Testing Synchronization in UMTS Networks

We know from experience that correct synchronization of network nodes is essential for Quality of Service. The quality of the carrier frequency of the radio interface is critical, in order for us to guarantee a low level of interference between adjacent cells. Furthermore, when a radio interface is based on TDD, it is vital that all the different Nodes B are synchronized together.Another service that will undoubtedly require high-quality synchronization is Location

Application Note *AN.VAJW.CELLULAR.2.0.UK*

The Widest Range of Test and Measurement Products

TrendCommunications

Mobile network operators are making major investments in implementing third generation cellular networks, 3G/UMTS. This calls for a remarkable effort from network equipment manufacturers, who need to face the problem of finding adequate specifications for the elements that form a part of the cellular network.

The 3GPP, formed by different standardization organizations, is a collaboration agreement to produce standards related to the 3G mobile network that builds on the existing GSM infrastructure. The 3GPP specifications are being constantly developed, and there are still many aspects that have not been clarified.

In the world of test and measurement, it is still not sure what are the exact needs of mobile operators when it comes to bringing these networks into service and monitoring them. It will not be possible to answer this question accurately while it is not clear how we are to put into practice the standards that are being developed. However, we can say something about the future course of events. One of the most relevant issues is access network synchronization and its management.

We know from experience that correct synchronization of network nodes is essential for Quality of Service. Succesfull handover, for instance, depends largely upon the quality of synchronization of the network elements involved.

The quality of the carrier frequency of the radio interface is also critical, in order for us to guarantee a low level of interference between adjacent cells. Furthermore, when a radio interface is based on TDD, it is vital that all the different Nodes B are synchronized together.

Another service that will undoubtedly require high-quality synchronization is Location. It is expected that the 3G Mobile Network would incorporate this type of services. This would enable technicians to use trilateration to find user equipment with exceeded error margins.The method used by the Location service calls for high-quality synchronization signals.

UMTS Network Architecture

As the UMTS network is a result of the evolution of second generation cellular networks (GSM), it shares many elements and characteristics with it.

The UMTS network can be divided into two parts: Access network and Transport network. The Access network connects users to the Transport network. Connections from mobile networks to fixed networks are made from the Transport network, and this is also the place from where the whole system is controlled.

The Transport network is shared with the existing network for GSM and GPRS systems. The Access network is the part going through the most important changes.

The 3GPP standards define the functions, interfaces and protocols for each part of the Access network.

In the case of the UMTS, its Access network is called the UTRAN, and it is formed by two elements, the Node B and the RNC.

- The UMTS Node B is similar to the GSM BTS. One of its novelties is Macrodiversity that makes it possible for one UE to be served from more than one Nodes B at a time.
- The RNC is one of the key elements of the UTRAN. It connects Nodes B to the Transport network. Node B resources are controlled from the RNC. Furthermore, the RNC controls connections with each UE individually. This way, access, power and microdiversity, as well as handover for each UE are controlled from the same element.

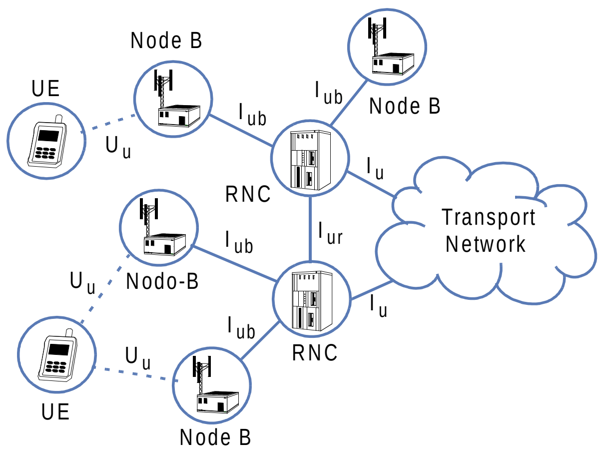

Figure 1 *UTRAN architecture*

The connection between the different elements of the UTRAN is flexible. For example, both SDH and PDH are possible for a connection between Nodes B and RNCs (I_{ub} interface) or RNCs only (I_{ur} interface). Radio connection with UEs is established by means of the u_u interface. Methods based on time and frequency multiplexing can be used for this radio interface. However, the most frequent solution is based on hybrid CDMA,TDMA or FDMA, and there are basically two methods of radio access, namely FDD and TDD.

The UTRAN is connected to the Transport network by using the I_u interface. The most important feature of this interface is that it enables us to interact both with circuits and with packet-based connections.

SYNCHRONIZATION OF THE UTRAN

The most relevant issues concerning the synchronization of the UTRAN are discussed in Standard TS-25.402. These issues are:

- *Network synchronization*, synchronization signal distribution across the UTRAN, and its integration into the networks that are connected to the UTRAN.
- *Node synchronization*, or discussion of the characteristics and limits for synchronization signals between Nodes B or between Nodes B and RNCs.
- *Transmission channel synchronization*, needed to guarantee frame transport between RNC and Nodes B.
- *Radio interface synchronization* between Nodes B and the UE.
- *Time alignment control* between the UTRAN and the transport network.

It is essential to control the network and node synchronization properly in order for the rest of the layers to be synchronized correctly. This application note describes the ways to evaluate if the network and its nodes are synchronized correctly.

NETWORK SYNCHRONIZATION

As explained in the previous section, network synchronization is related to specifying the synchronization distribution techniques and quality requirements needed in the nodes that form the UTRAN.

As the physical transmission layer in Node B/RNC and RNC/RNC connections is based on different levels of SDH, SONET, PDH and ANSI T-Carrier digital hierarchies, synchronization strategies are basically the same as the ones used for all the networks of this type.

According to the standard TS-25.402, the synchronization source available for each Node B should have more stability than 0,05 ppm, to guarantee enough quality for radio interface signals. To meet these objectives, it is recommended to use a synchronization source obtained from a PRC (G.811 clock).

To ensure quality for the UTRAN synchronization source at all times, it is necessary to have redundancy in the available synchronization inputs. GPS receivers are combined with PRC-originated synchronization signals transported in PDH or SDH links.

Node Synchronization

Node synchronization refers to the set of techniques related to estimating and compensating synchronization differences in different parts of the UTRAN, and it is used to minimize the interference between Nodes B.

In node synchronization, the UTRAN has different requirements in FDD and TDD modes. The reason for this is that in FDD mode, different frequencies are used to transmit and receive radio links. However, in TDD, both radio links share the same frequency. In TDD mode, cells must be synchronized, which is why less timing differences are allowed than in FDD mode.

The TS-25.402 deals separately with RNC/Node-B and Node-B/Node-B synchronization.

RNC/Node B Synchronization

The RNC/Node B synchronization works at user plane protocol layer, and its purpose is to keep the Node B frequency in line with the RNC frequency, when for some reason there is offset between the two nodes. Latency information calculated by the system itself is used to compensate this offset.

The quality of the frequency compensation mechanism may be replaced by wander due to cyclic temperature variations that affect the signal delay as the signal crosses the transmission medium. In other words, characterizing the synchronization source in terms of MTIE is important in order for the frequency compensation algorithm to work correctly.

Node B/Node B Synchronization

Synchronization between Nodes B is especially critical in TDD systems. In the case of FDD systems, it is enough to use the RNC/Node B synchronization protocol. In TDD systems, we must use a a special synchronization port in our equipment, or, alternatively, the air interface.

SHORT-TERM STABILITY TEST

It is advisable to analyze the stability of the synchronization signal in UTRAN nodes by carrying out at least two different measurements. This section describes the first of these two measurements, and the following section, the second.

The synchronization signal phase variation must always be maintained within the specified limits. However, for practical reasons, short-term stability (with a short-term observation period) is measured separately from long-term stability.

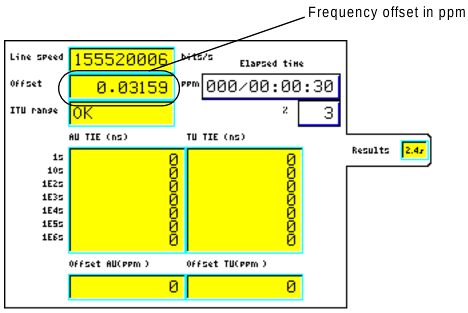

Figure 2 Analyzing the short-term stability of a clock, by using the frecuency meter of Victoria

To analyze stability in the short run, we can use the frequency meter included in the Victoria Jitter/Wander. It provides the value of offset in respect to the nominal value, directly in ppm.

LONG-TERM STABILITY TEST

To analyze the long-term stability of a synchronization source, it is not enough to carry out a short-term frequency offset measurement. A synchronization signal is often infected by long-term phase variations that cannot be diagnosed without a long-term measurement. An MTIE is to be applied in this case. It helps us to analyze and calculate phase variations in different time scales.

To analyze low-frequency phase perturbation, we need long observation windows. It is quite normal for an MTIE measurement to take several days.

The results of an MTIE measurement are usually represented graphically, simultaneously with a standard mask. In order to consider the test result as satisfactory, the MTIE graph must remain below this mask in every time scale analyzed..

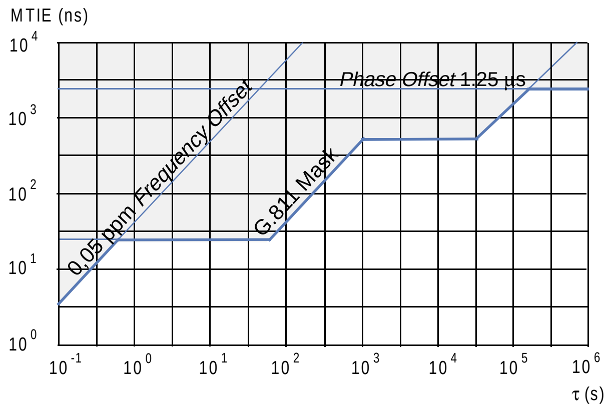

Figure 3 An MTIE mask for a Node B synchronization source in a UMTS network

The MTIE graph of the Node B is obtained by superimposing the different synchronization sources needed at this point of the network.

- First of all, the Node B must be synchronized according to G.811. For this, the Node B MTIE mask must be in line with the description found in this ITU-T Recommendation.
- The behavior of the frequency error in small time scales has a limit of 0,05 ppm according to the standard TS-25.402. Constant frequency offset has an MTIE graph that is represented by a straight line. In our case, these 0.05 ppm will cause variation that equals to 5×10^{-8} seconds for each second in the phase of the synchronization signal. In other words, the phase will vary 50 ns per second in respect to the nominal value. This way we will directly obtain the slope for a constant frequency offset.
- When it comes to TDD systems, the TS-24.402 also establishes phase variation limits for synchronization signals in different Nodes B. This limit is 2,5 µs between any two Nodes B of the same area. This is to say that no Node B can exceed its given nominal value. The MTIE graph for a phase variation of 1,25 µs is a horizontal line that crosses the vertical axis at 1,25 µs.

As expected, the line for constant frecuency offset crosses the G.811 MTIE graph at its bottom part. For short observation windows, G.811 is not valid to evaluate the behavior of the Node B synchronization source. Furthermore, if the system is TDD, the phase variation between cells must not be greater than 2,5 µs. This is shown in the MTIE graph as a horizontal line that crosses the G.811 mask at the part corresponding to very long term observation windows. G.811 is not valid for this type of windows, either, and must be seen as the most restrictive specification of 2,5 µs in the phase.

The MTIE measurement of Victoria enables you to:

- Display results as tables.
- View these same results as graphs, directly in the user interface of the tester. (You do not need extra software for this.)
- Use the mask you want and view it graphically together with your test results. This way, you can check if the synchronization source meets your requirements.
- Display MTIE results in real time. The values in the table and the different points of the graph are updated as new data is obtained.

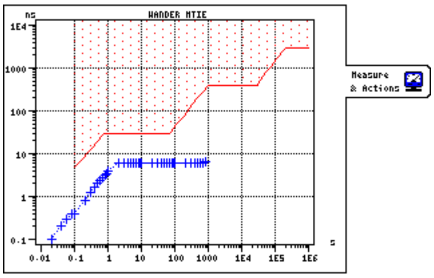

Figure 4 Analyzing the long-term stability of a synchronization source by carrying out an MTIE

The nature of wander measurements calls for a reliable synchronization signal, if we wish to obtain results. The reason for this is that any phase perturbation to be found is of such a long period of time that it cannot be filtered conventionally by a PLL as in jitter measurements. In a Node B MTIE measurement, this synchronization source can be obtained by different means. One of these is to use a GPS receiver intended for this purpose.

Conclusion

Controlling synchronization in a cellular UMTS network is crucial, and it has a considerable effect on the Quality of Service that can be offered to the user.

A 3G mobile service provider must check that the bandwidth provider of the network being used can offer synchronization signals with enough quality to meet the standards, as this is a very important factor when it comes to Quality of Service.

The characteristics of Victoria Jitter/Wander make it an essential tool when validating synchronization in an UMTS network:

- It is highly portable.
- It has multiple interfaces, both PDH and SDH.
- It gives quality and precision for results.
- There are automatic tests, and reports are easy to generate and print.

Index of Acronyms

3GPP: 3rd Generation Partnership Project
BTS: Base Transceiver Station
CDMA: Coded Division Multiple Access
FDD: Frequency Division Duplex
FDMA: Frequency Division Multiple Access
GSM: Global System for Mobile communications
GPRS: General Packet Radio Service
MTIE: Maximum Time Interval Error
PDH: Plesiochronous Digital Hierarchy
PLL: Phase Locked Loop
RNC: Radio Network Controller
SDH: Synchronous Digital Hierarchy
SONET: Synchronous Optical NETwork
TDD: Time Division Duplex
TDMA: Time Division Multiple Access
UE: User Equipment
UMTS: Universal Mobile Telephone System
UTRAN: UMTS Terrestrial Radio Access Network

Relevant Standards

[1]. 3GPP TS 25.401 *UTRAN Overall Description.*

[2]. 3GPP TS 25.402 *Synchronisation in UTRAN Stage 2.*

[3]. 3GPP TS 25.401 *UTRAN Iu Interface Layer 1.*

[4]. 3GPP TS 25.421 *UTRAN Iur Interface Layer 1.*

[5]. 3GPP TS 25.431 *UTRAN Iub Interface Layer 1.*

[6]. ETSI EN 300 462-3-1 Transmission and Multiplexing (TM); Generic requirements for synchronization networks; Part 3-1 The control of jitter and wander within synchronization networks

[7]. ITU-T Recommendation G.811 (09/1997) *Timing Characteristics of Primary Reference Clocks.*

[8]. ITU-T Recommendation G.812 (06/1998) *Timing Requirements of Slave Clocks suitable for use as Node Clocks in Synchronization Network.*

[9]. ITU-T Recommendation G.813 (08/1996) *Timing Characteristics of SDH equipment slave clocks (SEC).*

[10]. ITU-T Recommendation O.172 (03/2001) *Jitter and wander measuring equipment for digital systems which are based on the synchronous digital hierarchy (SDH).*

TrendCommunications

Trend Communications SL
Pujades, 60
08005 Barcelona (Spain)
www.trendcomms.com
infoline@trendcomms.com

Trend Communications Ltd
Knaves Beech Estate
Loudwater, High Wycombe
Buckinghamshire HP10 9QZ UK

International: .... +44 1628 524977
España:............. 93 300 3313
UK:.................... 01628 524977
Deutschland: 089 32 30 09 11

Italia: 02 73 91 414
France: 01 69 35 54 70
India:................. 22 8597 463/4
US: 256 461 0790