WHITE PAPER

Enabling TDM Business Services Across GPON Access Networks

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The telecom market continues to adjust to the new technology and consolidation drivers in the industry. Carriers such as Verizon, NTT, BT, and SBC are in the midst of massive business changes that will have repercussions from the financial ledger through to what services will be offered and how they will be delivered to customers.

Carriers are moving to a new paradigm. As traditional voice revenues fall and competition increases, carriers are bolstering income with new data applications and bundled “triple play” voice, video and data services. This bundling of service is driving demand for more bandwidth in the access market, and pushing new services to consumers.

As a bundling option, fiber-based access is taking the lead. Fiber-to-the-X (curb, premise, building, home) service delivers speeds hundreds of times faster than premium data services, and provides users with multiple phones lines, video-on-demand and high-definition television services and more.

PON (passive optical networks) are becoming the medium of choice for most carriers. Initially, U.S. carriers built out BPON (broadband passive optical network) networks to the home. Today, GPON (gigabit PON) networks are replacing these networks. In Asia, Korea Telecom is deploying EPON (Ethernet PON) networks, while in Japan NTT has announced the conversion of 30 million lines to GEPON (gigabit Ethernet PON).

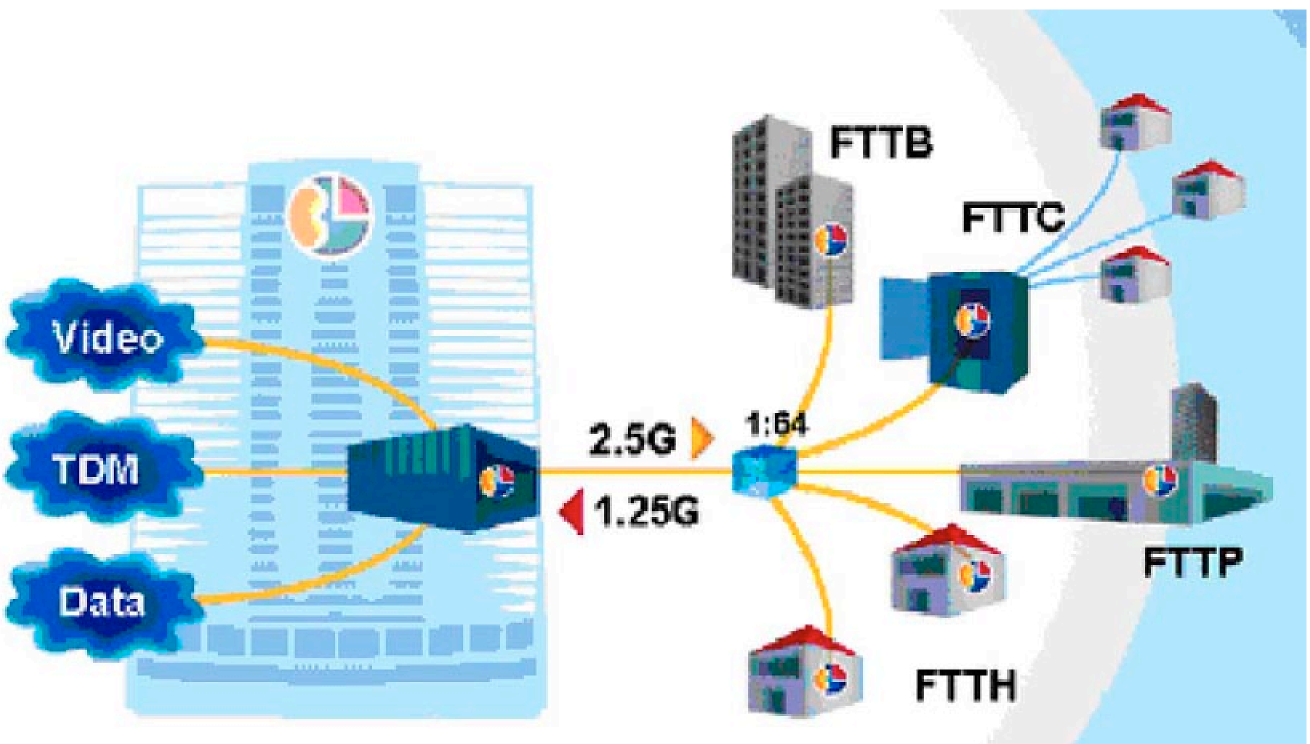

Figure 1: GPON access network

In the march towards these “new” technologies, one significant issue remains. How do carriers cost-effectively transport existing, revenue-generating TDM traffic across the new packet-based network? This paper will present CESoP (circuit emulation services over packet) as a viable solution that allows carriers to migrate towards a PON architecture that easily supports legacy services.

WHAT ABOUT TDM?

Carriers have two options when considering TDM traffic and PON networks. The first is to do nothing, and maintain their existing infrastructures to handle TDM services. The second option is to move legacy services to the new PON environment.

The “do nothing” option means maintaining the existing network, with its associated costs, until the last customer retires their TDM service in favour of a new packet-switched service. Capital expenditures could be limited to network maintenance, but operating expenses would continue at the current rates. However, income generated by TDM services is in serious decline.

In comparison, adding TDM services to the new PON infrastructure would allow carriers to more quickly retire older networks. Existing TDM traffic is instead delivered across a single, more cost-effective network, resulting in a greater revenue return on legacy services with corresponding declines in operating costs.

This requires a bridging technology that seamlessly carriers traffic between old and new infrastructures. But does it exist?

With the adoption of packet-based infrastructure as a ubiquitous unifying network, a second approach to delivering TDM services over packet has been standardized by the FSAN (Full Service Access Network) group and included in the ITU-T G.984 recommendation. This approach, known as CES (circuit emulation service), makes fewer assumptions about the underlying properties of the physical transport.

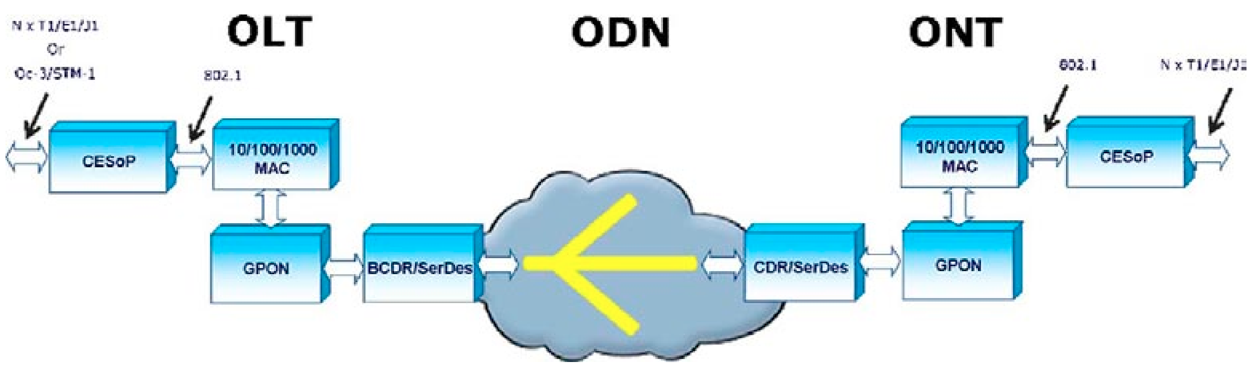

Figure 2: CES over GPON

CESoGPON (CES over GPON) refers to the delivery of TDM services over GPON using CES technology. Essentially, the GPON access network is considered ‘just’ another Ethernet cloud through which the TDM traffic is tunneled using circuit emulation pseudowires.

At the OLT (optical line termination), GPON access blades supporting TDM service do not need to include TDM circuitry and TDM backplane connectivity. Using CES/TDM interworking, the uplink aggregates all TDM traffic onto a higher speed SONET/SDH or PDH backhaul (Figure 3). CES aggregation at the OLT provides two services in GPON:

- Aggregation of all TDM service from the remote ONTs (optical network terminals) onto a T3/E3/STS-1 link;
- Cross-connect functionality to reduce the number of TDM uplinks to the backhaul, negating the need for an expensive external cross-connect device.

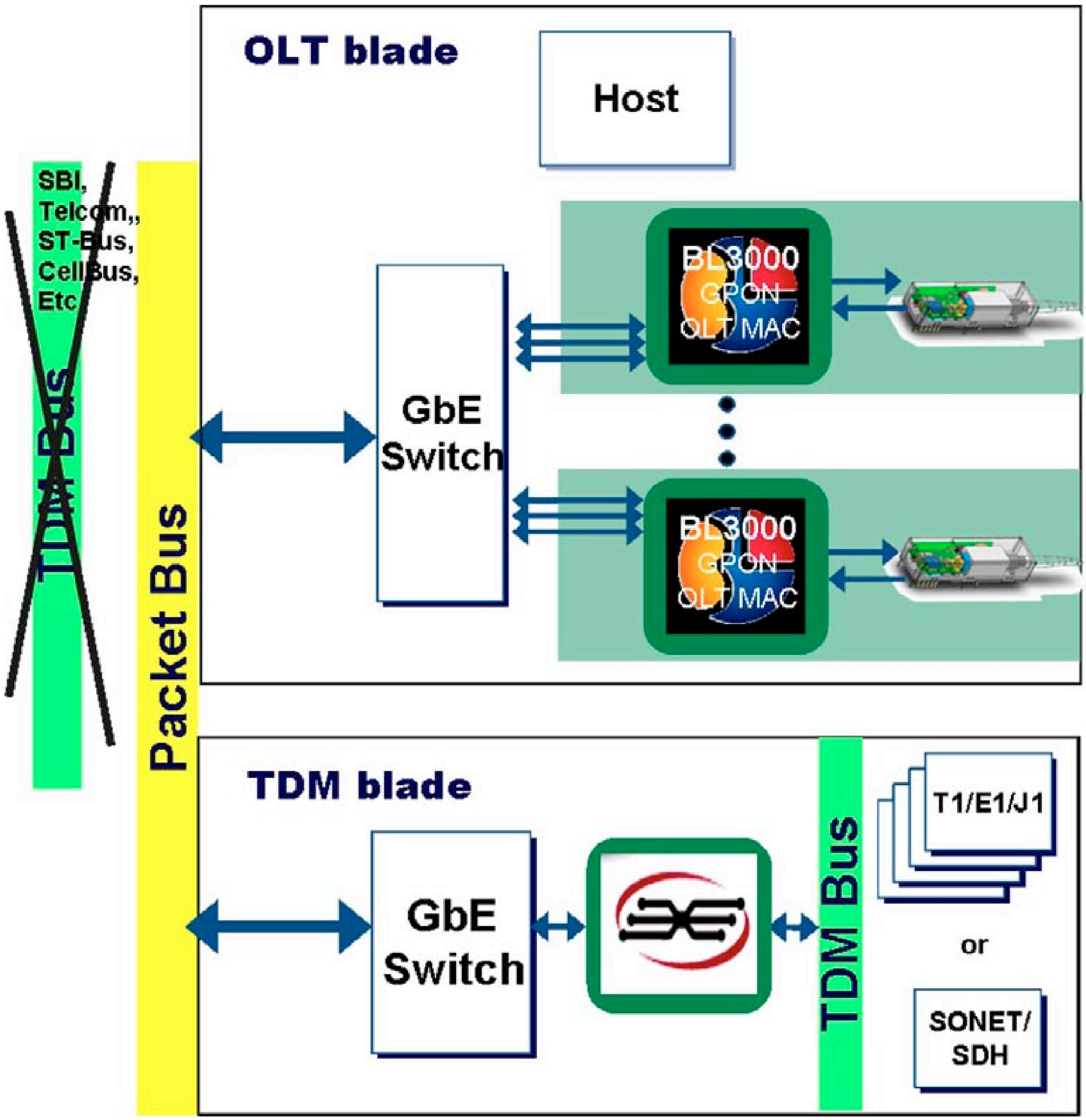

Figure 3: GPON OLT access blade – CESoP

CES is highly scalable and supports aggregation of large numbers of TDM circuits up to DS0 granularity and at rates of up to T3/E3/STS-1. This enables operators to easily match OLT TDM service capacity specific to business or residential requirements.

When located outside the OLT, the CES aggregation gateway (Figure 4) is connected directly to the OLT via a local Gigabit Ethernet connection. Alternatively, the CES aggregation gateway can be located remotely from the OLT on the far side of a packet backhaul link, such as a carrier Ethernet.

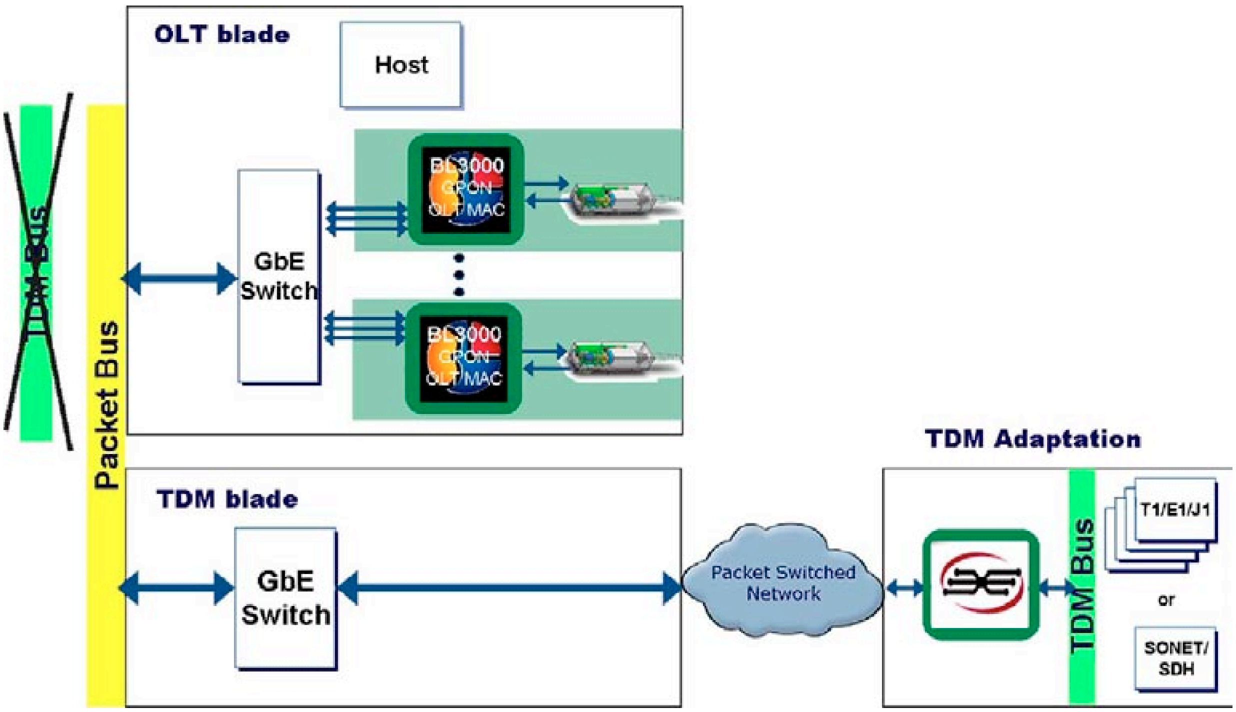

Figure 4: Remote aggregation of GPON TDM services

Eliminating costly TDM infrastructure simplifies OLT architecture. Removing complexity drives down costs and enables fast time-to-market delivery of both TDM services to business users and non-TDM services to residential and commercial customers that significantly represent the target market for GPON today. Eliminating the need for a direct TDM link next to the OLT also broadens GPON deployment beyond locations where TDM capacity is available today.

At the ONT subscriber premises side, CES interworking functionality is integrated into the ONT (Figure 5). The CES function interfaces a standard Fast Ethernet or GigE interface enabling multiple channelized or clear channel T1/E1/J1 TDM service ports. CESoGPON fully supports fractional T1/E1/J1 services up to single DS0 granularity. This is in addition to support for unstructured (clear channel) transport of N x T1/E1/J1 services where required. Fractional T1/E1 services comprise the majority of TDM services offered today and form an essential part of an operator's offering to commercial users.

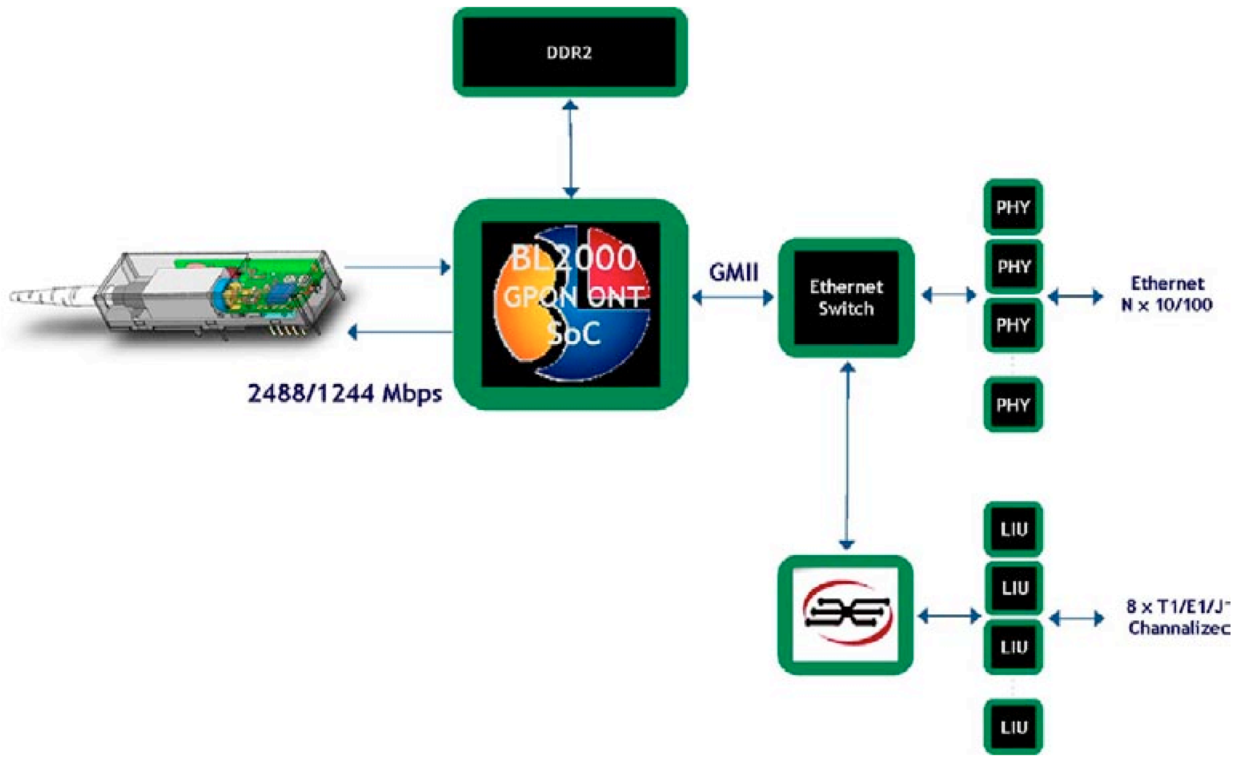

Figure 5: Multiple channelized or clear channel TDM channels

CES facilitates delivery of full and fractional leased line services from multiple operators over a single GPON thanks to its support of multiple clock domains and clock recovery. This provides GPON operators with the option of selling first mile leased line infrastructure service to other operators.

PRESENTING TDM OVER PACKET

TDM over packet technology has existed for some time. It's known by various names, such as CESoIP, CESoP, CESoMPLS, TDMoIP, CESoPSN (circuit emulation service over packet switched networks), and SATOP (structured agnostic service over packet switched networks). The technology has developed to the point where supporting legacy traffic over PON networks can be easily demonstrated and accomplished.

At its most basic, CESoP technology tunnels TDM services across a managed PSN (Packet Switched Network). In the specific case of a PON network, TDM traffic is tunneled from the ONT to the OLT. TDM traffic is packetized, put into a packet payload and transported across the PON. The payload is then received at the OLT and converted to TDM, aggregated and connected to the PSTN (public switched telephone network).

There are four key features that must be available for successfully deploying CESoP technology in PON equipment.

Standards-based

Carriers and equipment manufacturers need products that meet standards to ensure compliance and interoperability. The standards for CESoP service have been issued for various networks, such as MPLS and Ethernet. The GPON standards have within them a method of handling TDM (discussed in more detail below). However, there has been much debate on whether to use those standards, or the pseudowire standards that are discussed here.

There are five standards that govern CESoP services in PSNs. Three are relevant to the PON standards; they are the two pseudowire standards and the MEF (Metro Ethernet Forum) standard. The pseudowire standards comprise of two draft standards from the IETF. They are the unstructured service (SATOP) and the structured service (CESoPSN). The MEF 8 Implementation Agreement for the Emulation of PDH Circuits over Metro Ethernet Networks addresses carrying TDM traffic over an Ethernet connection. This standard supplements the IETF draft standards.

Timing and Synchronization

Unlike circuit-switched networks, PSNs do not have a timing structure. Timing is critical to ensuring the TDM system works properly, and performance must meet specific ITU and ANSI standards. Any PON system will have to handle the timing of the TDM trunk. In a TDM system, there are two ways to pass timing across the network. Each depends on the services that are available in the network.

Timing can be transported using the differential method. Here, a reference frequency or signal is available at both ends of the trunk. This is the situation with GPON networks. Each GPON ONT can be locked to the master frequency in the OLT, which in turn can be locked to the PRS (primary reference source) in the circuit-switched network.

With a reference available at both ends of the network, the incoming or transmit frequency of the T1/E1 circuit (assuming the frequency is asynchronous to the network clock) will be compared to the master frequency and a difference derived. This difference is in the form of a digital word that is transmitted across the GPON network and is used to recover the original frequency at the receiving end.

The second method is the adaptive method. In the adaptive mode, a reference is available at one end (typically the central office) of the network. Time information is conveyed using packets across the PON network and then recovered in the receiving block. The method used to recover the clock is very important.

The simplest form of adaptive clock recovery is the buffer fill method. This approach was adequate for ATM networks, but does not work in a PSN due to a larger amount PDV (packet delay variation). Another form of clock recovery is the averaging method, where the arrival time of the packets is averaged over a period of time. While better than the buffer fill method, this approach does not work for all network loads. A better method is to use statistical operations on the recovered clock to ensure the clock is recovered accurately.

Support for varied services

The TDM service that is picked must be capable of handling structured, unstructured and fractional TDM mode. These are standard T1/E1 services that must be supported.

Unstructured service, also known as unchannelized service, accepts TDM traffic and packetizes the whole frame without knowledge of the framing information. The frame bit is also transferred across the PON. In this way, unchannelized service can be thought of as bit-by-bit transfer.

Structured service, also known as channelized service, keys on the channel information or the DS0 level information. The service is able to switch and groom the traffic. This service will support N*64Kbps service, also know as fractional service, allowing carriers to sell services to the DS0 level.

Point-to-multipoint and multipoint-to-multipoint

To be most functional in a network, any TDM service should be able to support point-to-point (leased line service), point-to-multipoint (star configuration) and multipoint-to-multipoint (mesh configuration). Ideally, a PON network will support all three services, meaning both existing and emerging services can be easily supported.

An example of a new service is pseudo tie lines. Previously, companies used tie lines to connect TDM switches in a mesh network. This service fell out of favour because a T1/E1 circuit had to be leased for each connection. With the advent of the PSN, a CESoP function that supports multipoint-to-multipoint needs only one connection to the network, but can generate multiple packets, each with a different destination address. Thus tie line service once again becomes viable.

STANDARDS FOR PON SYSTEMS

What are the standards around PON systems?

GPON service is an extension of BPON that allows for more bandwidth in the uplink and downlink. The GPON standard is defined by the ITU with its set of recommendations, G.984.x. The FSAN group has also worked with the corresponding study group in ITU to develop the standards. The ITU and the FSAN are in the process of defining the new services for GPON such as TDM pseudowires.

Use in GPON systems

The first deployments of BPON systems have carried triple play services from the service provider to a home or to an apartment building. BPON systems will eventually be replaced with GPON networks because of their increased bandwidth capability. As the deployments grow, there will be a mounting need for the handling of legacy traffic, as well as timing distribution. Using TDM over packet techniques will allow service providers to handle legacy traffic.

Timing is critical for applications in PSNs, including GPON. The nature of the optical connection and the MAC for the OLT and the ONT are such that both the PDV and the distribution of the packets or the standard deviation will be low. This is an excellent criterion for clock recovery.

Equipment designers can select adaptive or differential timing. The differential mode is the preferred method of clock recovery, and allows the user to take advantage of the inherent clocking mechanism in GPON. Figure 6 outlines the differential mode in a GPON network.

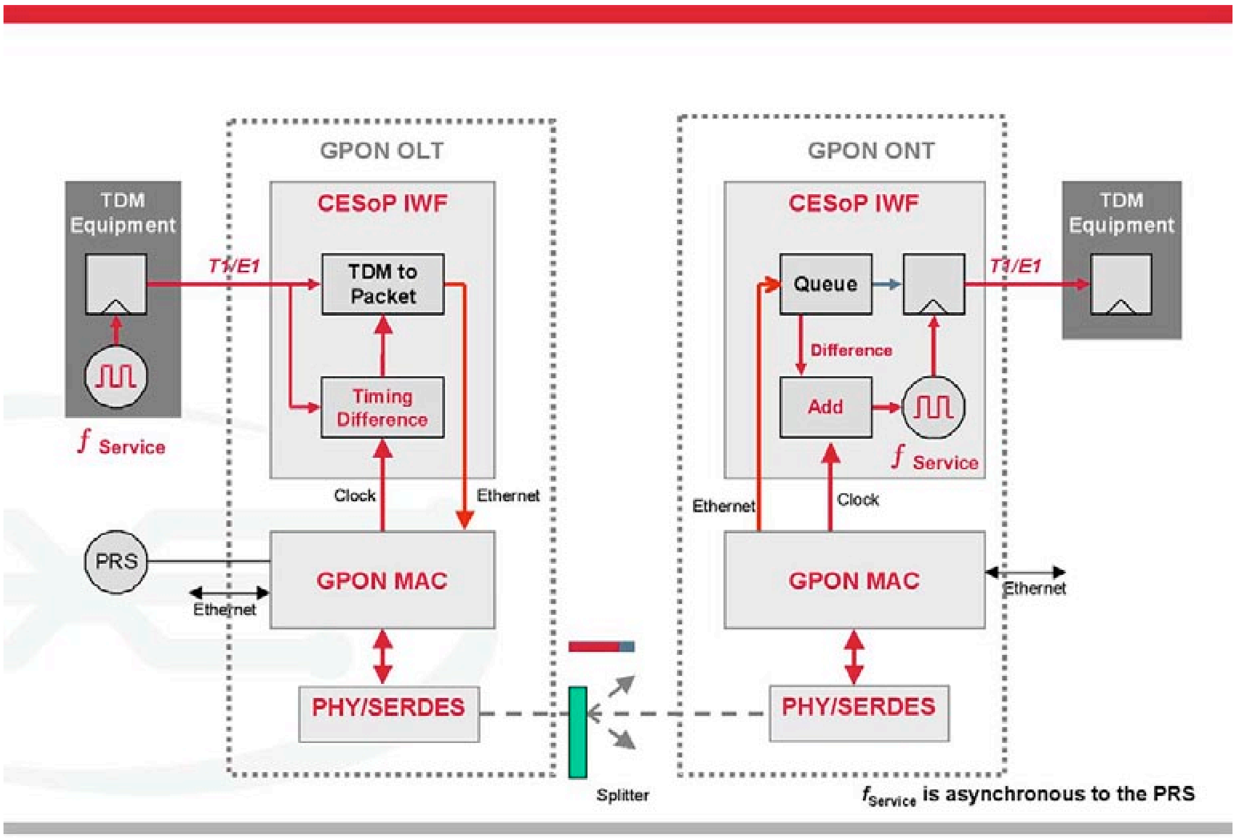

Figure 6: Differential Reference Clocking

Using differential mode ensures optimum clock recovery. It is immune from packet delay and PDV, and can operate over different network conditions.

Adaptive mode is also available. Adaptive timing is defined as the ability to recover the original clock information from the transmitted CESoP stream. The best performance is given by using statistical techniques on the recovered clock to minimize the error induced by the network. The induced error can be induced by packet loss, PDV, latency, or number of hops.

Figure 7 illustrates TDM transport over a GPON network and the benefit of using pseudowires. Using the GEM (GPON encapsulation mode) standard for TDM will only allow TDM to be carried across the GPON from ONT to OLT. With pseudowires, this reach is extended to points outside the GPON network. The network termination can be a CES gateway, seen in the right-hand side of the figure.

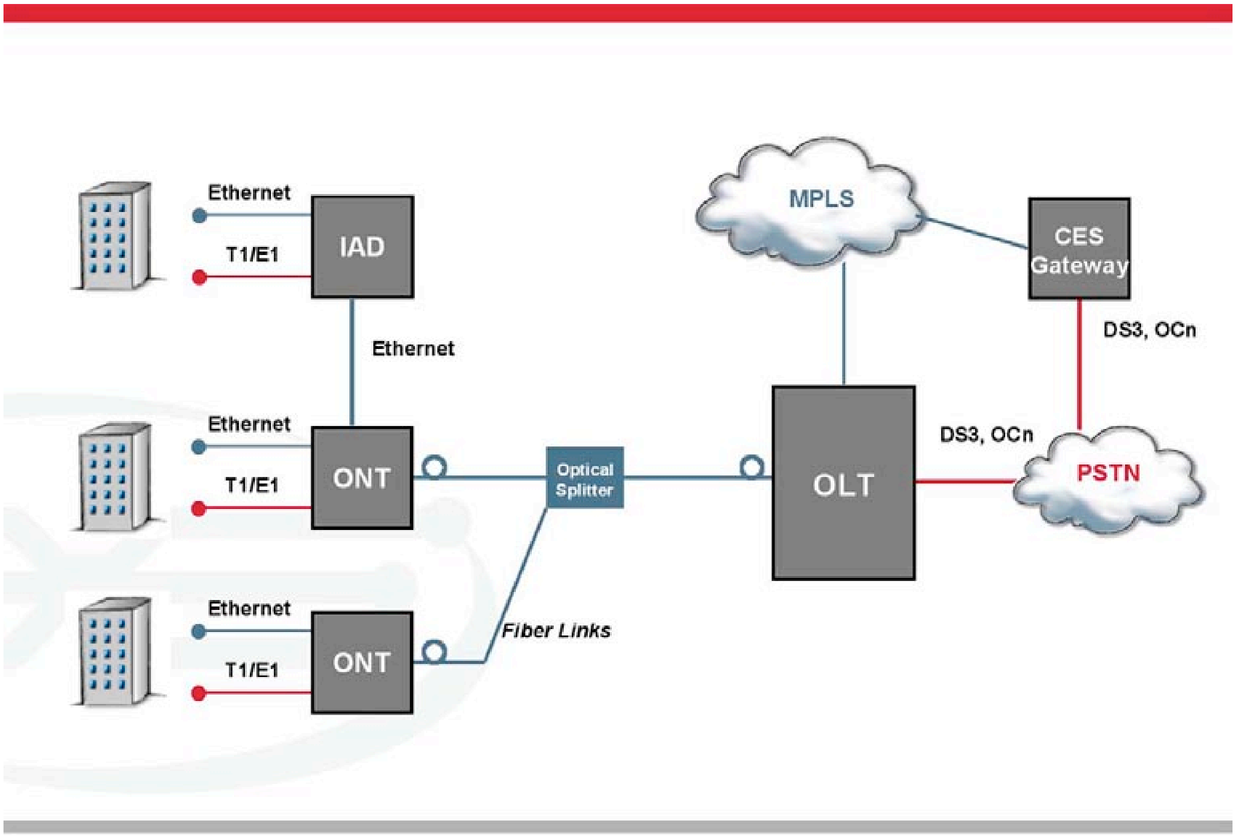

Figure 7: CESoP in an FTTX application: GPON

Figure 7 shows the typical configuration and features of a GPON network. The network is a PON with only two ONTs shown. The CESoP stream is sent from the OLT to the ONT. The TDM traffic can, but does not have to be, terminated in the OLT and the ONT. An IAD is connected to the OLT through an Ethernet link. This link is carrying TDM traffic from an adjacent building. On the right-hand side, the OLT can terminate the TDM traffic as shown by its connection to the PSTN, or it can be terminated in a CES gateway located elsewhere in the network.

INTEROPERATIONAL TESTING

The CESoP solution from Zarlink and the GPON solution from Broadlight was tested using a test network. Various tests were carried out showing compatibility between the two technologies and compatibility with standards. Table 1 shows the results of testing that was carried out on standard T1 and E1 trunks using the MEF protocol, CESoPSN protocol and the SATOP protocol. The tests were also run with differing payload sizes, representing different packet delays. The results were measured with commercially available T1 and E1 test sets. A pass represents that the trunk had not error conditions and it behaved as a normal T1/E1 trunk.

Test	Standard	E1/T1	Payload bytes	Protocol Stack	Equip. Results
1.b	Structured MEF	T1	192	EII / VLAN / MEF ECID / CESoETH	OK
1.d	Structured MEF	T1	24	EII / VLAN / MEF ECID / CESoETH	OK
2.a	Unstructured MEF	E1	256	EII / VLAN / MEF ECID / CESoETH	OK
2.b	Unstructured MEF	T1	192	EII / VLAN / MEF ECID / CESoETH	OK
2.c	Unstructured MEF	E1	32	EII / VLAN / MEF ECID / CESoETH	OK
2.d	Unstructured MEF	T1	24	EII / VLAN / MEF ECID / CESoETH	OK
2.e	Unstructured MEF	E1	128	EII / VLAN / MEF ECID / CESoETH	OK
4.a	Unstructured IETF SAToP	E1	256	EII / VLAN / IPv4 / UDP / RTP / SAToP	OK
4.c	Unstructured IETF SAToP	E1	32	EII / VLAN / IPv4 / UDP / RTP / SAToP	OK

Table 1. Interoperability Results

The clock recovery was tested in adaptive mode. This means that the CESoP part at the ONT side was performing the clock recovery. The performance was measured and found to be within 15ppb. With this result, the MTIE will be within the specified limits for a wander test. Fig. Y shows a typical case for a clock recovery measurement over a PON network. Although this measurement was not carried out in this test, from the clock parameters we can conclude that the performance will be the similar.

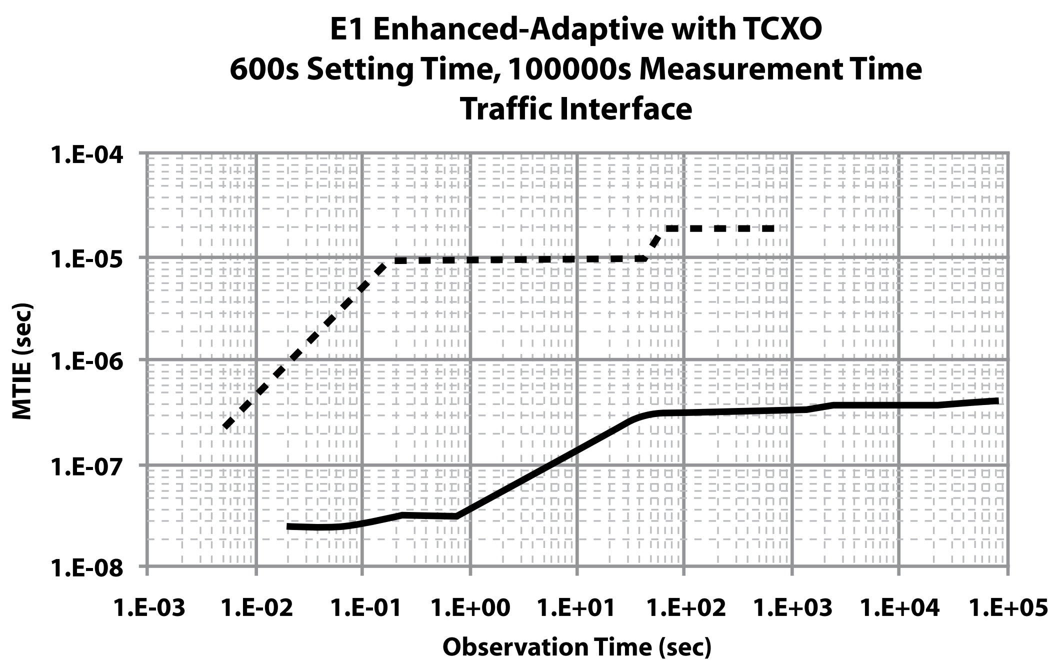

Fig.8. Typical MTIE results: adaptive timing

From the results of the testing, it can be sent that the CESoP performance is superior over the GPON network.

CONCLUSIONS

As carrier networks evolve, GPON systems must handle legacy traffic, such as T1 and E1 circuits. This requires a solution that is standards-based, has standard-compliant clock recovery, can offer service for different TDM modes and can support point-to-multipoint as well as multipoint-to-multipoint. GPON has the advantage of an inherent clock transported through the network. This allows differential clocking to be deployed in the network.

Results of the actual testing was presented. This shows the results of a TDM trunk across the Broadlight GPON system. The performance was comparable to a standard TDM trunk.

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