Ethernet Services and Service Delivery Technologies in the Metro

White Paper

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Introduction

The world of telecommunications is driven by changes in consumption patterns. These include changes from legacy TDM to VoIP, from TDM leased lines to Layer 1, Layer 2, and Layer 3 VPNs, from TDM-based 2G and 2.5G mobile networks to data-centric 3G networks, and from simple best effort high-speed Internet access to advanced triple play networks for small and medium businesses and home use.

The need for data connectivity across the WAN/MAN is ever growing. Enterprises with geographically distributed offices want to expand their Ethernet-based LANs to connect remote branches to their headquarters, and their business to the Internet. Internet Service Providers (ISPs) and other Application Service Providers (ASPs), such as Storage Service Providers (SSPs), require data connectivity to connect their Points of Presence (PoPs) and reach their customers. Moreover, mobile operators' demand for Ethernet connectivity is expected to rise, as they seek to exploit their massive presence in metro areas to provide new services. The ILEC and the MSOs have also begun to offer a triple play service, especially VOD services, and this significantly increases the bandwidth demand.

Ethernet service, the preeminent LAN technology, is gradually becoming the dominant service for WAN as well. To succeed in this migration, Ethernet services must meet a carrier-class standard, handle a great variety of service offerings (IP, ATM, and Ethernet, among others), provide protection mechanisms and Quality of Service (QoS), and be flexible enough to cope with the constant changes that are taking place in this environment.

As bandwidth-consuming data applications continue to increase, the metro network requires adaptable, scalable, transparent equipment that can provide flexible allocation of network bandwidth in a cost-effective way to satisfy that demand. This equipment should be easy to manage and monitor by means of a top-down GUI-based carrier-class management system.

This white paper describes the Ethernet services and major service delivery technologies existing today (their benefits and drawbacks), and in the final sections, discusses the “right” infrastructure for services delivery.

Ethernet Services

For many years, Ethernet has been the dominant networking protocol in the LAN. Its simplicity and compatibility not only make it easier to operate, but allow significant commoditization to make it extremely cost-effective.

The market for Ethernet equipment in the WAN is growing as enterprises require Ethernet services for more cost-effective bandwidth, and service providers wish to reduce their own network infrastructure costs in order to increase service profitability. This creates a demand for wide area Ethernet services.

The MEF (Metro Ethernet Forum) has defined the following three basic Ethernet connectivity services within and between metro areas:

- E-Line (point-to-point)
- E-LAN (multipoint-to-multipoint)
- E-Tree (rooted-multipoint)[1]

E-Line

- **Ethernet Private Line (EPL)**: Provides dedicated bandwidth and guaranteed throughput across a point-to-point connection. EPL is analogous to a "circuit-like" service such as a T1 service which is permanently reserved and dedicated for an enterprise customer.
- **Ethernet Virtual Private Line services (EVPL)**: Dedicated point-to-point VPN service connecting two customer sites over a shared bandwidth supporting statistical multiplexing and oversubscription. It takes advantage of Ethernet's lower-cost bandwidth to share resources amongst multiple customers. The EVPL service is aware of service attributes and can offer different QoS (delay, jitter, and frame loss), thus introducing a service differentiation offering to customers.

[1] Declared in Draft Ethernet Services Definitions Phase 2 Oct. 2006

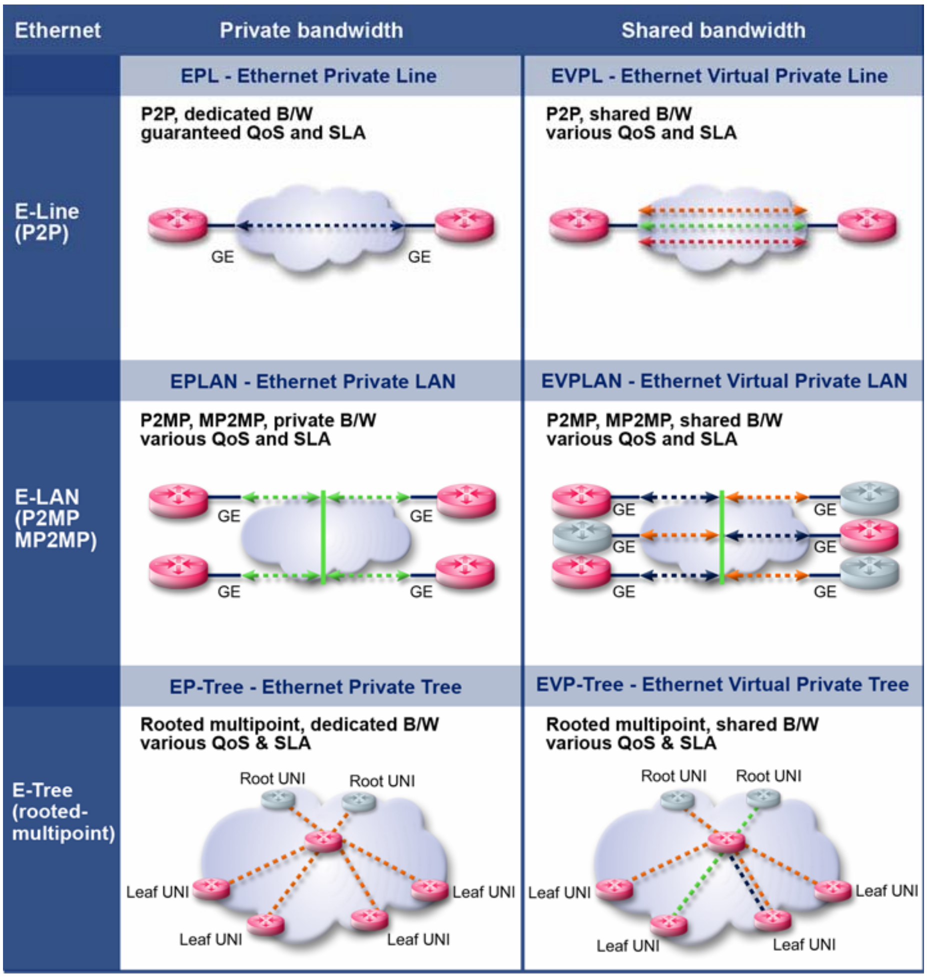

Figure 1: Types of Ethernet services: E-Line, E-LAN, and E-Tree

E-LAN

- **Ethernet Private LAN (EPLAN)**: An E-LAN service that provides multipoint connectivity over dedicated bandwidth. This service provides high-speed LAN interconnection amongst multiple customer sites which appear to be linked by a LAN segment. The sharing of network resources reduces the overall cost per Mb for the enterprise while retaining SLA requirements, QoS, and bandwidth flexibility.
- **Ethernet Virtual Private LAN (EVPLAN):** Provides a packet-based service that delivers secure any-to-any connectivity across a shared infrastructure supporting statistical multiplexing and oversubscription. This service allows greater bandwidth flexibility at a lower cost than would be possible with a Frame Relay type service. EVPLAN service supports multipoint-to-multipoint connectivity and

point-to-multipoint service. (P2MP is used mainly for multicast application and called Ethernet Multicast - Hub and Spoke. When using P2MP, a dedicated copy of the packet needs to be sent for each endpoint.)

E-Tree (rooted-multipoint)

- **Ethernet Private Tree (EP-Tree):** In its simplest form, an E-Tree service type can provide a single root for multiple leaf User-to-Network Interfaces (UNI). Each leaf UNI can only exchange data with the root UNI.
  This service uses bandwidth efficiently for video over IP applications, such as multicast/broadcast packet video. (Different copies of the packet only need to be sent to roots that are not sharing the same branch of the tree.)
  One or more CoS may be associated with this service. In more sophisticated forms, an E-Tree service type may support two or more root UNIs. In such a service, redundant access to 'the root' can also be provided, thereby allowing for enhanced service reliability and flexibility.

- **Ethernet Virtual Private Tree (EVP-Tree):** An EVP-Tree is an E-Tree service that provides rooted-multipoint connectivity across a shared infrastructure supporting statistical multiplexing and oversubscription.

Advantages of Ethernet Services

Ethernet services can reduce subscribers' capital expense (CAPEX) and operational expense (OPEX) in two ways:

- **Interface cost**: Due to its broad usage in almost all networking products, the Ethernet interface itself is inexpensive.

- **Scalability**: Many Ethernet services allow subscribers to add bandwidth in granular increments. Scalability of bandwidth, from 1 Mbps to 10 Gbps and beyond, allows subscribers to add bandwidth as needed, so they pay only for what they need.

Carrier-Class Ethernet

Early metro Ethernet service deployments made use of dedicated fiber and low-cost Ethernet switches. As customer demands increased, these services did not meet the carrier-class requirements necessary to ensure service levels. The customers demanded the same levels of performance they had from leased lines, Frame Relay, and ATM services. What was particularly lacking was the reliability, scalability, manageability, and security of traditional carrier-class products.

The Metro Ethernet Forum (MEF) has defined "Carrier Ethernet" as having the following attributes:

- **Scalability**: The ability for millions to use a network service that is ideal for the widest variety of business, information, communications, and entertainment applications with voice, video, and data. In addition, it must also have the bandwidth scalability from 1 Mbps to 10 Gbps and beyond, in granular increments.

- **Hard Quality of Service (QoS)**: Service providers must be able to offer customers different levels of service to match application requirements. While QoS mechanisms provide the functionality to prioritize different traffic streams, Hard QoS ensures that the service level parameters agreed on for each level of service are adhered to across the network. These match the requirements for voice, video, and data over converged business and residential networks. This requirement provides customers with the guaranteed deterministic performance they received from their existing leased lines service.

- **Reliability**: The demand for reliability and resiliency, as service providers typically boast "five 9's" or 99.999 percent network availability. This requirement provides the ability for the network to detect and recover from incidents without impacting users, and guarantees a rapid recovery time when problems do occur. The recovery time can be as low as 50 msec.

- **Service management**: Service providers require mature network and service management systems that provide a quick configuration of the network in order to support new services. This requirement also includes the ability to monitor, diagnose, and centrally manage the network using standards-based implementations, and to support carrier-class OAM.

- **TDM support**: While service providers see substantial growth potential in Ethernet services, existing TDM services are still a significant revenues source. Therefore, they must be able to retain and seamlessly interwork with existing TDM services as they migrate to a metro Ethernet network.

The challenge facing the equipment vendors is how to add this carrier-class functionality to Ethernet equipment.

Technologies for Enabling Metro Ethernet Services

Today, there are various Ethernet applications and services and several service technologies, as presented Figure 2.

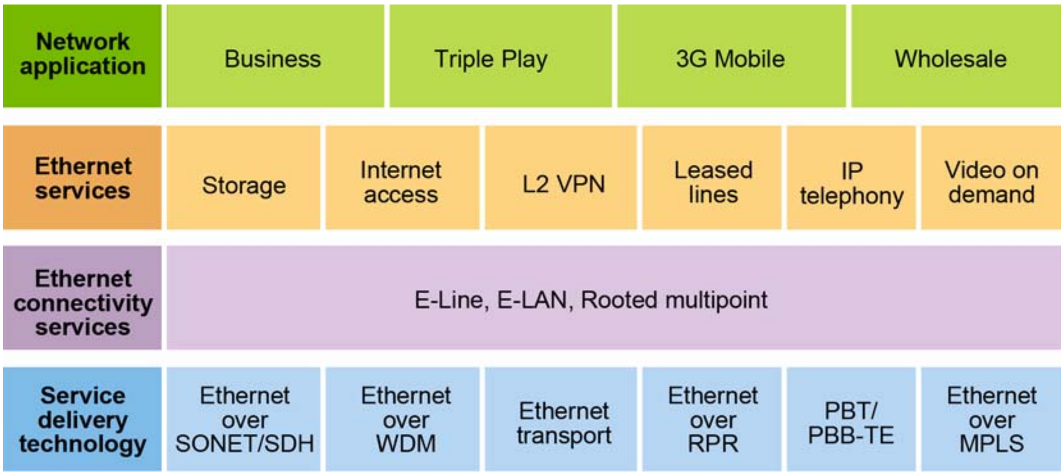

Figure 2: Summary of optical Ethernet applications and services

The following metro Ethernet service delivery technologies can be used:

- Ethernet over SONET/SDH (EoS):
  - Ethernet Leased Line over SONET/SDH (EoS LL)
  - Switched Ethernet (Layer 2) over SONET/SDH (SW EoS)
- Ethernet over DWDM (EoWDM)
- Ethernet over Fiber (EoF)/Ethernet transport
- Resilient Packet Rings (RPR)
- Provider Backbone Transport (PBT)/PBB-TE
- Ethernet over MPLS (EoMPLS)/T-MPLS

RPR, PBT, and EoMPLS carrier-class techniques can run on Ethernet transport (CESR product) or over SONET/SDH (MSPP/MSTP product).

EoMPLS and SW EoS have defacto become the metro Ethernet carrier-class service delivery technologies, while the rest address limited implementations and topologies.

All these service delivery technologies are described in the following sections.

Ethernet over SONET/SDH (EoS)

Typically used for Ethernet private line applications, Ethernet over SONET/SDH (EoS) is a point-to-point service with a native Ethernet interface. EoS was developed as a packet data transport solution which would allow the use of the existing deployed SONET/SDH infrastructure.

In the past, service providers simply mapped Ethernet directly to SDH. This was inefficient due to the SDH lack of granularity appropriate for Ethernet. Service providers often had to set much larger portions of bandwidth than the private line service actually required. For example, to provide a 10-Mbps private line Ethernet connection, service providers had to tie up a full 50-Mbps VC-3 circuit.

In addition, traditional TDM circuits had to be removed from service to add or subtract bandwidth, making them inflexible for scaling the networks.

Over the past several years, a series of new protocols has emerged that facilitates far more flexible, efficient provisioning of P2P Ethernet circuits over SDH. These include:

- **Virtual Concatenation (VCAT)** - for efficient use of bandwidth

  VCAT, defined in ITU standard G.707, allows service providers to provision data circuits in increments more suitable for Ethernet. Virtual concatenation allows granularities from VC-12 (low order) to VC-3/VC-4 (high order), and customizes Ethernet connections to match customers' bandwidth needs.

- **Generic Framing Procedure (GFP) –** for interoperability across multivendor networks

  GFP, defined in ITU standard G.7041, is a universally efficient generic all-encompassing protocol mapping Ethernet over SDH. As a result of its fixed and small overhead size, it maps and handles different data bit rates efficiently. GFP offers two modes of operation:

  - **Frame Mapped GFP (GFP-F)** - optimized for packet switching environments
  - **Transparent Mapped GFP (GFP-T)** - for delay-sensitive applications, such as storage area networking

- **Link Capacity Adjustment Scheme (LCAS)** – for bandwidth management flexibility and service robustness

  LCAS, defined in ITU standard G.7042, is a signaling protocol carried inband over SDH. LCAS provides dynamic bandwidth adjustment between two locations. It can change virtual concatenated path sizes without impacting the existing service, enabling bandwidth-on-demand (BoD) type applications.

  LCAS also provides an automatic recovery of an Ethernet link from SDH path failures within 50 msec. The capacity of the Ethernet link automatically decreases if one or more VCs fail, and automatically increases when the network fault is repaired.

The EoS model has been the leading method for transporting Ethernet due to its proven reliability and robust support of SLAs. This combination of Ethernet and SONET/SDH brings together the benefits of low-cost Ethernet interfaces with the proven reliability and OAM of SONET/SDH, providing a very reliable infrastructure for Ethernet services and packet transport.

Benefits of Ethernet over SONET/SDH

- Highest possible security available; using separate VC for service delivery
- High availability; relay on SDH protection and enhanced by LCAS functionality
- End-to-end simple provisioning
- High granularity; guaranteed service with a minimum of 2M bandwidth steps
- Relatively inexpensive cost as add-on to existing optical networks with spare capacity in MSPP products

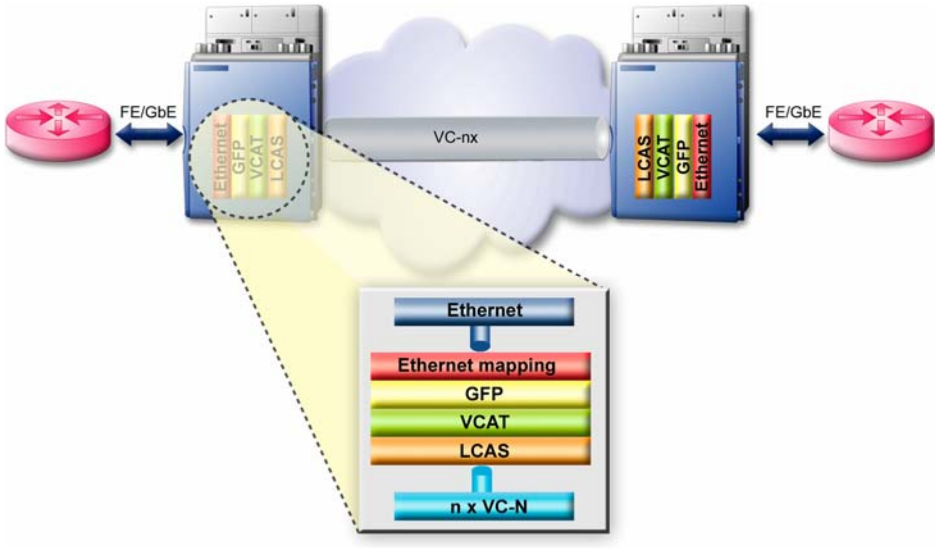

Figure 3: Ethernet over SDH – Ethernet private line

Switched Ethernet over SONET/SDH

Switched Ethernet over SDH shares an SDH connection amongst several customers. To ensure service quality, each customer is assigned a VLAN tag and specific QoS through:

- A committed information rate (CIR) for guaranteed bandwidth.
- A peak information rate (PIR) for traffic bursts.
- Traffic metering, shaping, and scheduling.

The main characteristics of Ethernet virtual services are:

- Enables customer separation based on a logical frame identifier (VLAN tags), and also supports Double Tagging/“Q-in-Q” (C-Tag and S-Tag). Double tagging improves the scalability of the limited range of possible VLAN instances (4096).
- Provides connectivity with a frame infrastructure that is shared between a number of customers.
- Performs bandwidth allocation per customer, not as a fixed allocation.
- Supports statistical multiplexing of the bandwidth amongst customers.
- Uses Spanning Tree Protocols to prevent loops (xSTP).

The most basic Ethernet virtual service multiplexes multiple customer flows within a designated infrastructure. Such Ethernet services can be referred to as Ethernet Virtual Private Line (EVPL) or Ethernet Virtual LAN services (EVLAN).

Benefits of Switched Ethernet over SDH

- Allows leveraging the existing network infrastructure while keeping capital investment at a minimum and produces additional revenue-generating opportunities.
- Secures service by separate customer traffic using VLAN.
- QoS support for real-time and premium services using basic CoS service differentiation.
- Resilience using xSTP restoration mechanism which provides greater than 50 msec, or relay on SDH protection and LCAS functionality in less than 50 msec.
- Efficient bandwidth usage with its statistical multiplexing benefits allowing one port to connect to multiple (up to 4,096) customer ports.
- Cost-effective Provider Bridge Ethernet over SDH/SONET in point-to-point, ring, hub-and-spoke, and mesh configurations.

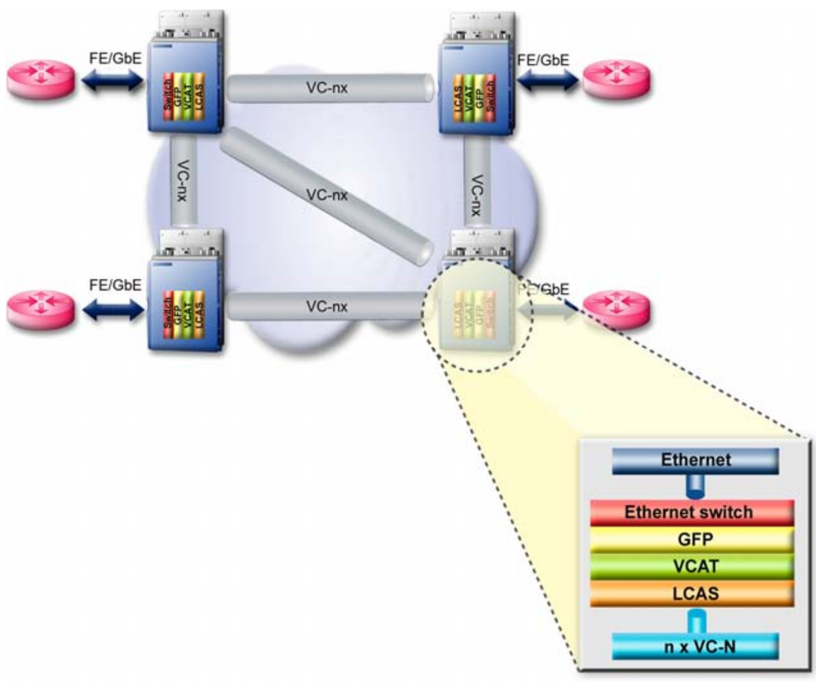

Figure 4: Switched Ethernet over SDH

Ethernet over WDM (EoW)

EoW is a point-to-point Ethernet Private Line (EPL) service. It is used when carriers need to offer ultra-high bandwidth services (GigE level and up) to connect customers' data centers and allow large file transfers between corporate sites, such as storage network applications. It is also used for other bandwidth-hungry applications, such as video transport, and to provide high fiber relief.

EoW is deployed using either Dense Wavelength Division Multiplexer (DWDM) or Coarse Wavelength Division Multiplexer (CWDM) technology. In general, carriers use less expensive CWDM to connect the customer site to the service provider POP, and DWDM between POPs for site-to-site traffic. However, some carriers may use DWDM across the entire network from customer site to POP.

EoW offers high potential resiliency by providing protection at less than 50 msec.

Service providers can offer Ethernet over WDM service at 1 Gbps and 10 Gbps.

In order to allow multiple clients to use the same wavelength, two new trends exist today in the EoW systems:

- **Sub-lambda grooming** – multiplexing of several client signals onto a single C/DWDM wavelength. Multiple low-rate services such as SDH/SONET, IP, ATM, and Gigabit Ethernet can be aggregated to a single wavelength. This is ideal for reducing network cost, saving wavelengths, and improving network reliability.
- **Switched EoW** – sharing a WDM connection amongst several customers and allowing Ethernet statistical multiplexing and oversubscription on Gigabit Ethernet services. This enables the support of EPL and EVPL services over the same C/DWDM infrastructure.

EoW's primary strength is fiber relief and GigE leased line data connection used to support storage, ultra-high speed data transport, and high bandwidth connections in the metro and core networks. For low bandwidth demands, EoW is less cost effective.

The main features of EoW are:

- Point-to-point and ring topologies
- Protected and unprotected services

Main Benefits of EoW

- End-to-end simple provisioning
- Ultra-high bandwidth
- High bandwidth scalability in wavelength granularity
- Efficient bandwidth usage: allows aggregation of several client interfaces on a single wavelength
- High resiliency: WDM systems can be built in rings which provide high resiliency over diverse paths with carrier-class 50 msec failovers
- Low latency for storage and other latency-sensitive applications

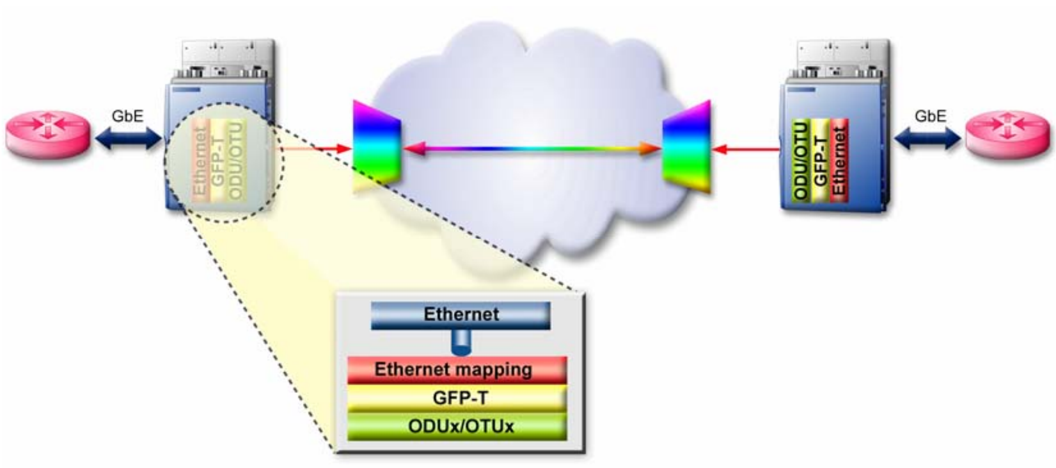

Figure 5: Ethernet over WDM – Ethernet private line

Ethernet over Fiber (EoF)/Ethernet Transport

Ethernet transport is primarily deployed in a point-to-point or mesh network topology, and delivers packet services over dark fiber. It is a connectionless technology.

Ethernet transport usually refers to simple Ethernet switches with Enterprise grade. It is usually used for LAN or Internet access connectivity.

The main Ethernet transport features/characteristics are:

- MAC learning
- VLAN for customer separation

- Spanning Tree Protocols (STP/RSTP) to prevent loops restoration; slower than the standard 50 msec
- Focusing on Ethernet connectivity, not services
- Providing basic port QoS without customer SLA
- Lacking scalability and reliability (depends on IEEE LAN protocols)
- Limited service management

Main Benefit of Ethernet Transport

- Low cost

Even though this type of product is usually very cost effective, it lacks the reliability, manageability, and scalability of a traditional SDH solution.

Ethernet over Resilient Packet Rings (RPR)

RPR, defined in IEEE 802.17, is a technology similar to SONET/SDH and optimizes the sharing of fiber optic rings for packet data traffic.

The main characteristics of RPR are:

- Uses a single ring technology in order to overcome multidrop limitations of the point-to-point nature of Ethernet.
- Utilizes both primary and backup rings.
- Spatial reuse: Stripping packets at destination nodes enables reuse of bandwidth around the ring.
- Allows service multiplexing.
- Supports per class QoS within an RPR ring.
- Less than 50 msec ring protection time after fiber cut.
- Efficient drop and continue multicast within the RPR ring.
- Fairness algorithm ensures that each node has a fair slice of the available bandwidth.
- OAM support is only available within the RPR ring (including SLA performance monitoring).

However, RPR is unlikely to be widely adopted for the following reasons:

- Only supports ring configuration; does not support mesh and star topology.
- Is a single ring protocol and does not support multi-ring which is required for end-to-end connection. Therefore, an overlay switching protocol, such as MPLS, must also be used.
- Does not support all MEF Ethernet carrier-class attributes:
  - No end-to-end solution is provided; service attributes and RPR capabilities are lost outside the ring.
  - Only supports three CoS (does not support DiffServ).
- Fixed constant bandwidth, requiring all nodes in the ring to run at the same speed. Even though there are some nodes adding and dropping traffic at a lower rate, these nodes are required to use high-speed connections.
- High cost. RPR cannot compete with the low costs of the equivalent high volume Ethernet MAC, as it uses a new RPR MAC chipset.

Provider Backbone Transport (PBT)/PBB-TE

PBT, also known as Provider Backbone Bridge-Traffic Engineering (PBB-TE), is a point-to-point Ethernet tunneling technology managed by an NMS.

PBT, based on PBB/draft 802.1ah, intends to offer SONET/SDH-like performance. PBB is a technology that reduces the MAC scaling burden within a service provider network by shielding the provider MAC addresses from customer MAC addresses refereed as "MAC-in-MAC" or "MiM".

How does PBT work?

- PBT is based on Ethernet. However, the following main functions of Ethernet are disabled:
  - MAC learning functionality
  - Broadcast and multicast
  - STP
- PBT gives the control of building the forwarding tables to the management.
- Ethernet switches based on the forwarding table information based on destination MAC address and VLAN ID (60 bits).

- Network operator is responsible for the resource reservation and for provision backup route for resiliency.
- Both paths (active and backup) are monitored by Connectivity Fault Management frames (CFM – draft IEEE802.1ag). In the case of a failure, switchover to backup is in the range of 50 msec.

PBT is more suitable for point-to-point business applications.

The drawbacks facing PBT/PBB-TE are the following:

- PBT/PBB-TE is not yet standardized and mature and therefore, it is expected that there will be changes.
- Not yet a field-proven technology.
- PBT only supports point-to-point services (P2P and MP2P):
  - MP2MP is not supported. VPLS services over PBT tunnels cannot work since PBT disables the MAC learning function.
  - Multicast (rooted-multipoint) is not supported and can only be implemented as many point-to-point connections. This results in inefficient management of the bandwidth in triple play networks. For example, delivering 200 MPEG2 (4 Mbs) IPTV channels to 50 IP-DSLAMs over a metro aggregation network using point-to-point connections (PBT) consumes network bandwidth of 40 Gbps, as follows:

    4 Mbs BW per channel (MPEG2) x 200 channels x 50 IP-DSLAMs

    The same case, using an efficient drop and continue multicast tree, consumes network bandwidth of only 800 Mbs, as follows:

    4 Mbs BW per channel (MPEG2) x 200 channels at each branch of the tree (This is only 2% of the bandwidth required in the PBT solution.)
- It adds complexity to the network by using PBB/PBT (MAC-in-MAC) in the core, and Provider Bridge (QinQ) in the edge. In addition, it has difficulties with scalability and STP restoration in the edge.
- All the resource reservation functions need to be controlled by the network administration. Therefore, the NMS requires high scalability or the network needs to use signaling in the control plane.

Ethernet over MPLS/T-MPLS (EoMPLS)

Multi-Protocol Label Switching (MPLS) is a protocol that provides an efficient forwarding and switching of traffic flows through the network.

MPLS technology enables service providers to build a cost-effective carrier-class Ethernet network over a new and/or existing SONET/SDH network, supporting any Ethernet-based application and services.

The main characteristics of EoMPLS are:

- A service-protocol that supports all the following possible services:
  - **P2P service -** using MPLS VPWS (Virtual Private Wire/line Service)
  - **MP2MP service -** using MPLS VPLS (Virtual Private LAN Services)
  - **P2MP hub and spoke service -** using VPLS star service
  - **Rooted multicast -** using MPLS multicast tree (efficient drop and continue) for IPTV services
- A converged network protocol that can encapsulate any L2 protocol (Ethernet, FR, ATM, PPP, etc.) and carry L3 IP protocol using Pseudo Wire (PW) tunnel.
- Supports any network topology: ring, multiple rings, mesh, star, dual homing.
- Supports multivendor interoperability (mature standard).

MPLS is a true carrier-class protocol that incorporates all carrier-class capabilities, such as:

- **Scalability**: Using MPLS label and distributed network architecture.
- **Hard QOS**: By using MPLS traffic engineering (TE) and Connection Admission Control (CAC), service providers can provide varying levels of QoS for different types of services and guarantee delivery.
- **Reliability** and less than 50 msec network protection: The Fast Re-Route (FRR) mechanism is used for providing less than 50 msec switchover in the case of a failure. FRR allows rerouting around a failed link or a failed node.
- **OAM**: OAM support within ITU-T Y.1711 and IEEE 802.1ag to allow verification of the tunnel status.
- **TDM support**: Through CES (Circuit Emulation Service) over Pseudo-Wire (based on IETF Martini and PWE3 drafts).

- **Service** m**anagement**: An MPLS-based network that requires managing tunnels and services can benefit from both worlds of service provisioning and management:
    - **NMS-based service provisioning:** Simplified MPLS network management by providing a point and click service provisioning and full control of the entire path of MPLS tunnels and services.
    - **Combined NMS and MPLS signaling**: This allows service providers to reduce the NMS scalability issue when combined with signaling, while still preserving the point and click service provisioning. With MPLS signaling the service provider can choose one of the following:
        - To provision the service using the signaling algorithm which finds the best path for the service.
        - To choose a path by using signaling with an explicit path ("NMS-like provisioning").

Transport MPLS (T-MPLS)

T-MPLS is an ITU-T draft based on the IETF MPLS standard. Its objective is to identify a subset of existing MPLS that will be able to provide connection-oriented packet transport. It also adds the following features: OAM –ITU-T Y.1711, Protection-ITU-T G.8131 APS (similar to FRR), and bidirectional LSP.

Some MPLS products are also intended to support the T-MPLS profile.

EoMPLS Summary

To summarize, Ethernet over MPLS implementations have the following advantages for service providers when being used in the metro:

- Reduces OPEX and CAPEX:
    - Keeps it simple with MPLS L2 capability (no IP in data plane).
    - Supplies a real converged data network by implementing the following:
        - Metro aggregation interoperability with the current IP/MPLS core routers and supplying end-to-end MPLS network from the access to the core.
        - Avoiding multiple networks of ATM, Frame Relay, and Ethernet by carrying these services as overlay.

  - Significantly reduces metro networks bandwidth requirements for IPTV delivery by using an efficient drop and continue multicast tree.
  - Reduces OPEX by implementing a well defined and robust OAM.
- Revenue-generation by adding the following new services:
  - Triple play
  - Business
  - 3G mobile aggregation
  - Wholesale/CoC
- Offers end-to-end (E2E) assured QoS service delivery for IPTV, VOD, and VOIP services by MPLS traffic engineering capability.
- Creates a possibility for mixed vendor networks for Ethernet services as a result of its abundant multivendor interoperability.

Comparison of Ethernet Service Delivery Technologies

The following table compares the different types of service delivery technologies.

Table 1: Comparative table Ethernet service delivery technologies

Service Attribute	EoSDH MSPP	EoWDM	EoF	RPR	PBT	EoMPLS
Topology	Ring, multi-ring, mesh, star	Ring, any with OADM	Star, dual homing	One ring only	P2P only (dual homing)	Ring, multi-ring, mesh, star, dual homing
Scalability BW	VC granularity SW EoS Eth policing	Wavelength granularity	Eth policing	Eth policing	Eth policing	Eth policing
Scalability Users	EoS LL - none SW EoS - QiQ	None	QiQ	QiQ	QiQ, MiM	MPLS label
Hard QOS	Yes	Yes	No	Yes	Yes	Yes, +CAC
CoS	EoS LL - guaranteed, SW EoS - 802.1p	Guaranteed	802.1p	802.1p	802.1p	802.1p DiffServ over MPLS
Restoration/ Resilience	EoS LL, SW EoS: 50 msec - SNCP, MS-SPRing, LCAS SW EoS – rSTP > 50 msec	Optical protection 50 msec	STP/rSTP/mSTP, > 50 msec	50 msec ring protection	Backup route 50 msec	FRR – 50 msec
Security	LL - SDH SW EoS – VLAN, SDH	Wavelength	VLAN	VLAN, RPR MAC	VLAN, MiM	VLAN MPLS PW, tunnel
MP2MP	EoS LL – No SW EoS – Yes	No	Yes	Yes	No	Yes
Multicast	SDH D&C or multicast VLAN	Och D&C	Eth multicast	RPR D&C	No	Eth multicast, rooted multipoint
Latency	Eos LL - low SW EoS - medium	Very low	Medium	Medium	Medium	Medium
OAM	Path PM, FM, CM	Link PM, FM, CM	802.1ag	RPR O&M	802.1ag	802.1ag Y.1711
Strengths	Low latency, TDM support Ring resiliency	Low latency, ultra-high BW	Low cost	Utilize both primary and backup rings	Simple management	Supports any protocol any service, traffic Eng
Limitations	Scalability	Only P2P	Non-ring based high TDM cost	Does not support mesh and star	P2P only, not standardized, NMS scalability	NMS scalability

The question then arises: Which is the “right” infrastructure for services delivery?

It depends! In some cases, overlay networks make sense. In other cases, reuse of existing networks is more effective. Service providers and equipment vendors need the flexibility to support all situations (infrastructure, architecture, technology, and so on). Ethernet services can be provided over a variety of network technologies to suit the needs of the application. The decision depends on the following:

- Expected capacity requirements
- Topology (ring, star, mesh)
- Installed base that can be leveraged
- Specific business case

Table 2: Network applications vis-a-vis service delivery technologies

Network Application	Examples of Services	Application Requirements	Suitable Service Delivery Technology (in red typical used tecnology)
Triple play DSLAM aggregation	VoD, GoD, VoIP, HSI	Statistical multiplexing E2E hard QoS	EoMPLS, RPR (only in one ring), PBT, SW EoS, EoW **
	IPTV/BTV	Statistical multiplexing E2E hard QoS Multicast	EoMPLS, EoW**, RPR (only in one ring)
Triple play CMTS aggregation	VoIP, HSI, GoD	Statistical multiplexing E2E hard QoS	EoMPLS, RPR (only in one ring), PBT, SW EoS, EoW **
Business Best Effort	HSI LAN connectivity W/O critical mission	Statistical multiplexing Low cost	EoF, SW EoS, RPR, EoMPLS, PBT, EoW**
Business with Critical Mission	VoIP, ERP, CRM Leased lines L2 VPN	Guaranteed bandwidth	P2P: EoS, EoW, PBT, SW EoS, EoMPLS, RPR MP2MP: EoMPLS, SW EoS, RPR (only in one ring)
	Storage	Guaranteed bandwidth Ultra-high bandwidth Low latency High resilience	EoW, EoS LL
3G (Release 5) Mobile backhaul (mainly for triple play services)	VoIP, GoD, Video streaming, L2/L3 VPN, Voice conference	Statistical multiplexing E2E hard QoS	EoMPLS, RPR (only in one ring), EoW**
Wholesale (Carrier of Carrier)	Leased lines BW services	Guaranteed bandwidth High resilience	EoW, EoS, SW EoS, EoMPLS, PBT, RPR

** The high bandwidth of EoW can overcome the requirement for statistical multiplexing, although today Switched EoW service delivery technology also exists.

What would be the ideal solution?

Taking into consideration all of the concerns and requirements, the ideal solution would consist of a converged multiservice platform with a packet-aware media. It would have to support carrier-class functions, such as availability, scalability, and resilience. It is recommended that it supports several service delivery technologies in one platform. In addition, it would need to integrate smoothly into an existing infrastructure and management, also supporting Greenfield networks, and thereby being cost efficient in an evolutionary approach.

Carrier-Class Ethernet Switch (CES) vs. Ethernet over MSPP

The Ethernet carrier-class techniques (MPLS/RPR/PBT) can be delivered directly on Ethernet Transport (CESR product, carrier-class Ethernet switch and router), or over SONET/SDH (MSPP/MSTP product). The following sections advise when to use each product type.

Ethernet over MSPP/MSTP

MSPP/MSTP is a converged platform that supports traditional and emerging services. It supports legacy services over SDH/WDM and emerging services over Switched Ethernet and MPLS in an efficient way. The MSPP/MSTP is a mature carrier-class, field-proven infrastructure in terms of reliability, protection within 50 msec, and wide OAM.

From a CAPEX perspective, MSPP is cost optimized as follows:

- In an existing next generation SDH network:
  - The Ethernet services allow leveraging of the network infrastructure while keeping capital investment to a minimum. It only allows a CAPEX incremental per user service demand, instead of a huge investment in network revolution.
  - Rapidly introduces new revenue-generating Ethernet services on existing SDH infrastructure.
  - Next generation SONET/SDH provides an evolutionary path to an all-IP network.
  - Has the ability to improve utilization by means of a single box per site, which supports both data and TDM/WDM services.
- In a new network (Greenfield):
  - When there is a mixed TDM and data network (especially if the TDM is more than 30% of the required bandwidth).
  - The data portion required for a segment is no more than several tens of GigE.
  - The data network is distributed, which enables segmentation of the aggregation in the network and reduces the capacity of the aggregation in each segment.
  - Low Ethernet fan-out per site.

MSPP is cost optimized from an OPEX perspective as follows:

- No need to deploy a second/new transmission layer for the data services.
- No need to manage and maintain two transmission networks (one for TDM and one for data).
- No need for training experienced personnel to handle a new management system.

Carrier-Class Ethernet Switch and Router (CESR)

CESR is a multiservice carrier-class Ethernet transport platform based on packet switch Ethernet transport that focuses on high fan-out and high capacity Ethernet services. To deliver TDM services, it uses Circuit Emulation Services (CES). However, CES have to overcome the challenges of delay and delay variance, clock generation, and distribution.

Carrier-class Ethernet Switch and Router (CESR) is preferable in the following circumstances:

- The customer builds a completely new datacom network (Greenfield).
- The data network is centralized – high Ethernet fan-out per site.
- The capacity of the metro aggregation is greater than many tens of GigE (N x 10 Gbps).
- Low TDM traffic is required (some of the CESR products do not support Circuit Emulation Services (CES) at all).
- Mainly L3 services are required.

ECI Ethernet Solutions

ECI Telecom Ltd. provides advanced telecommunications solutions to leading carriers and service providers worldwide. ECI Telecom's platforms provide carriers and service providers with carrier-class solutions to simplify the introduction of new revenue-generating services.

ECI has the "know-how" and the experience in carrier-class Ethernet solutions, and is fully operational in ILEC, CLEC, Cellular, MSO, utilities and military networks.

ECI supports all of the applications and Ethernet services (E-Line, E-LAN, E-Tree) detailed in this white paper, using the following service delivery technologies: Ethernet over MPLS, Switched Ethernet over SDH, Ethernet over SDH, and Ethernet over WDM. ECI has the flexibility to fit the appropriate solution to each specific customer and application, based on their MSTP/MSPP or CESR product lines.

This section details the following ECI product solutions:

- XDM® product line
- BG-20/30/40 product line
- Carrier-class Ethernet switching

XDM Product Line

The XDM system architecture meets the needs of today's telecommunications professionals for a MultiService Transport Platform (MSTP). It provides market-leading Next Generation SDH capabilities, advanced carrier-class Ethernet/MPLS services, and flexible WDM optical services through a single converged platform that integrates the best technologies available today. The XDM platforms provide complete flexibility and scalability, support any topology (multi-ring, mesh, star, rooted multipoint, and so on) with fully nonblocking cross-connect capabilities. The XDM platforms are managed by an E2E layered management system that offers the unique ability to manage all three layers through a single, unified, user-friendly graphic interface.

The following Ethernet cards are supported in the XDM product line:

- **MPLS carrier-class switch (MCS)** (XDM scales to MPLS from access to core)

  MCS5/MCS10: These MPLS and T-MPLS carrier-class switch cards enable next generation Ethernet applications, such as triple play, VPLS business connectivity, 3G Ethernet-based aggregation, and wholesale CoC bandwidth applications. MCS5/10 provides complete MPLS functionality, offering scalability and smooth interoperability with IP/MPLS core routers.

- **Switched Ethernet over SDH – Provider Bridge**

  Ethernet Interface and Switching Module (EISMB, EIS, EISM cards) Ethernet over SDH service cards provide cost-effective, Provider Bridge (QinQ) based EVPL and EVPLAN services, with high fan-out and multiple WAN interfaces. They offer VC-12, VC-3, and VC-4 granularity on their WAN ports, and guarantee QoS (support four classes of service). In addition, they include 64K ingress policing and user-configurable WRED, MAC learning, and Rapid Spanning Tree Protocol (RSTP).

- **Ethernet over SDH Leased Line**

  Data I/O cards (DIO_B ,DIOM): These EPL Ethernet over SDH service cards map multiple GbE and FE ports (electrical or optical) into virtually concatenated trails, with bandwidth ranging from 2 Mbps up to full capacity GbE, and a choice of granularity options down to 2 Mb steps. They support jumbo frames and flow control mechanism.

Ethernet over WDM

- **Combiners**: The XDM offers a variety of combiner card options for 2.5 Gbps and 10 Gbps. These cards multiplex several client signals onto a single C/DWDM wavelength using a built-in TDM matrix. The combiner cards support line side tunable lasers and hot-swappable client side SFPs/XFPs and a variety of GbE and SAN/TDM applications. XDM combiners are ideal for reducing network cost, saving wavelengths, and improving network reliability.

- **Multirate combiner**: Enables cost-efficient multiplexing of several different low rate signals, such as STM-1/4, GbE, and 1G/2G fiber channel onto a 2.7G OTN C\DWDM wavelength. The module also incorporates two network interfaces to provide 1+1 line protection on a single module.
- **Transponder 10 GbE LAN**: Provides the transport of full rate 10 GbE LAN with SPD/permeable transparency over a standard OTU2 (10.7G OTN) line interface and with an XFP client interface.
- **ADM on Card (AoC)**: The AoC is the next generation of optical service cards. It combines the cost efficiency of an optical platform with the granularity and flexibility previously available only in SDH networks. The AoC enables multiplexing of up to eight Ethernet/ Fiber Channel/TDM client interfaces onto a 10G optical ring (10.7G OTN). Additional benefits include its ability to route client signals to different locations along the optical ring, as well as per service selectable protection. Typical applications include E-Line services and multiservice applications.

BG-20/30/40 Product Line

BG is a miniature MultiService Provisioning Platform (MSPP).

ECI Telecom's BG family delivers a cost-effective and affordable mix of Ethernet, SDH, PDH, and PCM services.

The following Ethernet cards are supported in the BG product line:

- **BG-20B-L1** is ideal for EPL services. The bandwidth of each Ethernet service channel can be set to VC-12/VC-3/VC-4 granularity. It can also be adjusted and protected via LCAS.
- **BG-20B-L2 and ESW_2G_8F_E**, with its Layer 2 switch and multiple EOS links, are ideal for EVPL, EPLAN, and EVPLAN services, as well as aggregation unit in point-to-multipoint solutions. QoS is guaranteed for all of these services. VLAN stacking (Q-in-Q) and MAC Learning and Switching Multiple Spanning Tree Protocol (MSTP)/Rapid Spanning Tree Protocol (RSTP) functions are also supported.

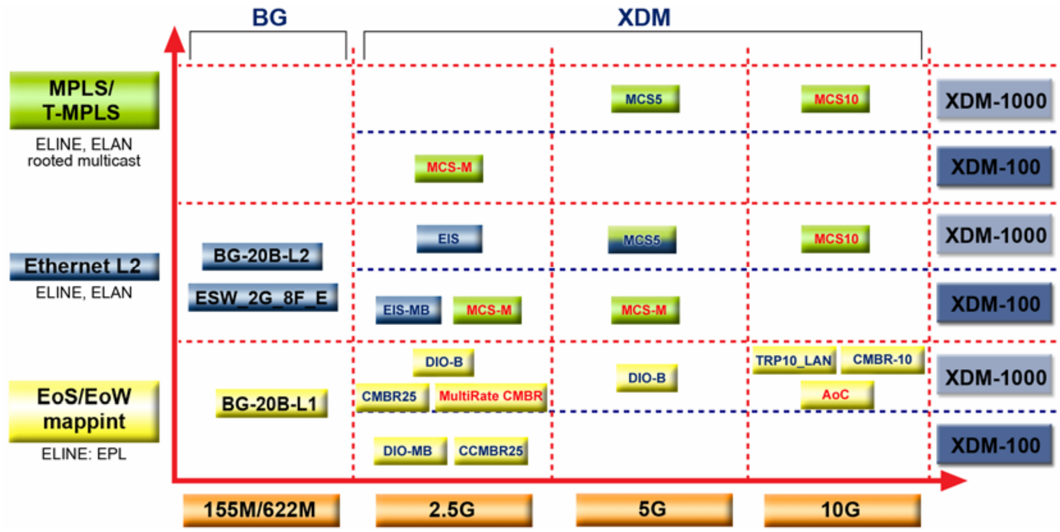

Figure 6: ECI's Ethernet service cards over MSPP products at a glance

ECI's Carrier-Ethernet Switching

The Carrier-Ethernet switching offering of ECI includes several platforms that are designated for the different switching layers of the metro transmission networks.

Metro Aggregation/Core Switch

It is an ideal metro aggregation/core switch that delivers scalable high-density Gigabit Ethernet and a 10 Gigabit Ethernet performance. It is a 17-slot, high-density, one-third rack chassis that supports up to 15 x 10G Ethernet ports, or up to 120 Gigabit Ethernet ports. It features 150 Gbps nonblocking switching, and boasts up to 450 million packets per second in provisioned throughput. It employs a standard MPLS-based architecture to deliver scalable flow management. It also features sub-50 msec failure recovery, redundant DC power, and full redundancy of all common equipment.

Metro Aggregation Switch

It is an ideal metro aggregation switch for compact POPs with small space (6.5 RU) and power availability. It delivers scalable high-density Gigabit Ethernet and a 10 Gigabit Ethernet performance, and supports up to 6 x 10G Ethernet ports or up to 48 Gigabit Ethernet ports. It features 80 Gbps nonblocking switching fabric that supports up to 180 million packets per second in provisioned throughput. The Metro aggregation switch employs a standard MPLS-based architecture to deliver mass deployed scalable services without the scalability limitations of a typical Enterprise class Ethernet switch. It also features sub-50 msec failure recovery, redundant DC power, full redundancy, and hot swappable common equipment.

Metro Edge Switch

A compact optical Ethernet edge switch delivers cost-effective 10/100 Ethernet, Gigabit Ethernet, or TDM-based customer access, one rack-unit high. The products in the series come with two 1000Base-X pluggable (SFP) ports for connectivity to the optical Ethernet metro network. The series is available either with AC or DC power supplies. Hot-swappable access modules include 10/100TX and 100 FX Ethernet modules, Gigabit Ethernet modules, and a variety of TDM Circuit Emulation Services (CES) modules, including E1/T1 and STM-1/OC-3. In addition, 4 Gbps nonblocking switching is supported and the series offers point-to-point, point-to-multipoint, and multipoint-to-multipoint connectivity, and supports up to 2,000 simultaneous connections.