WHITE PAPER ON TDD SYNCHRONIZATION

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Abstract

Synchronization is one of the most important issues for TDD systems, in which the signals are transmitted and received on the same frequency band. In order to facilitate TDD deployment in various scenarios, this white paper provides information of both technical solutions and industry progress on TDD synchronization, including the synchronization requirements, mechanisms/schemes and validation results. To facilitate fast development and flexible global TD-LTE deployment, several conclusions and recommendations are also summarized as below on synchronization in TDD systems:

- Synchronization is an essential requirement for TDD system deployment. It may also be necessary for FDD system if performance gain is expected by utilizing techniques such as interference cancellation (IC).
- Several synchronization methods exist, each with pros and cons. Synchronization based on GNSS is usually assumed to achieve the highest accuracy and easiest to implement for outdoor cells. However, in many scenarios such as indoor small cells, other mechanisms may be more appropriate.
- If over-the-air synchronization is considered, compared with UE-assisted synchronization, the schemes based on network listening could get more stable performance with little influence on UEs. Currently, the mature TD-LTE products supporting one-hop synchronization by network listening are ready for deployment, which could fulfill the synchronization requirement specified in 3GPP.

- Meanwhile, verification of the performance of multi-hop over-the-air synchronization is ongoing, which is targeted for indoor deep coverage for future.

[Considering the fast progress in the industrialization, the latest information will be captured in the later version].

Contents

1 Overview

1.1 Introduction

Nowadays, TD-LTE is developing very fast world widely. As one of the 4G mainstream techniques, it has attracted more and more attention with its well established and fast growing ecosystem. By June 2013, 17 TD-LTE commercial networks have been launched in 13 countries with over 3 million users. More operators are deploying commercial TD-LTE systems, or are engaged in the trials and studies.

In TDD systems, synchronization is one of the techniques to avoid UL/DL interference without losing spectrum in guard bands. Furthermore, it may also be beneficial to improve the system performance for features such as CoMP, eMBMS and feICIC.

Considering the various architectures in future network deployment (from macro to femtocells)， the proper synchronization method may differ significantly depending on the deployment case.

Considering GPS is no longer the only synchronization method,, it is necessary to provide a white paper on TDD synchronization in GTI, which includes the updated information on requirements, mechanisms/schemes, as well as the industry progress. It is expected that this white paper could supply robust solutions on key issue for TDD system and promote global TD-LTE deployment.

1.2 Objectives of the white paper

The objective of the white paper is to provide comprehensive information for TDD synchronization, including the requirements, mechanisms/schemes and up-to-date industry progress of TDD synchronization. It includes the following aspects:

- The necessity of TDD synchronization
- The synchronization requirements for TD-LTE and other IMT technologies
- The schemes for TDD synchronization
- The latest information on feasibility and performance testing of different TDD synchronization schemes
- Conclusions and recommendations on TDD synchronization

1.3 Terminology

Term	Description
BS	Base Station
CDMA	Code Division Multiple Access
CoMP	Coordinated Multi-Point
CRS	Common Reference Signal
DwPTS	Downlink Pilot Time Slot
eICIC	Enhanced Inter-cell Interference Cancellation
FeICIC	Further Enhanced Inter-cell Interference Cancellation
FDD	Frequency Division Duplex
GNSS	Global Navigation Satellite System
GP	Guard Period
GPS	Global Position System
IC	Interference Cancellation
MBSFN	Multicast-Broadcast Single Frequency Network
MMSE-IRC	Minimum Mean Square Error-Interference Rejection Combining
OFDM	Orthogonal Frequency-Division Multiplexing
OTA	Over The Air
PTP	Precision Time Protocol (a.k.a. IEEE-1588)
PRTC	Primary Reference Time Clock
TD-SCDMA	Time Division-Synchronous Code Division Multiple Access
TDD	Time Division Duplex
TD-LTE	Time Division Long Term Evolution
UE	User Equipment
WCDMA	Wideband Code Division Multiple Access

2 Synchronization of TD-LTE networks

2.1 Coexistence analysis

When more than one TDD network operate in the same band and geographic areas, severe interferences may happen if the networks are uncoordinated i.e. if some base stations (BSs) are transmitting while others are receiving: this can be easily understood for collocated macrocells on adjacent channels, since both out-of-band and spurious emission on the transmitter side and imperfect adjacent channel selectivity on the receiver side will desensitize or block the neighbor receiver, preventing him from properly listening to desired signals from terminals far away.

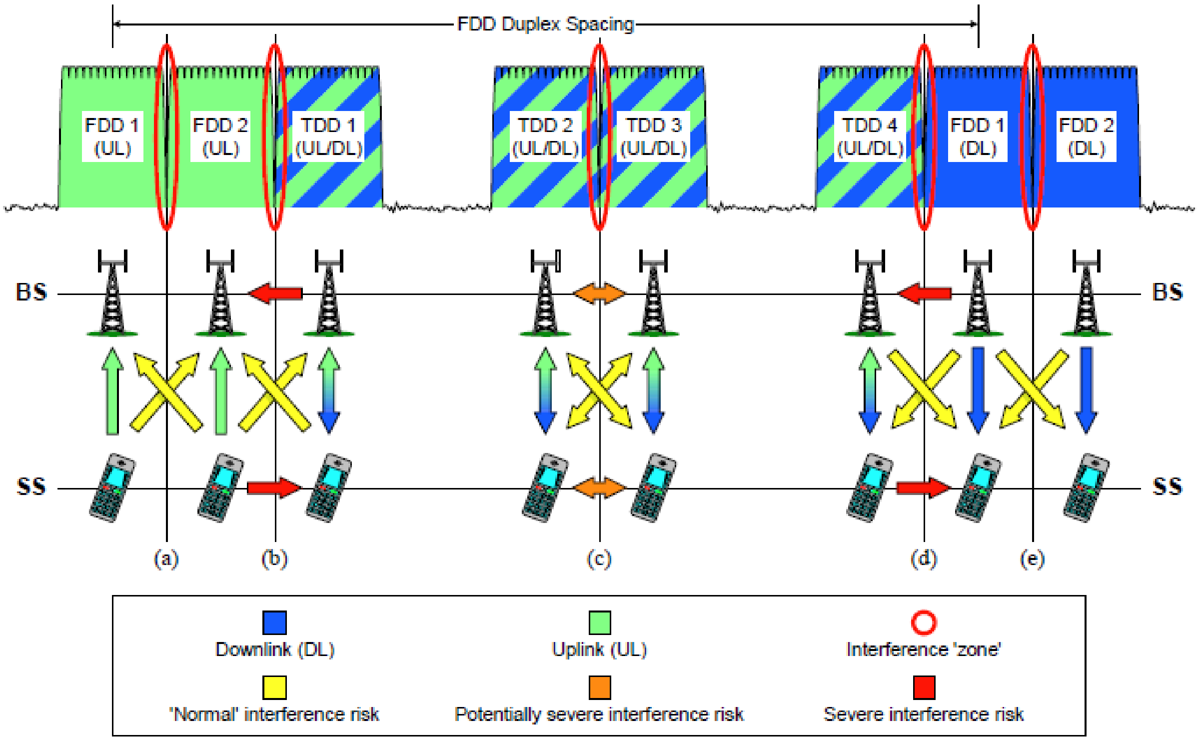

Figure.1 Interference among systems operating in the same band

In the case of FDD-TDD coexistence, it is impossible to avoid this issue without guard bands. However in the case of TDD-TDD coexistence, one way to avoid this issue without losing spectrum is to synchronize neighbor networks in order to make them transmit and receive at the same time.

It is well known that synchronization is one strict requirement for TDD system to avoid the inverse link interference (i.e. the inter-cell interferences of eNB to eNB and UE to UE). One example to show the interference introduced by asynchronization is depicted in Figure 2. This requirement is not only needed for the cells operated in the same frequency, but also for the cells operated in the same band if there is no sufficient guard band reserved.

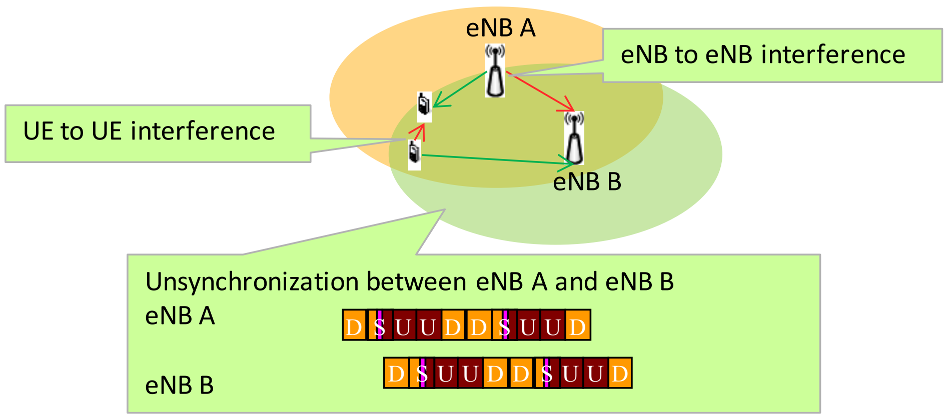

Figure.2 Interference introduced by asynchronization

The word "synchronization" can have many meanings (frequency synchronization, eNB-UE synchronization, carrier/symbol synchronization…). In order to make things clear, 3GPP has defined "synchronized operation" as "Operation of TDD in two different systems, where no simultaneous uplink and downlink occur",which means:

- Starting the frame in the same time
- Configuring compatible frame structures (length of the frame, and uplink/downlink ratio, guard period) so that all transmitter stop before any receiver starts

The following picture illustrates interference when start of frame is not aligned (1st row) or when TDD UL/DL ratio is not aligned (3rd row):

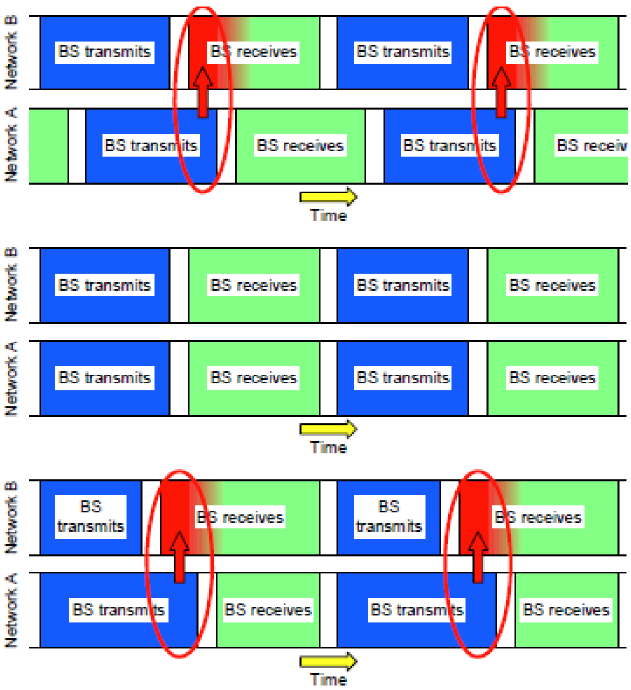

Figure.3 Interference caused by not aligned start of frame and UL/DL ratio

2.2 Other synchronization benefits

For both TDD and FDD deployment, it would be essential to consider the synchronization mechanisms between cells to bring benefit to the existing features (e.g. eICIC/FeICIC, CoMP as well as carrier aggregation) and some potential techniques for small cell enhancements discussed (e.g. efficient discovery and dual connectivity especially with single radio UL). For some other techniques such as advanced receiver at UE, the synchronized network would be beneficial to improve the receiver performance. For example, according to 3GPP RAN4 study, the UE demodulation performance with MMSE-IRC under synchronized network would be better than that under un-synchronized.

2.3 Clock accuracy requirements

In 3GPP, synchronization issue for TDD systems has been comprehensively investigated and the requirements have been defined for different kinds of TD-LTE BS types including wide area BS and Home BS, as illustrated in Table.1 and Table 2.

Table.1 Cell phase synchronization requirement for wide area BS (TDD)

Cell Type	Cell Radius	Requirement
Small cell	≤ 3 km	≤ 3 μs
Large cell	> 3 km	≤ 10 μs

Table.2 Cell phase synchronization requirement for Home BS (TDD)

Source Cell Type	Propagation Distance	Requirement
Small cell	≤ 500 m	≤ 3 μs
Large cell	> 500 m	≤1.33 + $T_{propagation}$ μs

Note 1: $T_{propagation}$ is the propagation delay between the Home BS and the cell selected as the network listening synchronization source. In terms of the network listening synchronization source selection, the best accurate synchronization source to GNSS should be selected.

Note 2: If the Home BS obtains synchronization without using network listening, the small cell requirement applies.

Synchronization is also required for other technologies or LTE features (including in FDD deployments). It is often on the order of 1μs, as illustrated in the following table.

Table.3 Synchronization requirements for IMT technologies

Technology	Phase/time accuracy
CDMA2000 (FDD)	[3μs]
WCDMA TDD (TS 25.402)	2.5 μs
TD-SCDMA (TS 25.836)	3μs
MBSFN over LTE (TDD or FDD)	1μs
CoMP over LTE (TDD or FDD)	[1μs]
WiMAX 802.16e TDD	1μs

3 Synchronization schemes

3.1 Introduction

There are several methods to achieve synchronization of the start of the frame for TDD systems, in which three mechanisms are often used and have been mostly identified by 3GPP, including:

- Synchronization by GNSS (e.g., GPS)
- Synchronization over backhaul network (e.g., IEEE 1588)
- Over-the-air synchronization (e.g. network listening)

These mechanisms will be described in detail in the following sub-sections.

3.2 Over-the-air synchronization

Over-the-air (OTA) synchronization is defined to achieve timing with the help of radio-interface based signals. Obviously, it is not limited by the coverage of GNSS signal or the backhaul condition. Two kinds of OTA synchronization methods are usually used including synchronization by network listening and UE-assisted synchronization, in which the cell providing synchronization for another cell is considered as a source cell while the cell requiring synchronization from another cell is considered as a slave cell.

3.2.1 Synchronization by network listening

In this method, a slave cell can directly acquire synchronization by detecting the signals from its source cell. The signals can be the existing reference signals or new signals if justified. In order to receive these signals, the slave cell would stop transmission and listen to its source cell in some certain interval.

The synchronization overhead mainly focuses on the downlink resource reserved for sniffing and the synchronization accuracy is impacted by the detecting/tracking accuracy at the eNB side. In addition, the propagation delay between the source cell and the slave cell should be considered and may cause additional synchronization error. Compensation can be performed if the propagation delay is large, e.g., by adjusting the timing with a random access procedure between the source cell and the slave cell.

3.2.1.1 MBSFN subframe based network listening

One approach for synchronization by network listening is to use MBSFN subframe, in which the slave cell stops transmitting and track synchronization in certain configured MBSFN subframes. This approach minimizes the impact on UEs and allows for multiple hops in the synchronization. Furthermore, all the nodes can track in a coordinated fashion (all declaring MBSFN subframes at the same time), thus minimizing interference.

Figure.5 Tracking based on MBSFN subframes

In order to perform multiple hops synchronization, stratum level is defined in 3GPP specification to indicate the index of source cell and slave cell. The stratum level of each cell is self-configured and could vary with changing RF conditions of its source cell. Each slave cell tries to track the synchronization from the available cell with lowest stratum level, which in turn allows the slave cell to be as close to GNSS time as possible. A flow chart is given in Figure 6 to demonstrate how to derive the stratum level and track synchronization based on MBSFN subframes.

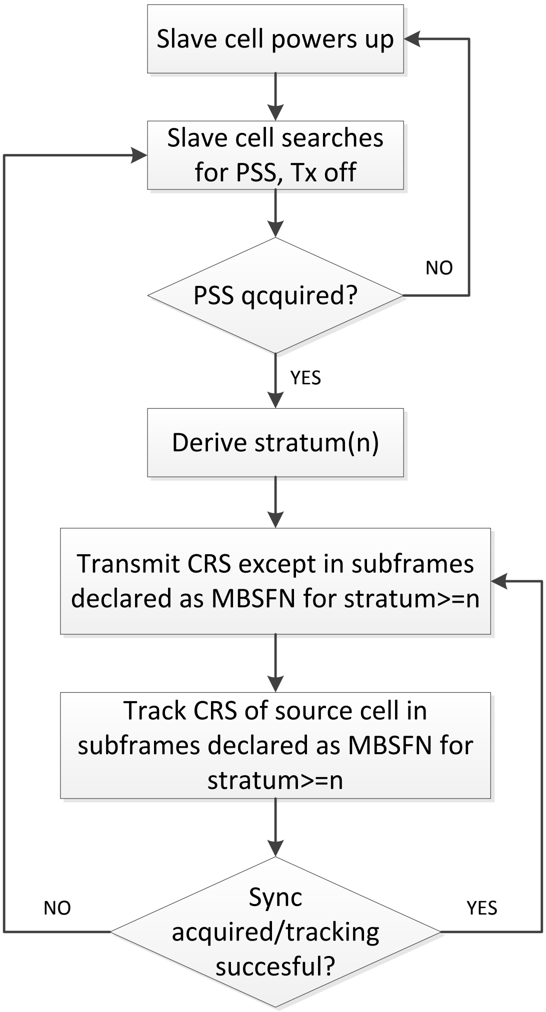

Figure.6 Procedure for Synchronization using MBSFN Subframes

The overhead incurred by this approach depends on the number of hops and would be equal to the number of hops times one subframe in every 320 subframes. (320ms corresponds to the highest configurable periodicity of MBSFN subframes). For a stratum-1 cell, the overhead is a little under 0.3%. It should also be noted that this approach can be used for FDD as well for deriving frequency synchronization (and potentially time synchronization if required in future releases).

3.2.1.2 TDD special subframe based network listening

There is another approach for synchronization by network listening, which takes advantage of TDD special subframe. With different configurations, the slave cell could utilize the guard period (GP) to track source cell's common reference signal (CRS) in DwPTS without additional impact on its normal transmission. CRS tracing can be done every radio frame to generate a statistic tuning value, which ensures more robust synchronization.

When the slave cell is power on, it may follow the UE's cell search process and get the synchronization from source cell. With this process, symbol timing, radio frame timing and source cell ID can be obtained by slave cell, which enables the slave cell to conduct the aforementioned CRS based synchronization tracking procedure.

In each slot, the CRS on antenna port 0 and antenna port 1 are located in the 1st, 5th, 8th and 12th OFDM symbols for normal CP while they are located in the 1st, 4th, 7th and 10th OFDM symbols for extended CP. The source cell can be configured with more DwPTS symbols (i.e. config1, 2, 3, 4, 6, 7, 8, detailed configurations are shown in Table 4) and the slave cell use other different configurations to pair with the source cell (such as config 0 or 5). Over the air synchronization could be performed by CRS tracking during the guard period configured by the slave cell.

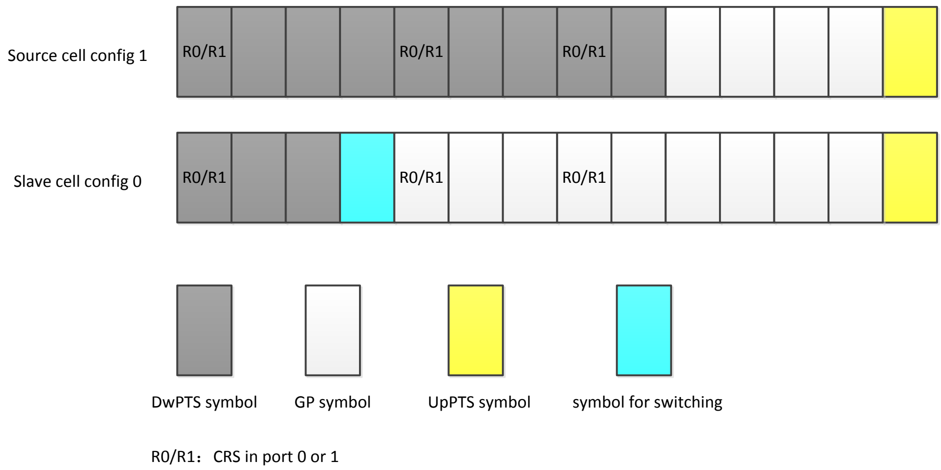

Figure.7 Synchronization based on special subframe configuration (Normal CP)

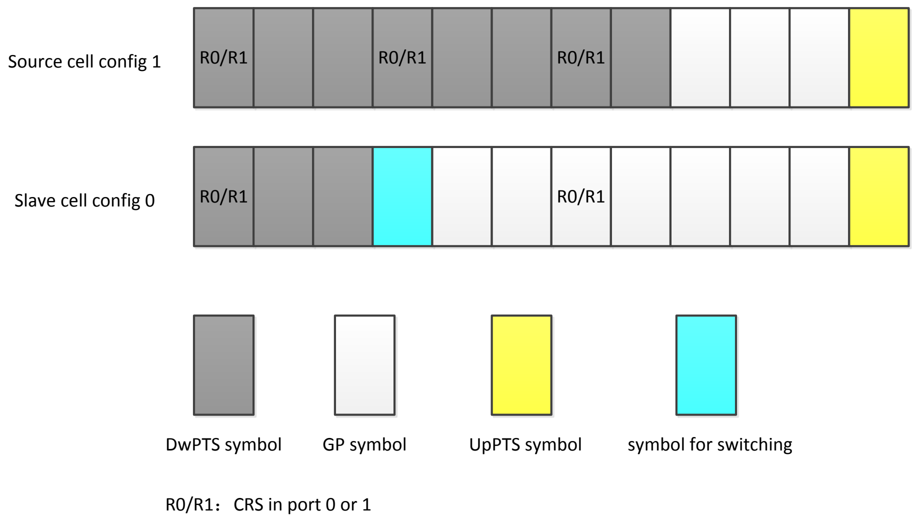

Figure.8 Synchronization based on special subframe configuration (Extended CP)

Table.4 Special subframe configurations specified in 3GPP

Config	Normal CP			Extended CP		
	DwPTS	GP	UpPTS	DwPTS	GP	UpPTS
0	3	10	1	3	8	1
1	9	4	1	8	3	1
2	10	3	1	9	2	1
3	11	2	1	10	1	1
4	12	1	1	3	7	2
5	3	9	2	8	2	2
6	9	3	2	9	1	2
7	10	2	2			
8	11	1	2			

This approach is based on different special subframe configurations and GP is used to track CRS of the source cell so as to achieve synchronization. There is neither impact on the air interface specifications nor interference issue between the source cell and the slave cell. However, it may not be so convenient to support multi-hop synchronization since it is usually difficult to choose a suitable special subframe configuration pair for both source cell and slave cell for each hop.

3.2.2 UE-assisted synchronization

In this method, the synchronization between the source cell and the slave cell can be achieved by some information obtained from UE. For example, a UE can detect the arriving timing of downlink signals from the source cell and the slave cell, or the source cell and the slave cell can detect the arriving timing from a UE's uplink signal. The network can derive the timing difference between the source cell and slave cell if such information can be well exchanged and used.

The synchronization overhead is mainly considered on the UE side which helps to acquire the synchronization and on the backhaul resource between the source cell and the slave cell. The accuracy for UE-assisted synchronization is impacted by the detection/tracking accuracy at the UE side. Additional complexity at UE side needs to be introduced for both TDD and FDD system if this method is not transparent to UEs.

3.3 Comparison of different synchronization schemes

The above mentioned synchronization schemes are summarized and compared in Table.5, including the accuracy, overhead, complexity and suitable scenarios. It is suggested to choose appropriate synchronization schemes in practical deployment.

Table.5 Summary and comparison of different synchronization schemes

	Synchronization by GNSS	Synchronization over backhaul network	Over-the-air synchronization
Synchronization accuracy	High (100ns order)	Good (sub-microsecond order)	Depends on detection/tracking accuracy at eNB/UE side (several microsecond order)
Synchronization overhead	-	-	For network listening: ◆ Reserved DL resource for listening slots; For UE-assisted synchronization: ◆ Overhead at UE side and on the backhaul resource
Cost/Complexity	Hardware cost	Backhaul cost	For network listening: ◆ No additional hardware cost for TDD system ◆ Additional receiver in DL and possible additional transmitter in UL for FDD system For UE-assisted synchronization: ◆ Additional UE complexity if this solution is not transparent to UEs for both TDD and FDD system
Scenarios	Not applicable to indoor;	Need good backhaul such as operator controlled fiber / Ethernet and hardware support for IEEE-1588v2	Can be applied to scenarios where synchronization by GNSS and over backhaul do not work

Considering the cost and backhaul limitation, over-the-air synchronization is more flexible to fulfill the requirements of different scenarios and the schemes by network listening are more likely to be used since it has no impact on UEs. A detailed summary is provided in Table.6 to further compare the two synchronization schemes by network listening introduced in section 4.4.1.1 and 4.4.1.2.

Table.6 Comparison of different synchronization schemes by network listening

Schemes by network listening	Based on MBSFN subframe	Based on special subframe
Principle of the scheme	Use MBSFN subframes for tracking CRS of source cell	Use DwPTS for tracking CRS of source cell
Performance (e.g. synchronization accuracy, speed, etc)	Meets synchronization requirement Provides flexible overhead-tracking periodicity tradeoff	Meets synchronization requirement CRS tracing can be done every Radio Frame, which ensure robust synchronization
Overhead (e.g. OFDM symbols per [320ms])	0.3% for stratum-1 nodes when using the lowest periodicity of only 1 MBSFN for tracking per 320ms	Maximum 12.86% with 2 switch point per RF Minimum 1.43% with 1 switch point per RF
Number of multi-hops supported	4	1, up to 2 with some cases of special SF configuration (e.g. Normal CP SSF Conf.4→ Conf. 2 →Conf. 5)
Compatibility and impacts on current network	Fully backward compatible	Fully backward compatible
Impacts on specifications	Either backhaul signalling or blind detection scheme used depending on operator deployment	No extra signalling is needed when supporting only single hop
Others	Could be used for either FDD or TDD mode	Could be used for TDD mode

4 Verification of synchronization

In order to verify the feasibility and performance of different synchronization schemes, several kinds of testing have been conducted by the vendors. Considering the fact that synchronization by GNSS could get excellent accuracy, the testing are mainly focused on synchronization based on IEEE-1588v2 and over-the-air synchronization.

4.1 Synchronization based on IEEE-1588v2

In Dec 2012, ZTE and China Mobile jointly conducted the performance testing of synchronization based on IEEE-1588v2, in which two Nanocell were developed and provided.

Figure 9 illustrates the IEEE-1588v2 synchronization test block diagram. As shown in the figure, the rubidium atomic clock is connected to the GPS, the output pulse signal pp1s of the rubidium atomic clock is connected to Channel 1 of the oscillograph, and the output 10MHz frame frequency signal is connected to Channel 1 of the frequency meter. The PTN is set to BC mode on the HeMS, IEEE-1588v2 protocol resolution of the synchronized clock server is performed, frames are reframed and then sent to the Nanocell (AP). The output pulse signal pp1s of the Nanocell (AP) is connected to Channel 2 of the oscillograph and the output 10MHz frame frequency signal is connected to Channel 2 of the frequency meter.

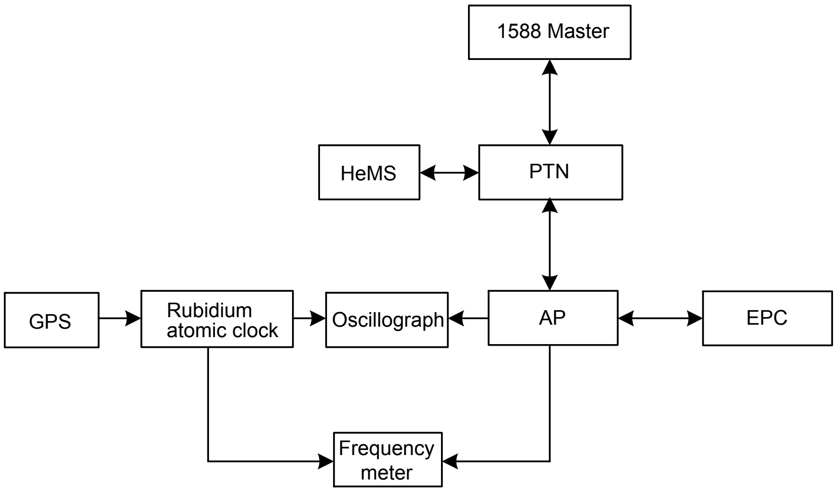

Figure.9 Test block diagram of synchronization based on IEEE-1588v2

The test was performed according to the following steps:

- Connect the clock synchronization server to the PTN. Interconnect the PTN with the AP. Set the PTN to BC mode on the HeMS.
- When the cell is set up normally, observe the IEEE 1588 clock of the AP till it gets into the locked state.
- Wait till the rubidium atomic clock locks the GPS.
- Read the output pp1s by the rubidium atomic clock and the AP on the oscillograph. Get the time deviation value.
- Read the output 10MHz by the rubidium atomic clock and AP on the frequency meter. Get the frequency offset value.
- Observe for an hour to get the test results.

According to the test results of synchronization based on IEEE-1588v2, the time deviation is less than ±500ns and the frequency offset is less than 0.1ppm. With more service loading, the clock is not affected.

4.2 Over-the-air synchronization

Currently, there is little eNB to derive synchronization through air-interface. Thus it is necessary to verify the performance of over-the-air synchronization. Recently, testing is mainly focused on the network listening methods so as not to introduce much complexity to UEs. As a functional verification, one-hop synchronization is tested at first stage and multi-hop synchronization will be further conducted in the near future.

4.2.1 Synchronization based on MBSFN subframe

In Dec 2012, ZTE and China Mobile jointly conducted the performance testing of over-the-air synchronization based on MBSFN subframe, in which two Nanocell devices were developed and provided.

Figure 10 illustrates the test block diagram of over-the-air synchronization. As shown in the figure, the Nanocell (AP1) is connected to the RGPS. The output pulse signal pp1s of the AP1 is connected to Channel 1 of the oscillograph and the output 10MHz frame frequency signal is connected to Channel 1 of the frequency meter. The output pulse signal pp1s of the Nanocell (AP2) is connected to Channel 2 of the oscillograph and the output 10MHz frame frequency signal is connected to Channel 2 of the frequency meter. When the clocks of AP1 and AP2 are locked and get into the working state, configure services on the HeMS.

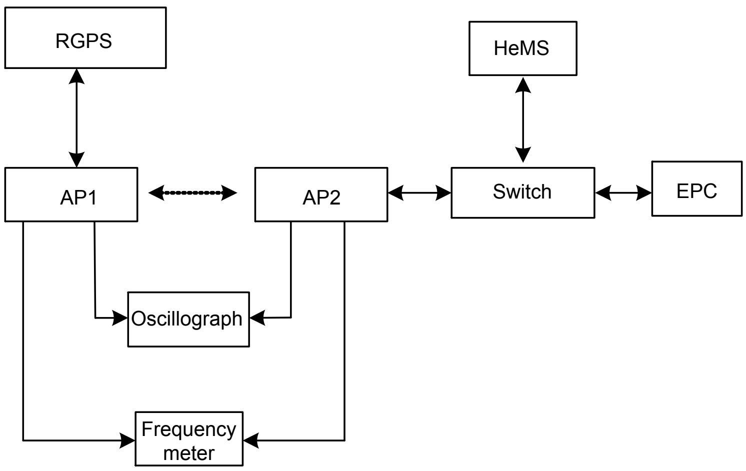

Figure.10 Test block diagram of synchronization based on MBSFN subframe

The test was performed according to the following steps:

- Make the AP1 to lock the RGPS.
- Set AP2 to over-the-air synchronization mode, in which one MBSFN subframe is configured per 320ms. Wait till the clock gets into the over-the-air state.

- Set up a cell, and then keep it for a while.
- Read the output pp1s by the source cell and slave cell on the oscillograph. Get the time deviation value.
- Read the output 10MHz by the source cell and slave cell on the frequency meter. Get the frequency offset value.
- Keep the system in the hold-on state for more than 12 hours and observe the test results.

According to the test results, the time deviation is less than 1us and the frequency offset is less than 0.1ppm. Furthermore, with over-the-air synchronization based on MBSFN subframes, additional tests were also performed on UE service origination, UE handover and multi-user access. The test results show that over-the-air synchronization has no influence on the services.

4.2.2 Synchronization based on TDD special subframe

In Aug 2011, Nokia Siemens Networks and China Mobile jointly conducted the performance testing of over-the-air synchronization based on TDD special subframe, in which two Home eNB (HeNB) devices were developed and provided.

Figure 11 shows a picture of the connection of the two HeNBs, in which one is connected to GPS and works as a source cell (master HeNB) while the other works as a slave cell (Slave HeNB) and performs over-the-air synchronization from the source cell. The distance between these two HeNBs is about 5-6 meters due to limitation of the Lab environment.

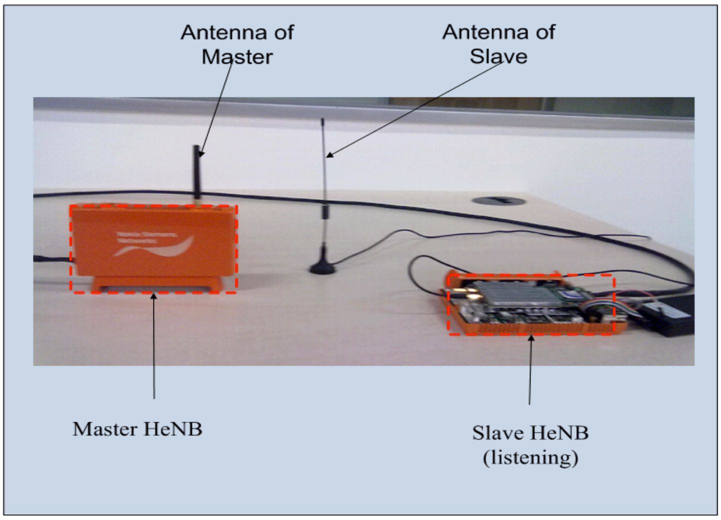

Figure.11 Connection of two HeNBs in the test

When the slave HeNB is power on, it follows the UE's cell search process and performs synchronization by tracking the CRS in DwPTS of master HeNB. In the test, the TDD UL/DL configuration is set to 1 and the special subframe configurations are set to 7 and 5 for master HeNB and slave HeNB respectively. 2.35GHz is taken as the carrier frequency and 20MHz bandwidth is considered with 2x2 MIMO structure for both spatial multiplexing and transmit diversity.

Figure 12 gives the test result of synchronization based on TDD special subframe, in which the synchronization accuracy is about 189ns. This result demonstrates a good performance for one-hop over-the-air synchronization and it can easily fulfill the requirement specified in 3GPP.

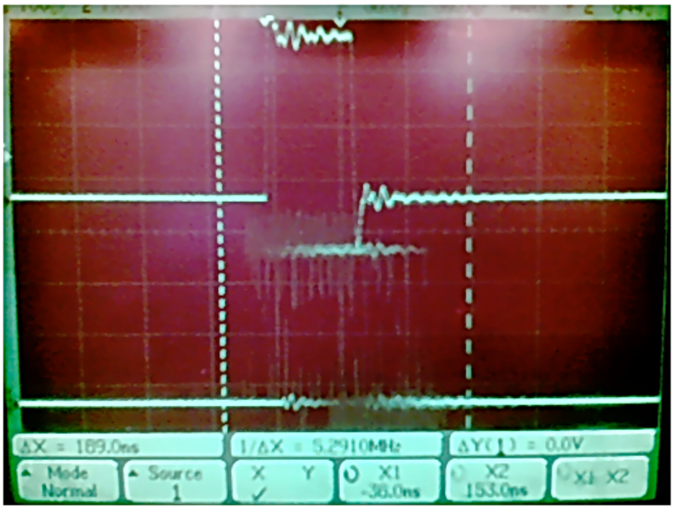

Figure.12 Test result of synchronization based on TDD special subframe

5 Summary and recommendations

Synchronization is one of the most important issues for TDD systems in which the signals are transmitted and received on the same frequency band. The UL/DL interference could be avoided with high synchronization accuracy and good performance could also be obtained.

In order to accelerate the TDD development and boost operators' commercial success, several conclusions and recommendations are summarized as below.

1) Synchronization is an essential requirement for TDD system deployment. It may also be necessary for FDD system if performance gain is expected by utilizing techniques such as interference cancellation (IC).

2) Several synchronization methods exist, each with pros and cons. Synchronization based on GNSS is usually assumed to achieve the highest accuracy and easiest to implement for

outdoor cells. However, in many scenarios such as indoor small cells, other mechanisms may be more appropriate.

- GNSS is suitable for scenarios that high synchronization accuracy is required while cost is not the primary factor.
- IEEE-1588v2 is suitable for the scenarios that good backhaul condition is assumed (e.g. operator controlled fiber / Ethernet)
- Over-the-air synchronization is suitable for the scenarios that GNSS and IEEE-1588v2 is not available. It is an important and flexible approach to get synchronization, especially for the scenarios with low cost required or difficult to modify the transport equipment.

3) If over-the-air synchronization is considered, compared with UE-assisted synchronization, the schemes based on network listening could get more stable performance with little influence on UEs. Currently, the mature TD-LTE products supporting one-hop synchronization by network listening are ready for deployment, which could fulfill the synchronization requirement specified in 3GPP.

- Synchronization scheme based on MBSFN subframe is optimal to support multiple hops.
- Synchronization scheme based on TDD special subframe has little influence on the system throughput and available resource.

4) Meanwhile, verification of the performance of multi-hop over-the-air synchronization is ongoing, which is targeted for indoor deep coverage for future.

6 Reference

[1] http://www.wimaxforum.org/technology/downloads/Service_Recs_Tech_Neutrality_-_FDD-TDD_Coexistence.pdf

[2] http://www.3gpp.org/ftp/Specs/archive/36_series/36.104/36104-b40.zip

[3] TR36.872, Small Cell Enhancements for E-UTRA and E-UTRAN: Physical Layer Aspects.

[4] TR36.829, Enhanced performance requirement for LTE User Equipment (UE).

[5] http://www.3gpp.org/ftp/Specs/archive/36_series/36.133/36133-b20.zip

[6] TR36.922, TDD Home eNode B (HeNB) Radio Frequency (RF) requirements analysis.

[7] R1-130024, Feasibility and benefits of radio-interface based synchronization mechanisms for operation efficiency improvement, Huawei, HiSilicon, 3GPP RAN1#72, St. Julian's, Malta, 28 January - 1 February 2013.

[8] R1-131164, Feasibility and benefits of radio-interface based synchronization mechanisms for operation efficiency improvement, Huawei, HiSilicon, 3GPP RAN1#72bis, Chicago, USA, April 15-19, 2013.

[9] R1-131856, Scenarios and solutions of radio-interface based synchronization mechanisms, Huawei, HiSilicon, 3GPP RAN1#73, Fukuoka, Japan, May 20-24, 2013.

[10] http://www.3gpp.org/ftp/Specs/archive/36_series/36.413/36413-b30.zip

[11] White Paper of Nanocell Technology (v1.0), China Mobile Research Institute