



## **Synchronization Deployment Considerations for IP RAN Backhaul Operators**

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With the growing demand for bandwidth, next-generation telecommunication service providers are migrating towards a converged packet-switched infrastructure extending from the core to edge of the network. This evolution is particularly evident within mobile networks where operators are attempting to reduce operational costs. Such cost reductions are accomplished by introducing an IP/Ethernet based infrastructure which extends from the Mobile Switching Center (MSC) all the way to the radio basestations at the network edge. Although the migration towards such next-generation mobile backhaul architecture provides significant benefits, it also presents a number of challenges to service providers. One of the key challenges is to ensure critical synchronization of all network elements is maintained when migrating from circuit-switched (i.e., TDM, SDH/SONET) to packet-switched (i.e., IP) technologies.

Several techniques exist today for network synchronization. Network Time Protocol (NTP) and Precision Timing Protocol (PTP or IEEE1588-2008) are two popular packet-based protocols for delivery of end-to-end synchronization across IP networks. This paper will focus on the use of PTP for synchronization but the arguments made are applicable to NTP as well.

## Synchronization Requirements

Synchronization is critical in legacy, circuit-switched networks for the alignment of traffic-bearing frames at each transport network element. Synchronization information is embedded within each frame and is recovered by all network elements along the circuit-switched path. This ensures the entire transport network is synchronized end-to-end, to a common reference clock in the network. Equipment at the network edge (such as a Base Transceiver Station (BTS) or NodeB installed at a cell site) is also synchronized to the same reference clock. On the other hand, an IP network consisting of routers and switches does not support this end-to-end synchronization chain. Consequently, packet-based synchronization techniques are required in order to deliver synchronization signals across IP networks to various devices at the network edge.

Cellular wireless networks are based on Frequency Division Duplex (FDD), Time Division Duplex (TDD) and Code Division Multiple Access (CDMA) techniques. Basestations use radio frequency (RF) signals at the air interface for communication with neighboring basestations and handsets. The 3<sup>rd</sup> Generation Partnership Project (3GPP) defines synchronization requirements at the air interface for various wireless technologies. These requirements are specified in terms of frequency accuracy and/or phase accuracy applicable at the RF interface of a basestation's transceiver. Wireless technologies that use FDD techniques require frequency synchronization, while technologies that use TDD and CDMA techniques, require both frequency and phase synchronization. Table 1 summarizes synchronization requirements for various wireless technologies.

The lack of synchronization at the basestation leads to RF interference. The resultant effect is degraded call quality, increased dropped calls during handoffs, excessive call setup times, lower bandwidth and inefficient usage of spectrum. Since wireless carriers compete on all of these important customer quality issues and pay millions or billions of dollars to acquire spectrum licenses, one can see how important synchronization is for the operator.

**“Synchronization is as important as power at the cell site.”**

**- CTO of European mobile backhaul provider**

**Table 1 – Synchronization requirements for wireless air interface technologies**

Wireless system	Frequency accuracy	Phase accuracy
GSM 2G	±50 ppb	Not required
UMTS	±50 ppb	Not required
CDMA2000 (US, Asia, 3GPP2)	±50 ppb	±3 µs; (± 10 µs worst case)
WCDMA (3GPP, Europe, Asia) and GSM	±50 ppb	±1.25 µs between timing reference and BTS; ±2.5 µs between basestations
Mobile WiMAX	±50 ppb	±2.5 µs down to ±1.0 µs for some WiMAX profiles
Pico RBS (WCDMA and GSM)	±100 ppb	±3 µs

In order to guarantee that the air interface requirements listed in Table 1 are met, operators generally require that timing equipment provide a frequency output that is accurate to within  $\pm 15$  ppb. This stricter requirement is needed in order to provide margin for the basestation, which takes the timing signal in as input to its internal phase locked loops and then modulates the signal for transmission over the air interface.

In addition to the air interface synchronization, there are a number of additional requirements imposed by the wireless operator on the IP Radio Access Network (RAN) backhaul provider. These are required by the legacy TDM interfaces (T1/E1, DS3) that are transported over the IP RAN using packet techniques such as Pseudo-Wire Emulation (PWE). The edge devices in the IP RAN must deliver the traditional TDM services to the basestation with the same quality as that provided by the legacy wireline service provider.

The ITU-T has defined several standards for synchronization for these legacy services. These standards (for example, G.823, G.824) specify jitter and wander limits in the form of synchronization masks for traffic-bearing links and synchronization interfaces in the network. Key among these, are the Maximum Time Interval Error (MTIE) and Time Deviation (TDEV) masks for synchronization interfaces – commonly known as sync masks. Synchronization signals at cell sites must comply with the sync mask in order to guarantee optimum performance of wireless networks.

### Synchronization Service Level Agreements

In addition to the synchronization requirements, the IP RAN backhaul network must meet fundamental performance levels and availability for the services it transports. Performance parameters for legacy services include Errored Second Ratio (ESR), Severely Errored Second Ratio (SESR), Bit Error Ratio (BER), Frame Delay, Jitter (bit), Delay Difference, MTIE, TDEV, and frequency accuracy. Some representative values for these performance parameters are shown in Tables 2 through 4.

**Table 2 – Transmission error performance requirements**

Performance parameters	Objective
Errored Seconds Ratio (ESR)	< 0.0005
Severely Errored Seconds Ratio (SESR)	< 0.00016
Bit Error Rate (BER)	< 1E-9

**Table 3 – T1/DS1 frame delay and jitter performance requirements**

Performance parameters	Objective
One-way frame delay	< 6 ms
Jitter (peak-to-peak) (UIpp)	< 20 ns (< 0.032 UI)
Delay difference	< 125 $\mu$ s

**Table 4 – Time/frequency accuracy performance requirements**

Performance parameters	Objective
MTIE	ITU G.824 (G.823) for T1 (E1) synchronization
TDEV	ITU G.824 (G.823) for T1 (E1) synchronization
Absolute frequency accuracy	< $\pm 15$ ppb

In order to meet the above requirements, the IP RAN backhaul provider has to meet additional performance criteria placed on the end-to-end packet transport network. Chief among these are the one-way delay, jitter (packet), packet loss rate, and throughput bandwidth. Representative values are shown in Table 5. Superior network synchronization is key to meet and monitor the objectives for delay and jitter in the milliseconds and throughput accuracy to 1ppm.

**Table 5 – Ethernet transmission delay, jitter and loss rate performance requirements**

Performance parameters	Objective
One-way delay	< 4 ms
Jitter	< 2 ms
Packet loss ratio	< 6.25E-7
Throughput bandwidth	Provisioned rate $\pm 1.0$ ppm (e.g., 10 MBps $\pm 10$ bps)

Ultimately, the wireless operator imposes the above requirements on the IP RAN backhaul provider, which then has to meet them. Contractually and financially, this is done in a Service Level Agreement (SLA), which specifies the performance parameters rolled up as Service Availability requirements. This is represented in terms of Error Free Seconds Ratio (EFSR), Annual Service Availability and Mean Time To Repair (MTTR) and perhaps other objectives as shown in Table 6. In order to bill for its services, the IP RAN backhaul operator must not only meet the service availability requirements but must also prove it is meeting the requirements by monitoring the network and providing reports.

**Table 6 – Service availability requirements**

Performance parameters	Objective
Error Free Seconds Ratio (EFSR)	99.95%
Annual service availability	99.995%
MTTR	< 2 hours

Poor synchronization in the network and at the cell site can lead to greater jitter, more errored seconds and severely errored seconds, data loss due to frame slips, and long recovery times, which greatly impact MTTR. Superior timing and synchronization at the cell site leads to fewer outages, fewer errored-seconds and reduced MTTR.

A service outage begins when a cell site is not in compliance with the technical performance specifications listed above. The wireless service provider assesses penalties on the IP RAN backhaul provider that increase as the duration of the outage increases since most of the technical performance specifications must essentially be met.

**Table 7 – Service outage penalties**

Service outage length	Credit per service
< 30 minutes	None
30 minutes to 1 hour	5% of monthly service charge
Each hour > 1 hour up to 4 hours	An additional 5% of monthly service charge
4 hours to 6 hours	50% of monthly service charge
Over 6 hours	100% of monthly service charge

## Synchronization Techniques

Historically, the most common synchronization approach for cell sites requiring frequency only (FDD, GSM and UMTS) has been for the basestation to derive timing and synchronization from the traffic-bearing T1/E1 interface. In these cases, the T1/E1 signal must meet the G.824/G.823 sync masks for jitter and wander. For these basestations, these requirements must still be met by the IP RAN backhaul provider with the same or better performance as the legacy wireline carrier that it is replacing.

Global Navigation Satellite System (GNSS—for example, GPS) is an approach to synchronizing cell sites that require phase (TDD, CDMA and WiMAX). While a GNSS-based technique provides accurate phase and time, it does have several drawbacks, which make it unreliable or unavailable under certain geographic and atmospheric conditions. GNSS is exceedingly susceptible to interference—intentional or unintentional—and is well known to be vulnerable to long-duration outages during solar activity such as solar flares. Furthermore, excessive installation costs and recurring operational costs are driving mobile operators to turn to other cost-effective techniques for delivering synchronization to their cell sites.

NTP and PTP (IEEE1588-2008) are two popular packet-based protocols for delivery of end-to-end synchronization across IP networks. Of these two protocols, PTP is considered to be more suitable for telecom networks and is being widely considered by mobile operators for the synchronization of wireless networks.

A PTP-based network synchronization solution consists of a grandmaster device serving timestamped packets to a number of slave devices over an IP network. The network itself is a complex array of routers and switches, interconnected across a variety of physical media. Network delays and delay variation (packet jitter) make the task of synchronization across such a network quite challenging. The key to addressing this problem lies in an optimized synchronization algorithm that has the ability to dynamically adjust itself to changing network behavior.

The grandmaster is typically installed in the core or aggregation regions of the network while a slave clock is installed at a cell site. A slave clock may either be embedded into or situated external to a BTS or a cell site router. An embedded slave clock is designed into a piece of equipment such as a cell site router and provides synchronization signals for consumption within the equipment. On the other hand, a standalone slave clock is installed as a separate device external to the equipment that uses the synchronization signals. A standalone slave clock is ideal for existing cell sites that are being upgraded to IP RAN backhaul or any site where there are more than one generation of wireless basestation or where there are more than one wireless carrier sharing the IP RAN backhaul.

## **Network Design Considerations**

Network architects and operators who are designing next-generation networks must be aware of several key considerations for deploying synchronization solutions across their networks. A proper understanding of these aspects will go a long way in mitigating operational hurdles and improving the overall efficiency of the network.

### **Network Characteristics**

Today's backhaul networks use a variety of physical media: fiber, copper, point-to-point microwave, PON, etc. Each of these network types has unique characteristics that affect packet delay and delay variation. The slave clock has a significant role to play in filtering and processing timing packets that traverse these disparate network types. An effective synchronization solution must be capable of delivering consistent and accurate synchronization across all these networks.

### **Frequency and Phase Recovery**

As shown in Table 1, wireless systems have a need for frequency synchronization, phase synchronization, or both. Frequency synchronization can be achieved by adaptive timing techniques or by one-way packet-based timing protocols. The adaptive technique recovers timing signals based on the arrival rate of data packets and does not use specific timing packets for this purpose. Hence, this technique may also be referred to as an "in-band" technique. By contrast, an "out-of-band" technique employs special timing packets to transfer time from the grandmaster to the slave clock. While unidirectional transfer of timing packets from the grandmaster to the slave clock may be sufficient to achieve frequency synchronization, phase synchronization requires that timing packets be exchanged in both directions, i.e., from grandmaster to slave and from slave to grandmaster. Depending upon the specific wireless technology being deployed, network operators must consider the need for unidirectional or bidirectional timing flows in their network.

### **Interoperability**

With the growing popularity of PTP, a number of equipment vendors are integrating PTP solutions into their products. A typical deployed network could possibly consist of grandmasters and slave devices from different vendors. In order for these devices to interoperate it is important that they are standards-compliant. Interoperability testing entails testing several aspects of functionality such as:

- Basic protocol compliance and options supported;
- Message parameters and values supported;
- Multicast and unicast modes;
- PTP profiles;
- Message rates.

### **Vendor Independence**

As noted earlier, an embedded slave clock essentially provides synchronization signals that are consumed within the device into which it is embedded. These signals are rarely terminated on external connectors and hence are not available for other devices to use. In contrast, a standalone slave clock provides synchronization signals that can be connected to physical synchronization ports (BITS, 1 PPS or Time-of-Day ports) of various devices regardless of the manufacturer. This approach provides network operators a synchronization solution that is both vendor-independent and flexible to support multiple basestation sites and multiple carrier sites whereas an embedded solution in a basestation only works for the station where it is embedded.

## **Synchronization Performance and Holdover**

3GPP standards specify synchronization requirements at the air interface for various wireless technologies. Other telecom standards such as ITU-T's G.811, G.812, G.823 and G.824 specify synchronization requirements at physical interfaces in the telecom network. An effective synchronization solution must meet both 3GPP and ITU-T requirements. The ITU G.8261 standard specifies network topologies, traffic patterns and test cases for testing synchronization performance in IP networks using symmetric and asymmetric data rates. Synchronization solution vendors are required to validate the performance of their solution in a G.8261 network consisting of a certain number of network hops. Thus, G.8261 serves as a useful reference point for network operators to compare synchronization solutions from different vendors.

*Holdover*—the ability of a clock to provide an accurate timing signal in the absence of a reference timing input—is another key consideration in picking the right synchronization solution. The importance of holdover is best illustrated with an example. Imagine a scenario where a grandmaster clock is providing timing packets to 200 slave clocks located at cell towers that are geographically distributed. In a normal situation, the grandmaster is locked to a global reference such as GPS or to a master atomic clock. The slaves are all locked to the grandmaster and the synchronization signals generated by the slaves meet 3GPP and ITU-T specifications. Assume now that during the course of routine maintenance, a technician inadvertently pulls out a cable from, or misconfigures, one of the routers in the network, thereby disconnecting the grandmaster from the slaves. The 200 slave clocks now stop receiving timing packets and begin drifting in frequency and phase. In the absence of holdover, these clocks will exceed the ITU G.823 synchronization mask for phase accuracy in typically less than 15 minutes and cause degraded performance in the entire geographic region. For longer outages, the accumulated drift can result in an accumulation of over 125  $\mu$ s of delay difference (see Table 3) resulting in a frame slip. However, if the 200 slaves enter into a holdover state, they will continue to provide an acceptable timing signal while the problem in the network is diagnosed and resolved. A slave clock with excellent holdover can then still provide frequency and phase during a network outage or grandmaster-unreachable event without causing a service availability issue for outages up to 4 to 6 hours for the G.823 requirement and up to 3 days before a frame slip. Therefore, holdover performance is a key to meeting service availability requirements.

## **Synchronization lock time**

When a grandmaster or slave clock is powered up, or when a synchronization reference is restored after failure, the device will typically take some time to qualify the reference and declare that it is usable. If the failure is related to the loss of GPS signals at the grandmaster, the qualification involves both satellite re-acquisition and oscillator lock time. Regardless of the cause of the failure, it is important that the grandmaster and slave clocks quickly re-qualify a restored synchronization reference and come out of a holdover mode. Lock times are typically longer during cold start (i.e., when the system is powered up) than during warm start (i.e., soft system reboot). Since wireless operators specify MTTR in their Service Availability SLA, it is important that the timing system locks quickly, stays locked or in non-service-impacting holdover and reacquires quickly. As noted in Table 7, service outage penalties accrue even as quickly as 30 minutes and increase rapidly thereafter. Therefore quick reacquisition of lock upon restoration is a key consideration as is the ability of the system to holdover through the network outage so that synchronization is never out in the first place.

## **Bandwidth usage/Quality of Service**

Network operators often measure the efficiency of their network in terms of revenue-per-bit, which is a ratio of the total revenue earned to the total bandwidth served per user. This metric is obviously maximized when bandwidth usage is minimized. Minimizing the bandwidth used for synchronization purposes thus directly affects the Return on Investment (ROI) of the network. Synchronization bandwidth can be minimized by reducing the number of messages exchanged between the grandmaster and the slaves. In the presence of high network delay variation (or jitter), a slave clock will typically expect to receive a larger number of timing packets from the grandmaster than it would under quieter network conditions. It is advised that the operator assign timing packets to the highest (or higher) Quality of Service (QoS) levels with Expedited Forwarding (EF). High QoS with EF will reduce the jitter seen by the timing packets and reduce the number of timing packets.

In terms of network bandwidth usage, one must consider the total number of clients and the protocol specifics. PTP supports a number of profiles, such as "Telecom Profile," which requires unicast forwarding of SYNC and DELAY\_RESP packets from the grandmaster to the slave (downstream) and unicast forwarding of DELAY\_REQ packets from slave to grandmaster (upstream). Typical timing packet rates

are 32 packets per second. Timing packets are about 800 bits in length. This results in upstream and downstream bandwidth usage of about 25.6 kbps and 51.2 kbps per slave. A network of 200 slaves then requires 5 Mbps/10 Mbps upstream/downstream. If the operator supports multicast, it can use the “Brilliant Profile” to reduce the bandwidth requirements to 5 Mbps in each direction since the SYNC packets can be delivered in multicast.

In general, a well-designed synchronization algorithm can use fewer timing packets and still cope with high levels of network jitter, thus minimizing the bandwidth used for synchronization and ensuring higher revenue-per-bit numbers for the operator.

### Serviceability

Carriers and service providers spend a significant portion of their budget on equipment maintenance. Expensive truck rolls can be avoided by remotely managing synchronization equipment through industry-standard interfaces such as SNMP and HTTP. Even if a truck roll is unavoidable, standalone slave clocks can be easily serviced using field replacement units. Servicing an embedded slave clock is non-trivial and typically requires bringing several traffic-bearing links down and causing significant operational risks.

### Network monitoring

The end-to-end network is rarely owned entirely by a single operator. Portions of the network are owned by different carriers, who lease out the links or sell bandwidth to service providers. As dictated by SLAs between a carrier and its customers, the carrier is expected to guarantee a certain level of service, which is measured using several metrics such as network delay, jitter, packet loss, synchronization quality, etc. A well-designed synchronization solution can provide such metrics to carriers and service providers as a value-add to the basic synchronization function. It is expected that these metrics can be easily integrated into the carrier’s or operator’s network management system through standard management interfaces.

### Synchronization Solutions from Brilliant

With deep-rooted experience in IP technologies, Brilliant Telecommunications, Inc., has developed a broad portfolio of products specifically designed to address the complex timing and synchronization requirements in today’s fast-paced networking environments. Brilliant’s product portfolio includes PTP (NTP) grandmasters (servers) and slaves (clients) in the form of standalone devices as well as embedded solutions.

The Cern C-2000 is a Primary Reference Source that supports both PTP and NTP. The C-2000 uses GPS as a timing reference and serves PTP/NTP timing packets to slave clocks or clients situated at the network edge. The standard product uses an OCXO as the local oscillator and provides up to three days of holdover. For longer holdover times, a Rubidium-based oscillator option is available and can provide holdover for up to 7 days. Besides serving timing packets, the C-2000 also provides eight BITS timing outputs, a 1 PPS output that is phase-aligned to GPS, a 10 MHz output and others. With its broad range of outputs, the C-2000 serves as a timing source for next-generation and legacy applications. The C-2000 is designed for industrial temperatures and is available in a 1-RU form factor as a 19-inch rack-mountable unit.



The BT-750 is a standalone slave clock that receives PTP/NTP timing packets from a grandmaster (such as the C-2000) and generates legacy timing (BITS) outputs for synchronizing equipment at cell sites. The standard BT-750 uses an OCXO as the local oscillator and provides up to three days of holdover. The synchronization algorithm has been tested for frequency and phase accuracy in a variety

of network types including Fast Ethernet, Gigabit Ethernet, xDSL and microwave networks across more than 10 hops. The synchronization performance in these tests exceeds the G.823 sync mask requirements with a significant margin. The BT-750 is available in a 1-RU form factor and takes up half a 19-inch rack, permitting two units to be co-located for redundancy purposes. The BT-750 also

supports software options to double up as a non-intrusive network monitoring tool that provides useful information such as upstream and downstream network delays and jitter.

Brilliant's embedded solutions include timing modules and FPGA-based software for deep integration into equipment such as routers, switches, basestations, etc.

## Synchronization in Microwave Networks

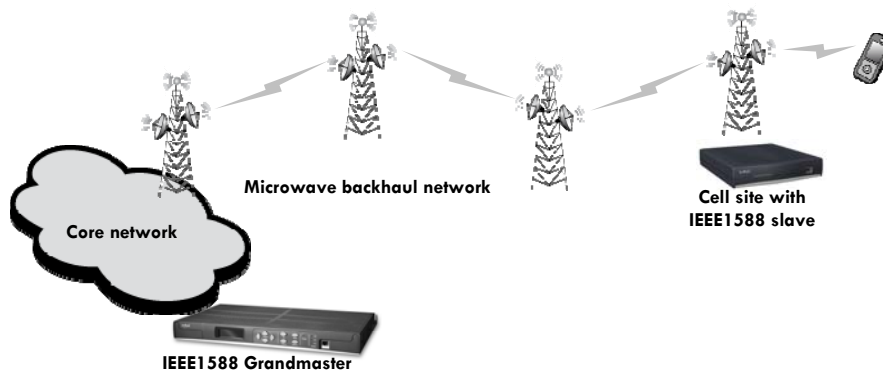
Microwave networks are a popular alternative to wired networks for the transport of voice, video and data. While some service providers have been deploying entire networks consisting of microwave links, others are using a combination of wired and microwave links, particularly to provide last-mile connectivity in some geographic regions. Some of the advantages of microwave links include:

- Easy installation and faster network rollout;
- Lower capital expenditure when compared to wired network infrastructure;
- Lower operating costs;
- Network design flexibility.

Despite the many advantages, microwave networks come with some disadvantages too. Microwave propagation happens along the line of sight and is affected by several factors, such as the dielectric constant of the atmosphere, weather fronts, rain attenuation, multipath fading and delay distortion due to impedance mismatch in waveguides. These factors cause not only signal impairments, but also variable transmission delays especially when radios implement Automatic Modulation Rate (AMR). This makes delivery of packet-based timing across microwave networks particularly challenging since timing packets also experience higher packet delay variations.

Figure 1 shows a typical multi-hop microwave backhaul network for transporting IP traffic from a 3G cell site. The network also delivers synchronization signals from the IEEE1588 grandmaster located in the core to the IEEE1588 slave at the cell site. The slave recovers synchronization signals from a stream of timing packets delivered across the microwave hops. These synchronization signals are consumed by a number of devices at the cell site and are also used for the synchronization of the radio interface at the cell tower.

**Figure 1 – Delivery of synchronization over a multi-hop microwave network**

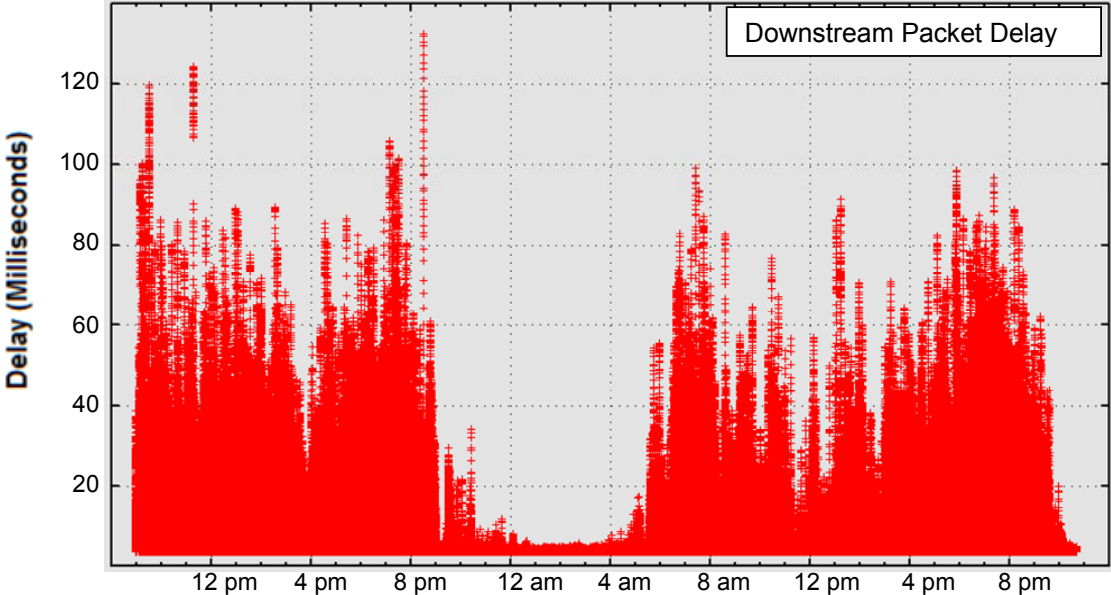


Figures 2 and 3 show a typical example of downstream and upstream packet delays measured across a 5-hop microwave network. The downstream and upstream minimum delays are 3.5ms and 3.1ms, respectively. The downstream jitter is 130ms. The upstream jitter is generally 3ms but with a burst to over 100ms.

These levels of delay and jitter as well as the large jitter events pose a significant challenge to timing and synchronization systems which must filter through the noise to deliver phase accuracy less than just 3 $\mu$ s. Indeed, when delay and jitter are in excess of 100ms this reduces the quality of VoIP as measured by Mean Opinion Score (MOS). These test results clearly show that there are significant periods of time where VoIP is impacted.

Figure 4 shows the performance of Brilliant's BT-750 in a microwave backhaul field trial network. The MTIE chart is the carrier accepted measure for phase accuracy and stability and Brilliant's performance clearly exceeds the G.823 SEC MTIE requirements.

**Figure 2 – Downstream delays in a 5-hop microwave network**



**Figure 3 – Upstream delays in a 5-hop microwave network**

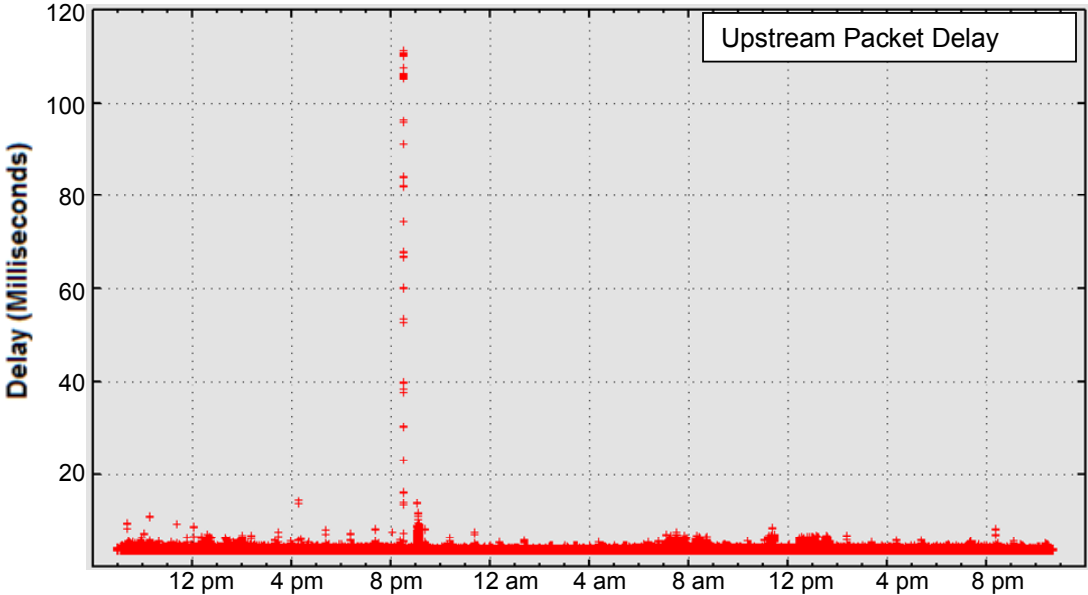
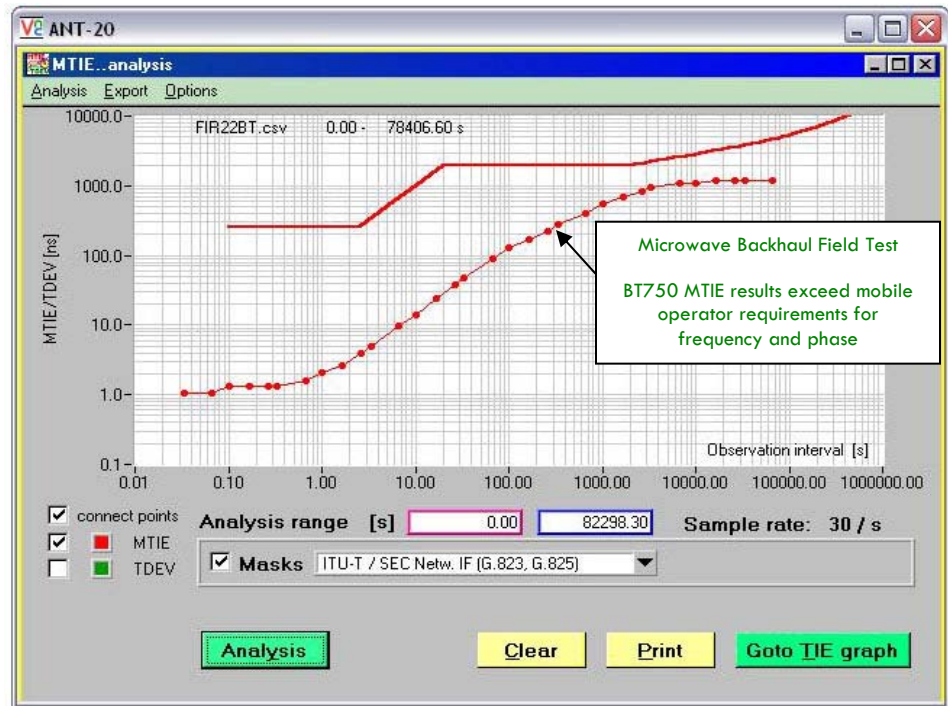


Figure 4 – Brilliant network timing over a microwave network



As discussed earlier in Table 5, packet delay and packet jitter are important performance metrics that are an integral part of an SLA between a wireless service provider and an IP RAN backhaul network provider. Since huge penalties are tied to SLA conformance, precise measurement of these metrics is the key to saving or losing millions of dollars in penalties. Fortunately, a well-designed end-to-end synchronization solution can facilitate precise measurement of network delays and jitter. The granularity of the measurement will depend on the phase accuracy of the recovered timing signal at the slave. Field testing shows that Brilliant’s products provide accuracy to better than 3 $\mu$ s in these demanding networks.

Brilliant’s TimeProbe software is an optional component that runs on a slave device (such as the BT-750 or an embedded timing module) to provide access to critical performance data. When installed on a slave device, the TimeProbe software periodically measures network delays and jitter and maintains an internal log of this information. Network operators and service providers can use industry-standard management interfaces such as HTTP or SNMP to retrieve this information. An important feature—Threshold Crossing Alarms—allows operators to configure the software to trigger an alarm whenever the network delay or jitter exceeds a preset threshold, such as 4ms delay with 2ms jitter for TDM and 100ms delay with 30ms jitter for VoIP. This capability provides a crucial early warning to operators about impending and/or existing problems in their network.

**Figure 5 – TimeProbe charts showing delay and jitter measurement**

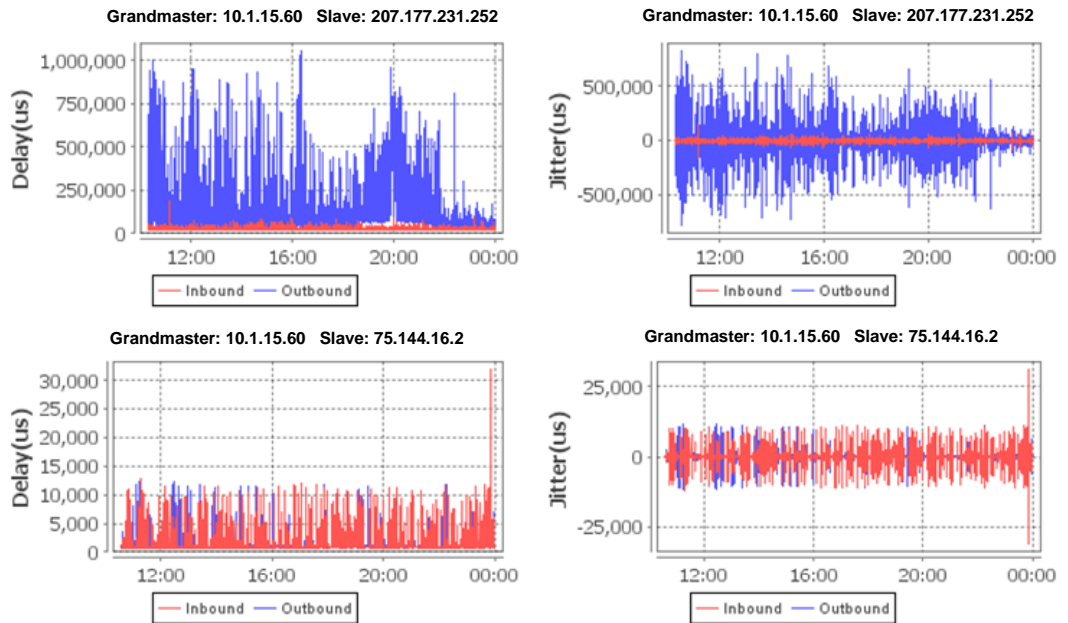


Figure 5 shows sample delay and jitter charts generated by TimeProbe agents installed on a grandmaster with IP address 10.1.15.60 and slaves with IP addresses 207.177.231.252 and 75.144.16.2.

The key features of TimeProbe include:

- Installable option for Brilliant’s BT-75x or embedded slave modules
- Integrated into SyncEMS platform
- Non-intrusive measurement of Key Performance Indicators (KPIs) between grandmaster and slave devices across IP network
  - Integral part of service provider’s network operations
  - Provides real-time and historical measurement of delay, jitter and packet loss
- Microsecond accurate delay and jitter measurement
  - One-way and two-way statistics
  - Metrics measured between grandmaster and slave acting as end points
- Statistics based on class of service
  - Web-based chart view
  - Historical statistics view
- Threshold Crossing Alarms for early warning of impending network problems

The TimeProbe software thus provides key insight into network performance for operators and allows them to leverage their investment in synchronization solutions through additional, value-added features that enable SLA conformance.

## Summary

The mobile wireless network infrastructure has a strong dependence on accurate synchronization at various points in the network. While a number of techniques are available to synchronize these points, packet-based out-of-band techniques that employ timing protocols are gaining prominence within the telecom industry. In particular, PTP is being viewed by the industry as the de-facto mechanism for delivery of synchronization across IP networks. It is important that service providers and carriers understand the key parameters involved in deploying PTP in their networks. Brilliant's products have been designed with these key parameters in mind, based on years of experience gained through live network deployments as well as multiple ongoing field trials in a variety of access network types.

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