Delivering Ubiquitous Ethernet Services using an Array of Access Technologies

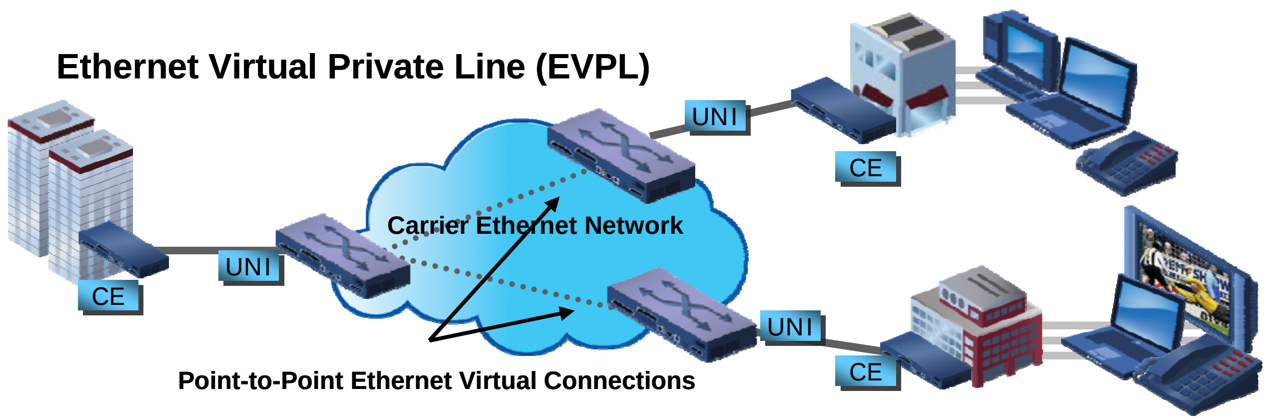
Abstract

This MEF white paper provides an overview of the various access technologies (also referred to as "first-mile" or "last-mile" technologies) that are used to deliver MEF-compliant Carrier Ethernet services. The goal of this white paper is to illustrate the fact that Service Providers who wish to deliver a ubiquitous Carrier Ethernet service can and should deploy a number of available access technologies to ensure they can reach all of their business customers' locations.

Carrier Ethernet and MEF Ethernet Services

The MEF has defined Carrier Ethernet as a ubiquitous, standardized, carrier-class service and network with five attributes that distinguish it from familiar LAN-based Ethernet. These attributes are standardized services, scalability, reliability, management and quality of service.

The basic Carrier Ethernet service building blocks are E-Line (Ethernet Private Line and Ethernet Virtual Private Line), E-LAN and E-Tree. This white paper discusses their deployment in the access network.



Introduction

Corporate IT managers are exploring ways to add network capacity while maintaining or reducing their recurring operating expenses. Increasingly, businesses are moving away from traditional TDM, Frame Relay or ATM circuits and turning to Carrier Ethernet Services to address these apparently conflicting needs. Service providers have responded with rich offerings that combine heretofore unmatched scalability and flexible bandwidth options with reliability and quality of service previously only available with "old-school" telecom circuits.

Industry forums and standards bodies like the MEF, IEEE, ITU-T and IETF have developed the necessary extensions to the original Ethernet protocol, making it suitable for service provider applications. For its part, the MEF has documented numerous technical requirements for building and managing feature-rich business-class Ethernet services. In addition, the MEF has developed a successful certification program to verify that equipment and services satisfy these requirements.

The Carrier Ethernet technology and market have evolved to the point where purpose-built hardened equipment is now used to deliver MEF-certified services. The MEF technical work resulted in the formal definition of the carrier-class Ethernet that has come to be known simply as Carrier Ethernet. The customer base for Ethernet services has also evolved from large Enterprises located in fiber-rich metropolitan centers to those with globally distributed operations and mid-sized businesses in suburban and rural settings.

This last point is critical: this shift in the market has created opportunities and advantages for service providers who can offer ubiquitous coverage in a cost-effective and timely manner.

This paper focuses on informing the reader about the applications and individual advantages of currently available access technologies. The primary audience of this paper is the service provider who is interested in delivering an Ethernet service without boundaries. However, businesses who are consumers of Carrier Ethernet services may also find it informative.

A Growing Opportunity with Real-World Challenges

According to data from Vertical Systems, Carrier Ethernet Services grew 41% in 2008 and will be a 31 billion dollar worldwide market by 2012. Carrier Ethernet has been globally embraced by more than 50 service providers and 100 equipment manufacturers. This figure is growing at an annual rate of 40%.

The number one challenge facing service providers today is the difficulty of providing access to all their customer locations. While tremendous investments have been made to build out their fiber plant, no single provider can deliver on-net access to wide area Ethernet services with the same coverage as their traditional services. The good news is that service providers and equipment vendors have been actively working together to tackle these challenges.

Ubiquity Requires Multiple Access Technology Solutions

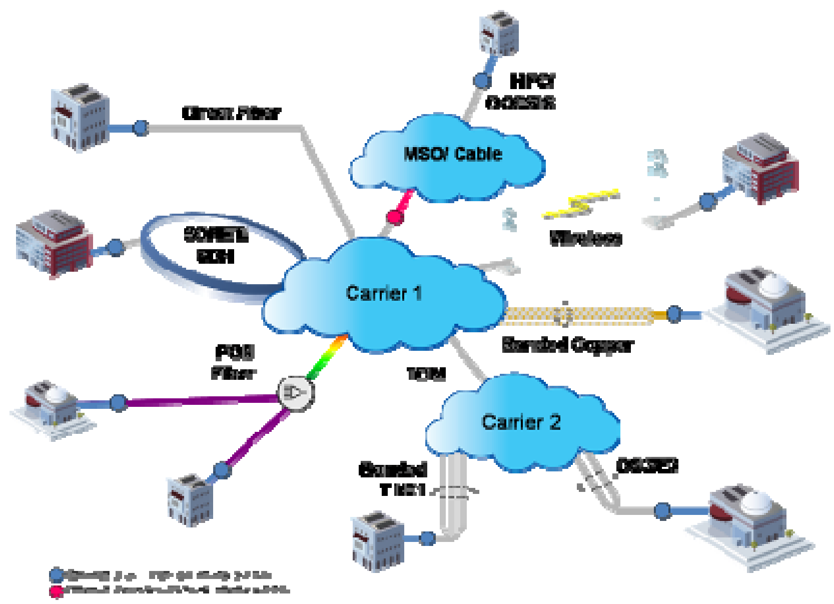
With the evolution from "best-effort" Ethernet services to higher-performing MEF-certified services, the primary obstacle confronting Ethernet service delivery is the difficulty expanding the Ethernet service footprint and making it available ubiquitously. Or, at a minimum, making it available to the locations where business users want to purchase it.

The need for ubiquitous Ethernet service delivery has driven the development and deployment of a variety of access technologies, each optimized for different access situations. Rarely can carriers find a single access technology that can address all the access requirements of their region. This problem is even more pronounced when carriers follow customers out-of-region into other carriers' territories.

Fortunately, it is now possible to deliver a consistent MEF-certified Ethernet service over a variety of access architectures using MEF-certified equipment from multiple vendors. Some of the technologies used to deliver MEF-certified services include the following access alternatives:

- Ethernet over Fiber (Active Fiber, PON, SONET/SDH)
- Ethernet over PDH (T1/E1, DS3/E3)
- Ethernet over Copper (EFMCu)
- Wireless Ethernet (WiMAX, Broadband Wireless, Microwave)
- Ethernet over HFC/DOCSIS

The network drawing on the following page illustrates an access architecture that uses several of these technologies. When properly deployed, the only difference among the Ethernet services delivered across this variety of access technologies is the maximum bandwidth that can be transported over each technology. The underlying service definitions and SLAs can be identical, providing the end user with a seamless Ethernet experience even while a variety of different access technologies are in play.



Each of the access technologies illustrated above have their strengths in certain applications. The table below describes these applications at an introductory level. The sections that follow will provide greater detail on the advantages of each individual technology.

Summary of Carrier Ethernet Access Technologies			
Carrier Ethernet Access Method	**Technology Alternatives**	**Deployment Scenarios (When to use the technology)**	**Advantages**
Ethernet over Fiber	- Active Ethernet - Ethernet over SONET/SDH - Passive Optical Network	- On-net buildings - Greenfield - Dense Metro area - 1Gbit/s or greater bandwidth requirements	- Highest bandwidth - Noise immunity - Security - Long reach - SONET/SDH leverage existing - Growth potential via xWDM
Ethernet over PDH	- Bonded T1/E1 - DS3/E3 and bonded DS3/E3	- Remote branch offices - Off-net customer locations (out of region, type 2) - SMB	- Leverage existing transport - Universally deployable - Lower CAPEX - No reach limitations - Well understood provisioning - Resiliency through bonding
Ethernet over Copper	- 2BASE-TL - 10PASS-TS	- Remote branch offices - On-net or off-net - SMB - Campus settings - Traffic monitoring	- Ubiquitous copper availability - Rapid deployment - Low cost unbundled local loop - Resiliency through bonding
Wireless Ethernet	- Terrestrial microwave - WiMAX - Broadband wireless - Free space optics - WiFi	- Remote branch office - Campus setting - No fiber or copper available - Mobility required	- Installation requires no trenching - Rapid deployment - Some alternatives offer mobility
Hybrid Fiber Coax	DOCSIS 2.x/3.x	- Work at home - SOHO/SMB - Remote branch office	- Extensive coverage - High performance options - Deep penetration into residential and suburban geographies

Ethernet over Fiber

For applications where it is available or where the bandwidth requirements dictate it, delivering Ethernet over optical fiber is an excellent choice. With virtually unlimited bandwidth support, noise immunity and the ability to traverse long distances, optical fiber can provide the performance for the applications of today and those envisioned for tomorrow.

Active Ethernet

One of the most common Ethernet over Fiber architectures is point-to-point, where the connection is from the Service Provider's aggregation switch to a Network Interface Device (NID) located at the customer premises.

Active fiber deployments are an excellent choice for service providers when the customer is in an on-net building in a dense metropolitan area or in a new infrastructure build-out. Fiber optics as an access medium is also needed when Ethernet speeds are 1 Gbps or higher.

Benefits of Active Ethernet

One major benefit of using fiber optic access technology is its ability to future-proof bandwidth and distance requirements. Fiber offers easy scalability to meet and adapt to the increasing customer needs, which results in customer satisfaction and service differentiation that enables profitability and customer retention. Beyond its bandwidth capacity, fiber also offers additional benefits such as being able to transmit over greater distances and its inherent immunity to noise and interference.

The CAPEX investment in fiber optic infrastructure is a one-time investment with minimal recurring operational cost. Fiber's ability to service 100 Mbps, Gigabit and 10 Gigabit data rates as well as multiplex multiple channels using Wavelength Division Multiplexing (WDM) enable it to support any foreseeable future data rates.

The distances that can be supported by a fiber infrastructure are limited only by the active interface hardware. Using standard optics, 2 km-150 km distances can be easily achieved.

Ethernet over Passive Optical Networking (xPON)

PON is a point-to-multipoint optical access architecture that facilitates broadband communications between an optical line terminal (OLT) at the central office and multiple remote optical network units (ONUs) over a purely passive optical-distribution network with a reach of approximately 40 km. PON supports from 1 to 128 users per single strand of fiber.

PON is a cost-effective access method because it conserves fiber for service providers offering high bandwidth business and residential access applications, green field deployments, mobile backhaul and any upgrade from twisted pair or coaxial copper networks.

Benefits of PON

PON's most obvious benefit is the increase in the bandwidth delivered to the subscriber compared to legacy copper technologies. Using PON, service providers can launch new bandwidth-intensive applications. Other benefits of PON are: 1) significant reductions in fiber infrastructure, 2) large reductions in electrical cost and 3) reduced maintenance requirements.

The Ethernet Passive Optical Network (EPON) standard was developed by the IEEE and the Gigabit Passive Optical Network (GPON) by the ITU-T. EPON supports symmetrical 1 Gbps communications. GPON provides 1.25 Gbps upstream and 2.5 Gbps downstream. MEF services are supported on both platforms. Standards are also underway at CableLabs for translation of DOCSIS management commands into Ethernet formats to manage EPON fiber access equipment. An upgrade path to 10 Gbps exists for both PON types with work being done by the IEEE and ITU-T.

Ethernet over SONET/SDH (EoS)

Often the best way to deliver Ethernet service is to use what you have available – period. With SONET and SDH equipment deployed nearly everywhere fiber is, using this existing and highly reliable transport technology can be an obvious decision. While early implementations from equipment vendors were lacking support for service differentiation and granular QoS, newer products are MEF-certified and deliver a variety of sophisticated services from 1 Mbps up to over 1 Gbps. Ethernet interface cards are available for modern SONET/SDH transport equipment and low-cost external devices are available for use when leasing transport or when the existing SONET/SDH equipment can't support the services the carrier wishes to offer.

Benefits of Ethernet over SONET/SDH (EoS)
Delivering Ethernet services over SONET/SDH allows the service provider to leverage infrastructure that is already in place using familiar transport technology. SONET/SDH networks have traditionally been regarded as the "gold standard" for resiliency. This well-understood technology is widely available wherever fiber has been pulled. In addition, modern circuit bonding protocols, such as virtual concatenation (VCAT), have helped make Ethernet services over SONET/SDH available at fractions of the line rate, eliminating stranded capacity and further driving down costs.

Ethernet over PDH

If neither SONET/SDH nor Dark Fiber facilities are available, service providers have found that the existing PDH network, consisting of traditional DS1/E1, DS3 and E3 standards enable them to deliver Carrier Ethernet to locations that would otherwise be unreachable.

Ethernet over Bonded T1/E1

T1 at 1.544 Mbps and E1 at 2.048 Mbps have been the dominant access technologies for business voice and data services for decades. From their humble beginnings as voice trunk line technologies to their more recent achievement as the gold standard of Internet access for small and medium-sized businesses, T1s and E1s have proven to be well-understood and versatile last-mile technologies.

These lines reach nearly every business in the modern world. Ethernet can be transported over T1 and E1 as a single link or bonded group of links allowing service providers to deliver Ethernet at rates from 1 Mbps up to 16 Mbps. Bonding brings with it the additional benefit of resiliency – a feature demanded by many enterprise customers. Because there are multiple links involved in the access method, it is inherently protected against interruptions of one or more of those links – for example by a backhoe or an excavator.

There are three standardized methods for delivering Ethernet over T1/E1 lines. These are: multilink point to point protocol (MLPPP), GFP/VCAT and G.bond or EFM. While each technology has its strengths, they all deliver comparable performance and are available from multiple equipment vendors.

Benefits of Bonded T1/E1
The number one benefit that comes from using bonded T1/E1 for delivering Ethernet services is that service providers are able to reach all of their customer locations, regardless of geography and proximity to their facilities. In addition, the familiarity and turnkey nature of T1/E1 circuits means services can be turned up quickly, whether access is on net or off net, allowing the service provider to recognize revenue sooner and to decouple sales efforts from the infrastructure build outs associated with many alternative technologies.

Ethernet over DS3/E3

Just as T1/E1 is a desirable access technology for delivering Ethernet service, DS3 and E3 circuits provide another alternative using readily available transport technology. Using DS3 and E3 circuits and circuit bonding, the service provider can offer Carrier Ethernet services at flexible rates from 1 Mbps – 130 Mbps. Ethernet over DS3/E3 is not only used as a retail service access technology, but is often used as a low-cost infrastructure alternative for backhaul between remote co-location facilities and points of presence.

Benefits of DS3/E3
The primary benefit of using DS3/E3 is to deliver Ethernet at rates greater than 3 Mbps over the existing transport infrastructure. Rapid service turn-up and revenue recognition are additional side benefits of leveraging this infrastructure.

Ethernet over Copper

Ethernet in the First Mile over Copper (EFMCu) allows fast deployment of resilient symmetrical Ethernet Access/Backhaul links over existing voice-grade copper infrastructure, providing a very economical alternative to fiber. There are two standardized EFMCu technologies:

- Long reach 2BASE-TL, delivering a minimum of 2 Mbit/s and a maximum of 5.69 Mbit/s over distances of at least 2700 m, using standard G.SHDSL.bis technology over a single copper pair.
- Short reach 10PASS-TS, delivering a minimum of 10 Mbit/s over distances of at least 750 m

(2460 ft), using VDSL technology over a single copper pair.

Extensions to these standard technologies developed by some equipment vendors have enabled some service providers to improve on the rate/reach curves provided by the standard implementations.

Both EFMCu technologies support an optional aggregation or bonding of multiple copper pairs (up to 32), providing higher bandwidth, longer reach and improved resiliency. The aggregate bandwidth, in excess of 100 Mbps, offered by copper bonding solutions meet the needs of most bandwidth-intensive Metro Ethernet applications.

Benefits of Ethernet over Copper

Using the existing voice-grade copper infrastructure keeps deployment costs to a minimum, as there is no requirement for new cabling inside or outside the residence or business.

By reducing service provider capital expenditures for implementation, EFMCu serves as the easiest, lowest-cost, and immediately deployable solution for providing feature-rich, high-speed access and services to subscribers.

With Ethernet over Copper, service providers, governments and private enterprises have a cost-effective solution for extending their Ethernet networks without having to deploy fiber.

Eliminating the need to install fiber optic cable removes a fundamental barrier that has inhibited the adoption of Ethernet in the public network. Using the multi-pair bonding service providers can offer high performance (10-100 Mbps) service over a reliable infrastructure with resiliency built right in. EFMCu using multi-pair bonding provides the subscriber with a fiber-like experience and gives the service provider the ability to universally offer Ethernet services over both fiber and copper media.

Ethernet over Copper can also lower recurring operational costs for CLECs or ILECs who are operating as CLECs in out-of-region territories. Using EFMCu, carriers can deliver Ethernet services over leased dry copper, which is typically much less expensive than alternatives.

EFMCu is an attractive access solution for both residential and business users and is spectrally compatible with other legacy PSTN/ISDN, T1/E1 and DSL services so they can co-exist in the same cables.

Wireless Ethernet

Where wireline services are not available or practical, delivering Ethernet over a point-to-point wireless access network can make a previously infeasible connection practical. Also, where mobility is required, broadband wireless services from mobile service providers may provide an excellent connectivity option.

Terrestrial Microwave

A microwave link uses microwave frequencies (above 1 GHz) for line of sight radio communications (20 to 30 miles) between two directional antennas. Microwave link transceivers are now available with standard Ethernet interfaces that can be used to deliver carrier Ethernet services. The distance and throughput that can be achieved is a function of frequency and antenna size. For example, 100 Mbps Fast Ethernet can be achieved reliably over 8 miles at 11 GHz but will perform poorly over 15 miles due to rain fade at that frequency. 100 Mbps Fast Ethernet can be achieved reliably up to 30 miles at 6 GHz.

The use of microwave links avoids the need to install cables between communication equipment. Microwave links may be licensed (filed and protected by government agencies) or may be unlicensed (through the use of low power within unlicensed regulatory limits).

Broadband Wireless

EVDO (**Ev**olution of Existing Systems for **D**ata **O**nly) is a common upgraded service of cellular providers with CDMA (Code Division Multiple Access) systems. EVDO Rev. A allows for a maximum data transmission rate of approximately 3.1 Mbps on the forward (downstream) channel. The EVDO Rev. A system uses the same reverse channel which limits the uplink data transmission rate to approximately 1.8 Mbps. The EVDO system has an upgraded packet data transmission control system that allows for bursty data transmission rather than for more continuous voice data transmission.

GSM (**G**lobal **S**ystem for **M**obile) is the most popular standard for mobile phones in the world. Its promoter, the GSM Association, estimates that 80% of the global mobile market uses the standard. Release '97 of the standard added packet data capabilities, by means of General Packet Radio Service (GPRS). The latest version of packet data communications are UMTS (Universal Mobile Telecommunications System) and HSDPA/HSPA+ (High-Speed Downlink Packet Access/ High-Speed Packet Access). These technologies enable download speeds of up to 42 Mbps (22 Mbps in upload). One of the main advantages of HSPA+ is its optional all-IP capability that is using native Ethernet connection to the base station.

LTE (Long Term Evolution or 3GPP) is the name given to a project within the Third Generation Partnership Project to improve the UMTS mobile phone standard to cope with future technology evolutions. Goals include improving spectral efficiency, lowering costs, improving services, making use of new spectrum and re-farmed spectrum opportunities, and better integration with other open standards. Being based on an all-IP infrastructure and native Ethernet connectivity, LTE should provide 100 Mbps peak download rates.

WiMAX (Worldwide Interoperability for Microwave Access).

WiMax was created by the WiMAX Forum and is a wireless point-to-multi-point data transmission technology that is based on the IEEE 802.16 standards. With its latest version, 802.16e adds mobility and better support for quality of service as well as symmetrical transmission capability of typically 40 Mbps for fixed and 15 Mbps for mobile implementation. As a "last mile" broadband wireless access, WiMAX can be used in the following applications: replacement to legacy T1/E1, delivery of triple-play services, backhaul technology for Wi-Fi hotspots and mobile backhaul and for mobile emergency response services.

Free Space Optics (FSO)

FSO is an alternative to the radio frequency wireless technologies previously described. While the most common use of optical transmission is through fiber optic cable, FSO enables service providers to connect two points at a medium to long distance (from an access perspective) through the air and provide Gigabit Ethernet speeds. As light is used instead of electro-magnetic signal, there is no need to purchase expensive radio spectrum, making FSO a complement to copper and fiber communications.

Ethernet over HFC/DOCSIS

Hybrid fiber-coaxial (HFC) is an industry term for a broadband network which combines optical fiber and coaxial cable. It has been commonly employed by MSO/cable TV operators since the early 1990s.

The fiber optic network extends from the cable operators' master/regional head-end, to a neighborhood's hub site, and finally to a fiber optic node which serves anywhere from 25 to 2000 homes. A master head-end will usually have satellite dishes for reception of distant video signals as well as IP aggregation routers. Some master head-ends also house telephony equipment for providing telecommunications services to the community.

By using frequency division multiplexing, an HFC network may carry a variety of services, including analog TV, digital TV (standard definition and HDTV), VoD, telephony, and high-speed data.

Data over Cable Service Interface Specification (DOCSIS) is an international standard developed by CableLabs and contributing companies. DOCSIS defines the communications and operation support interface requirements for a data over cable system. It permits the addition of high-speed data transfer to an existing Cable TV (CATV) system. It is employed by many cable television operators to provide Internet access and Business Services over their existing (HFC) infrastructure.

With its large coverage and available performance, HFC/DOCSIS technology is a valuable asset for Cable TV/MSO providers to deliver Ethernet-based services to the SOHO/SMB and high-speed Internet access to residential customers.

Case Study – Ubiquitous Ethernet Services in Action

Rexon Massey, Inc. is an environmental science company located in Florida. They specialize in data collection and analysis. Their instruments measure hydrology, chemistry, strain, pressure, chromatography, vibration, temperature, particulates, aerosols, and other critical variables of interest to business, industry and government. Monitoring services are provided for clients large and small throughout the southeast in both urban and rural areas. Data throughput requirements range from a few hundred kbps to 500Mbps depending on the application. They also have truck-based mobile facilities used for temporary installations.

A ubiquitous, flexible, secure and diverse network is required to support all of Rexon Massey's customers. IT Director Osvaldo Cardoso, working with the local cable operator in northern Florida created a network that meets his challenging requirements. Because most of the Rexon Massey equipment has Ethernet ports, over time he has created a large Ethernet WAN to collect data from remote locations.

The local cable company manages the primary network. It was able to reach many of the customer monitoring locations with an EPON network that supports business and residential subscribers in the region. In some cases the MSO contracts with the local ILEC or CLEC to reach locations using bonded T1s and SONET and in some cases mid-band Ethernet over bonded copper pairs. To meet the needs of extremely remote off-net locations, Cardoso created a wireless system for the mobile facilities that can be connected to most service provider's facilities. The core regional network aggregates these signals for transmission over the MSO fiber on dedicated CWDM wavelengths.

Sample Access Connections into Rexon Massey's E-LAN Service				
B/W	**Access Media**	**Access Technology**	**Service Provider**	**Application**
500kbps	Wireless	Wifi	CLEC	Hydrological pressure measurement
100Mbps	Fiber	Ethernet	MSO	Remote imaging and chemical analysis
4Mbps	Copper - Twisted Pair	EFMCu	ILEC	Water, air, wind, temperature
50Mbps	Fiber	Ethernet	MSO	Motion and air quality measurement
10Mbps	Fiber	Ethernet	MSO	Motion and air quality measurement
500kbps	Wireless	Broadband Wireless	Wireless Operator	Hydrological pressure measurement
10Mbps	Copper – T1	Ethernet over Bonded T1	ILEC	Air quality measurement
150Mbps	Fiber	Ethernet over SONET	CLEC	Remote imaging and chemical analysis
2Mbps	Copper - Coaxial	HFC/DOCSIS	MSO	Chemical analysis
500Mbps	Fiber	Direct Fiber Ethernet	MSO	Remote imaging and chemical analysis
6Mbps	Wireless	Microwave	MSO	Solar, humidity, wind and other
3Mbps	Copper - Coaxial	HFC/DOCSIS	MSO	Chemical analysis

Integrating diverse access media and protocols into a seamless Ethernet services network is facilitated by work at the MEF. MEF specifications on UNI Type 1 and Ethernet service definitions ensure that there are commonly accepted service parameters and hardware interfaces to connect Ethernet ports anywhere on the network. OAMP work by the MEF ensures that Cardoso has the management tools necessary to monitor network performance and diagnose network issues. Cardoso uses E-LAN configurations to separate traffic into VLANS to ensure data integrity.

Rexon Massey's work is only possible with high-speed, real-time data input and analysis. Ethernet services provide the necessary platform for gathering this data on a cost-effective heterogeneous network. Cooperation among Massey's service providers ensures they can collect data wherever they have customers.

Summary

In conclusion, in order to realize the full potential of an Ethernet service offering, and in order to maximize the revenue from these services, delivering ubiquitous Ethernet is critical. Only by doing so can service providers deliver services everywhere, to all customer locations, using the technology that is best suited for each application.

Follow up or Questions

Please send any question or comment to the following email address: access@metroethernetforum.net.
Your email will be treated confidentially within the Access Technologies Working group. We will respond within one cycle of our bi-weekly working group meetings.

MEF Specifications and Access Technology Standards

The table below summarizes the various standards used to deliver Ethernet over the access technologies discussed in this paper.

Carrier Ethernet	MEF Specification	
E-Line, E-LAN and E-Tree Services	MEF 6.1 Metro Ethernet Services Definitions Phase 2 MEF 10.1 Ethernet Services Attributes Phase 2	
PDH/Circuit emulation	MEF 3: Circuit Emulation Service Definitions, Framework and Requirements MEF 8: Implementation Agreement for the Emulation of PDH Circuits	
Mobile Backhaul	MEF 22: Carrier Ethernet for Mobile Backhaul Implementation Agreement	
Test/Certification	MEF 9: Ethernet Services at the UNI MEF 14: Traffic Management	
Carrier Ethernet Access Method	**Technology Alternatives**	**Applicable Standards**
Ethernet over Fiber	Active Fiber	- IEEE 802.3-2005
	Ethernet over SONET/SDH	- ITU-T X.86 encapsulation - ITU-T G.707 and G.7043 (GFP-VCAT)
	Passive Optical Network	- IEEE 802.3-2005 (EPON) - IEEE 802.3av (10GEPON) - ITU-T G.984 (GPON)
Ethernet over PDH	Bonded T1/E1	- RFC1990 (Multilink PPP) and RFC3518 (BCP) - ITU-T G.7041 and G.7043 (GFP-VCAT) - ITU-T G.998.2 (G.bond)
	DS3/E3 and bonded DS3/E3	- ITU-T X.86 encapsulation with optional link aggregation - ITU-T G.7041 and G.7043 (GFP-VCAT) - ITU-T G.998.2 (G.bond)
Ethernet over Copper	2BASE-TL	- IEEE 802.3-2005 2BASE-TL using ITU-T G.991.2 (G.SHDSL.bis)
	10PASS-TS	- IEEE 802.3-2005 10PASS-TS using ITU-T G.993.1 (VDSL)
Wireless Ethernet	Terrestrial microwave	- IEEE 802.3-2005 user interface
	WiMAX	- IEEE 802.16
	Broadband wireless	- 3GPP Rel. 7 (HSDPA/HSPA+) - 3GPP Rel. 8 (LTE) - CDMA2000 EV-DO rev.A – TIA-856 (EVDO)
	Free space optics	- IEEE 802.3-2005 user interface
	WiFi	- IEEE 802.11
Hybrid Fiber Coax	DOCSIS	- DOCSIS 1.x, 2.x, 3.0, EuroDOCSIS

Glossary of Abbreviations

3GPP	Third Generation Partnership Project (Standardization body developing GSM technologies)
3GPP2	Third Generation Partnership Project 2 (Standardization body developing CDMA technologies)
ADM	Add Drop Multiplexer
ARP	Address Resolution Protocol
ATM	Asynchronous Transfer Mode
BCP	Bridging Control Protocol
BPDU	Bridge Protocol Data Unit
BWA	Broadband Wireless Access
CDMA	Code Division Multiple Access
CFM	Connectivity Fault Management
CLEC	Competitive Local Exchange Carrier
CWDM	Coarse Wave Division Multiplexing
DOCSIS	Data over Cable Service Interface Specification
DS3	Digital Signal level 3
DSL	Digital Subscriber Line (as in xDSL)
E1	European PDH signal level 1
E3	European PDH signal level 3
EFM	Ethernet in the First Mile
EFMCu	Ethernet in the First Mile Copper
E-LAN	Ethernet-LAN Service
E-Line	Ethernet Point-to-Point
EoS	Ethernet over SONET/SDH
EPL	Ethernet Private Line
EPON	Ethernet Passive Optical Network
EVC	Ethernet Virtual Connection
EVDO	Evolution of Existing Systems for Data Only
EVPL	Ethernet Virtual Private Line
FSO	Free Space Optics
GFP	Generic Framing Protocol
GPRS	General Packet Radio Service
GSM	Global System for Mobile
HFC	Hybrid Fiber Coax
HSDPA	High-Speed Downlink Packet Access
HSPA	High-Speed Packet Access
IEEE	Institute of Electrical & Electronics Engineers
IETF	Internet Engineering Task Force
ILEC	Incumbent Local Exchange Carrier

ITU-T	International Telecommunication Union – Telecommunication Standardization Sector
LAN	Local Area Network
LLDP	Link Layer Discovery Protocol
LTE	Long Term Evolution
MEF	New name for entity formerly known as Metro Ethernet Forum
MLPPP	Multi-Link Point-To-Point Protocol
MSO	Multiple Service Operator (Comcast, COX, Time Warner Cable, etc)
NID	Network Interface Device
OAM	Operations, Administration and Maintenance
OLO	Other Licensed Operator
OLT	Optical Line Termination
PDH	Plesiochronous Digital Hierarchy
QoS	Quality of service
RFI	Request for Information
RFP	Request for Proposal
RFQ	Request for Quotation
SDH	Synchronous Digital Hierarchy
SHDSL	Single-Pair High-Speed Digital Subscriber Line
SLA	Service Level Agreement
SLO	Service Level Objectives
SLS	Service Level Specifications
SMB	Small and Medium Business
SOHO	Small Office, Home Office
SONET	Synchronous Optical NETwork
T1	Telecommunications level 1
TDM	Time Division Multiplexing
UMTS	Universal Mobile Telecommunications System
UNI	User to Network Interface
VCAT	Virtual Concatenation
VDSL	Very High Speed Digital Subscriber Line
VLAN	Virtual LAN
VoD	Video on Demand
WiMAX	Worldwide Interoperability for Microwave Access
WDM	Wave Division Multiplexing

Disclaimer

About the Metro Ethernet Forum

The MEF is a non-profit organization dedicated to accelerating the worldwide adoption of Carrier Ethernet. The MEF comprises leading service providers, local exchange carriers, cable operators, network equipment manufacturers and other prominent networking companies that share an interest in Carrier Ethernet. As of March 2009, the MEF has 154 members.

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