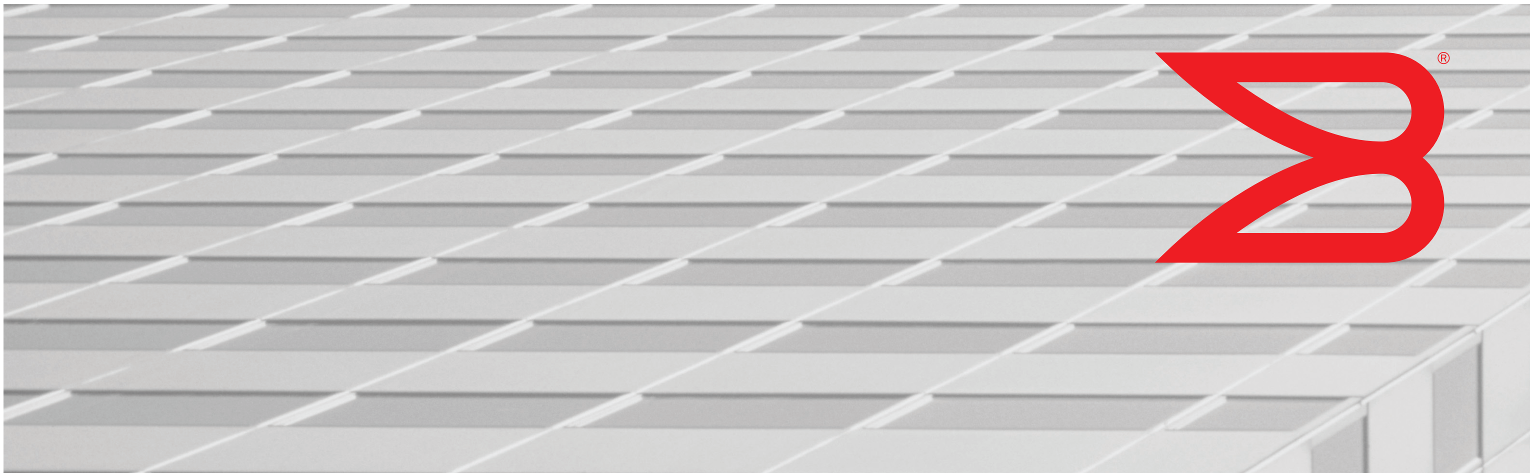

IP NETWORK

What is Carrier Grade Ethernet?

The ability to transport Ethernet over different transport technologies raises the exciting proposition of Ethernet services not only in campus or metro networks but also at a global level.

BROCADE

The ability to continuously adapt has made Ethernet a significant innovation in facilitating unified communications. Since the invention of Ethernet in the 1970s, Ethernet has proven itself to be a technology that can adapt to evolving market needs. Ethernet was initially developed as a LAN standard for connecting at 10 Mbps speeds but has subsequently been upgraded to offer 100 Mbps, 1 Gbps, and now 10 Gbps speeds over both copper and fiber media.

Ethernet is one of the most significant disruptive innovations of this generation—and has now evolved from Local Area Networks (LANs) to the Metro Area Network (MAN). The implications of these capabilities are immense.

With Ethernet now the de facto standard for networking in any enterprise, customers of Ethernet services can enjoy the ease-of-use benefits that come from long familiarity with Ethernet and apply this knowledge to address their Wide Area Network (WAN) connectivity needs. A number of standards groups, including IEEE, IETF, ITU and MEF, are working to enhance standards for Ethernet services. This paper explains the fundamentals of Carrier Ethernet and examines how service profiles and Service Level Agreements (SLAs) can be defined in Carrier Ethernet.

CARRIER ETHERNET COMPARED WITH TRADITIONAL LAN-BASED ETHERNET

Ethernet has been around as a LAN technology for over two decades. So, what distinguishes Carrier Grade Ethernet from traditional LAN-based Ethernet?

Carrier Grade Ethernet, or Carrier Ethernet, is a ubiquitous, standardized service defined by five attributes described in the following sections. The key phrase is “standardized service.” Carrier Ethernet services can be delivered not only over traditional (native) Ethernet-based networks but can also over other transport technologies. Examples of underlying transport mechanisms that could be used are:

- Native Ethernet
- MPLS-based Layer 2 Virtual Private Networks (VPNs)
- IEEE 802.1ad Provider Bridges
- Ethernet over SONET

This unified approach to Carrier Ethernet cost effectively extends the compelling benefits of Ethernet to help both service providers and end users of Carrier Ethernet services achieve substantial savings. Unparalleled economies of scale result from business, residential, and wireless networks sharing the same infrastructure.

FIVE ATTRIBUTES OF CARRIER ETHERNET

Carrier Ethernet has five attributes, shown in Figure 1 and described in this section.

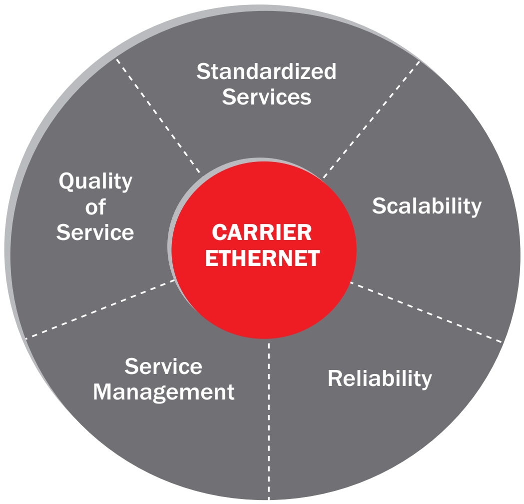

Figure 1.
The five attributes of Carrier Ethernet.

Attribute 1: Standardized Services

The Metro Ethernet Forum (MEF) has currently defined two standardized service types for the delivery of Carrier Ethernet. These services are defined from the perspective of the User Network Interface (UNI), that is, the demarcation point between a provider's Ethernet network and a customer's private network.

E-LINE is a point-to-point Ethernet Virtual Connection (EVC) between two user network interfaces in an Ethernet network (see Figure 2). An E-LINE service type can be offered in two flavors by a provider:

- **Ethernet Private Line (EPL)** service provides a point-to-point service between two UNIs and offers a high degree of transparency for customer frames. A dedicated physical interface is used to provide this transparency, so the EPL service requires very little coordination between the provider and the customer. An EPL service is an ideal replacement for an existing leased line service that a customer may be using.
- **Ethernet Virtual Private Line (EVPL)** service offers the additional ability to do service multiplexing at the UNI. In other words, an EVPL service provides the capability to offer more than one EVC at a UNI, with some customer frames sent to one EVC and others sent to another EVC. An EVPL can also provide multiple Class of Service (CoS) levels at a UNI for different customer frames. An EVPL is an ideal replacement for an existing point-to-point Frame Relay Connection or an ATM Permanent Virtual Circuit (PVC) that a customer may be using.

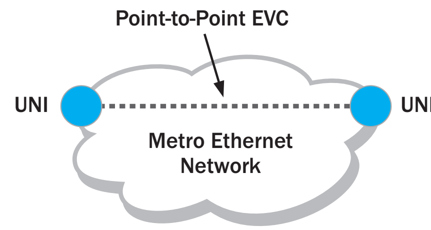

Figure 2.
An E-LINE service.

E-LAN is a multipoint-to-multipoint Ethernet Virtual Connection that offers multipoint connectivity between multiple UNIs in a Carrier Ethernet network (see Figure 3).

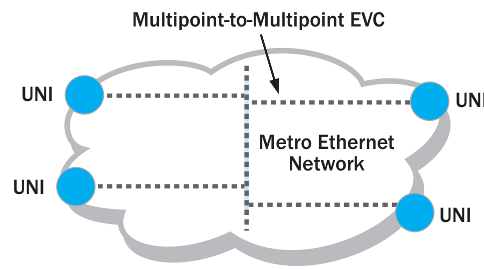

Figure 3.
An E-LAN service.

As part of these standard service definitions, attributes are defined for each service. These attributes allow a provider to customize the service to end user expectations and build resulting Service Level Agreements (SLAs). Examples of service attributes that could be offered for each service are:

- Physical speed offered at the UNI
- Bandwidth profile at each UNI using parameters that include:
  - Committed Information Rate (CIR)
  - Committed Burst Size (CBS)
  - Excess Information Rate (EIR)
  - Excess Burst Size (EBS)
- Bandwidth profile per Class Of Service (CoS) identifier
- Layer 2 Control Processing behavior, for example, should the network peer discard or forward Layer 2 protocol frames such as BPDUs and GARP frames at the UNI?

This approach to offering standardized services requires no changes to customer LAN equipment or networks. By defining a choice of granular bandwidth and QoS options, providers have the freedom to define a service that can be customized to the end user needs. The use of advanced QoS service attributes also makes Carrier Ethernet ideally suited for the delivery of multi-play services (voice, video, and data) over a converged infrastructure. In this regard, the work done by MEF on Carrier Ethernet also complements the work of other recognized standards such as the DSLForum TR-101, which defines the migration to Ethernet-based Digital Subscriber Line (DSL) aggregation networks.

Attribute 2: Scalability

A 2006 market study from In-Stat found that one of the most compelling reasons for migration to Ethernet was the scalability offered by Ethernet. With many businesses seeing capacity growth rates of 20 to 30 percent per annum, Ethernet scalability is seen as vital to meeting this capacity demand. Ethernet is already available in a wide range of interface speeds from 10 Megabits per second (Mbps) to 10 Gigabits per second (Gbps). The Higher Speed Study Group (HSSG) of IEEE is already working on defining the standards for a

100 Gigabit Ethernet (GbE) interface. Intermediate speeds between standard Ethernet physical rates can be achieved using Link Aggregation.

At the other end of the spectrum, mid-band Ethernet allows voice-grade copper lines to deliver speeds of 2 Mbps or increments thereof using bonding. Intermediate speeds between standard Ethernet physical rates can be achieved using Link Aggregation. No other technology comes even remotely close to offering such a broad range of bandwidth options. Contrast this with frame relay services, for example, which typically top out at T3 (45 Mbps) speeds.

An appealing attribute of Carrier Ethernet is the ability for a user to easily upgrade the bandwidth of an existing Ethernet service without requiring the service provider to do a truck roll in most cases. This is because of the ability to have a single physical interface that can scale to 10/100/1000 Mbps, so that bandwidth changes to a user service profile can be done easily via software control at the Network Operations Center (NOC). This capability can also enable the delivery of several interesting applications such as requesting bandwidth on demand for a short period of time, customer self-provisioning portals, and more.

Scalability transcends the availability of faster interfaces. The ability for millions to use a network service that is ideal for the widest variety of business, information, communications, and entertainment applications is testimony to the versatility of a Carrier Ethernet service. What this means is that irrespective of the type of application, Carrier Ethernet provides the necessary Quality of Service (QoS) guarantees required for these applications to be seamlessly delivered over a common infrastructure.

The third dimension to scalability is geographical reach. Carrier Ethernet spans metro, national, and global networks. Work is ongoing at MEF to also standardize the interconnection of Ethernet networks operated by different service providers to further increase the reach of such services and offer customers a consistent end-to-end service.

Attribute 3: Reliability

Traditional LAN-based Ethernet was often perceived as a best-effort connectivity mechanism. Carrier Ethernet in contrast offers the capability to rapidly detect and recover from node, link, or service failures to offer a very high availability service to the end user. Recovery from failures, when they do happen, occurs in less than 50 milliseconds. This capability meets the most demanding quality and availability requirements for the delivery of mission-critical enterprise applications, high-quality voice and video services, and in the most generic case, any application requiring a demanding SLA.

Attribute 4: Quality of Service

As mentioned previously, Carrier Ethernet offers a wide range of granular bandwidth and QoS options. By defining attributes that are associated with the service, advanced SLAs can be offered to deliver the performance required for a target application. Carrier Ethernet allows the assurance of advanced SLAs using QoS guarantees that are made possible by service attributes associated with the service type:

- Committed Information Rate (CIR): a rate that is guaranteed by the provider's network at the UNI
- Frame loss: a guarantee to deliver customer frames, the ratio of undelivered frames to total customer frames received by the network
- Delay: a commitment to end-to-end network latency between two customer UNIs less than this target
- Delay variation: a commitment to no more than a specified jitter or variation in latency

For example, voice typically requires low delay and low-delay variation guarantees. Many financial applications that distribute time-sensitive information also require low frame loss guarantees in addition to delay and delay-variation guarantees.

Attribute 5: Service Management

The fifth critical service attribute that distinguishes Carrier Ethernet is the ability to monitor, diagnose, and centrally manage the network using standards-based vendor independent tools. In order to do such advanced service management, tools are required to:

- Rapidly provision services
- Diagnose connectivity-related problems reported by a customer
- Diagnose faults in the network not only at the end-points but also at intermediate points in a network
- Measure the performance characteristics of a service being delivered

Several tools have been standardized or are in the process of standardization to help accomplish these tasks:

- IEEE 802.3ah OAM provides tools for link monitoring, remote failure indication, and remote loopback on a link.
- IEEE 802.1ag Connectivity Fault Management provides tools for service-level OAM and detecting, isolating, and reporting connectivity faults in a provider network. The IEEE 802.1ag draft is currently at an advanced stage of standardization in the IEEE 802.1 Working Group.
- ITU Y.1731 covers connectivity management and also provides tools to measure performance parameters for a service such as frame loss ratio, frame delay, and frame delay variation.
- MEF 15 defines the requirements for management of network elements by an external management system.

Providers can use these advanced tools for managing the services in a Carrier Ethernet network.

ANALYST PERSPECTIVE

The rapid progress in the work done by standards bodies mentioned previously and the benefits experienced by early adopters of Carrier Ethernet services have reinforced the positive perspective of analysts tracking the Carrier Ethernet market.

Bryan Van Dussen, Director at In-Stat Research states, “Other than IP, few network services have the potential to transform business networking like Ethernet. It is the ideal complement for businesses & users that rely on network-centric applications” (“Assessment of Ethernet Enterprise Demand Drivers,” talk given by Bryan Van Dussen, In-Stat Research to MEF on October 31 2006).

Infonetics Research estimates that worldwide Ethernet services revenue jumped 132 percent between 2004 and 2005 to $5.9 billion (“Ethernet Services Market Size and Forecast”, Infonetics Research, April 2006). Further, Infonetics forecasts that worldwide Ethernet services revenue will increase 280 percent between 2005 and 2009 to $22.5 billion. Of this, Asia Pacific is estimated to account for over 40 percent of total Ethernet service revenue, EMEA over 30 percent, and North America over 20 percent.

Analysts Charles Carr and Steve Koppmann of Gartner say that “EPL in new deployments is simpler to implement and generally less costly for the customer than traditional private line service and frame relay from a total cost of ownership (TCO) perspective” (“Ethernet Private Line Offers Cost-Effective Alternative to Frame Relay, Standard Private Line”, Gartner Research, 23 August 2005).

HOW CAN END USERS BENEFIT FROM CARRIER ETHERNET?

End users currently using legacy services such as leased lines, ISDN, frame relay, or ATM services can realize substantial benefits by migrating to Ethernet services. These benefits result from the lower price per bit when using Ethernet service and simplified operations achieved by extending the use of Ethernet to the WAN. Table 1 provides some examples of how end users can take advantage of Carrier Ethernet services offered by their provider.

Current Service Model	Alternative to Consider when Exploring Carrier Ethernet
Leased Line	Ethernet Private Line (EPL)
Frame Relay Connection or ATM PVC	Ethernet Virtual Private Line (EVPL)
Several point-to-point leased lines or ATM/FR PVCs from remote sites to a central hub	E-LAN service for true multi-point connectivity

Table 1.
Taking advantage of Carrier Ethernet services.

Service Profile and SLAs for Carrier Ethernet

Following is an example of a service profile with associated service attributes. The service level specification should be specified at each UNI as well as for the specific Ethernet Virtual Connection service offered by the provider's network.

An end user, Jay Corporation, wants to purchase a point-to-point "gold" Ethernet Private Line (EPL) service with a 5 Mbps committed rate from a service provider. Assume that there are two UNI interfaces to the provider's network located in San Jose and New York. These UNI interfaces are called *epl_jay_uni_sanjose* and *epl_jay_uni_newyork,* and the EVC that extends between these two UNIs is *epl_jay_evc*. Assume also that frames from gold users are mapped to Class of Service 6 by the provider's network. Tables 2 and 3 show the service attributes that define the service profile for this service.

UNI Service Attribute	Value
UNI identifier	epl_jay_uni_sanjose
Physical medium	IEEE 802.3-2002
Speed	10 Mbps
Mode	Full Duplex
MAC layer	IEEE 802.3-2002
Service multiplexing	No
Bundling	No
All-to-one bundling	Yes
UNI Ethernet Virtual Connection ID	epl_jay_evc
Customer VLAN ID/EVC map	All frames from the customer are mapped to epl_jay_evc
Maximum number of EVCs	1
Layer 2 Control Protocols processing	Tunnel STP/RSTP/MSTP BPDUs, 802.1x frames, LACP frames, GARP frames Discard PAUSE (802.3x) frames
Bandwidth profile per ingress UNI	Committed Information Rate (CIR) = 5 Mbps Committed Burst Size (CBS) = 5000 bytes Excess Information Rate (EIR) = 0 Excess Burst Size (EBS) = 0

Table 2.
Service profile for a user at the UNI.

Table 3.
Service profile for the EVC *epl_jay_evc* offered by the Carrier Ethernet network.

EVC Service Attribute	Value
EVC identifier	epl_jay_evc
EVC type	Point-to-Point
UNIs associated with this EVC	epl_jay_uni_sanjose, epl_jay_uni_newyork
Customer VLAN ID preservation	Yes
Customer VLAN CoS preservation	Yes
Unicast service frame delivery	Deliver unconditionally
Multicast service frame delivery	Deliver unconditionally
Broadcast service frame delivery	Deliver unconditionally
Layer 2 Control Protocols processing	Tunnel STP/RSTP/MSTP BPDUs, 802.1x frames, LACP frames, GARP frames Discard PAUSE (802.3x) frames
Service performance assured by the provider's network	CoS ID = 6 Frame delay <= 10 milliseconds Frame-delay variation <= 2 milliseconds Frame loss ratio <= 0.005 percent

Note that if Jay Corporation now wants a higher CIR of say 8 Mbps at one or both of the UNIs, there is no requirement for a truck roll—a simple change to the CIR value in the service profile is sufficient for the provider to meet this request.

BROCADE SOLUTIONS FOR DELIVERING CARRIER ETHERNET SERVICE

As an early and active member of the MEF, Brocade has incorporated requirements from the MEF specifications in its new generation of products. A provider can choose from a range of underlying transport technologies when delivering Carrier Ethernet service over a Brocade infrastructure. These include:

- High-performance Layer 2 switching
- Newer Ethernet switching standards such as IEEE 802.1ad (Provider Bridges) or IEEE 802.1ah (Provider Backbone Bridges)
- MPLS-based offerings to facilitate converged networks
- Ethernet transport over SONET networks

The Brocade NetIron MLX and XMR product lines are certified for both MEF 9 and MEF 14. Providers planning Carrier Ethernet service delivery can therefore deploy these platforms with the assurance that the service will be in full compliance with the corresponding MEF specifications.

Both the Brocade NetIron MLX and XMR platforms are built with a capacity of 100 Gbps of full-duplex bandwidth per full slot. Both platforms are based on a distributed, high-performance, ultra-low latency, network-processor-based architecture. This combination provides unparalleled scalability, flexibility, and headroom for future growth in a provider's network, thereby providing investment protection for several years. The NetIron MLX and XMR platforms provide the broadest range of service flexibility, starting from 8 Kbps all the way up to 80 Gbps trunks. Both inbound and outbound traffic policing are supported in granular increments of 8 Kbps across this entire range.

The Brocade NetIron CES 2000 Series is a 1U compact edge/aggregation platform that is purpose-built for Carrier Ethernet service delivery to the edge of the network. Built for compliance with MEF 9 and MEF 14 specifications, the NetIron CES 2000 Series of switches support both PBB and PB technologies. When used in combination with the NetIron XMR and MLX routers in the backbone, scalable Carrier Ethernet services can be delivered by combining VPLS/VLL technologies in the core with PB/PBB technologies at the edge of the network.

The Brocade NetIron XMR, NetIron MLX, and NetIron CES 2000 product families are all powered by the Multi-Service IronWare operating system, which leverages over 12 years of routing and switching expertise.

For a provider, these benefits directly translate into advanced, high-margin SLAs that can be offered to end users. For example, the low-latency architecture of Brocade platforms can be used by a provider to offer very low end-to-end delay and jitter commitments in the network. The fine granularity of traffic policers along with the advanced QoS architecture on these platforms aids a provider in offering granular CIR commitments to end users. By deploying equipment that is purpose-built for wire-speed performance, very low frame loss guarantees can be easily incorporated into an SLA.

Each product is available in several form factors. An operator can choose the optimal model to match a particular site's needs.

SUMMARY

Carrier Ethernet and Ethernet-based services are seeing rapid adoption globally. The compelling attributes of Carrier Ethernet, that is, standardized service definitions, scalability, reliability, Quality of Service, and service management, have contributed to the increased interest in Carrier Ethernet services. These services help providers realize significant savings in operational expenses annually and offer providers a strong competitive advantage. Similarly, end users can realize substantial savings and higher performance by switching to a Carrier Ethernet service from their network service provider. Brocade's offerings for this fast-growing market allow cost-efficient, highly scalable delivery of high-performance Carrier Ethernet services.

To learn more, contact your Brocade sales representative or visit www.brocade.com.

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