



Packet Synchronization in Cellular Backhaul Networks

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INTRODUCTION

For carriers to leverage cost-effective IP networks to handle the increased bandwidth expected from 3G and 4G services they need to know the issues surrounding time synchronization and the solution provided by IEEE1588v2, a standard for network-based timing and synchronization. This whitepaper explores the issues surrounding the need for synchronization and the solution provided by the IEEE standard. Additionally, we look at the solution provided by Semtech's ToPSync™ technology.

THE NEED FOR SYNCHRONIZATION

Synchronization is a fundamental technology building block of today's service provider networks. The performance of the traditional wired T1/E1, SONET, and SDH networks are based upon constrained clock control theory and PLL design. This type of synchronization signal is closely bounded frequency. The synchronization signal delivery system used in today's practice is based on the physical layer of the transmission system providing a clock signal. This signal is disciplined by electronic circuits to provide the frequency accuracy, stability, phase movement control, wander filtering and edge jitter (phase noise) levels specified in volumes of standards documents. Each "end customer service" has a specific set of performance requirements detailed in these documents. This performance is defined by the various international standards bodies and is well understood.

There are two mobile wireless network synchronization schemes. One that uses the same technology as wired networks. This is used to provide FDD (frequency division duplex) radio-based mobile wireless network synchronization signals for ingress/egress of data and accurate radio frequency. For example WCDMA FDD is the most popular method of radio air interface used in GSM systems.

The second is synchronization of TDD (time division duplex) radio based mobile wireless networks. This radio technology requires both the frequency accuracy from the above discussion, plus phase alignment and, in certain cases, time alignment between all basestations in the cell network. Examples of TDD radio systems are CDMA, CDMA2000 and Mobile WiMAX 802.16e. The traditional wired "circuit" oriented synchronization signal delivery system cannot be used because there is no phase or time relationship between signal termination points on the clock distribution network.

All four mobile wireless network synchronization requirements require having an inter base station aligned timing reference. This is essential to guarantee transport channel alignment for handoff and guard band protection. For 3GPP

specified FDD systems, frequency accuracy better than 50 ppb (parts per billion) is required. The 3GPP TDD systems require an inter base station time alignment of 2.5 μ s to 10 μ s in addition to the 50ppb frequency accuracy. The IEEE 802.16e mobile WiMAX requirements are 20ppb of frequency accuracy and 1 μ s of phase alignment. Ensuring the fulfillment of these requirements reduces the call drop rate and improves the quality of services by decreasing the packet loss. This is how it works today and will continue to work when new backhaul techniques are implemented.

So what's the big deal if this technology is so well understood and bounded by standards? Simple, T1/E1 circuit-based technologies are dedicated to the individual service they are delivering. Each service end point bears the cost the entire circuit path 24 hours per day, 365 days a year. Considering the scale of billions of circuits worldwide, the costs of service delivery present a significant barrier to profitably providing higher bandwidth service offerings. For example these circuits can consume up to 40% of the total operating expense for a mobile wireless operator. The cell phone customer pays for this in their ARPU (Average Revenue Per User). This market force is driving the move to the shared resource of packet based Ethernet backhaul. The cost per megabit ratio comparison of a T1/E1 circuit versus ethernet based packet backhaul averages 6 to 1.

With these metrics it is easy to understand the motivation of the service provider to migrate to the cheaper Ethernet transport. This brings us to the reason for this whitepaper and the Semtech ToPSync semiconductor product family. This family includes master and slave semiconductors in fit-for-purpose devices.

The provision of synchronization for the future mobile networks will pose new challenges triggered by the following factors:

- New mobile networks will offer new content-rich services, demanding higher capacity and greater speed backhaul links (e.g. IPTV, VoIP)
- New mobile network technologies such as mobile WiMAX and LTE are bandwidth hungry. They are also capable of a much higher degree of radio spectrum efficiency than today's systems. This is key particularly for licensed spectrum usage.
- The physical layer transport for traditional systems will be packet-based most likely using Ethernet. Carriage of voice and data traffic in the 3GPP UMTS R5 and above specifies usage of IP for data and that compressed voice be carried via VoIP.
- There will be an increased number of cell sites due to the need for a higher signal to noise ratio to support the increase in bandwidth delivered to the users. Increasing the bit density of the radio channel to pack more traffic requires more nodes and different timing distribution techniques.
- Ethernet is the only candidate for transport technology for future backhaul networks given the lower cost of the facility and switching equipment. Ethernet is inherently asynchronous.

The migration towards a packet-based transport network poses the challenge of providing the level of synchronization requirements defined in the 3GPP, 3GPP2 (LTE) and IEEE 802.16e (WiMAX) specifications. Semtech's ToPSync technology is the only **PROVEN** solution to this problem.

The transmission of the clock information over a packet network eliminates the need for alternative mechanisms, such as GPS or prohibitively expensive oscillators placed at the receiving nodes. This provides significant cost savings in network equipment as well as in ongoing installation and maintenance. This synchronization solution transmits dedicated timing packets, which flow along the same paths with the data packets reducing the cost of synchronization and simplifying implementation.

The ToPSync products use IEEE1588v2, Precision Time Protocol to carry the synchronization data. Semtech has been the leader in definition and development of the IEEE1588v2 standard. Semtech is also an active member of the ITU Study Group 15 Question 13. This group is responsible for the creation and documentation of world wide telecom synchronization standards. The IEEE1588v2 protocol is fully compatible with all Ethernet or IP networks. The IEEE1588v2 protocol is designed to enable a properly designed network to deliver frequency and phase or time with precision rivaling a GPS receiver. The ToPSync IEEE1588v2 implementation can supply FDD and TDD radio systems and circuit emulation services (CES)-based transport systems with the synchronization signals they require. This greatly reduces the costs of clocking all wireless basestation equipment.

Although IEEE1588v2 systems add small amount of additional traffic to the network load, they have the following advantages:

- They work in the data path, the most redundant and resilient part of the network, resulting in “always on” operation
- Multiple transmission paths reducing redundant clock system costs.
- Usage of a single synchronization session for all basestation traffic.
- Support for legacy systems in mobile networks, where Circuit Emulation Service is employed to carry both TDM traffic (2G,) and ATM traffic (3G)
- Support for any generic packet-based transport (such as IP RAN)
- Configurable packet rates for network conditions to maintain accuracy (e.g. packet rate <1pps to >1,00pps)

For all these reasons Semtech’s implementation of IEEE1588v2, called ToPSync, is the technology of choice to provide synchronization for the future wireless networks.

Semtech’s ToPSync has been extensively tested in these scenarios and has proven viable. It is very important for service providers and equipment vendors to understand IEEE1588v2 is a protocol only. The clock recovery algorithm used by ToPSync is the synchronization solution and this is Semtech’s alone.

The main features characterizing ToPSync and the IEEE1588v2 standard are:

- It employs a two-way methodology, where packets are sent back and forth from the clock master to the clock slaves. This feature overcomes high-amplitude, ultra-low frequency wander that defeats other methods such as adaptive clock recovery techniques.

- It is virtually independent of the physical media and can flow over low-speed twisted-pair, high-speed optical fiber, wireless or even satellite links without requiring equipment design modifications
- It is not limited to TDM circuit emulation like the in-band solutions, but it can support CES better than adaptive clocking by distributing a precise network clock to every IWF (inter working function) node in the system
- It can be used for any pure, packet-based network, hence providing synchronization for future backhaul networks to be deployed by mobile operators
- It can distribute either time/phase, frequency or both
- It could be used by telecom operators to sell a synchronization service to customers (residential, wireless operators, etc.)
- It is resilient because a failed network node can be routed around.
- It is resilient because the synchronization can come from one or more PRC connected grandmaster clock nodes.
- The IEEE1588v2 packets are fully Ethernet and IP standards compliant and backward compatible with all existing Ethernet and IP routing and switching equipment.
- There is no requirement for intermediate switches or routers to be IEEE1588v2 aware. They see these timing packets as normal packet data.

As pictured below in figure 1, IEEE1588v2 protocol calls for synchronization packets with time stamps to be sent from master clocks to all slave clocks and for individual slave clocks to send time-stamped packets to the master. The clock grandmaster maintains a time base locked to a primary reference clock and establishes a separate synchronization session with each of the slaves it serves. The master and slave exchange timing packets according to the syntax of the 1588v2 protocol. This process provides the Semtech ToPSync timing clock recovery algorithm with the time stamps it needs to precisely recreate the master time base. From this time base, the synchronization signals used by the network equipment are synthesized. The ToPSync algorithm filters most noise, packet queuing delay and propagation delay created by the transport network.

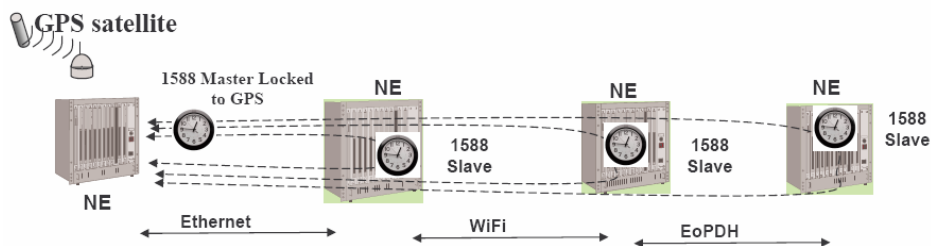


Figure 1: IEEE 1588 V2 packet flow example.

The ToPSync semiconductor is suitable for all wired and wireless service provider network applications. Typically each synchronization session produces approximately 5kbps of traffic (in each direction, uplink and downlink), which represents a small portion of the total capacity, typically between 100 Mbps and 1 Gbps, in a backhaul network.

In April of 2005, Semtech started the world's first IEEE 1588 proof of concept field trial. The test bed of the live trial is shown in Figure 2. Two ToPSync boards, acting as pre-IEEE1588v2 master and slave, are connected to a live metro Ethernet backbone operated by a major US carrier. The master was locked to an atomic clock. The synchronization packets traveled through the metro Ethernet before reaching the slave board, which is connected to an Agilent Omniber 718 measuring the time interval error.

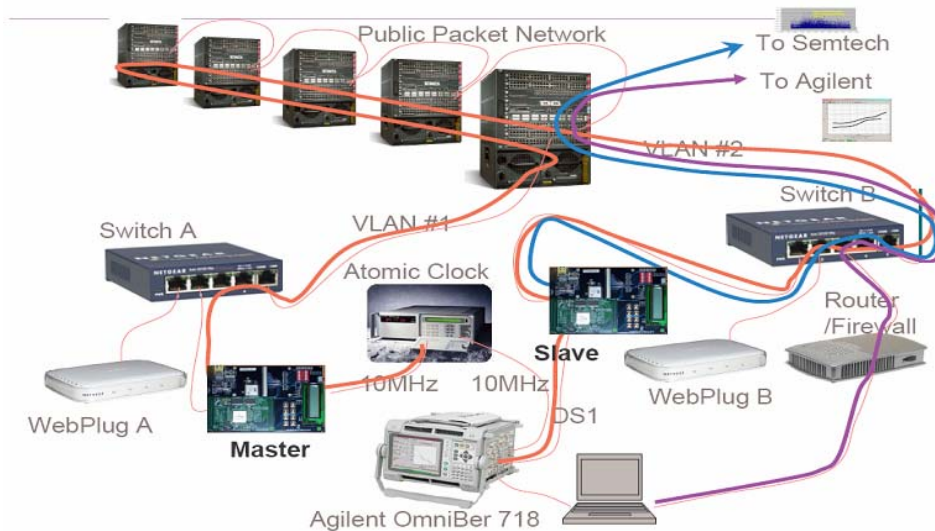


Figure 2: Semtech IEEE 1588 V2 live trial test bed

Figure 4 shows the results of the measured Maximum Time Interval Error. The top picture shows the MTIE against the G.823 synchronization interface mask for an E1 as used in a GSM base station. The measured MTIE is well below the mask, confirming the excellent clock recovery capabilities of the ToPSync algorithm. The picture at the bottom of Figure 4 shows that periodically the results also exceeded the PRC synchronization mask for this trial; this is not a typical result and is shown only for example purposes.

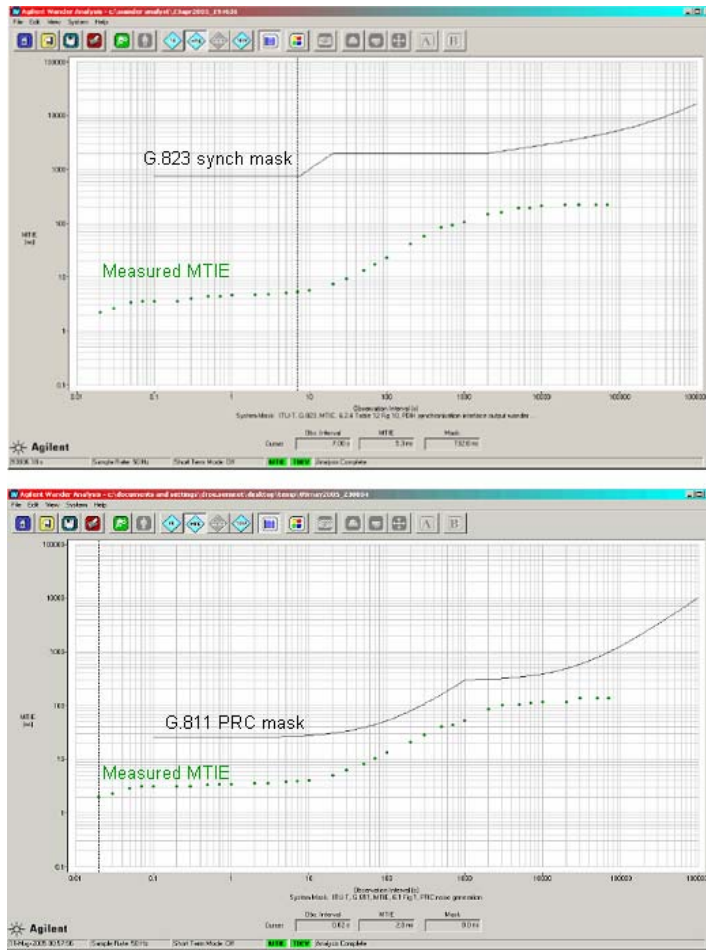


Figure 4: Measured MTIE from the trial against G.823 E1 sync interface and G.811 (PRC) masks

Since this initial field trial, Semtech's ToPSync technology has been extensively tested by the world's leading telecom equipment manufacturers and service providers. The results of these extensive, years-long testing programs are a highly robust and well-proven packet clock recovery algorithm that outperforms all others.

For example the results of extensive testing of the Semtech ToPSync technology by Vodafone were presented at the November 2007 ITSF (International Telecoms Synchronization Forum) in London. The testing suite employed by Vodafone followed the ITU G.8261 specification with some special implementations unique to Vodafone. These results concluded the Semtech ToPSync technology performed superbly.