# Consolidating Advanced Services and On-Demand Content with GbE over 10Gbps DWDM

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## Abstract

The significant upgrades of the cable plant over the last few years allow operators not only to deliver advanced packet cable services, but also offer profitable On-Demand content such as Video-on-Demand (VOD) and network-based Personal Video Recorder (NPVR) services to their customers. With On-Demand servers as well as EdgeQAM Modulators migrating from proprietary interfaces such as DVB-ASI to commodity, high-volume Gigabit Ethernet (GbE) technology, the opportunity exists to migrate the majority of legacy as well as new packet cable services onto the GbE transport infrastructure deployed for VOD. This paper describes deployment architecture and management of an efficient GbE transport infrastructure that allows operators to offer all these services and in the process lower their infrastructure as well as operational costs.



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## *Introduction*

Operators today are rolling out on-demand services such as VOD and network-based PVR to compete with digital broadcast satellite providers and find new revenue sources beyond the flat rate cable TV and Internet access services. In the future, operators also want to be able to provide services such as HDTV on demand, interactive gaming, and Voice-over-IP (VOIP) selectively and cost effectively over the same infrastructure without building another network overlay. Significant work has gone into defining an architecture and infrastructure over the last few years for delivering two-way, IP-based services over the cable network, including upgrading the HFC plant to two-way operation. The PacketCable™ end-to-end architecture designed for such two-way packet services defines the framework for delivering and managing IP/Packet based service in the cable network.[1] What may have gone unnoticed is that all these services are based on Ethernet-framed MPEG over IP or Ethernet-framed IP packets, leading to the obvious opportunity to consolidate all these different services and traffic types over an Ethernet-based transport infrastructure.

This paper discusses how Gigabit Ethernet (GbE) transport, and particularly GbE transport over 10Gbps WDM, not only fulfills all the requirements for new VOD services, but also easily allows integration with legacy broadcast, new on-demand services, as well as PacketCable traffic over a highly scalable and cost effective transport infrastructure.

The paper also discusses what criteria should be used to evaluate equipment based on ease-of-installation, operational features and manageability once the network has been deployed, and different ways to integrate the new on-demand video traffic onto the operator's fiber infrastructure.

## *Transport Technologies for VOD*

At 3.8 Mbps and 19 Mbps per stream for digital TV and HDTV on-demand, respectively, VOD requires by far the largest transport bandwidth to date in the cable network. With typical numbers for simultaneous usage and homes passed per remote hub, VOD traffic can easily amount to multiples of Gigabits of MPEG-2 traffic between the VOD servers and each remote hub. Furthermore, low latency and jitter are required in order not to exceed the jitter tolerance of the server/EdgeQAM combination. These bandwidth demands call for a more efficient and much more cost-effective transport infrastructure so that new VOD services can be deployed while at the same time providing a quick (less than one year) return on the investment. The currently deployed transport infrastructure is ill equipped for these bandwidth requirements. Upgrading the current SONET infrastructure to OC192 is way too costly, while OC192 ATM systems aren't even available. First-generation WDM systems that carried a single service such as DVB-ASI over a wavelength are neither scalable nor cost effective, and in particular did not have the operational features required to manage and maintain the network.

With all services now being IP/MPEG-over-Ethernet based, GbE and 10G DWDM are the obvious answers for MSOs needing large transport bandwidth without negatively impacting the business model for VOD service rollouts. VOD servers as well as EdgeQAM vendors migrating away from proprietary and expensive technologies such as DVB-ASI and adopting

the standard, ubiquitous, and inexpensive GbE as the interface of choice have hastened this development. With DOCSIS™ being IP/MPEG-based as well,[2] an GbE/IP based transport infrastructure will also allow operators to consolidate new packet cable services eventually onto the same high-performance network.

A low-cost, simple, and reliable Ethernet based transport architecture needs to be deployed for VOD and other packet services, and GbE over 10Gbps DWDM is that technology. GbE over 10Gbps DWDM not only solves the VOD rollout problems today, it also allows consolidating all the other PacketCable, VoIP, as well as legacy DVB-ASI broadcast and HDTV services over the same infrastructure. GbE "Virtual Wire" transport extends the benefits and simplicity of fixed bandwidth Layer-1 connections of SONET to the much simpler technology, without having to implement complex QoS mechanisms, fairness algorithms, and preempting traffic in protection switching situations as required for Resilient Packet Ring and ATM technologies. Consolidated GbE into 10Gbps DWDM trunks allows the operator to deploy a much lower cost transport, yet future-proof technology for the bandwidth hungry on-Demand applications while being able to migrate legacy and new PacketCable services onto the same infrastructure. A final benefit of Ethernet also allows introducing packet switching into the transport network for better aggregation, content sharing, to accommodate distributed content architectures, or to improve statistical content sharing across multiple customers. Lastly, where Layer-1 redundancy is not required, packet switching can provide alternate stream source and downstream pathing for improved resiliency where.

## *GbE over 10Gbps DWDM Transport Architecture*

Figure 1 shows how a 10 Gbps Ethernet-based DWDM transport network allows a cost effective and extremely simple VOD deployment. This architecture is unique as it provides and guarantees low latency, fixed bandwidth GbE connections between the VOD servers at the headend and the EdgeQAM modulators at the remote hubs. These "Virtual-Wire" connections eliminate the cost and complexity of ATM, SONET, and RPR technologies that should be avoided in cable transport architectures.

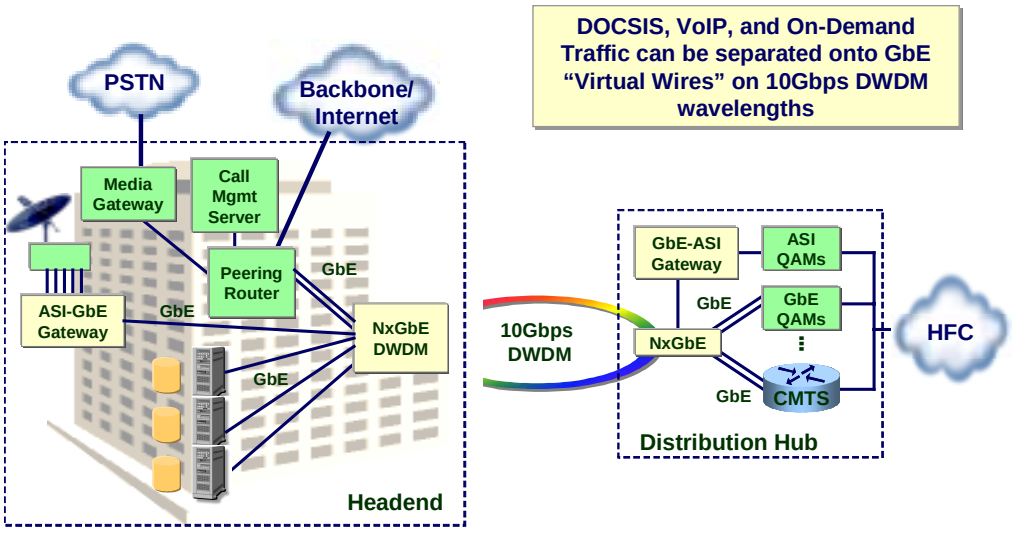


**Figure 1: GbE over 10Gbps DWDM for VOD, Network PVR, and PacketCable Services**

There are enough issues that need to be considered to achieve different QoS levels on DOCSIS/CMTS and the VOIP network elements – the last thing operators want to deal with is the interaction of service specific QoS issues with QoS administration of the transport network. RPR in particular is vulnerable to QoS and fairness issues after a protection-switching event, unless nearly half of the bandwidth on the ring is reserved for protection. A "Virtual Wire" GbE-based 10G DWDM transport infrastructure avoids these problems while keeping capital as well as operating costs low, and optionally providing dedicated protection paths in case the operators choose to protect the service from fiber cuts.

GbE and multiplexing of these GbE "Virtual Wire" connections into 10Gbps DWDM wavelengths reduce the cost of transport bandwidth and the number of wavelengths that need to be supported in the transport network. MSOs can start with a single wavelength with only a few GbE ports enabled, and can scale to eight GbE connections per wavelength and 32 wavelengths – an aggregate bandwidth of 256 Gbps. Protection from fiber failures can be added on a per-wavelength or per-fiber basis.

Because of the Layer-1 "Virtual Wire" attribute, GbE over 10Gbps DWDM can be adapted to point-to-point, hub-and-spoke, and ring architectures on dark as well as lit fiber, and with or without optical protection switching per GbE, per wavelength, or per fiber. Because of the non-intrusive nature of WDM, it is also possible to deploy the new GbE and 10Gbps DWDM wavelengths on the same fiber as the existing broadcast or transport network. For example, multi-GbE transport for VOD can be deployed over the same fiber pair by passively adding a new wavelength for VOD to the existing OC3/12/48 SONET or ATM traffic ("SONET WrapAround"). Alternatively, the existing SONET/ATM traffic can be translated to a new wavelength riding alongside the GbE traffic. Similarly, business services can be integrated over the same installed transport infrastructure.

The cost points of GbE and 10Gbps DWDM-based transport allow operators to install a transport infrastructure for VOD and achieve payback from this investment in less than a year[3], and then migrate other legacy as well as all new IP packet-based services over to this Ethernet-based transport infrastructure.

## *Centralized and Distributed VOD Server Deployments*

With the flexibility and lower cost of the "Virtual Wire" GbE over 10Gbps DWDM transport solutions, it becomes possible to have ultimate flexibility in deploying centralize, distributed, and hybrid solutions for VOD deployments. Probably the most efficient architecture for VOD is through centralization of all the servers at the headend and connecting the GbE server cards at the headend with the EdgeQAM modulators at the remote Hubs through the GbE over 10Gbps DWDM transport infrastructure. DVB-ASI to GbE gateways can be deployed at either end should either VOD server or EdgeQAM still have legacy DVB-ASI interfaces instead of the newer and more cost effective GbE interfaces. With GbE interfaces, there is also the opportunity to perform packet aggregation and content distribution by introducing VOD-specific layer-2 packet switching functionality as part of the transport network.

For first-generation distributed VOD deployments, the opportunity exists to centralize at least part of the content to select headends as the amount of content exceeds what can be deployed

in a distributed fashion. Depending on the server technology, this can either be accomplished using GbE or Fibre Channel transport over 10Gbps DWDM.

## *Multiple Services Ready Transport Infrastructure*

Once a managed scaleable GbE-based transport infrastructure is deployed, operators are now ready to cost effectively offer multiple services over a shared backbone. This includes core broadcast video services, high-speed data backhaul for residential users, back-office traffic, as well as the transport of commercial services traffic out to business and public sector customers.

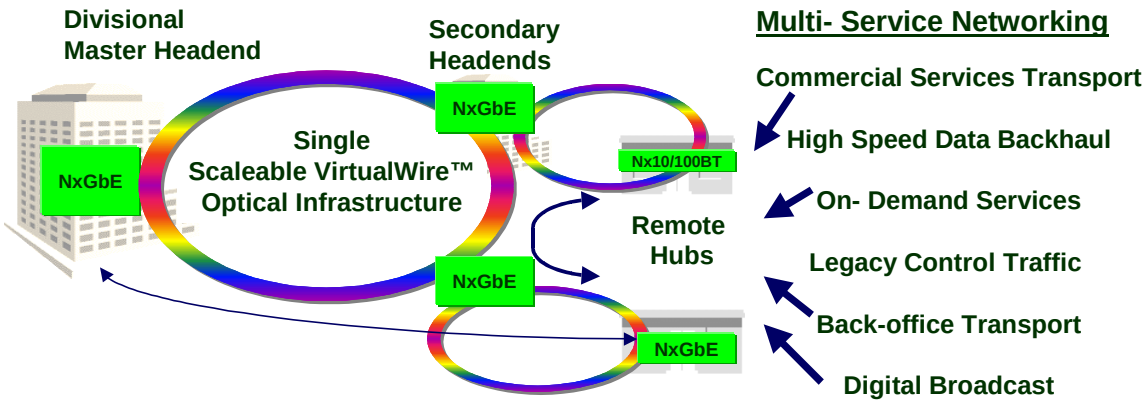


**Figure 2: Multiple services share the "virtual wire" optical transport system without contention**

## *Deployment Considerations for a 10G DWDM Ethernet Transport Infrastructure*

Simple engineering rules, rapid installation and rapid configuration of network nodes are of importance to keep deployment and operational costs low. Distances up to typically 80km can be easily achieved on regular G.652 fiber today with 10Gbps WDM systems. Only beyond that, dispersion compensators and additional optical amplification may be required for the few long-reach links. New innovations will push this to 100km and beyond, so that optical regeneration will rarely be needed in most deployments.

WDM filters should always be deployed to allow for expansion to additional wavelengths even if only a single 10Gbps wavelength is required for the initial service rollout. This way, additional capacity as well as other protocols (or services) can be added in a transparent fashion to the transport system without service disruption. In addition to 10Gbps DWDM, individual GbE connections can be deployed using Coarse WDM (CWDM) technology with few homes passed, while DWDM and 10Gbps technology is deployed more typically at nodes with more than 2 GbE drops. CWDM and DWDM technologies can coexist on the same fiber and rings, and it is even possible to add DWDM channels to nodes that previously only were reached by CWDM GbE connections, all without having to replace equipment.

In the rare case where distances are large enough to require placement of an optical amplifier, it is important that the right amplifier is chosen. Conventional optical amplifier design can

cause significant problems when new wavelengths are added for capacity or existing wavelengths are rerouted along a different path. Because of the analog nature of first-generation amplifiers, adding and dropping wavelengths can cause other wavelengths to change in power or exhibit surges in optical power that can damage optical receivers. A good optical amplifier has not only dynamic gain equalization, so that the power remains constant across all channels no matter how many channels are added or dropped, but also supports transient suppression. This new generation of optical amplifiers can also significantly simplify network design because of their constant gain independent of WDM channel count and configuration (typically on the order of 20 dB), future proof the system, and completely eliminate operational issues such as gain adjustments and loss rebalancing that were required in older WDM systems during capacity upgrades.

## *Managing the 10Gbps DWDM Ethernet Transport Infrastructure*

Once the GbE based transport infrastructure is deployed, cable operators need to manage configuration and capacity changes and monitor the health of the system. They also need to receive and process alarms in case the system performance deteriorates due to bad fiber splices, dirty connectors, or after a fiber cut that initiated a protection switch but now requires the original fiber route to be repaired. With increasing traffic and customers, cable operators realize that the ongoing operations and manageability of the network is just as important as the initial cost of the equipment.

The SONET equipment deployed by MSOs and Telcos alike did fit the need for manageability, fault monitoring and isolation, and early alarming and binning of Bit Errors before service affecting faults occur. Just because a more cost effective and higher bandwidth transport technology is deployed to enable new services like VOD, the operator should not make any compromises in its manageability, performance monitoring, and fault alarming and isolation. State-of-the-art GbE and 10Gbps DWDM Ethernet transport equipment offers exactly the same operational, administrative and performance monitoring capabilities as SONET, yet at a fraction of the cost. Some vendors even offer protection switching on a per GbE or per-wavelength basis that exceeds the performance of SONET protection rings. Unlike RPR rings that make protection switching decisions on a per-packet basis at Layer-2, and therefore require a careful modeling of QoS and fairness algorithms under normal, as well as under protection conditions to ensure packet delivery under all conditions, 10Gbps and GbE WDM transport equipment protects at Layer-1 and guarantees connectivity and packet delivery under all circumstances.

Alarming is another area that operators need to think about. Equipment should be able to generate alarms (e.g., SNMP or TL-1 traps) from failures as simple as a fan failure indicating that a defective fan should be replaced in the near future, to signal degrade traps as a fiber splice is deteriorating or a dirty connector sees additional losses because of temperature changes in a hub location. But even more important is that failures can be quickly identified in nature and location and can be addressed by the operator before customers are calling saying they can't receive the service they are paying for.

The last aspect of manageability of the network comes to light when software on the network elements needs to be upgraded to enable new features or capabilities. Operators should be careful to only select equipment that can be upgraded to the next software revision in a hitless fashion (i.e., without affecting service to the customer).

## *Summary*

Optical Gigabit Ethernet as a transport technology in cable deployments is the first transport technology that can deliver PacketCable, On-Demand content, and SMB business services natively without conversion from IP/Ethernet to another protocol such as ATM or SONET. Coupled with the efficiency of multiplexing GbE onto a 10Gbps DWDM wavelength, GbE over 10Gbps DWDM offers the only transport solution today that not only can carry existing and future PacketCable services, but also guarantees rapid payback for the bandwidth hungry On-Demand rollouts such as VOD.

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[1] "PacketCable 1.0 Architecture Framework Technical Report," PKT-TR-ARCH-V01-991201, December 1, 1999, CableLabs, www.packetcable.com

[2] "DOCSIS Overview," CableLabs DOCSIS Team, January 2003, http://www.cablemodem.com/downloads/slideshow.ppt

[3] Gary Southwell, "Accelerating On-Demand – The Case for 10Gbps DWDM," Communications Technology, December 2002