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Synchronization Implications of FTTH and FTTC Architectures

WHITE PAPER

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Overview

The competitive requirements for telcos to deliver the *Triple Play* of voice, data and video in order to compete with the services offered by cable companies has regenerated excitement surrounding broadband optical access systems based on Passive Optical Networking (PON). The economic downturn may have stalled implementations of new technologies while the communications industry focused on maximizing revenue from existing infrastructure (such as DSL over copper wires), but the *Triple Play* has brought PON back into the forefront of emerging technologies. PON components are the building blocks used to unlock 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.

PON technology has three application-specific technologies.

1) APON: ATM (Asynchronous Transfer Mode) Passive Optical Networking.

2) EPON: Ethernet Passive Optical Networking.

3) BPON, WDM: Broadband Passive Optical Networking, Wave Division Multiplexing.

This paper will focus on APON passive optical networking applications and the associated synchronization requirements. Synchronization is a key element for broadband architecture deployments designed to support real time services. Real time services depend on high-quality synchronization to ensure smooth transmission. As traffic passes across the network boundaries between the access network and the supporting transport and switching networks, synchronization to a common, accurate clock is needed to minimize slips – slips that cause packet loss or retransmission – and to reduce buffering, which introduces additional latency and jitter. APONs provide support for high quality of service (QoS) for all types of traffic that real time broadband access technology must transport.

Relevant Aspects of APON

A brief synopsis of APON specifications is provided below.

a) Line rate:
   Symmetrical 155 mb/s downstream/upstream
   Asymmetrical, (Optional), 622 mb/s downstream, 155mb/s upstream
b) Maximum fiber distance: 20 KM
c) Number of fiber splits, typically: 32, (Optional 64)

A brief description of APON components and terminology used is listed below.

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 which allow the fiber to be split without a reduction in the bit rate.

The following diagram, Figure 1, depicts an example of an APON solution designed to support the *Triple Play* of voice, data, and video.

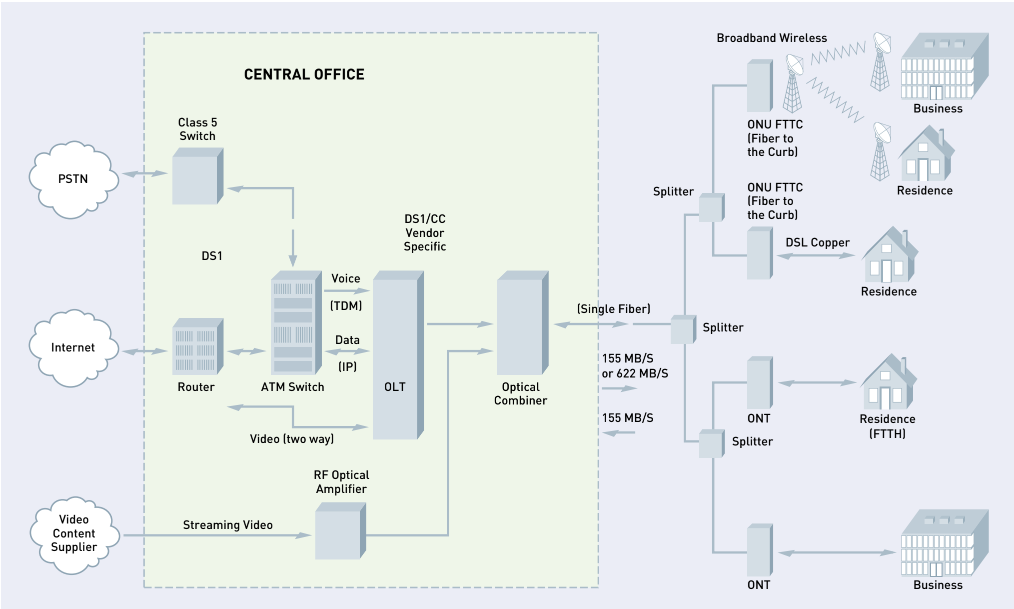

FIG.1 APON solution designed to support the Triple Play of voice, data, and video.

The APON 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. APON solves this problem by incorporating Time Division Multiple Access (TDMA) with a grant mechanism for upstream traffic. Synchronizing the OLT and the ONT 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.

The notion of ranging is simple. All ONT devices are placed at the same virtual distance from the OLT as depicted 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 simultaneously.

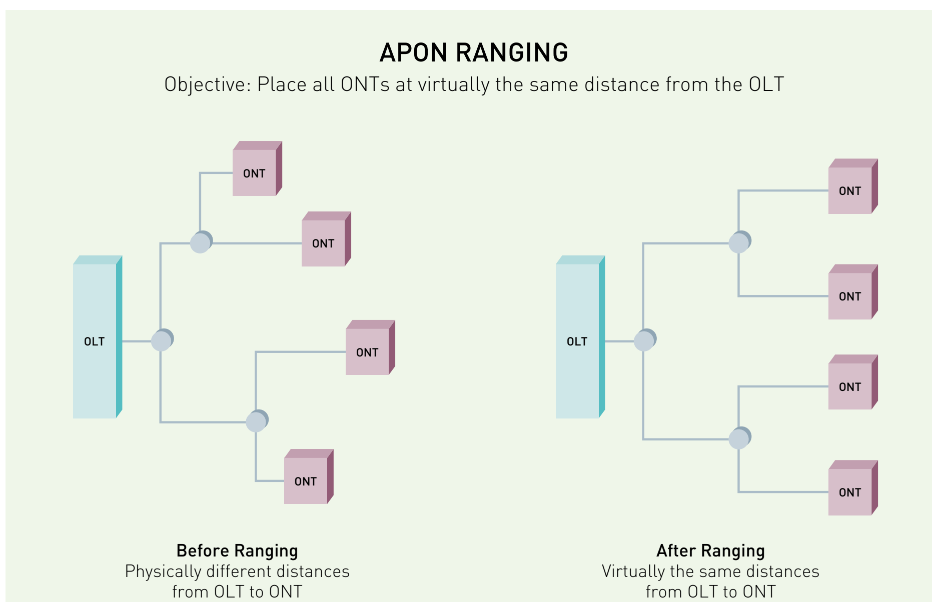

FIG.2 APON Ranging

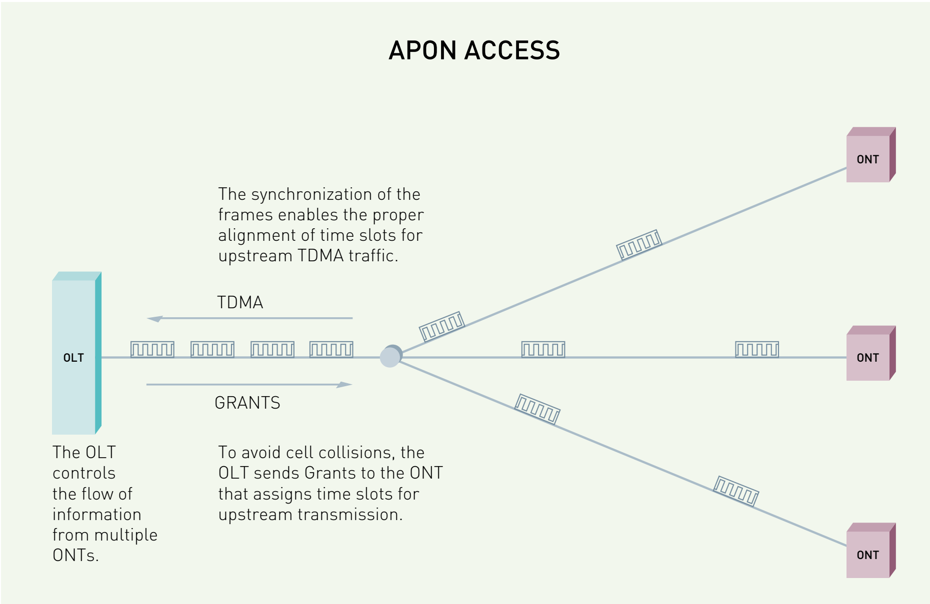

FIG.3 APON Access

Time Division Multiple Access (TDMA) is a well-known technique that has been 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. Synchronization is critical. The OLT provides a *grant* that allows an ONT access to a time slot. Good synchronization is required to support collision avoidance and ensure low cell-delay-variations. Figure 3 is a graphical depiction of TDMA applied in APON access.

The Need for Synchronization

Synchronization in APON broadband access deployment 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 network quality timing reference can be extracted. This mandates the availability of such a timing reference at the ONT and/or ONU.

APON 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.

APON Optional 1 kHz Synchronization Field
There is a field available in a frame that allows for an option to insert a 1 kHz timing marker for transmission from OLT to ONT for the purpose of aligning counters in the OLT to counters in the ONT in order to maintain frame alignment. With an accurate and stable synchronization reference available to the OLT, this method of maintaining frame alignment should be more reliable and stable than the Burst Mode Synchronization method.

The International Telecommunication Union (ITU) recommendation G.983.1, for APON in subsection 8.2.3.1 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.

Figures 4 and 5 on the next page provide examples of synchronization schemes that support the ITU recommendations.

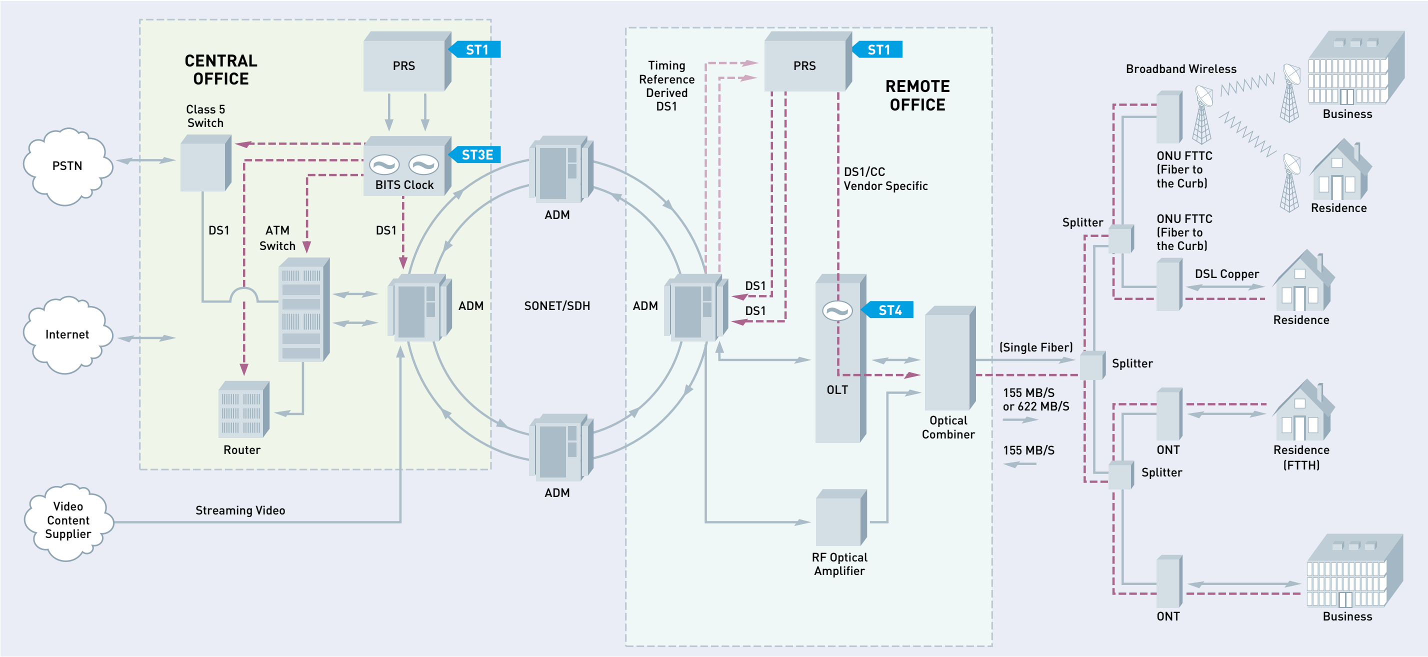

FIG.4 The Stratum 1 clock source is transported over SONET to the BITS clock in Office "B" where the OLT is located. A network failure or rearrangement that results in the BITS clock in Office "B" losing its Stratum 1 reference will result in the BITS clock entering holdover at the Stratum 3 level, which meets compliance to the G.983.1 recommendations.

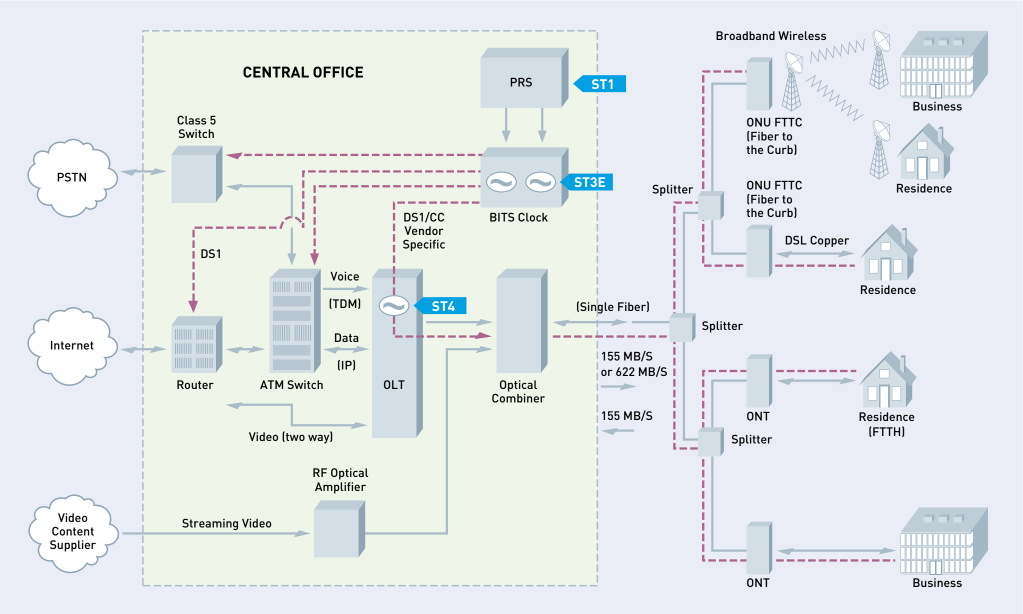

FIG.5 This illustration shows the BITS clock co-located in the same facility as the PRS Stratum 1 source and the OLT. A failure of the PRS would result in the BITS clock entering holdover and providing the required clock accuracy for all office elements including the OLT until the PRS can be restored.

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