Precision Timing, Built into the Optical Layer

Executive Summary

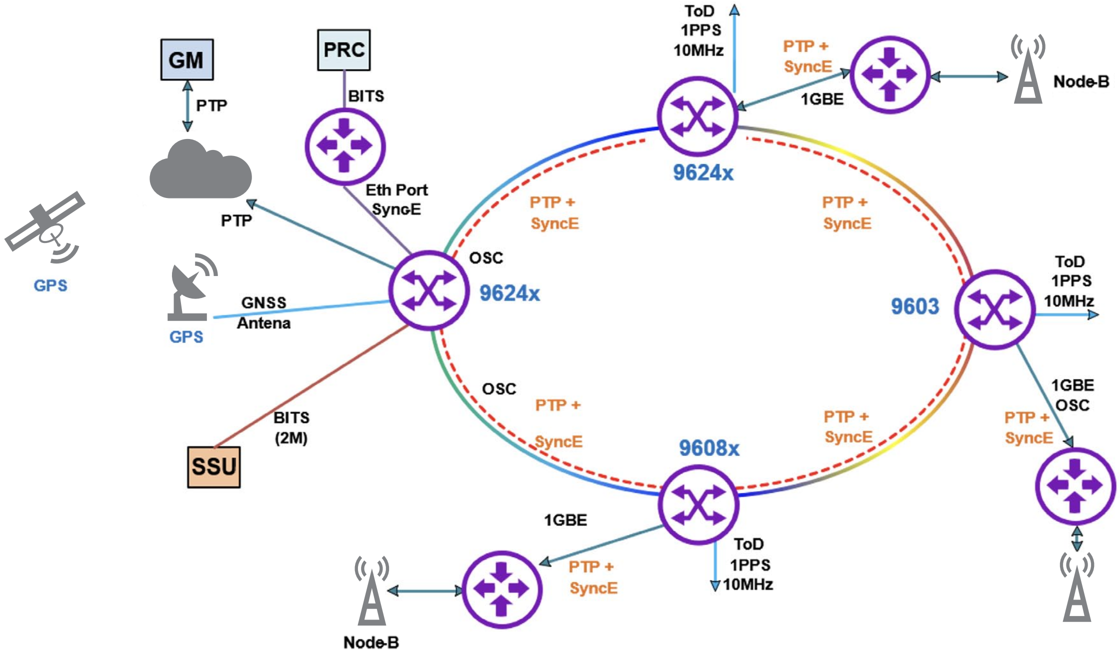
Synchronization is a foundational service layer—not an overlay—essential to packet-optical networks powering 5G, cloud, and critical infrastructure. Precise phase and frequency delivery is critical to maintaining network performance and reliability in these increasingly demanding environments.

However, delivering synchronization over DWDM introduces impairment challenges not seen in legacy TDM systems. Ribbon's OSC_8T synchronization architecture addresses these challenges by embedding timing directly into the optical layer, providing a scalable and standards-based framework for robust, end-to-end synchronization.

Synchronization Challenges in Optical Networks

There are numerous challenges faced by network operators in synchronizing their networks. Timing error accumulates as signals traverse multiple optical hops and packetized transport segments. Each additional segment introduces incremental deviation, making it increasingly challenging to preserve precise synchronization end to end.

This challenge is further exacerbated by physical and environmental factors. Fiber asymmetry, along with temperature and other environmental variations, introduces phase deviations that can drift over time and impact overall timing accuracy.



Ribbon OSC_8T Synchronization Architecture

Integrated optical timing reduces reliance on external systems and simplifies overall network deployment. By embedding timing capabilities directly within the transport layer, operators can streamline their synchronization architecture while improving resiliency.

Ribbon's OSC_8T synchronization architecture incorporates both Sync-E and IEEE 1588v2 PTP within the optical transport system, enabling precise delivery of frequency and phase across the network. This integrated approach eliminates the need for separate timing infrastructure while maintaining high levels of synchronization accuracy.

Support for multiple timing inputs—including GNSS, external clock sources, and packet-based timing—provides deployment flexibility and redundancy. Network operators can dynamically select and prioritize inputs based on availability and network conditions.

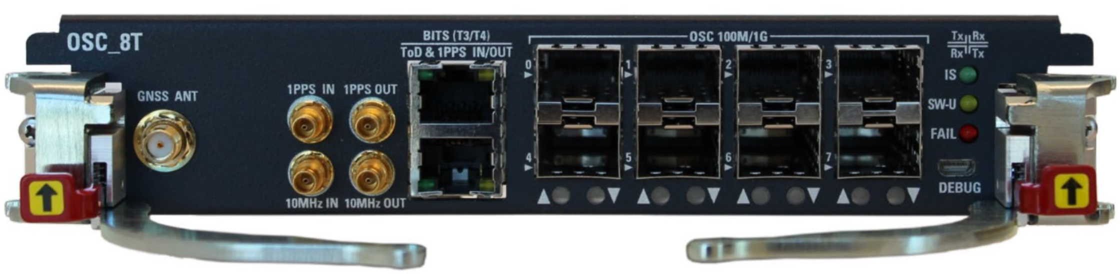
Non-disruptive switching between timing sources ensures continuous synchronization, even during failures or degradations. This capability maintains service integrity without impacting traffic forwarding or network performance.

Standards Compliance and Timing Roles

Ribbon's synchronization architecture aligns with ITU-T G.826x and G.827x standards, ensuring compliance with widely adopted frameworks for frequency and phase synchronization in telecom networks. This standards-based approach provides a strong foundation for consistent timing performance across diverse deployment scenarios.

It supports key roles within timing architectures, including Telecom Grandmaster, Boundary Clock, and Time Slave Clock. This flexibility enables the platform to function effectively at different points in the network, adapting to varying synchronization requirements.

By adhering to these standards and supporting multiple timing roles, the solution ensures seamless interoperability in multi-vendor environments. This enables network operators to integrate and scale their networks without being constrained by vendor-specific limitations.



Ribbon OSC_8T Synch Architecture Implementation: OSC Timing Modules

Timing and synchronization in Apollo are delivered via OSC_8T cards installed in Apollo 96xx platforms. The OSC_8T handles timing source selection, synchronization, and distribution across the OSC using PTP and SyncE over OTN networks. It provides full SyncE and PTP support for frequency and phase/time alignment. OSC_8T modules are required whenever timing is needed, with up to three cards supported per platform.

OSC_8T modules offer a comprehensive set of timing interfaces, including 8 SFP ports for OSC/PTP, BITS connectivity (E1/T1), ToD and 1PPS I/O, dedicated SMB ports for 1PPS and 10 MHz signals, and a built-in SMA GNSS antenna.

OSC_8T modules enable three synchronization modes, with native support for SyncE, BITS, and IEEE 1588v2, and offer the following clock I/O options:

- Clock inputs
  — BITS_in (T3): E1/T1 or 2 MHz, selectable by management interface
  — Free running (internal): Oven Controlled Crystal Oscillator (OCXO) with Stratum 3E compliance
  — Line timing: Clock recovered from any Ethernet interfaces
  — IEEE 1588v2 recovered clocks (PTP massages) or external inputs
- Clock outputs:
  — BITS_out (T4): E1/T1 or 2 MHz, selectable by management (including SSM handling)
  — IEEE 1588v2 Primary PTP massages or external outputs (1PPS, ToD, Clock)

In the OSC_8T we are using High precision timing GNSS module supporting:
  — Anti-jamming
  — Anti-spoofing

Interfaces and Deployment Models

Ribbon's synchronization solution supports a wide range of synchronization interfaces, including Sync-E, PTP, GNSS, 1PPSand Time of Day (ToD) inputs and outputs. This comprehensive support enables precise delivery of frequency and phase across diverse network environments.

By integrating multiple timing sources and protocols, the platform enables hybrid synchronization architectures. Operators can combine frequency-based, phase-based, and satellite-derived timing methods to meet specific network requirements and resiliency goals.

This flexibility makes the solution well suited for GNSS-based, packet-based, or mixed deployments. It allows operators to adapt their synchronization strategy based on infrastructure availability, performance needs, and operational constraints.

Supporting Out of Band Synchronization on DWDM Networks

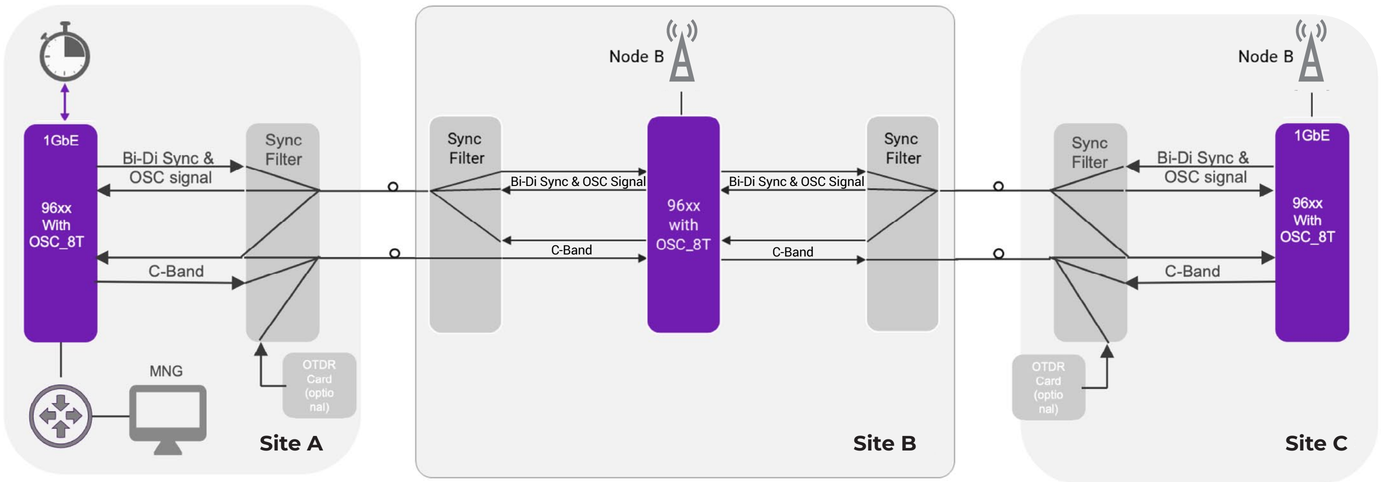


Figure 2: Apollo Synchronization Filter Placement

Modern networks demand highly accurate timing over DWDM to support next-generation applications. Apollo platforms address this with advanced synchronization filters that ensure precise frequency and phase/time distribution.

Apollo filters deliver timing over an out-of-band Optical Timing Channel (OTC) using a bi-directional wavelength on a single fiber, enabling efficient transport across WDM links. Timing is generated by a Boundary Clock (BC)—either Neptune-based or third-party—connected through Apollo's single-fiber filters, minimizing asymmetric delay with dual-wavelength transmission.

Key Sync Filter Characteristics:

- High-accuracy filter: OTC over adjacent DWDM S-band channels (1511.05nm and 1511.8nm), reducing delay to ~1.3 ns/100 km (this option is a unique value proposition for the Ribbon OSC_8T architecture)

In both cases, the OTC operates independently without consuming C-band DWDM capacity. Figure 2 illustrates the basic principles of how to place the filters to effectively deliver the synchronization signal over the Apollo optical network.

Operations, Performance, and Benefits

Accurate timing is critical to network performance, regulatory compliance, and overall service reliability. Treating timing as a core capability ensures consistent operation across applications that depend on precise synchronization, particularly in modern, high-performance networks.

Centralized management provides visibility into timing accuracy and the quality of timing sources, enabling proactive monitoring and control. This approach allows operators to quickly detect issues and maintain synchronization integrity across the network.

Hardware timestamping further enhances accuracy by minimizing error accumulation as timing information is processed and transported. At the same time, the solution is designed to support scalable, high-availability architectures, ensuring reliable operation as networks expand.

Together, these capabilities create a future-ready platform optimized for 5G and other timing-sensitive applications. The result is a robust synchronization foundation that supports evolving network demands while maintaining consistency and resilience.

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