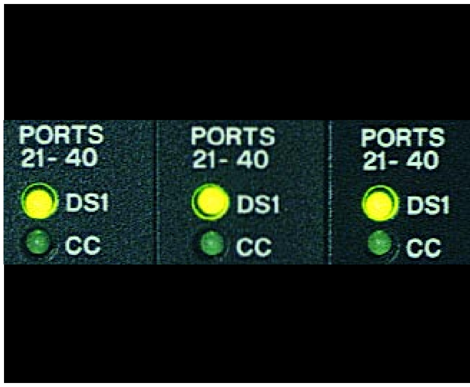
Symmetricom

Synchronization in 3G Networks Based on the Universal Mobile Telecommunication System (UMTS)



WHITE PAPER

Table of Contents

Synchronization in 3G Networks Based on the Universal Mobile Telecommunication System (UMTS)

Introduction

The demand for a greater variety of mobile and fixed wireless services has led to the introduction of third generation (3G) systems. Today, several 3G networks based on UMTS have been deployed and new networks are being launched globally. According to the UMTS Forum, 3G networks will represent a total operator-retained annual revenue of more than $300 billion by 2010. 3G networks provide traditional (2G) services such as voice and SMS but they also allow the introduction of many more services to users worldwide. In effect, 3G/UMTS unifies telephony, mobility, internet and computer technology.

Some of the driving factors behind 3G are increased bandwidth, internet access, multimedia/MMS services, real time applications such as video conferencing, streaming video, online gaming and location-based services. In short, 3G/UMTS offers a consistent set of services to mobile computer and phone users irrespective of where they are in the world, including services that in the past were available only in a wired environment. Inevitably, 3G operators will face many complexities with delivery of these new services, e.g. bandwidth, Quality of Service (QoS) and handover, all of which are essential to the success of 3G business models. Synchronization has a major impact on all these parameters.

As with all telecom technologies, synchronization is fundamental to 3G networks. Traditionally, synchronization in wireless networks was implemented only when things went wrong or it had been derived from other networks operated by a different provider, possibly a competitor. However, most 3G operators have realized that neither method is suitable and, furthermore, reliance on an external entity diminishes their control of synchronization quality. Consequently 3G networks need a robust synchronization architecture designed from the ground up to ensure that they will be prepared to meet the challenges at the network level and benefit from being able to maintain bandwidth requirements, maximize traffic throughput, and provide adequate Quality of Experience (QoE) for the end-user.

This paper begins by briefly describing synchronization in 2G networks and it goes on to introduce the UMTS architecture, the various UMTS synchronization standards and the synchronization issues facing 3G operators. It also presents examples of best practices for UMTS network synchronization based on experience gained from Symmetricom customers who have implemented 3G networks.

GSM Networks

GSM has been enormously successful as a wireless technology. It has been implemented in more than 200 countries with a staggering number of subscribers. Thus, commercially, GSM is the most popular choice for operators to migrate from 2G to 3G.

GSM (2G) Network Overview

A typical GSM network is made up of three main subsystems, the Network and Switching Subsystem (NSS), the Base Station Subsystem (BSS) and the Mobile Station (MS). The NSS contains mainly the switching elements such as the Mobile Switching Center (MSC). This is the gateway to the fixed or switched network and it handles subscriber management, including Visitor Location Registers (VLR), Home Location Registers (HLR), Authentication Centers (AuC) and so on. The BSS contains principally the Base Station Controller (BSC) and the Base Transceiver Station (BTS).

A simplified view of the key elements of a GSM network is provided in Figure 1. The interface between the MSC and the BSC is termed the *A-Interface*. The link between the BTS and BSC is referred to as the A_{bis} interface; U_m is the (radio) interface between the BTS and the MS.

GSM Synchronization Issues & Requirements

One of the fundamental requirements of GSM implementations is that the BTS requires a frequency accuracy of 0.05ppm ($5x10^{-8}$) at the radio interface (ETSI EN 300 912). A key driver for this requirement is mobility and the associated Doppler shift experienced by a moving MS. To put this frequency accuracy in perspective, if a mobile unit experiences a handover between two BTSs, the (possible) frequency delta of $1x10^{-7}$ is equivalent to a velocity of over 100 km/h. If the system must support the location of mobile handsets based on either the TOA (*Time of Arrival*) or TDOA (*Time Difference of Arrival*) approaches, then the frequency accuracy required can be two orders of magnitude more stringent.

There are a number of ways to achieve this frequency accuracy in a BTS and three methods are mentioned here.

The first is to use an autonomous clock such as a rubidium atomic standard or a GPS-disciplined clock (either rubidium or OCXO based) at the base station. This solution eliminates the need to rely on the clock derived from the transport links between the BSC and the BTS. The free-running behavior of a good rubidium standard is more than adequate to meet the (minimum) requirement of 0.05ppm. Availability of a GPS reference provides a BTS with a PRC (see G.811) level of accuracy; a combination of GPS reference

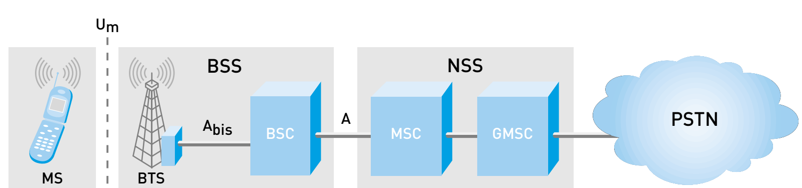


FIG.1 Simplistic view of a GSM network (excluding the subscriber management functions)

and rubidium holdover can maintain the ≈1×10^{-11} accuracy for extended periods of time even when the GPS reference becomes unavailable for some reason.

The second is to use a quartz oscillator (typically an OCXO) within the base station that is steered by the recovered clock derived from the transport links between the BSC and the BTS. Whereas this approach is feasible if the transport links, typically E1s, are carried over the PDH hierarchy, it is not recommended if the links are transported as a bearer channel over SDH. This is because the synchronization quality carried in SDH tributaries can be severely degraded by the wander generated by pointer adjustments. The wander generated by SDH pointer movements can be large enough that the recovered clock from a bearer channel is unsuitable as a reference source for this purpose.

The third method is, in essence, a combination of the first two methods. In particular, it is well known the quartz oscillators, even relatively inexpensive units, have excellent short-term stability. GPS as a reference has excellent long-term stability. The transport links commonly have very good medium-term stability. The trick, as it were, is to generate a clock with an overall stability that is characteristic of the best reference for the long-term, medium-term, and short-term behavior. Symmetricom pioneered such designs using patented methods for implementing multiple-input frequency locked loops (MIFLLs). The BesTime algorithm achieves this desirable behavior and has been incorporated into many clock designs.

It is also essential that the MSCs and the BSCs are properly synchronized. The MSC is arguably the most critical point of any GSM infrastructure. Timing errors at the MSC lead to data errors and poor usage of capacity and generally poor interoperability with other networks. Cascading failures can, in extreme cases, bring down an MSC and downstream elements. By deploying very accurate clock systems throughout the network, and especially at the MSC, such failures can be eliminated. Considering that many BTSs do not have an autonomous reference and rely on the link with the BSC to recover a timing reference, it is obvious that inadequate synchronization quality at the BSC will cascade down to the BTS and hence the radio interface and MS as well.

Best Practices for Synchronization of GSM Networks

In most GSM networks, synchronization is derived from the PSTN at the MSC and distributed through the rest of the network using, typically, E1 links carried over PDH systems. In this scenario, each node would, in an ideal world, meet the relevant synchronization standards. All nodes would be locked and they would track the clock from an upstream network element. Any jitter and wander added in transit would, again in an ideal world, be filtered at each transit point. In reality, this is not the case for a number of reasons:

- Synchronization is under the control of the PSTN and its quality may not be guaranteed.
- Synchronization failures degrade performance across the network often without the origin of the problem being self-evident.
- Every node will have its own clock subsystem comprising of clock recovery and filter (typically a frequency-locked loop). The low frequency (wander) components in the recovered clock are followed (not suppressed) and locally generated oscillator noise added in. Clearly, if there is a cascade of such nodes, excessive clock noise could be introduced in transit (wander, jitter, phase transients, etc.).
- As networks evolve and new technologies are introduced, synchronization can no longer be distributed in the same way. For example, some of the links are no longer PDH but are now being carried over SDH (at least partially). This leads to excessive wander being introduced by the transport network and so the E1 links may no longer be suitable for distribution of synchronization.
- Connections between the MSC and the BSC and the BSC and BTS are often provided by other operators, possibly competitors, which means lack of control over the quality or distribution of synchronization.
- Problems also occur when network element clocks fail, go into holdover, or even free-run. In this condition they are no longer traceable to the network G.811 clock, causing frequency drift, frame slips and radio frequency instabilities.

All these problems degrade network performance. Consequently, operators need to take a proactive approach by deploying appropriate synchronization solutions. In general, the synchronization plan adopted by wireless networks is to deploy G.811 references at the MSCs with G.812 holdover clocks and associated distribution equipment, i.e. SSUs (synchronization supply units). All network clocks in other network elements such as the BSCs are then engineered to be traceable to the G.811 reference at the MSC (or equivalent). Normally, clocks at these nodes have local GPS references to serve as a back-up or even as the primary reference, especially in cases where the transport between MSC and BSC is operated by a third party.

An example of a GSM network showing the clocks required at the MSC and BSC is shown in Figure 2 below. The PSTN has its PRC system and so does the MSC. This is commonly known as plesiochronous synchronization. The G.811 clocks ensure a near-zero slip rate and thus provide carrier-class interconnect performance over the transport segment as well as connectivity to the PSTN. The BTS is then slaved to the clock in the BSC.

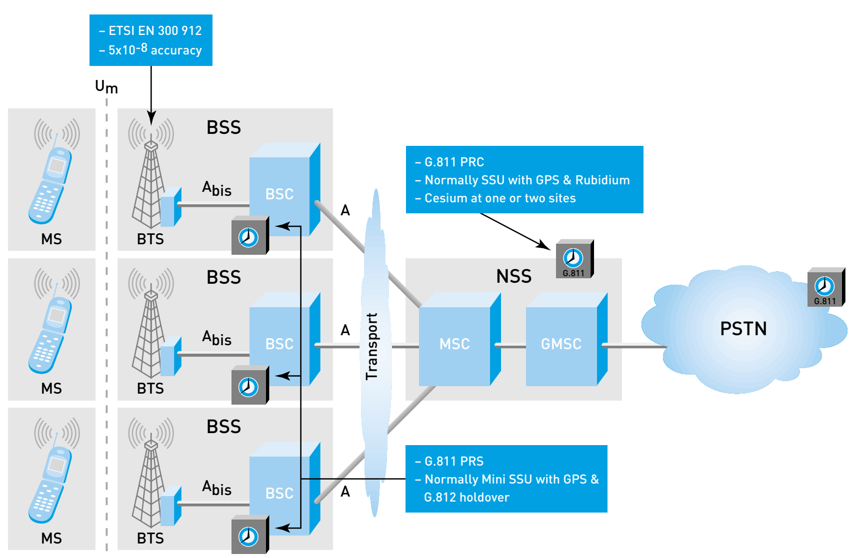


FIG.2 GSM network showing the clock placement and typical features required at these sites

3G/UMTS Networks

UMTS Network Overview

UMTS utilizes packet-based transmission offering services such as text, voice, multi-media, video and data rates up to 2Mbit/s.

The UMTS technology was chosen as the natural course for GSM operators in terms of the services and speeds offered. Additionally, the major standards bodies, manufacturers and operators have endorsed UMTS. Today, GSM or 2G networks have a customer base of about 1.4 billion users in more than 200 countries and represent over 75% of today's digital wireless market. For these reasons, UMTS 3G is a fundamental part of the future strategy of all major mobile operators.

The UMTS architecture separates the traffic layers, i.e. the Core Network, UMTS Terrestrial Radio Access Network (UTRAN) and the user equipment (UE). This is illustrated in Figure 3. UMTS and UTRAN architecture are defined in ETSI TS 125 401.

UMTS Terrestrial Radio Access Network (UTRAN)

The UTRAN is really the infrastructure that connects the user equipment to the Core Network. A UMTS base station is referred to as a Node B; the associated control equipment is termed Radio Network Controller (RNC).

As depicted in Figure 3, the UTRAN is made up of several radio network subsystems (RNSs), each of which is controlled by an RNC. An RNC is typically connected to several Node Bs. Existing 2G elements such as the MSC can be extended to satisfy some of the UMTS requirements, but RNC, Node B, and the user equipment are completely new elements. The UTRAN also provides the air interface (U_U) access method for user equip-ment. The RNC is similar to the GSM BSC and it controls one or more Node Bs. The RNC performs many functions including control of radio resources, handover manage-ment, macro-diversity (combining/splitting of data streams transferred over several Node Bs). A Node B fulfils almost the same role as a GSM BTS and is made up of a number of radio transceivers.

Wideband CDMA (WCDMA) is used for the UTRAN air interface. WCDMA has two basic modes of operation, namely, Frequency Division Duplex (FDD) and Time Division Duplex (TDD). In the FDD mode the carrier frequency employed by the user equipment in the upstream (towards network) direction is offset from the carrier frequency employed in the downstream (from network) direction and communication is continuously full-duplex (bi-directional). In the TDD mode, often called "ping-pong", the two directions of transmission occupy non-overlapping time-slots and full-duplex operation is synthesized, although communication is instantaneously half-duplex.

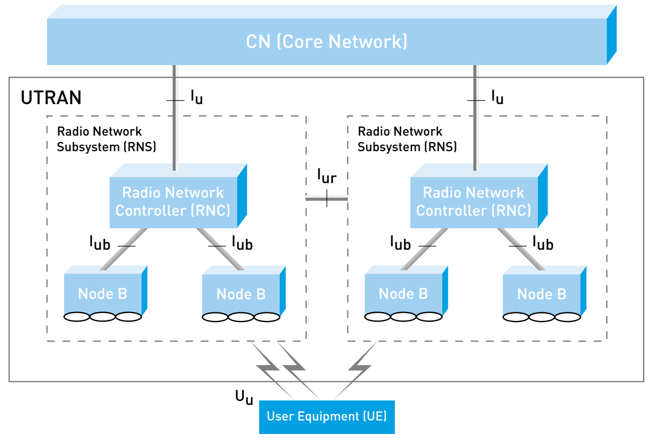


FIG.3 UMTS & UTRAN Architecture as defined in ETSI TS 125 401

Core Network

The primary role of the core network (CN) is to provide switching, routing and transit for user traffic. In addition, the core network also contains the subscriber and network management functions. The basic core network architecture for UMTS is based on GSM with GPRS, though, clearly, all equipment has to be adapted for UMTS operation and services.

The core network is divided into circuit and packet switched domains. Circuit switched elements include the Mobile services Switching Center (MSC), the visitor location register (VLR), and the Gateway MSC. Packet switched elements are the Serving GPRS Support Node (SGSN) and the Gateway GPRS Support Node (GGSN). Both domains share some network elements such as EIR, HLR and AUC.

Connectivity in a 3G network

ATM Transport

Asynchronous Transfer Mode (ATM) has been defined by 3GPP and ETSI as the transport technology in UMTS core and access networks. It is used in the interconnection of the UMTS

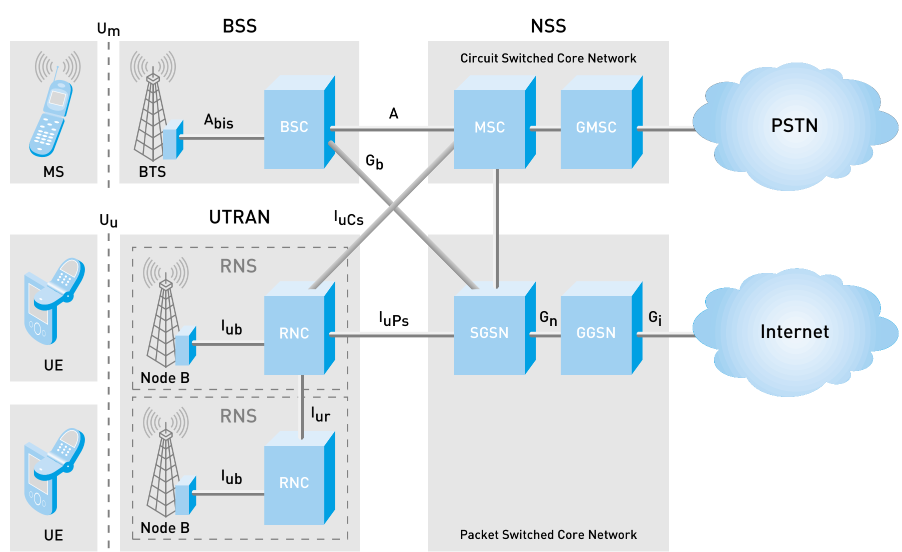


FIG.4 UMTS Network architecture showing the various elements, interfaces and GSM support

network elements, viz., Node B, Radio Network Controller (RNC), Mobile Switching Center (3G-MSC) and Serving GPRS Support Node (SGSN).

The ATM infrastructure uses both ATM Adaptation Layer type 2 (AAL2) and ATM Adaptation Layer type 5 (AAL5) at the I_u interfaces. AAL2 is used for circuit switched connections (real-time traffic) and AAL5 for data and signalling.

Synchronization in ATM
All packet networks experience delay in one form or another. There is propagation delay, packetization delay, queuing delay, buffering delay, encoding delay, etc. Cell transfer delay (CTD) is the delay experienced by a cell between network entry and exit points and includes propagation and queuing delays at various intermediate switches and service times at queuing points. Cell delay variation (CDV) is a measure of the cell transfer delay variance. In essence, CDV is jitter. In order to avoid cell loss due to jitter, *jitter-buffers* are required to account for the difference between maximum delay and minimum delay. Unfortunately, inclusion of jitter-buffers increases the overall connection latency with the associated deleterious effect on the Quality of Experience (QoE) for voice calls.

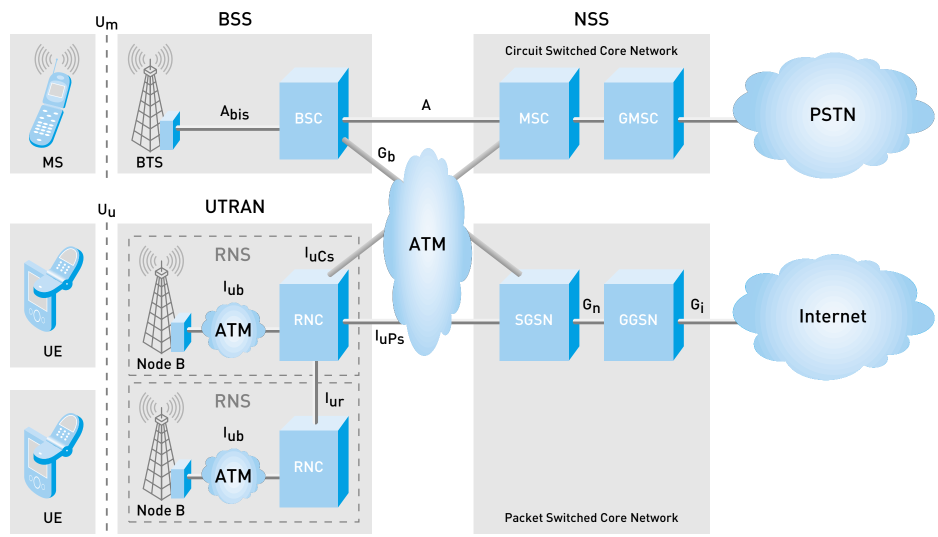


FIG.5 ATM transport in a UMTS network

Synchronization issues arise while transporting voice, video, data, etc. over ATM due to cell delay variation. The presence of jitter introduced by the ATM network may distort the reconstructed clock at the receiver. Recovery of the network clock is critical to assure all data packets reach their final destination at the correct time and are reassembled without any losses, gaps, or errors. It is strongly recommended that G.811 timing be deployed at the ATM nodes to guarantee that data packets reach their destination at the right time and are reassembled without losses, gaps, or errors that have a significant degradation of QoE for the real-time services carried over AAL2.

Concentrator Hubs
The bandwidths in 3G networks are much greater than those in 2G or GSM networks and thus a much larger number of base stations are required. As a consequence, operators manage traffic from Node Bs to their respective RNCs using ATM access concentrators over STM-N connections. This method greatly reduces costs as it minimizes the backhaul requirement at the I_{ub} interfaces (from the Node Bs to the RNCs). These sites are known by different names including Fiber Hubs, Transmission High Sites, Transmission Nodes, Access Aggregators, etc. In many cases, these hubs are BSCs that have been transformed with the addition of ATM and SDH elements, both of which require precise synchronization.

Quite often, the ATM systems at these sites use the Adaptive Clock Recovery (ACR) method for extracting a clock reference. This is not network synchronization in the traditional sense. ACR was developed to transfer a rough time-base between the origination point (the "transmitter") and the destination (the "receiver") that was adequate to ensure that jitter buffers did not overflow/underflow because of a frequency offset between the transmitter and receiver (overflow because of excessive CDV cannot be mitigated by adaptive clock recovery). It is essentially a recovered clock based on the average cell/packet rate. Whereas in principle the recovered clock at the receiver is representative of the transmitter's time base if the cells/packets have a well-defined constant rate (at the origination point), CDV in the transmission path tends to destroy the uniformity to the point that averaging must be done over very long (excessively long) periods of time. As a result, it is not sufficiently robust to pass synchronization effectively and reliably. This is especially true considering the bounds on clock noise specified in the 3G (or just about any other telecommunication wireless) standards.

The contraindication of ACR as a method for delivering a clock reference has been borne out in practice. A major international mobile operator found this method was not adequate, as it could not guarantee the quality of synchronization at such an important part of the network. One needs to remember that these are the nodes from which the air interface stability is derived. It is, however, feasible to transport clock references using ACR if the transport network is well controlled to keep the peak CDV within tight bounds, the spectral characteristics of the CDV introduced is benign, and the underlying oscillator providing the averaging function capable for long integration times (such as a rubidium atomic reference).

Physical Interfaces
ATM and the UMTS standards do not identify any specific physical interfaces to be used for the physical layer in the UTRAN I_u interface. It is therefore critical to plan and control the source and distribution of synchronization so that it is useable *irrespective* of the physical interfaces used. Figure 6 shows a typical UMTS network's physical interfaces.

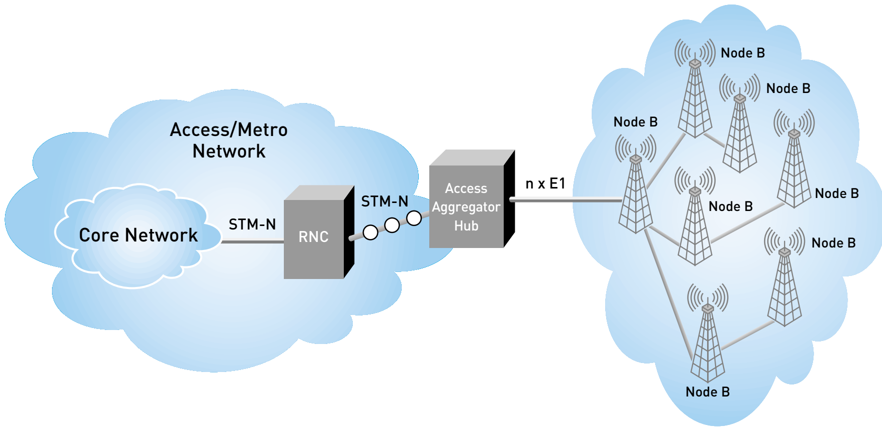


FIG.6 UMTS network's physical interfaces

ETSI Standards for UMTS

The ITU established the radio transmission standards for 3G systems in an initiative known as IMT-2000. In Europe, ETSI was responsible for generating the UMTS standards. The Third Generation Partnership Project (3GPP) was formed in 1998 to continue the technical specification work.

The most relevant ETSI standards that deal with the aspect of synchronization in UMTS networks are presented below.

1. TS 125 401: UTRAN Overall Description

This document describes the overall architecture of the UTRAN, including interfaces and assumptions on the radio and I_U interfaces (RNC to CN).

2. TS 125 402: Synchronization in UTRAN Stage 2

This is an overall reference document that deals with the Stage 2 specifications of different synchronization mechanisms within the UTRAN and the U_U. A summary of the main points of TS 125 402 is provided below:

2.1. General

The standard identifies different UTRAN synchronization issues and specifies the performance requirements of:

- Network Synchronization
- Node Synchronization
- Transport Channel Synchronization
- Radio Interface Synchronization
- Time Alignment Handling
- Uplink Synchronization.

2.2. Network Synchronization

Network synchronization describes distribution of synchronization references to the UTRAN Nodes and the stability of the clocks in the UTRAN.

One of the primary objectives is to achieve frequency accuracy better than 0.05ppm ($5x10^{-8}$) at the Node B in order to properly generate signals on the radio interface.

It is interesting to note that the general recommendation is to implement synchronization that meets the requirements of G.811, which calls for an accuracy better than $1x10^{-11}$.

For the RNCs, the standard recommends implementation of clocks that meet G.812 type I, II or III which implies the use of SSUs that offer sufficient holdover to meet the $5x10^{-8}$ accuracy requirement for a period of time that allows intervention in case of problems. It is recommended that the holdover clock used is based on a rubidium atomic standard although a high performance quartz (OCXO) may meet the requirement at a marginally lower cost. Rubidium has the holdover advantage; the time before manual or operator intervention is required can be very long. The SSU configuration also has the advantage of being able to survive synchronization failures owing to its protected architecture.

2.3. Node Synchronization

This relates to estimation and compensation of timing differences among UTRAN nodes. Two types of synchronization are identified, "RNC-Node B" and "Inter Node B". Their requirements differ between FDD and TDD modes.

Inter Node B is used in the TDD mode to compensate the timing differences among Node Bs in order to achieve a common timing reference. A common timing reference allows intercell synchronization within neighboring cells to minimize cross-interference.

RNC-Node B defines the process of obtaining timing differences between RNC and its Node Bs.

For TDD Node Bs, the relative phase difference of the synchronization signals at the input port of any Node B in the synchronized area shall not exceed 2.5µs.

For FDD Node Bs, synchronization is handled via RNC-Node B synchronization. If an accurate timing reference is not used at the Node Bs, this procedure will lead to a load on signalling between the RNC and the Node B.

Location based applications will set additional requirements on Node Synchronization.

To summarize, these are the requirements of TS 125 402:

2.4. TS 125 411 UTRAN I_U Interface Layer 1 (interface between RNC & CN)

- Jitter & wander – ITU-T Recommendations G.823, G.824, and G.825
- Overall synchronization – ITU-T Recommendation G.811
- TS 125 104 & TS 125 105: Radio Tx & Rx
- Stability: 5 x 10^{-8} over one time slot (2/3ms).

The synchronization requirements are depicted in Figure 7 below.

The Importance of Synchronization In UMTS Networks

Summary 3G Synchronization Issues

This section raises some very important points as to where and why synchronization impacts UMTS networks. Poor synchronization is not always the reason why these problems are experienced. However, audits taken in several networks have identified poor synchronization as a major factor in the performance of their networks. A summary of issues gathered from several operators around the world and comments associated with them is provided below.

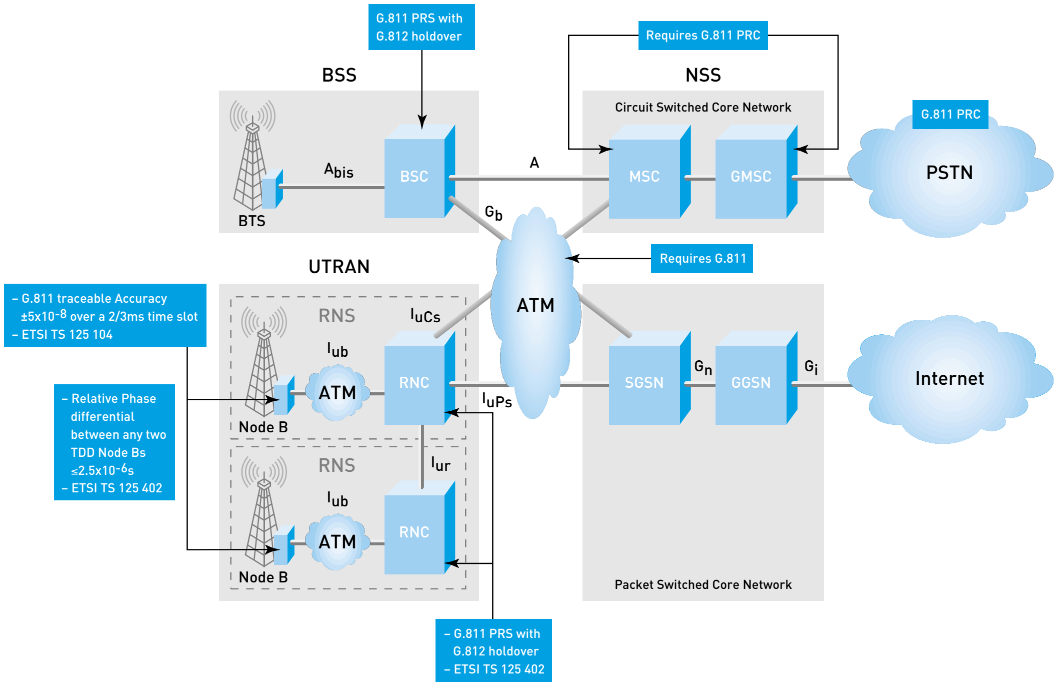


FIG.7 UMTS network showing the clock stability requirements as defined by the ETSI standards

1. Synchronization impacts QoS/QoE. Good QoS/QoE is crucial in highly competitive arenas.
   - WCDMA requires very good RF performance to minimize interference, enable successful handover, and maximize traffic throughput.
   - 3G networks are made up of a variety of very sophisticated technologies, most of which require synchronization to operate effectively.
   - 3G networks must maintain a high level of interoperability with other networks, especially legacy circuit-switched networks.
   - The high degree of standardization in 3G implies that the quality of synchronization, over and above that which is mandatory, may well be the technological edge required in a competitive situation.

2. Interworking between 2G & 3G is essential as networks evolve from 2G to 3G.
   - Air interface stability is essential for handover between 3G and 2G. Operators have experienced problems with handover as a result of differences in frequencies of the base stations. One operator found that the frequency offset was due to synchronization being derived from different sources, which arose from the use of diverse backhaul vendors. This is typical of situations where the operator does not have total control of synchronization.

3. Operators have found that current synchronization methods are insufficient for 2G, let alone 3G.
   - For networks to operate reliably at all times it is important that they have control of their own synchronization.
   - Many 2G operators still rely on synchronization derived from the incumbent (wireline carrier) or a third party provider.
   - The amount of traffic handled in 3G is large, making it far too important to ignore synchronization or to have it under the control of a third party.
   - 3G networks bring evolution complexities such as mixes of technology and convergence. Wireless operators have found that having their own synchronization platforms allows them to deal with these complexities, to work with different transport vendors more effectively, to ease planning requirements, and reduce the operational expenses associated with trouble-shooting network problems.

4. ATM systems use Adaptive Clock Recovery methods
   - This is not network synchronization. The recovered clock is based on the average cell/packet rate and it cannot therefore achieve the level of accuracy required for transmission of real time services or carrier frequency.

5. The introduction of aggregator hubs at remote sites is a cost effective way of concentrating traffic at the access layer before transporting it to the core network.
   - To enable this, ATM and SDH technologies are being used at these sites. Therefore synchronization is necessary for them to work effectively.

Synchronization Best Practices for UMTS Networks

Synchronization in wireless networks is often implemented only when things go wrong or when it affects network performance, e.g. high level of dropped calls, poor handover performance, degraded QoS/QoE and reduced traffic throughput. These can all lead to financial losses and loss of customers.

There are several ways of identifying synchronization problems in a network. Symmetricom and its partners provide audits that help operators measure and identify these. However, recent experience has shown that synchronization needs to be implemented at the onset to ensure that operators are fully prepared to deliver the demanding services and Quality of Experience that 3G customers will expect.

There are essentially three main aspects to network synchronization of 3G networks. The first is the 2G part of the network that is synchronized in the same manner as described earlier in this paper under "Best Practices for Synchronization of GSM Networks". The second is the aspect of the ATM infrastructure that needs to be synchronized as covered in the section titled "Connectivity in a 3G network". The third is the aspect of the UTRAN part of the network.

Synchronization of UMTS networks is achieved using some general guidelines together with the ETSI standards requirements. The ETSI standards are summarized earlier in this paper as well as in Figure 7. There are, however, three fundamental objectives for 3G operators to take into account:

1. The entire network must be G.811 traceable.
2. It is essential to maintain a stable air interface frequency.
3. Every element (node) must be properly synchronized in order to provide a high quality of voice and data traffic.

In order to achieve the first objective, it is important to ensure that the core network has its own G.811 PRC systems. Figure 8 shows a UMTS network that implemented its own synchronization platform. This is based on a real application within a major international wireless operator.

The operator has implemented Primary Reference Clocks (PRC) at two key sites. Each PRC comprises a cesium clock, GPS and an SSU. All other switching centers (MSC) are equipped with SSUs and GPS. Each SSU receives a reference from the PRC site via the SDH network and the GPS module provides a local Primary Reference Source (PRS).

As mentioned earlier in this paper, the access aggregator sites concentrate the traffic from several Node Bs. In some cases, the aggregators are co-located with the RNC and thus receive synchronization from the same system that feeds the RNC. However, more often than not, the aggregators are located at remote sites and thus the operators implement PRSs at each of these sites. These tend to be affordable solutions with holdover capability that will ensure the accuracy of $5x10^{-8}$ is maintained in the event that the PRS reference is lost.

Optionally, the clocks at these nodes can re-time feeds from 3rd party providers to guarantee the required level of quality and availability or to provide a way of providing clean synchronization to elements that do not have an external clock input.

In all examples, the operators implement an element management system with the aim of reducing OPEX savings by providing remote management of all the synchronization elements.

Conclusion

It is a known fact in the telecom industry that synchronization enables network operators to transport bits of information within and across network and national boundaries without losing bits of information along the way.

The benefits and reasons for deploying a synchronization platform in wireless networks are numerous. Here are just 10 of them.

1. Facilitates interoperability between different systems - 2G and 3G inter-system handover.
2. Facilitates interfacing to the PSTN/circuit switched networks.
3. Provides accurate and reliable air interface frequency.
4. Improves successful call handovers.
5. Ensures QoS/QoE is maintained thus increasing customer retention.
6. Improves new service adoption.
7. Facilitates efficient bandwidth utilization and decreases network load (fewer re-initiated calls).
8. Provides control of synchronization quality whether using own transport or third parties.
    a. Maintain quality of voice and data traffic over backhaul.
    b. Eliminate wander and jitter introduced by cascaded synchronization.
    c. Adds redundancy and reliability through holdover introduced by the use of SSU technology.
9. Allows operators to evolve their networks more effectively.
10. Conformance to standards.

It is crucial to achieve synchronization integrity because networks are expected to operate 24 hours a day all year round. This requires a highly accurate frequency source at all network elements that can only be accomplished by implementing a good synchronization network.

Some of the solutions can be derived from the best practices described in this paper and some may require a combination of concepts because of the complexity of today's networks.

In summary, it is essential to consider the following when building or evolving a network:

- The synchronization solution has to meet the requirements of the standards bodies.
- More importantly, it has to be sufficiently robust to enable the network to operate and perform consistently at all times.
- It must be simple to implement and manage.
- It should allow the network to grow and evolve.
- It should require minimum intervention.

Symmetricom designs, manufactures and markets atomic clocks, network synchronization systems and timing solutions for wireline and wireless networks. Symmetricom has gained recognition throughout the world as a leader in synchronization and timing. We offer our experience, professional services and solutions for all synchronization and timing needs.

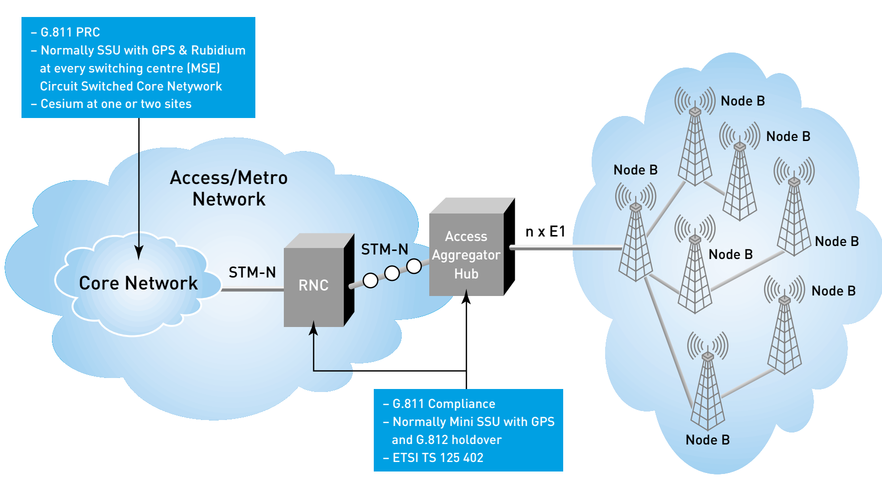


FIG.8 Example of a UMTS network showing the clock requirements

Glossary

2G	Second generation
3G	Third generation
3GPP	Third-Generation Partnership Project (of ETSI)
AAL2	ATM adaptation layer type 2
AAL5	ATM adaptation layer type 5
AMPS	Advanced Mobile Phone Service
ANSI	American National Standards Institute Standards Committee
ATM	Asynchronous Transfer Mode
AuC	Authentication Center
BSC	Base Station Controller
BSS	Base Station Subsystem
BTS	Base Transceiver Station
CBR	Constant bit rate (data stream)
CDMA	Code division multiple access
CDMA2000	3rd Generation Code Division Multiple Access
CN	Core network
CRNC	Controlling RNC
CWTS	China Wireless Telecommunications Standard
D-AMPS	Digital AMPS
EDGE	Enhanced Data rates for GSM Evolution
EIR	Equipment Identity Register
ETSI	European Telecommunications Standards Institute
FDD	Frequency division duplex
FDMA	Frequency division multiple access
GGSN	Gateway GPRS support node
GMSC	Gateway MSC
GPRS	General packet radio service
GSM	Global System for Mobile Communication
HLR	Home location register
HSCSD	High Speed Circuit Switched Data
IMT–2000	International Mobile Telecommunications 2000
ITU	International Telecommunications Union
I_u	Interface between RNC and CN
I_{ub}	Interface between Node B and RNC
I_{ur}	Interface between two RNCs
ME	Mobile equipment
MS	Mobile station
MSC	Mobile Services switching Center
NE	Network element
Node B	UMTS base station
NSS	Network Switching Subsystem
OAM	Operation, administration, and maintenance
PDH	Plesiochronous digital hierarchy
PRC	Primary Reference Clock
PRS	Primary Reference Source
PSTN	Public switched telephone network
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio access network
RNC	Radio network controller
RNS	Radio network subsystem
SDH	Synchronous digital hierarchy
SGSN	Serving GPRS support node
SONET	Synchronous optical network
STM	Synchronous Transport Module
STM-n	Synchronous Transport Module level n
TD–CDMA	Time Division–Code Division Multiple Access
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
UE	User Equipment
UMTS	Universal Mobile Telecommunication System
UTRA UMTS	Terrestrial radio access
UTRAN UMTS	Terrestrial radio access network
U_u	UMTS air interface
VBR	Variable bit rate
VLR	Visitor location register
WCDMA	Wide-band code division multiple access

References

1. ETSI Standards TS 125 401, TS 125 104, TS 125 402 & TS 125 411 and EN 300 462-3-1
2. ITU Recommendations G.803, G.810, G.811, G.812, G.822, G.823, G.825G G.703, G.704, G.709, G.783
3. Mobile Switch Center (MSC) and Base Station Controller (BSC) Synchronization white paper by Symmetricom, Inc. January 1999
4. ATM Networks and Synchronization white paper by Symmetricom, Inc., October 2002

SYMMETRICOM, INC.
2300 Orchard Parkway
San Jose, California
95131-1017
tel: 408.433.0910
fax: 408.428.7896
info@symmetricom.com
www.symmetricom.com