

# Carrier Ethernet

## The Challenges of Ethernet Access



**data communications**

The Access Company

## Abstract

Next generation packet switched networks, and Ethernet in particular, are increasingly gaining traction in the WAN due to intrinsic advantages, such as network simplicity, high bandwidth capacity, scalable and flexible service provisioning, and most-importantly significant savings in capital investments for equipment and service deployments. Ethernet is also a technology that enterprises are already familiar with for internal LANs and should have no trouble adopting for network services. That said, upgrading Ethernet WAN services from “best-effort” to Carrier Ethernet is not challenge-free, given the diversity of existing access and transport networks, the need to establish end-to-end service reliability and measurable performance guarantees, and the prerequisite of ensuring service continuity for legacy applications over Ethernet backhaul.

This reference guide provides essential information on the key issues involved in deploying new Carrier Ethernet services. It reviews the specifications for Ethernet connectivity, service and traffic management and outlines emerging standards for Ethernet OAM (operation, administration and maintenance). It also includes an introduction to RAD's intelligent Ethernet demarcation solutions, so that service providers, incumbents and alternative carriers gain understanding on how they can cost-effectively and ubiquitously extend Carrier Ethernet services to the subscriber premises over any access, while ensuring same service attributes and user experience.

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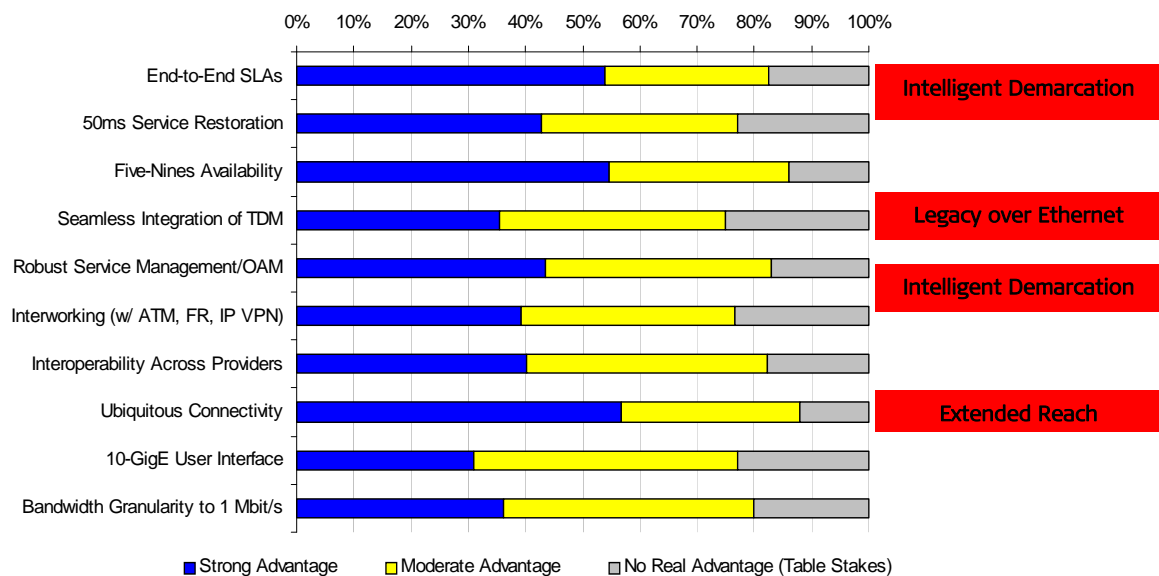
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## The Challenges of Ethernet Access

The upsurge in market demand for Ethernet network services has presented significant challenges for incumbent and alternative carriers alike. In a 2006 survey conducted among service providers, the following requirements were rated as fundamental in delivering carrier-grade Ethernet service:

- Providing ubiquitous Ethernet connectivity;
- Enabling end-to-end quality of service (QoS); and
- Supporting legacy applications over Ethernet backhaul



*Figure 1: Carrier-rated technology features*

(Source: Heavy Reading 2006 survey)

### Ubiquitous Ethernet Connectivity

Most carrier transport networks have been PDH/SDH/SONET-based and are expected to remain so in the near future, while fiber-to-the-business (FTTB) is reportedly connecting less than 15 percent of businesses in metro area networks (MANs). When adding to that the high popularity DSL technology is still enjoying among residential users and small to medium business enterprises (SMEs), it becomes clear that in order to provide a universal Ethernet service and reach a large customer base with current infrastructure, carriers need

solutions that would allow them to extend consistent Ethernet services with common attributes over a diverse variety of access technologies.

### **End-to-end Quality of Service**

Ethernet in the wide area network (WAN) has traditionally been an economical, “best effort” service with no provider commitments or service guarantees other than a designated bandwidth capacity. In order to sustain profitability and curtail operating expenditures (OpEx), carriers need tools to cost-effectively monitor and manage their services end-to-end, while providing SLA (Service Level Agreement) guarantees for various service types required by their customers, such as mission-critical applications, voice, etc. Moreover, as Ethernet traffic is likely to traverse several networks, owned by separate providers and possibly of different technologies, carriers need to ensure transparent hand-off of traffic and easy fault localization. OAM (Operation, Administration and Maintenance) is a known mechanism for enabling such degree of network control in ATM, however it had not been considered part of typical Ethernet WAN technology. OAM-enabled Ethernet also allows carriers to manage their services end-to-end throughout the network, using such features as connectivity verification, error detection, performance monitoring, and alarm indication.

### **Supporting Legacy Services over Ethernet**

Packet switched networks (PSNs), and Ethernet in particular, are being increasingly considered alternatives for TDM networks, primarily due to the lower capital expenditures (CapEx) involved in deploying Ethernet equipment, as well as the lower OpEx and higher bandwidth rates such networks are offering. Nevertheless, many operators wish to continue delivering their revenue-generating legacy services in their migration to new networks. As a result, seamless TDM and ATM integration over Ethernet transport is heavily influencing carrier acceptance and is considered one of the basic attributes that define carrier-class Ethernet. Pseudowire (PW) circuit and service emulation enable cost effective and highly reliable support for TDM and ATM services, by allowing carriers to converge legacy traffic within the Ethernet network environment using a single access link and same end-to-end traffic control features.

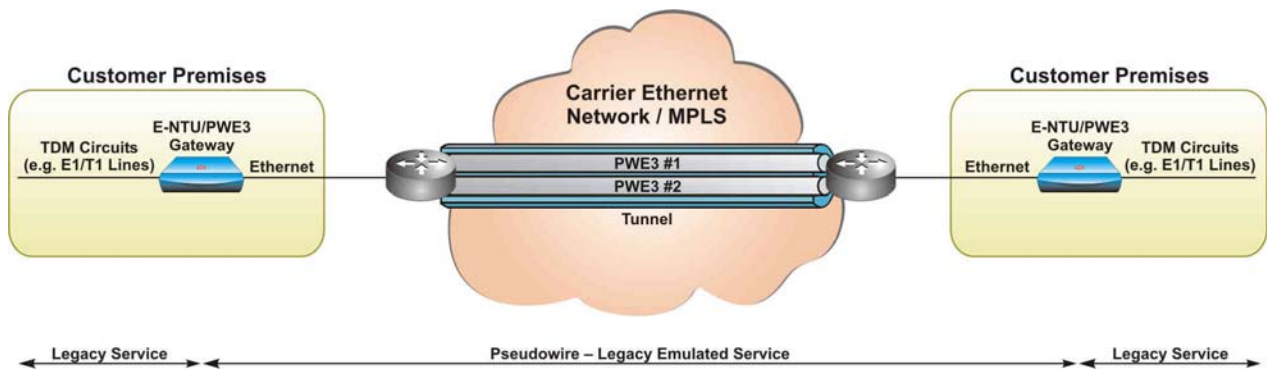


Figure 2: Pseudowire emulation of legacy services over PSN

### Ethernet Demarcation

Realizing carrier control over the entire service path involves extending network visibility into user premises. This is achieved by connecting customer premises equipment (CPE) to the network with provider-owned demarcation devices that are deployed at customer locations, thereby enabling a clear separation between the user and the network. Such implements are known as Customer Equipment (CE), Network Termination Equipment (NTE), Network Termination Units (NTUs), Network Interface Devices (NIDs), Network Interface Units (NIUs), Ethernet Demarcation Devices (EDDs) or Network Demarcation Devices (NDDs). Intelligent Ethernet NTUs (E-NTUs) are a key element in meeting the various challenges service providers are confronted with, by offering additional advanced functionalities such as service and link OAM, end-to-end traffic management starting at the service hand-off point (UNI – User Network Interface), extensive fault monitoring and diagnostics, uplink redundancy, and automated SLA verification.

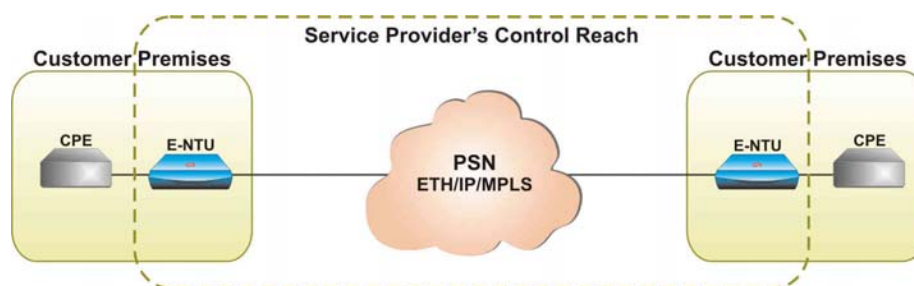


Figure 3: Ethernet network demarcation

## Ethernet Equipment Interoperability

Another important aspect of Ethernet's progress towards carrier services is the ability to add features and equipment as technology evolves. Establishing interoperability between network components from various manufacturers is therefore essential for both service providers and vendors. Multi-vendor interoperability offers service providers a migration path to new services by encouraging their confidence in relatively easy and reliable installations, and by helping them avoid the constraints of single source, proprietary network designs. At the same time, interoperability allows vendors to gain access into established networks and benefit from low entry barriers into new markets and applications. The European Advanced Networking Test Center (EANTC) stages annual multi-vendor carrier Ethernet interoperability tests. Its largest, and most diverse, test to date was performed in September 2007, examining some 65 devices from 24 vendors.

## Carrier Ethernet

One of the primary drivers to Ethernet technology's progress from enterprise-level LANs to carrier-class networks and services has been the extensive standardization work carried by several industry organizations. Each of these institutes defines Ethernet in a manner consistent with its respective area of interest, resulting in a wide spectrum of standards covering different aspects of the technology. The IEEE 802 project – the first to address standardized Ethernet specifications – has established a set of LAN/MAN standards. ITU-T, however, regards Ethernet as a collection of packet-based layer networks, while IETF views it as a support tool for IP networks connecting the edge router and the end-user terminal. Yet another organization heavily influencing the shape of network communications is the Metro Ethernet Forum (MEF), a global industry alliance promoting Carrier Ethernet deployment, which defines it as a ubiquitous, carrier-class service.

According to the MEF, five attributes distinguish carrier-grade Ethernet service from traditional LAN-based Ethernet:

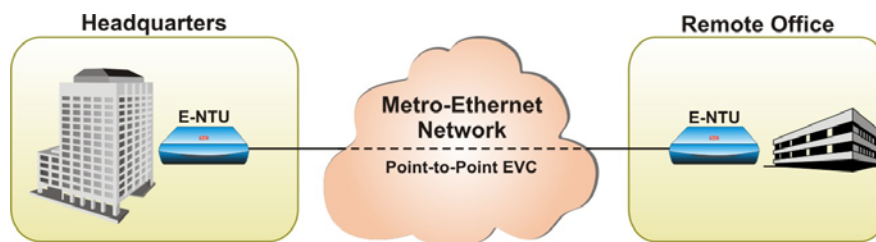
- Standardized Services
- Scalability
- Reliability
- Quality of Service (QoS)
- Service Management

The term “Carrier Ethernet” originally applied only to Metro networks. However, with Ethernet’s growing popularity and the resulting need to ensure acceptable service quality throughout the service path – starting at subscriber premises – and guarantee enforceable service level agreements (SLAs), it was expanded to core and access networks as well. New standards and specifications are being developed to address the above attributes, specifically covering aspects such as connectivity, service and traffic management. As a result, new terminology is used to indicate particular Carrier Ethernet network elements, which originally did not exist in enterprise Ethernet LANs.

## Connectivity

**User Network Interface (UNI):** The demarcation point between the provider’s network and a subscriber. Each subscriber requires a dedicated UNI, supplied by the service provider and typically implemented in an NTU (Network Termination Unit) or EDD (Ethernet Demarcation Device). The UNI presents a service access point to the user, connecting at data rates of 10 Mbps, 100 Mbps, 1 Gbps or 10 Gbps. UNI service attributes typically include connection specifications and bandwidth profile parameters.

**Ethernet Virtual Connection (EVC):** An end-to-end logical connection associating two or more UNIs, in a point-to-point or multipoint-to-multipoint topology. Identified by Service VLAN ID (SVID), an EVC allows transparent delivery of traffic over the metro Ethernet network and prevents leakage of information, by separating user traffic from other users and from internal network control signals. EVC service attributes include parameters such as CE-VLAN ID (customer edge VLAN ID) preservation, frame delivery criteria and QoS values.



*Figure 4:* Ethernet virtual connection

## Services

MEF identifies three types of standardized Carrier Ethernet services, each of which corresponds with a set of UNI attributes and EVC attributes:

**E-Line:** A point-to-point connection, where each EVC links two UNIs. E-Line services can be of either of two variants:

- **Ethernet Private Line (EPL):** An E-Line-type service in which only one point-to-point EVC is supported by the same physical interface at both UNIs, i.e. no service multiplexing is allowed. EPL may be delivered as a guaranteed bandwidth service, whereby the carrier provides SLA-based rate and performance commitments and allocates network resources accordingly, similar to a leased line service.

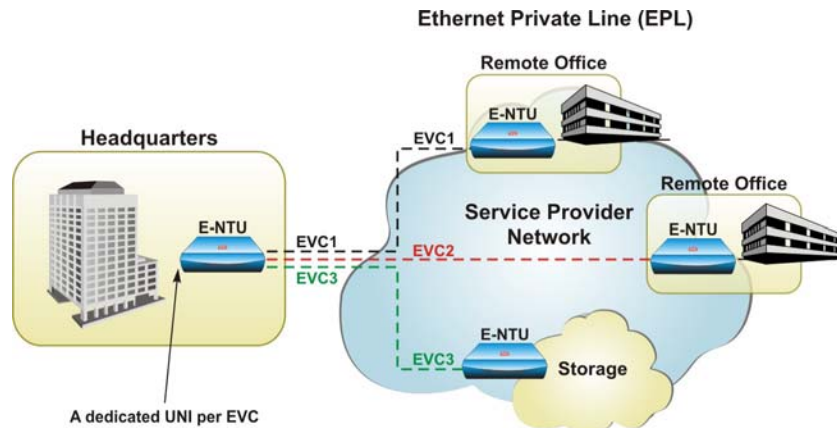
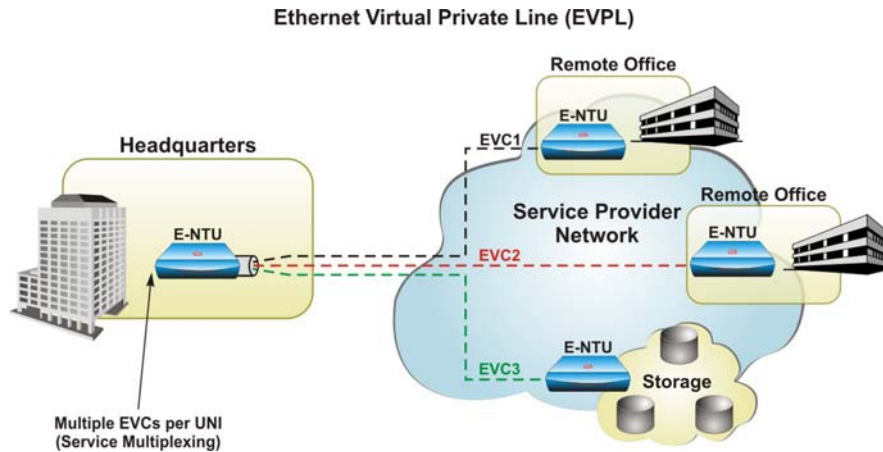


Figure 5: Ethernet private line service

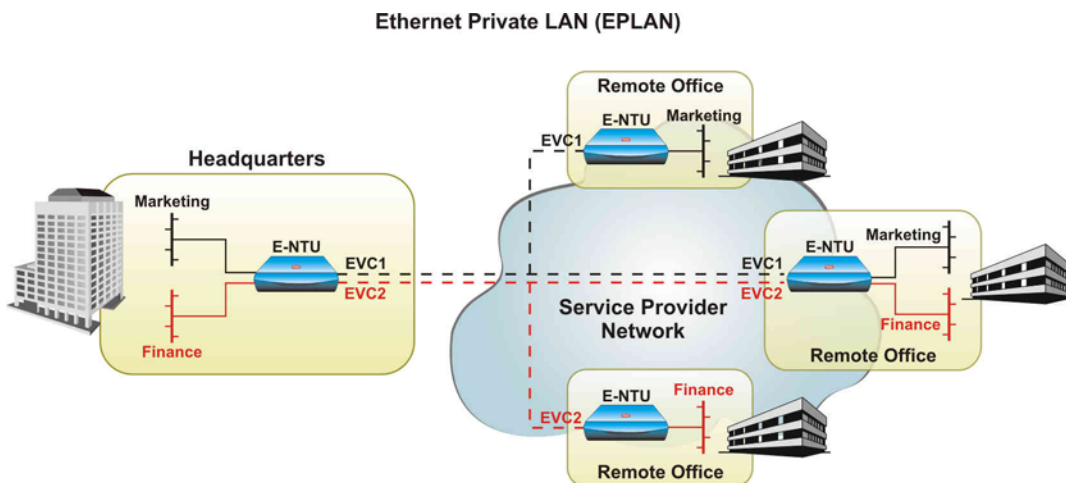
- **Ethernet Virtual Private Line (EVPL):** An E-Line service allowing service multiplexing so that a single UNI supports multiple EVCs. As data frames may be mapped to different EVCs, an EVPL service is not required to provide full frame transparency, unlike an EPL service. User traffic is distinguished by different VLAN IDs and transported over common network resources, thereby necessitating traffic policing/shaping functionalities at the provider network ingress.



*Figure 6: Ethernet virtual private line service*

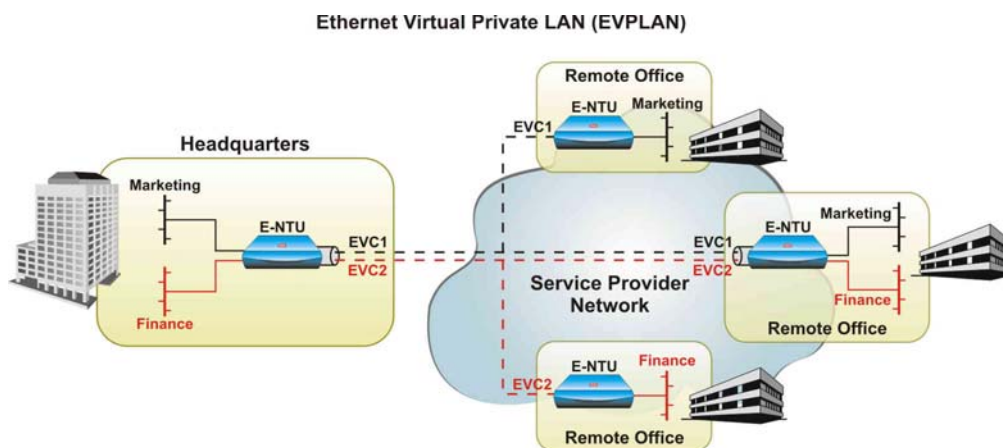
**E-LAN (Ethernet Local Area Network):** A multipoint-to-multipoint topology, where each EVC links more than two UNIs. The following are designated as E-LAN services:

- **Ethernet Private LAN (EPLAN):** A multipoint service requiring a dedicated UNI per EVC, in which service multiplexing is prohibited. Other service attributes are similar to those of a point-to-point EPL service.



*Figure 7: Ethernet private LAN service*

- **Ethernet Virtual Private LAN (EVPLAN):** An E-LAN-type service allowing EVC multiplexing at the UNI, similar in attributes to an EVPL. A flow based EVPLAN service enables service multiplexing for applications such as departmental LAN differentiation – by service, location or user function – at the UNI level.



*Figure 8: Ethernet virtual private LAN services*

**E-Tree:** A service using a multipoint rooted EVC, whereby one or more of the UNIs are classified as “Roots”, while all other UNIs are designated as “Leaves”. Traffic delivery is permitted between a Root and a Leaf, in both directions, but prohibited between Leaves. Specific Root/Leaf subsets and the corresponding traffic delivery rules depend on particular service definitions.

### Mapping Traffic into EVCs

The standardized services described above present several alternatives for network optimization and increased management capabilities, while offering service differentiation to meet diverse customer needs:

**All-to-one Bundling:** All frames from a UNI are mapped to a single EVC, regardless of CE-VLAN ID. An all-to-one bundling map is not compatible with service multiplexing and requires that all UNIs connected by the same EVC are configured with the same service attribute, i.e., no other bundling alternatives are allowed. When implementing all-to-one bundling in Ethernet services, specific CE-VLAN ID/EVC mapping schemes are typically not applied. This eliminates the need for customer-provider coordination and ensures CE-VLAN preservation.

**Bundling:** One or more CE-VLAN IDs are mapped to a single EVC, while multiple EVCs are supported by a single UNI. When implemented, bundling schemes typically ensure CE-VLAN ID preservation and offer an efficient use of available bandwidth, but necessitate customer-provider coordination for specific CE-VLAN ID/EVC mapping schemes.

**One-to-one Bundling:** A bundling attribute in which each EVC is exclusive to a single CE-VLAN at the UNI. It does not imply CE-VLAN preservation but requires customer-provider coordination. One-to-one bundling allows EVC multiplexing at the UNI.

### Quality-Related Attributes

User-provider SLAs include detailed specifications for various service parameters that are defined per EVC and per priority queue, or class of service (CoS), within the EVC. Critical SLA attributes pertain to bandwidth profile and service performance, namely:

**Frame Loss:** Measures the number of frames lost/discarded out of all frames that should have been delivered within a specified time interval.

**Frame Delay:** Defines the travel time across the network for delivered frames and is measured end-to-end as the customer views it, i.e., between ingress UNI-N (network side of the UNI) and egress UNI-N.

**Frame Delay Variation:** Specifies the variation in frame delay as measured by comparing the time interval between consecutive frames at the ingress UNI to the delay in arrival of the same frames at the egress UNI.

## Bandwidth Profile Parameters

An important requirement in promoting Ethernet services to carrier class is the ability to control bandwidth utilization. By implementing rate limiting and policing, service providers are able to manage their network resources efficiently, shape network traffic and charge customers according to contracted usage. At the same time, subscribers benefit from flexibility in tailoring their network services to their specific needs, by purchasing scalable bandwidth rates that fit their traffic requirements. Ethernet bandwidth profile parameters are defined in SLAs and are set in the NTUs connecting customer premises equipment (CPE) to the network. The predominant bandwidth attributes are:

**Committed Information Rate (CIR):** Defines the average bandwidth that the service provider guarantees the user, regardless of network conditions. CIR is typically offered in increments, and must be less than or equal to the UNI rate.

**Committed Burst Size (CBS):** Defines the maximum number of bytes allowed for a burst of back-to-back Ethernet frames. Should a frame size exceed the Committed Burst Size, the frame will be either buffered or discarded (see Excess Burst Size).

**Excess Information Rate (EIR):** Defines an average rate of Ethernet frames allowed into the network based on a "best effort" basis. Service performance for these frames is not guaranteed and depends on available bandwidth. The combined CIR and EIR must not exceed the UNI rate.

**Excess Burst Size (EBS):** The purpose of EBS is to control congestion by allowing user traffic to briefly exceed the CBS threshold and still remain within service boundaries. EBS frames are permitted into the network without performance guarantees and may be queued if bandwidth is not available. Ethernet frames exceeding the EBS threshold are discarded, as are frames exceeding the CBS if EBS is set to zero.

## Bandwidth Profile Enforcement

The Metro Ethernet Forum has defined a leaky bucket algorithm – trTCM (two-rate-three-color marking), implemented via two token buckets to enable a uniform enforcement of the contracted bandwidth profiles.

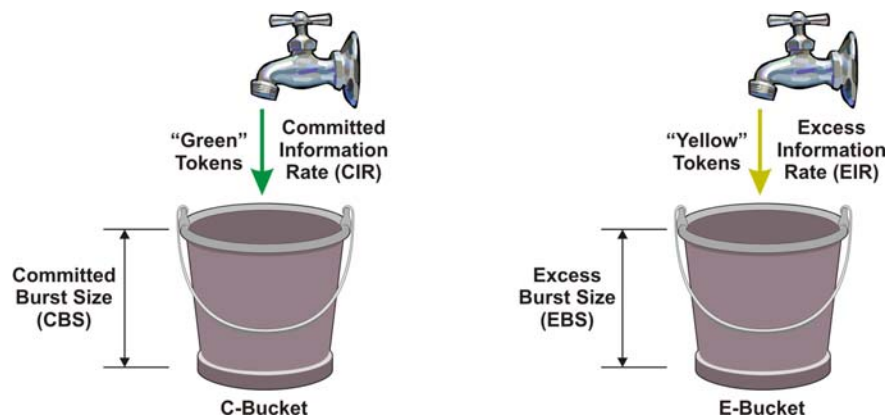


Figure 9: Ethernet bandwidth profile parameters

When using the trTCM algorithm, the “C” bucket refills constantly per CIR, with maximum quantity of “token” bytes in it determined by the CBS and the product of  $\frac{CIR}{8} \times \Delta T$ , where  $\Delta T$  is the time interval between arriving frames. Compliant ingress frames, i.e. having frame size that is lower or equal to the quantity of available “C” tokens at the frame’s arrival time, are marked as “GREEN” and admitted to the network. Non-compliant frames are transferred to the “E” bucket. Here, too, the bucket refills constantly according to EIR, with maximum quantity of “E” bytes determined by  $\frac{EIR}{8} \times \Delta T$  and the EBS. Conforming frames are marked as “YELLOW” and admitted to the network on a best-effort basis, labeled with lower priority than the GREEN frames. Frames exceeding the EBS are marked as “RED” and discarded.

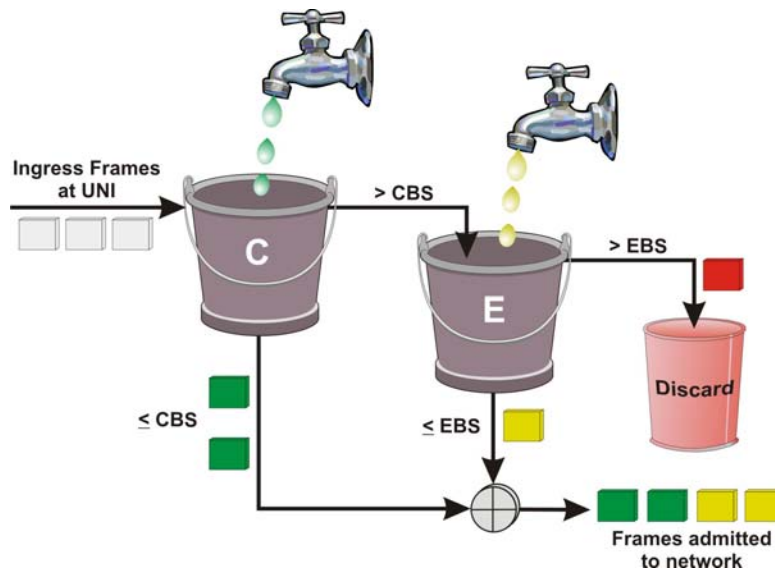


Figure 10: Ethernet two-rate-three-color rate limitation

Another bandwidth profile parameter, the Coupling Flag (CF), controls the number of frames that are designated as Yellow. A "0" CF value confines the long-term average bit rate of Yellow frames to the contracted EIR. A CF value of "1", however, signifies that such boundary equals the combined rate of EIR and CIR, depending on the volume of Green frames. It should be noted that, in both cases, the burst size of Yellow-declared frames is bounded by EBS.

The various traffic profiles can be defined either per UNI, per individual EVCs within a UNI, or per CE-VLAN Class of service within a single EVC, as can be seen in figures 11 through 13. In the latter case, user-defined priority levels are assigned to delay-sensitive traffic (e.g. VOIP), premium traffic (e.g. billing) and low priority/"best effort" traffic (e.g. Internet service).

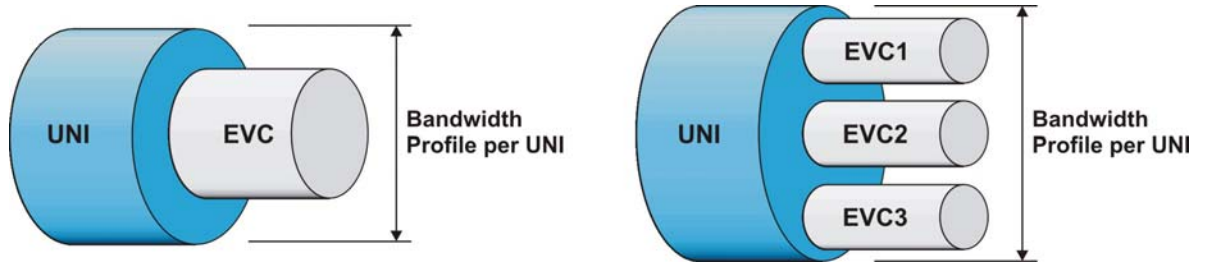


Figure 11: Ethernet bandwidth profile per UNI

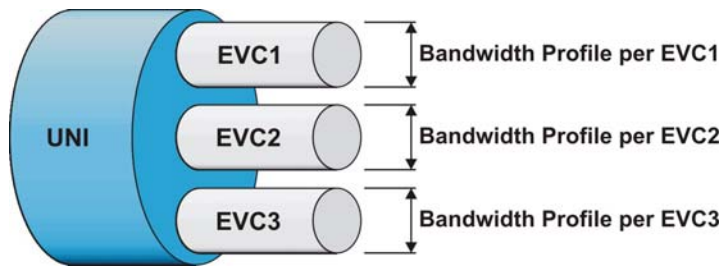


Figure 12: Ethernet bandwidth profile per EVC

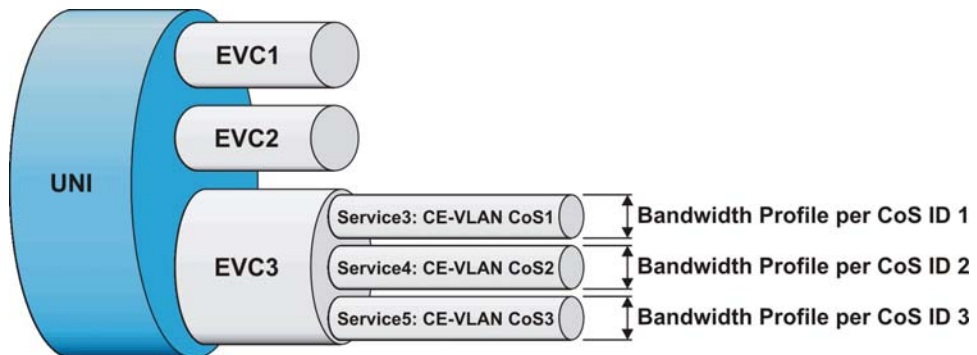


Figure 13: Ethernet bandwidth profile per CE-VLAN

## Ethernet OAM

OAM is a set of functions designed to monitor network operation in order to detect network faults and measure its performance. As Ethernet evolves from enterprise-level LANs to carrier-class networks and services, it requires automated end-to-end management and monitoring by service providers. As a result, Ethernet is the most recent communications protocol to adopt OAM capabilities such as connectivity verification, fault detection, performance monitoring, and alarm indication. OAM functionality allows network operators to measure quality of service attributes such as Availability, Frame Delay, Frame Delay Variation (“Jitter”) and Frame Loss. Such measurements enable identification of problems before they escalate so that users are not impacted by network defects. Furthermore, these capabilities allow the operators to offer binding SLAs and generate new revenues from rate- and performance-guaranteed service packages that are tailored to the specific needs of their customers.

Effective end-to-end service control also enables carriers to avoid expensive truck rolls to locate and contain faults thereby facilitating reduction of maintenance costs. Intrinsic OAM functionality is therefore essential in any carrier class technology and is a “must have” capability in intelligent Ethernet network termination units.

### OAM Standards

A significant milestone in making Ethernet services carrier-grade is the development of industry standards. The IEEE (Institute of Electrical and Electronics Engineers), ITU (International Telecommunication Union) and MEF (Metro Ethernet Forum), have been working in close cooperation to establish complementary, rather than overlapping, Ethernet OAM standards:

**IEEE Standard 802.3-2005 (previously 802.3ah, Clause 57) – “Ethernet Link OAM”** was originally developed for Ethernet in the First Mile (EFM) applications and was also known as “EFM OAM”. It relates to a single Ethernet link within a network. In addition to defining Ethernet delivery over copper, fiber and PON (Passive Optical Network) media, IEEE 802.3-2005 specifies the following link monitoring OAM procedures:

- Discovery
- Remote failure indication, including link fault, dying gasp and other critical event indications
- Remote loopback testing
- Link performance monitoring
- Management Information Base (MIB) variable retrieval
- Organization-specific functions

**IEEE Standard 802.1ag – “Ethernet Service OAM”**, covers the scope of Ethernet service over any path, whether a single link or end-to-end, enabling service providers to fully monitor Ethernet service regardless of the layers supporting the service, the network path over which Ethernet traffic is traversing, or the various network operators involved. IEEE 802.1ag is also termed “Connectivity Fault Management (CFM)”. It divides a network into maintenance domains in the form of hierarchy levels, which are then allocated to users, service providers and operators. CFM assigns maintenance end points (MEPs) to the edges of each domain and maintenance intermediate points (MIPs) to ports within domains. This helps define the relationships between all entities from a maintenance perspective, to allow each entity to monitor the layers under its responsibility and easily localize problems.

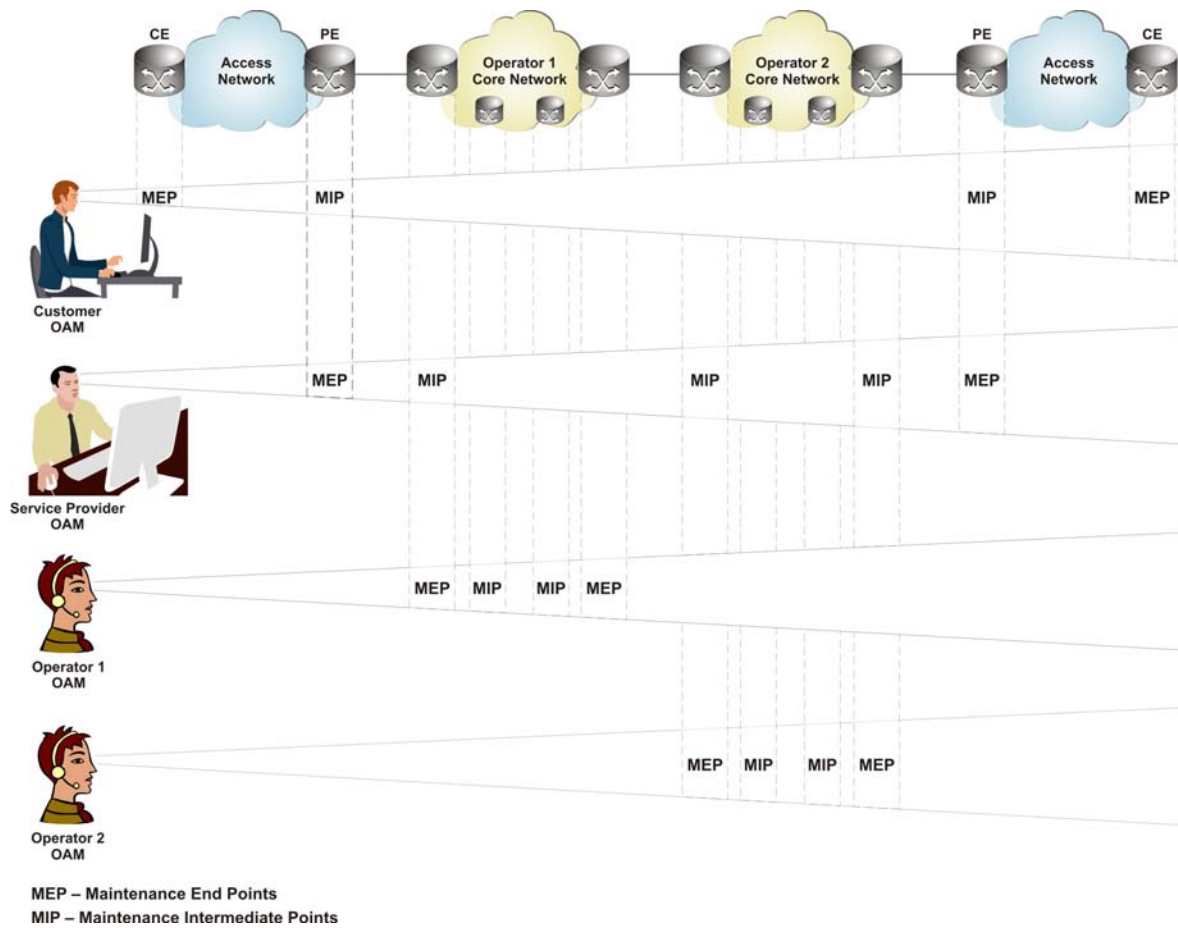


Figure 14: Ethernet service OAM

The following procedures are included in IEEE 802.1ag standard:

- Connectivity check
- Loopback
- Link trace

ITU-T Standard Y.1731 – “OAM Functions and Mechanisms for Ethernet Based Networks” uses different terminology than IEEE 802.ag and adds the following Ethernet Service OAM features:

- Fault Management:
  - Ethernet Alarm Indication Signal (ETH-AIS)

- Ethernet Remote Defect Indication (ETH-RDI)
- Ethernet Locked Signal (ETH-LCK)
- Diagnostics:
  - Ethernet Test Signal (ETH-Test), including throughput measurements
- Performance Management:
  - Frame Loss Measurements (ETH-LM)
  - Frame Delay Measurements (ETH-DM)
  - Frame Delay Variation Measurements

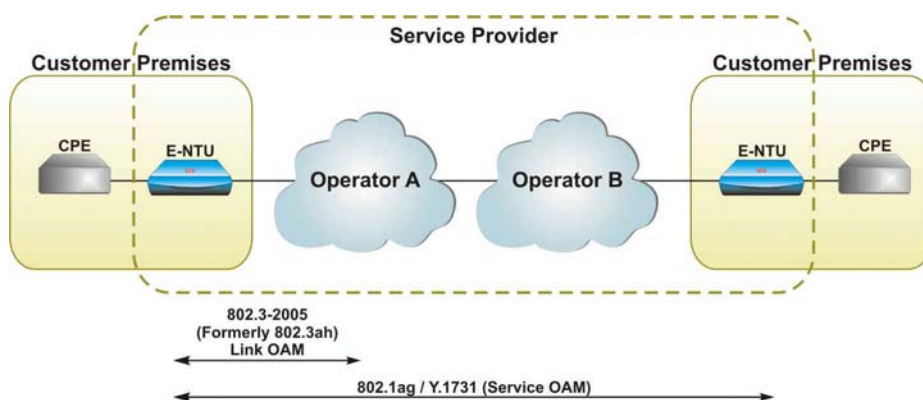


Figure 15: Ethernet OAM

**MEF Technical Specification 17 – “Service OAM Requirements and Framework”** is currently at Phase 1 and marks MEF’s effort to outline the requirements from Service OAM mechanisms, specifically among Metro Ethernet (ME) network elements. MEF 17 addresses the following Services OAM functionalities:

- Fault Management (including detection, verification, localization and notification)
- Performance Monitoring (including performance parameters measurements)
- Auto-discovery (including discovering service-aware network elements within provider networks)
- Intra-provider and inter-provider Service OAM

## RAD's EtherAccess Portfolio



As a leading vendor in the evolving Carrier Ethernet Access market, RAD has developed a suite of sophisticated products offering Ethernet access functionality and versatility that are unmatched in the market. RAD's EtherAccess® portfolio was developed to allow providers to extend their customer reach, regardless of the available access infrastructure, while enabling proactive service management and SLA enforcement with smart Ethernet demarcation. The EtherAccess product line is also designed to support operators in migrating their legacy services to packet networks, to reduce service costs and prevent customer churn. Featuring intelligent Ethernet demarcation units, aggregators and integrated access devices, EtherAccess products ensure a consistent user experience by incorporating common service attributes over fiber, DSL and copper circuits. Furthermore, EtherAccess' design include support for standardized Ethernet Virtual Private Line (EVPL) and Ethernet Private Line (EPL), bringing end-to-end service control to a multi-vendor, multi-access technology environment.

### EtherAccess Products

RAD's EtherAccess product suite features intelligent Ethernet demarcation units, aggregators and integrated Ethernet in the First Mile (EFM) access devices over fiber, DSL and copper circuits:

EtherAccess Products	
<a href="#">Egate-100</a>	Gigabit Ethernet over TDM Aggregation Gateway
<a href="#">RICi-16</a>	Ethernet over Bonded PDH Network Termination Unit (NTU)
<a href="#">RICi-155GE</a>	Gigabit Ethernet over Two STM-1/OC-3c NTU
<a href="#">RICi-4E1/T1, RICi-8E1/T1</a>	Fast Ethernet over 4 or 8 E1/T1 NTUs
<a href="#">ETX-102, ETX-202</a>	Carrier Ethernet Demarcation Devices
<a href="#">ETX-201</a>	Carrier Ethernet Demarcation Devices

EtherAccess Products (Cont.)	
<a href="#">ETX-202A</a>	Carrier Ethernet Demarcation Devices
<a href="#">LA-210</a>	DSL EFM Network Termination Unit (NTU)
<a href="#">IPmux-24</a>	TDM Pseudowire Access Gateway

### Carrier-Grade Service Features

EtherAccess products have been incorporated with advanced carrier-grade features, enabling complete service management with remote monitoring and automated diagnostics, to ensure five nines (99.999%) reliability and network resiliency as well as end-to-end performance guarantees and service differentiation per customer requirements. EtherAccess portfolio's main standardized service features include:

- **Ethernet OAM** functionalities for **Ethernet Link OAM** as well as **Ethernet Service OAM**, including connectivity check, link trace, MAC swap loopback, dying gasp, and other remote failure indication signals, full path redundancy and fault propagation. EtherAccess products comply with IEEE 802.3-2005 (formerly 802.3ah), IEEE 802.1ag, and with ITU-T Y.1731 standards.
- **MEF**-certified service attributes conforming to **MEF 9** and **MEF 14** specifications, to support **E-Line** and **E-LAN** service topologies and the rollout of EPL and EVPL services.
- Traffic management capabilities with **traffic classification and prioritization** and **bandwidth control** per user port, per Ethernet flow and per class of service, allowing QoS enforcement and SLA measurement for real-time, priority and best effort-services. Performance guarantees are further enhanced with bandwidth profile attributes such as Committed Information Rate, Committed Burst Size, Excess Information Rate and Excess Burst Size.
- Separation between different user traffic as well as between user and management traffic, enabling services such as inter-office LAN connectivity, Internet access and secure virtual private networks (VPNs). Additional **V-LAN Stacking (Q-in-Q)** functionality allows transparent delivery of user traffic and class of service differentiation.

- Network optimization features for **Ethernet over PDH/SDH** services, employing standard encapsulation and bonding protocols such as ITU-T G.8040 **GFP** (Generic Framing Procedure), ITU-T G.7043 **VCAT** (Virtual Concatenation) and ITU-T G.7042 **LCAS** (Link Capacity Adjustment Scheme). GFP, VCAT and LCAS protocols eliminate SDH/SONET bandwidth restrictions and provide bandwidth-on-demand flexibility for delay-sensitive applications.
- **Legacy service emulation support** for applications such as PBXs connectivity and cellular transport. Using **pseudowire** and clock recovery mechanisms for **timing synchronization** per ITU-T G.823 and G.824 specifications, EtherAccess products prevent packet delay variations and packet losses caused by clocking issues in end-to-end TDM and ATM services over Ethernet backhaul.
- Multi-pair aggregation utilizing EFM bonding for **2Base-TL Ethernet over SHDSL** access, allowing carriers to leverage their installed DSL infrastructure to deliver Ethernet services where fiber is not present.
- Verified **interoperability** with non-proprietary equipment, encouraging operator confidence in system reliability and bringing end-to-end service control to a multi-vendor technology environment.

### Optimizing Carrier Ethernet Service

The support offered by RAD's EtherAccess products for Carrier Ethernet services over diverse access networks has significance extending beyond the resolution of technological challenges. With EtherAccess solutions, carriers benefit from enhanced service provisioning capabilities that had been formerly unavailable for Ethernet services, affecting their revenues, market positioning and growth strategy:

**Balanced transition to PSNs:** Service providers wishing to offset the revenue erosion associated with the high costs of legacy services are offered a scalable migration path to packet networks. With RAD's EtherAccess products, providers can leverage their investment in TDM and ATM equipment in their transition to new services, while continuing to deliver their on-going voice and data service commitments. Moreover, by converging all services in a single network environment with unified management procedures, carriers avoid additional capital investments in dedicated infrastructure equipment.

**Customer retention:** Users have been increasingly demanding higher bandwidth speeds at lower rates. The EtherAccess product line helps carriers easily respond to market changes and meet the demand for low cost, high-speed services. Furthermore, it enables them not only to prevent subscriber churn but also to increase their customer base by extending their reach and offering access-transparent, ubiquitous Ethernet connectivity.

**Cost reduction:** EtherAccess product suite has been designed to facilitate cost effective deployments with quick installations and “pay as you grow” scalability. Moreover, remote network control with automated fault detection and management features allow providers to reduce their OpEx, by avoiding expensive truck rolls and other manual service elements. This issue is of particular importance in light of the typically low price points of Ethernet services, which compel carriers to maintain stringent control over their OpEx.

**Improved service:** EtherAccess’ proactive service monitoring, bandwidth optimization and traffic shaping capabilities enable carriers to utilize their network resources more efficiently and avoid long downtimes. Such capabilities also allow flexibility in tailoring network services to individual traffic needs, and establish measurable and binding SLAs.

**Carrier-grade business model:** With EtherAccess’ enhanced QoS attributes, service providers can generate new revenues by offering customized, SLA-based packages for Ethernet services, including previously unavailable rate guarantees for mission critical applications. EtherAccess smart demarcation devices also allow carriers to offer fine bandwidth rate granularities and charge customers by contracted usage.



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