ELECTRONICS AND ELECTRICAL ENGINEERING
ISSN 1392 – 1215 2011. No. 8(114)
ELEKTRONIKA IR ELEKTROTECHNIKA

T 180 TELECOMMUNICATIONS ENGINEERING
TELEKOMUNIKACIJŲ INŽINERIJA

The Research of Frequency Synchronization in Carrier Ethernet Backhaul with SyncE Technology

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crossref http://dx.doi.org/10.5755/j01.eee.114.8.691

Introduction

There are major changes undergoing in mobile carrier networks. The introduction of mobile broadband services is the main driving force. The deployments of Long Term Evolution (LTE) will significantly increase the ratio of packet data traffic to TDM traffic in the backhaul [1]. LTE can support a theoretical peak downlink data rate of 330 Mb/s (4x4 MIMO) [2]. Legacy backhaul networks are optimized for circuit switched voice traffic in which the transmission from Base Transceiver Station (BTS) to a base station controller (BSC) is realized using static time division multiplexing (TDM) circuits. TDM networks are inefficient for packet transfer. Therefore it is not possible to deliver LTE service through TDM backhaul and maintain profitability [1].

The LTE standard, finalized in early 2009, defines major architectural changes such as System Architecture Evolution (SAE). It is important to note that LTE focuses on all-IP approach. Current mobile standards use a mix of circuit-switched and IP technologies to support legacy services. Both the data and control planes are based on IP protocol in LTE standard. This delivers a simplified operational model in combination with flatter network approach.

Multiprotocol Label Switching Transport Profile (MPLS-TP) is a scalable packet forwarding technology, which enables traffic engineering, Quality of Service (QoS) and fast recovery from node and link failures. The stack of IP/MPLS allows wire emulation (pseudo wire) for TDM, ATM, SDH/SONET and Ethernet services over packet switched networks. E-LAN and E-Line services for Ethernet are provided by the virtual private LAN service (VPLS) and virtual private wire service (VPWS). During our experiment we will investigate the carrier backhaul network based on MPLS-TP technology.

Basically there are three possible backhaul migrations from legacy TDM networks to packet networks scenarios [3]. The first scenario is to adapt the operators legacy TDM backhaul to support both TDM and packet data traffic. Second scenario is where two separate data traffic networks are build, TDM and packet based. In these two scenarios BS are synchronized from legacy TDM backhaul network. In the third scenario the backhaul network is fully packet based, for carriers which are new to the market. In second and third scenario we need have possibility to deliver synchronization through packet network. The main goal of this paper is the research of Synchronous Ethernet (SyncE) ITU-T G.8261, G.8264, G.8262 possibilities to deliver BS frequency synchronization.

For the transfer of frequency synchronization, SyncE is the ideal solution. It combines the cost effectiveness of the Ethernet with synchronization transfer capabilities of SDH. The alternative to Synchronous Ethernet would be to install GNSS receivers and antennas in all base station sites.

The physical layer

As defined in ITU-T G.8261, Synchronous Ethernet is using physical layer for node synchronization to the same frequency. Mobile Carrier Ethernet realizations are usually deployed as a high-speed point-to-point connection where physical layer (ETY) works great in asynchronous mode as packets get buffered at each node. In Synchronous Ethernet, the link frequency is linked to a traceable primary reference source. The clock is recovered at PHY of incoming interface, on all the nodes along the path, and than it is locked to the phase-locked loop (PLL) (Fig.1) [4]. The process is similar to SDH/SONET which provides highly precise frequency synchronization. However SyncE does not support the distribution of time of the day information, due to that reporting functions in mobile networks are limited as stated in ITU-T G.8264.

In SyncE networks the control of the level of jitter and wander is very important. In ITU recommendations, the so called Network Limits are specified – the maximum acceptable wander and jitter for different classes of interfaces in the network.

Table 1 shows synchronization requirements for different wireless technologies.

Table 1. Synchronization requirements

Wireless technology	Interface	Maximal frequency offset	Maximal phase offset	Time of day maximal offset
GSM	Radio	50 – 250 ppb	-	-
	Transport	0.01 ppb	4.3 µs	-
CDMA/CDMA2000	Radio	50 – 250 ppb	-	1 µs
WCDMA/UMTS	Radio	50 – 250 ppb	-	2.5 µs (TDD)
	Transport	15 ppb	-	-
	RNC, net sync	0.01 ppb	4.3 µs	-
TD-SCDMA	Radio	50 – 250 ppb	-	-
WiMax fixed	Radio	15 ppm	-	-
	Transport	-	-	1 µs (TDD)
WiMax mobile	Radio	15 ppm	-	1 µs (TDD)
	Transport	16 ppb	-	-
LTE	Radio	50 – 250 ppb	10 – 50 µs (TDD)	-

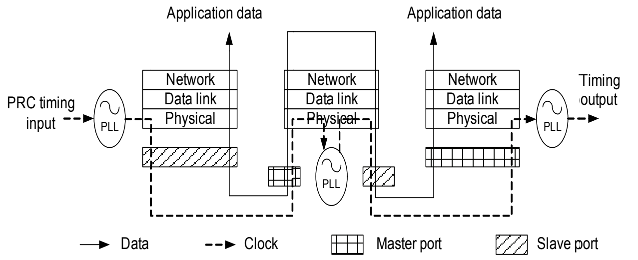

Fig. 1. Clock and data path in SyncE

It is acknowledged that methods such as IEEE 1588-2009 PTP also may be used for the purpose of synchronization transfer, but because of its sensitive to the effects of traffic load, physical level Synchronous Ethernet provides the best technical solution for guaranteed frequency stability and accuracy.

Although Synchronous Ethernet can only be used when all nodes along the path supports SyncE interface, it only can be used for frequency synchronization.

System design and experiment

Our experimental setting was a UMTS base station in mobile carrier`s laboratory, which has Synchronous Ethernet connection. For synchronization measurement we used SyncTester OSA 5565 STS. SyncTester is portable measuring device with high stability rubidium oscillator (precision $\pm1\times10^{-11}$) which is designed for SDH/SONET and PDH synchronization signal quality measurement. WinSTS program is the controlling program for the device, which executes mathematical calculations and displays graphical data. We used two NEC MN5200 switches with SyncE support for frequency synchronization transfer [5]. It is a one hop installation. The master switch is synchronized to a Stratum 1 PRC. Experimental setting is shown in Fig.2.

Synchronization measurements were taken in 10000 s long period of time. During the experiment we measured TIE,MTIE,TDEV,MADEV and frequency precision parameters (Ym), but for our analysis we will use only MTIE, TDEV and Ym. The measurements were taken from a operating base station on the mobile carrier premises. The operator was the first in the region to install NEC SyncE equipment and the measurements were taken during the test run of the equipment.

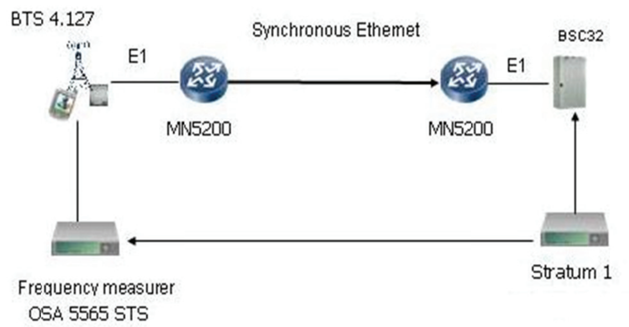

Fig. 2. Experimental set

Maximal time interval error (MTIE)

MTIE (µsec) is largest peak-to-peak TIE value for all intervals τ during measuring period T. MTIE is calculated using this formula

$$MTIE(n\tau_0) =$$

$$= max_{1\le k\le N-n}[\max(x_i)_{k\le i\le k+n} - \min(x_i)_{k\le i\le k+n}]\,. \qquad (1)$$

In the ITU-T G.8262 are described timing characteristics of a synchronous Ethernet equipment slave clock. Wander is defined as the long-term variations of the significant instants of a digital signal from their ideal positions in time. Input wander tolerance (MTIE) mask is shown in Fig. and measured results in Fig.4:

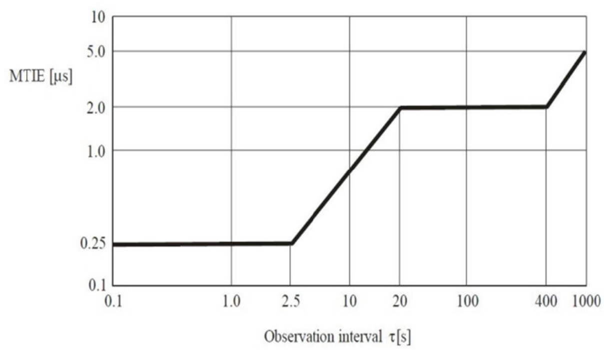

Fig. 3. Input wander tolerance mask (MTIE), ITU-T G.8262

As we can see from the graphs the measured wander on SyncE interface is 1E-3 smaller than it is recommended in specifications. This is the safe zone for temperature influence on oscillator and for the wander which can be summarized (collected) after several hops.

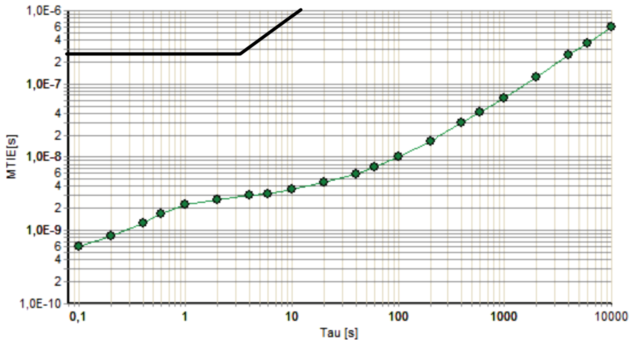

Fig. 4. Experimental results on MTIE

Time deviation (TDEV)

TDEV (μsec) is the expected shift of signal phase error function x(t). TDEV is the square root of Time Variance (TVAR). TDEV is defined with

$$TDEV(n\tau_0) \cong$$

$$\cong \sqrt{\frac{1}{6n^2(N-3n+1)}\sum_{j=1}^{N-3n+1}\left[\sum_{i=j}^{n+j-1}(x_{i+2n}-2x_{i+n}+x_i)\right]^2}, \quad (2)$$

where τ = nτ0 – observation interval; τ0 – sampling interval; xi – measured phase(time) error at the ith sampling time. The recieved TDEV measurment is shown in Fig. 5.

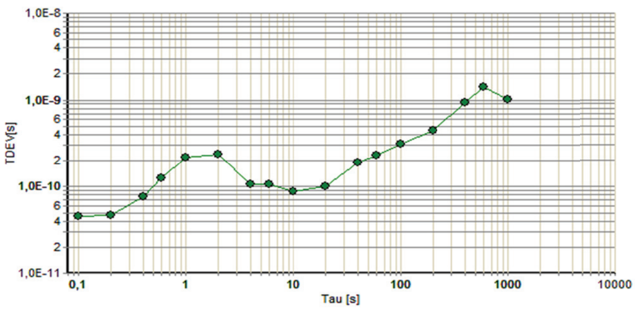

Fig. 5. Experimental results on TDEV

In Fig. 6 is shown the TDEV input wander tolerance mask from ITU recommendation.

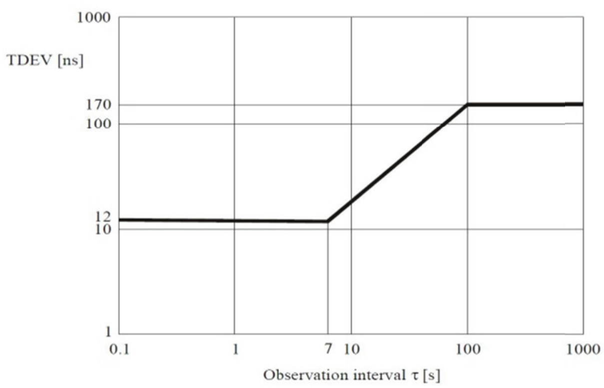

Fig. 6. TDEV mask, ITU-TG.8262

The measured time deviation (Fig.5) is much smaller than it is recommended, so the mask (Fig.6) does not fit into the graph. That means that tested SyncE equipment showed excellent results on frequency synchronization transfer.

Frequency shift

Frequency shift is calculated using

$$y(t) = \frac{f - f_{nom}}{f_{nom}}, \quad (3)$$

where f – measured frequency; f_{nom} – frequency from stratum 1.

Measured freqency offset is not greater than 1 ppb, the results are shown in Fig. 7:

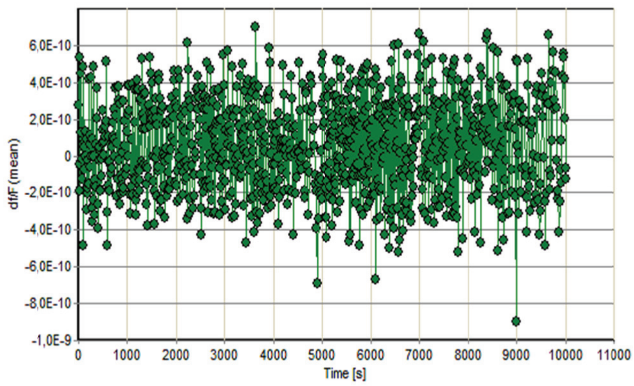

Fig. 7. Measured frequency shift

Taking into consideration that SyncE technology was developed for 4th generation mobile network needs, the results from synchronization test are promising. We received a synchronization signal with 1ppb offset (Fig.7), while the maximal offset is around 50 ppb (table 1.). That means that SyncE equipment is passed the ITU recommendation test and it is fully capable of transmitting the synchronization signal through packet switched network along with payload without any influence on synchronization.

Conclusions

Experimental results show that using Synchronous Ethernet is possible to achieve a very high level of frequency transfer performance phase shifts within a few tens of nanoseconds. The only disadvantage to SyncE technology that is not capable of synchronizing the time of day, but IEEE 1588v2 addresses this issue. The Combination of synchronous Ethernet with IEEE 1588v2 [6] is a key answer for carrier's backhaul network evolution to all-IP networks. This precision is comparable to SDH/SONET transport networks. It provides a secure synchronization transfer in combination with the migration from circuit switched to packet switched Ethernet backhaul network. Due to the fact that SyncE is using physical layer, synchronization is not effected by traffic load or packet delay variation. One of the major benefits of SyncE that it does not fundamentally change the Ethernet technology nor standards which describes it. The defined layers within the Ethernet allow such modernization. SyncE is fully compatible with legacy synchronization networks. This Ethernet solution provides considerable flexibility for mobile operators.

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Received 2011 02 15

A. Busarovs, V. Bobrovs, J. Porins. The Research of Frequency Synchronization in Carrier Ethernet Backhaul with SyncE Technology // Electronics and Electrical Engineering. – Kaunas: Technologija, 2011. – No. 8(114). – P. 31–34.

Fourth generation mobile networks, such as LTE Release 10, increases the demand for carrier backhaul capacity to gigabits per second. With mobile backhaul networks migrating from TDM-based to packet-switched network infrastructures, the transport technology needs to face synchronization requirements. This article describes the results of frequency synchronization measurements in working SyncE network on a mobile carrier premises. Ill. 7, bibl. 6, tabl. 1 (in English; abstracts in English and Lithuanian).

A. Busarovs, V. Bobrovs, J. Porins. Dažnio sinchronizavimo tyrimas taikant nešlius Etherneto tinkle ir SyncE technologiją // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2011. – Nr. 8(114). – P. 31–34.

Ketvirtosios kartos mobiliojo ryšio tinklai, tokie kaip LTE, didina paklausą nešlių, gebančių perduoti informaciją gigabitų per sekundę eilės duomenų perdavimo sparta. Keičiantis technologijoms, būtina spręsti perduodamų duomenų paketų sinchronizavimo klausimus. Pateikiami mobiliojo ryšio operatoriaus patalpose atlikto dažnio sinchronizavimo matavimo, taikant SyncE technologiją, rezultatai. Il. 7, bibl. 6, lent. 1 (anglų kalba; santraukos anglų ir lietuvių k.).