Business Models for Video Transport

The Economics of Intelligent Packet Transport for Video Services

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1.0 The Evolution to Intelligent Packet Transport

Adding data awareness to the metro transport network creates new business models that preserve current revenues and provide the foundation for migration to all packet architectures. Consolidation of transport and switching onto a single platform opens the possibility of offering new services, creating new service models and lowering hardware and operating costs. The Packet ADM is built upon standards based technologies and provides the following benefits.

- Standard SONET/SDH OC-192/STM64 PHY for traditional OAM
- Standard RPR for per-CoS traffic management
- Guarantees SONET/SDH-like sub-50msec protection switching for all services
- Uses standard MPLS control and forwarding plane for scalable service delivery
- Automatic end-to-end provisioning across multiple network topologies
- Automatic path management across multiple network topologies.

The combination of technologies included in this new class of transport equipment means that carriers can now offer video, voice and data services on a single platform that is efficient, scalable and can deliver the economics required to make new services profitable. Some of the benefits that accrue from the Packet ADM design are:

- It minimizes capital costs through efficient traffic management on a shared packet ring and eliminates logical hub-and-spoke or meshed solutions that overuse fiber, require more optical ports and results in deployment of excessive switching capacity.
- It reduced capital expenditures by consolidating L2/L3 and transport devices into one network element.
- It minimizes operational cost through convergence of all required data functions for transport and aggregation into a single transport network element.
- It provides the most efficient transport solution for broadcast and multicast traffic through the use of the RPR MAC, which requires duplication of broadcast traffic only at the very edge of the network.
- It provides a native control protocol that enables statistical multiplexing gains that result in greater revenue potential per Mbps of bandwidth.
- It is a scalable 10Gbps packet-based transport solution that can meet any demand, current or future, for video, data and voice services.

The combination of SONET/SDH, Ethernet, MPLS (VCAT, LCAS, Pseudo-wires), and RPR at 10Gbps creates the ability to simultaneously lower capex and opex while creating the opportunity to offer more services. Listed below are the key features that are critical to the economic models presented later in this paper.

1) Support for four classes of service

The Packet ADM supports four classes of service over the shared packet ring. This allows service providers to match end-users' applications to the right CoS on its network. All classes-of-service are reclaimable and no bandwidth is ever stranded.

2) Flexible classification of end-user traffic

The Packet ADM provides four classes of service of packets labeled with 802.1p bits for VLAN segregated traffic or labeled by TOS or DSCP bits in the IP header. These capabilities allow classification of traffic according to the marking done by the customer CPE or according to the marking performed by the broadband access network element.

3) Strict separation of traffic

The Packet ADM carries all services as standard MPLS pseudo-wires and guarantees hard separation between network services. A clear separation between control plane and forwarding plane functions guarantees maximum separation and resiliency.

4) Efficient transport of multicast – only one copy is carried over the ring

The use of the standard RPR MAC represents a scalable and efficient way to deliver large amounts of broadcast and multicast traffic on physical ring topologies. Alternative solutions require deployment of a logical hub-and-spoke architecture on the physical fiber ring, which preclude efficient transport of multicast traffic. Hub-and-spoke designs require more fiber, more virtual connections and multiple copies of multicast streams to be broadcast simultaneously. All recipients can get a multicast stream from only one copy on the ring.

5) Efficient bandwidth management

Corrigent's Packet ADM solution delivers packets over a shared ring using statistical multiplexing, spatial reuse, and efficient allocation of protection bandwidth to deliver more services and therefore more revenue per equivalent amount of bandwidth.

- *Statistical multiplexing* – The RPR-based shared media enables multiple nodes to share the same network resources and thus take advantage of effective statistical multiplexing. Bursty services share the same resource, and the allocation of bandwidth to support excess traffic becomes significantly more efficient.
- *Spatial reuse* – The RPR shared media natively provides the ability to spatially reuse unused spans on the shared ring. Spatial reuse allows reuse of bandwidth not only on different spans than the ones carrying a service, but also on asymmetrical services.
- *Efficient allocation of protection bandwidth* – RPR allows flexible allocation of protection bandwidth on a per service basis. The Packet ADM allows a carrier to provision protection for the committed-rate portion of any service.
- *Fairness* – The RPR MAC guarantees fair distribution of bandwidth across the ring. While Connection Admission Control (CAC) mechanisms guarantee that high-priority traffic is delivered with the appropriate SLA, the RPR fairness algorithm dynamically allocates free bandwidth in a fair manner to all excess and best effort traffic over the shared ring

6) Complete transparency to end-user traffic

The Packet ADM carries all services transparently, without any manipulation of end-user traffic. All end-user control traffic is also carried transparently, and all traffic management is done on a per-CoS basis, in a manner transparent to specific end-user traffic.

7) Preserves the SONET/SDH-based operational paradigm

Corrigent's CM-100 Packet ADM is a transport network element that allows a carrier with existing SONET/SDH equipment to continue to maintain their existing SONET/SDH-based operational paradigm.

8) Support for Ethernet-based E-Line & E-LAN services for business users

Corrigent's CM-100 Packet ADM supports the full range of Ethernet-based E-Line and E-LAN services and for metro networks it an efficient solution for Ethernet-based traffic from business users.

9) Support for the full range of TDM services

Carriers that operate a legacy broadband access infrastructure can seamlessly migrate to a packet-based access aggregation solution with the Corrigent's CM-100 Packet ADM. Carriers can also use the Packet ADM transport solution to provide traditional private line services (on DS-1/E1 interfaces) to enterprise customers.

10) Resiliency and no single-point-of-failure

The standard RPR MAC guarantees that all traffic provisioned over the shared packet ring, including point-to-point, broadcast and multicast traffic, is restored within less than 50msec after a link or node failure. Unlike SONET/SDH five-nines availability can be guaranteed for all classes-of-service, including best-effort traffic. In addition services can be partially protected so that no user ever has to go unprotected or buy more protection bandwidth than is required.

2.0 The Economics of the Packet ADM

Metro transport equipment requires a number of improvements as carriers move from circuit based services to predominately packet traffic. One is the amount of revenue they can support on NG SONET/SDH platforms make it difficult to reach profitability given prevailing service and bandwidth prices. Another is the cost of building and managing networks with transport and switching in separate devices. In addition L2 switches alone do not provide the features that enable resilience, SLAs and strict QoS required by many customers and SONET/SDH equipment does not handle data efficiently or enable new data services or business models.

Much of the infrastructure installed to support new data applications has control at Layer 3 meaning higher long run operational expense. With the continued emphasis on limiting capital and operational expenses there is a need for a new device that overcomes these problems.

The following sections present quantitative models for gains that can be realized with intelligent metro transport. We will describe some of the features and functions that make Corrigent a solution that delivers more profit today and will support carrier requirements far into the future. The quantitative analysis provided is designed to give planners and managers financial models for comparison of alternate approaches to packet transport.

NG SONET/SDH and the Packet ADM

Traditional SONET/SDH and NG SONET/SDH contain fundamental design limitations that make the business case for them difficult for networks with high percentages of packet traffic.

- Every connection must be individually configured. This introduces higher operational and capital expenses.
- Bandwidth is dedicated, regardless of the actual traffic on the connection, resulting in inefficient allocation of scarce bandwidth.
- It has been difficult on SONET/SDH networks to match bandwidth to user requirements because the granularity of the service offerings is designed for voice applications.
- Service creation and management has been difficult because SONET/SGH have no awareness of the traffic they carry. This results in the inability to distinguish between applications and their required service characteristics.

These limitations result in higher equipment costs, lower bandwidth utilization, lower revenue and the constrained ability create and offer services tailored to today's demands.

The Packet ADM was designed overcome many of these limitations. Using only industry standard interfaces and protocols, Corrigent has created a platform that is capable of delivering significantly more revenue for the same bandwidth, at lower capital and operational cost when compared to other metro solutions.

L2/L3 Solutions and the Packet ADM

Point-to-point L2/3 solutions cannot provide the efficiencies of the Packet ADM. Some of the reasons include:

- They often lack carrier-class functionalities that allow management, monitoring, resiliency, and easy provisioning that can support mass deployment of services.
- They are characterized by wasteful hub-and spoke economics; when deployed over a physical fiber ring, they require at least one fiber pair (or wavelength) per node on the

ring, more expensive long-reach optical interfaces (to reach the hub over the entire ring circumference), and twice the overall number of trunk ports compared to a logical ring topology (when diverse routing is required for resiliency)

- They do not benefit from efficient delivery of broadcast and multicast traffic and require duplication of multicast traffic early at the hub and transport of the duplicated traffic to each node in the metro/access ring
- They provide limited statistical multiplexing and oversubscription capabilities.
- They provide slow service restoration (on the order of seconds) after a link or node failure using Rapid Spanning Tree Protocol (RSTP). These solutions can guarantee fast protection switching using MPLS fast-reroute but that becomes cumbersome to provision and monitor and cannot provide protection to maintain the efficient delivery of multicast traffic. RPR handles these issues automatically in the MAC at Layer 2.
- L2/L3 data solutions require different technical expertise to operate than transport network elements and are deployed as separate overlays to the existing transport networks. Overlay networks have proven to be more expensive and complex to create, own and operate.

Creating a transport device to support new services without the limits noted above requires the combination of standard technologies in a novel fashion. The Packet ADM based on MPLS, Ethernet, SONET/SDH and RPR provides a way to deliver new high bandwidth data services and TDM services on the same platform with economics that make both services compelling.

Financial Models: Linking Technology to Profit

The models shown below demonstrate how the Packet ADM performs financially compared to alternatives based on different network criteria. These business models are representative of actual network results. Every network is unique and the flexibility of the Packet ADM means that its' actual benefits are best calculated using specific data from real networks. These tools are provided as a template to demonstrate the many ways that the Packet ADM provides superior ROI.

The Packet ADM creates a shared ring with a common signaling and control plane implemented in the standards based IEEE 802.17 MAC. Capital and operating expenses are lower when management and switching functions are automated at lower layers of the OSI model due to reduced manpower required for designing and maintaining network wide QoS.

Point-to-point connections must be individually and manually configured. The common control plane among nodes in the Packet ADM network enables the automation configuration of services between endpoints without configuration of each intermediary point. This means that customers and services can be added to the ring once and their configuration information can be replicated across all the switches without further intervention. This saves significant operational cost for network technicians and operators.

Ethernet switches using standards based technologies are always configured in point-to-point topologies. Ethernet rings exist but they are proprietary implementations. Likewise, Wave Division Multiplexing is configured in logical point-to-point topologies even when the physical topology is a ring. Indeed SONET/SDH is topologically a ring but the configuration manpower requires creation of individual point-to-point circuits.

The manpower and operational expense required for these activities is difficult to quantify, although from the foregoing discussion it is logical that they should be lower in the Packet

ADM network. However, CapEx is more straightforward. The following model demonstrates that equipment expenses as well as OpEx are reduced in the Packet ADM network.

2.1 Model #1: More Bandwidth

Conclusion: ~40% more bandwidth available at the same data rate

The Packet ADM architecture yields significant advantages when compared with point-to-point (Pt-toPt) technologies like SONET/SDH, WDM or Ethernet Private Line configured on either switches or routers.

As an illustration let's examine a Pay TV service that offers 100 channels over an RPR ring verses a point-to-point approach. These 100 broadcast channels, in aggregate, will consume approximately 350 Mbps of bandwidth from the servers to the nodes. Each customer receives identical feeds simultaneously. This is where a key distinction between Corrigent and other solutions becomes apparent.

For this illustration let's compare a 10Gbps Packet ADM with a point-to-point solution. Each of the ten 1Gbps connections is discreet. Therefore, each connects the head end with only one of the Gig E uplinks from the aggregation equipment either over WDM or SONET/SDH equipment. This means that the 350Mbps worth of feeds from the 100 Pay TV channels must be sent on each lambda or connection individually. Therefore, the bandwidth consumed by Pay TV is 350 Mbps x 10 connections or 3.5Gbps out of the total 10Gbps available. Each 1 Gbps connection feeding the Gig uplinks will receive its' own individual Pay TV signal even though it is identical to the Pay TV signals simultaneously going to the remaining 9 connections.

The Corrigent solution is quite different. Since all signals are aggregated and multiplexed in the CM-100 we use multicasting protocols supported by RPR at Layer 2 to make more efficient use of the ring bandwidth. Since the Pay TV signals are identical we only need to send them around the ring once. Then each node can replicate them out each 1 Gig port to the aggregation equipment.

With the Packet ADM the portion of ring bandwidth used for this service is 350Mbps or 1/10 of that required for point-to-point solutions. As Table 1 shows this frees an additional 3.15 Gbps of ring bandwidth

Corrigent Multicast Efficiency by Technology	Packet ADM	Point-to-Point
Bandwidth Consumed by Pay TV	350Mbps	3.5Gbps
Bandwidth Available after Multicasting	9.6Gbps	6.5Gbps
Bandwidth Advantage of Packet ADM	**3.15Gbps**	

Table 1

2.2 More Revenue

Conclusion: ~ 47% Higher Revenue for VoD
Conclusion: ~ 10:1 Advantage for PPV traffic

If we translate the bandwidth advantage of 3.15Gbps into the amount of extra services and revenue that can be addressed with this bandwidth we begin to get an idea about the revenue advantage of the Packet ADM. Video on Demand is an important new service to consider. Every viewer receives a unique unicast video stream. Table 2 shows a revenue advantage of more than 40% for VoD traffic using an average of 3.5Mbps per video stream.

Corrigent Multicast Efficiency by Technology	Packet ADM	Point-to-Point
VOD Streams available in remaining bandwidth	2742	1857
Revenue Generating Capacity @ $5 per VoD	$ 13,710	$ 9,285
Advantage Packet ADM	**$ 4,425**	

Table 2

Another important benefit of the multicast capabilities of the Packet ADM is for Pay-per-View (PPV) delivery. It is worth noting that PPV is a premium service that is broadcast rather than unicast to each subscriber. Only one copy of the stream needs to traverse the ring irrespective of the number of customers taking the service. This translates into much higher Revenue per Mbps for PPV shows that are viewed by even a small sample of the available audience. Table 3 shows that the ring solution has a 10:1 revenue generating advantage when compared with point-to-point technologies.

Multicast Efficiency for Pay-Per-View				
Number of PPV Customer for 1 PPV stream	100	300	500	1000
Revenue / PPV customer	$5	$5	$5	$5
Total Revenue	$500	$1,500	$2,500	$5,000
Bandwidth consumed on Ring (Mbps)- Pt-to-Pt	35.0	35.0	35.0	35.0
Bandwidth consumed on Ring (Mbps) – PADM	3.5	3.5	3.5	3.5
Revenue / Mbps – Pt-to-Pt	$14.29	$42.86	$71.43	$142.86
Revenue / Mbps – PADM	$142.86	$428.57	$714.29	$1,428.57

Table 3

As bandwidth utilization and video traffic increases this extra capacity becomes even more important. The Packet ADM is designed to support higher service requirements and can therefore be amortized over a longer useful life.

2.3 Model #2: Lower Capex

Conclusion: Up to 50% Lower CapEx for some portions of the network

The Packet ADM architecture consolidates network elements resulting in significantly lower CapEx. Due to the reduction of network elements OpEx is reduced as well. The use of RPR traffic management and MPLS control plane means fewer network elements in the metro network. The Packet ADM combines transport elements with switching elements into one device. This results in a flatter, lower cost networks.

Figure #1 below represents a point-to-point design that shows L2/L3 switching devices connected to a transport node. In Figure #2 you see a comparable design using the Packet ADM. The functions of the ADM and the L2/L3 device have been consolidated into one intelligent transport node. When you compare this design to one using SONET/SGH with L2/L3 switching /routing the savings are significant.

Figure #1 shows how a configuration of L2/L3 switches requires 1) twice the amount of fiber and 2) more optical ports to achieve the same connectivity as the Packet ADM. This demands twice the investment in fiber and an increase in ports required to build the metro transport network.

Figure #2 shows a Packet ADM network that supports the transport functions of the traditional ADM while simultaneously supporting the L2 traffic management and switching functions provided by the Layer 2/3 switching equipment.

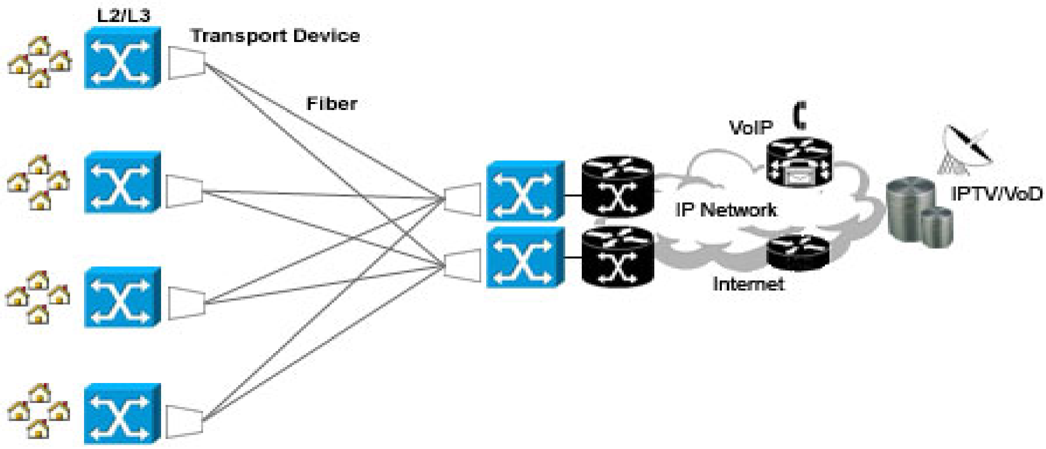


Figure #1

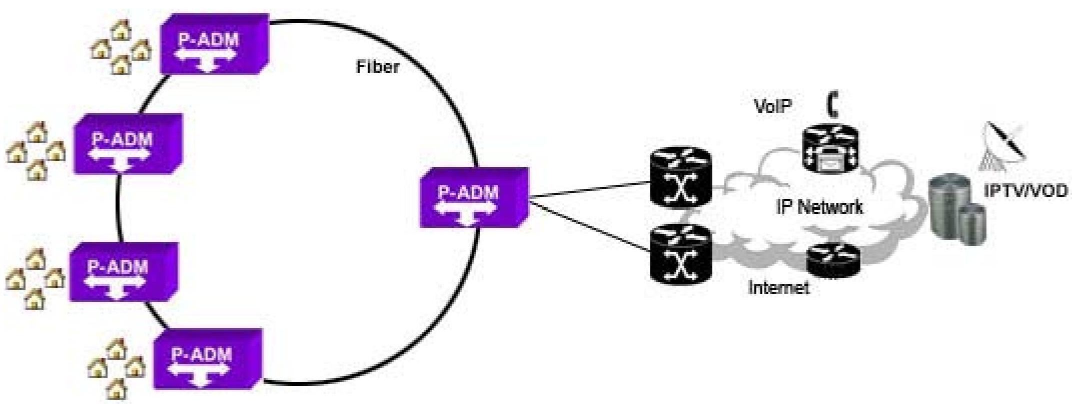


Figure #2

2.3.1 Fiber Route Savings

Conclusion: ~ 60% savings on fiber facilities

Notice that to connect the nodes to the L2/L3 Network in the diagram above requires twice the amount of fiber to achieve the same connectivity as the Packet ADM. This demands twice the investment in fiber to build the metro transport network.

Formula A – Point-to-Point Fiber Cost
Cost of Fiber from Hub#1 to Network x 2 = Fiber Cost A
Cost of Fiber from Hub#2 to Network x 2 = Fiber Cost B
Cost of Fiber from Hub#3 to Network x 2 = Fiber Cost C
Cost of Fiber from Hub#4 to Network x 2 = Fiber Cost D
Hub & Spoke Fiber Cost =

Formula B – Ring Fiber Cost
Cost of Fiber from Hub #1 to Hub #2 = Fiber Cost E
Cost of Fiber from Hub #2 to Hub #3 = Fiber Cost F

Cost of Fiber from Hub #3 to Hub #4 = Fiber Cost G
Cost of Fiber from Hub #4 to Hub #5 = Fiber Cost H
Cost of Fiber from Hub #5 to Hub #1 = Fiber Cost I
Ring Fiber Cost =

Using published average fiber cost per mile per month from the Wall Street Journal May 12th, 2005 pg. B10 of $400 we can calculate the relative cost of these two approaches. To make the calculations simple, we will assume that all ADMs and PADMs are an equal 10 miles apart from one another. Using these two figures and the formulas presented above yields the following results.

Total Cost for Fiber in Hub and Spoke Configuration = $384,000
Total Cost for Fiber in Ring Configuration = $240,000 = 100%
Savings with RPR Ring = $144,000 = 62.5%

The point-to-point approach represented by the hub and spoke architecture results in 62.5% higher fiber cost for the equivalent connectivity.

2.3.2 Optical Port and Equipment Savings

Conclusion: > 30% fewer optical ports required

The Hub and Spoke architecture requires the use of both a transport device, in this case, an ADM and a L2/L3 switch. The RPR ring collapses the functions of these two devices into the CM-100 PADM. This reduces equipment requirements and costs for optical ports and rack space in CO facilities.

Optical Port Comparisons	Segment 1 Ports	Segment 2 Ports	Segment 3 Ports	Segment 4 Ports	Segment 5 Ports	Hub A Ports	Hub B Ports	Totals
Hub and Spoke								
L2 / L3 Switch	1	1	1	1	0	0	0	4
ADM	2	2	2	2	0	6	6	20
Router	0	0	0	0	0	2	2	4
Total								**28**
Ring								
Packet ADM	2	2	2	2	2	2	0	12
Router						2	0	2
								14

Table 4

Table 4 above compares the optical ports required for the two architectures. More equipment involves higher costs for buying, installing, configuring, maintaining and troubleshooting equipment and individual ports. The hub and spoke design requires 28 optical ports verses only 14 needed for the Packet ADM ring design.

Management of a L2/L3 switch and SONET/SDH device at each location presents more challenges as well. Integrating these functions into the Packet ADM and managing that one device using existing OSS systems presents additional operational savings.

2.4 Model #3: More Revenue per Mbps of Bandwidth

Conclusion 1: Much higher oversubscription ratios possible
Conclusion 2: Significantly higher overall revenues are possible with Packet ADM

The common control plane of the Packet ADMs gives every switch on the ring real-time knowledge about the state of each link on the ring. This link congestion awareness combined with ring wide fariness mechanisms, enforced by the Packet ADM insures delivery of services within their defined QoS and SLA parameters.

In this environment, best effort and lower priority traffic will never interfere with guaranteed traffic. Therefore, higher ratios of oversubscription of Best Effort traffic are possible. In addition, Best Effort traffic can be assigned bandwidth that is always available, then even under conditions of heavy network load, Best Effort traffic is never starved of bandwidth.

These two mechanisms, 1) the absolute inviolability of High Priority traffic and 2) the guarantee of some bandwidth to BE traffic allow carriers to sell higher oversubscription ratios for Best Effort traffic without concern about poor performance of either service. This translates to 1) higher revenues, 2) more profitable services, 3) more subscribers on a ring 4) reduced equipment requirements and 5) a more competitive service offering.

Table 5 below provides a comparison of revenue available from Best Effort internet access services running on a ring in conjunction with IPTV services. The comparison is between a ring of Packet ADM nodes and L2 / L3 switches connected over CWDM.

A network model with 11 nodes in each scenario is shown in Figures #3 and #4 below. Each node has either a) L2/L3 switches with CWDM equipment or b) a Packet ADM to create a metro backbone connecting the head end gear (video servers, codecs, etc.) with the last mile aggregation equipment (DSLAMs, etc.).

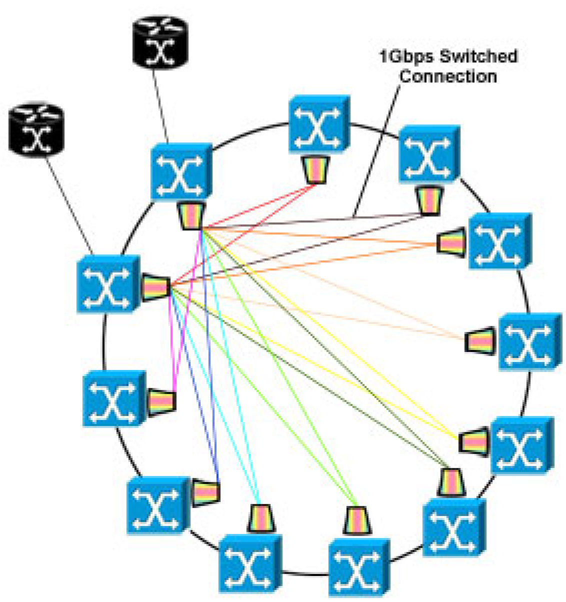
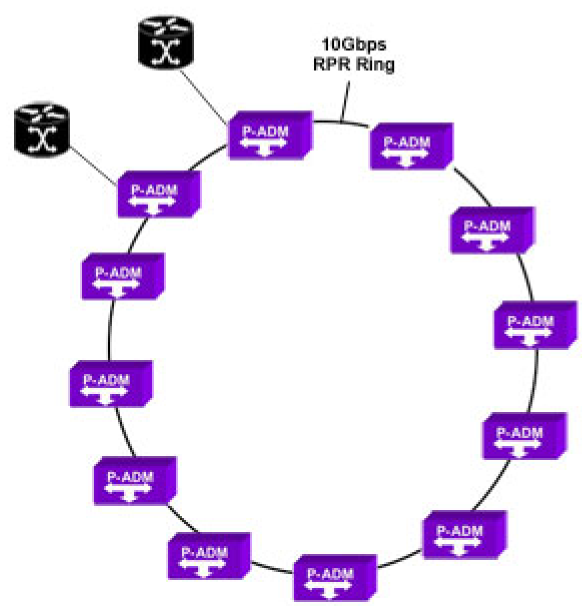


Figure #3



Fiigure #4

Two nodes serve as redundant headends along with the video servers, internet routers and video codecs. These nodes have no local customers connected to them. The other 10 nodes are dispersed geographically to aggregate customer feeds to 3,200 customers. Total bandwidth for the two networks would be identical at 10Gbps. The ring architecture would run at 10Gbps. Each of the 10 spokes would have a 1Gbps data rate that in aggregate would be identical to the ring.

The Packet ADM ring has the ability to assign a portion of the bandwidth to Best Effort traffic. For this example, we assign 500Mbps for Best Effort services. Under conditions of full load this 500Mbps would always be available to BE traffic. The analysis shows that even if the rings additional 900 additional video stream capacity is completely used, there are still 500Mbps available for BE traffic while the point-to-point network would have a deficit of 3.5Gbps at similar usage. This would obviously result in complete starvation of internet access traffic as well as the inability to capture the revenue of 900 video requests.

Oversubscription Analysis *	**RPR**	**CWDM**
Total Bandwidth Available	10Gbps	10Gbps
Bandwidth Reserved for Best Effort (BE = internet access services)	500Mbps	500Mbps
Size of Video Stream	3.5Mbps	3.5 Mbps
Multicast Bandwidth Usage (3.5Mbps x 100 channels x # of Segments)	350Mbps	3.5Gbps
Total Bandwidth Available After Multicast (Gbps)	9150	6000
Maximum VoD streams Available After Multicast	2614	1714
Max Simultaneous VOD Streams as a % of Customers	82%	54%
Bandwidth Available for BE traffic @ 54% VoD Usage	3.150Gbps	0
Bandwidth Available for BE traffic @ 82% VoD Usage	500Mbps	(3.5Gbps)
** Assumption - 100 Broadcast Channels*		

Table 5

Under full video load and with 100% of the internet users active there would be an average of 156kbps per user for BE traffic. The Packet ADM ring is also capable of allocating the 500mbps proportionally to the BE users that are on the network. For example, if 1000 BE users were on the network under conditions of full VoD load conditions then each user would get 500kbps. If only one BE user were on the network then they could consume the entire 500Mbps if their network connection allowed them to burst up to that data rate. Further, BE traffic can consume the entire ring bandwidth if no other traffic is present.

These features allow service providers to generate more revenue for a number of reasons.

- They provide additional bandwidth that can be used for more video revenue
- They guarantee that BE traffic will never be starved of bandwidth
- They allocate all available bandwidth to BE traffic during non-peak conditions creating a tremendous user experience
- They increase the oversubscription ratios that can be achieved.

These mechanisms mean that network performance is a science not an art. In the point-to-point models traffic must be estimated and preprovisioned. If the initial estimates are incorrect performance of some services degrades and this degradation could affect both high priority and low priority services. If overprovisioning is used network resources are wasted raising costs. Conversely, with the Packet ADM ring performance of the ring under conditions of full load is known and predictable. The ability to instantaneously know and enforce service performance enables higher oversubscription and higher revenue for BE traffic.

3.0 Conclusion

The Packet ADM represents a quantum improvement in metro network transport equipment. It combines the rapid and robust restoration traditionally associated with transport and sophisticated packet handling that enables new services. The ability to automatically and predictably provision and enforce service policies lowers operational costs. Ring-wide congestion state knowledge combined with a sophisticated CAC and multicasting capabilities give carriers a metro platform that delivers more revenue per Mbps and insures SLA enforcement for both TDM and new packet based services on the same platform.

The examples shown above are only some of the implications of this architecture. Other examples that demonstrate increased savings and revenue require more detailed network assumptions that are beyond the scope of this paper. The examples presented here are illustrative of how implementations of protocols from MPLS, Ethernet, RPR and SONET/SDH taken together enable the Packet ADM to deliver both lower overall costs and higher overall revenue for carriers interested in delivering TDM and packet services on one metro transport element.

Author: Mannix O'Connor – Director, Corporate Marketing Corrigent Systems

Mr. O'Connor has been involved with building optical transport equipment and networks for more than 10 years. He was Secretary of the IEEE 802.17 and is currently a Co-Chair of the Metro Ethernet Forum. He holds an MBA in Finance from George Washington University.

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