CONVERGED DATA NETWORK ARCHITECTURE (CDNA)

Michael J. Emmendorfer
Charter Communications

Abstract

What is CDNA? First, CDNA is the migration of all services (Voice, Video, Data) both serving residential and commercial customers over a Common Network Architecture, including optical transport, Internet Protocol (IP) core, IP distribution, various IP/media access layer technologies (coax, fiber, or wireless). Second, CDNA is a methodology with the objective to reduce layers of the network by converging component functionality within the network elements, as well as increasing the remaining network functionality to support any service over any access layer technology. Third, CDNA is the convergence to a Virtual National Backbone using MPLS (Multi-Protocol Label Switching) technology.

In summary, CDNA takes a holistic view of the network and has three fundamental principles: 1.) Convergence of Services over Common Network Architecture, 2.) Convergence of Network Layers (Reducing Network Elements and Increasing Service Functionality), 3.) Convergence to a Virtual Core Backbone using MPLS Technology

This white paper will illustrate an overview to our Converged Data Network Architecture, including our evolutionary plans, and benefits as well as challenges to this target network architecture.

CONVERGED DATA NETWORK ARCHITECTURE (CDNA)

Executive Summary

Charter Communications – like most Multiple System Operators (MSOs), Regional Bell Operating Companies (RBOCs), and Service Providers – is preparing for an "All IP World," and is at various stages of implementing this IP strategy throughout our networks. This white paper is an overview of Charter Communications' strategy and approach for a Converged Data Network Architecture (CDNA). The network will need to support all voice, video, data products serving residential and commercial customers over one common infrastructure. Some of these service and lines of business include Internet Data Services, Telephony, Interactive TV, Video On Demand (VOD), All Digital Video, Multi-Media Services, and a host of local and national based Commercial Products and Services.

The CDNA target architecture will continue to evolve over time. It is important to note that CDNA is not limited to coaxial-based technologies and architectures as stated in the abstract, but rather a holistic view of the network end-to-end with target architecture to support any service through any network technology (coax, fiber, or wireless).

The Convergence of Services over common network architecture, such as commercial and data services across an MPLS enabled CMTS, as well as switch/router platforms, will allow for the replacement of historic services such as Frame Relay, and has been deployed since 2002. Charter views MPLS first as a service or revenue enabling technology, second as a network label switching technology, and finally the ability to logically partition services across the network. We have continued to converge some services over our IP distribution and optical transport network infrastructure, which includes Residential Voice and Data Services, VOD, Simultrans (All Digital Video), and Commercial Services to various enterprise customers

The Convergence of Network Layers in the metro area will reduce the cost to the MSO, and our target is to enable access layer elements as well as distribution layers with DWDM optical interfaces, by-passing the traditional transport layer as well as aggregation routers. The third generation cable platform providing video and data service is being formulated. There are new revenue generating services and the ability to create CAPEX and OPEX expenditures by enabling the legacy access layer platforms (CMTS) to support a full range of commercial and residential products lines.

Charter's vision is to create convergence to a Virtual Core Backbone implementing MPLS Technology, and will allow us to take the lead in various data, telephony and commercial services.

The opportunities and benefits of CDNA have just begun to emerge, and others will be realized over time. We are able to leverage multiple Lines of Business (voice, video, and data) to support the network infrastructure, and improve the economics for all lines of business, both from a capital and operation perspective.

The benefits to a CDNA strategy will create the vehicle for integration of services, improve the customer experience, increase loyalty, and defend our customer base. The CDNA architecture is a migration away from proprietary systems to standards-based products that will enable us to accelerate the advanced service deployment while driving down operational efficiencies in terms of leveraging a common work force and fewer network systems.

There are challenges that we have encountered and options that need to be considered as we make our way to a truly converged network. A few of the challenges include driving full service features on the 1st and 2nd Generation CMTS, defining the 3rd generation CMTS/Edge QAM to support the full breath of commercial services to address competitive threats (a possible PON replacement technology), integration of long reach DWDM optics on distribution as well as the access layer elements with fault management capabilities.

Introduction

This white paper is an overview of a target network architecture based on business, operations, and technical requirements to support Residential and Commercial Data Services, Telephone Services (VoIP), VOD, iTV, Simultrans, All Digital, and other IP-based Products & Services, internally called Converged Data Network Architecture (CDNA).

Charter Communications has convergence at various portions of the network today, and others will emerge over time. This paper has three fundamental principles for a CDNA strategy.

First, we will begin with the Convergence of Services over a Common Network

Architecture supporting Commercial and Residential customers with several product offerings including Data, Voice, and Video. An advantage of convergence of services across a common network is economies of scale and the ability to offer more features and integrated services for the consumer.

Second, the methodology of Convergence of Network Layers with the convergence to IP will inherently force the migration of services from legacy platforms (often proprietary) to IP network elements (which will be standards based). In addition, this second principal of the convergence of the network is increasing functionality and allowing the service provider to reduce layers of the network and also enhance the remaining layers functionality to support the convergence of services across a common network. This can fundamentally change the network architecture.

Finally, the third principle is the Convergence to a Virtual Core Backbone using MPLS VPN Technology. MPLS technologies have been in operation and offered as a service by backbone service providers for years. However, the adoption of this technology in the cable industry has, until recently, been only in the hands of a few across the world; and of those few most are only using MPLS as a network label switching technology and for traffic engineering across a backbone or MSO core network. In 2002, Charter embraced MPLS as a Service / Revenue enabling technology to position services against the RBOCs and Service Providers utilizing MPLS VPN (RFC 2547 bis) as well as other MPLS based technologies.

BUSINESS REQUIREMENTS AND SERVICE DRIVERS

Charter Communications offers four core services that are starting to cross-pollinate with each other as outlined below. This hybrid approach will require more feature sets as the services evolve, but it can be classified into the following service categories: Video, Voice, Data, and Network.

Video Based Transaction Services

- VOD, SVOD, HDTV, etc.
- Migration to a All Digital Network
- Interactive Set-Top and DVR
- Migration to End to End IP Based VOD and Content Services

Voice Based Transaction Services

- Primary Line Voice Services
- Business Class Telephone Services
- Multimedia Voice Service (SIP)
- Integration with Video Products

Data Based Transaction Services:

- Unified Mail Services
- Web Hosting and DNS
- Centralized Storage and Data Back-Up
- PC-based Virus/Spam Protection

Network Based Services

- Bandwidth Speeds (Tiers)
- Quality of Service
- Network Based Virus Protection
- Security and VPN Services
- Bandwidth Management
- Single or Multi-Site Connectivity Products
- LAN Extension Services
- Transparent LAN Services
- Frame Relay Replacement
- Routing Services
- TDM and SONET Services
- Network Storage Transport Services

ENGINEERING AND OPERATION REQUIREMENTS

The CDNA architecture requires centralized management (NMS & EMS) and full Fault Management, Configuration, Accounting, Performance, and Security (FCAPS). A key driver for CDNA is reducing the complexity of the network, reducing the layers of the network, and differentiated products for service delivery. Also, accelerating the convergence of services and network architectures with the requirement of high reliability and availability across standards-based platforms will advance services deployment, and drive operating efficiency.

FUNCTIONAL TRACKS

Charter has taken an approach to partition the end-to-end *service delivery network* into Functional Tracks that represent common types of services and/or technological areas of concentrations. This paper will concentrate on Track 2 – Converged Data Network Architecture (CDNA) with an example illustrated below in figure 1.

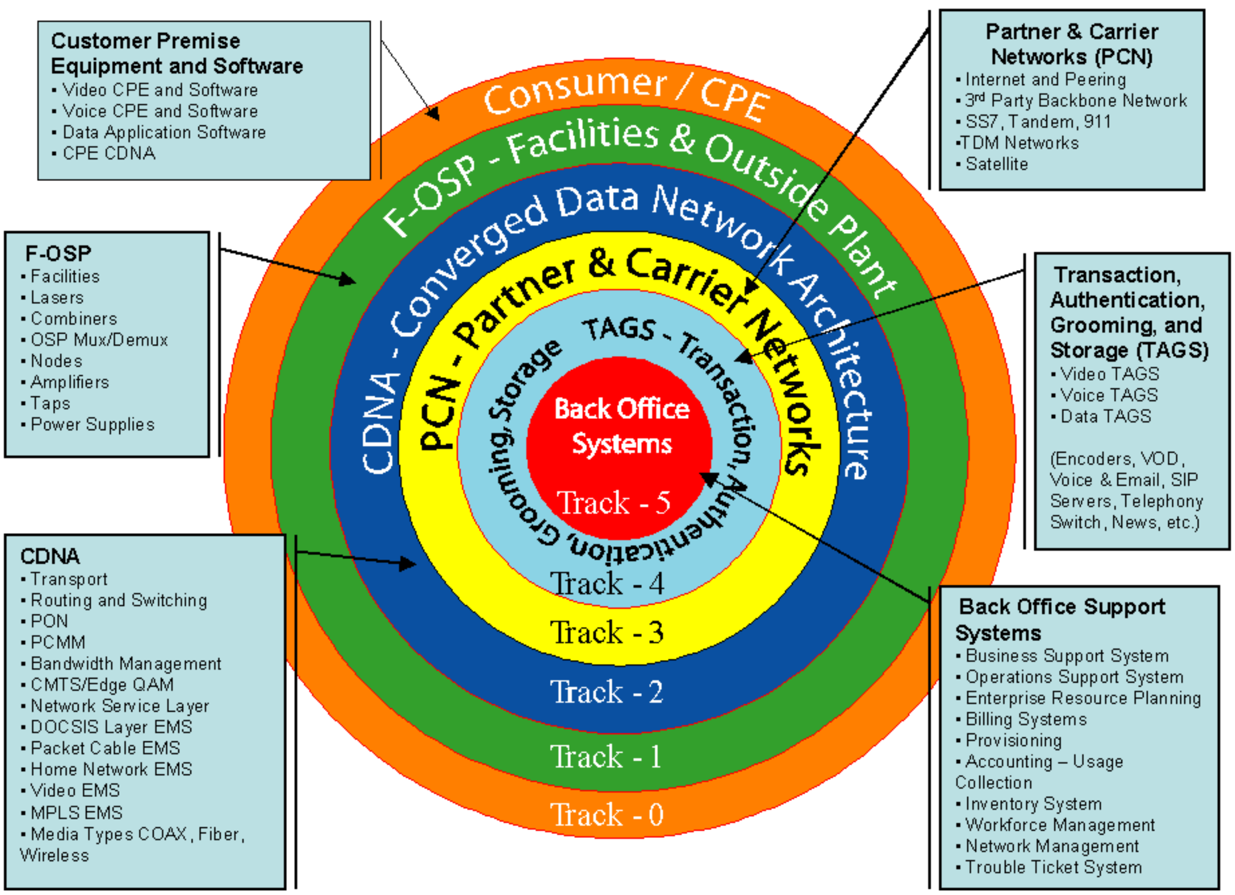

Figure 1: Functional Technical Tracks

THE CDNA TECHNICAL AND MIGRATION STRATEGY

Overview

Reaching our target architecture of full convergence of all services across one network will certainly "not happen over night" since this is an evolutionary path. The following section is a high-level strategy for CDNA, and a migration plan to the target architecture. The target architecture has four layers, including optical transport, Internet Protocol (IP) core, IP distribution, and various IP/media access layer technologies (coax, fiber, or wireless). This next section will examine the Access Layer to increase functionality to offer new services as well as technology improvement to allow seamless integrations. The Figure below is the end-to-end a high-level strategy for CDNA:

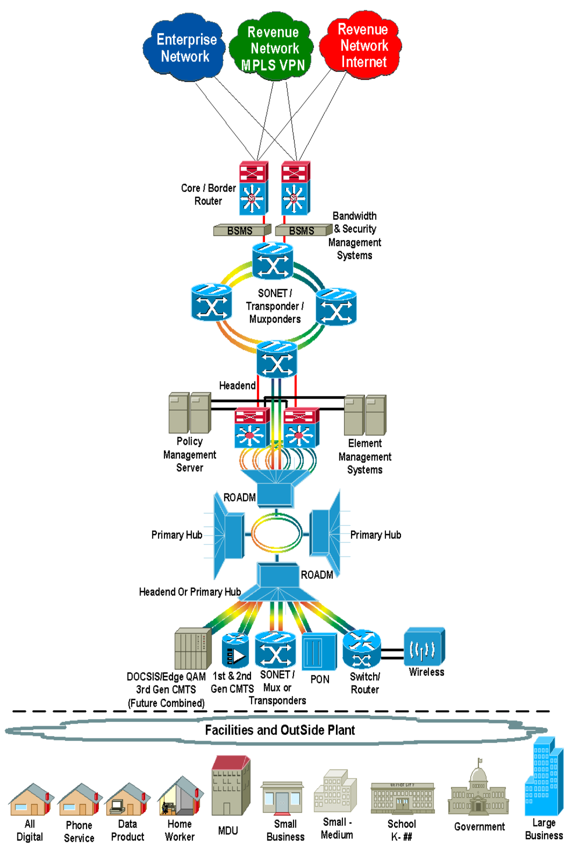

Figure 2: CDNA End-to-End

The figure below is the CDNA access layer component support residential and commercial voice, video, and data service, both end-to-end IP and MPEG.

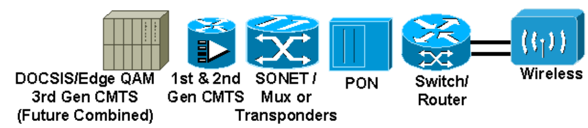

Figure 3: Next Generation Access Layer Elements (Headend and Primary Hub)

Stage 1 Service Enabling Legacy Access

Charter's objective is to increase functionality of the current CMTS infrastructure with software enhancements, including Sub-interfaces, VRFs, Layer 3 MPLS, MB-BGP, IS-IS Routing Protocol, and others. This will enable the MSOs to leverage an existing CMTS infrastructure for new revenue streams with higher margins. This asset continues with its financial depreciation schedule, but with software we enable a new revenue stream like those to support commercial services; specifically services to replace the incumbent provider. Figure 4 below represents MPLS enabled CMTS to provide frame relay replacement services to support our Commercial Business Unit.

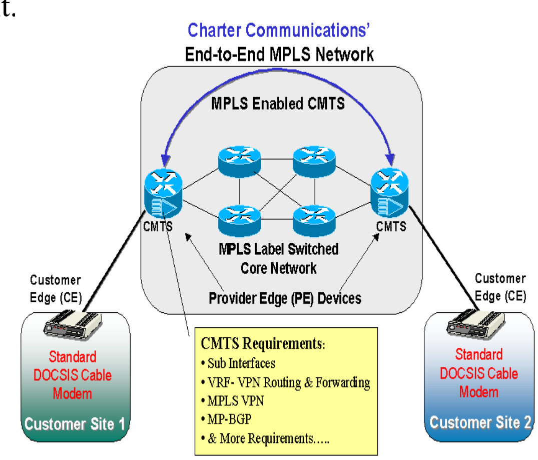

Figure 4: Delivering Commercial Services with MPLS VPN enabled CMTS Delivering

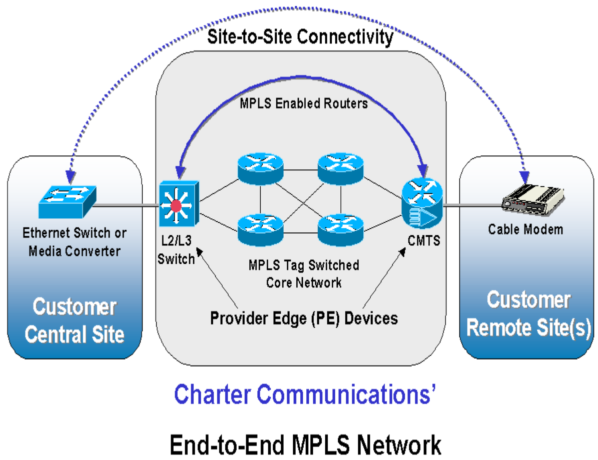

Figure 5: Commercial Services using MPLS VPN enabled CMTS and Switch/Router

The illustration in **Figure 5** enables the customer to use our IP VPN to connect remote site(s) to a central office. This example has the customer provisioning their PCs and SIP phones with their own IP address space, their SIP phones use our provided private network to use 4 digit dialing as well as off-net dialing.

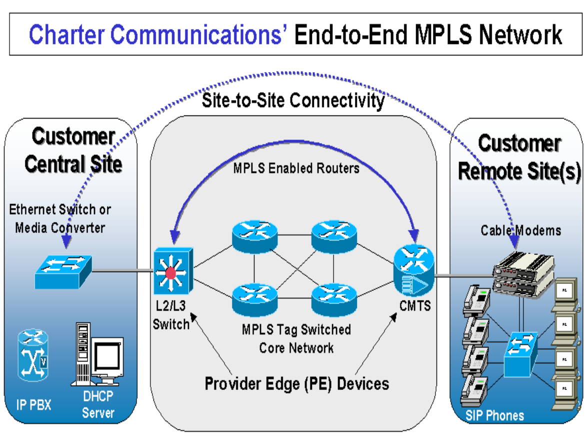

Figure 6: Customer Traffic Transparency across Charter's Network

We are exploring additional service enhancement to the CMTS, which may include Layer 2 Services for Transparent LAN Services, using EoMPLS, QinQ (*802.1q Tunneling), as well as VPLS. These technologies are traditionally found on switching platforms. There are critical service and management features for the next generations / 3rd CMTS/Edge QAM.

We launched Passive Optical Network (PON) technology in 2002 and SONET services in 2000 to support commercial product offerings such as Ethernet and TDM services, our service enabling strategy is to place CWDM optics in the access network between the Charter facility and the customer, to conserve fiber assets.

Stage 2 Converged IP Distribution for All Services

Charter has placed over its Distribution layer network Residential Data Services, Commercial Services, Voice Service, VOD Services, All Digital video product offering.

Stage 3 Transport Network Migrations

Charter CDNA Architecture will greatly change the Optical Transport network in the metro market; to that end Charter has begun a migration of IP traffic off of SONET as well as RPR over SONET, to transponder and muxponder.

Stage 4 Bandwidth and Security Management System (BSMS)

What is BSMS? BSMS is unified solution for bandwidth management (high bit rate application management) as well as Security Management (Intrusion Prevention Systems, Protection from DDOS, and targeted services security protection). Charter implemented BSMS in our large markets; as a result of this deployment we captured the following statistics:

- Avg. of 40,000 malicious packets for every 100k subscribers per day.
- In one of Charter's larger markets there were 14 million malicious packets events in 30 hours
- Attacker Ratio: For every 1 attack that comes into a Charter Network there are 11 attacks from our subscribers going out

A case study: BSMS Value Assessment and Network Worms

Impact of Network Worms and Malicious Attacks Measurement from July 2003 – November 2003

- **August 11:** The Blaster Network Worm was introduced
- **August 22:** The SoBig Virus Hit was introduced

Table 1: Call Center and Operation Impact from Network Worm (Source: Jon Mandani, Charter Communications)

MONTH	HSD Repair Calls **% Increase** from July	HSD Truck Rolls **% Increase** from July
July	-	-
August	70%	26%
September	105%	18%
October	47%	16%
November	8%	(-8%)

We deploy BSMS at the border of our network at the Internet drain; this does not protect or manage traffic to and from our subscribers, which would be on net. As we approach convergence of Voice and Video on one IP network this feature has a considerable increase in importance. Our BSMS strategy is a requirement for the next generations / 3rd CMTS/Edge QAM, Passive Optical Network, and Switch/Router.

Stage 5 Convergence to a Virtual Core Backbone using MPLS

The creation of a Virtual National Backbone using MPLS creates cost savings and revenue generation opportunities thought not possible because of geographic separation from our facilities (Headend, Hubs, and Offices). Charter plans to create a Virtual Backbone using MPLS, using two technical approaches representing two business needs:

1. **MPLS -** Charter becomes a customer of a MPLS-enabled service provider establishing connectivity to remote offices and facilities around the country to support the internal enterprise network. This effort replaces the frame relay technology that is currently implemented.

2. **Hierarchical VPNs** – For Charter to become an MPLS VPN Service Provider would require connectivity across an MPLS VPN enabled service provider nationwide. This enables some key features:

   a. Commercial Services to provide connectivity and QoS to our customers between our current network footprint as well as outside service areas. Global customers are now possible across this virtual network.

   b. MPLS enabled service (VoIP and others) to provide connectivity and QoS across carrier networks to other Charter sites or partners.

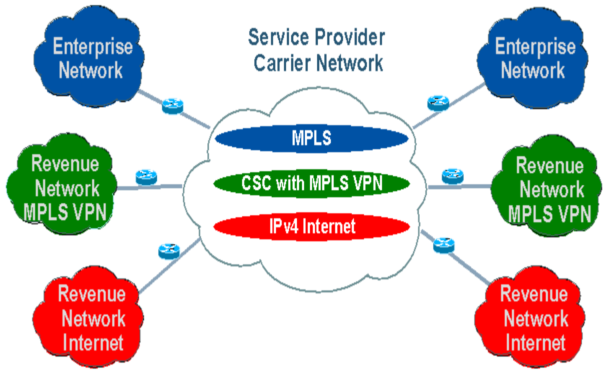

Figure 7: Connectivity Across MPLS Carrier

This opportunity is realized by the ability to offer services where an MSO's backbone or metro network cannot reach without a significant capital investment.

We are considering placing other services across our MPLS Virtual Backbone as well as the Hierarchical VPNs.The diagram on this page illustrates the Internal Enterprise Network (MPLS), Revenue Network MPLS VPN - Hierarchical VPNs, and Internet.

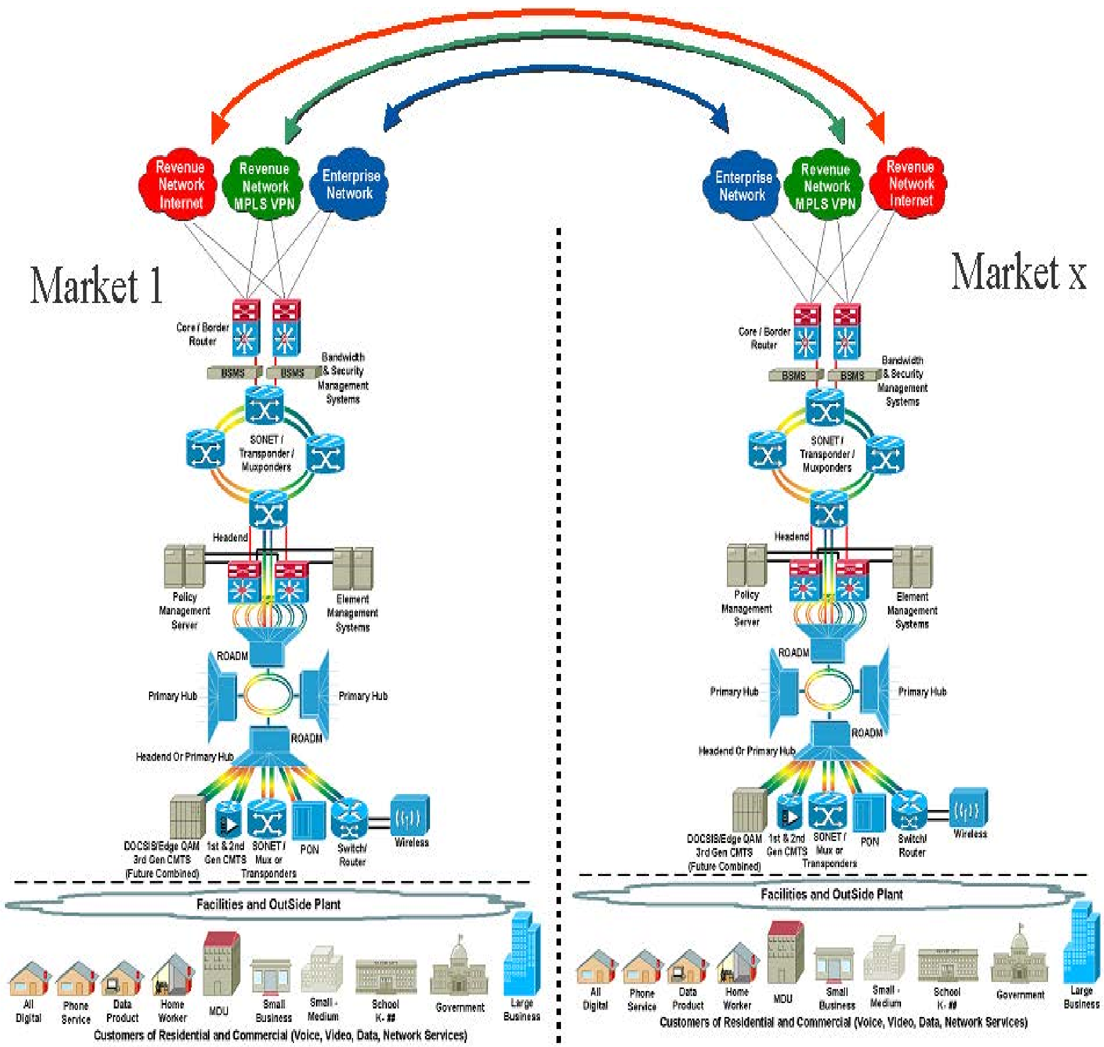

Figure 8: Illustration of Interconnect of two (2) MSO markets connected over MPLS enabled Carrier(s) utilizing MPLS, Hierarchical VPNs, and Internet Access.

There are a multitude of technical considerations for Hierarchical VPNs and MPLS:

- Using the RFC 3107 - Carrying Label Information in BGP-4 to interface with the carrier, aka BGP send label
- DSCP for IPv4 to Carrier MPLS EXP
- EXP MPLS to Carrier MPLS EXP
- Depth of label stacking for your MPLS VPN Carrier
- Multicast over MPLS VPN
- MPLS Monitoring Visibility

Stage 6 ITU DWDM Enable Distribution and Access Layer with ROADM Technology

The integration of long reach ITU Dense Wavelength-Division Multiplexing (DWDM) Gigabit Interface Converter (GBIC) (or SFP) "natively" on access layer elements, like that of CMTS, L2/L3 Switches, PON, Edge QAM, as well as the switch/router distribution layer elements could bypass the transport layer in the metro markets. In fact, aggregation L2/L3 switch/router(s) located at primary hubs would not be required as well, with native DWDM optics on the access layer elements.

Assets already deployed in primary hub locations could be re-allocated from Switch Aggregation and Optical Metro Transport Distribution to Access Layer devices used for revenue generation. **Figure 8** illustrates this proposed design; this architecture reflects the optical transport layer as well as L2/L3 Aggregation Layer Switch at the Primary Hub (s) as these components are not required.

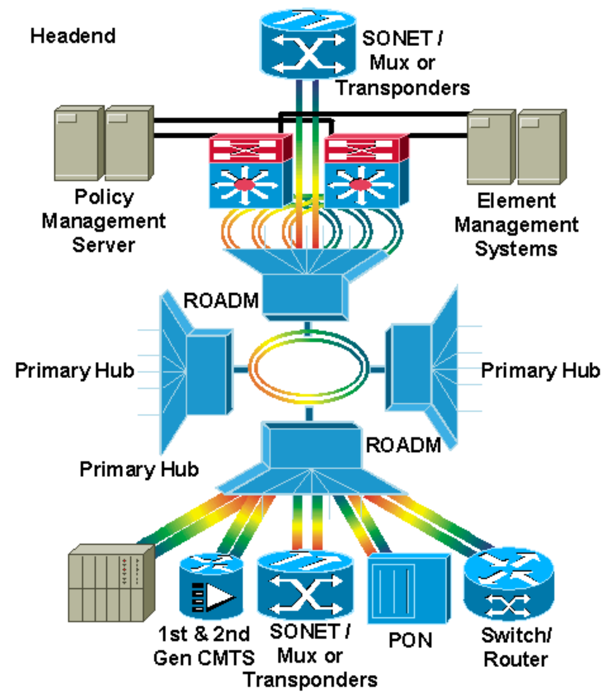

Figure 9: ITU DWDM GBIC (or SFP) "natively" on Access Layer & Distribution Layer

There are a host of challenges with native ITU DWDM Ethernet Interfaces (1) Gigabit and/or (10) Gigabit that will need to be address and solutions developed, however once realized the capital and operational savings are significant.

Though work to improve router switch over and convergence time, like those found in RFC 3623 - Graceful OSPF Restart and other similar standards to improving the protection capabilities of the router to be at parity with SONET scheme. However the photonic level impairment measurements protection schemes inherent with SONET/SDH and ITU G.709 are not available, such as:

1. Performance monitoring Fault management, errors, alarms, and performance monitoring like which exist in SONET/SDH and ITU G.709, for optical layer problems.

2. SONET/SDH and ITU G.709 defined threshold are met for link impairments a message for automatic protection switching (APS) occurs.
3. POS interface contains this protection.

Below, is a set of questions to the industry surrounding protection schemes for Ethernet without wrappers (G.709) so that protection scheme like those defined by SONET/SDH and ITU G.709 could be available for native Ethernet?

1. How can ITU DWDM Ethernet Interfaces (1) Gigabit and (10) Gigabit obtain the optical measurement for Errors, Alarms, and Performance Monitoring similar to that of SONET/SDH and ITU G.709, WITHOUT placing a wrapper around the Ethernet frames?

2. How can Ethernet get the equivalent of signal degrade bit error rate measurements (link up but degraded) and issue the equivalent of SONET APS to a Router's IGP to force a re-convergence of a link that is not down and the IGP hellos and dead timers (even if default setting are reduced) does not declare the link down?

3. Keeping Ethernet enacted could an equivalent signal degrade BER measurement over IP link monitor and measure a consistent stream for degraded link and issue an alarm and/or issue a signal to the IGP to converge.

These performance measurements and protections scheme are important with UDP stream (VoIP or Video), TCP data traffic may not detect the impairment, voice and video could be affected.

Reconfigurable Optical Add/Drop Multiplexer (ROADM) is being considered as part of the CDNA strategy for per lambda optical wavelength managements.

Stage 7 The 3rd Generation CMTS Platform

Charter has defined an Edge Layer that can support services and technology, independent of media (coax, fiber, and wireless), this integration of the services will provide greater serviceability of commercial services, arguably one of our industry's fast growing segments. With regards to the next generation coaxial platform, known as the third generation CMTS, also known as the modular CMTS is certainly the "buzz" these days.

As discussed earlier in the paper we use the 1st and 2nd generation CMTS platforms to deliver data and voice service to residential customers, in addition we also offer advanced services to commercial customers. Charter partitions the CMTS logically to create management sub-interfaces for provisioning and management, as well as for revenue services. This partitioning enables Charter to apply routing rules, security rules, or service for revenue generation per logical interface.

Charter is interested in this next generation platform because we see this not just as a platform that can provide integrated Data and Video services, but this has the potential to provide high bit rate services to commercial subscribers and to augment a Passive Optical Network.

BENEFITS

We hope CDNA will provide capital expense savings through economies of scale and standards platform architecture. We believe that operational expense savings and increase network availability, manageability (remote), and a shared work force supporting many services, but one network should improve the economics of all line of business.

Convergence will enable fewer facilities for complex and expensive transaction processes (Encoding, Storage, Telephony Switching, Email, Hosting and eventually few Headends.

CHALLENGES

There are two core challenges as part of the CDNA strategy, Ethernet Optical management and monitoring, like those found in SONET and ITU G.709. In addition, the feature and functionality of the 3rd generation CMTS/Edge QAM, especially in the areas of logical interfaces for management and security as well as commercial services capability (bandwidth and services).

CONCLUSIONS

Convergence to IP end to end will emerge over time for the cable operator, and legacy technology are increasing using IP for transport services, as this evolves over time we are well positioned to support this migration. This architecture can have significant cost savings.

Michael J. Emmendorfer
Charter Communications
MEmmendorfer@chartercom.com