Delivering voice services over EPON

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Ethernet passive optical network (EPON) technology has emerged as a key solution for delivering triple-play services to residential and business users over packet-based fiber access systems. While data and video will benefit from the increased bandwidth afforded by EPON, the voice component is not as greatly served in the move to packet networks.

This article discusses the challenges in deploying voice-over-EPON and introduces Circuit Emulation Services-over-Packet (CESoP) as a potential solution.

Time-sensitive voice traffic requires far less bandwidth but much more care than data services. Voice latencies are helped by plentiful bandwidth and QoS mechanisms in EPON, but voice is sensitive to both short- and long-term network impairments. Network congestion, insufficient queue resources in an Ethernet switch, a routing change, or a more serious impairment such as a link or path failover will result in lost packets and degraded voice quality. To help, voice-over-packet receivers are equipped with packet-loss concealment schemes.

Voice is also synchronous. A PBX must be synchronized to the PSTN to deliver T1/E1 service. Otherwise, the framers in a PBX will incur periodic buffer slips that will affect QoS. Even for a plain old telephone service (POTS) line, if the receiver is not correctly synchronized to the sender, repeated, periodic buffer slips will appear as a burst of lost packets.

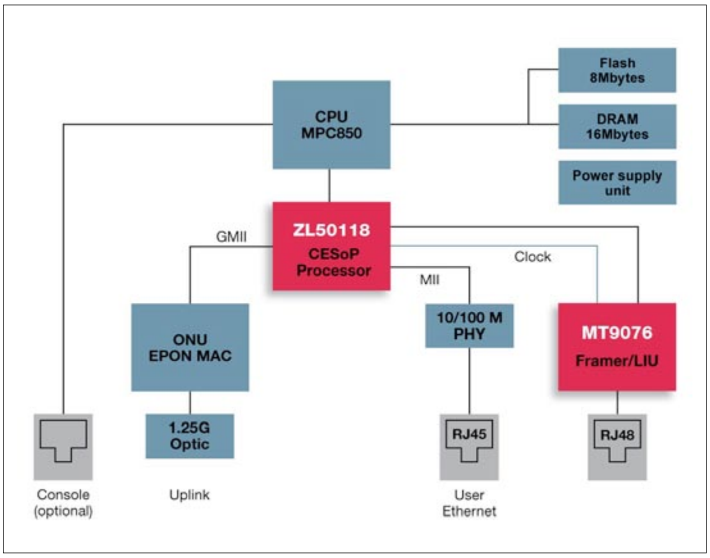

Figure 1: By adding a CESoP block, the ONT has been upgraded to support T1/E1 services, whether fractional, leased line or private line.

Enabling business services

Previous PON flavors were based on ATM technology, which included AAL1 support for circuit-switched services. The absence of this support within EPON means equipment is unable to provide a complete offering, including T1/E1 access, leased line or private line services, for business users.

CESoP is an established technology that tunnels circuit-switched traffic across a packet-switched network. CESoP is a technology match for EPONs, allowing support for T1/E1 services for businesses as well as Nx64kbps residential voice service.

CESoP packetizes the time division multiplex (TDM) traffic or voice samples, including the data and signaling, as either unstructured private line data or structured Nx64kbps voice channels. These packets are then transported across a packet network, such as an EPON. At the far end, the ingress packets are smoothed using a receive jitter buffer. The TDM circuits or voice samples are then extracted from the packets and played-out onto the TDM circuit.

T1/E1 service

An optical network terminal (ONT) for business users provides many 10/100Mbps Ethernet interfaces, but does not directly support T1/E1 services. Instead, a business office has many digital handsets connected to a PBX, which is connected through a T1/E1 line to the PSTN.

CESoP is a natural choice to service this market with EPON. By adding a CESoP block, the ONT has been upgraded to support T1/E1 services, whether fractional, leased line or private line (**Figure 1**).

CESoP meets the challenges in providing voice and T1/E1 services over a packet-based network. Packetization latency may be as low as 125µs (one frame) or a larger 1ms (eight frames), especially in a relatively non-bandwidth-constrained network such as EPON. The packet network latency itself across an EPON should be less than a few milliseconds upstream and even less downstream.

The receive jitter buffer latency is matched with the EPON and would be in the order of a couple milliseconds in the upstream direction and less in the downstream direction. In total,

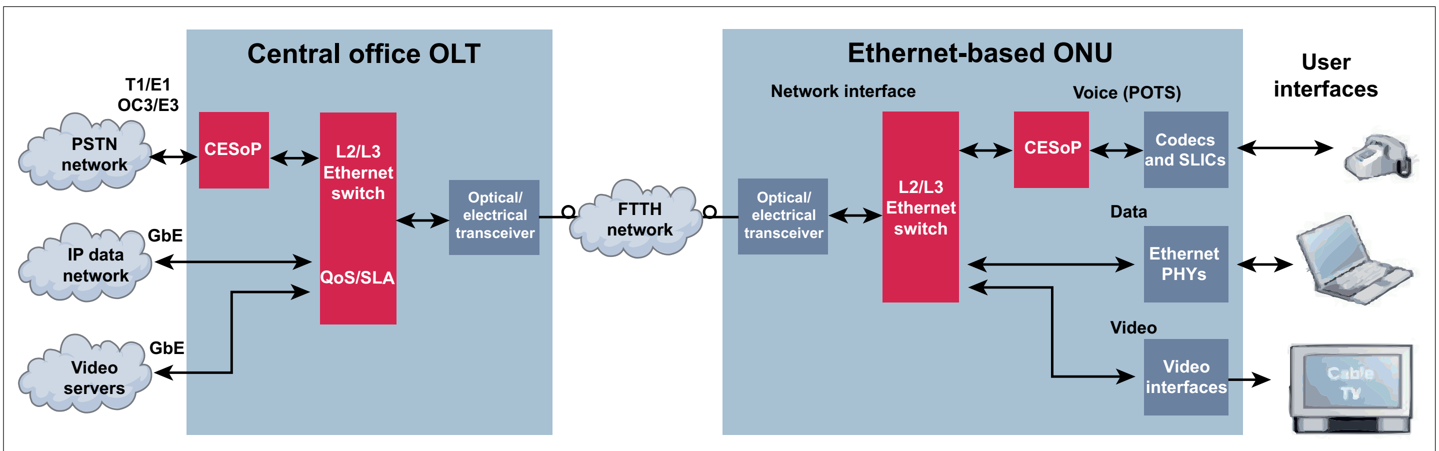

Figure 2: An ONU targeting residential service may support voice service by connecting a VoIP phone through its Ethernet interface.

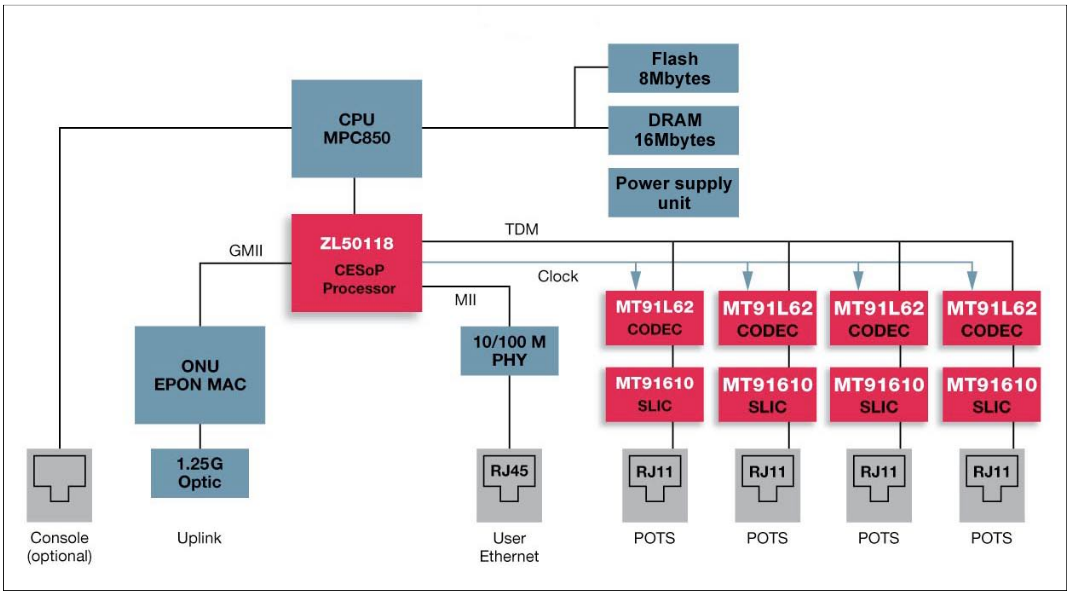

Figure 3: For an ONU with 32 analog POTS lines (32 x 64Kbps), the CESoP connection bandwidth may be 2.5Mbps when taking the packet header overhead into consideration.

one-way latency may be in the order of 5ms upstream and 3ms downstream. Measured lab values were 1,900μs upstream and 800μs downstream, even under loaded data traffic conditions (with one frame packetization).

The timing and synchronization aspect of T1/E1 service has been incorporated into the CESoP standards. Timestamps and sequence numbers are used in the CESoP packet headers to transfer timing information from the PSTN to the customer premises equipment. In a plesiochronous digital hierarchy environment, each T1/E1 connection may have independent timing via a different clock source. Each direction of an individual T1/E1 connection may also have independent timing. CESoP allows operation where each T1/E1 is synchronous with each other or where they are all asynchronous.

When voice packets are late or lost in the EPON, the CESoP connection will replace those missing packets with appropriate "filler" data to minimize the effects on voice quality.

Best performance of CESoP connections across an EPON may be achieved in several ways. Selecting a low frames/packet value reduces overall latency, and using a managed QoS-aware switch and enabling QoS mechanisms in the EPON prioritizes CESoP traffic over background data traffic. This may require the use of the virtual LAN protocol in the CESoP packet header and/or the setting of the ToS bits in the IP header. The CESoP inter-working function jitter buffer should also be sized to a value suitable for the packet delay variation of the packet network—too small and there will be packet discard; too big and there will be unnecessary latency.

CESoP for POTS

An optical network unit (ONU) targeting residential service may support voice service by connecting a VoIP phone through its Ethernet interface, or using VoIP or CESoP through one or more POTS interfaces to provide traditional analog phone service. **Figure 1** shows an ONU implementation that uses CESoP to provide POTS.

The choice of VoIP or CESoP depends on the application, complexity and cost. CESoP is as a very simple mechanism to transparently carry a few voice channels from a residential customer to the PSTN, and provides several advantages versus VoIP.

VoIP typically implements three main blocks: voice processing, packet processing, and control and signaling (**Figure 2**). In comparison, CESoP removes the voice processing block entirely. Thus, it simplifies the complexity, and lowers the cost of the hardware and software in the customer equipment.

CESoP tunnels the voice channels back to the PSTN-connected optical line terminal, avoiding the need for local intelligence to handle call-control processing and gateway signaling functions. Thanks to the abundant bandwidth available in EPON, a CESoP connection to carry all the voice channels provided by an ONU may be established permanently. For an ONU with 32 analog POTS lines (32 x 64Kbps), the CESoP connection bandwidth may be 2.5Mbps when taking the packet header overhead into consideration.

The use of CESoP over EPON enables voice services for residential and business applications. CESoP may be used to provide fractional, leased line or private T1/E1 service for business customers or Nx64kbps voice channels over POTS lines for residential customers. Focusing on business customers, the ability to provide T1/E1 service to a PBX is critical to offering a complete triple-play package. The quality of the CESoP connections allows EPON to effectively deliver the same voice performance and quality as a pure TDM network.

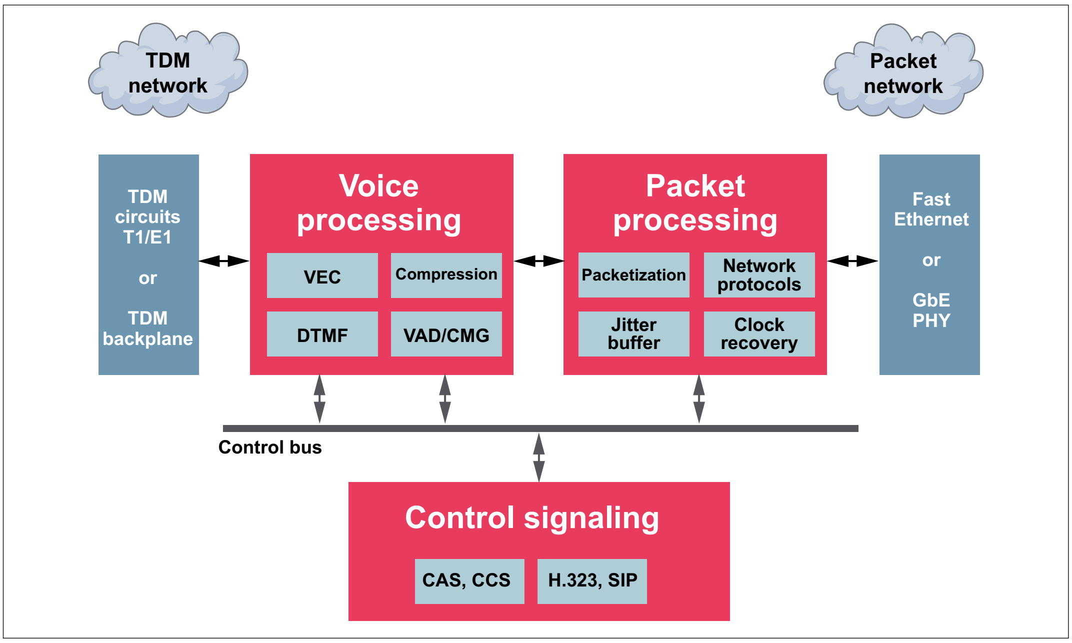

Figure 4: VoIP typically implements three main blocks: voice processing, packet processing, and control and signaling.