Communications Services Solutions

White Paper

Unlocking Business Opportunities in the Metro Market

by Allan Sturgeon and Gordon Message: September 2002

Agilent Technologies

Contents

The metro market landscape

The Metropolitan Area Network (MAN) is one of the few promising markets in the depressed current state of the telecommunications business. For the short term at least, the future seems to be metro rather than long-haul. During the "gold-rush" years of 1999 and 2000, long-haul capacity was expanded massively. A recent estimate by analysts at market research firm Ryan Hankin Kent (RHK) put current long-haul capacity utilization in North America at about 35%. The focus is now on metro as this is where the bandwidth bottlenecks exist, limiting the revenue potential of the high-capacity long-haul network and slowing the development of new revenue-generating services.

The bandwidth and data processing capability of enterprise LANs often exceeds the capacity of access to and throughput of the metro networks providing the WAN service. These also often lack the necessary flexibility to meet enterprise requirements. Even the on-line performance of the ubiquitous home PC is usually limited by network speed. In several countries there are plans for large-scale broadband Internet access, and as more users switch to ADSL, cable modems and eventually Ethernet in the First Mile (EFM), the pressure on bottlenecks in the MAN between access and core networks will increase. For many service providers, the MAN is becoming the point of service delivery and the key to profitability.

The metro market also presents interesting new opportunities for data traffic staying entirely within the metropolitan area. In 1998 only 20 percent of IP [DH1]traffic stayed in the metro network[1], with 80 percent in the core, while by 2005 the prediction is that 90 percent will stay in the metro. Typical applications are Storage Area Networks (SANs), Virtual Private Networks (VPNs) and Internet caching. In these emerging growth opportunities, reducing the cost per transmitted bit is paramount - although Internet traffic is still growing at 80 to 100 percent per year, according to RHK, revenue has only been growing at 17 percent while the equivalent cost per bit has declined by 45 percent.

However, the metro market is not immune to the contraction in telecom spending. In a recent report from RHK[2], analysts estimated that the North American metro equipment market has declined 50 percent to around $4 billion from its peak in 2000, with growth resuming after 2003. Metro DWDM transport equipment sales have held up well at around $600 million, in stark contrast to the fall in the long-haul DWDM market, while next-generation SONET/SDH products show sustained growth as service providers demand better functionality and lower cost.

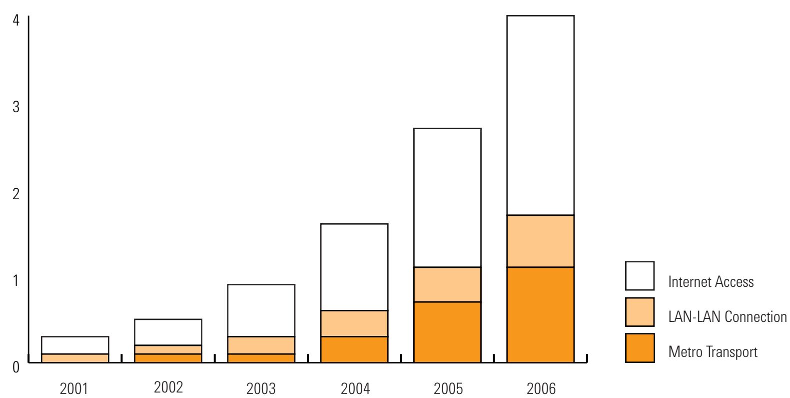
Another forecast, by Infonetics Research, showed that the closer the equipment is to the customer, the more sales it generates - growth of 15 percent for metro in a recent quarter versus a decline of 30 percent for long-haul. Metro edge equipment is forecast to grow from $1.7 billion in 2002 to $6.5 billion in 2005.

While Metro is important, the real buzz is Ethernet. Customers have high expectations that the economies of Ethernet in the LAN will be mirrored in the WAN. In the USA, metro Ethernet service is being sold 50 to 75%[3] cheaper than comparable SONET-based services, such as frame relay. Some industry experts are using an eight to one (8:1) rule of thumb: on average a new SONET/SDH installation in the metro would cost eight times as much as a new Ethernet MAN (E-MAN) installation. The comparison between Internet access via SONET and E-MAN in the USA, given in the table below, illustrates the potential for low service cost with Ethernet technology:

Internet access with SONET	T1 Circuit (1.5 Mb/s) @ $1,200/month	$800 per Mb/s per month
	T3 Circuit (45 Mb/s) @ $25,000/month	$555 per Mb/s per month
Internet access with E-MAN	100 Mb/s @ $1,000/month	$10 per Mb/s per month
	1 Gb/s @ $10,000/month	$10 per Mb/s per month

According to Pioneer Consulting, global Ethernet service provider revenues are forecast to grow from $217m in 2001 to $14B in 2005[4]. A recent forecast from RHK for North American Ethernet service provider revenues shows a similar growth profile:

North American Ethernet SP Revenues ($ billion)



To win in these growth metro markets, service providers need to satisfy a number of emerging customer expectations:

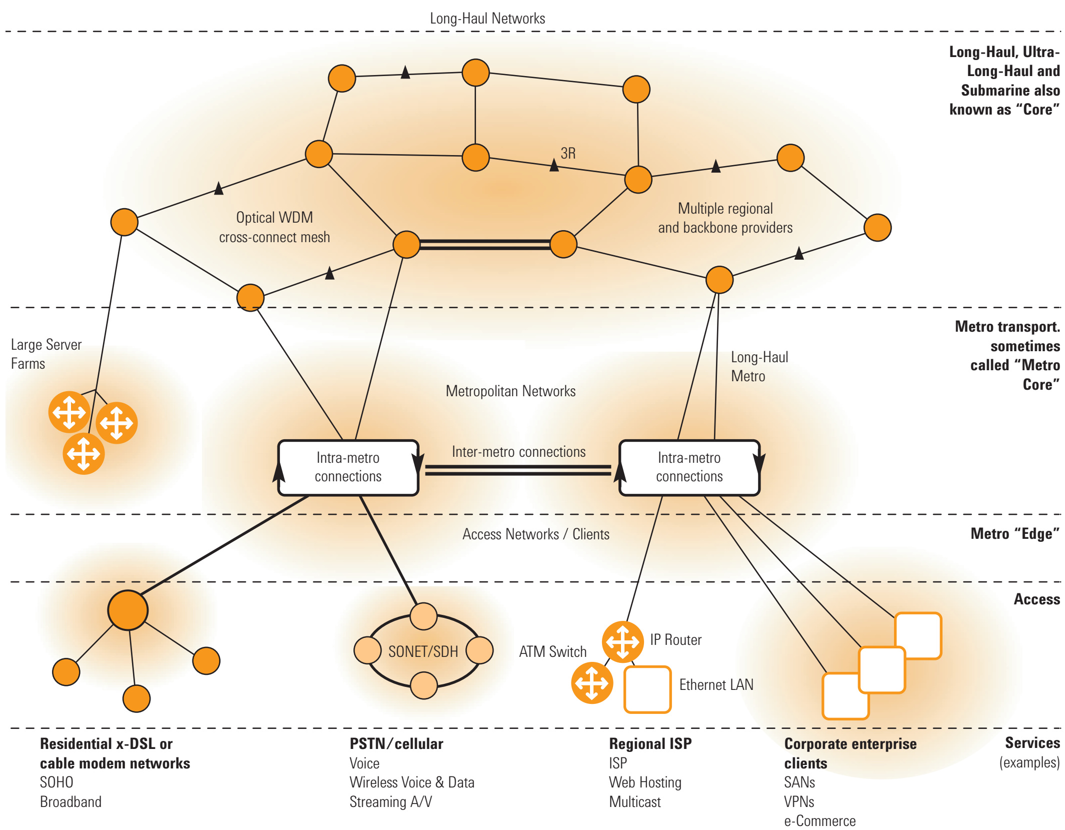
- Flexible service in terms of bandwidth provisioning, grade of performance (QoS and resilience) and ideally metered billing so they only pay for what they use.
- Ability to connect to the WAN using simple, inexpensive and ubiquitous Ethernet interface without additional equipment, to realise transparent LAN interconnection and reduction in unit costs.
- Opportunity to use data warehousing (offsite storage), web hosting, IP-VPNs and other outsourced IT services including integrated voice and data to reduce management costs.

In this paper we'll look at the emerging metro architectures designed to satisfy these customer expectations, particularly in the Ethernet arena, and investigate the challenges of installing and maintaining these next generation metro networks. The paper reviews QoS and deployment issues at multiple layers of the protocol stack, with more detailed discussion on lower layer transport-related performance criteria and test methodologies.

Metro architectures and protocol stack developments

The hypothetical network of Figure 1 shows the broad range of customer services converging in metro networks. A portion of this traffic transfers to the high-capacity core network that uses either a mesh or ring architecture.

Figure 1: Overall Network Diagram



Metro networks often divide into metro-edge (the collector/aggregation segment) and metro-core (the higher capacity segment where bandwidth management occurs). The metro-edge network interfaces to a wide range of access technologies (ADSL, T1/E1, SONET/SDH, 10/100E, GigE), while the metro-core network operates with high-bandwidth interfaces and DWDM optics, usually with 10 Gb/s per wavelength interconnecting to the 10 Gb/s core network. Today, most metro networks use SONET/SDH rings for aggregation, bandwidth management and protection.

Legacy SONET/SDH networks were optimized for fixed-bandwidth voice and TDM services such as digital leased line (T1/E1, DS3, E3). Ring protection schemes react in less than 50 ms, and achieve very high survivability through reserved protection bandwidth. Customers and service providers are very confident with familiar SONET/SDH networks, but particularly in metro applications SONET/SDH is inefficient in handling the varying bandwidth requirements of data. All this means that the cost per bit is far higher than a native Ethernet network using statistical multiplexing.

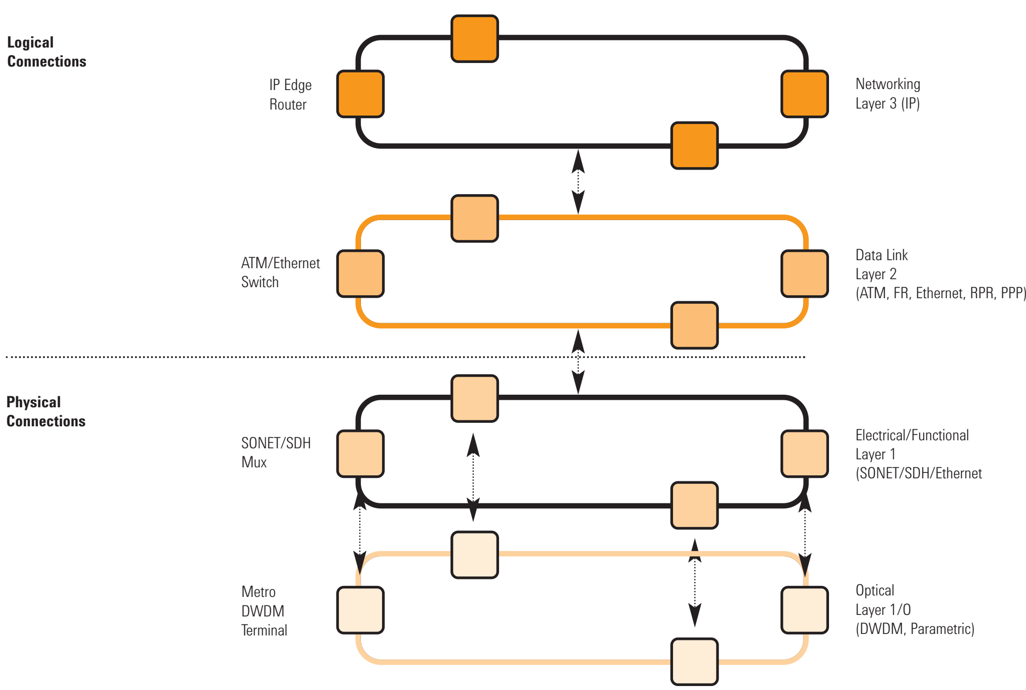
To take advantage of the large installed base and the high reliability and manageability of SONET/SDH, various schemes have been developed in the next generation of equipment to make SONET/SDH more data friendly. Apart from proprietary solutions, the ITU and ANSI standards committees have been developing industry standards to enhance SONET/SDH and give it a bandwidth efficiency closer to the statistical multiplexing of a data switch network. Of course, being a TDM-based solution it provides bandwidth guarantees, avoiding the bandwidth contention and congestion problems of a packet switched network, but with lower bandwidth efficiency. This compromise is attractive to many service providers who would like to retain the QoS of legacy networks.
The standards-based scheme for Data over SONET/SDH (DoS) consists of three elements:

- Virtual Concatenation (VC), which provides a more flexible channel bandwidth allocation (usually multiples of 1.5 Mb/s) to more closely match the data channel than the payload bandwidth increments of legacy STS-1/3/12 (STM-0/1/4).
- Link Capacity Adjustment Scheme (LCAS), which provides end-to-end signalling for dynamic adjustment of capacity using VC.
- Generic Framing Procedure (GFP), which provides a simple encapsulation method for frame-based data traffic (Ethernet, IP/PPP, RPR, Fiber Channel, ESCON etc.) over the TDM transport path that could be SONET/SDH or the OTN.

More detailed discussion on these new standards is available in Reference 2.

Most attention has focused on next-generation SONET/SDH equipment (sometimes referred to as Optical Edge Devices (OEDs) and Multi-Service Provisioning Platforms MSPPs)), but the MAN is also a multi-layer network with several options at the physical and logical level. This multilayer structure is shown in Figure 2.

Figure 2: Layered model of metro network



Each of these layers can be used as a convergence layer for aggregation of traffic and bandwidth management, depending on the type of service being offered to customers and the granularity of bandwidth management. In general, packet processing at Layers 2 and 3 creates logical connections through MAC addresses, VLAN tags or Multi-Protocol Label Switching (MPLS) labels, although this is now also possible with coarser granularity in the functional and optical layer when an MPLS or similar control plane is implemented.

Today however, most metro networks operate with a separate physical layer infrastructure based on SONET/SDH rings (possibly operating over metro DWDM) which support a network of data switches, most commonly frame relay or ATM. With growing interest in direct Ethernet services, the layered boundaries are blurring, and new SONET/SDH equipment may well provide Ethernet tributary interfaces and in some case layer 2 switching and statistical multiplexing of customer traffic.

These metro developments are summarized in Table 1. At each protocol layer, the service provider can offer a range of services depending on the capability of the network equipment. Some examples are shown in the table, along with the accompanying performance issues. These become more complex as the services become more content-based and application specific.

Table 1: Metro developments by protocol layer

Protocol Layer	Technical Developments	Possible Service Opportunities	Performance Issues
Optical Layer 1/0	OTN standards (ITU-T G.709) Hot-swappable transceivers Lower cost DWDM components Banded optics, OADM GMPLS control plane	Wavelength service SAN services (Optical Ethernet service)	Optical QoS on wavelength service Can fiber characteristics support 10 Gb/s and later 40 Gb/s? BER $<10^{-12}$ for SAN
Electrical /Functional Layer 1	GFP standard (ITU-T G.7041) Virtual Concatenation LCAS 10GbE Next-generation SONET/SDH GMPLS[5] control plane	Native Ethernet Private Line GbE service Bandwidth on demand Bandwidth wholesaling Support for ESCON/FICON etc.	Inter-working for virtual concatenation standards Meeting leased line SLAs Inter-working with customer Ethernet services BER $<10^{-12}$ for SAN
Data Link Layer 2	Ethernet VLAN tag (802.1p/q) Rapid spanning tree (802.1w) Carrier-class Ethernet switches Resilient Packet Ring (RPR) Layer 2 restoration (MEF[6]) 10GbE	Native Ethernet Private Network Transparent LAN Service (TLS) Differentiated services Programmable bandwidth from 1 Mb/s to 1 Gb/s in 1 Mb/s increments or less. Metered billing Network connected outsourced services.	Differentiated service guarantees Reliable forwarding by VLAN tag and ToS field. Stat mux performance under heavy traffic load.
Networking Layer 3	IP VPN standards MPLS standards QoS mechanisms IPv6 Multi-service edge routers	IP-VPNs VoIP service Integrated voice/data Internet access Data warehousing Differentiated services Application-based QoS	VoIP voice quality IP-VPN security IP VPN SLAs Performance guarantees under traffic load.

Restoration and QoS options

Most metro networks rely on Layer 1 SONET/SDH or fiber ring protection to provide a high level of survivability, albeit at the price of stranded protection bandwidth. This underpins most SLAs in terms of "five nines" availability and guaranteed error performance. Service providers are understandably reluctant to move away from these high standards, particularly when they carry significant amounts of legacy traffic. On the other hand, if the traffic is predominantly data, with perhaps a peak to average ratio of 5:1 or 10:1, it doesn't always make sense to have so much protection bandwidth out of service all the time. Not everyone wants premium service; a lower grade of service can be attractive if the price is right.

An option is to provide the protection or restoration at Layer 2 or 3, and use all the transport facilities all the time but with lower occupancy. The service provider can in theory offer a variety of services from fully protected to unprotected by setting the appropriate priority bits in the packet headers. Similarly, high grade traffic can be given precedence while other traffic can be pre-empted when congestion or failure occurs.

Layer 2 mechanisms for implementing this strategy include MPLS protection paths (either predefined or set up on demand), Resilient Packet Ring (RPR, IEEE 802.17) and restoration schemes based on the Ethernet MAC such as rapid spanning tree (802.1w) and the proposals of the Metro Ethernet Forum (MEF). With the possible exception of RPR, none currently matches the speed of SONET/SDH protection so there is a trade off between cost and performance, as summarized in Table 2.

Table 2: Restoration and QoS options

Restoration Layer	Advantages	Disadvantages
Facilities Protection Optical/Functional Layer Layer 1	Very fast (<50 ms). Guaranteed availability and error performance for all services. Self-contained, not network wide. Bandwidth guarantee. Tried and tested. Fully standardized.	Higher costs. Stranded bandwidth for protection. Inefficient bandwidth use. No differentiated service. Only protects transmission facility, not switch/router line card failure.
Service Restoration Data Link Layer Layer 2/3	Lower costs. Service related restoration. Differentiated service options. Stat-muxing and pre-emption give bandwidth efficiency. Protects against line card failure in switch.	Some schemes may not operate fast enough (seconds rather milliseconds). Possible network instability. Performance compromised under heavy traffic load. Difficult to guarantee performance and reassure customers. So far not widely tested. Standards (MPLS, RPR) still being developed.

Ethernet - evolution or revolution?

Ethernet is the de facto standard in enterprise networks and its widespread deployment (over 350 million Ethernet ports are in use today) has the potential for lower cost because of the economies of scale in manufacture and R&D. Native Ethernet in the MAN and WAN eliminates equipment and protocol conversions, saving on both Capex and Opex costs, particularly as Ethernet switches allow very quick and flexible provisioning of service bandwidth and bandwidth profile parameters. If Ethernet networks could provide "carrier class" performance today, there probably would be a revolution! Ethernet in the MAN is a potentially disruptive technology.

The pure Ethernet over DWDM network, sometimes referred to as Optical Ethernet, still requires further development to get it to "carrier class", although some networks have already been built using high-performance Ethernet switches incorporating optical transceivers to operate directly over dark fiber (unserviced [DH3]fiber path). In these networks, Ethernet is used both as a switching and transport protocol.

New developments could make Optical Ethernet a powerful contender for the MAN in the next couple of years. Maturing RPR and MPLS protocol standards would provide the restoration algorithms, and the recently ratified 10 GbE physical layer standard is an ideal interface to the DWDM optical network. Already component manufacturers have produced hot-swappable transceivers using direct-modulation lasers that promise much lower cost and operate satisfactorily over inter-nodal metro distances. As these technologies mature, Optical Ethernet could set new expectations for cost per bit in the metro market for both Capex and Opex. The MEF white paper (Reference 3), describes work going on to make Optical Ethernet "carrier class".

In 2002, many service providers have been rolling out new Ethernet services including private line, switched network services and transparent LAN interconnection. Most of these are implemented using Ethernet over SONET/SDH (EoS), allowing the new service to run alongside the legacy leased line and voice services that generate most of the revenue. This is the evolutionary approach, and is clearly lower risk, allowing the service provider to guarantee performance using the proven capabilities of SONET/SDH. From an operations viewpoint, there are advantages too, as staff are familiar with SONET/SDH and can build on existing expertise. In a recent report from RHK, metro Ethernet port revenues are forecast to grow from $150M in 2002 to $800M in 2006, with a 57 percent share for the EoS application even in 2006. As the market for Ethernet and SAN services expands, some wavelengths in the metro DWDM system could be allocated exclusively to the new services, and use native Ethernet transport.

Next generation SONET/SDH multiplexers have smaller footprints, much better scalability and flexibility and, using new capabilities such as virtual concatenation and LCAS mentioned earlier, can get closer to the bandwidth efficiency and programmability of Ethernet switches. Proponents of the EoS approach also point to progressively higher levels of integration in chip design, and recently Agilent Semiconductor Products Group along with other component manufacturers announced 10 Gb/s hot-swappable transceivers suitable for SONET/SDH, available in 2003. More convergence on the costs of EoS and Optical Ethernet is probable over the next few years.

Given the predominance of Ethernet over SONET/SDH at the present time, the remainder of this paper focuses on the deployment issues for next-generation SONET/SDH and the underlying metro DWDM system. The latter would of course be applicable in the Optical Ethernet scenario, where the DWDM system itself could provide ring protection against fiber breaks.

Developing business, improving productivity and cutting costs

To unlock the business opportunities in the metro market, service providers need to focus on several aspects including:

- Providing new value-added and differentiated services that satisfy customer needs in IT and outsourcing.
- Offering faster provisioning of services and responsiveness to customers' changing requirements and problems.
- Migrating seamlessly from existing TDM services to new-age data services.
- Finding ways to substantially reduce unit costs, particularly for new broadband services.
- Improving productivity of skilled staff, and keep training costs down.

In general, service velocity (both physical provisioning and turning-up service to customers) is the key differentiator.

Each service provider decides what range of services to offer in the metro market and this determines the type of network and equipment they install (see Table 1). A network with fewer protocol layers and less equipment is potentially cheaper, however if its protection is less secure, which puts more pressure on the troubleshooting teams when failures occur. In general, network resilience is a function of how much spare bandwidth is available. An over-provisioned network such as SONET/SDH or a lightly-loaded packet network might be able to sustain more than one simultaneous failure without significant performance degradation. On the other hand, an Ethernet network relying on statistical multiplexing and over-subscription to provide economical operation is more susceptible to soft failures, such as QoS degradation across the whole network, if just one part is malfunctioning.

If the service provider already offers legacy voice and leased line data services, then finding the best way of migrating to next-generation services within the existing architecture is a priority from both a Capex and Opex perspective. Ideally, the installation and maintenance procedures should be a logical extension of current practice, rather than a big upheaval requiring much staff retraining.

For example, testing the new Ethernet services is easier if it is integrated within a familiar SONET/SDH transmission test set, rather than requiring an additional unfamiliar protocol analyzer. This is Agilent's approach, by offering a multi-port Ethernet (10/100 and GigE) test capability in their SONET/SDH transmission testers. Making measurements such as frame loss, latency and throughout on an Ethernet network is more complex since the frames must have the right MAC addresses and the correct Frame Checksum (FCS) or they are dropped by the switch, making the measurement results meaningless. For most Ethernet equipment (unless it is completely transparent), a bit error is not propagated and so conventional Bit Error Rate (BER) measurements familiar in SONET/SDH are not possible. Hence the need for a new set of performance criteria. Fortunately, in line with Agilent's strategy of delivering tools that deliver extreme productivity improvements (XPI), such results are available with minimal extra effort, and most of this complexity can be hidden by an Agilent test set using automatic routines. This way staff find it easy to migrate from pure SONET/SDH to Ethernet services on the network, and the roll out of new services is achieved with the lowest possible strain on resources to simplify guaranteeing the necessary ROI.

Such test tools satisfy many installation and maintenance tasks in new Ethernet networks. However for more complex application and service-related issues (for example Voice over IP and media streaming), Agilent also offers protocol analyzers, such as the Network Analyzer and Agilent Advisor, that can provide fast results at different levels of detail, with the minimum of incremental training. Again the goal is to increase productivity by using tools that allow engineers and technicians to apply their level of expertise to get meaningful results so they can concentrate on resolving issues. Even though service offerings are becoming more complex, service providers need such aids if they are to reduce the time-to-service and time-to-repair. Distributed test systems and dispatch test tools must be designed to improve productivity, simplify procedures and reduce the number of return visits to network sites and customer premises.

Focusing on the optical network infrastructure and next-generation SONET/SDH equipment discussed earlier, the typical measurement requirements are shown in Table 3:

Table 3: Metro test requirements

Protocol Layer	Performance Issues	Typical Test for I&M	Agilent Test Solution
Optical Layer 1/0	What is optical QoS on wavelength service Can fiber characteristics support 10 Gb/s and later 40 Gb/s? BER <10-12 for SAN	Check fiber meets minimum specification for loss and reflections. Check DWDM channel power and wavelength. Check dispersion characteristics can support 10/40 Gb/s data rate.	N3900A Modular Network Tester
Electrical /Functional Layer 1	Inter-working for virtual concatenation standards Meeting leased line SLAs Inter-working with customer Multi-port Ethernet services BER <10-12 for SAN	Check system BER at line and multiple tributary interfaces. Identify and confirm path mappings and VC configuration.	J2126/7A 2.5/10 Gb/s Portable transmission testerwith multi-port Ethernet
Data Link Layer 2	Differentiated service guarantees Reliable forwarding by VLAN tag and ToS field. Stat mux performance under heavy traffic load.	Check customer service at 10/100 and GbE interfaces. Perform RFC 2544 compliance tests Check VLAN and ToS tagging.	J2126/7A 2.5/10 Gb/s Portable transmission testerwith multi-port Ethernet

Improved productivity is a combination of optimized work practices and the best test tools that keep things simple through automated routines and by providing all the required capability in a single instrument. Often there is a need to repeat measurements on multiple ports or multiple channels within a single port. The ability to make automated parallel measurements saves a great deal of time, and indeed because of the Layer 2 frame requirements referred to earlier, it is essential to provide multi-port operation for Ethernet testing.

Agilent has a comprehensive range of dispatch and distributed test tools designed to help service providers cut time-to-service and time-to-repair. The emphasis is improved productivity - Agilent calls it eXtreme Productivity Improvement or XPI for short - aiming to substantially reduce costs and improve quality in the competitive MAN services market.

End game?

The metro market is full of promise for those service providers who can respond quickly to customer needs and meet the goals of reducing costs. The next three years will be an interesting period as different technologies and network architectures compete in the market place. Some, like DWDM and SONET/SDH, will continue to improve in terms of functionality and port density. Others, such as new Ethernet protocols and RPR, are still in standards development and have yet to be proved in wide-scale deployment. If they succeed, Optical Ethernet could yet prove to be the disruptive technology that rewrites the tariff book.

It is certain that bandwidth demand in metro will increase massively in the coming years, pointing to much greater use of optical transport and optical switching to meet bandwidth cost objectives. Customer traffic will be largely Ethernet, so nearly all metro equipment from DWDM terminals to packet switches will have Ethernet interfaces.

Every service provider's network requirements are different depending on existing networks and services, and which new services they plan to develop. However, the common goal is to keep costs and provisioning times down to a minimum and ensure technical staff operate with the highest productivity.

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[5] Generalized Multi-Protocol Label Switching

[6] Metro Ethernet Forum

Biographies

Gordon Message

Business Development Manager
Sales Development Operation
Agilent Technologies

Gordon Message is based in the UK and has responsibility for Agilent's Communications Service Solutions Optical Transport Program in Europe. This role combines marketing activity related to installation and maintenance with investigation into the dynamics of telecommunications customer's operational practices and equipment use models for service roll out and support.

Message joined Hewlett-Packard Test & Measurement (later Agilent Technologies) in 1983 and has held a number of support and field sales roles.

Prior to his current role, Message led Agilent's test equipment financing activity in the UK to provide customers with alternatives to direct capital purchases.

He holds a BSc in Electrical Engineering from University of Newcastle upon Tyne, is a Chartered Engineer and a Member of the Institution of Electrical Engineers. He has just completed an MBA with a dissertation that focuses on marketing aspects of the telecommunications industry.

Allan Sturgeon

Marketing Manager
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Allan Sturgeon was recently appointed Marketing Manager for the Transmission and Transport Test (TTT)Operation of Agilent Technologies based in South Queensferry, Scotland.

Prior to this role, Sturgeon was a product marketing manager responsible for building customer awareness for a portfolio of products focused on core transmission testing, and designed to address installation and maintenance applications.

Sturgeon originally joined Hewlett Packard's test and measurement arm, now Agilent, in 1982, as a product marketing engineer for telecom products. He held a number of sales management positions for more than six years for the Test and Measurement Group in several European locations, including Amsterdam and Russia. Sturgeon was also responsible for the telecom business in Eastern Europe, the Middle East and Africa.

Sturgeon began his career at the British Post Office, now British Telecom, designing stored process control systems.

He holds a BSc in Electrical Engineering from Edinburgh University.

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