Decision Point

Choosing the right backhaul architecture for next-generation DSL networks

A BTI Systems white paper

OVERVIEW

Adoption of DSL has increased rapidly in the years since the technology was first introduced. Between 2005 and 2006, worldwide DSL subscriptions leapt upward by 32 percent to 172 million. By 2010, they're expected to reach 371 million.

The world's enthusiasm for DSL makes sense. DSL allows traditional copperline networks to support higher-bandwidth services, and makes it possible for service providers to continue using their copper infrastructures—to leverage their technology investments—despite the fact that those infrastructures were never built for the IP-dominated world of communications today.

Current DSL backhaul networks were implemented more than a decade ago based on SONET/SDH/ATM architectures. They now struggle to cope with the demands of new applications, and to meet expectations of Quality of Service (QoS) in a multimedia environment. They're being pushed ever closer to the brink of obsolescence by four powerful forces of change:

1. New high-speed DSL standards such as ADSL2+, VDSL, and VDSL2, whose requirements aging transport technologies can't fulfill.
2. Standard and high-definition video, IPTV, and other bandwidth-hungry applications that push existing DSL backhaul networks to—if not beyond—their limits.
3. Faster, more reliable IP-based transport modes that are displacing the traditional methodologies on which today's DSL backhaul networks are based, such as ATM, TDM, and SONET/SDH.
4. Rising QoS expectations for video and high-speed data services, which cannot be met by the latency or resiliency characteristics of present-day DSL backhaul networks.

Clearly, the time has come for operators to upgrade their backhaul infrastructures. But how, exactly? Three options have emerged as contenders: Ethernet over SONET/SDH; Ethernet over fiber; and Ethernet over WDM. This paper examines the relative strengths of each in light of present and future realities and concludes that of the alternatives Edge-optimized Ethernet over WDM is the best-rounded and answers the full range of DSL backhaul needs.

Backhaul Backgrounder
A component of the transport network sometimes referred to as "the second mile," backhaul is the first network leg upstream of the DSLAM. It interconnects remote DSLAM devices in cabinets, huts or small central offices (COs) to the metro backbone network; its traffic flows on fiber-based bandwidth.

Transport from the DSLAM to the service aggregation point in the Metro Core (the BRAS or broadband network gateway) is invariably implemented in multiple stages. The metro backbone, typically a fiber ring, then transports the traffic to the primary metro CO, which contains service routers, video servers and other such equipment.

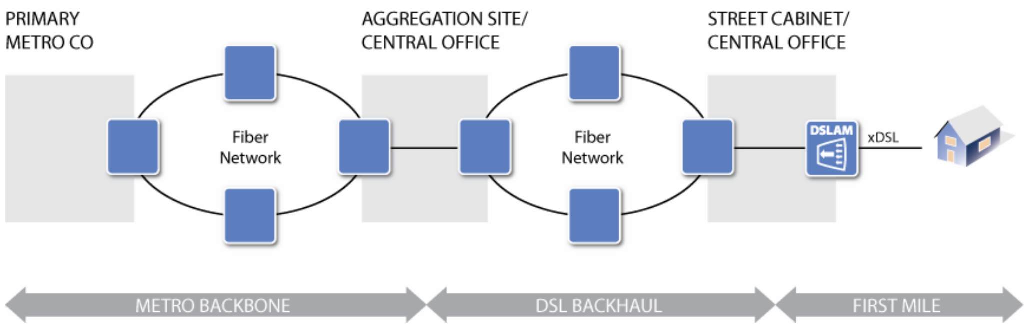


FIGURE 1: DSL BACKHAUL

PART 1: THE DRIVERS OF CHANGE

Starting with Standards

In the late 1990s, DSL deployments were geared toward delivering basic voice and Internet services. ADSL was the reigning standard, with typical capacities of 1.5Mb/s downstream and 128kb/s upstream that were perfectly adequate at the time.

Things have changed. Bandwidth demands are rocketing upward, fuelled by file sharing, multimedia applications and sites like YouTube. New standards such as ADSL2+, VDSL and VDSL2 have emerged to support 'fat traffic' over legacy copperline infrastructures. The table below shows the evolution of DSL-related standards and just how radically the requirements have changed. VDSL2, with more than 50Mb/s capacity for downloads, is now the preferred technology for new and upgraded DSL networks.

While the new standards deliver more bandwidth than their predecessors, there's a cost. As capacity pushes higher, the distances copper can reach get shorter and DSLAMs have to be deployed farther out in the network to compensate. DSL backhaul networks are in a position of having to extend their reach. At the same time, they must contend with the restrictive physical conditions imposed by cabinets, huts, and small offices at the perimeter of the metro network. Space, power, cooling and environmental factors are all critical to the design of good backhaul solutions.

Family	ITU	Name	Ratified	Max. Speed
ADSL	G.992.1	g.dmt	1999	7Mb/s downstream 800 kb/s upstream
ADSL2	G.992.3	G.dmt.bis	2002	8Mb/s downstream 1 Mb/s upstream
ADSL2+	G.992.5	ADSL2+	2003	24Mb/s downstream 1Mb/s upstream
VDSL	G.993.1	Very high data rate DSL	2004	55Mb/s downstream 15Mb/s upstream
VDSL2 – 12MHz	G.993.2	Very high data rate DSL2	2005	55Mb/s downstream 30Mb/s upstream
VDSL2 – 30MHz	G.993.2	Very high data rate DSL2	2005	100Mb/s downstream 100Mb/s upstream

Bandwidth Demands and their Implications

When it comes to bandwidth, video changes everything. Or, to put it more inclusively, *multimedia* changes everything, with video really the main driver. Web-based TV, networked video games and digital music are rapidly displacing traditional sources of entertainment. Service providers are deploying IPTV offerings to compete with cable operators. It's inescapable: DSL infrastructures have to be able to support video. Today's bandwidth requirements are 10 times greater than those when existing DSL backhaul networks were engineered. A single DSLAM serving 1,000 customers can easily require more than 800Mb/s to deliver a standard triple-play offering of voice, data and video services—nearly a full Gigabit. Yesterday's DSL backhaul simply can't keep up.

Going IP

Service providers are quickly transitioning their networks from traditional TDM and ATM to IP/Ethernet methodologies. IP/MPLS has replaced ATM as the preferred architecture at the core due to its scalability, economy, and service-rich capabilities. At the metro edge, carrier-based Ethernet is displacing PDH and SONET/SDH services and transport.

The DSLAM has not gone untouched by this trend. At the end of 2006, 48.5 percent of all DSL port shipments were IP/Ethernet based. Rather than an ATM OC-3, the physical network interface is now one or more low-cost GbE ports. Customer and service segmentation are realized via Ethernet LANs.

These changes are necessary for DSL backhaul networks to 'keep up' with the demands placed upon them. ATM-based solutions cannot scale adequately to support local GbE connectivity. Neither can they match the service flexibility or cost-effectiveness of IP/Ethernet networks.

Meeting Latency and Resiliency Requirements

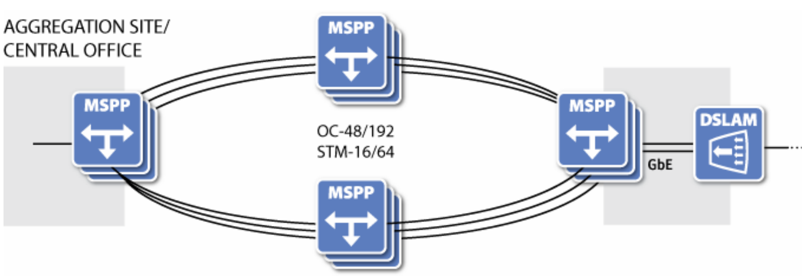
Beyond bandwidth, new multimedia applications impose stringent latency and resiliency requirements. Compressed video, for example, is extremely susceptible to data loss. A single dropped packet can cause several seconds of lost video service to the end customer, who is expecting a seamless viewing experience. Frequent packet losses will erode QoS to below acceptable levels, with the end result that providers will lose customers. In a competitive era when churn is already high and retention is a prized objective, this is decidedly unsuitable.

New backhaul solutions must be rugged, reliable, and resilient while at the same time minimizing latency. And they need to provide instantaneous network restoration in the event of a fiber cut or other failure. Like poor QoS due to packet loss, network disruptions and downtime can be the kiss of death for service providers.

PART 2: THE OPTIONS FOR NEXT-GEN DSL BACKHAUL

Ethernet over SONET/SDH, Ethernet over fiber, and Ethernet over WDM are the three leading solutions proposed to meet the needs of the next generation of DSL backhaul networks. While each has its advantages, two of the methodologies also have some technical and business deficiencies that operators ought to appreciate before adopting either.

Ethernet over SONET/SDH



Sticking with SONET/SDH affords operators an elegant, non-disruptive migration path—and provides a single technology platform to support both ATM-based DSLAMs and new-generation IP devices. For these reasons, Ethernet over SONET/SDH is widely considered to be the natural next step for their SONET/SDH-based DSL backhaul networks, and solutions using the Generic Framing Procedure (GFP) are now both mature and widely available.

A further advantage of SONET/SDH networking is its resiliency. SONET/SDH devices are designed expressly for the carrier environment, architected for 99.999% availability. Through

UPSR and BLSR topologies, SONET/SDH systems provide 50msec line protection against fiber cuts. They also have extensive embedded performance-monitoring capabilities for rapid fault isolation.

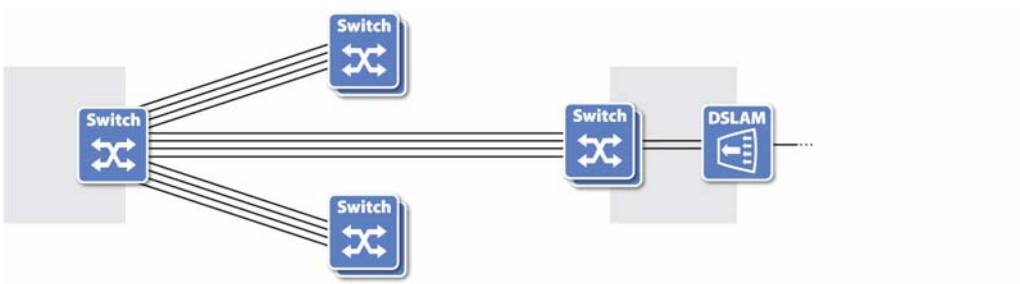
Scalability, however, is a major challenge for Ethernet over SONET/SDH: saturation occurs rapidly in backhaul handling so-called 'full-fill' GbE. This line-capacity limitation requires the stacking of multiple rings. Fiber is quickly exhausted, and stacked chassis at remote locations and in co-located environments can also consume excessive space and power on the rack.

The actual ease of migration to Ethernet over SONET/SDH will vary from operator to operator, determined in particular by the vintage of existing equipment. In some cases, it will simply be a matter of swapping out a tributary card. In others, large quantities of equipment may need replacement.

Ethernet over SONET/SDH

Advantages	**Disadvantages**
Seamless legacy integration	Limited scalability: 2.5G or 10G line rate
Sub 50ms protection against fiber cuts	May need 'forklift' for Ethernet upgrade
Mature, carrier-grade technology	Stacked chassis may exceed space and power restrictions

Ethernet over Fiber



Ethernet over Fiber is the simplest approach in which GbE signals from new IP-DLSAM devices are overlaid across dedicated fiber directly back to the aggregation switch. The IP-DSLAMs are deployed in a star configuration around the Ethernet switch, with a physical ring topology used for the supporting fiber.

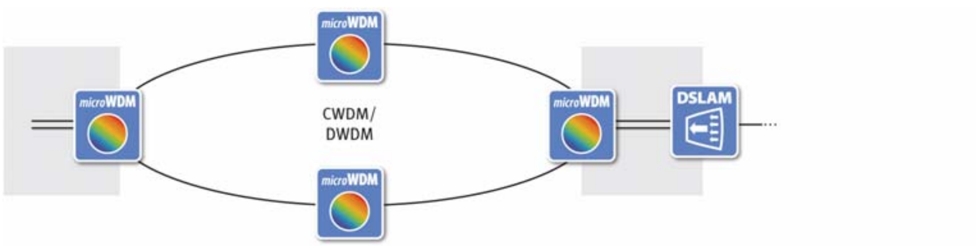
Ethernet over fiber seems at first to present a good low-cost option, but it's attended by the very real danger of rapid fiber capacity depletion—because every GbE connection requires a separate fiber pair. It also suffers from poor resiliency, which is typically derived from redundant fiber routing, with restoration realized via Layer 2/3 protection schemes. Yet using common 802.3ad Link Aggregation and RSTP/MSTP techniques, restoration may take a couple of seconds or longer—durations that are in no way acceptable for video applications.

Ethernet over fiber backhaul can be effective when deployed in scenarios where fiber is abundant and the number of subscribers is limited. In such cases, the risk of outage is marginally acceptable. Yet for large-scale, growth-oriented DSL backhaul deployments, its limitations are significant.

Ethernet over fiber

Advantages	**Disadvantages**
Simple to deploy	Rapid fiber exhaust
Low cost	Slow restoration
	Low availability
	No legacy integration

Ethernet over WDM



BTI's *micro*WDM achieves the scalability of CWDM and DWDM within compact, low-power, physical systems. Available in an environmentally harden version and engineered for deployment in outside plant cabinets and huts, BTI's *micro*WDM solution is ideal for DSL Ethernet over WDM backhaul applications.

BTI's product line provides high and low density, feature rich edge systems which are one or two rack units in size. The product family shares a common suite of BTI functional modules and operates—on average—at less than 100 watts power consumption.

Scalability is a key differentiator. *micro*WDM solutions can expand to 32 wavelengths on a single fiber pair. At up to 10Gb/s *per wavelength*, that amounts to a total system capacity of 320Gb/s, more than 100 times that of an OC-48/STM-16 SONET/SDH ring.

BTI's *micro*WDM solution also offers carrier-grade resiliency. Integrating SONET/SDH UPSR/SNCP protection on client transponder modules, *micro*WDM achieves sub-50ms restoration in the event of a fiber outage.

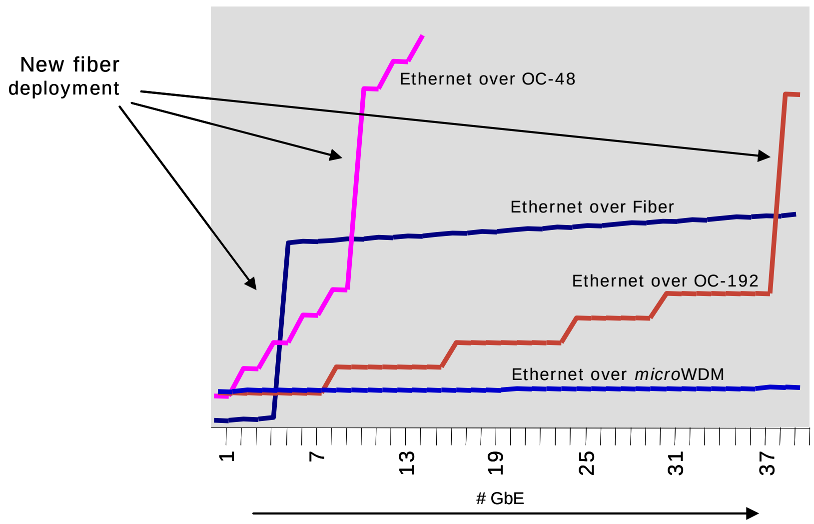
Ethernet over *micro*WDM

Advantages	**Disadvantages**
Highly scalable	Not optimized for low-rate services (example: copper, PDH)
Sub-50ms protection against fiber cuts	
Carrier-grade	
Suitable size, power, and cost for optical edge	
Hardened for extended temperature deployments	

PART 3: COMPARING THE COSTS

Network operators are understandably concerned about containing the capital cost of upgrading the network. A fair measure is to assess the capital expense (CAPEX) in relation to the bandwidth gained. A typical metro network deployment provides a good basis for comparison, with a four-node ring and with all DSL traffic hubbed back to a single aggregation site over a 12-pair fiber cable. Traffic growth is assumed to be linear and spread evenly across each site, and all new DSLAMs are presumed to be GbE-based.

As the graph below shows, Ethernet over SONET/SDH solutions rapidly consume their capacity as the network scales. Upgrades to 10G line-rate systems can delay fiber exhaust, but the cost can be prohibitive if the network grows beyond 2GbE per site. Additional fiber must be deployed (at considerable cost). Similar capacity issues arise, as described in the previous sections of this paper, with Ethernet over fiber solutions. *micro*WDM, on the other hand, scales in an almost perfectly linear fashion, clearly presenting the most cost-effective option when CAPEX is weighed against bandwidth.



PART 4: SUMMING IT UP

Ethernet over SONET/SDH is an attractive, short-term solution for upgrading SONET/SDH-based DSL backhaul networks due to its seamless architectural continuity, yet ultimately does not provide the scalability required for GbE growth. Ethernet over fiber can be quite effective in limited overlay deployments where video services are not required or where the number of subscribers is (and will remain) low enough that scalability is not an issue. Yet for high-growth, triple-play situations, it has neither the capacity to scale nor the resiliency to deliver acceptable QoS.

Of the three, *micro*WDM offers the most compelling alternative. With its WDM-based scalability it can grow easily to keep pace with future network deployments. With its carrier-grade resiliency, it delivers the network restoration required to support new video and multimedia services—answering today the demands that tomorrow's DSL backhaul networks will face.

About BTI Systems

BTI Systems helps service providers respond rapidly and cost-effectively to the skyrocketing demand for bandwidth in today's gigabit world. Our Netstender™ platform—the industry's first *micro*WDM system with an open photonic-layer architecture—extends high-bandwidth transport services to the metro network's edge. By consolidating key transport capabilities (DWDM/CWDM, optical multiplexing, amplification, dispersion compensation and wavelength translation) within a single network element, Netstender delivers industry-leading capital and operational savings while future-proofing networking capabilities. Addressing the needs for fiber relief and reach extension—and enabling 10G, 1G, and metro Ethernet service overlays—Netstender allows carriers to deliver gigabit services economically while dramatically increasing their overall market footprint. For more information, visit www.btisystems.com