Extending The Reach Of TDM Equipment Using CESoP

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While service providers evolve towards packet-based networks, there is still a large installed base of circuit-switched equipment to consider, as well as customers who rely on TDM-based services. How does a service provider extend the reach of its existing TDM network and services, without deploying more legacy equipment? How does a service provider deliver valued TDM service to a new business park where there is no installed infrastructure?

As part of our continued series on Circuit Emulation Services-over-Packet (CESoP), we'll explain how this technology offers an ideal approach for extending the reach of existing circuit-switched networks and services.

Evaluating The Evolving Network

"Packet" and "IP" may be the hottest words in our industry today, but there is still a large installed base of circuit-switched equipment and networks designed and optimized for voice applications, from SONET/SDH, through DS3/E3, down to T1/E1 rates.

Increasing volumes of native packet traffic being carried across these networks is pushing operators towards a converged packet-switched network (PSN) infrastructure. This network migration lowers equipment and operating costs, while allowing operators to more quickly and easily introduce new revenue-generating applications and services.

But what about services and customers that still rely on the installed circuit-switched infrastructure? Clearly, the service provider is not keen to add new TDM-based equipment. One answer is CESoP, which allows a service provider to provide TDM services across a PSN that is then connected back to the existing circuit-switched network. The extension may be for business customers who required private line, leased line or fractional T1/E1 service, or to provide residential POTS in rural areas.

Introducing CESoP

Based on standards from the ITU (Y.1413), Metro Ethernet Forum (MEF 8), MPLS-Frame Relay Alliance (MFA 8.0.0) and draft standards from the IETF, CESoP is a fast-emerging technology that allows circuit-switched services to be carried across a PSN.

CESoP involves packetizing TDM circuit traffic, including data and signaling, as either unstructured private line data or structured N x 64 kbit/s voice channels. These packets are then transported across an Ethernet, IP or MPLS network. At the far-end the ingress packets are smoothed using a receive jitter buffer. The TDM circuits are then extracted from the packets and played-out onto the TDM interface.

Fig. 1: Circuit Emulation Across A PSN

Legacy TDM Network Extension Business

Consider the case where a service provider has a SONET/SDH ring to carry voice and data traffic and would like to provide both TDM T1/E1 and Ethernet service to a business park in a different geographic location. The service provider uses a packet-based network (Layer 2 Ethernet) to extend the reach of the SONET/SDH ring.

Fig. 2 shows both data and voice services carried over the SONET/SDH ring. This section will focus on the TDM traffic. An add/drop multiplexer located on the SONET/SDH ring provides connections for multiple T1/E1s that are taken as VT1.5/VC-11 from the SONET/SDH frame. The T1/E1s may be packetized in unstructured or structure-agnostic fashion to provide private line or leased line service. Alternatively, they may be broken into fractional T1/E1s or structure-aware connections providing N x 64 kbit/s (N x DS0) bandwidth to business customers.

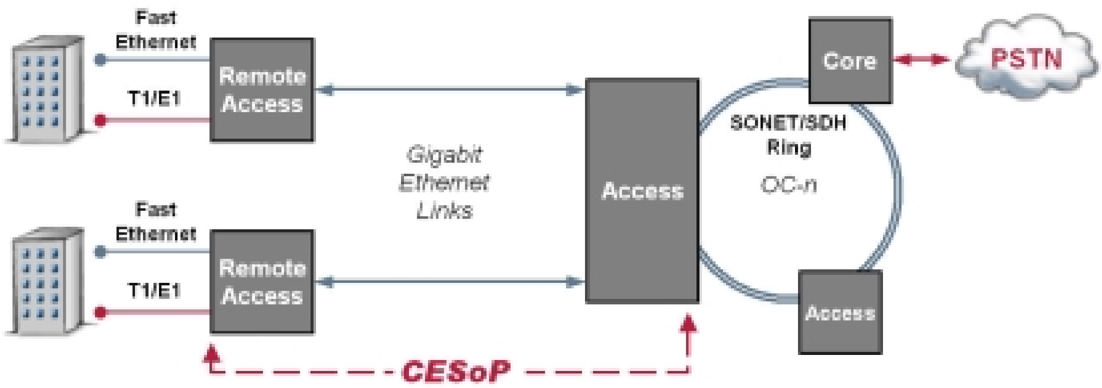

Fig. 2: SONET/SDH Extension

The packetized TDM connections are then carried across the PSN to a remote integrated access device (IAD). The PSN may be as large as a Metro Ethernet ring, or as simple as a point-to-point fiber connection. The IAD will receive the packetized TDM connections, recover both the timing and data for the TDM connections, and provide the final interface (T1/E1) to the customer equipment, such as a PBX. Note that the IAD is completely packet-based from both a physical and management point-of-view. The TDM service is carried across the PSN in CESoP packets and does not require a separate TDM network, specialized management functions, or physical hardware constraints such as an internal TDM-based architecture.

Residential POTS Service

Consider a second case where a service provider wants to offer simple POTS service to residential rural customers. The service provider does not have an installed infrastructure to service this rural area, although they have existing TDM-based equipment deployed with an uplink connection to the PSTN. The choices are to deploy additional TDM equipment, packet-based equipment running Voice-over-IP (VoIP), or packet-based equipment running CESoP.

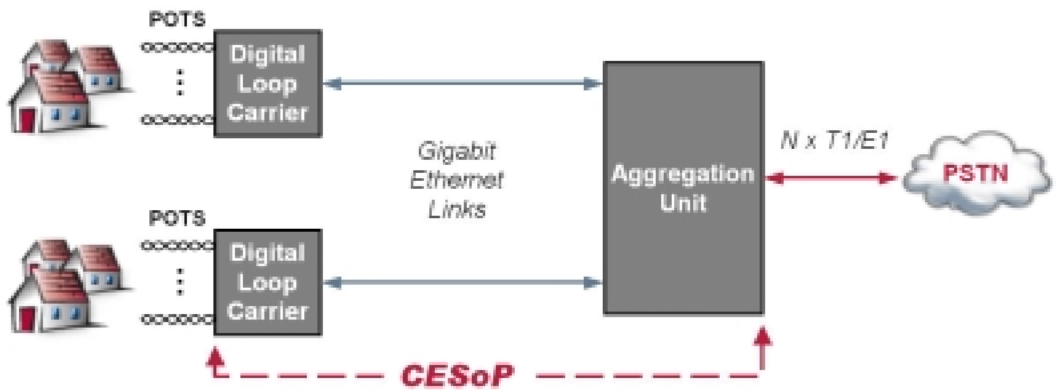

Fig. 3: TDM Extension For DLC And BB-DLC

To ensure the lowest operational and equipment costs the service provider decides to use packet-based equipment over packet connections. Now the choice is between rolling out VoIP equipment, or transparently transporting a few DS0s to a remote digital loop carrier (DLC) using CESoP. Fig. 4 illustrates a small customer-located box running CESoP to provide POTS service.

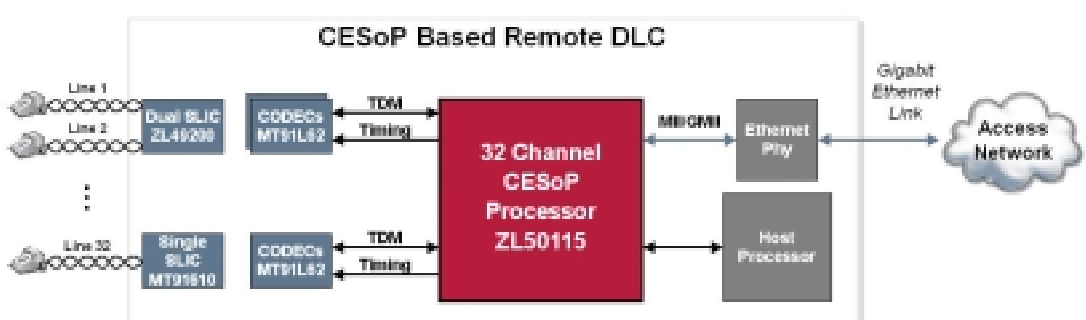

Fig. 4: CESoP With POTS Service

CESoP offers several advantages over VoIP which will typically implement three main blocks: voice processing, packet processing, and control and signaling. The voice processing function consists of echo cancellation, compression, tone detection and generation, as well as VAD and CNG for silence detection and suppression. The packet processing function consists of conversion between TDM and packets (packetization), implementing the PSN protocol stack, providing a jitter buffer to compensate for packet delay variation (PDV) and clock recovery (optional). The control and signaling consists of telephony functions and PSN call control, such as H.323 or MGCP.

CESoP removes the voice processing block entirely, lowering the cost and significantly simplifying the hardware and software in the customer equipment (including any licensing or royalties). CESoP tunnels the DS0s back to the PSTN, avoiding the need for local intelligence to handle call control processing and gateway signaling functions. CESoP has been specifically targeted to carry DS0 (such as ITU-T G.711 voice) traffic using a simple, straightforward approach.

Meeting TDM Requirements

The end-to-end latency of a TDM connection directly impacts voice quality. It would be ideal to keep the latency of a CESoP connection to the same order of magnitude as a TDM connection. The additional latency penalties incurred by a CESoP connection, above that of a TDM connection, are the packetization delay to assemble DS0s into a packet, the routing and switching delays through the PSN, as well as the jitter buffer delays on packet reception to accommodate PDV.

The packetization delay may be as low as 125 µs with CESoP, but more typically will be 1 ms to pack eight frames of TDM traffic into a single packet. The routing and switching delays are a function of the size and complexity of the PSN, but may be lower with the appropriate quality of service (QoS) capabilities. The jitter buffer delays are again reflective of the size of the PSN and may be in the order of 1 ms or less for a well-controlled and prioritized connection.

There are different latency specifications that should be considered when extending an existing TDM infrastructure over packet-based networks. By keeping the end-to-end delay of the voice connection under 25 ms, echo cancellation as specified in ITU-T G.131 "Control of Talker Echo" is not required. ITU-T G.114 "One Way Transmission Time" provides an upper limit of 150 ms of one-way latency in order to provide acceptable performance for voice applications.

There are also equipment-specific latencies, including those specified for DLCs. Telcordia GR-303-CORE and GR-8-CORE specify one-way latency between the local digital switch (LDS) and the two-wire interface on the DLC in the order of 3 ms. This is the latency starting from a T1 connected to the PSTN, across a CESoP connection, and ending at the POTS interface of the DLC. There has also been discussion of latency targets for voice-over-packet equipment, namely from GR-303-ILR where the one-way latency goal for access systems should be less than 25 ms.

A constraint on latency may also be generated by bandwidth limitations. Latency and bandwidth have an inversely proportional relationship when performing CESoP. A reduction in latency results in increased bandwidth use, whereas an increase in latency results in decreased bandwidth use. However, for TDM extension applications (especially over Gigabit Ethernet connections) the bandwidth may be sacrificed to reduce overall latency.

Given some of the target latency values outlined above, it would be difficult for VoIP-based equipment with 20 ms packetization delays to meet some of the technical requirements. In comparison, CESoP-based equipment can achieve one-way latency of less than 1 ms across the CESoP portion of the connection, including a dedicated point-to-point Ethernet network where sufficient bandwidth is available.

While latency is the main concern for TDM extension CESoP also offers other performance aspects to ensure TDM quality. By carrying G.711 DS0 channels without compression there is no voice quality degradation normally associated with low bit rate compression techniques. Good performance against bit error rate measurements, such as errored seconds (ES) and severe errored seconds (SES), may be obtained by keeping packet lengths short. Allocating sufficient bandwidth to CESoP connections, or appropriately applying QoS policies on the managed PSN, reduces packet loss rates comfortably below 1%.

Synchronization Enables Quality

A primary concern when providing synchronous TDM circuit emulation service across an asynchronous PSN is clock synchronization. In a traditional TDM circuit-switched network the clock is "built-in" to the physical layer service, whether T1, E1, T3, E3, SONET or SDH.

In a PSN, such as a typical Ethernet network, no reliable means of recovering or synchronizing network clocks is provided. The burden of providing clock synchronization functionality falls upon the inter-working function (IWF). For an Ethernet network designed to carry asynchronous data packets, and considering the variable quality of PSNs, this is not a trivial challenge.

When extending an existing TDM network there are a variety of timing standards that may be applicable. Some of the common timing synchronization standards are ANSI T1.403 (North America) and ITU-T G.823 (Europe) traffic interface. More stringent timing synchronization standards that may also be required are ANSI T1.101 in North America and ITU-T G.823 synchronization interface in Europe.

Inter-Shelf and Inter-Box Communication

In technical terms, one closely related application to TDM extension is inter-shelf or inter-box communication. (Packet backplanes are similar to these two applications, but are not be discussed here.)

Much of today's existing equipment has TDM-based backplanes, whether ST-BUS, MVIP, H-MVIP, H.100, H.110 or proprietary. CESoP offers a unique way to interconnect shelves within a rack or to interconnect multiple boxes. One or more CESoP connections could be established between two boxes or shelves, with each connection carrying a number of DS0 N x 64 kbit/s channels.

This type of connection has the advantage of easing interconnection, where readily available packet hardware such as Ethernet switches are used to connect all the shelves or boxes. A line card presently used to carry T1/E1 BITS between boxes for timing synchronization is also freed up, by using CESoP-based timing recovery from the timestamps or sequence numbers in the headers of the CESoP packets.

The technical challenges for this type of application are similar to those of TDM extension. It is imperative to reduce latency to the same order as TDM. This would require a low packetization rate such as 125 µs, or one frame. This low packetization rate would not necessarily incur a significant bandwidth penalty, as the effects of N x 64 trunking in the CESoP connection would greatly outweigh the packet header size. Packet loss or packet network quality should not be a factor in this application considering the localized nature of the PSN.

Conclusion

CESoP is a technology that allows an existing circuit-switched network to be extended into new areas without adding TDM-based equipment or increasing the footprint of the legacy infrastructure. CESoP allows TDM and native packet-based data to be readily converged in a single hardware architecture and network infrastructure. CESoP provides a simple mechanism to deliver TDM service, from DS3/E3 and private line DS1/T1 down to fractional T1/E1 or POTS service over a PSN to remote customers.
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