Pseudowire for Network Optimization: Evolution from TDM to Ethernet at a Lower Cost

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1.1 Introduction

Expansion of wireless Ethernet technology has prompted a remarkable growth of new networking technologies which had been evolving as a chain of successive next generations: from to 2G to 2.5G to 3G to most recently 4G and LTE, each generation delivering faster and fancier features and conveniences to end users. With the advent of these next generation technologies come the challenging economic questions and business decisions they pose to network operators with legacy infrastructures that cannot convert an entire network overnight. The TDM devices deployed will remain operational, as T1/E1 leased lines currently account for 40-60% of the operational expenses incurred by cellular operators. There are no benefits in not using what had already been paid for whereas dismantling old equipment and replacing it with new will result in additional expenditures that most operators prefer to postpone for as long as possible. Furthermore, replacing existing TDM networks with an all-IP infrastructure will also require replacement of the end-use equipment, which poses additional challenges and expenditures. The general phrases “truck roll” or “rip and replace” are not commonly welcomed by anyone in this industry.

The proliferation of Packet Switched Networks (PSN) combined with the need to sustain legacy TDM networks and the fact that for many applications the pricing of IP traffic has dropped below the tariffs associated with traditional TDM service, resulted in the need for an alternative method of exploiting IP networks for telephony service. This method uses IP networks as a drop-in replacement for native TDM networks or, in other words, it transports existing native TDM services over PSN over Ethernet.

The main challenge for this transport with the legacy T1/E1 networks lies in their synchronous circuit-switched design which was not meant to support asynchronous packet-switched broadband on Ethernet. The transport of native TDM services requires emulation of TDM circuits within the PSN, which lead to the emergence of a circuit emulation technology called “TDM pseudowire” or simply “pseudowire”. In these networks native services are transported through a “pseudowire tunnel”. The internal data service carried by pseudowire is invisible to the core network or, in other words, the core network is transparent to the circuit emulated data streams. It is important to notice that the native services may be low-rate TDM, SDH/SONET, ATM, Frame Relay while the PSN may be Ethernet, MPLS, L2TP or IP (either IPv4 or IPv6).

Originally developed to provide a competitive solution of voice transmission, pseudowire has become the major technology for transmitting TDM service over a PSN. Offering a cost-effective migration path from a TDM network to a PSN infrastructure, pseudowire technology eliminates the need to replace the end-user equipment, removing the obstacle that could have threatened or at the very least significantly delayed the deploy ability of new networks.

This paper discusses the benefits of pseudowire as the logical solution to the problem of evolution from TDM to Ethernet as these benefits are exemplified by the DragonWave line of Service Delivery Unit (SDU) products. The paper pays particular attention to those benefits of the DragonWave SDU products that allow operators to reduce the Total cost of ownership (TCO) of backhaul by a large margin.

1.2 Proactive Approach to Uncertain Future

The evolution of networking technology is posed with a high degree of uncertainly as to what specific technologies would become dominant and when this will happen due to the unknown timing of migration to Ethernet ports on base stations. Facing this uncertainty while trying to avoid premature expenditures on new technologies, network operators need to support rapidly growing user demands for bandwidth and types of services, which requires a much higher capacity than the existing TDM lines can support. Low capacity services can be delivered with T1s, whereas higher capacity services will require T3/E3/Optics, which means additional upfront CAPEX costs along with recurring leasing costs. Add to this building management considerations as well as construction delays, and the network expansion necessary to support new user demands quickly becomes cost prohibitive. Capable of accommodating rapidly growing user demands without the deployment of additional T1/E1 lines, pseudowire offers to network operators, an elegant cost-effective and forecast tolerant solution.

1.2.1 Network Convergence

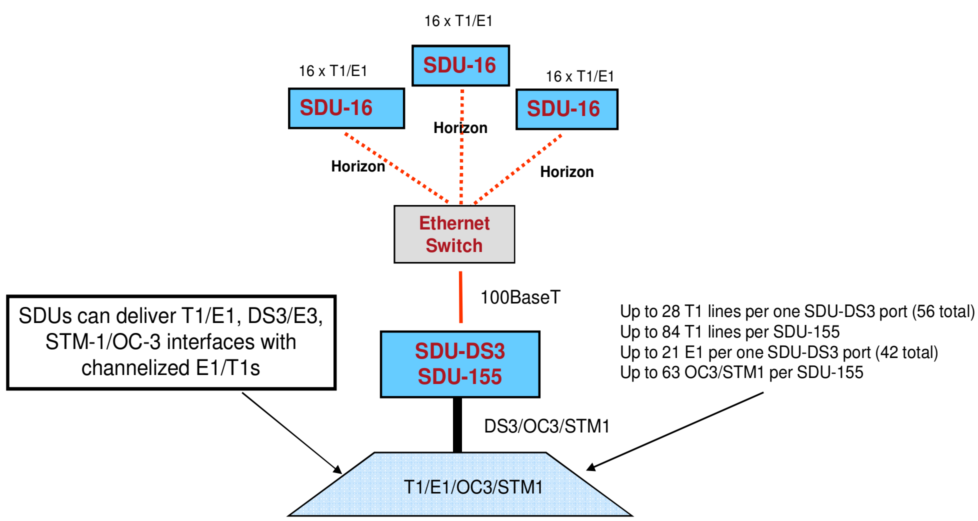
Compared with the equivalent SONET/SDH approach, a pseudowire approach offers superior efficiency and flexibility. By aggregating various services into a single converged Ethernet network, pseudowire effectively removes capacity limitations from the synchronous TDM networks. This means that operators can leverage business models based on all the advantages of Ethernet as a converged packet network without sacrificing revenues from the legacy TDM services. Enabling an economical network convergence, pseudowire has a full range of networking applications: from TDM access line service (TALS) to TDM Line Services (T-Line) to Cellular Backhaul.

DragonWave offers several flexible pseudowire options under the common name of a Service Delivery Unit (SDU). DragonWave's SDU products seamlessly transport TDM traffic over Ethernet enabling customers to easily migrate to native IP networks while still supporting legacy TDM services and meeting stringent synchronization requirements. The SDU combines Ethernet, up to 6 switched GbE ports (2 optical and 4 electrical) as well as pseudowire functionality into a single box. DragonWave offers three SDU options: **16 port T1/E1 version, 2 port DS3 version, and an OC3/STM1 version**. Up to three SDUs can be deployed into a single Rack Unit (1RU) high slot and cascaded to provide as many ports as required by the customer traffic requirements. Using an optional pseudowire plug-in with DragonWave's Horizon Duo, a carrier could run 16 T1/E1 lines, two DS3/E3 connections, or one OC3/STM1 over a single Gigabit Ethernet connection. That means ongoing monthly cost savings for mobile operators that otherwise have to lease T-1 lines for approximately $200-400 a month per T1.

1.2.2 Network CAPEX Efficiencies

Pseudowire provides a single output point for multiple sites to aggregate to, i.e. enabling aggregation of T1s to OC3. This aggregation helps to avoid complex and expensive T1 to T1 handoff and interconnect at intermediate sites. Eliminating internal TDM handoffs, pseudowire minimizes the need for distributed Add/Drop/Mux (ADM) or crossconnect boxes. As a result, the lower capital costs are achieved via the eliminated need for distributed Add/Drop/Mux (ADM) or cross-connect boxes, taking these costs out of the network TCO.

Aggregation of Multiple Sites with DragonWave pseudowire SDU



When compared with native TDM services for mixed traffic applications, pseudowire delivers up to 25% more T1/E1s per RF channel, which results in lower cost per T1/E1 - allowing operators to reduce their backhaul costs by a significant margin.

Pseudowire allows TDM to be carried as Ethernet at intermediate sites. This removes T1/E1 interfaces and cabling for intermediate pass-through, drastically simplifying the network and avoiding the need for high count T1 radios.

1.2.3 Simplified Operations and Management

Merging TDM networks with PSN networks requires choosing either a circuit or packet-based network. Given that packed-based networks are lower cost and more flexible in provisioning for bandwidth, they are better matched to the needs of new generation networks. By enabling a unified packet-based network, pseudowire simplifies operations and management, because a unified network means only one network needs to be operated.

The DragonWave SDUs offer a convenient future proof transition to an all-IP infrastructure, eliminating the need to manage the TDM connections at each intermediate network point. The network does not need to be changed as the traffic mix changes from TDM circuits to packet-based traffic.

By aggregating various services into a unified converged packed-based network and eliminating complex and expensive internal TDM handoff as well as shielding the core network from changes in the traffic and thus significantly simplifying network management and operations, a pseudowire approach represents a far more economical and proactive solution than the equivalent TDM approach, fully delivering to the goal of forecast tolerance.

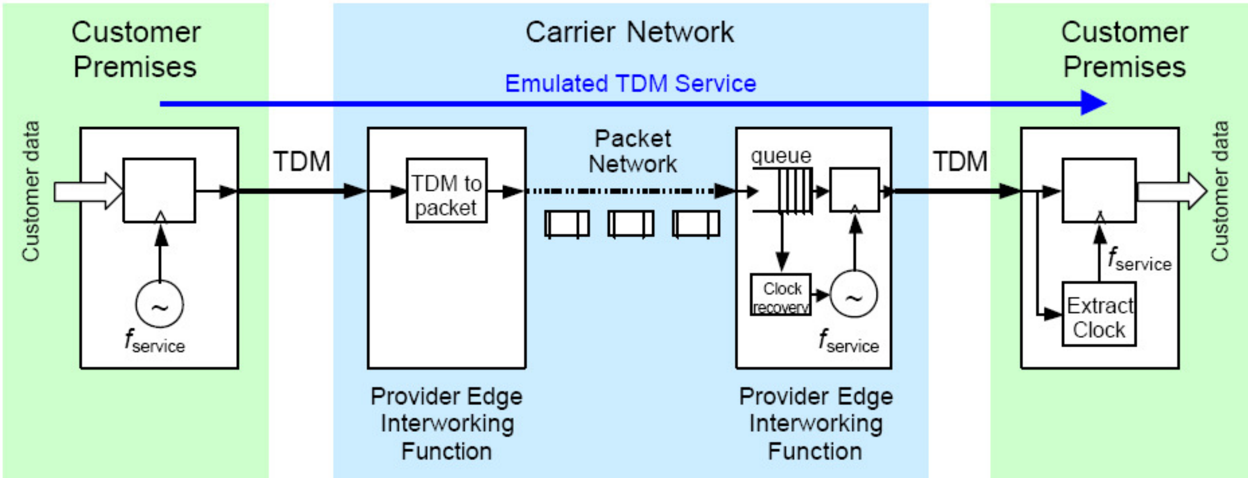
1.3 Technical Challenges Associated with Pseudowire Emulation

Being the most economical and dynamic solution for converged networking, pseudowire is, nonetheless, posed with certain technical challenges. The main technical challenges associated with deploying pseudowire technology are clock synchronization and network engineering. For clock synchronization the main issue is how to maintain synchronous TDM timing over an asynchronous Ethernet network. For network engineering the main challenge lies in the fact that end-to-end networks need to be purposefully engineered to handle tributary networks with different mixes of traffic and network topology, e.g. packet delay variation, packet loss and overall latency. Not all pseudowire products currently available on the market are engineered to handle such specific network requirements.

There are also technical difficulties associated with providing a robust yet cost-effective protection scheme as well as such design factors as cross-integrating various types of pseudowire emulators along with 3rd party equipment along with network diagnostics and management, all of which needs to be enabled in order to deploy a high capacity converged network capable of carrying various mixes of services. We will proceed by addressing each of these technical challenges and illustrate how DragonWave's SDU solve them all in the most efficient and cost-effective manner.

1.3.1 Clock Synchronization

One of the key challenges in TDM transport is that the clock on both of the TDM segments of the link must be at the same frequency. Figure 1 illustrates the challenge. It shows a private leased line between two customer sites, connected by an emulated link across a carrier's packet network.



The TDM service frequency *fservice* at the customer premises must be exactly reproduced at the egress of the packet network. The consequence of a long-term mismatch in frequency is that the queue at the egress of the packet network will either fill up or empty, depending on whether the regenerated clock is slower or faster than the original. This will cause loss of data and interruption of the service.

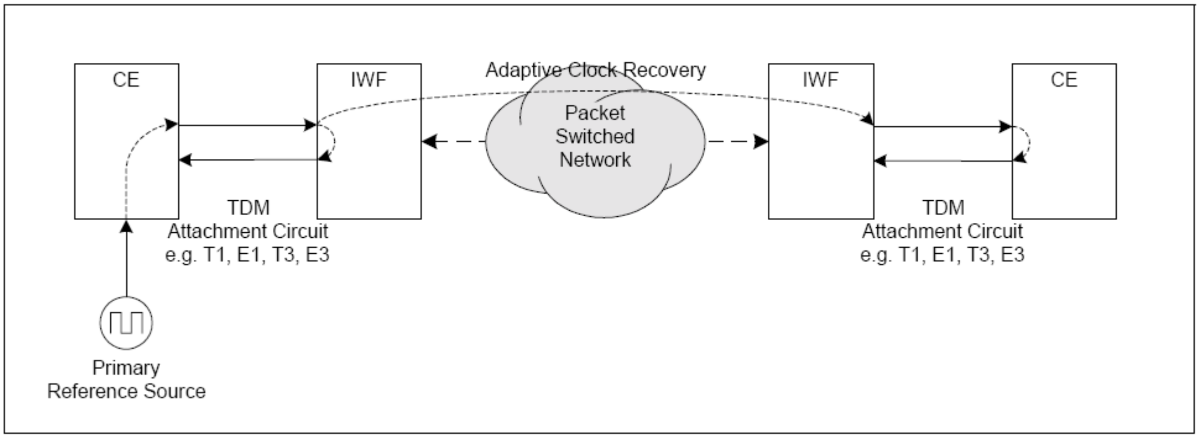
With a packet network, that connection between the ingress and egress frequency is broken, since packets are asynchronous in time. Therefore, unless there is an external means of clock distribution, the inter-working function at packet egress will be required to recover the frequency of the original TDM service clock by some means.

1.3.1.1.1 Clock Recovery Techniques

There are two main methods of clock recovery in DragonWave's SDU products: adaptive and differential. The adaptive clock recovery uses the Timing-over-Packet (ToP) technology to recover timing information. Differential clock recovery, on the other hand, uses a known common clock at either end of the packet network (e.g. a GPS reference clock or Building Integrated Timing Supply (BITS) timing) to synchronize timing in the network.

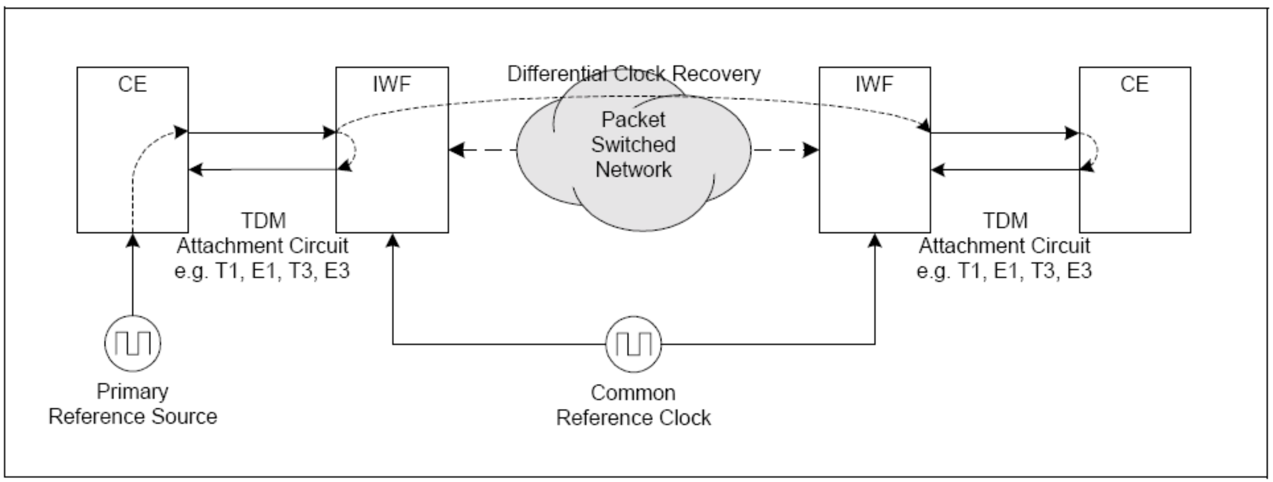
1.3.1.1.1.1 Adaptive Clock Recovery

Adaptive clock recovery controls the output clock to maintain the average jitter buffer depth at the design value. However, using only the jitter buffer, the adaptive recovery cannot differentiate between network packet delay variation and input timing variation. DragonWave uses timing over packet technology which allows the receiver to measure the network delay variation and subtract that information so that the output clock tracks only the input clock and ignores network delay variation. The timing recovery is compliant with H.823 and stratum 3 specifications for well engineered packet networks.



1.3.1.1.1.2 Differential Clock Recovery

Unlike adaptive clock recovery, differential clock recovery uses a known common clock at either end of the packet network. This eliminates any interaction with the packet delay variation in the packet switched network, however it requires the additional cost of an external clock distribution mechanism (such as a GPS receiver).



1.3.2 Network Engineering

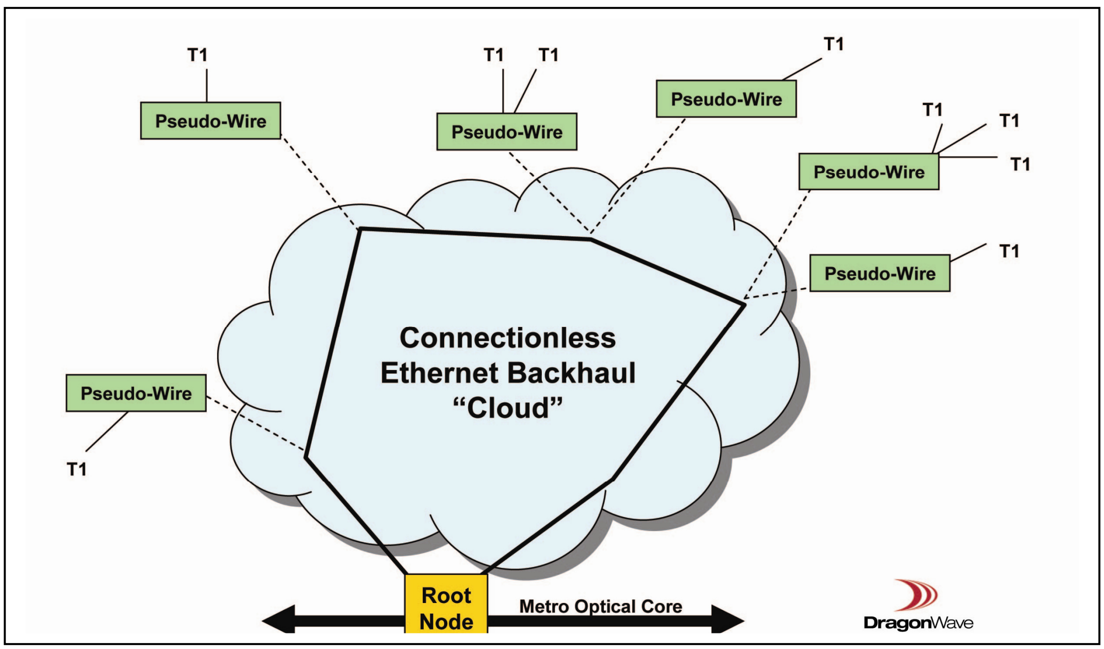
It is impossible to guarantee performance on an unconstrained network, so network engineering becomes an important consideration associated with pseudowire technology. In other words, the characteristics of a network need to be proactively engineered to handle different applications to guarantee low latency, packet delay variation, and packet loss. Using high fidelity wireless networks the residual bit error rate is very low and so the Packet Loss Concealment (PLC) challenge typically associated with pseudowire emulators is not applicable.

Furthermore, pseudowire traffic should always be prioritized in order to ensure timely delivery in the face of congestion. DragonWave supports a full range of advanced Ethernet functionalities such as 802.3.ah, 802.1ag, and Y.1731, including flexible prioritization based on 802.1p, Q in Q, MPLS or DSCP priority fields.

In mobile backhaul networks there are also strict delay requirements that need to be met for base stations to work. DragonWave offers ultra low-latency radios and very low latency SDUs, which result in low packet delay variation. Supported by the underlying mesh/ring network architecture, DragonWave's low latency radios and low residual bit error rate can deliver on the most stringent network requirements.

1.3.3 Deploying a Network with Pseudowire

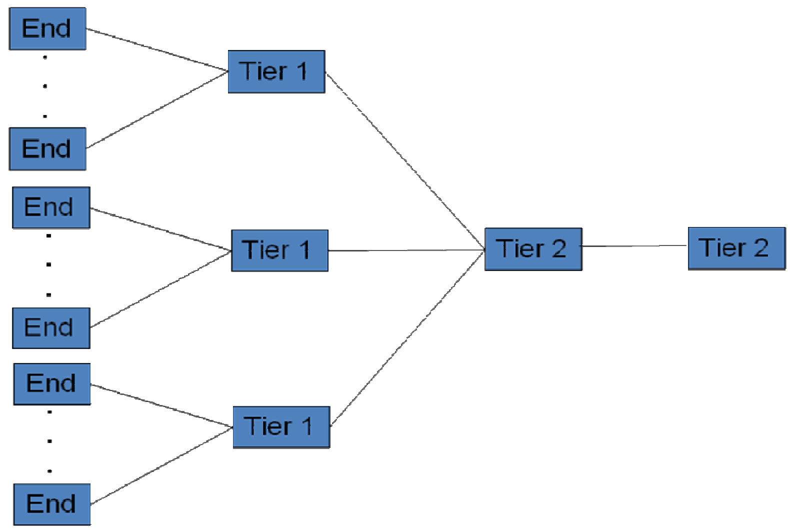
A simple point-to-point network would include radio and networking equipment, intermediate bridges or switches, multiple pseudowire emulators, 3rd party vendor radio or networking equipment, multiple T1/E1 lines, and a fiber connection to a hub.



An Ethernet networking benefit for TDM transport is that virtual 1:3 cross-connecting can be realized in the aggregation of T1 tail circuits without additional equipment. Additionally, the connectionless nature of Ethernet allows highly flexible deployment of T1 circuits anywhere in the network, since Ethernet allows the re-targeting and re-configuration of available network capacity with great ease.

1.4 Economic Comparison of TDM and Pseudowire

In order to illustrate the economic benefits of pseudowire over an equivalent TDM approach, let us compare their respective costs in a network deployment. Let us assume a network model based on a hub-and-spoke 3-tier architecture with 12 T1s per site.



1.4.1.1.1 Model Summary

- Hub-and-spoke 3-tier architecture
    - 12 x T1s per site
- TDM radio (2 x OC3 limit)
    - 10 end sites, 3 x 1st tier hub sites, 1 x 2nd tier hub
    - 14 sites x 12 Ts/site = 168 x T1s = 2 OC3s
- Packet Radio (370 Mbps limit)
    - 1.8 Mbps pseudowire per T1
    - 12 end sites, 3 x 1st tier hub sites, 1 x 2nd tier hub
    - 16 sites x 12 T1s/site x 1.7 Mbps per T1 = 345 Mbps
- **A Fiber hub is connected to the MSC via a leased OC48 circuits or GbE Virtual Private Line**
    - 3 microwave sub-circuits per fiber hub

1.4.1.1.2 Pricing assumptions

We also need to make certain pricing assumption.

- **TDM Radio**
    - OC3 Link $11,000
    - 2x OC3 Link $20,000
    - Installation & Cabling $7,000
    - Power & Misc $5,000
    - OC3 ADM $4,000
    - OC-48 ADM $8,000

Packet Radio

- 20 Mbps Link $6,500
- 100 Mbps Link $9,500
- 400 Mbps Link $12,500
- Installation & Cabling $6,000
- Power & Misc $3,000
- 16 T1 SDU PWE $2,000
- OC3 SDU PWE $3,000

Leased Line

- OC48 Leased Line $9,000 per month
- GbE Virtual Private Line $3,000 per month

1.4.1.1.3 Cost Summaries

Based on the network model and pricing assumptions presented above, the following cost summaries emerge:

1.4.1.1.3.1 TDM Radio, TDM at the Core

- CAPEX per site to fiber hub - $27,952 (100%)
- Equivalent cost per month per T1 to MSC - $74 (100%)

1.4.1.1.3.2 Packet Radio, TDM at the Core

- CAPEX per site to fiber hub - $18,531 (66%)
- Equivalent cost per month per T1 to MSC - $52 (71%)

1.4.1.1.3.3 DragonWave Pseudowire End to End

- CAPEX per site to fiber hub - $17,980 (64%)
- Equivalent cost per month per T1 to MSC - $42 (56%)

As we can see from this comparison, using a DragonWave pseudowire solution for T1 backhaul versus a TDM solution shows a clear advantage - 35% CAPEX reduction - for the DragonWave approach. When coupled with the lower cost Ethernet leased lines enabled by the pseudowire approach, the equivalent monthly cost per T1 advantage increases even further to 45% reduction for pseudowire versus TDM.

This analysis does not take into account the reduction in TCO offered by the zero foot print and integrated antenna solutions supported by DragonWave. DragonWave is one of the few vendors who supplies all-integrated outdoor networking equipment as well as equipment capable of supporting 1.6Gbps of full duplex bandwidth per link. All-outdoor equipment eliminates the requirement for indoor microwave equipment, which reduces footprint and decreases monthly site lease costs. Having microwave equipment permanently placed outdoors, i.e. on a roof or on a tower, offers an additional benefit of reduced installation costs, simplified cabinet wiring, and simplified troubleshooting, all of which helps reduce spending even further.

DragonWave is also one of the few vendors who are capable of providing integrated antenna solutions. The integration of RAN antenna panels together with backhaul antennas to form a single multi-beam antenna eliminates the need for a second antenna lease. The small form factor of the DragonWave product line enables the company to provide a highly successful antenna integration solutions, which helps to reduce the total lifecycle costs of a network.

Furthermore, DragonWave is one of the few vendors offering networking equipment based on mesh/ring architecture. Mesh/ring architectures allow improved and cost-effective redundancy as well as highly flexible scalability while providing access to both the working and protection bandwidth under normal conditions.

There are additional benefits of using the DragonWave solutions. Flex bandwidth pricing from DragonWave allows customers to reduce upfront CAPEX costs in cases where customers' initial demand for bandwidth is lower, without reducing the upgrade capability. DragonWave's adaptive modulation allows engineering links at lower throughput while still gaining access to the full throughput under normal conditions, which gives increased capacity for best effort services.

And finally, there are added operational benefits. Using a pseudowire approach significantly reduces the cost of churn for the network as traffic types evolve over time; it provides the ability to add Ethernet services at no additional cost and; and it also allows network operators to offer new packet-based services to their existing voice-only customers as well as customers with variable classes of services.

1.5 Conclusion

As a result of novel pseudowire networking technologies, network operators can deploy a highly scaleable Ethernet-based metro backhaul network while retaining the capability to cost-effectively support legacy TDM backhaul functionality. The DragonWave SDU pseudowire technology supports the migration path from a TDM to a PSN infrastructure without compromising functionality or services and without requiring any additional investment in network upgrades.

Responding to the market needs for a future proof approach, DragonWave has proactively engineered networking solutions capable of supporting the current evolutionary networking demands in the most efficient, forecast tolerant, and cost-effective way. The DragonWave low-latency radios combined with the SDUs which can accommodate large packet delay variations can deliver the target performance across a wide variety of network topologies. The mesh/ring network architecture, along with low latency radios and low residual bit error rate, can deliver on the most stringent network requirements. DragonWave's pseudowire employs Timing-over-Packet technology in addition to jitter-buffer processing in order to robustly deliver stratum-3 TDM performance. The DragonWave pseudowire supports a full range of advanced Ethernet features (802.1q, 802.1p, 802.3.ah, 802.1ag, Y.1731), user-settable efficiency/delay, user-settable jitter buffer size, full and cost-effective redundancy, and a wide range of network diagnostics and management features.

As we attempted to demonstrate in this paper, the DragonWave SDU technology is presently the most thorough and proactive pseudowire solution in the industry, designed to help operators to significantly reduce costs on one of the most expensive elements in mobile networks: integrating TDM services into a single converged PSN infrastructure.

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