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white paper

Full Service Broadband Metro Architecture

The metro network plays a key role in enabling residential, business and mobile users to access any broadband service anywhere, while delivering flexibility and efficiency for the network operator.

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Introduction

The metro network is a key part of the Full Service Broadband Architecture, transporting traffic between access and service nodes and also providing transport-based connectivity services in its own right. The metro network must be optimized for all geographical areas, from dense urban to sparse rural. To do this, the metro network faces three challenges:

The metro convergence challenge
– a single network to deliver all services

A standards-based metro architecture must scale to carry large numbers of residential, business and mobile services, each according to their service level agreements (SLAs) and be adaptable for current and future deployment scenarios.

The key carrier-grade packet layer technologies for the metro network are Ethernet and MPLS. Ethernet Provider Bridging and Provider Backbone Bridging meet the need for high-capacity aggregation in a switched metro network, while MPLS and MPLS-TP will be used to provide connections across a routed metro network to extend existing backbone IP/MPLS connectivity and VPLS services into the metro.

Complementing the packet layer, Optical Transport Network (OTN) and high-capacity wavelength division multiplexing (WDM) enhance resilience, boost fiber capacity and deliver high-speed business services directly to customer locations.

The metro flexibility challenge
– a network optimized for every situation

The metro network architecture must be adaptable for geographic reach, launch and unpredictable adoption of new services and increasing bandwidth – while providing deterministic performance for high-value services. This demands scalability in transport and switching with the optimized location of single, multiple or distributed service nodes.

The metro cost challenge
– a network with low cost of ownership

The metro must have a low total cost of ownership despite its high capacity, large distances and varied service mix. A converged metro network will reduce capital expenditure compared to separate service-specific networks, and operational costs can be lowered by using carrier-grade equipment in a resilient network design, enabling the right level of network automation and ensuring that Operations Administration and Management (OAM) tools align across the range of transport technologies in use.

Whichever connection-oriented packet technology is employed, a technology-agnostic control plane can be used to automate restoration and assist with connection provisioning in both packet and OTN / WDM layers.

By meeting these three challenges, the metro network plays a key role in enabling residential, business and mobile users to access any broadband service, anywhere. It delivers flexibility and efficiency for the network operator, enabling new services and customer types to be added more cost-effectively compared with service-specific networks.

Full Service Broadband in the Metro

The metro network is a key part of the Full Service Broadband Architecture, transporting traffic between access and service nodes and also providing transport connectivity services.

After years of talk about fixed–mobile convergence (FMC) and next generation networks (NGN), the technology has become available to enable fixed and mobile operators to take a major leap forward. They can now deploy an open, standards-based architecture that offers cost-effective evolution for new fixed and mobile Full Service Broadband opportunities.

Figure 1[1] shows the functions required by a service provider to deliver the full range of standard and IMS-enabled broadband services to mobile, residential and business users through both wireline and wireless access. The metro network's dual role is highlighted as part of the transport for the service delivery platforms as well as providing transport connectivity as a valuable service in its own right.

The metro network simultaneously supports several different business models: aggregated *retail* service delivery to residential and business customers; delivery of *wholesale* services on behalf of other service providers; *inter-carrier* services for use as backhaul or infrastructure links; and also *interconnect* and *peering* services.

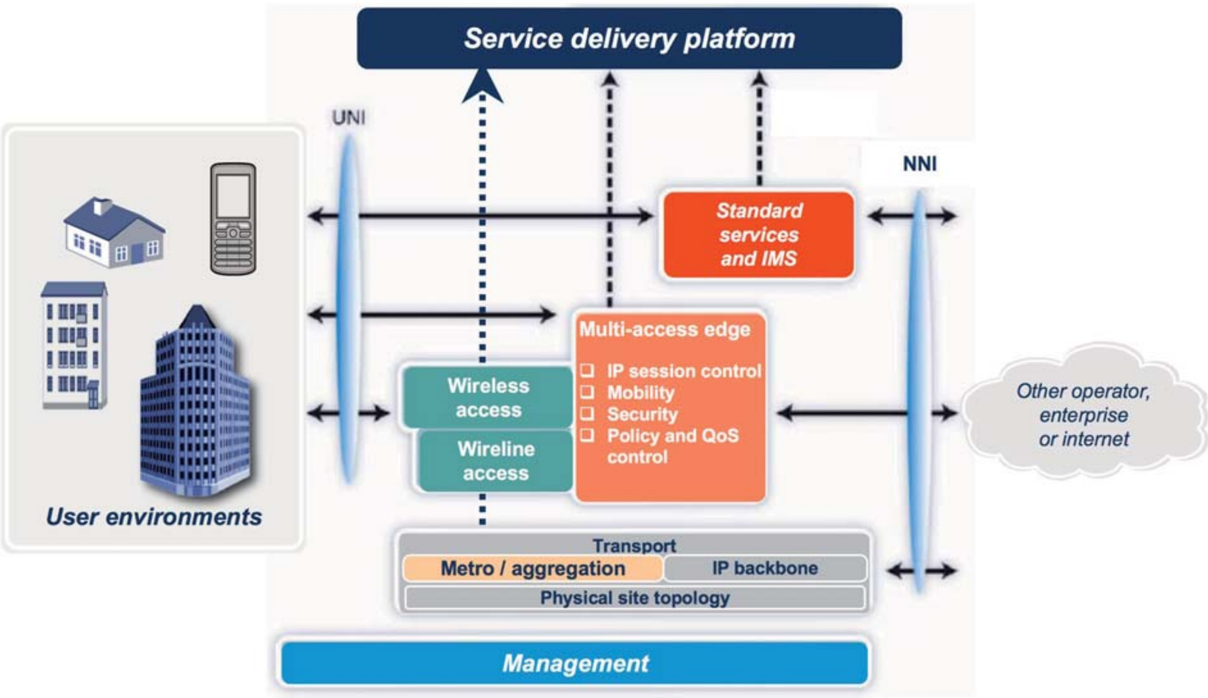

Figure 1: Full Service Broadband architecture

[1] *from the Ericsson Full Service Broadband Architecture white paper [2]*

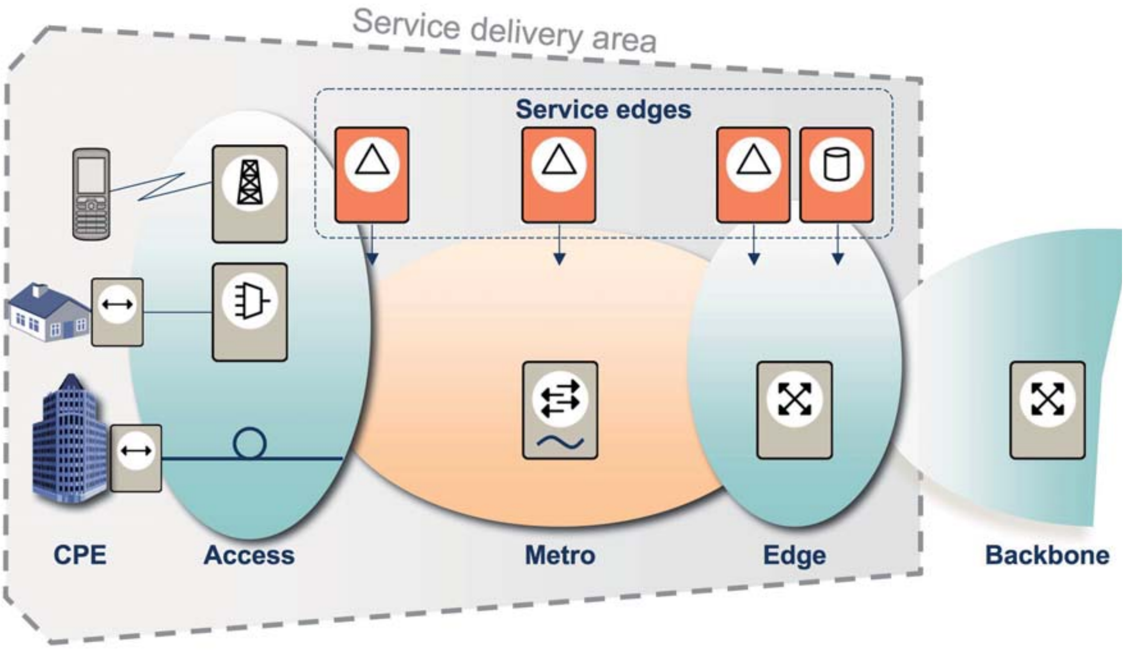

Figure 2: The metro context

Figure 2 illustrates the location of the metro network, connecting users through access systems to service edges. To optimize overall cost-effectiveness, service edge nodes can be placed independently of the transport topology, at the edge of the network backbone, or in intermediate buildings in the metro network.

Access functions and the metro

Access systems deliver mass-market services to residential and mobile users and also deliver higher bandwidth services to business customer sites.

For fixed services, access nodes support "first mile" technologies appropriate to the service and delivery scenario, including the various types of digital subscriber lines (DSL), fiber to the x (FTTx), meaning to the home/business/curb, etc., passive optical networks (PON), or fixed wireless systems. For mobile users, the access function is represented by radio base stations supporting second and third generation mobile systems and the developing mobile broadband technologies.

Service edges and the metro

Traffic for services such as IP Virtual Private Networks (IP-VPN) or those requiring access to media resources, the public internet or other application systems is transported by the metro network to and from "service edge" nodes – the physical realizations of the Full Service Broadband "Multi-Access Edge" functionality.

Service edge nodes can be flexibly located to provide the performance and resilience required by each service, close to the access nodes or centralized in the edge node.

Thus the term "metro" refers not so much to a city and its surrounding suburbs as to the footprints, large or small, enclosed by service delivery areas.

The key use cases

To fulfill its role in the Full Service Broadband Architecture – delivering mobile, business and residential services – the metro network faces three key challenges, whether it serves urban or rural areas.

These challenges are illustrated by the mobile, business and residential use cases described below.

- **The metro convergence challenge** – a single network to deliver all services
- **The metro flexibility challenge** – a network optimized for every situation
- **The metro cost challenge** – a network with low cost of ownership

Mobile backhaul

Mobile base stations are located to provide maximum coverage and must be connected to the mobile core network at minimum cost. To achieve this today, approximately 60 percent of all mobile base stations are connected by microwave links into main backhaul networks of leased lines or fiber links.

The Ericsson white paper "High-speed technologies for mobile backhaul" [3] describes how new, higher bandwidth mobile services[2] need cost-effective IP and Ethernet packet transport backhaul from base stations. Existing transport technologies – such as E1/T1; Asynchronous Transfer Mode (ATM); and Synchronous Optical Networking / Synchronous Digital Hierarchy (SONET/SDH) – will also continue to be used for several years. These can be delivered natively through the metro, or over converged packet-based metro transport where this would reduce the total cost of ownership.

The Metro Ethernet Forum is working to define how mobile traffic can best be carried between base stations and core networks over Ethernet networks.

To carry mobile traffic, the Full Service Broadband Metro must:

- Provide point-to-point and multipoint Ethernet transport services
- Scale its capacity cost effectively
- Support a range of quality of service (QoS) classes, such as very low delay variation for packet-based synchronization (e.g. using Network Time Protocol or the IEEE 1588 Precision Time Protocol); low absolute delay for interactive services; and best-effort delivery for general web traffic
- Support Ethernet transport and OAM efficiently over bandwidth-optimized microwave extensions to the metro network.

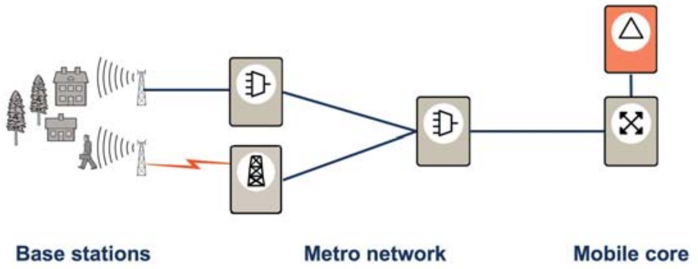

Figure 3: Mobile backhaul

[2]Such as delivered by the 3rd Generation Partnership Project (3GPP) mobile systems

Business services

Leased line and VPN enterprise service transformation

Businesses ideally want to interconnect multiple sites cost-effectively, reliably and transparently, meaning at close to local area network (LAN) speeds (typically 1 Gbps, some up to 10 Gbps). They can then achieve significant internal savings by consolidating their Information and Communication Technology (ICT) infrastructures, while still providing full-speed application access for their users. Meanwhile, metro operators see Carrier Ethernet services as a good solution, enabling replacement of separate TDM, frame relay or ATM services by E-Line, E-LAN or E-Tree services, complementing IP-VPN services.

Figure 4 shows a simple point-to-point service example from the enterprise viewpoint.

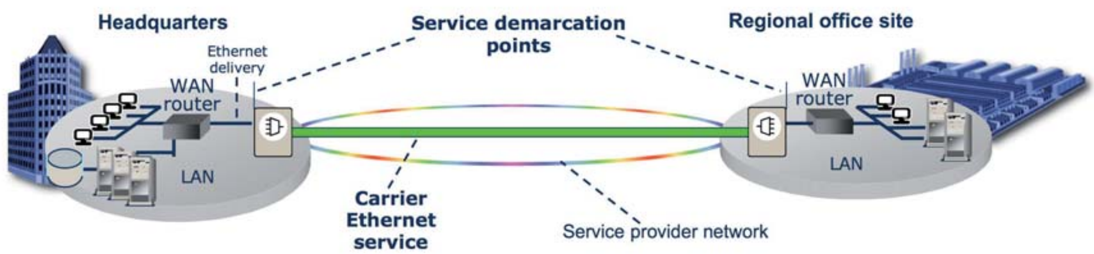

Figure 4: Carrier Ethernet services for business

A high performance Full Service Broadband Metro also benefits businesses interconnecting storage area networks (SAN), using remote backup services or content delivery networks (CDN), for which operators are now delivering very high-speed services up to tens of Gbps. The table illustrates the impact of high speed on backup of business data.

Time for a 10 Terabyte backup

At OC-3/STM-1	> 1 week
Single ESCON	1 week
At 1 Gbps	1.5 days
Over 6 OTN channels of 10 Gbps	~ 30 minutes

Business internet access

Businesses are also consolidating and improving their high speed internet access to ensure a robust Web presence but also to extend transparent application access to remote offices and nomadic workers using increasingly high-speed fixed and mobile broadband internet access.

So, to deliver future business services, the Full Service Broadband Metro must:

- Provide E-Line, E-LAN and E-Tree Ethernet connectivity services
- Provide metro connectivity to IP-VPN and internet access services
- Provide transport for specific, high-speed, non-Ethernet protocols
- Be highly reliable
- Have low total cost of ownership and operation.

Residential services

In the competitive residential broadband market, the bandwidth available to residential and Small Office/Home Office (SOHO) users is approaching levels usually expected in a large office LAN and is enabling remarkable application developments.

Here, Full Service Broadband will support the trend toward nomadic access to personalized services, rather than simply delivering services to fixed locations. This is achieved by coordination between the access nodes and service edge systems.

However as shown in figure 5 and described below, the metro network has a key role to play.

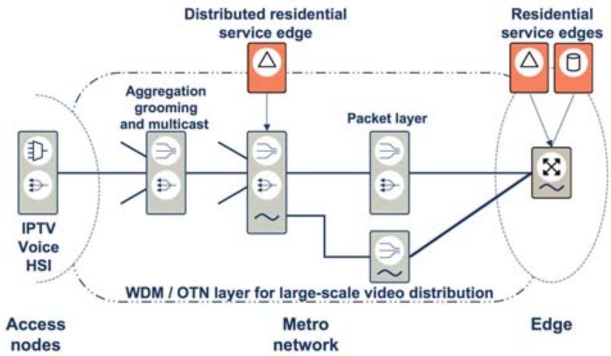

Figure 5: Delivering residential services

IPTV

A successful IPTV service must meet very high user expectations for service availability, quality and responsive interactivity, with a strong focus on service personalization. This requires redundancy, flexibility and scalability in the metro network, combining unicast delivery with fixed or dynamic multicast for efficient usage of metro bandwidth. Internet Group Management Protocol awareness (e.g. group join/leave suppression and query proxy) can also reduce the IPTV service edge load.

High-speed internet access

The metro network must scale to provide the required "internet" capacity. Several applications including rich media delivery, peer-to-peer media distribution and automatic software updates are all increasing the network load. Many people are now also producers of image and video media, driving the need for metro bandwidth and the increased uplink capacity available from more symmetric access technologies.

Multimedia and voice

Multimedia and voice services, in general controlled from the service provider's IP Multimedia Subsystem (IMS) or Softswitch via the service enablers in the overall architecture, can be delivered using a range of in-home technologies – simple terminals, set-top boxes, home LANs or in-home GSM cells. In terms of the metro network, these services span a range of bandwidths, and many need low media delay.

So, to deliver successful residential services, the Full Service Broadband Metro must:

- Groom high bandwidth services into the metro OTN / WDM layer
- Support low-delay and low-loss transport of interactive and IPTV services
- Support localized content injection points and optimized fixed and dynamic multicast
- Be extremely reliable, since with many providers to choose from, residential users will not tolerate loss of service any more readily than business users.

Meeting the convergence challenge

A standards-based metro architecture can carry all service types securely, reliably and be adapted for any deployment scenario. The key metro technologies are Ethernet, MPLS and OTN/WDM.

The converged metro network architecture

Traffic from mobile, business and residential services is increasingly either IP or Ethernet – or can be adapted using technologies like pseudowire emulation for transport over such packet networks. It is therefore becoming possible to deliver any type of service over a single “converged” high-speed metro network. Figure 6 shows a converged metro network using packet and wavelength processing to aggregate traffic for highly scalable, efficient transport between service edges and access nodes. It supports huge numbers of service instances with their associated service level agreements (SLA) and high bandwidth services that justify dedicated wavelength transport in the metro network, close to the access nodes.

The metro network provides services such as Metro Ethernet Forum [7] E-Line, E-LAN or E-Tree between locally–connected customer sites. It also backhauls IP-VPN or internet traffic to service edges, as described by the Broadband Forum [1] and supports high-bandwidth services, such as unicast or multicast IPTV.

Traffic management safeguards customer SLAs for quality of service. A wide range of physical and logical metro topologies is possible, including stars or rings, allowing alternative paths to protect affected transport connections from the effects of faults. This provides reliable, competitive delivery of high-value services.

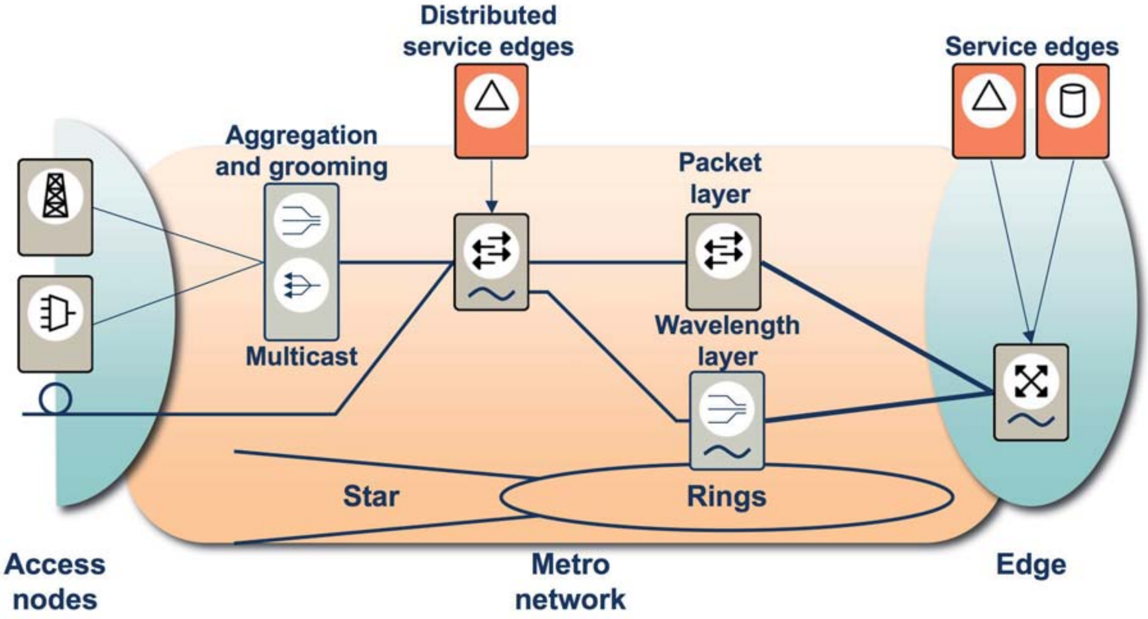

Figure 6: The metro network

Metro technologies

Transport type	Technology		
	Traditional	Current	Future
Connectionless packet transport	IP Ethernet	IP Ethernet (PB) VPLS / MPLS	IP Ethernet (PB, PBB) VPLS / MPLS
Connection-oriented packet transport	FR ATM	Ethernet (PB) VPLS / MPLS	Ethernet (PBB-TE) VPLS / MPLS MPLS-TP
Circuit and optical transport	SONET/SDH ML-PPP, NG-SONET/SDH Ethernet (IEEE 802.3ah) C/DWDM	Ethernet up to 10GBE LAN POS (SONET/SDH) up to 40G OTN / WDM up to nx 40G	Ethernet up to 100GBE OTN / WDM up to Nx 120G DWDM

Figure 7: Developing metro technologies

Figure 7 is a summary of the technology developments that are providing the required metro functionality.

In this table, connection-oriented transport systems are those that establish a stateful relationship or path between end points in order to guarantee ordered packet delivery and optionally to reserve network resources for the traffic. Connectionless transport systems carry packets without first establishing such a specific relationship or path.

Service providers can use IP routing in metro nodes to provide efficient delivery of IP traffic for certain services. MPLS is the technology for providing connections across such a routed metro network, for example to extend existing core MPLS connectivity and VPLS or VPWS services into the metro area. The standard for a transport profile of MPLS (MPLS-TP) is being developed to provide simpler, provisioned connectivity where full IP and MPLS functionality is not required.

In a switched metro network, Ethernet meets the need for scalable, high-capacity aggregation, using the IEEE Ethernet technology standards for Provider Bridging [4] and Provider Backbone Bridging [5], approved in June 2008. By fully encapsulating customer data in a network provider Ethernet frame, PBB also improves the isolation security between customer and provider network domains. Standards development continues on the traffic-engineered variant of PBB (PBB-TE) [6] for managed, connection-oriented Ethernet packet transport. Where an Ethernet metro network is required to carry synchronization, the metro nodes can use IEEE1588[3], to enhance end-to-end timing accuracy.

Packet technologies are becoming available both in optical and microwave metro products with the required fault tolerance, scalability and fault management. They can optionally be complemented by Optical Transport Network (OTN) technology to transport the packet and other high-speed payloads over WDM.

[3]*Also known as the Precision Time Protocol (PTP)*

Meeting the flexibility challenge

The same metro architecture can be adapted in terms of geographic reach, new services, bandwidth carried and support for single, multiple or distributed service nodes.

Service flexibility

The metro network provides transport-level services between locally–connected customer sites and also provides backhaul to service edges. The metro network must have the flexibility to introduce new services, extending and adapting them as users unpredictably change their service subscriptions, without disturbing existing services.

During the migration of services from TDM to packet transport, hybrid metro nodes will support the coexistence of TDM, ATM and packet traffic, while pseudowire emulation of legacy services over IP/MPLS or Ethernet transport will provide important transitional flexibility.

Flexibility for local conditions

We have seen that the metro network is defined geographically by service delivery footprints, large or small, illustrated in Figure 8. At one extreme, in dense urban areas, the metro network might consist simply of fiber links. In sparse rural areas, it will use multiple stages of aggregation to optimize service delivery. This flexibility is required every time the network reach is extended, bandwidth increases, or more service nodes are installed. The metro network must be built from a consistent range of inter-operable equipment, packaged for local conditions to deliver the very same quality of experience to all consumers.

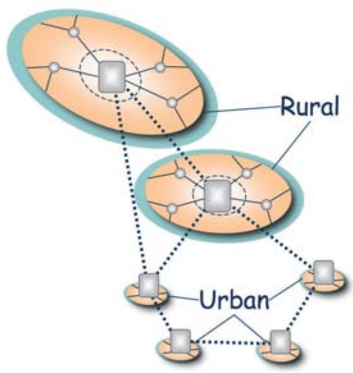

Figure 8: Adapting the metro network

Flexibility for bandwidth growth

The historic access bottleneck is being removed for residential, business and even mobile users – requiring both increased metro capacity and traffic engineering to allocate bandwidth resources. Operators need the flexibility to adjust resource allocations, add new nodes and to upgrade links, all without disturbing services.

The access function for a single large business site or for high bandwidth services (IPTV for example) can fully load a packet traffic port. Such full-rate traffic may be carried by a metro OTN/WDM transport layer for cost-effective delivery, avoiding redundant packet processing.

Meeting the low-cost challenge

The metro must have a low total cost of ownership despite large distances and a varied service mix. Low costs can be achieved by using carrier-grade equipment in a resilient network design with automation and good OAM tools.

The capital cost of a multi-service metro network can be minimized by converging delivery of all services on to a single network using modern, high-speed technology and adopting global standards to reduce component costs. Such a converged network must be complemented by appropriate network automation, coupled with network OAM and service-oriented operational support systems (OSS).

Metro control plane

A common network control system such as Generalized Multiprotocol Label Switching (GMPLS) brings some key advantages to network control and service provisioning. Figure 9 shows GMPLS controlling various connection-oriented network technologies.

In conjunction with resource and admission control systems (RACS), GMPLS accurately manages the network resources, reducing errors in provisioning primary and restoration paths. In the event of a fault, the control plane can dynamically calculate an alternative path.

In a multi-layer metro network (e.g. packet transport over OTN) separate instances of the control system are required for each layer, although operational complexity can be reduced by using a single, familiar control system technology in all layers.

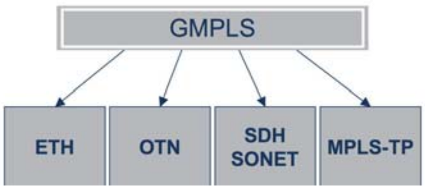

Figure 9: GMPLS control

Operations

In general, operational costs can be minimized by simplicity in the network design and in network elements – switching is typically less expensive than routing in this regard. Good OAM tools are part of carrier-grade networking, further lowering operational costs through unambiguous detection of failures or performance issues, triggering protection actions and providing effective diagnosis. MPLS, Ethernet and OTN technologies all support the layered OAM needed in a multi-carrier situation.

OAM data is provided to the OSS to support billing, service assurance and effective planning of scheduled maintenance activities in order to minimize future service disruption. The metro operator will use OSS to allocate resources semi-permanently to all uses and users of metro capacity, consistent with an overall resource allocation strategy and longer-term facility upgrade plans. Low operational costs derive from so-called “flow-through provisioning” that automates end-user service changes.

Recommendations and conclusions

A converged metro network carrying mobile, business and residential services will reduce capital expenditure compared to separate service-specific delivery networks. Such a converged network must scale to carry large numbers of services and requires robust network and service management systems to ensure that each service meets its SLA requirements for quality and reliability.

The total cost of ownership of the metro network can be reduced by aligning the mechanisms for network control, OAM and OSS systems for the packet and OTN/WDM layers. Technology-agnostic GMPLS control should be used to automate restoration and assist with connection provisioning for both packet and OTN layers.

Metro networks should allow service edges to be optimally located to support evolving bandwidth and services, thus supporting so-called single-edge, multiple-edge and distributed-edge architectures. These service nodes should be highly scalable to support very large numbers of deterministic service flows.

The key carrier-grade technologies for a flexible, converged metro network are MPLS, MPLS-TP, Ethernet and OTN/WDM, all based on global standards. The traditional principles of layered networking should be used to deliver scalable transport services and also to backhaul user traffic to other service edges as required.

Ethernet technology (Provider Bridging and Provider Backbone Bridging) should be used for high-capacity aggregation in a switched metro network, while MPLS-TP should be used to provide deterministic connections across a routed metro network and extend existing backbone IP/MPLS connectivity and VPLS services into the metro area.

An Optical Transport Network can be used to carry the packet traffic, adding resilience, using WDM to boost fiber capacity and delivering very high-speed business services. In general, metro networks should be designed to carry some services entirely in the packet layer, while others can be more optimally transported in an OTN layer.

Glossary

3GPP	3rd Generation Partnership Project
ATM	Asynchronous Transfer Mode
CDN	content delivery network
CPE	customer premises equipment
CWDM	coarse wavelength division multiplexing
DSL	digital subscriber line
DWDN	dense wavelength division multiplexing
E-LAN	Ethernet LAN service
E-Line	Ethernet line service
ESCON	Enterprise System Connection
E-Tree	Ethernet tree service
FMC	fixed-mobile convergence
FR	frame relay
FTTx	Fiber to the x, where x can be N (node), C (curb), B (building) or H (home)
GMPLS	Generalized Multiprotocol Label Switching
GSM	Global System for Mobile communications
HSI	high speed internet
ICT	Information and Communications Technology
IEEE	Institute of Electrical and Electronic Engineers
IGMP	Internet Group Management Protocol
IMS	IP Multimedia Subsystem
IP	Internet Protocol
IPTV	Internet Protocol Television
IP-VPN	Internet Protocol Virtual Private Network
LAN	local area network
ML-PPP	Multilink Point-to-Point Protocol
MPLS	Multiprotocol Label Switching
MPLS-TP	Multiprotocol Label Switching – Transport Profile
NGN	next generation network
NG-SDH	Next Generation Synchronous Digital Hierarchy
NG-SONET	Next Generation Synchronous Optical Networking
NTP	Network Time Protocol
OAM	Operations Administration and Management
OSS	operational support system
OTH	Optical Transport Hierarchy
OTN	Optical Transport Network
PB	Provider Bridging
PBB	Provider Backbone Bridging
PBB-TE	Provider Backbone Bridge Traffic Engineering
PON	passive optical network
POS	packet over SONET/SDH
PSTN	public switched telephone network
PTP	Precision Time Protocol (IEEE1588)
QoS	quality of service
RACS	Resource and Admission Control Subsystem
RAN	radio access network
SAN	storage area network
SDH	Synchronous Digital Hierarchy
SLA	service level agreement
SOHO	Small Office/Home Office
SONET	Synchronous Optical Networking
STM-1	Synchronous Transport Module
TDM	time division multiplexing
UNI	User Network Interface
VDSL	Very high-speed digital subscriber line
VoD	video on demand
VPLS	Virtual Private LAN Service
VPN	virtual private network
VPWS	Virtual Private Wire Service
WAN	wide area network
WCDMA	Wideband Code Division Multiple Access
WDM	wavelength division multiplexing

References

[1] Broadband Forum – Architecture and Transport Working Group. TR-101 Technical Report. April 2006. DSL Forum TR-101. *Migration to Ethernet-Based DSL Aggregation.* Available at: http://www.broadband-forum.org/technical/download/TR-101.pdf [Accessed 25 November 2008].

[2] Ericsson white paper. June 2008. *Full Service Broadband Architecture.* Available at: http://www.ericsson.com/technology/whitepapers/broadband/fsb_architecture.shtml [Accessed 25 November 2008].

[3] Ericsson white paper. October 2008. *High-speed technologies for mobile backhaul.* Available at: http://www.ericsson.com/technology/whitepapers/broadband/high-speed_mobile_backhaul.shtml [Accessed 25 November 2008].

[4] Institute of Electrical and Electronics Engineers, Inc. March 2006. *IEEE802.1ad – Provider Bridges*. Available at: http://www.ieee802.org/1/pages/802.1ad.html [Accessed 25 November 2008].

[5] Institute of Electrical and Electronics Engineers, Inc. June 2008. I*EEE802.1ah – Provider Backbone Bridges.* Available at: http://www.ieee802.org/1/pages/802.1ah.html [Accessed 25 November 2008].

[6] Institute of Electrical and Electronics Engineers, Inc. May 2007. *IEEE Standard for Local and Metropolitan Area Networks-Virtual Bridged Local Area Networks – Amendment: Provider Backbone Bridge Traffic Engineering.* Available at: http://www.ieee802.org/1/pages/802.1ay.html [Accessed 25 November 2008].

[7] The Metro Ethernet Forum 2008. April 2008. *MEF 6.1 Metro Ethernet Forum Service Definitions – Phase 2*. Available at: http://metroethernetforum.org/PDF_Documents/MEF6-1.pdf [Accessed 25 November 2008].