RFDESIGN
RF AND MICROWAVE TECHNOLOGY FOR DESIGN ENGINEERS

Changes in base station backhaul drive new sync solutions

As more mobile network operators deploy high-speed data services using IP backhaul, the need for stable and accurate frequency reference becomes more critical. This need is particularly apparent for applications such as successful hand-offs between base stations and the transport of real-time services.

By Barry Dropping

Mobile operators are racing to deploy high-speed data services in order to acquire and retain lucrative mobile professional users. Because high-speed data services require increased backhaul capacity, mobile operators are seeking alternative, lower-cost backhaul methods in order to meet increasing data demands. At the same time, cost-reduction measures must not sacrifice consistent and high-quality service. As the network shifts to an Internet protocol (IP) backhaul, maintaining precise frequency distribution throughout the network is essential for maintaining service level assurance. The quality of synchronization mobile operators put into their network directly impacts the quality of service (QoS) that comes out of their network.

The transmission of voice, video and data through any communication network requires a stable frequency reference, and precise frequency synchronization is especially critical in mobile networks for the successful call signal hand-off between base stations as well as for the transport of real-time services. Global system for mobile communications (GSM) and universal mobile telecommunications system (UMTS) base stations must hold a carrier frequency accuracy of ±50 parts per billion (ppb) over the 10-year service life of the equipment. If individual base stations drift outside the specified 50 ppb limit, mobile hand-off performance decays, resulting in high dropped-call rates, impaired data services, and, ultimately, lost customers. The problem is, as more networks transition to an IP-centric backhaul, these changes in the backhaul also impact how the network derives an accurate sync feed.

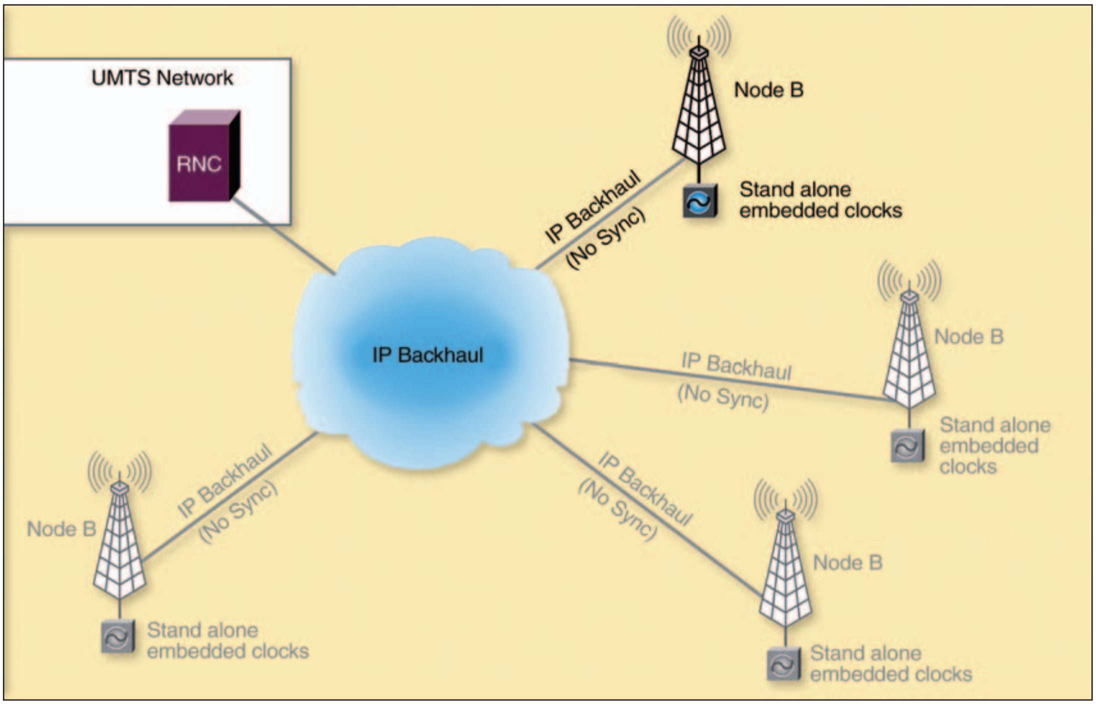

Figure 1. The transition to high-capacity IP backhaul drives the need for stand-alone embedded clocks in UMTS Node B base stations.

Timeframe	Base Station Transport	BTS Sync Reliability/Availability
Yesterday	Tightly controlled transport provided by the PTT/ILECs	Reliable sync recovery
Today	Complex menu of alternate backhaul providers and transport topologies	Uncertain sync recovery
Tomorrow	High-capacity, low-cost IP/Ethernet backhaul pipes	Sync recovery no longer available

Table 1. Mobile operators need to take direct control of synchronization at their base station sites to assure high QoS.

Node B Sync Technology Options	Strengths	Weaknesses
Span Line Timing	• Lowest-cost solution relying on existing backhaul network to provide synchronization	• Unpredictable and reliant on the facilities provider(s) • No longer an option when the backhaul shifts to IP/Ethernet transport
Embedded Rubidium Oscillator	• Most robust solution • Install and forget • Greatest stability over 10+ year service life of the base station	• Moderate initial Capax increase
Embedded Quartz Oscillator	• Lower initial equipment cost	• Likely to drift and result in higher dropped-call rates over time • High Opex (truck rolls to tune oscillator)
Embedded GPS	• Stratum 1 traceable • Provides time and location data	• Higher Opex to install and maintain GPS antenna runs • Reliant on GPS

Table 2. Compact Rubidium oscillators provide the most robust solution over the life of UMTS node B base station equipment.

Factor	Result
Before—Minutes of use per drop	159.4
After—Minutes of use per drop	200.1
Delta (improvement)	40.7
	25.5%

Notes:
- T1 backhaul transmission links were verified as good
- Based on one full week of data before the installation and two full weeks after
- Minutes per use per drop is defined as (total minutes of voice traffic)/(total number of dropped calls)

Table 3. Reduction in dropped calls was realized by a major GSM operator when backhaul synchronization signals were retimed.

GSM base stations have traditionally derived their long-term frequency accuracy from locking a relatively low-performance quartz oscillator embedded in the base station to a recovered clock signal from a T1/E1 leased line backhaul facility. Timing signals based on a primary reference source (PRS) transmitted over the backhaul keep the embedded oscillator calibrated to within sufficient accuracy. Without a well-synchronized backhaul feed to lock to, the oscillator frequency would drift out of specification in a matter of months, requiring regular and costly service calls to manually calibrate oscillators across base stations throughout the network. Thus, a reliable and accurate clock source is required for accurate synchronization.

It is important to note that even base stations that still make use of a T1/E1 time-division multiplexing (TDM) backhaul are beginning to experience levels of degradation that reduce QoS to the point that customers notice. Latency, jitter and wander were fairly consistent in the past, given how well-timed T1 lines were. However, as many backhaul providers increase the use of circuit emulation or IP encapsulation technologies to reduce their infrastructure costs, consistency of synchronization suffers. In addition, many providers are now transporting T1/E1s over a synchronous optical network (SONET) that introduces large phase deviations due to SONET pointer adjustments. SONET pointer adjustments can significantly degrade the stability of synchronization seen at the base station. The introduction of such errors can be large enough to isolate a base station, effectively cutting it off from its source of synchronization. As synchronization instability increases, so does the number of dropped calls, as does the number of customers that consider migrating to the competition.

Until recently, synchronization of GSM base stations has been taken for granted.

Until recently, synchronization of GSM base stations has been taken for granted. As long as the T1/E1s were well timed, the base station could hold the 50 ppb requirement indefinitely. However, as backhaul transport evolves toward IP, base stations can no longer rely on recovering synchronization from the network side. In order to maintain consistent, quality connectivity, base station equipment manufacturers and backhaul service providers must take timing into consideration. New methods of synchronization are required to meet rising expectations of next-generation mobile users (Table 1).

Timing isolation through IP

When base stations carried just voice traffic, a single T1/E1 connection typically provided enough bandwidth for the backhaul connection. The rollout of third-generation (3G) data services, however, has increased the bandwidth needs for the backhaul connection significantly and moving to T3/E3 connections is simply too expensive.

Transport networks are rapidly evolving to IP-rich topologies. This offers mobile operators the increased backhaul capacity they require for deployment of high-bandwidth data services and the cost advantage of IP transport. However, the move to Ethernet backhaul will eliminate the option for base station clock recovery from the backhaul facility. Operators will need to move to an independent source of synchronization at the base station to meet the UMTS 50 ppb requirement (Figure 1).

In addition to traditional span line clock recovery where the base station recovers an accurate clock from the T1/E1 backhaul feed, UMTS Node B infrastructure suppliers are introducing high-quality embedded clock options to be ready for IP backhaul. Many of these options mirror code-division multiple access (CDMA) 2000 designs where GPS clocks are embedded into the base stations to provide a time-of-day reference needed for call hand-offs. CDMA networks have always relied on embedded GPS-based clocks with precision rubidium or quartz oscillators, making them inherently prepared for the evolution to IP backhaul from a sync quality point of view. Table 2 provides a summary of base station clock options for UMTS.

Using rubidium-based oscillators is the most robust solution for independent synchronization of UMTS base stations, as rubidium oscillators are proven to meet the 50 ppb requirement over the full service life of the equipment. Quartz oscillators, on the other hand, are subject to higher native aging rates and warm-up/restabilization characteristics that make it difficult to assure compliance to the 50 ppb requirement for more than a few years. This exposes network operators to QoS degradation and potentially high maintenance costs associated with manually calibrating quartz oscillators to bring them back on frequency after only a few years in

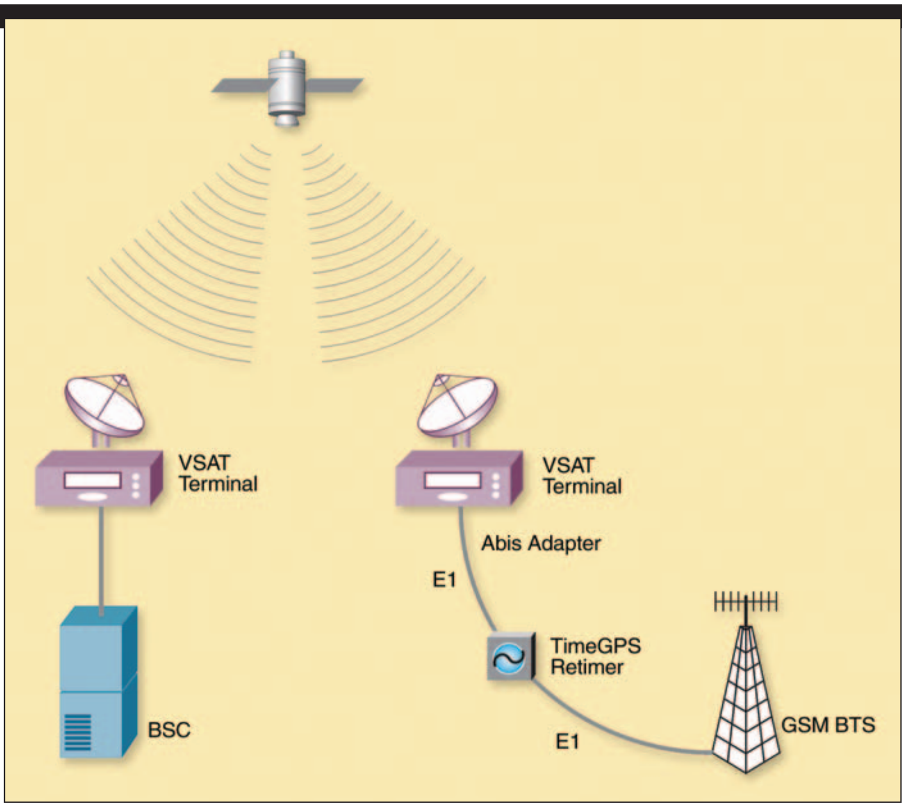

Figure 2. Satellite backhaul providers rely on GPS-based retimers to insert quality synchronization onto the T1/E1 feed to the base station.

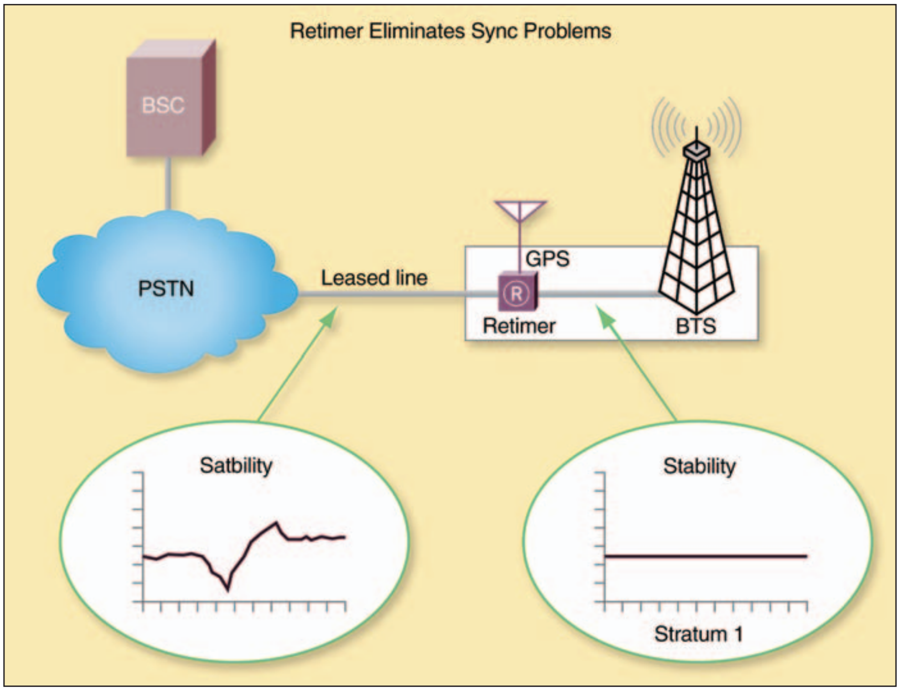

Figure 3. Circuit emulation and IP encapsulation introduce instability to network timing signals.

One of the more promising technologies currently under study is the Institute of Electrical and Electronics Engineers (IEEE) 1588 Precision Time Protocol.

the field. The danger to the operator is that this type of failure is undetectable until QoS issues reach a critical threshold.

GPS-based timing

A problem occurs for legacy GSM base stations that have relied on recovering synchronization from traditional T1/E1 backhaul lines provided by the incumbent local exchange carrier/public telephone and telegraph (ILEC/PTTs) to maintain their 50 ppb frequency accuracy requirement. Changing the backhaul to circuit emulation services (CES), such as the satellite transport as shown in Figure 2, requires that a local source of synchronization be placed at the base station to deliver an accurate clock reference since the satellite network cannot support the 50 ppb requirement on its own. There are two ways to achieve this: 1) install an external GPS clock to externally time the base station equipment, or 2) use a GPS-based retimer as shown in Figure 2.

A GPS-based retimer buffers incoming traffic and clocks it back out with PRS level accuracy (Figure 3). A retimer can be transparently introduced to an existing base station as the retimer is placed on the backhaul feed directly before the base station. The timing signal the base station receives is reclocked to be precise and stable, enabling accurate synchronization between base stations.

Note that the retimer itself requires access to a PRS-based clock. Typically, this is achieved using an integrated GPS receiver. Such a retimer should implement a cut-through mechanism to preserve communications when the GPS signal is not available, eliminating the retimer as a point of failure. When cut-through is enabled, the base station will revert to the original backhaul timing scheme and its original dropped call rate without the retimer. In this way, retimers can only improve quality, never reduce it.

Retimers can result in a dramatic reduction in dropped calls. A five-cell field trial conducted in September 2004 with a major GSM operator resulted in a 25.5% reduction in dropped calls when the backhaul synchronization signal was retimed (Table 3). The five base stations involved in this test were experiencing relatively high dropped

Accurate synchronization is the Achilles' heel of today's mobile cellular networks.

call rates, and synchronization impairments on the backhaul lines were suspected as the root cause. Note that these measurements include call hand-offs with base stations not using retimer synchronization feeds. While there was still significant improvement in these cases, the most substantial improvement was realized when both base stations involved in the call hand-off were retimed.

Stability over IP

Certainly, the future is moving toward IP and lower operating costs. To achieve this without an external synchronization source such as a global positioning system (GPS) retimer, however, carriers must find a way to reliably tunnel timing signals through the IP network. One of the more promising technologies currently under study is the Institute of Electrical and Electronics Engineers (IEEE) 1588 precision time protocol. The IEEE 1588 standard was developed to support Ethernet local area network (LAN) environments for applications such as factory automation where distributed motors and servos need to be accurately time synchronized. At this time, the IEEE has opened a working group to study the feasibility of enhancing the IEEE 1588 protocol for use in telecom wide area network (WAN) applications. The IEEE 1588 precision time protocol is based on a master clock exchanging two-way timing packets over Ethernet with slave clocks embedded in the equipment requiring synchronization. For example, carriers would place master clocks in their network, which would serve multiple local base stations, typically within a few hops from the master clock.

To support IEEE 1588, all base stations would have a client that would calibrate itself to the master clock using a two-way protocol. The master clock could be implemented as a stand-alone server located in the wireless network, or within a metro Ethernet network.

Primary technical challenges faced by IEEE 1588 for applicability in telecom networks include whether carriers will be able to constrain the number of network hops between master clocks and slave clocks, as well as whether delay variation can be sufficiently contained as too much jitter and wander would compromise IEEE 1588 accuracy. Realistically, standardization activity has just begun and it may take considerable time for the standard to emerge. In addition, the performance of IEEE 1588 over a wide area network in various traffic conditions and backhaul network bandwidth/speeds is yet to be studied or understood. In the mean-time, carriers will still need to address increasing instability in their backhaul connections.

The future of the telecom industry is IP. However, in order to keep customers long enough to enjoy infrastructure savings, carriers must implement mechanisms for maintaining quality connectivity through synchronization accuracy. Accurate synchronization is the Achilles' heel of today's mobile cellular networks. The cost of customer churn as a result of poor QoS from dropped calls and other sources can dwarf the savings achieved by moving to IP. While efforts are in motion to increase the reliability of clock signals transported over IP, carriers need mechanisms they can deploy today. Stand-alone compact rubidium oscillators, and GPS-based PRS feeds and retimers restore stability to critical timing signals essential for accurate synchronization in a manner completely independent of whichever backhaul flavor a particular base station employs. For base stations that have not yet moved to IP, retimers can effectively compensate for the creeping degradation of the TDM network. RFD

ABOUT THE AUTHOR

Barry Dropping joined Symmetricom in October 1999 following Symmetricom's acquisition of Hewlett-Packard's communication synchronization business as director of wireless OEM products. Before coming to Symmetricom, Dropping spent 15 years at Hewlett-Packard where he served in a variety of management positions across engineering, marketing and operations. Dropping holds a BS in Electrical Engineering Technology from the DeVry Institute. He can be reached at BDropping@symmetricom.com.