Delivering Services over RPR: A Real World Example

Laura Tanner
Nortel Networks
3500 Carling Avenue
Ottawa, ON
K2H 8E9
Phone: (613) 763-2326
ltanne1@nortelnetworks.com

Dan Estes
Cox Communications
Suite 300
1400 Lake Hearn Dr. NE
Atlanta, GA 30319
Phone: (404) 269-8715
dan.estes@cox.com

1. Introduction

In all facets of the business market, real demand for higher bandwidth services, any-to-any connectivity, and native Optical Ethernet interfaces is growing. Furthermore, businesses are increasing their focus on business continuity and disaster recovery, which prompts demand for a wider portfolio of Optical Broadband services. Multi-System Operators (MSOs), like Cox Communications, often find themselves in a favorable position to address the demand for enterprise broadband services, given their broad fiber assets and presence in their metro markets.

Entering the enterprise services market is a daunting task: it is a challenging process to measure and fulfill demand while faced with limited resources and extremely tight capital. This paper takes one of Cox's large markets in Southern California as a real world case study of market assessment and technology selection and follows that decision through the growth and expansion phase.

1.1 Market Drivers for Optical Broadband Services

Enterprises have never needed broadband connectivity services more than they do today. While the data-centric nature in many enterprises is increasing, so is the concern about safe-guarding intellectual property and records. Investments in data centers, data storage, business continuity and disaster recovery solutions continue to rise, driving increased broadband connectivity requirements. Additionally, the enterprise computing model itself is transforming. Today's enterprise computing centers are highly distributed due to the high cost of connectivity to link sites. Plummeting bandwidth prices are allowing enterprises to migrate to a new computing paradigm—one based on computing centralization with robust business continuity. Each of these facts drives enterprise demand for new broadband services. These services are referred to as Optical Broadband services in this paper.

Optical Broadband services are projected to grow substantially in the next few years. A synthesis of the projections of several industry reports from analysts such as Yankee Group, RHK, and Vertical Systems group is shown in Figure 1. These global projections forecast that Optical Broadband services will grow to one quarter of retail data services by 2005 [1].

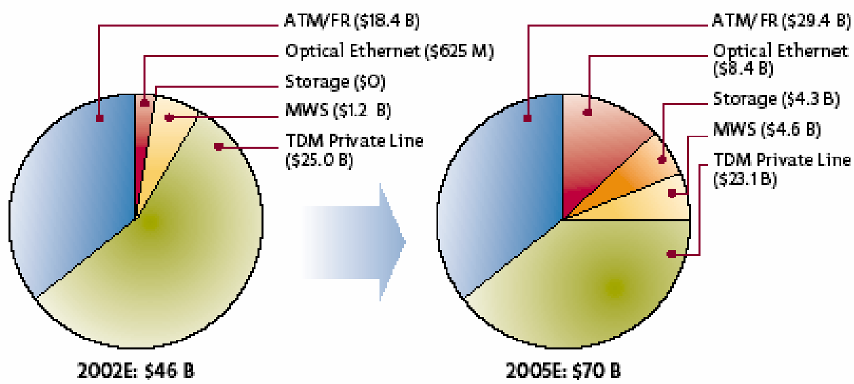

Figure 1: Optical Broadband services Growth

The growing nature of enterprise data requirements drives significant growth in the demand for Optical Broadband services. The time is right for MSOs to facilitate the emerging IT computing transformation with robust high-bandwidth connectivity services. By utilizing advances in optical network technologies and leveraging existing fiber assets, MSOs can offer such services, and this paper details Cox San Diego's process in doing just that.

1.2 Cox Communications San Diego

Cox Communications' San Diego market is an excellent example of the diverse commercial requirements that exist in today's "have-it-all" world. A conglomerate of businesses extends from the Pacific bay on the south side to the mountains on the east. The large military and industrial base provides a high-tech, knowledgeable clientele who demand the best and have high expectations for service reliability and usability. Cox Communications has a very good reputation from the residential services it is delivering, which range from traditional broadcast video to high speed Internet access using cable modems. Cox's other strategic asset is its fiber infrastructure. During the network upgrade to Hybrid-Fiber/Coax, Cox designed ring-in-ring fiber layouts to increase the reliability of the residential network. In this design, they used their knowledge of the local business requirements to allocate spare fibers for commercial purposes in this design. They also engineered the network with reliability in mind, providing back-up power and redundant optics in the base plan. Thus, Cox was in a good position to address enterprise demand for Optical Broadband services. But as a prerequisite to metro network deployment, the MSO needed to find the right network technology to deploy to address the specific service demand in the San Diego market. And prior to technology selection, Cox sought to better understand the services demand in the San Diego market via a market analysis, as discussed in Section 2.

2. Market Opportunity Analysis

Prior to wide-scale deployment of Optical Broadband services infrastructure across their San Diego fiber infrastructure, Cox proceeded cautiously, seeking to justify any investment. This motivated the undertaking of a market study, which provided Cox with an understanding of the demographics and demand for the services to be offered. This information was used to drive service definitions and ultimately as a tool in the selection of the correct network technology. In addition, the market opportunity analysis provided focus by suggesting geographical areas and business demographics with the highest likely demand for Optical Broadband services.

2.1 Market Analysis: Purpose

The goals of the market opportunity analysis were threefold. First and foremost, the analysis served to confirm that the opportunity to address business demand for optical broadband services was significant and worth addressing. Second, the market opportunity analysis yielded results that demonstrated the geographic applicability of broadband services in the market. Finally, the detailed demographic analysis was performed with the goal of highlighting which broadband services were in high demand, and which market verticals were most worth targeting.

2.2 Market Analysis: Process

The most important step of the market analysis was the definition of the target business. In this activity, target businesses were defined as business sites in bandwidth-intensive vertical markets with 10 or more employees. Bandwidth-intensive business verticals were identified by Standard Industrial Classification (SIC) code, and include verticals such as finance, communications, healthcare, manufacturing, and government.

Since business sites may be single or multi-business units, the second phase of the market analysis involved determining target buildings by summarizing business sties in the same locations. This enabled Cox to prioritize multi-site locations over single-business sites. Thus, while the market analysis yielded a set of target business sites, it also highlighted the important multi-tenant business buildings. It was these buildings which formed the focus of the target market. This isolation of the target market is shown graphically in Figure 2.

In the market analysis for Cox San Diego, the total addressable market was defined as containing all bandwidth intensive buildings located within 1 mile of Cox's fiber plant. Mapping software was used to isolate this market geographically. Figure 2, below, presents a visual representation of the market analysis procedure which focuses in on the addressable business sites.

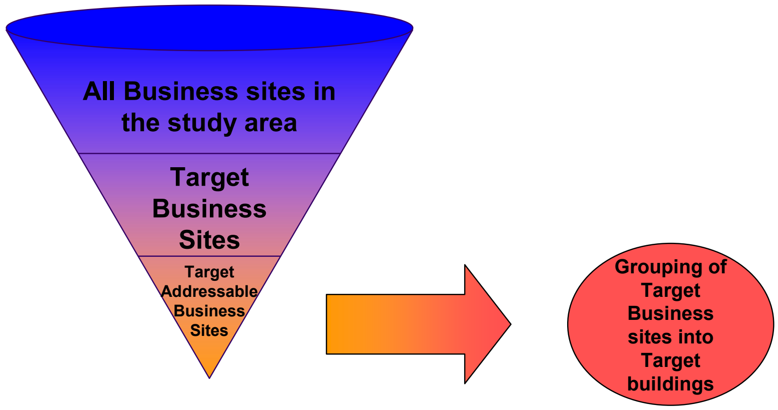

Figure 2: Market Analysis Process

Figure 3, below, shows an example of the geographical analysis performed (shown for a sample metro area). Further, clusters of businesses are highlighted to suggest areas for target marketing.

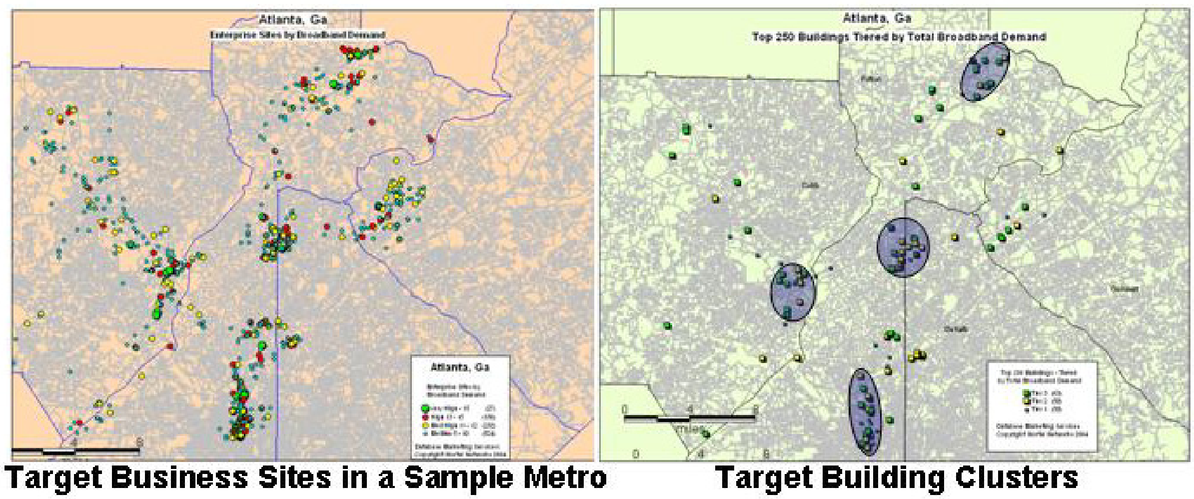

Figure 3: Geographical Market Analysis [2]

While a detailed discussion of the geographical analysis results and details of Cox San Diego's addressable market are outside of the scope of this paper, some notes on the market analysis are discussed. Specifically, scrutiny of the addressable market yielded some general results worth noting. In Cox San Diego's target market, for example, 44% of target addressable business sites were classified as most likely to have a high bandwidth demand, driving Optical Broadband services rather than the more traditional copper-based services. In addition, the breakdown of different industry verticals within Cox San Diego's target market suggested that target marketing towards the financial vertical, for example, would prove worthwhile. Finance, Communications, Multimedia and Utility proved to be the verticals with the highest potential aggregate demand.

While the market analysis suggests where Cox should deploy Optical Broadband services based on target enterprise density, it also helps Cox to define a set of services suitable for delivery to the target vertical markets. Section 3 introduces the services set that Cox San Diego defined to address their market, and the requirements that these services place on the metro network architecture.

3. Service Definitions

The market opportunity analysis demonstrated that there was significant demand for Optical Broadband services, particularly Optical Ethernet services, in the San Diego area. Also in demand were Optical

Broadband Private Line services. A delineation of the different services being offered by Cox Communications is presented below.

3.1 Optical Ethernet Services

Optical Ethernet in the metro area network (MAN) has emerged as an efficient and flexible way for enterprises to support applications like Internet access, transparent LAN, router interconnection, storage, voice, video, and others. These services are in demand across a variety of market segments, based on the nearly universal need to support the increasing bandwidth requirements of said applications. The way in which each service maps to application and market segment is described below.

Ethernet services can be either "private" or "virtual". A private service involves provisioning dedicated interconnectivity to two or more enterprise locations. This provides the enterprise customer with dedicated bandwidth and dedicated switching. A virtual services is a shared bandwidth service. In virtual Optical Ethernet services, customer separation must be maintained across the network via some sort of "service identifier", as discussed in Section 4.3.

Optical Ethernet services can additionally be defined by the level of connectivity they offer to the enterprise customer's sites. Thus, they can be point-to-point, point-to-multipoint, or any-to-any. An Optical Ethernet "line" service implies point-to-point connectivity, while a "LAN" service is one which provides point-to-multipoint or any-to-any connectivity.

Thus, Optical Ethernet services comprise the following four service types:

- Ethernet Private Line
- Ethernet Private LAN
- Ethernet Virtual Private Line
- Ethernet Virtual Private LAN

These services are described in detail in [3]. The following sections outline the requirements that each of these services place on a metro area network.

3.1.1 Optical Ethernet Private Line

Optical Ethernet Private Line (OEPL) can be directly compared to a traditional Time-Division Multiplexing (TDM)-based Private Line service. An OEPL service provides a dedicated connection between two customer locations, originating and terminating on native Ethernet interfaces. Such a service provides high bandwidth and meets the stringent latency and jitter requirements of LAN extension, PBX interconnection, or router interconnection applications. Thus, while this service is suitable for many enterprise types, it is of interest to businesses looking for high bandwidth interconnectivity between two sites. Target verticals include financial, communications, and government.

Optical Ethernet Private Line SLAs can be differentiated by offering guaranteed service parameters, such as latency and uptime. Further, Ethernet Private Line services can be offered as protected or unprotected services. Thus, OEPL services drive several specific network requirements. First, the network must be able to support dedicated bandwidth circuits providing native Ethernet connectivity. Second, these circuits must be able to support SLAs, and provide the ability to measure latency and uptime. Finally, customers have come to expect sub 50-ms resiliency in Private Line services, making this another network requirement. These service-driven network requirements were used in Cox's selection of their metro network technology.

3.1.2 Optical Ethernet Private LAN Services

A multi-site customer requiring the dedicated bandwidth, low latency, high availability and security of a managed private network may opt for an Optical Ethernet Private LAN (OEPLAN) service. OEPLAN provides its customers with dedicated bandwidth to interconnect sites in an any-to-any fashion, with the ability to tune bandwidth on a per-port basis. This service simplifies the connectivity model for a multi-site enterprise by eliminating the need for a mesh of point-to-point services, thus reducing operational complexity. Further, an Ethernet Private LAN service supports the enterprise's multicast and broadcast traffic. Thus, this type of service is well-suited to enterprises' transparent LAN requirements, supporting end-user applications such as distance education, client-server applications, video or intranet broadcasting. As such, this type of service is of particular interest to the financial, multimedia, and education vertical markets.

OEPLAN services drive network requirements over and above those presented by OEPL. That is, OEPLAN services drive the requirement for dedicated bandwidth and switching to be provided with any-to-any connectivity for a multi-site enterprise. Furthermore, Optical Ethernet Private LAN services require the network to offer dedicated switching per-service, and efficient support for multicast and broadcast traffic. Finally, these services require the ability to measure per-service SLA parameters such as availability and latency in an any-to-any fashion.

3.1.3 Optical Ethernet Virtual Private Line Services

Customers looking for secure point-to-point connections without the dedicated bandwidth of OEPL services are best-suited for Optical Ethernet Virtual Private Line (OEVPL) services. An EVPL is a point-to-point service delivering a shared bandwidth connection between two endpoints. Given this definition, OEVPL services are well suited for applications like LAN extension and Internet access. Thus, these services are suitable for two-site enterprises with a non-dedicated bandwidth requirements, in verticals such as utilities, retail, and government.

The most basic network requirement associated with Optical Ethernet Virtual Private Line services is the ability to statistically multiplex multiple services across the network while maintaining customer separation. Further, rate limiting and network engineering features are helpful in the implementation of these services as they simplify service delivery. Like other Optical Ethernet services, OEVPL services require a network technology that can measure per-service SLA parameters.

3.1.4 Optical Ethernet Virtual Private LAN Services

Optical Ethernet Virtual Private LAN (OEVPLAN) services fulfill the requirements of multi-site customers requiring secure any-to-any services without dedicated bandwidth. EVPLANs provide flexible, shared bandwidth connectivity to multi-site enterprises over native Ethernet interfaces and support broadcast and multicast traffic. Thus, OEVPLAN services are well suited to similar applications and market verticals to those of OEVPL services.

OEVPLAN services present the same network requirements as OEVPL services, with the obvious additions of any-to-any connectivity and efficient support for multicast and broadcast traffic.

3.2 Optical Broadband Private Line Services

Optical Broadband Private Line services are TDM or Synchronous Optical Network (SONET)-based services sometimes referred to as "legacy private line". Private Line services include those that are electrical: DS1 and DS3, and those that are delivered optically: OC-3, OC-12, OC-48 and OC-192. These provide customers with dedicated-bandwidth, point-to-point circuits with framing based on TDM. Business applications supported via Optical Broadband Private Line services include PBX interconnection, PSTN access, Internet access, router interconnection, low speed data, and legacy circuits via ATM or Frame Relay. Such services are required by a wide range of industry verticals.

Support for TDM services requires an underlying SONET or TDM-compatible infrastructure. Such an infrastructure needs to support the stringent timing requirements of TDM, and provide the dedicated bandwidth connectivity required of these services.

3.3 Services Requirements: A Summary

Based on the market analysis, Cox Communications looked to deliver the five services defined in Sections 3.1 and 3.2 into the San Diego market. The table below summarizes the key requirements that these services place on the network.

Network Requirement	Motivation/Rationale	Relevant Services
1) Ability to measure service parameters such as latency & availability	Required to deliver customer SLAs	Optical Ethernet services
2) Sub-50ms protection	Expected by customers	Optical Ethernet Services
3) QoS and rate limiting of customer traffic	Required service feature	Optical Ethernet Services
4) Efficient support for multicast and broadcast traffic	Required for applications such as video / distance education	OEPLAN, OEVPLAN
5) Dedicated bandwidth point to point connectivity	Service definition	OEPL, Optical Broadband Private Line Services
6) Dedicated bandwidth any-to-any connectivity	Service definition	OEPLAN
7) Dedicated per-service switching	Service definition	OEPLAN
8) Shared bandwidth point to point connectivity	Service definition	OEVPL
9) Shared bandwidth any-to-any connectivity	Service definition	OEVPLAN
10) Underlying SONET/TDM-compatible infrastructure	Service definition	Optical Broadband Private Line Services

Table 1: Optical Broadband Service Requirements

Cox examined a range of different network topologies to determine their effectiveness in delivering the service set defined in Sections 3.1 and 3.2. Resilient Packet Ring (RPR) was chosen as the most effective technology to satisfy these requirements. Section 4 provides an introduction to RPR technology, while Section 5 details the way in which RPR fulfills the requirements delineated above.

4. Resilient Packet Ring

This section details the nature of RPR as a network technology and services delivery vehicle. Rather than explain herein how RPR fulfills the service requirements explored in Section 3, this section serves as an introduction. Section 5 details Cox's specific RPR implementation and explains how RPR fulfills the requirements presented by the services demanded in Cox's San Diego market.

4.1 An introduction to RPR

RPR, is a standard in progress borne out of the need to bring sub-50ms ring-based resiliency to an efficient, packet-switched network architecture. Simply defined, RPR network architecture involves one or more rings which forward packet-based traffic from Ethernet ports using distributed Ethernet switching. These rings, or RPRs, may operate over an underlying transport layer such as SONET/SDH. Currently being defined by the IEEE 802.17 working group, RPR aligns the ubiquity and operational simplicity of the Ethernet protocol with the ring-based, service-oriented nature of metro service provider networking. As such, RPR provides efficient packet forwarding over rings with spatial re-use, enables sub 50ms restoration, topology discovery, and can be deployed over existing SONET/SDH infrastructure.

RPR is well-suited to the delivery of the services detailed in Section 3. Taking advantage of RPR's bandwidth sharing and oversubscription features enables the delivery of EVPL and EVPLAN services; while Ethernet Private service can be delivered by providing a customer with a dedicated RPR. Ethernet Private LAN services, in fact, are most effectively delivered over RPR, as other network architectures today are unable to cost-effectively support dedicated switching on a per-customer basis.

Figure 4, below, shows an example of a multi-service RPR deployment over a fiber ring. Customer premises equipment is deployed to offer services in both single and multi-customer sites. One RPR, shown in red, is used to deliver Virtual Optical Ethernet services, and as such is shared by multiple customers. A separate RPR, represented by the green ring, is deployed over the same physical ring to deliver Optical Ethernet Private LAN to a multi-site enterprise customer. Finally, an Optical Broadband Private Line service is shown in blue.

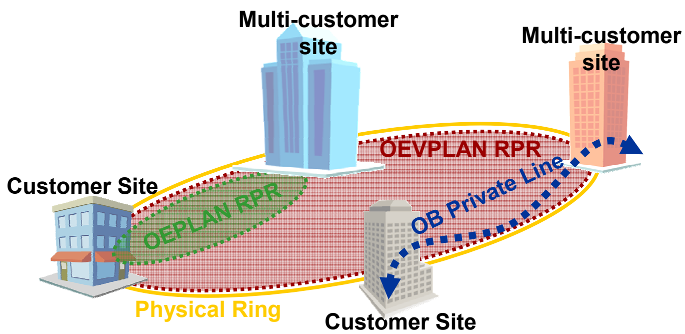

Figure 4: RPR deployment, An Example

While Figure 4 introduces the concept of how RPR can be deployed in the metro area network, the following Section 4.2 provides further detail on the features of RPR which enable efficient and flexible service delivery.

4.2 The Features of RPR

RPR lends itself well to services delivery based on several key features, including efficient packet forwarding, resiliency, flexibility, quality of service, and traffic engineering features. Each of these is described briefly in the following sections.

4.2.1 Efficient Packet Forwarding

By providing any-to-any connectivity over a layer 2 architecture, RPR eliminates the need to provision a full mesh of circuits to deliver services, as in legacy technologies like Frame Relay or ATM. Further, by using topology discovery and shortest path forwarding over a ring infrastructure, RPR increases several-fold the effective bandwidth in the network as compared to circuit-based technologies. Furthermore, cut-through switching enables this type of efficient packet forwarding to occur with minimal latency and jitter. Given its packet forwarding efficiency, RPR is effective and scalable for offering any-to-any Optical Ethernet services.

4.2.2 Resiliency

With its sub-50ms fault restoration scheme, RPR offers the level of resiliency that enterprise customers have come to expect from their connectivity services. Further, RPR can be delivered over a SONET-based infrastructure, which enables the delivery of traditional TDM-based Optical Broadband Private Line services in conjunction with services delivery over RPR.

4.2.3 Flexibility

RPR is a flexible technology in that it can be deployed over various types of physical fiber deployments, and can interwork with different types of underlying protocols. Specifically, since RPRs need not be mapped 1:1 to the underlying fiber rings, multiple RPRs can be deployed over a single ring to offer multiple services, as shown in Figure 4. In addition, a single RPR can be extended across multiple physical fiber rings, enabling flexible deployment options to suit specific service requirements. Finally, RPR technology can interwork with Ethernet on Fiber, Ethernet on SONET (EoS), Dense Wave Division Multiplexing (DWDM), and Layer 3 routed networks as required.

4.2.4 Quality of Service (QoS)

Since RPR was designed to deliver QoS-aware services, it has been defined to deliver consistent, end-to-end QoS. Bandwidth policing and traffic queuing are performed on traffic ingressing the RPR, which manages potential congestion while ensuring that on-ring traffic reaches its destination.

4.2.5 Traffic Engineering

While RPR uses auto-discovery mechanisms to maintain a shortest path forwarding table for normal traffic, features also exist to modify the default traffic forwarding mechanisms. This flexibility means that RPR implementations can accommodate different types of traffic patterns. Specific traffic forwarding mechanisms available in RPR equipment may include load sharing and static routing.

The above features define RPR as a technology. The following sections explain the deployment of RPR as a network technology to deliver Optical Broadband services. This discussion leads to a description of how RPR satisfies the requirements seen by Cox San Diego, as summarized in Section 3.3.

4.3 MAC-in-MAC Encapsulation

For Cox Communications San Diego, the ability to implement the required service delivery features and functionality was an important requirement of the selected network technology. Specifically, Cox was looking for a solution which provided customer separation/security, Ethernet broadcast traffic containment, customer VLAN transparency (the ability to transport customer VLANs across the network unchanged), and the separation of service provider and customer addressing schemes. For these requirements, Cox turned to a technology called MAC-in-MAC encapsulation.

MAC-in-MAC involves the encapsulation of the customer's Ethernet frame into a service provider Ethernet header for transport through the service provider network. Confronted with the potential challenges of deploying Optical Ethernet services over an RPR network, Cox Communications chose a MAC-in-MAC encapsulation solution to address several challenges of deploying Optical Ethernet in the metro. The way in which Cox's chosen RPR solution addresses these challenges via MAC-in-MAC encapsulation is detailed below.

4.3.1 Customer Separation/Security

MAC-in-MAC encapsulation labels customer traffic with a service identifier and a service provider header. This ensures that, while MAC-in-MAC traffic can still be transported over different physical networks, it provides absolute customer separation. This enables the delivery of shared bandwidth services such as Optical Ethernet Virtual Private Line and LAN. In addition to providing customer separation, the service identifier facilitates per-service measurements across the network.

4.3.2 Ethernet Broadcast traffic containment

RPR technology relies on broadcasting Ethernet frames in order to perform auto-learning of any given network topology. While this broadcasting scheme is efficient in local area networks (LANs), it can become a problem as Ethernet networks are made to scale to a large number of users, such as in an RPR deployment. In an Ethernet-based MAN, where traffic shares a broadcast domain, there is a risk that broadcast messages will congest network bandwidth. MAC-in-MAC encapsulation, by providing a Service Provider header, can ensure that customer broadcast traffic is treated as unicast across the metro network, yet is broadcast to the particular customer's sites. As such, broadcast traffic is contained and is manageable.

4.3.3 Customer VLAN Transparency

While early Optical Ethernet service offerings employed Virtual LANs (VLANs, or 802.1Q) to provide customer separation, it is preferable for such service offerings to leave customer VLANs untouched as their traffic crosses the metro area. This feature enables customers to continue using VLANs to segregate their MAN and LAN traffic, while also preventing issues caused by customer VLAN duplication across the service provider network. Since MAC-in-MAC encapsulation provides a header that is incremental the that of customer Ethernet traffic, it is transparent to the customer's use of VLANs.

4.3.4 Separation of Service Provider and Customer Addressing

When MAC-in-MAC is used as the service identifier, the customer premises device performs the encapsulation of customer Ethernet frames into service provider Ethernet frames. As such, it is responsible for learning the customer addressing scheme while the service provider core switches need only learn the addresses for the edge service switches. This limits the number of addresses that must be learned by the metro RPR network, hence improving overall network scalability and thus facilitating the delivery of wider scale services.

In addition to providing VLAN transparency, MAC-in-MAC encapsulation enables Cox to use the Ethernet feature set independently of the customer's use of Ethernet features like spanning tree, link aggregation, 802.1p and 802.1Q. Since MAC-in-MAC completes the separation of services and infrastructure, it decouples the scaling of the Optical Ethernet services from the network architecture, readying an RPR network for wide scale services delivery. For more information on MAC-in-MAC, please see [4].

5. Cox San Diego's Network Deployment

While Section 4 introduces the reasoning behind Cox Communications' selection of RPR as a services delivery technology, Sections 5 provides the motivation behind the specific network deployment in San Diego. Both the metro access and core networks are discussed.

5.1 RPR Access Network

Cox deployed RPR based on current and anticipated demand in high business density areas in San Diego.

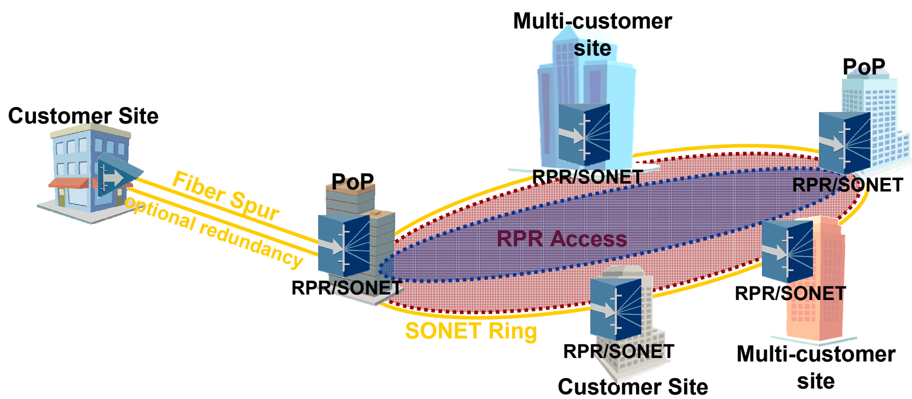

Figure 5: Cox's RPR Access Network

Figure 5, above, conceptually represents Cox's access RPR network. As discussed in Section 4, RPR provides shared or dedicated, resilient, any-to-any connectivity to Cox's customers across a fiber ring infrastructure. While this implementation is well-suited to ring based fiber deployments, some businesses were interconnected to RPR sites via point to point fiber spurs, as shown in Figure 5. This deployment, driven by physical fiber infrastructure, is enabled by customer premises equipment that provides consistent service demarcation features (MAC-in-MAC encapsulation, QoS, bandwidth policing) to that of the RPR infrastructure. While still delivering redundant access to the customer, this deployment option is suitable for lower density areas or single customer sites for whom a full RPR and/or SONET build-out is not cost-justified.

5.2 Why RPR in Cox San Diego's Access Network

Cox San Diego looked at several alternative delivery platforms to meet their service delivery needs, including traditional SONET, Gigabit Ethernet with media converters and directly-connected Layer 2 switches, and dedicated wavelengths on DWDM. Traditional SONET systems offered the protection that many of the business customers required but their poor utilization of bandwidth, for example when entire STS payloads were devoted to single customers even though they used one-fifth of that bandwidth at peak times of the day, was unattractive. Directly-connected switches were also considered. These networks would bridge point-to-point locations into a redundant ring. Unacceptable was the fact that protection of the data traffic would depend on router re-convergence, which could take minutes in a large scale deployment. Dedicated wavelengths on a DWDM platform were also considered. In this case, however, the cost of the optics and limited number of drop points quickly eliminated that option. None of these alternatives met the needs as did Resilient Packet Ring.

RPR allows Cox to provide Optical Ethernet services along with traditional Optical Broadband Private Line services like DS1 or DS3. The inherent protection provided by the protocol allows service level agreements to be established with the customers that guaranteed 50 millisecond switching times and rapid recovery in the event of a fiber cut or node failure. Since RPR was designed as a packet data protocol, efficient bandwidth utilization is made possible. Thus, RPR enables the delivery of a full suite of services, from dedicated bandwidth Optical Ethernet Private Line/LAN services to "best-effort" shared bandwidth virtual services. Thus, a customer can be provided with a committed information rate that reserved bandwidth in an OEPL service or a best effort or guaranteed class of service for customers who want a high speed connection at a lower price. Most importantly, RPR allows Cox to essentially sell the same bandwidth to multiple customers, meaning that compared to SONET, fewer electronics have to be deployed for the same level of customer satisfaction. The bottom line is: RPR increases the margins on Cox's Optical Broadband services.

5.3 RPR: Optical Broadband Service Requirements Fulfillment

While Section 5.2 qualifies the reasons for which Cox chose RPR as their services delivery technology, this section investigates how RPR delivers on the specific requirements listed in Section 3.3, and reviewed below, in Table 2. Cox Communications' investigation of various service delivery technologies revealed that an RPR implementation, coupled with MAC-in-MAC, fulfilled all of their requirements. This is summarized in Table 2, which details how each requirement is fulfilled by the selected solution.

Network Requirement	Requirement Fulfillment	Relevant Services
1) Ability to measure service parameters such as latency & availability	Provided by Nortel Networks RPR solution and MAC-in-MAC technology	Optical Ethernet services
2) Sub-50ms protection	IEEE 802.17 RPR Definition	Optical Ethernet Services
3) QoS and rate limiting of customer traffic	IEEE 802.17 RPR Definition and Nortel Networks RPR solution	Optical Ethernet Services
4) Efficient support for multicast and broadcast traffic	IEEE 802.17 RPR Definition	OEPLAN, OEVPLAN
5) Dedicated bandwidth point to point connectivity	Delivered by dedicated customer RPR or Ethernet on SONET on Nortel Networks RPR Solution	OEPL, Optical Broadband Private Line Services
6) Dedicated bandwidth any-to-any connectivity	Delivered by dedicated customer RPR	OEPLAN
7) Dedicated per-service switching	Delivered by dedicated customer RPR	OEPLAN
8) Shared bandwidth point to point connectivity	IEEE 802.17 RPR Definition	OEVPL
9) Shared bandwidth any-to-any connectivity	IEEE 802.17 RPR Definition	OEVPLAN
10) Underlying SONET/TDM-compatible infrastructure	Provided by Nortel Networks RPR solution	Optical Broadband Private Line Services

Table 2: Optical Broadband Service Requirements Fulfillment

Cox selected a solution that couples MAC-in-MAC service technology with RPR to deliver on requirements for per-service parameters and customer separation, as per requirement 1 in Table 2. Further, as introduced in Section 4, RPR provides sub-50ms resiliency, shared bandwidth, QoS, and efficient support for multicast and broadcast as part of the IEEE 802.17 definition. Thus, requirements 2, 3, 4, 8 and 9 are provided via RPR technology. In addition, Cox's RPR solution provides flexible service implementations, which enable Cox to dedicate an RPR (or a point to point EoS circuit) to a customer, thus delivering requirements 6 and 7. Finally, since the RPR solution deployed by Cox Communications is delivered over a SONET system, it can also deliver Optical Broadband Private Line services as per the tenth requirement. Thus all of Cox San Diego's key service requirements are fulfilled by the deployed RPR solution, as shown in Table 2.

5.4 Ethernet on SONET Metro Network Core

An RPR access network was chosen by Cox based on the numerous reasons described in Sections 5.2 and 5.3. The flexibility of mature optical solution sets available today means that RPR can interwork with other technologies across the metro for services delivery. Specifically, since it is possible to interwork RPR with EoS infrastructure, it may make sense, as it did in Cox's case, to deploy a SONET network in the metro core with EoS and Layer 2 switches for RPR interconnection.

Figure 6 introduces Cox's end-to-end network, including the metro core.

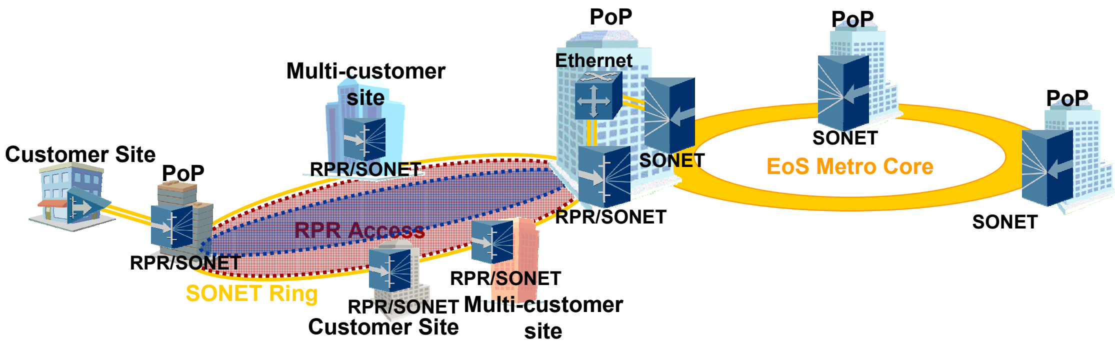

Figure 6: Cox's End-to-end Network

In conjunction with their Ethernet on SONET metro core, Cox deployed a highly resilient Layer 2 Ethernet switching architecture to interconnect access RPRs and to hand-off traffic at the metro core points of presence (PoPs). Cox chose to add the Layer 2 Ethernet switching component to their core network to provide a further level of traffic aggregation, as shown in Figure 7.

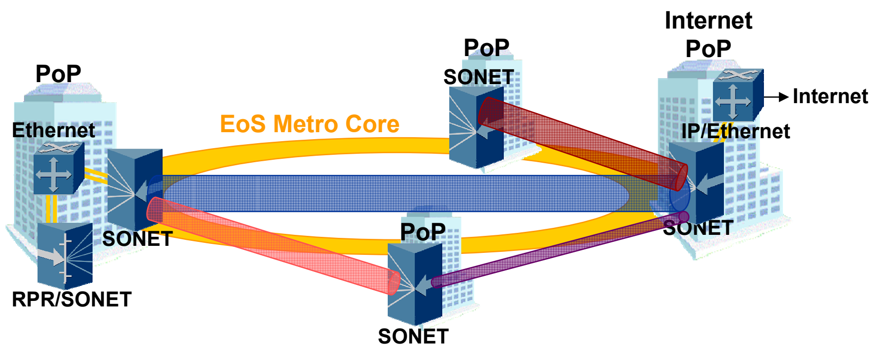

Figure 7: Cox's Layer 2 Switching deployment with Ethernet on SONET

5.5 Why Ethernet on SONET in Cox San Diego's Metro Core

While traffic for Optical Ethernet LAN services is generally distributed across the metro in a meshed fashion, Internet access traffic is generally hubbed to the Internet-handoff PoPs. Since Cox anticipated that a high volume of Internet-bound traffic would prevail on its RPR network, a hubbed core traffic pattern was expected. Cox chose an EoS solution with Layer 2 switches for this reason. Deploying such a solution enables Cox to provision protected trunks from the access network to the core Internet PoPs, while also providing connectivity for meshed and legacy TDM traffic. EoS circuits can be incrementally provisioned based on changing traffic patterns. While RPR could also have been deployed as a metro core solution, Cox favored the circuit-based nature of an EoS solution for providing core connectivity.

While EoS trunks are provisioned by Cox based on traffic patterns, Layer 2 Ethernet switching minimizes the load across this portion of the network by providing RPR aggregation, statistical multiplexing, and inter-RPR switching for access traffic. The deployment of Layer 2 switches further improves bandwidth efficiency across the metro core network by providing local switching for traffic local to the RPR access network.

The deployment of Layer 2 Ethernet switches in Cox's network is consistent with the company's end-to-end services deployment strategy. The Layer 2 switches deployed offer hardware redundancy and link aggregation, consistent with the RPR equipment. Interconnectivity between different platforms can also be implemented in a redundant fashion. Furthermore, the deployment of a Layer 2 switch is compatible with the MAC-in-MAC encapsulation used for service identification in Cox's network. Finally, a Layer 2 switching architecture, coupled with the provisioning of EoS trunks in the metro network core enhances the flexible, any-to-any connectivity delivered throughout Cox's network.

6. Network Implementation Phases

One challenge that MSOs face when undertaking a new deployment of metro infrastructure is of balancing capital expenditure with revenues over time. That is, even in a healthy market, the "build it and they will come" approach must be avoided at all costs. Thus, Cox San Diego underwent a three-phased approach to network deployment. This cautious phasing process enabled early service revenue to pay for later deployment phases, thus minimizing risk associated with the project. The three phases of deployment can be described as

1. Opportunistic Initial build
2. Strategic Access build
3. Metro Core completion.

Each of these phases as they were undertaken by Cox Communications San Diego are detailed in the following sections.

6.1 Opportunistic Initial Build

The first phase of Cox San Diego's RPR network deployment occurred even prior to the market analysis described in Section 2. This phase, the opportunistic initial build, was prompted by Cox's win of some strategic customer bids. This lead to the deployment of an initial small-scale RPR network to serve some independent customer builds (ICBs). While these initial deployments provided the obvious benefit of recurring revenue for Cox San Diego, the opportunistic initial RPR network build delivered other important benefits. First, the deployment accustomed Cox to RPR technology implementation and service delivery. Second, and more importantly, the initial build-out provided the opportunity for Cox to build operational and service models appropriate to both corporate policies and the deployed infrastructure. All of the these better prepared Cox for a larger scale deployment of RPR.

6.2 Strategic Access Build

The second phase of Cox Communications' RPR network build was well-planned based on the market and technological analyses. Cox deployed an initially small-scale RPR network in market areas with a high density of high-bandwidth businesses near Cox's fiber assets. This deployment enabled Cox to offer services to a reasonably-sized target market, while still keeping capital expenditure in check.

6.3 Metro Core Completion

With the any-to-any connectivity demanded by multi-site businesses in Cox's market, services delivered over the strategic RPR access network build were bound to demand metro core bandwidth for interconnection. Thus, Cox San Diego completed the EoS metro core portion of their network as a third phase. The phased approach to network deployment enabled the metro network to be scaled appropriately to service the connectivity demands of Cox's multi-site business customers.

7. Optical Broadband Services Management

Network management is key to the successful delivery of Optical Broadband services. To enable Cox's Network Operations Center (NOC) personnel to effectively configure, activate and manage such services and to accurately manage the configuration of their Ethernet devices, they required a service provisioning and configuration application. The service provisioning and configuration tool as deployed by Cox Communications is discussed in this section.

The first step of network provisioning is the auto-discovery of network resources and their configuration. The provisioning application's central server automatically synchronizes with the Cox RPR network on a daily basis, and can be configured to synchronize in real-time when changes are made to the network elements. This ensures the application's database reflects an up-to-date image of Cox's network element data at all times to enable accurate service provisioning. Once the network is accurately auto-discovered, the provisioning application can display a topology view of the entire Layer 2 infrastructure so that services can be provisioned.

Upon receipt of a customer order, the NOC personnel start the service activation process. The provisioning application's database provides the information necessary to provision the service, such as device, port and RPR availability in the desired location. Once the operator determines there are sufficient resources to activate the service, a work order is opened, which initiates the service. All changes to the network are recorded and tracked through the application's work order interface. This provides a full audit history of what changes are made to the network. It also enables changes to be reversed if necessary, thereby reverting the network to its previous configuration.

With the right provisioning tool, activating an end-to-end service is as simple as opening a work order, selecting an existing customer or entering a new customer name, selecting a service from a list of pre-defined services, selecting the end-points and path of the service and then entering some service specific parameters. On Cox's RPR network, all of this can be completed with one application, whereas previously Cox personnel had previously needed to perform these steps on a per-node basis and then track the changes manually with a spreadsheet. The service templates enable Cox personnel to pre-define their services to ensure services are activated consistently end-to-end. Settings such as Quality of Service, ingress bandwidth rate, can be pre-defined in the service templates. When a Cox operator selects a provisioning template, for example – Cox OEVPL 100 Megabit service – then can ensure that each service instance is configured with a consistent set of network element parameters, thereby providing service consistency. As soon as the work order is activated and all the changes are applied to the network elements, the customer's service is up and running. Enabling customers to receive Optical Broadband services can now be performed by Cox NOC personnel in a matter of minutes.

In addition to service activation, the service provisioning tool maintains a network-wide view of services delivery. This enables the correlation of a customer to that customer's services, to the resources provisioned to deliver that service. The association of a service to a resource is critical for services troubleshooting, and provides significant advantages over the more traditional port-oriented view of the network. For example, when a customer alerts the MSO that there is a problem, Cox can enter the service identifier and quickly view the topology of that customer's service across the RPR network. The Cox operator can then run the provisioning tool's service continuity check, which will determine the availability and latency of a service, flagging any issues. Thus, operational expense is saved by reducing the time spent troubleshooting service issues.

The services view provided by the service provisioning tool is also useful in the case of a network fault, such as a fiber cut or equipment failure. The services view enables Cox to quickly determine which customers are affected by such a failure. The operator simply queries the database to see which customers and services have been affected. In the event of a hardware failure the configuration of the network element can be restored from the backup configuration file thereby ensuring customer outages are kept to a minimum.

This ability to restore software images and to manage network element software configurations in a scheduled and phased fashion is critical to successful operations management. The provisioning application provides the Cox operators with options to backup network element image and configuration files on a regular basis and to manage the number of copies that are stored in the database. The Cox operators can also create network element templates and then store them in the provisioning tool's database. This ensures that each time a new RPR card or customer premises device is deployed, it is configured with a standard template (for example: all ports disabled, Internet Service Identifier 103 assigned to all customer facing ports, etc) thereby reducing potential mis-configurations and deployment costs. This same functionality can be used for software delivery of new releases of network element software. For example, Cox can push a new software load to one or two devices for testing, before pushing the rest across the network at a scheduled interval, while maintaining the ability to revert to the previous version.

One of Cox Communication's goals in delivering services over an RPR network was one of efficiency. While RPR delivers efficiency at the network level by providing efficient any-to-any connectivity for native Ethernet interfaces, the right service provisioning tool delivers operational efficiency by providing key features such as network-level service awareness, service templates and activation, backup and restore, and troubleshooting.

8. Conclusion

There is growing demand for Optical Broadband services in today's enterprise market, and MSOs are well-suited to address this demand, given their existing network assets, customer base, and operational expertise. Cox Communications San Diego undertook a cautious approach to services delivery with the goal of minimizing risk and maximizing profitability. This included a thorough market analysis which led to a better appreciation of the target market, and clear Optical Broadband Service definitions.

By using the service definitions to define network technology requirements, Cox was able to select and deploy a metro network best-suited to their service delivery goals. This technology was Resilient Packet Ring over SONET, which is best-suited for Cox's Optical Broadband services offer. Nortel Networks RPR solution enables efficient delivery of the full suite of Optical Broadband services, including Optical Ethernet services and Optical Broadband Private Line.

By scrutinizing their target market and using services definitions to select the right metro network, Cox was able to fulfill enterprise demand while maximizing return on investment.

9. References

[1] Nortel Networks Whitepaper, "Optical Broadband Services delivered through Service Innovation", *available at*: http://www.nortelnetworks.com/solutions/opt_ethernet/doclib.html, 2003.

[2] P. Caldwell, "Cox Communications San Diego Market Analysis", July 2002.

[3] Nortel Networks Whitepaper, "OE Services: New Paths to Profitability", *available at*: http://www.nortelnetworks.com/solutions/opt_ethernet/doclib.html,

[4] M. Holness, "Service Provider Ethernet Switching", WD14-15_Ethernet_Switching, s*ubmission to the ITU Telecommunications Standardization Secto*r, Q12/15, May 2003.