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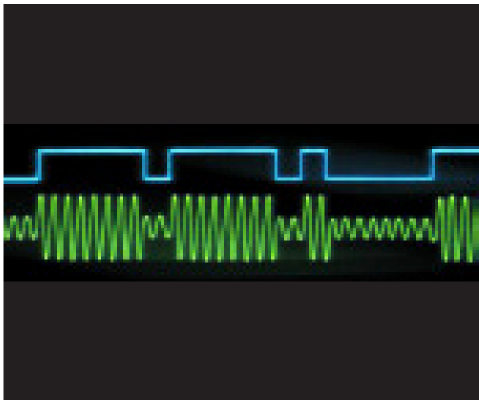
Passive Optical Networks



WHITE PAPER

Passive Optical Networks

Unlocking the Bandwidth Potential of Fiber with Precise Sync

The need for Telcos to deliver the triple play of voice, video and data in order to compete with services offered by cable companies has reignited focus on broadband optical access systems based on Passive Optical Networking (PON). PON components are key to unlocking the bandwidth potential of fiber.

Fiber to the Pedestal (FTTP) has two sub-categories designed to deliver broadband services to homes and businesses: Fiber to the Home (FTTH) and Fiber to the Curb (FTTC). Passive fiber splitters are used to split the fiber to allow users access to the total available bandwidth for the application.

This paper specifically addresses GPON (Gigabit PON) applications and the associated synchronization requirements for the smooth transmission of real-time services over broadband networks. As traffic passes across network boundaries (between the access network and the supporting transport and switching networks) synchronization to a common, accurate clock is needed to minimize slips and reduce buffering. Slips typically result in either complete packet loss or the need for retransmission, and buffering introduces additional latency and jitter. GPON must support a high performance quality for all real-time traffic carried over broadband access topologies.

The GPON access solution typically allows a maximum of 32 (64 optional) users to share the available bandwidth of the split fiber. This creates issues such as cell collisions if several users attempt to send traffic in the upstream direction at the same time. GPON solves this problem by incorporating Time Division Multiple Access (TDMA) with a grant mechanism for upstream traffic. Synchronizing the OLT (Optical Line Termination) and the ONT (Optical Network Termination) to a common reference is a requirement for maintaining frame alignment in order to achieve a Constant Bit Rate (CBR) for upstream traffic. A ranging technique is also used to support collision avoidance.

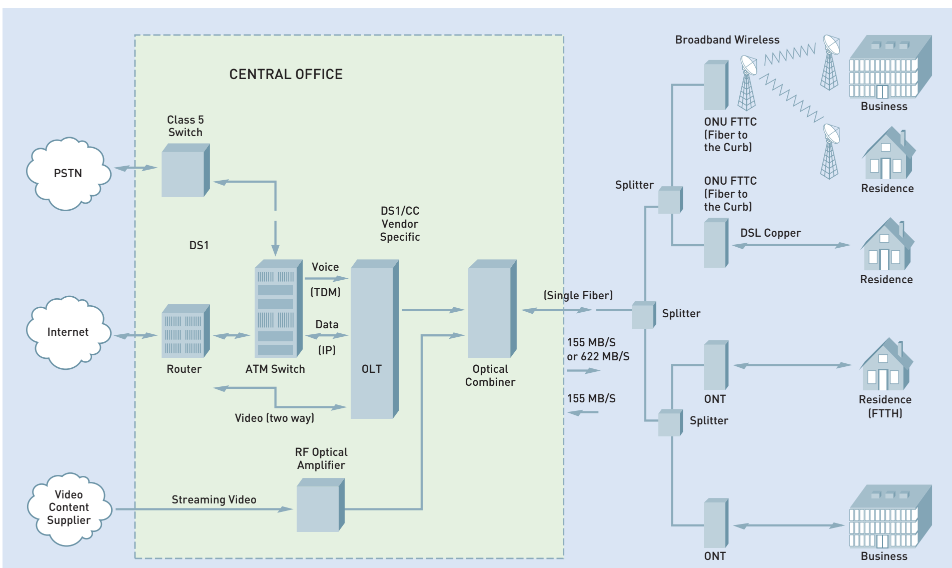


FIG. 1 An example of a GPON solution designed to support the triple play of voice, video and data.

The notion of ranging is simple. The intent is to place all ONT devices at the same virtual distance from the OLT. This is demonstrated in Figure 2. The intent is to delay the onset of transmission from the closer nodes such that, in principle, "simultaneous" transmissions from any two nodes will arrive at the OLT at the same time.

Time Division Multiple Access (TDMA) is used in a variety of applications, including cellular telephony and cable. The key to TDMA is the establishment of time slots or transmission windows created and maintained by the OLT. The OLT provides a grant that allows an ONT access to a time slot. Precision synchronization is needed to avoid collisions and ensure low cell delay variations. Figure 3 is a graphical depiction of TDMA applied in a PON access.

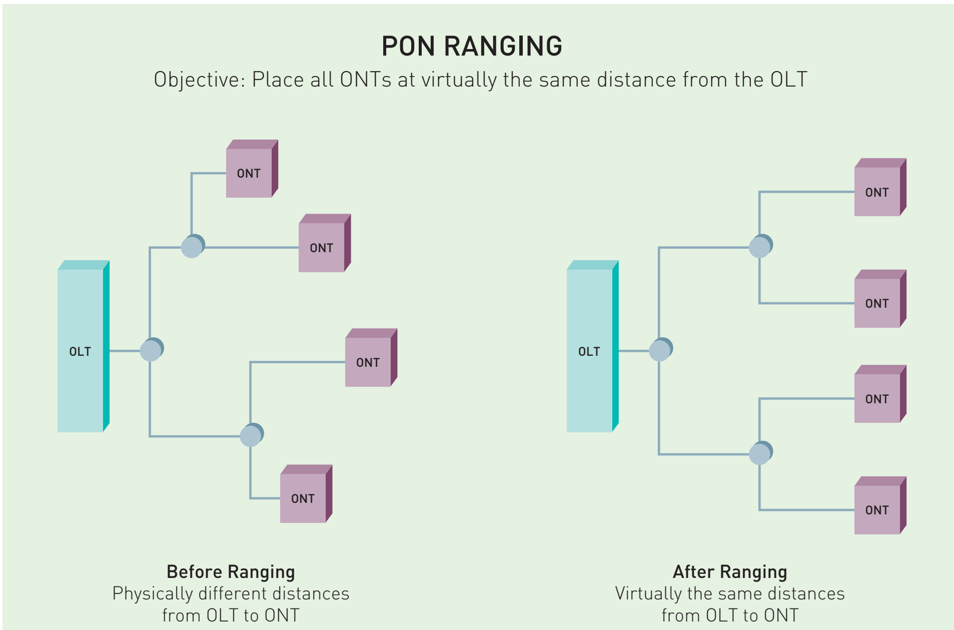


FIG. 2 PON ranging.

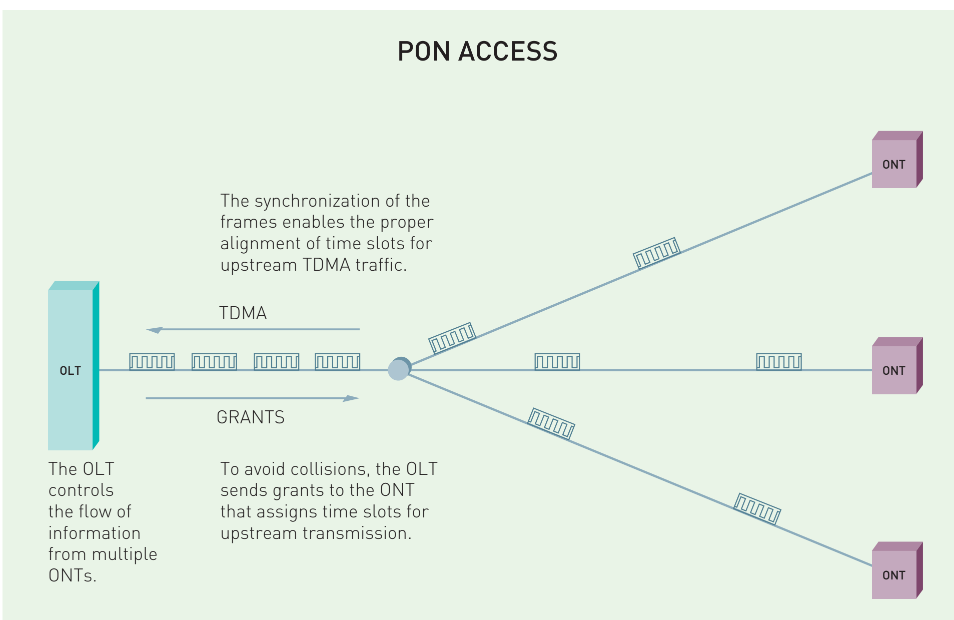


FIG. 3 PON access.

Sync Ensures Performance Quality

Precise synchronization in GPON broadband access deployments enhances quality of service parameters in three ways:

1. Synchronizing the PON network to the Public Switched Telephone Network (PSTN) and the ATM/data network to a common clock reference that is highly accurate (typically Stratum 1) reduces or eliminates slips at the network boundaries that degrade quality of service. The quality of real time services is affected by retransmission of packets, which is a result of slips.
2. Synchronizing the components of the PON architecture allows the upstream cell traffic to be mapped into the TDMA stream in the proper time slots.
3. Several legacy services, such as ISDN (BRI as well as PRI), are essentially synchronous and the terminal equipment relies on the network to provide a signal from which a quality timing reference can be extracted. This mandates the availability of such a timing reference at the ONT and/or ONU.

GPON Frame Synchronization

A burst mode synchronization scheme is used to align the bit rate of the ONT to the OLT during transmission of upstream TDMA traffic. Burst mode synchronization is an adaptive clock recovery method that enables the ONT to recover clock from the first few overhead bits of a frame.

GPON Optional 8 KHZ clock recovery

The frame length for GPON is 125 microseconds, the same as the SONET/SDH frame length. ONT and ONU devices can recover a 8 KHZ clock that is extracted from the GPON frames in the same fashion that SONET/SDH recover clock at the physical layer. With an accurate and stable synchronization reference available to the OLT, this method of maintaining frame alignment should be even more reliable and stable than the burst mode synchronization method.

The International Telecommunication Union (ITU) recommendation G.984 for GPON related to synchronization states the following:

> *When the OLT and end office are in the normal operating state, the nominal bit rate of the OLT to ONU/ONT is traceable to a Stratum 1 clock accuracy of 1x10-11 or better. When the end office is in the free running mode, the rate of the downstream signal is traceable to a Stratum 3 clock accuracy of 4.6x10-6 or better. When the OLT is in the free running mode, the accuracy of the downstream signal is that of a Stratum 4 clock, 3.2x10-5 or better. Degradation in the synchronization quality of the PON architecture from Stratum 1 quality to a less accurate Stratum level such as Stratum 3 or 4 will affect the ability of the PON to pass traffic error free into other networks that still maintain Stratum 1 accuracy. The ONU/ONT shall transmit a signal upstream equal to the accuracy of the downstream signal in order to maintain synchronization of the PON.*

The optical access architecture will be required to support legacy digital services such as ISDN BRI and ISDN PRI for an unspecified time in the future. The requirements for meeting the slip rate objectives of all digital networks enhances the need for placement of a holdover clock with access to a Stratum 1 clock source at the OLT location.

The following diagrams depict synchronization schemes that support the ITU recommendations:

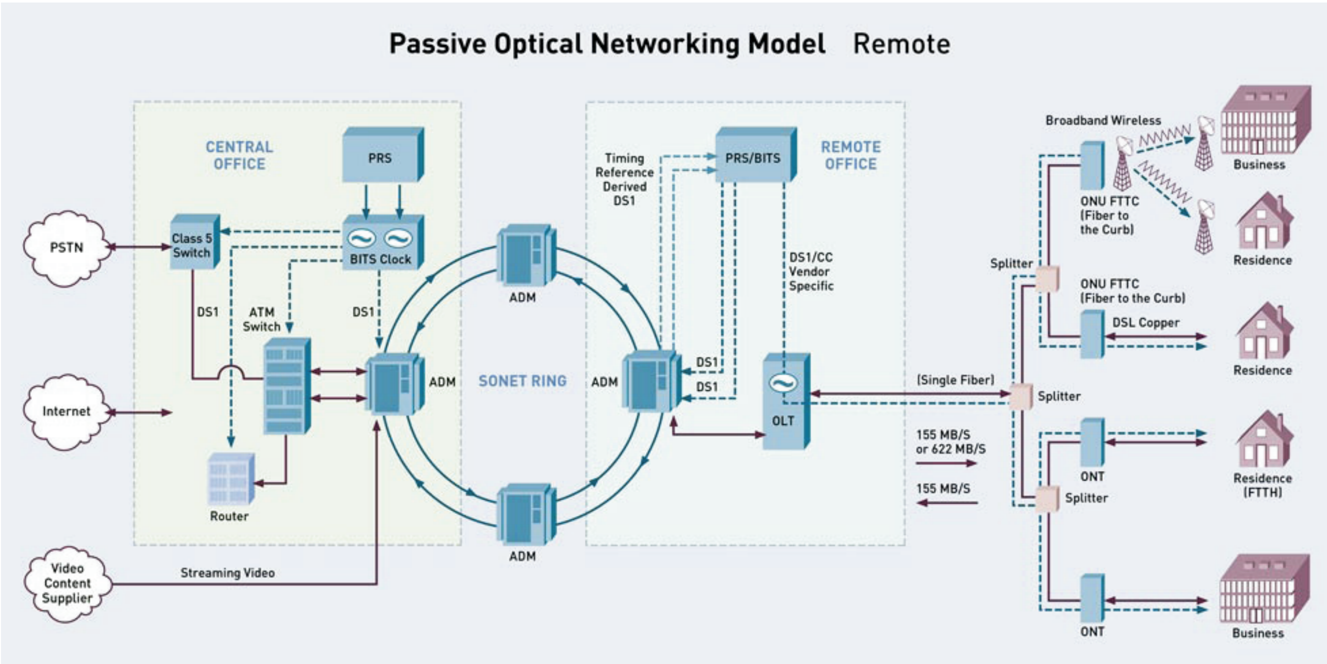


FIG. 4 In this illustration, the Stratum 1 clock source is transported over SONET to the BITS clock in the remote office where the OLT is located. A network failure or rearrangement that results in the BITS clock in remote office losing its Stratum 1 reference will result in the BITS clock entering holdover at the Stratum 3 level, which meets compliance to the G.984 recommendations.

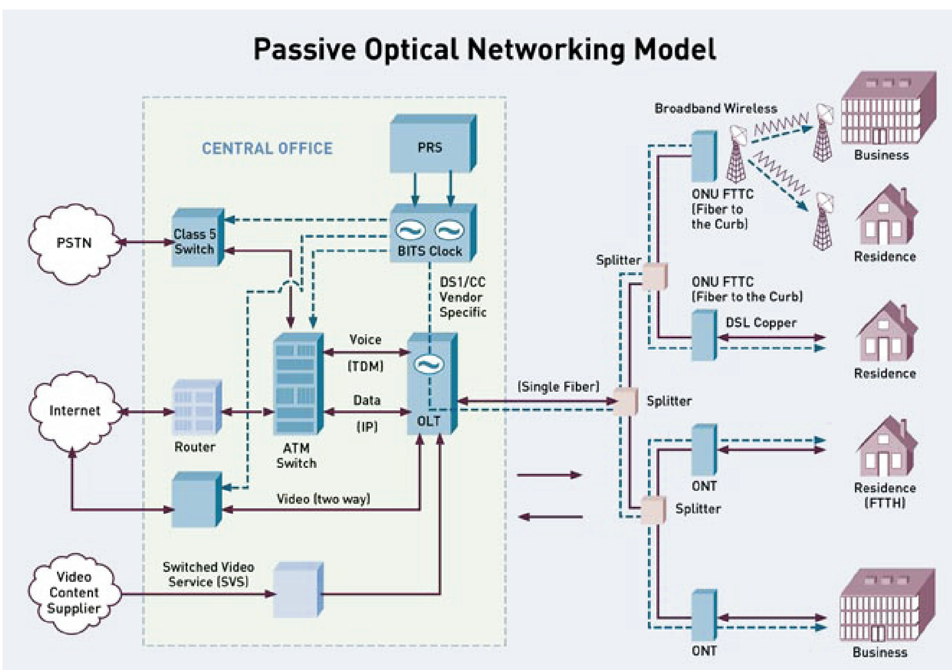


FIG. 5 This illustration shows the BITS clock co-located in the same facility as the PRS Stratum 1 source and the OLT. A failure of the PRS would result in the BITS clock entering holdover and providing the required clock accuracy for all office elements including the OLT until the PRS can be restored.

Synchronization to Remote OLTs

As detailed previously, all OLTs need stratum 1 traceable synchronization to support legacy TDM services. Remote OLTs located in street cabinets present additional challenges. First generation remote OLTs are provided with physical layer synchronization over TDM backhaul SONET/SDH transmission. As backhaul transitions to Ethernet to increased bandwidth and reduce costs, remote terminals are isolated from physical layer synchronization traceability. The two primary methods for delivery of synchronization over Ethernet to remote terminals are Synchronous Ethernet, and IEEE 1588 (Precision Time Protocol).

- Synchronous Ethernet: The ITU has recently completed work on the definition of Synchronous Ethernet (G.8261, G.8262, G.8263) to address the need for delivery of frequency synchronization over Ethernet transmission networks. The basic difference between native Ethernet and SyncE is the transmit PHY clock. Today IEEE 802.3 Ethernet requires the transmit clock to have a free-running clock of 100ppb. In SyncE, the transmit clock must be 4.6ppb and traceable to a Stratum 1 clock via an external SSU/BITS reference or the receive clock. By simply enabling the transmit and receive clocks of Ethernet to be linked together, SyncE can be used to deliver frequency synchronization to remote OLTs as is done with SONET/SDH.
- IEEE 1588-2008 PTP: IEEE 1588 is an advanced time transfer protocol designed to pass precision timing over Ethernet networks. IEEE 1588 is fully compatible with existing switched Ethernet networks. The protocol is based on a server/client architecture where precise timestamps are passed over Ethernet to align the client clock to the server clock.

Remote OLTs available today can support Synchronous Ethernet and/or IEEE 1588 PTP. Synchronization traceability for SyncE is very similar to SONET/SDH. The SyncE enabled switch in the central office would be timed by the BITS clocks in the same way that SONET/SDH equipment is timed today. The remote OLT can then recover physical layer synchronization from the incoming SyncE feed. IEEE 1588 equipped remote OLTs require placement of an IEEE 1588 master server in the central office. Figure 6 shows a typical remote OLT deployment where the IEEE 1588 client clock embedded in the OLT is receiving precision timestamps from the IEEE 1588 master server blades installed in the central office BITS clock.

GPON for Mobile Backhaul

GPON can be used as an alternative specifically for DSL because of scalability and bandwidth reasons. The same benefits of leveraging the SSU and PTP Blades at the Central Office also apply in this scenario (i.e., no hardware engineering required).

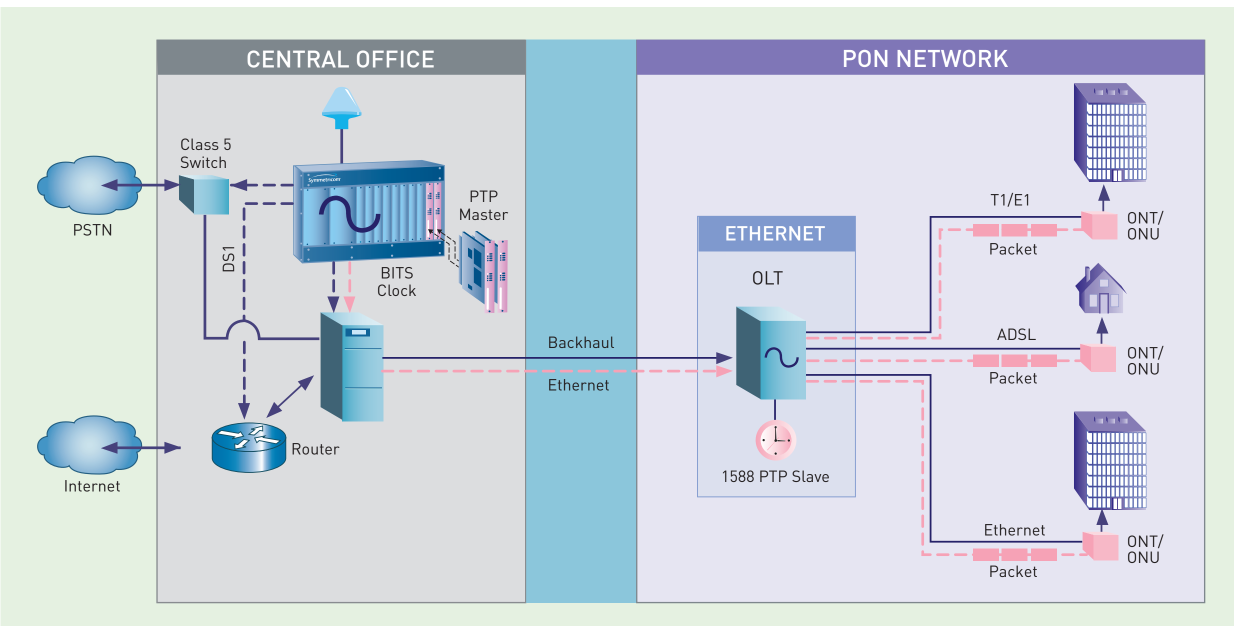


FIG. 6 Remote OLTs require synchronization distribution over Ethernet backhaul. IEEE 1588 client clocks in the OLT can be synchronized to IEEE 1588 master server clocks installed in the central office BITS clock.

Summary

Carriers are rapidly deploying FTTX solutions to deliver content rich triple play services. Synchronization is a key enabling technology supporting deployment of advanced PON equipment. OLTs require precise synchronization to assure delivery of high QOS services. Synchronization planning for OLTs includes direct BITS connection for CO based equipment, and evolution to Synchronous Ethernet and IEEE 1588 PTP to support delivery of synchronization to remote OLTs.

For more information on Synchronous Ethernet or IEEE 1588 Precision Time Protocol, please refer to the following white papers:

http://www.symmetricom.com/media/files/secure/application-notes/Preparing_Sync-E.pdf

http://www.symmetricom.com/media/files/secure/application-notes/AN_1588PTP.pdf

GPON Glossary

1) **OLT: Optical line termination.** A broadband multi-service device that controls the flow of information to and from all subscribers through the optical port.

2) **ONU: Optical Network Unit.** Used in Fiber to the Curb (FTTC) applications where it is not practical to extend the fiber reach all the way to the customer premise.

3) **ONT: Optical Network Termination.** Used in fiber to the home (FTTH) to terminate the optical signal at the customer premise and provide the electrical interface to the customer equipment.

4) **Passive fiber splitters:** devices that are approximately the size of a pen that allow the fiber to be split without a reduction in the bit rate.

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