

# Packet-Based Primary Reference Source for Synchronizing Next Generation Networks

Responding to consumer demand, service providers are expanding and upgrading their telecommunications networks to add more capacity and support next generation services. As these networks expand they also need to ensure the non-stop availability of their timing and frequency synchronization reference, commonly known as a "Primary Reference Source" (PRS) to maintain Quality of Service (QoS), avoid dropped calls, support video streaming services, and enable LBS applications such as 911 calls.

There are several changes occurring in mobile networks. Firstly, as backhaul transitions to Ethernet, the physical layer synchronization chain is no longer available when access to the legacy TDM reference inputs are removed. Secondly, the network cellular architecture is changing with the shift towards small cells/femtocells making it economically prohibitive to deploy GPS receivers at every base station. Lastly, GPS does have known vulnerabilities to jamming and spoofing and requires a reliable back-up to ensure service delivery across the network. To future proof networks and ensure optimal reliability

throughout the network, there is a compelling need for a stable, cost-effective, and robust packet PRS that will provide synchronization for packet networks.

Until recently, there have only been two types of primary reference sources from which to choose: Cesium, and GPS. Standalone Cesium atomic clocks are simple to install and robust because they do not receive timing based on an external signal but generate it internally. However, they are relatively expensive and in practice are restricted to core sites of the network. GPS-based PRS on the other hand may be lower cost initially, but can have high set up costs because deployment requires the installation of a GPS receiver, an antenna, and cables, and requires roof and cable run access. GPS systems are also limited to locations with "line of sight" visibility to the satellites from which they derive timing, and so cannot operate in urban "canyons."

Now, however, there is a new, robust, cost-effective PRS solution that does not use a GPS antenna: Packet PRS. Based on a Precision Timing Protocol (PTP) reference derived from a centralized IEEE

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1588 PTP Grandmaster Clock, Packet PRS provides Stratum 1 quality clock timing input over an Ethernet infrastructure to a Synchronization Supply Unit (SSU) and is ideal to use in core and colocation sites as standalone PRS or as a backup to GPS. As displayed in the Primary Reference Source Hierarchy shown in Figure 1.

This white paper explains how Packet PRS works and how communications networks will benefit from its deployment.

### Traditional Network Synchronization

All nodes in a synchronized telecommunications network must be referenced, or traceable, to a PRS that offers Stratum 1 performance in accordance with recognized industry standard ITU-T G.811. In traditional Time Division Multiplexed (TDM) digital communications networks, sync was maintained by employing two types of synchronization element, Primary Reference Clocks (PRC) and distribution clocks, over a physical circuit. The PRC or PRS (using either Cesium or GPS) provides the reference frequency signal for the synchronization of other clocks within a network, or section of a network. Distribution clocks (called BITS, SSU or SASE depending on configuration, region deployed, and the specific standards body) select one of the external synchronization links coming into a station as the active synchronization reference. The synchronization from a PRS site to the SSU/BITS is carried over SONET/SDH networks using derived T1/E1 signals from the optical line rate. The high availability requirement of SDH-based networks mandates the use of multiple site PRS preferably located in different geographical regions. As displayed in the Current TDM Network in Figure 2.

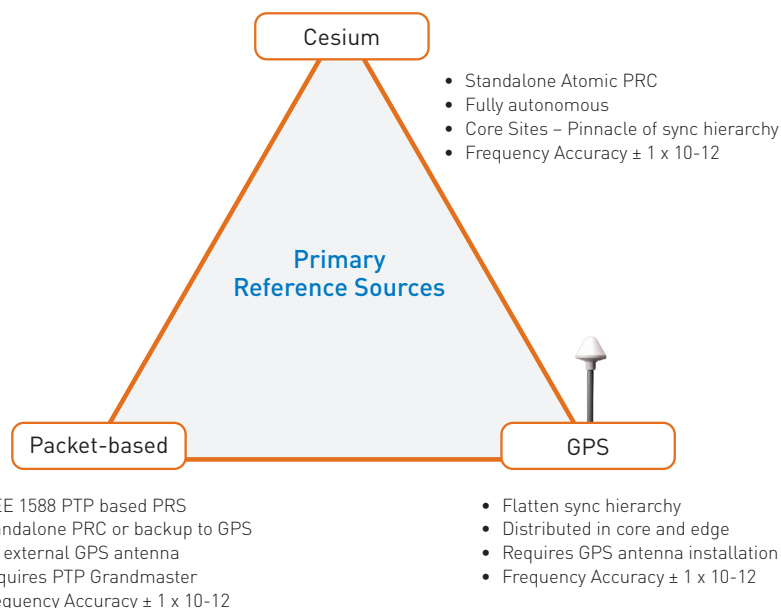


Figure 1: Primary Reference Source Hierarchy

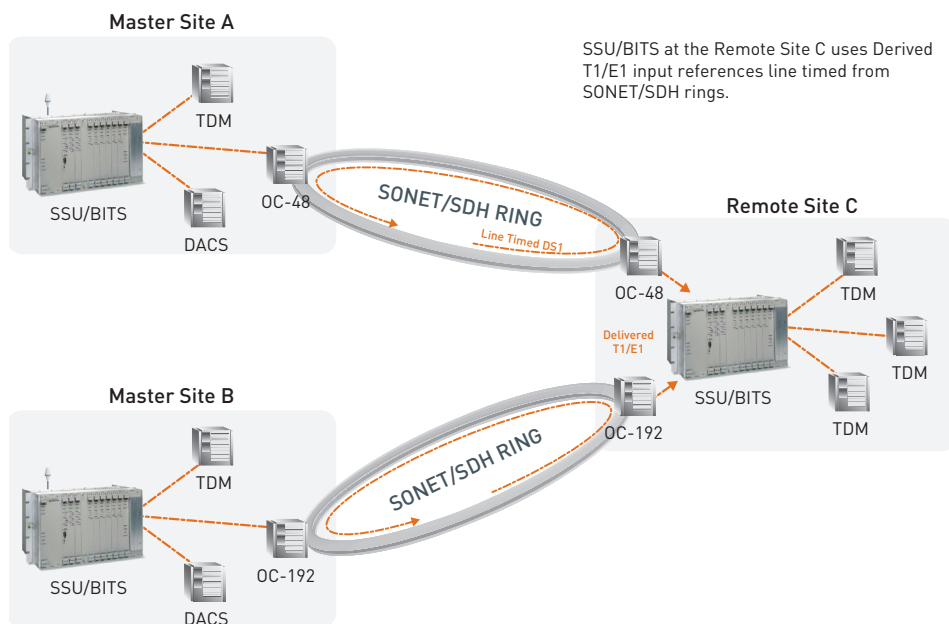


Figure 2: Current TDM Network

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### The Synchronization of Packet-Based Networks

The migration of TDM networks to packet-based Carrier Ethernet or IP/MPLS networks will cause the Synchronization chain to break. The Ethernet network elements cannot deliver frequency synchronization when T1/E1 input references are removed. As displayed in New Ethernet Network in Figure 3 the SSU/BITS can be front-ended with an IEEE 1588 PTP slave clock—the Packet PRS—which delivers PRS quality T1/E1 to the SSU clocks. The Packet PRS receives timing from one or more central IEEE 1588 Grandmaster Clocks that is co-located with a GPS or cesium PRS. When using such a Packet PRS the network should be setup to deploy IEEE 1588 GMC (or 1588 PTP Grandmaster Blades in the SSU/BITS) in geographically redundant Central Offices (CO) for diversity based risk mitigation. As displayed in PRS Distribution in Packet Networks in Figure 4.

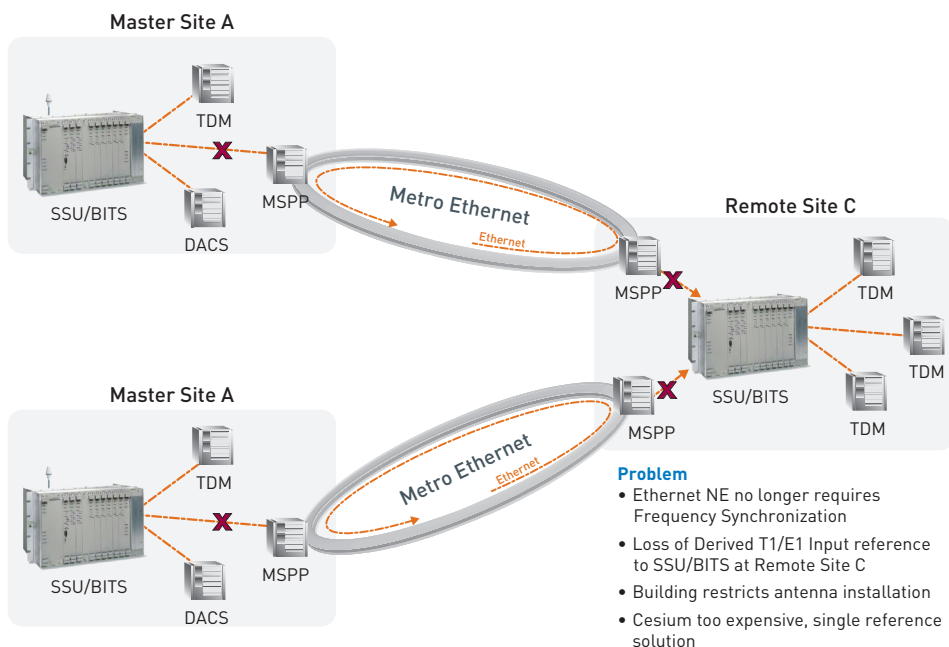


Figure 3: New Ethernet Network

### How Packet PRS Works

Using a rubidium miniature atomic clock combined with a state of the art Soft Clock 2.0 algorithm, Packet PRS reconstructs a PRS Stratum 1 quality clock from the IEEE 1588 PTP packets coming from a GMC in a central site, thus maintaining the synchronization chain that is otherwise missing in the packet network. The 1588 packets are converted into T1/E1 signals that meet the G.811/ST1 PRS mask. As displayed in MTIE Plot Comparison and Network Requirements in Figure 5.

For it to function in this capacity, Packet PRS must comply with industry standards and follow the specifications for a stratum 1 clock as defined in ITU-G.811. Symmetricom® test results show that even after losing PTP reference for up to 48 hours (bridging + holdover), the wander in output in the Packet PRS is still within the MTIE mask. Thus it meets and exceeds Telcordia GR 2830 requirement section 6.4.2: "Upon losing reference, output shall maintain PRS performance for at least 6 hours and unacceptable region should not be entered for the first 48 hours after

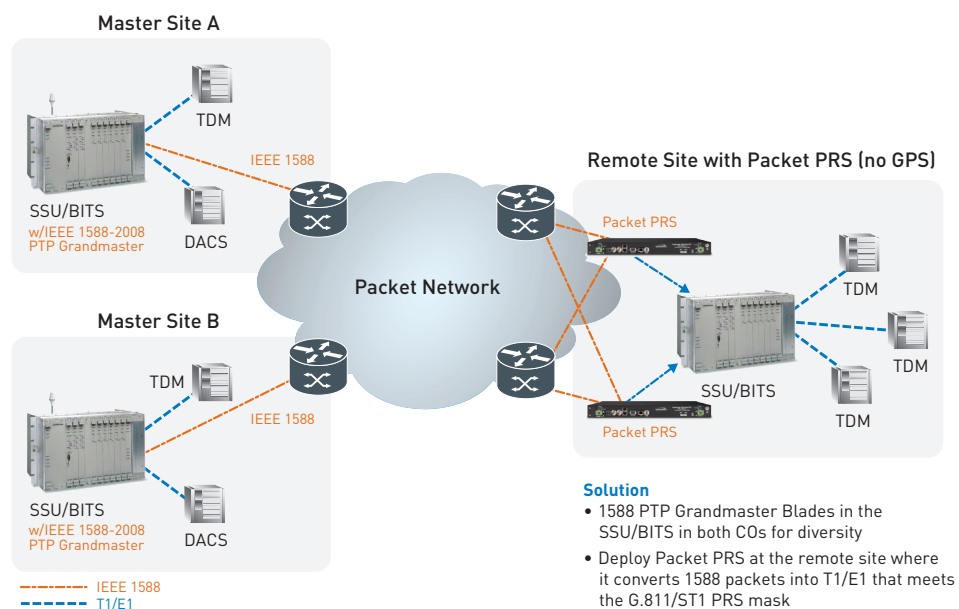


Figure 4: PRS Distribution in Packet Networks

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the allowed impairment.” As displayed in Rubidium Performance in Packet PRS in Figure 6.

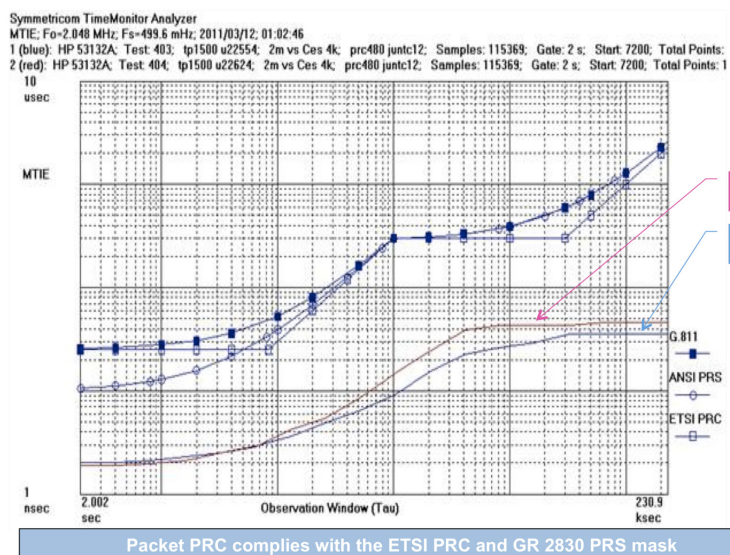
Symmetricon has developed the TimeProvider® 1500 (TP1500) Packet PRS, the first non-GPS, non-Cesium PRS, combining the power of Rubidium holdover technology with advanced IEEE 1588-2008 soft clock algorithms to provide a Stratum-1 PRS in compliance with industry PRS standards. TimeProvider 1500 meets or exceeds the most stringent test criteria

required to claim Stratum-1 level PRS performance: it fully complies with the ITU-T G.811 Stratum 1 and GR 2830 PRS performance specifications and also meets the ITU-T G.8261 specification for providing precise timing over IP, packet-based networks.

### Deployment Scenarios

TimeProvider 1500 applications include but are not limited to: GPS difficult sites with no roof access; sites with an unreliable GPS signal as in urban canyons or tunnels;

sites vulnerable to GPS interference due to jamming and spoofing; and as a back-up to GPS, supporting frequency and time services. The ability to synchronize to another non-located Grandmaster Clock over a packet-based network ensures 24/7/365 availability in the event of GPS service interruption. As displayed in the Hybrid Network with PTP Packet Sync shown in Figure 7, as Ethernet replaces TDM, creating a hybrid network, some SSU/BITS will lose their synchronization source. Front-ending these



Bandwidth Capacity	Maximum Loading	Intermittent Congestion	QoS	Recommended Hop Count
Minimum 1 GigE	80% Average	100% load for less than 100s	Highest Priority	Frequency (10 hops) Time (5 hops)

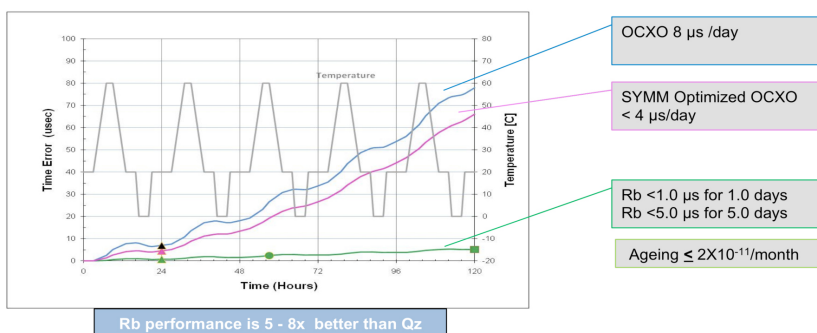
Packet PRS meets all requirements under full dynamic loading and impairments as specified in G.8261- “Timing and Synchronization aspects in Packet Networks” – Appendix VI Test Cases 12 to 17

Figure 5: MTIE Plot Comparison and Network Requirements

## Improving Mobile Backhaul Network Reliability with Carrier-Class IEEE 1588-2008 (PTP)

downstream clocks with TimeProvider 1500 Packet PRS will enable them to continue supplying synchronization to both SDH/SONET and Synchronous Ethernet infrastructure environments in the hybrid network that will be the reality for most operators for a considerable time.

Furthermore, TimeProvider 1500 can serve as a tool for carriers seeking to provide accurate one-way Service Level Agreement (SLA) measurements to their enterprise account customers. Because IEEE 1588 is a server/client time transfer protocol allowing client engines to be embedded in network endpoints for accurate time synchronization, it enables accurate one-way SLA measurements.



- ▶ Rubidium coupled with state of the art Symmetricom Soft Clock 2.0 provides the PRC quality clock
- ▶ Rubidium enables out performing Holdover and Bridging specs as per G.811/GR.2830
  - After losing PTP reference, the system shall be able to maintain PRS performance up to 6 hours.
  - After losing PTP reference, the wander in output shall be within the “degraded” MTIE mask for up to 48 hours.

Figure 6: Rubidium Performance in Packet PRS

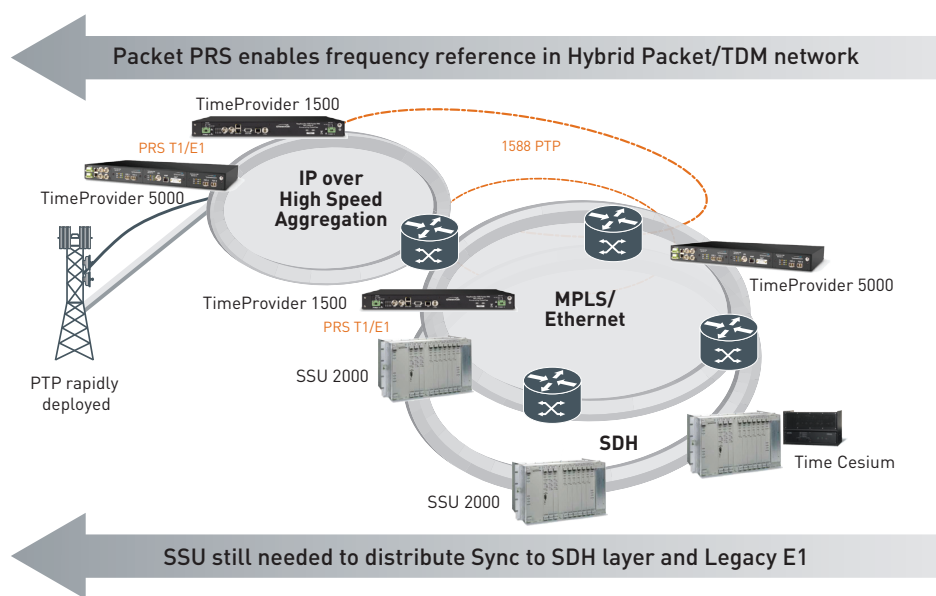


Figure 7: Hybrid Network with PTP Packet Sync

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### Conclusion

Carriers now have a new choice for deployment and diversity of primary reference sources in their networks. The TimeProvider 1500 provides a secure and cost effective solution to support rapid migration to Carrier Ethernet in the core, and is immune to potential GPS antenna vulnerabilities such as interference or jamming. Symmetricom has combined the innovative technologies of its Rubidium

oscillator and IEEE1588 PTP Soft Clock algorithm to deliver the stable robust timing required by today's evolving networks. Both innovative and unique, the TimeProvider 1500 delivers the precise and accurate synchronization that networks need as they migrate from TDM to next generation synchronous-aware packet-based technologies. As displayed in the PRS Deployment Chart shown in Figure 8.

Type of Primary Reference Source	Antenna Type	Telecom Outputs	Equipment Costs	Install Complexity	Main Applications
Standalone Cesium Atomic Clock	None	T1 (DS1) /E1 10MHz/1PPS	High	Low	<ul style="list-style-type: none"> <li>• Pinnacle of the sync hierarchy; used in core sites</li> <li>• Source of sync for SSU/BITS SONET/SDH Hubs and ADMS class 5/End office</li> </ul>
GPS-Based Reference Clocks	Window Wall Rooftop	T1 (DS1) /E1 10MHz/1PPS TOD	Medium	High	<ul style="list-style-type: none"> <li>• Offices with line of sight visibility to satellite</li> <li>• Decentralized synchronization nodes in a distributed sync network</li> <li>• SONET/SDH Hubs and ADMS</li> <li>• Synchronous Ethernet</li> </ul>
IEEE 1588 PTP Packet-Based Clock	None	T1 (DS1) /E1 10MHz/1PPS TOD	Low	Medium	<ul style="list-style-type: none"> <li>• Used in core and colocation sites as standalone PRS or as a backup to GPS-based PRS</li> <li>• Provides sync input to an SSU/BITS based on an external PTP reference from a GMC in a master site</li> <li>• GPS difficult sites</li> <li>• SONET/SDH Hubs and ADMS</li> <li>• Synchronous Ethernet</li> </ul>

Figure 8: PRS Deployment Chart