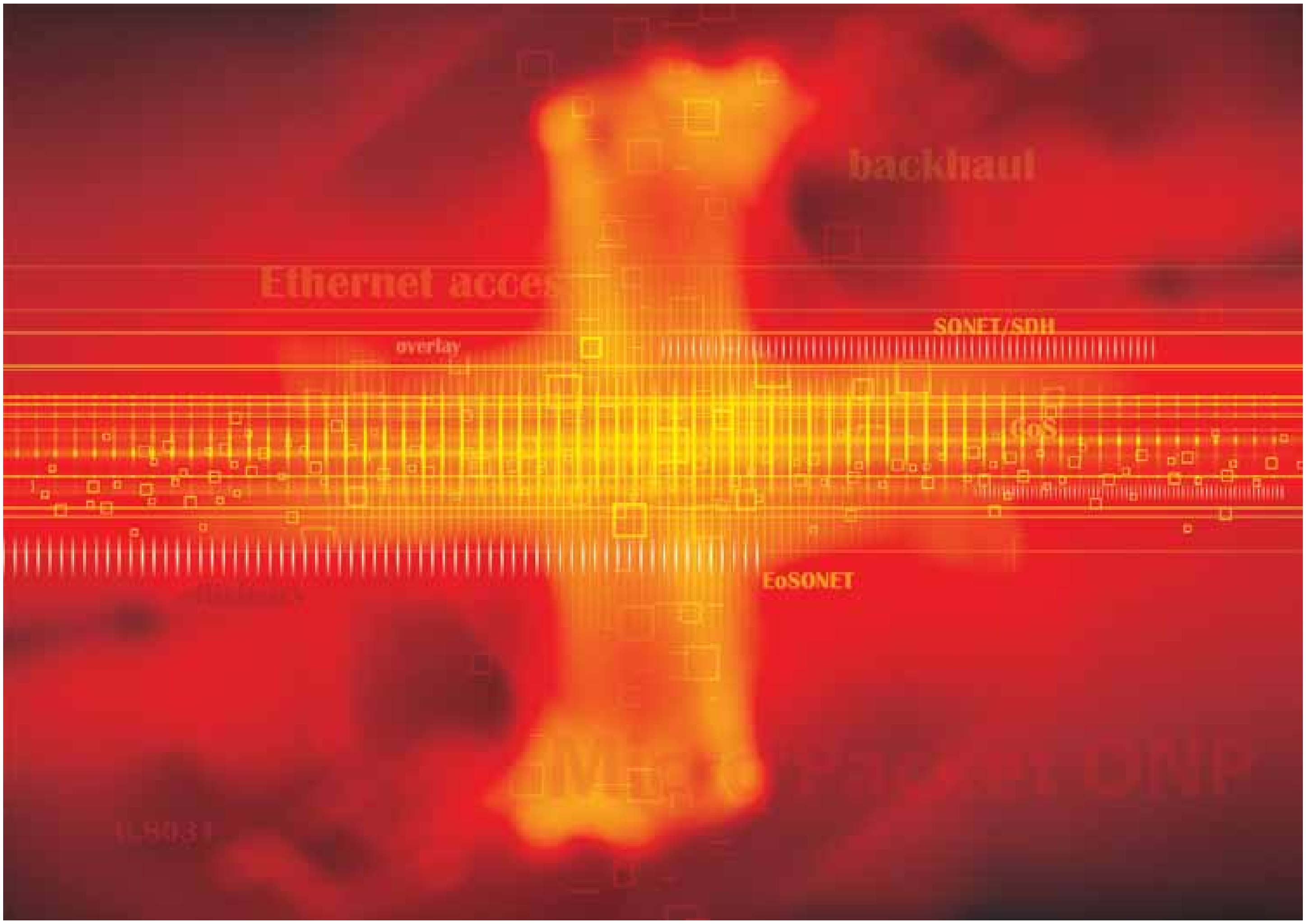
The Micro Packet ONP: Leveraging Today's Optical Network For Next-Generation Ethernet Access



Ethernet has become the most popular interface to attach end-users to the range of Ethernet and IP network services. Ethernet is simple, lower cost and familiar and, therefore, easy for end users to own and operate. A single Ethernet jack can support multiple connections and a wide range of access bandwidths. This enables end-users to grow connectivity and bandwidth easily over time. Ethernet services are often priced less expensively per bandwidth unit than TDM-based network services. With the emergence of Connection-Oriented Ethernet (COE) networking, Ethernet now promises to deliver the reliability, performance, and security of SONET/SDH, but with the networking efficiency inherent to Ethernet.

Connection-Oriented Ethernet (COE) using Ethernet Tag Switching brings advanced traffic engineering capabilities to Carrier Ethernet. Connection-Oriented Ethernet accomplishes for Ethernet what SONET technology accomplished for DS1s and DS3s by enabling network providers—for the first time—to deploy a single, long-lasting Ethernet infrastructure for all Ethernet private line and access/backhaul applications. By invoking per-flow traffic engineering, resource reservation and connection admission control along with the latest Ethernet OAM and protection standards, COE delivers the performance, reliability and security of SONET/SDH networking, while retaining the networking efficiency of native Ethernet networking. To read more about COE, please see the Fujitsu white papers, "Connection-Oriented Ethernet – Completing the Ethernet Revolution", and "Connection-Oriented Ethernet – Operational and Deployment Considerations"

In addition to enterprise services, Ethernet networking is becoming important for backhaul applications, including backhaul of 3G and 4G mobile services and backhaul of services accessed via IP DSLAMs. Service providers who can rapidly provide Ethernet gain an important competitive advantage.

Existing MSPP access networks can be an important asset for service providers to leverage to decrease the time and cost of delivering Ethernet access and backhaul services. Driven by the continued increase in T1 and T3 traffic, MSPP access networks number in the tens of thousands and are continuing to grow. Not only are the access platforms themselves proliferating, but many network operations staff are more familiar with these platforms than with specialized Ethernet equipment.

This white paper describes the emergence of the Micro Packet ONP and how COE capability can be added to the existing MSPP-base to:

- Improve service velocity
- Deliver higher quality, differentiable Ethernet services
- Lower access costs
- Improve backhaul networking efficiency

Packet Optical Networking Platforms (Packet ONPs) integrate traditional layer 1 optical networking such as SONET/SDH and photonic networking with Connection-Oriented Ethernet. An "open platform" Packet ONP implementation enables network providers to create a universal aggregation, transport, and private line services infrastructure that equally serves Ethernet and traditional TDM networking needs. To read more about Packet Optical Networking, please see the Fujitsu white paper, "Packet Optical Networking Platforms - Delivering the Connected Experience"

Traditional Ethernet Networking with MSPPs

The MSPP base offers several advantages for delivering Ethernet over SONET (EoS) access and backhaul services:

- Rapid service delivery – because the MSPP equipment is already deployed on the premises
- Low access equipment cost – avoids the cost of deploying an overlay Ethernet network
- High quality – the availability, security and connection performance of traditional EoS is high

At the same time, the traditional approach of Layer 1 EoS offering MEF EPL services has some limitations:

- Added cost because network bandwidth is typically only allocated in 50 Mbps (or larger) increments
- Added cost in hub-and-spoke networks because there is no Ethernet aggregation in the SONET network.
- Each end-user Ethernet port results in a dedicated Ethernet port on the PE device or the customer location.
- Sub-rate services lack QoS. Because the EoS services are not aware of individual flows, ingress policing cannot distinguish between high- and low-priority traffic.

Ethernet Overlay for Access

These traditional limitations in EoS efficiency and CoS awareness have driven some service providers to create Ethernet access network overlays. Although these overlay networks can be more network efficient, they have their own limitations:

- Service velocity may be impaired because it can be difficult to find new fiber, install new racks/cabinets and commission new nodes and rings.
- Access cost may be increased – two cabinets, two separate elements at the same customer premises location and separate fibers back to the CO.
- Performance may not be differentiable – most Ethernet access networks support only simple priority-based queuing and can provide only a statistical SLA. Many overlay Ethernet access networks rely on spanning-tree protocol which provides slow restoration (500 ms) and requires complex provisioning.
- Reliability may be poor – Ethernet access platform configurations may be fixed and therefore do not provide five-nines availability for any service.

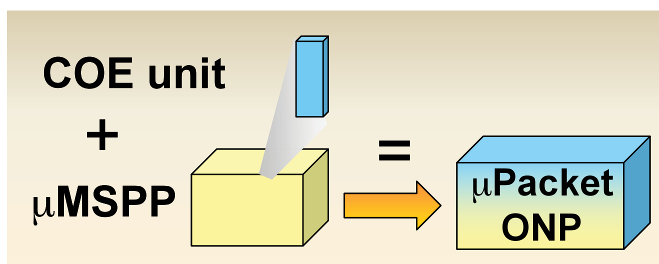
Traditional EoS and overlay Ethernet access approaches both have their benefits, but also some limitations, as summarized in Figure 1.

	Ethernet over SONET	Overlay Ethernet
Service Velocity	• Fast: •Inserting a card	• Slower: • New fiber • Deploying new element/ cabinet/rack
Access Equipment Cost	• Lower premises equipment cost • Single fiber pair	• Higher: • Cost of 2nd box • Cost of 2nd fiber pair
Network Efficiency	• Network inefficiencies • Hub site inefficiencies	• Efficient Ethernet networking • Hub node aggregation
Performance	• Highest security • Highest performance • Highest reliability • CoS unaware	• Lower security • Lower performance • Lower reliability • CoS aware

Figure 1: EoS and Ethernet Overlay Scorecard

COE into Micro MSPPs – the Micro Packet ONP

By deploying COE units into existing "micro-MSPPs" in the access network, network providers can achieve the best of both worlds. Each of the following advantages is discussed at length in the sections that follow:



- Increased service velocity by inserting a card into an existing system, versus building new cabinet and finding new fiber
- Differentiable service – lowest Ethernet packet loss, latency, jitter; security against MAC DoS attacks, highest reliability, and multi-CoS over single EVC awareness
- Low access equipment cost – a single unit versus a new platform
- High network efficiency – 1 Mbps bandwidth granularity, aggregation of Ethernet traffic at hub site locations, reduction of PE router ports, and oversubscription options

Increasing Service Velocity

Customer premises and OSP locations are notoriously difficult to engineer. In OSP cabinet installations, many factors, including municipal regulations and right-of- way issues, minimize the physical size of the cabinets. Therefore, OSP cabinets are often constructed as compactly as possible and there may be no space in the cabinet for installing additional platforms. If a requirement for additional Ethernet service emerges, existing cabinets often cannot be retrofitted.

In addition to costing thousands of dollars, deploying a new cabinet can take months to complete, which destroys the service velocity. However, if the cabinet contains an existing micro-MSPP that can be upgraded with COE, new Ethernet requirements can be met by installing a new unit into an existing chassis.

In addition to saving time by avoiding OSP cabinet deployment, the Micro Packet ONP solution avoids delays that may occur when deploying an Ethernet overlay network. Examples are pulling new fiber, installing a new platform, and commissioning a new overlay access ring.

Differentiable Service Offering

COE uniquely provides deterministic performance and reliability that is typically lacking in metro Ethernet services. At the same time, COE imposes no bandwidth restrictions on the end-user and provides an unlimited number of access service instances.

This deterministic performance is made possible by per-flow queuing and CAC, which are unique to COE. As illustrated in Figure 2, with per-flow queuing, each traffic scheduler in the access network is equally aware of all EVCs and CoS instances that are vying for transmission opportunities. Therefore, each CoS instance or EVC can receive exactly the queuing treatment required to meet the SLA. This is a substantial improvement over most Ethernet access platforms that provide only simple port-based priority queuing.

With port-based priority queuing, the traffic scheduler can only make distinctions between high- and low-priority traffic, and cannot distinguish different high-priority EVCs or CoS instances. Therefore, most metro Ethernet SLAs are statistical in nature, allow for greater latency, jitter and packet loss, and impose ingress bandwidth limitations on end users. With COE, Ethernet SLAs can be much tighter than conventional metro Ethernet SLAs—with negligible packet loss and lowest latency and jitter—without the need to overprovision the network or restrict the bandwidth profiles of end user ingress traffic.

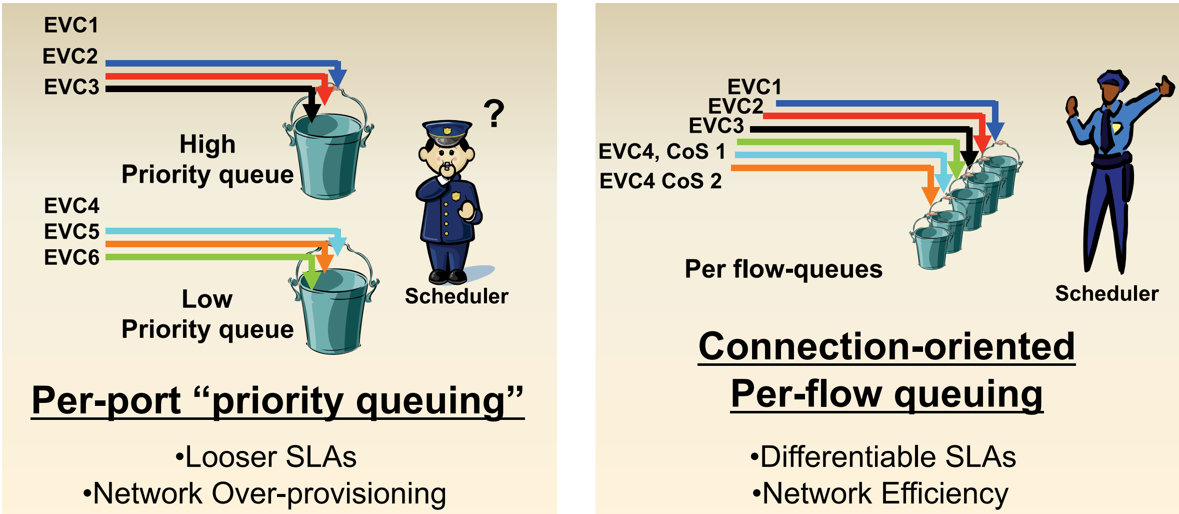


Figure 2: Contrasting Per-Port Priority Queuing with Connection-Oriented Per-Flow Queuing

In addition to superior EVC performance, COE uses ITU standard G.8031 Ethernet linear protection. This enables network providers to create dedicated protection architectures over point-to-point or ring physical topologies. These protect individual connections or tunnels containing multiple connections with 50 ms switching speed. Since the working path resources are pre-reserved and guaranteed in the network, it is a simple matter to create identical protection resources that travel over different fibers, as shown in Figure 3. G.8031 has an APS protocol that functions similarly to GR-253 SONET Line APS, but operates either on individual EVCs or on tunnels that carry multiple EVCs. In this way (in conjunction with 802.1ag continuity fault management), the network provider can create structures that function like SONET UPSR and protect against link, node, or individual EVC/tunnel failures.

In addition to improving the protection switching speed over IEEE 802.1s spanning tree, G.8031 is much simpler to provision because it does not require the complex provisioning of MSTP tables.

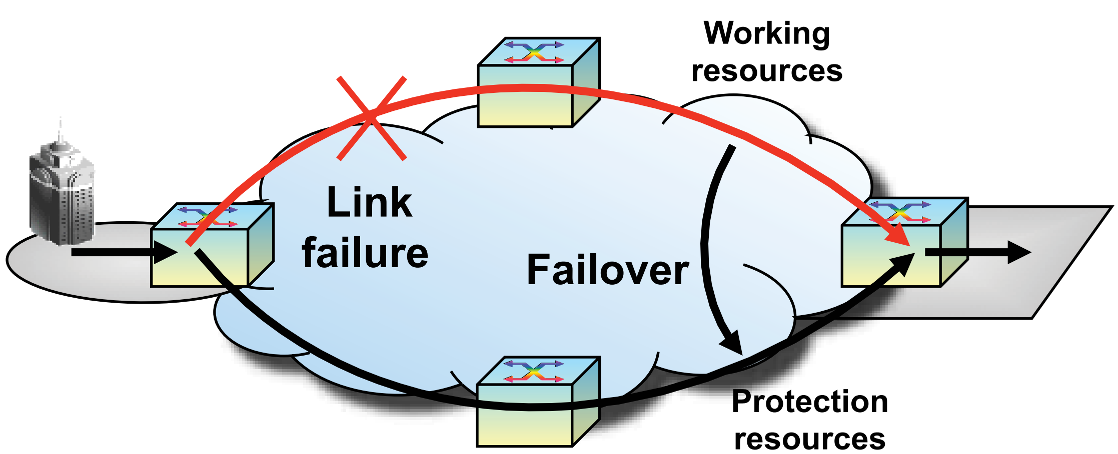


Figure 3: Access Network with G.8031 Ethernet Linear Protection

Enhanced Network Efficiency

Micro Packet ONPs offer considerable access network efficiency by:

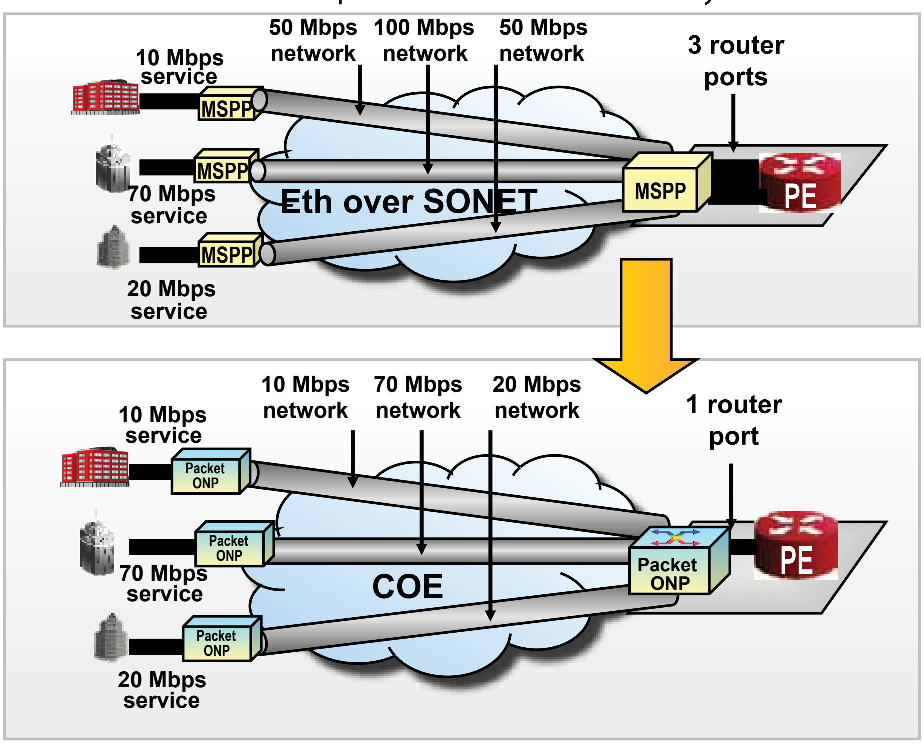
- Using transport network bandwidth judiciously
- Providing Ethernet aggregation that can greatly reduce the number of required PE router ports for IP service access applications.

Figure 4 depicts a simple access scenario and compares the amount of required network bandwidth and router ports for two possible approaches:

- A simple Layer 1 EoS approach
- A Packet Optical networking approach using COE.

In the EoS scenario, each Ethernet port at the customer location is transported using a dedicated VCG that, in general terms, is oversized compared with the actual service requirement. Each customer port then maps directly to a dedicated port on the PE router or switch device.

In the COE scenario, the network bandwidth matches the service bandwidth and the traffic is aggregated in the access network so that only one router port is required. In this simple example, the use of COE reduced the access network bandwidth by a factor of 2 in comparison with EoS. By using oversubscription with COE, the access bandwidth requirement can be reduced by a factor of 8.



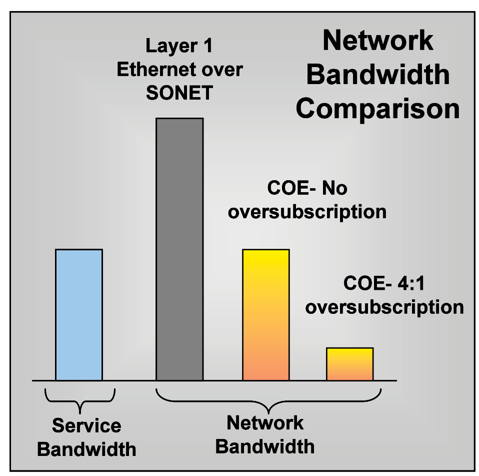


Figure 4: Access Network Scenarios – Comparing EoS (Top) to Packet Optical with COE

Using COE in the access network can significantly reduce the number of PE router ports required for Ethernet access to IP services. Figure 5 shows an example of an access network with 100 GE end user ports, with an average of 200 Mbps of Ethernet service bandwidth each. With EoS, since each end user port appears directly on the PE router, there will be 100 x 1GE PE ports generated (this is actually 200 ports if 1:1 GE client protection is required at the handoff between the access network and the PE router).

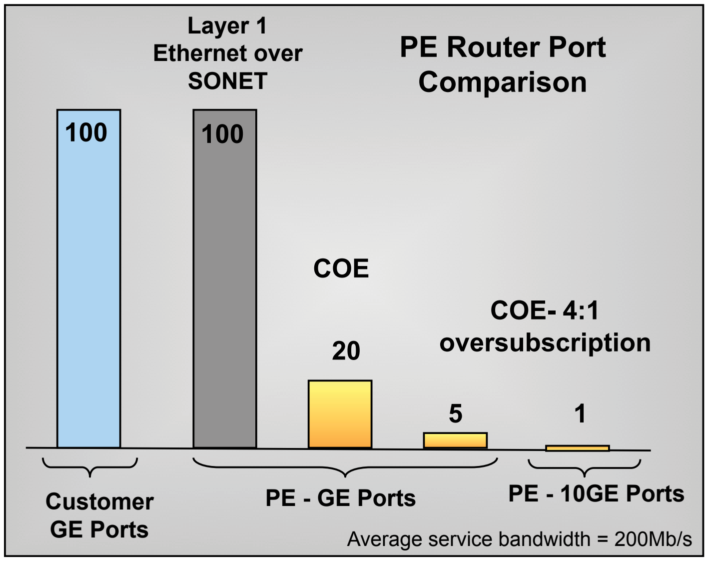


Figure 5: PE Router Port Reduction Using COE

By using COE to perform Ethernet aggregation in the access network, this number can be reduced significantly to 20 x 1 GE ports. By providing 4:1 oversubscription, the number of ports can be reduced to 5. Further, since the handoff interface is not restricted to the same physical layer or port speed as the customer Ethernet port, this handoff to the PE router can be accomplished with a single 10 GE port.

Superior Access Network Cost Performance

By integrating Layer 1 and COE, Micro Packet ONP systems enjoy the same fundamental network cost benefits of their larger Packet ONP cousins. For access applications, especially in cases where the Micro Packet ONP is on premises delivering TDM services, there is a substantial economic benefit compared with an Ethernet overlay network. The Ethernet traffic can be served by adding units to the existing element rather than deploying a second Ethernet element. This Ethernet traffic can be carried over same network fibers as the TDM traffic, rather than requiring a fiber overlay.

Carrying the Ethernet traffic over the same fiber pair as TDM traffic is accomplished by defining a VCG network in the existing SONET network and reserving this for COE traffic. Ethernet traffic from each access location can optionally be placed into that same VCG, as shown in Figure 6. Thus, the Ethernet traffic receives the same G.8031 network protection, 1 Mb/s bandwidth granularity and oversubscription capabilities as if it were riding a native Ethernet uplink.

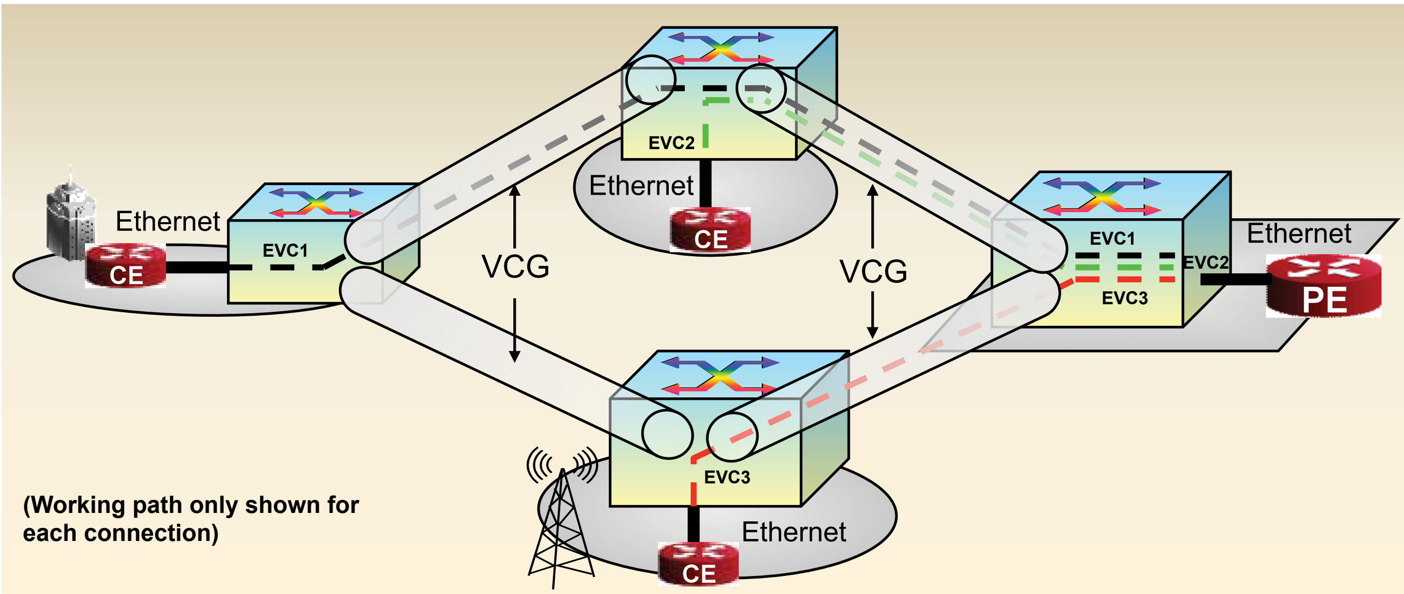


Figure 6: Carrying COE Traffic Over the Existing SONET Access Ring

In part by leveraging this unique capability, Micro Packet ONP networks provide much more economical Ethernet access than do Ethernet overlay networks. Figure 7 shows a transport capital cost comparison between adding COE to the existing MSPP base and the cost of deploying an Ethernet overlay network.

The Micro Packet ONP solution has a fundamental cost advantage in scenarios where the access elements are already deployed as an MSPP and simply upgraded with COE units. This also provides an additional economic benefit by allowing the access ring to scale beyond 1 Gb/s to 2.5 Gb/s without a ring speed upgrade.

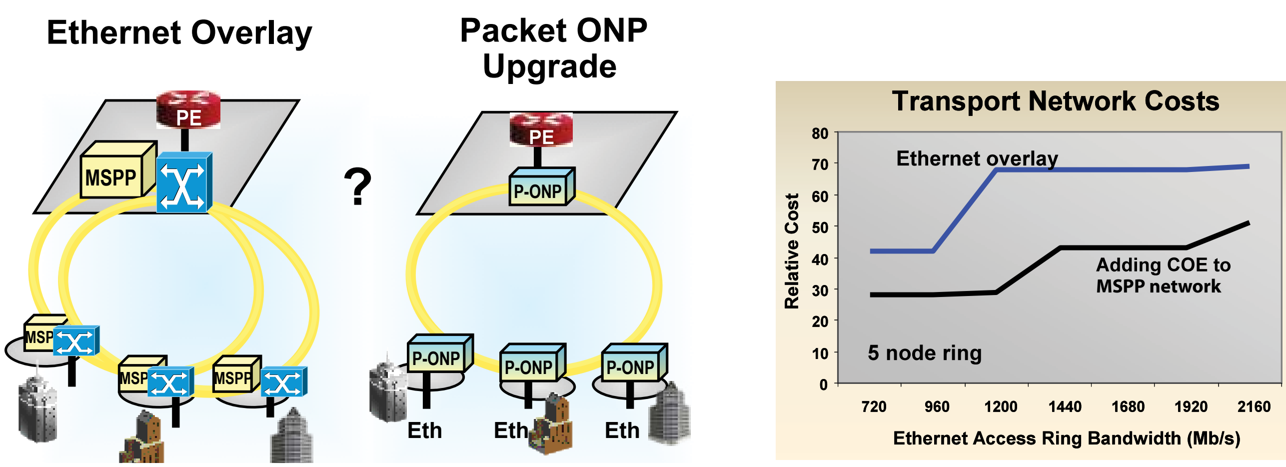


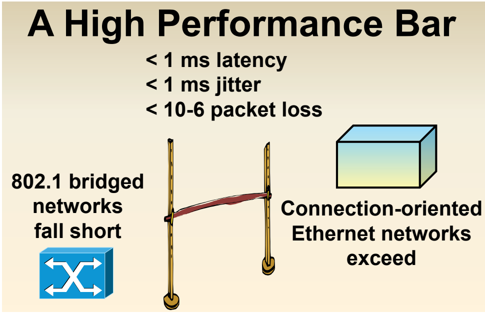
Figure 7: Micro Packet ONP Provides Access Network Cost Advantage Over Ethernet Overlay Networks

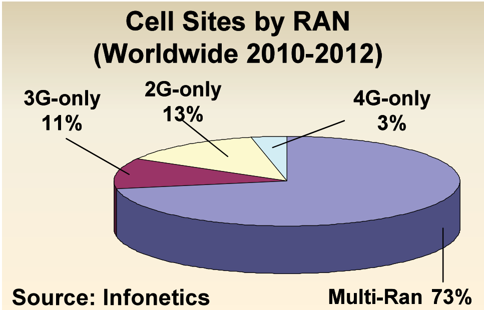
Applications

The Micro Packet ONP solution has unique benefits in several access applications, including full-service mobile backhaul, DSLAM backhaul, and wholesale and retail Ethernet services access.

Full-Service Mobile Backhaul

Providing backhaul for mobile services from cell site locations to mobile offices is a strongly growing business, fueled by the revolution in mobile broadband services.





For economical bandwidth growth, mobile backhaul services require COE networking that meets the stringent performance requirements for mobile applications. The mobile provider's packet loss, latency, and jitter requirements are often more stringent than can be provided with connectionless "switched" services provided using 802.1 provider bridging.

In addition to this COE requirement, there will be an ongoing need for T1 backhaul. This is because most cell sites support multiple mobile operators, and each operator may be implementing more than one wireless (RAN) technology. So while 3G and emerging 4G mobile services will result in Ethernet handoffs to the backhaul network, many mobile providers will continue to deliver T1 handoffs to the backhaul provider for 2G traffic. According to industry estimates, nearly 75% of all cell sites will have multiple generations of mobile service.

As shown in Figure 9, the backhaul provider benefits in several ways by utilizing a Micro Packet ONP system at cell sites:

- Deploying a single-access platform for all mobile providers and mobile service needs, resulting in the fastest service velocity and lowest network cost
- Offering a differentiable COE that uniquely meets the stringent loss, latency and jitter requirements of mobile service backhaul
- Having efficient network aggregation that can deliver an aggregated handoff to the mobile provider at the mobile office
- Utilizing native TDM support without having to replace existing backhaul technology or retrain field personnel
- Having integrated Ethernet NID functionality with Y.1731 and 802.1ag at the cell site for demarcation with mobile providers' cell site gateway platforms.

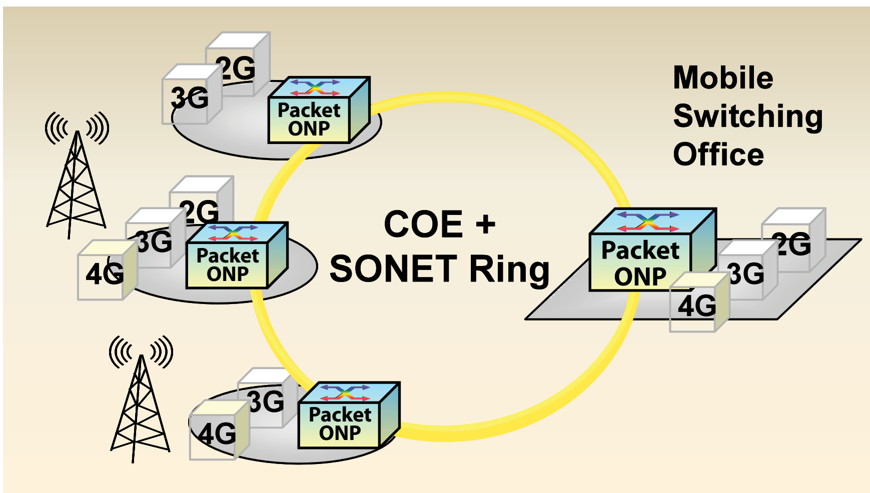


Figure 9: Full-Service Mobile Backhaul Network Using Micro Packet ONPs

Wholesale and Retail Ethernet Access and Connectivity Services

By upgrading the Micro MSPP base to a packet optical network, service providers can offer differentiated wholesale and retail Ethernet access and connectivity services.

Wholesale Ethernet access services are a growing market as enterprise users migrate away from frame relay and ATM-based VPN services. Wholesale Ethernet access is more complex than TDM-based access. This is because Ethernet pricing is not uniform, Ethernet services are not always available, and Ethernet services are often defined differently depending upon the transport technology involved. Wholesale Ethernet services require:

- Rapid deployment of access connectivity to the retail provider
- Y.1731 and 802.1ag Ethernet service fault and performance management
- Survivable last-mile access
- MEF-compliant ENNI interface

On top of those basic requirements, wholesale Ethernet access providers will benefit by deploying the emerging MEF-defined universal tunnel access service (UTAS), in which a single Ethernet access tunnel connects the retail provider PoP location to end user equipment. With this approach, the wholesale access provider only provisions the tunnel once, whereas the retail service provider adds multiple services to the tunnel over time, without needing to rely on the access provider for circuit additions.

In addition to the growing wholesale opportunity, a substantial business opportunity is emerging for high-value retail EPL services. Nearly all metro Ethernet services today are based on either costly Ethernet over Layer 1 networks (like EoS or EoDWDM), or on lower performance connectionless "switched" Ethernet networks comprising 802.1 bridges. Furthermore, most metro services are actually provided using identical equipment. E-LINE connectivity services using COE (including EPL and EVPL) uniquely offer the reliability, performance, and security of EoS while delivering the network efficiency of connectionless switched services.

Figure 10 shows a unified access network architecture for retail and wholesale Ethernet services. This architecture can leverage the footprint of the existing MSPP base with upgraded Micro Packet ONPs at the customer locations and core Packet ONP systems at the hub/PoP sites. By utilizing the EoX Gateway functionality in the hub site, the access provider can terminate a wide variety of access networks. For more information on Packet ONP EoX Gateway applications, please see the Fujitsu white paper, "Unlocking Ethernet Access and Backhaul with the EoX Gateway," available from the Fujitsu Website.

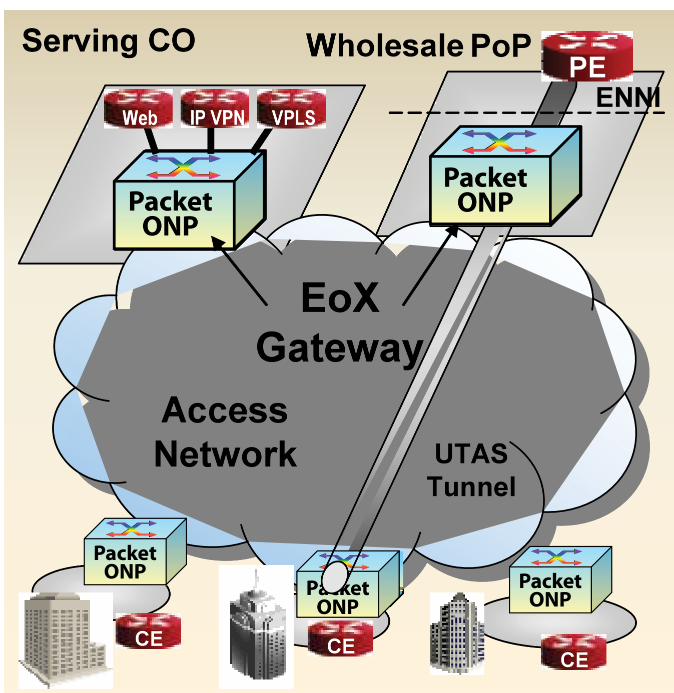


Figure 10: Retail and Wholesale Ethernet Access Service Architecture – Micro Packet ONPs and EoX Gateways

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DSLAM Backhaul Applications

Traffic on DSLAM systems is growing rapidly, fueled both by residential broadband services and growing SMB user traffic served over these DSL access networks. In many cases, new "IP DSLAM" deployments are being installed adjacent to the previous generation of ATM DSLAMs. The IP DSLAMs use GE uplinks, driving Ethernet networking requirements, while the ATM DSLAMs use DS3 uplinks, driving SONET uplink requirements.

In both cases, the backhaul network must provide aggregation from a large number of remote sites back to multiple routers at a hub CO. The network must also provide high reliability, including network and client facility protection and card-level equipment protection. Figure 11 shows the packet optical solution, where a single network provides highly reliable, aggregated backhaul for both types of DSLAM backhaul over a single fiber pair with a single set of platforms.

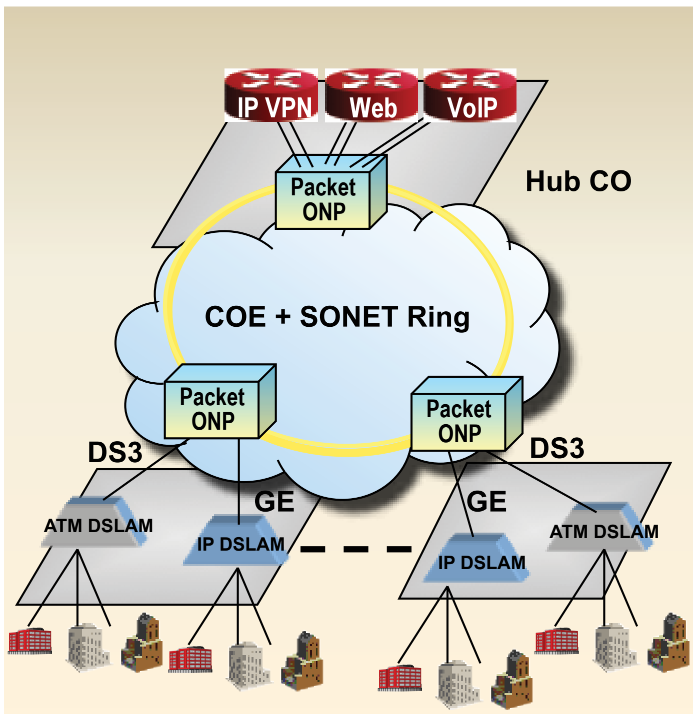

Figure 11: A Single Packet ONP Network for Multiple Generations of DSLAM Backhaul

Summary

Ethernet has become the most popular interface to attach end users to the range of Ethernet and IP network services. With the emergence of COE networking, Ethernet now promises to deliver the reliability, performance, and security of SONET/SDH, but with the low network cost and bandwidth flexibility inherent to Ethernet.

Existing SONET access networks—numbering in the tens of thousands—constructed with "micro-MSPPs" are a vital asset that service providers can leverage to decrease the time and cost required to deliver Ethernet access and backhaul services.

Micro Packet ONP platforms result from the integration of COE into "micro-MSPP" systems. These platforms allow service providers to leverage existing access networks to realize four important benefits:

1. Dramatically increase velocity for turning up new services by installing a COE unit into an existing system, as compared with deploying an overlay Ethernet access network.
2. Offer a differentiable COE service that delivers the performance, reliability, and security of SONET with the network efficiency and aggregation of native Ethernet.
3. Increase network efficiency compared with classical EoS approaches by providing 1 Mbps bandwidth granularity and aggregation, resulting in network bandwidth reductions and PE router port reductions.
4. Substantially lower access cost by using embedded equipment and allowing the new COE traffic to optionally ride over the existing SONET layer.

Micro Packet ONP solutions provide these four benefits in mobile backhaul, DSLAM backhaul, and Ethernet services access applications.

Term	Definition
APS	Automatic Protection Switching
ATM	Asynchronous Transfer Mode
CAC	Connection Admission Control
COE	Connection-Oriented Ethernet
CO	Central Office
CoS	Class of Service
DSLAM	Digital Subscriber Line Access Multiplexer
DSn	Digital Signal n (1 or 3)
DWDM	Dense Wavelength Division Multiplexing
ENNI	Ethernet Network-Network Interface
EoS	Ethernet over SONET
EoX	Ethernet over any underlying technology
EPL	Ethernet Private Line
EVC	Ethernet Virtual Circuit
EVPL	Ethernet Virtual Private Line
GE	Gigabit Ethernet
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
ITU	International Telecommunications Union
MAC	Media Access Control
MEF	Metro Ethernet Forum
MSPP	Multiservice Provisioning Platform
NE	Network Element
NID	Network Interface Device
ONP	Optical Networking Platform
OSP	Outside-Plant
Packet ONP	Packet Optical Networking Platform
PE	Protected Ethernet
PoP	Point of Presence
QoS	Quality of Service
RAN	Radio Access Network
SDH	Synchronous Digital Hierarchy
SLA	Service-Level Agreement
SMB	Server Message Bus
SONET	Synchronous Optical Networking
TDM	Time Division Multiplexing
UNI	User-Network Interface
UTAS	Universal Tunnel Access Service
VCG	Virtual Concatenation Group
VPN	Virtual Private Network

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