than any other paths, good performance gain can be expected by using USTS.

# 6. Impacts to WGs

## 6.1. WG1

### 6.1.1. Node B hardware requirements

Very small Node B hardware requirement to support USTS because

- The same scrambling /channelisation codes are used but differently used for USTS.
- TAB command is transmitted by puncturing TPC every 20 msec.
- Measuring round trip propagation delay already exists.

### 6.1.2 Computational complexity at Node B

Small increase in computational complexity is expected

- to compare the received arrival time with the desired arrival time continuously and then, set TAB commands.

<Note> RNC calculates initial synchronisation time, using the PRACH Propagation delay reported from Node B.

### 6.1.3 Transmission timing control at UE

Transmission timing needs to be adjusted at UE side

- at initial synchronisation phase
- during tracking process
- transmission gap at non-USTS-to-USTS transition during soft handover procedure

### 6.1.4 Impact on closed loop power control loop delay

If the timing of the uplink can be adjusted at the initial synchronisation phase and during the call (downlink timing stays the same), then UL/DL relative timing does not stay fixed. This relative timing is up to $T_{ref}$ and the UE capability (CLPC processing power). In indoor and micro cell (urban area) cases, appropriate values for $T_{ref}$ can be found so that UL/DL relative timing is not less than $T_0$ and accordingly, CLPC delay is kept at 1 slot, when using USTS.

Moreover, since USTS can mitigate the effect of imperfect power control by using orthogonal property of channelisation codes, the impact of CLPC delay is expected to be quite small compared to the performance gain of USTS.

# 6.2. WG2

## 6.2.1. RRC layer

RRC Connection Request Message needs to include **USTS indicator** to notify whether the UE supports USTS or not.

The following RRC messages should include some information related to USTS such as scrambling code, channelization code, and initial synchronization information.

- RRC Connection Setup Message (RRC Connection Re-establishment Message)
- Radio Bearer Setup Message (Radio Bearer Reconfiguration Message)
- Transport Channel Re-configuration
- Physical Channel Reconfiguration

## 6.2.2. RLC Layer

- No impact on RLC layer

## 6.2.3. MAC Layer

- No impact on MAC layer

## 6.2.4. Interface between RRC and PHY layer

Inter-layer interface primitive between RRC layer and physical layer should include some parameters for USTS

- CPHY-RL-Modify-REQ
- CPHY-RL-Setup-REQ

# 6.3. WG3

<Note> WG3 has its own technical report (TR 25.839).

RNC calculates $T_{INIT\_SYNC}$ with $T_{ref}$ and PRACH Propagation delay. RNC assigns scrambling and channelisation codes for USTS and informs the relevant information and USTS indicator of Node B.

## 6.3.1 Iub Interface

The following parameters should be added in the NBAP message, RADIO LINK SETUP REQUEST:

- USTS indicator (To notify whether the UE supports USTS or not)
- USTS UL Channelisation Code Number (To determine channelisation code for USTS)

From *USTS UL Channelisation Code Number* and *Min UL Channelization Code length*, the channelization code for USTS can be retrieved.

In case of soft handover, the UE should execute the mode change from non-USTS to USTS after deleting the original radio link. For this, the RTT(Round Trip Time) parameter in NBAP message, DEDICATED MEASUREMENT REPORT, will be used for calculation of $T_{INIT\_SYNC}$.

### 6.3.2 Iur Interface

In case of handover, SRNC should indicate whether the UE supports USTS or not. For this, USTS indicator parameter should be added in RNSAP message, RADIO LINK SETUP REQUEST.

### 6.3.3 Iu Interface

No impact on Iu Interface

## 6.4. WG4

FFS

# 7. Backward compatibility

Since the USTS capability is negotiated during call-setup phase, a UE based on Release 99/4 can be used in Release 5 UTRAN with USTS capability without any impact. And similarly, a UE based on Release 5 with USTS capability can be used in Release 99/4 UTRAN without any impact by the same reason.

Consequently, the backward compatibility is guaranteed with USTS in Release 5.

# Annex A: Change history

| Change history | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Date** | **TSG #** | **TSG Doc.** | **CR** | **Rev** | **Subject/Comment** | **Old** | **New** |
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| Document history | | |
|---|---|---|
| **Date** | **Version** | **Comment** |
| November 21, 2000 | 0.0.0.0 | First draft |
| | | |

| Document history | | |
|---|---|---|
| **Date** | **Version** | **Comment** |
| | | |

Editor for 3G TR xx.xxx is:

Duk Kyung Kim
SK Telecom
Tel. : +82 31 710 5167
Fax: +82 31 710 5177
Email : kdk@sktelecom.com

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