RAD
data communications

Technology Backgrounder

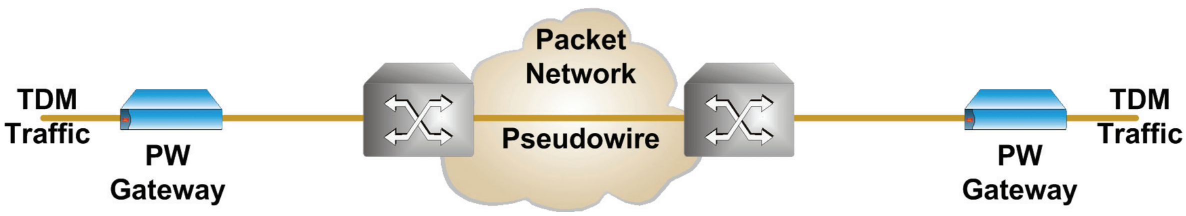
TDM Pseudowire

Pseudowire, or as it is formally known in the standards bodies, Pseudowire Emulation End to End (PWE3), is a mechanism that emulates the attributes of a service over a packet switched network (PSN), such as Ethernet, IP or MPLS. In the case of TDM, a pseudowire will emulate the attributes of a TDM service such as an E1, T1 or a fractional n x 64 TDM service. This technical backgrounder provides a quick introduction to TDM pseudowires and an overview of the currently available TDM pseudowire types.

An Introduction to Pseudowires

Pseudowires(PWs) as a technology originate from the contributions made to the IETF PWE3 working group, which defined the transport of legacy layer 2 services over an MPLS network. These papers were coined the Martini Drafts (some were wryly dubbed Dry Martini) after one of the lead authors, Luca Martini. As such, pseudowires have been in existence for nearly a decade, mainly in the core and edge of the network, typically transporting ATM and Frame Relay traffic over a carrier IP network.

RAD has pioneered TDM pseudowires in the access sector, introducing a TDM pseudowire technology in 1999 at ITU World Telecom in Geneva. Known as TDMoIP®, this implementation extended the original pseudowire definition into the access network and to the customer premises. This technology has enabled carriers and corporate customers alike to provide TDM connectivity and services over a packet network. TDMoIP pseudowire supports all types of TDM services: framed, unframed, with or without Channel Associated Signaling (CAS), enabling a smooth migration to packet networks.



The Technology Challenges

TDM pseudowire technology addresses these main challenges in emulating a TDM service over a packet network:

- "Packetization" and Encapsulation of TDM Traffic
  The TDM traffic has to be "packetized" and encapsulated before being sent to the PSN. Specific packet connectivity information is dependent on the type of PSN: Ethernet, MPLS or IP.
  The encapsulation process places a pseudowire control word in front of the TDM data.
- Attenuate Packet Delay Variation (PDV)
  Packet networks create latency and more important PDV, also known as jitter. The TDM service cannot function with the jitter inherent in packet networks and so the pseudowire emulation must be able to smooth out the jitter of the packet network. This is done by using a *jitter buffer,* which stores packets on the receive side and transmits them smoothly to the TDM link.
- Compensate for Frame Loss and Out-of-Sequence Packets
  Packet networks by their nature experience loss of frames and misorder of

frames (as a result of congestion, routing paths, etc). The pseudowire emulation mechanism must detect and mask these phenomena from the TDM service as much as possible.

- Recover Clock and Synchronization
  Legacy TDM devices require a synchronized clock to function, but the packet switched network by nature is not synchronous. The pseudowire emulation mechanism must regenerate the original TDM timing accurately across the packet network.

Available Pseudowire Types

Following the successful deployment of TDMoIP gateways by RAD, other flavors of TDM pseudowires have been developed under the aegis of the IETF. These pseudowires are known as Circuit Emulation over PSN (CESoPSN) and Structure Agnostic TDM over Packet (SAToP).

CESoPSN TDM pseudowire technology supports framed and channelized TDM services over packet switched networks. The main difference between TDMoIP and CESoPSN is the way CESoPSN packetizes the TDM data. Where TDMoIP packetizes TDM data in multiples of 48 bytes, CESoPSN uses multiples of the TDM frame itself.

SAToP (RFC 4553), or Structure Agnostic TDM over Packet, is a TDM pseudowire technology that differs from TDMoIP and CESoPSN in that it treats the TDM traffic as a data stream and ignores the framing or the timeslots (DS0). It provides functionality similar to TDMoIP in its unframed mode.

TDM PW Type	TDM Service Support	Advantages	Limitations & Disadvantages
SAToP	Unframed	Low overhead Lowest end-to-end delay Flexible packet size	TDM service is more susceptible to frame loss and re-sequence No DS0 grooming can be performed
TDMoIP	Unframed, Framed, Channelized	Complete support of TDM services in one protocol	Higher delay when transporting several time slots due to n x 48 byte frames
CESoPSN	Framed, Channelized	Lower packetization delay when transporting several time slots (DS)	No support for Unframed, must use SAToP

Table 1 - TDM Pseudowire Types

How to Choose a Pseudowire Type

We recommend using three criteria when choosing a TDM pseudowire type:

- Service offered – What type of service is being offered, unframed, framed or channelized?
- Network bandwidth constraints - What is the overhead that can be sustained by the available bandwidth?
- Single or multiple technologies – Is the carrier able to handle multiple pseudowire technologies to achieve optimal results, or will it sacrifice some performance for the sake of simplifying its network operations?

Let us consider the service first. SAToP should be used for unframed E1/T1, such as clear channel or fractional n x 64 services with a serial interface, especially in bandwidth-constrained environments such as DSL. This is because SAToP is the most simple and efficient TDM pseudowire type, using the least amount of overhead and with the most flexible packet size.

TDMoIP or CESoPSN should be used if the service is framed, either fractional or channelized. Furthermore, if the service requires only a few timeslots (DS0) and it is delay sensitive (such as voice), CESoPSN will have reduced delay, as its minimum packet size is smaller than TDMoIP's 48 bytes.

If a carrier provides a mix of these services and would like to reduce the number of technologies used, TDMoIP is the most comprehensive pseudowire type. TDMoIP includes support for framed, channelized and unframed services with the additional benefit of HDLCoPSN, a pseudowire that optimizes and transports HDLC-based protocols across a packet network. Thus, TDMoIP pseudowire is a single technology that supports all TDM service types.

Standardization and Interoperability

The IETF led the way in defining all three flavors of TDM pseudowire under the PWE3 work group. Other bodies, such as ITU-T, MFA Forum and MEF, have also defined TDM pseudowires following the definition of the IETF.

Although defined by the standards bodies, interoperability is not self-evident when deploying TDM pseudowires. At the time of writing, vendor solutions must be tested before deployment to verify interoperability.

Table 2 - TDM Pseudowire Standards

TDM PW	IETF	ITU-T	MFA Forum	MEF
TDMoIP	TDMoIP	Y.1413, Y.1453	IA 4.0,4.1	MEF 8
CESoPSN	CESoPSN	Y.1413, Y.1453	IA 8.0.0	MEF 8
SAToP	RFC 4553	Y.1413, Y.1453	IA 8.0.0	MEF 8

A Word on Clock Recovery

The main challenge with any of the TDM pseudowire standards is the issue of clock recovery. There is no standard definition as to how to perform the clock recovery itself, and each vendor implements a proprietary solution. Specific TDM services have distinct clock recovery needs; the most demanding one is that of cellular backhaul. Additionally, clock recovery performance is highly dependent on the underlying packet network. The ITU-T has defined a standardized way to measure clock recovery performance under the G.8261 specification. Advances in synchronization over packet networks are being made today with IEEE1588v2 and synchronous Ethernet defined in G.8261. These efforts are not yet fully standardized, but are expected to be an important contribution to establishing a robust mechanism for distributing clock and synchronizing packet networks.

TDM Pseudowire Support at RAD

RAD has introduced TDM pseudowire support in many of its products. These include the Link Access integrated access device product family, the ACE cell-site and RNC concentrator product line and Gmux-2000 pseudowire access gateway, in addition to the TDM pseudowire pioneering IPmux product line. RAD continues to lead the way with its leading clock recovery algorithm conforming to G.8261, providing up to G.823 synchronization mask and under 16 ppb (parts per billion) clock accuracy. RAD has also developed its own ASIC-based TDM pseudowire processor featuring all TDM pseudowire standards and the world-leading clock recovery algorithm. The added benefit of RAD's TDM pseudowire ASIC is the ability to support a mix of CESoPSN, SAToP and TDMoIP in a single pseudowire gateway.

References and further reading:

ITU-T: Y.1413, Y.1453, Y.1414, Y.1452, G.8261

MEF: MEF 3, MEF 8

MFA: IA 4.0, 4.1, 5.0, 5.1, 8.0.0

IETF RFC 3985, 4197, 4553, draft-ietf-pwe3-tdmoip, draft-ietf-pwe3-cesopsn

"Taking an inside look at TDMoIP", Yaakov Stein & Brian Stroehlein.
"Technology 101, TDMoIP", Yaakov Stein