Ethernet in the First Mile

Making Universal Broadband Access a Reality

Introduction

The link between the end user and the public network is vital for the delivery of broadband applications to residential and business subscribers. Until the present, the technologies in this first mile link have caused a bandwidth bottleneck.

Referred to as the “milkshake through a straw” scenario, DSL and cable modem links operate at 5-10% of the capacity of even a modest local area network (LAN). Even T1 lines, at 1.5 Mbps, are application bottlenecks—faster to be sure, but not fast enough—and at much greater cost.

Ethernet in the first mile is intended to change all this, using existing physical infrastructure, whether it be telephone lines or dark fiber links. This will revolutionize the access network just as it did the enterprise network where Ethernet is dominates in homes and businesses alike.

As an access technology, Ethernet has three distinct advantages over legacy first mile technologies:

- A simple, globally accepted standard that ensures interoperability
- Future-proof transport for data, video and voice applications.
- The most effective infrastructure for data services

Two industry groups are working closely together to create and promote one global standard that will guarantee total interoperability: the Institute of Electrical and Electronics Engineers, Inc. (IEEE) 802.3ah Task Force and the Metro Ethernet Forum (MEF). While the 802.3ah Task Force is working on developing the EFM standard, the Metro Ethernet Forum is building market awareness, driving consensus, and preparing interoperability demonstrations.

The First Mile Bottleneck

The first mile (also called the last mile, the subscriber access network, or the local loop), is the link between the end user and the public network. It is the communications infrastructure of the business park, the neighborhood, or a single building (such as an office building, hotel or apartment). Essentially, the first mile is a figure of speech for the link from the subscriber or user to the network; therefore, it may be greater or less than a mile.

On one end of the first mile is the network operator's equipment, the Access Node (see Figure 1), which resides in a Point of Presence (POP) such as a Central Office (CO) or a remote site such as a curb or a building. Acting as the entrance or exit to the public network, this node receives, concentrates and directs data to and from high-speed core networks.

On the other end of the first mile is the business or residential subscriber, located in a home, in an office or on a campus. Currently, the subscriber connects to the public network using Customer Premises Equipment (CPE) and a variety of access network technologies: PSTN/ISDN, Digital Subscriber Line (DSL), coax cable, T1/E1, T3/E3, or OC3/STM-1.

With the introduction of EFM technologies in the market, the end user connects to the public network with a simple, familiar Ethernet interface.

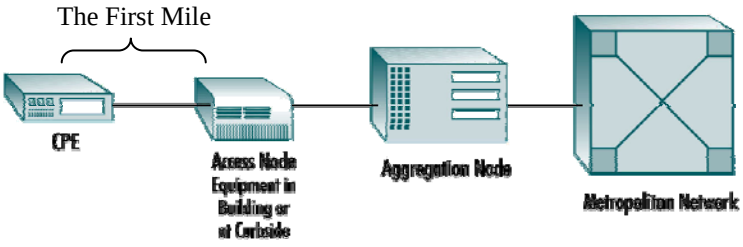


Figure 1: Simple Access Model for EFM networks

A subscriber using EFM will have a familiar Ethernet interface connecting directly to an Ethernet LAN or to a terminal that offers legacy interfaces for the current access technologies

Growing Demand for Business Access

Residential and business users, equipment suppliers, and network operators are demanding solutions to the first mile bottleneck. From the subscriber's point of view, current access technologies are plagued by bandwidth constraints, availability, ease of use, and high cost.

Most residential users today have access speeds of less than 56 Kbps, while many business subscribers have T1/E1 (1.5 Mbps) or lower speed access. At these speeds, traffic flowing to and from high-speed metropolitan and core networks—and within the business LAN—slows to a crawl while traversing the access network. Even subscribers with faster cable or DSL access connections experience slowdowns when using bandwidth-intensive applications due to the various protocol conversions that take place between Ethernet and legacy technologies such as Asynchronous Transfer Mode (ATM).

For their part, network operators need to lower operational expenses, create new revenue sources, and scale networks more efficiently. They also seek ways to eliminate the complex provisioning process for the access network. Using disparate systems tailored to the various access technologies deployed, these operators employ rigid, inflexible procedures to configure the different types of access network equipment, such as Digital Cross-connect Systems (DCS), channel banks, and CSU/DSUs. In addition to being time consuming and cumbersome, these provisioning procedures are expensive and prone to error.

The bottom line is that operators and manufacturers need ways to reduce the investment uncertainties associated with too many protocols and equipment types in current access networks. Ethernet offers a cost-effective infrastructure for data services, future-proof transport for data, video and voice applications, and a simple global standard that will ensure interoperability.

Ethernet Provides Universal Broadband Access

Today there are hundreds of millions of Ethernet ports deployed worldwide in business and residential applications of all sizes.. Just as Ethernet revolutionized enterprise networking, it is now poised to be the single technology that will deliver universal broadband access for high-end user applications, and enable a true end-to-end, seamless technology for communications.

As a network access technology, Ethernet offers a long list of quantitative and qualitative advantages over legacy first mile technologies. These advantages can be grouped into three important benefits:

- A simple global standard that will ensure interoperability
- Future-proof transport for data, video and voice applications
- The most effective infrastructure for data services

Global Standard

EFM is a single global standard enabling complete interoperability worldwide. Following the Ethernet tradition of being a clear, comprehensive, and complete standard, designed for very high volume applications, EFM's capabilities will reduce investment uncertainties for all stakeholders in the access network value chain, from technology providers to application developers to end users.

Future-proof Transport for Data, Voice and Video

EFM offers the ultimate connectivity and bandwidth for multimedia applications. For most residential and business users today, faster speed equates to faster Internet access. Residential users of tomorrow, however, will access new digital entertainment services, such as DVD-quality movies-on-demand and interactive games. Business users will work collaboratively on-line, use their IP networks for telephony, and outsource their data storage. And media-rich learning experiences will offer high value for both types of users. Network operators will have limitless opportunities to deliver new

applications and services, and therefore will increase their sources of revenue.

The key is access network. Current broadband technologies are a bottleneck for users who want to access bandwidth-hungry, media-rich applications and services. EFM will change all that. The promise of EFM is future-proof transport for all data, video and voice applications that can be foreseen.

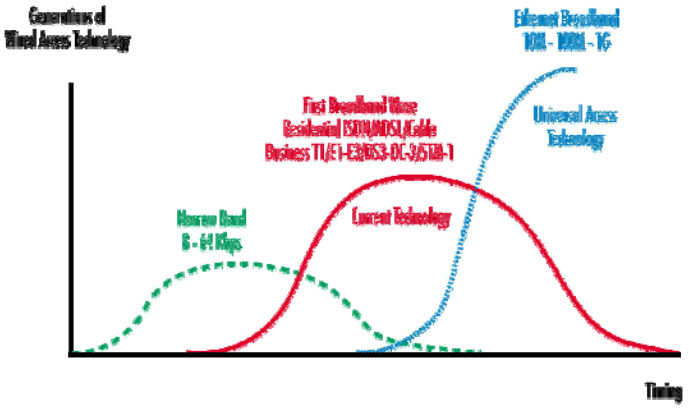


Figure 2: EFM offers future-proof transport for data, video and voice applications

Most Effective Infrastructure for Data Services

Today, Ethernet is well known in both business and residential networks. Most local area networks deployed in business use Ethernet, and most residential broadband connections (DSL and cable) have an Ethernet connection to the PC or LAN. EFM brings this familiar technology to the access network, eliminating the need for any conversion between Ethernet and other technologies.

Ethernet provides the most effective infrastructure for data services in the access network, and—with the advent of EFM—will be universal from the user through the network to the far end. This important benefit will result from three factors:

- the EFM infrastructure will be scalable
- it will create a single end-to-end protocol, and
- network operators will be able to use a single approach for different network architectures.

Scalability

Bandwidth choices are limited in the circuit-switched telephone infrastructure. A subscriber can order a DS0 (64 Kbps), T1/E1 (1.5 Mbps), T3/E3 (45 Mbps), or an OC3/STM-1 (155 Mbps). Obtaining a new service is often complex, because the various types of access network equipment involved in service provisioning must be configured in multiple steps. Provisioning is a cumbersome, lengthy, and costly process.

EFM, on the other hand, scales easily and is simple and flexible to provision. Ethernet scales in small increments over the same physical media, yet allows the service provider to control the subscriber rate through software. Providers can provision extra bandwidth on demand, or can provide a dynamic bandwidth service for *ad hoc* needs, all under a common management scheme and methodology.

In addition to meeting subscriber needs, EFM also scales cost-effectively to meet market penetration demands. Current access network solutions, such as DSL and cable, are adequate for low-level market penetration in neighborhoods, where subscribers are spread out over a large geographical area. But an EFM access solution is well suited for multi-tenant/multi-unit residential or office buildings, where there are large numbers of densely located users. While today's access solutions focus on coverage, EFM focuses on penetration.

Single End-to-End Protocol

Considering Ethernet's huge installed base, it's easy to see that most residential and business subscriber traffic begins and ends as IP over Ethernet. Currently, as the traffic proceeds through the first mile to the central office, and out over the wide area network (WAN), it must travel through an array of protocols and over a variety of equipment.

Protocols may include point-to-point protocol (PPP), ATM, and synchronous optical network or synchronous digital hierarchy (SONET/SDH). End-to-end networking equipment includes modems, digital subscriber line access multiplexers (DSLAMs), routers and switches. As the complexity of protocol translations and equipment increases, so does network cost See Figure 3

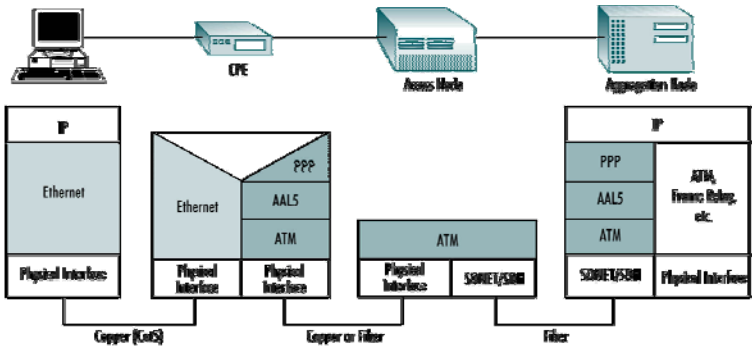


Figure 3: Numerous Protocols in the First Broadband Wave

An EFM solution flattens the access network and provides a unifying medium throughout the LAN and WAN. Ethernet is the only end to end transmission protocol (Figure 4). Network operators reduce equipment costs and operational expenses, and fewer protocol translations consume less bandwidth.

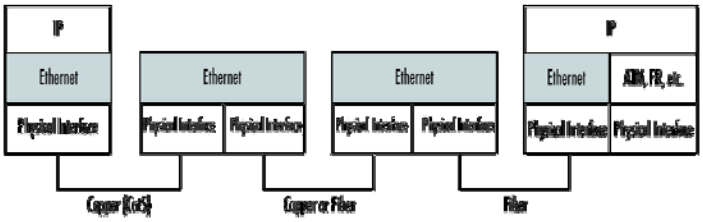


Figure 4: EFM Simplifies the Access Network

Single Approach for Different Architectures

The first mile, which may be within a neighborhood, a business park, a campus, or a single building, is unique in terms of the environments and the distances involved, and for its wide range of cable media: twisted-pair copper wire in various grades (Category 1-5), fiber optic cable, and coaxial cable.

EFM supports all these situations, providing a single approach for transmitting Ethernet traffic over three different topologies:

- copper cabling point-to-point networks
- fiber optic point-to-point networks
- fiber optic point-to-multipoint networks

This flexibility allows network operators to deploy the right solution for each part of the network, and to manage it all with single set of tools and processes, leading to gains in efficiency and OPEX, as well as new revenue opportunities.

Providing a unifying medium between the LAN and the WAN, and between the user and the network, the EFM standard describes a single approach for transmitting Ethernet traffic over all three topologies listed above.

Three Topologies: One Architecture

The following table maps the EFM topologies described above to the solutions provided by 802.3ah.

Topology	Solution
Copper cabling point-to-point networks	EFM Copper (EFMC) over the existing copper wire (Cat 3) at speeds of at least 10 Mbps up to at least 750 meters, or 2 Mbps up to 2700 meters
Fiber optic point-to-point networks	EFM Fiber (EFMF) over Single Mode Fiber at speeds of 100 and 1000 Mbps up to at least 10 kilometers
Fiber optic point-to-multipoint networks	EFM PON (EFMP): optical fiber at a speed of 1000 Mbps up to 20 kilometers

In addition, EFM Hybrid (EFMH) topologies can be created through network operators intermixing the three topologies listed above.

The EFM standard also defines operations, administration, and maintenance (OAM) aspects of the technology, which local carriers and network operators can use to monitor, manage, and troubleshoot access networks. The same management protocols and architectures work across all EFM topologies.

EFMC Copper (EFMC)

Twisted-pair copper wiring (telephone line) dominates the first mile. EFMC is ideally suited to exploit the existing voice-grade copper infrastructure in the first mile, within residential neighborhoods as well as buildings.

Millions of subscribers are currently using DSL technology for moderate-speed (128 – 384 Mbps) Internet access. While DSL solutions today rely on cell-based ATM transport, EFMC standardizes the delivery of bandwidth-efficient Ethernet packets directly over copper at 10+ Mbps in both directions. There is also a long-range option (EFMC LR) that provides less bandwidth (2 Mbps) but at a very great distance for copper communication (2700 meters).

Using the existing voice wire infrastructure keeps deployment costs to a minimum: There is no need for new cabling inside or outside the residence or business. By reducing service provider capital expenditures for implementation, EFMC is an easy, low-cost, and immediate solution for providing feature-rich, high-speed access and services to subscribers.

Limited deployments for this application take place today, but the EFM standard will eliminate the proprietary nature of these early pre-standard implementations while adding vendor interoperability required for large public networks and mass volumes. EFMC is an attractive access solution for both residential and business users, and can coexist with ISDN and PSTN in the same cables.[1]

EFM Fiber (EFMF)

A second 802.3ah objective is to standardize the physical layer specification for point-to-point fiber with Ethernet at speeds of 100 Mbps and 1 Gbps, and spanning lengths of at least 10 km over singlemode fiber. The 10 km reach enables a broad range of applications without costly infrastructure builds.

EFMF specifies a 1 Gbps, full-duplex singlemode fiber transport for the access network: a direct point-to-point connection from the CO to the subscriber's building. It also supports both single and dual point-to-point fiber options for 100 Mbps access. At either link speed, EFMF provides cost-effective opportunities for replacing expensive T1 and T3 lines, and is also viable for fiber to the home (FTTH) applications.

This effort will drive down costs of singlemode fiber to a point where it will replace multimode fiber and allow operators to build a complete network based solely on the longer-reach singlemode fiber.

Like EFMC, some EFMF deployments do take place today; however, the EFM effort offers added benefits to these deployments by supporting longer distances.

EFM PON (EFMP)

A PON (Passive Optical Network) is a single, shared optical fiber that uses inexpensive optical splitters to divide the single fiber into individual strands feeding each subscriber. Using these techniques, EFM PON (EFMP) builds a point-to-multi-point fiber topology that supports a speed of 1 Gbps for up to 20 km.

While subscribers are connected via dedicated distribution fibers to the site, they share the Optical Distribution Network (ODN) trunk fiber back to the Central Office.

PONS are called "passive" because, other than at the CO and subscriber endpoints, there are no active electronics within the access network. Eliminating the need for electrical equipment in the first mile network is a key facet of the EFMP topology. Another advantage is that much less fiber is required than in point-to-point topologies.

Management of Ethernet in the First Mile

The 803.ah standard includes OAM definitions and methods for EFM copper and fiber networks. Local carriers, service providers and network operators will use OAM procedures to manage and monitor links and troubleshoot problems. Although many Ethernet OAM definitions already exist in SNMP management information base (MIB) structures, 802.3ah extends and adapts them for first mile operation scenarios. Supported procedures include performance monitoring, loopback testing, fault detection and isolation.

Network operators have the freedom to choose and mix the three EFM topologies based on their business models, network architectures, and subscriber needs. They can build or upgrade their access networks with multiple EFM topologies and manage them with a common set of tools and OAM procedures.

[1] EFMC is spectrum compatible with ISDN and PSTN.

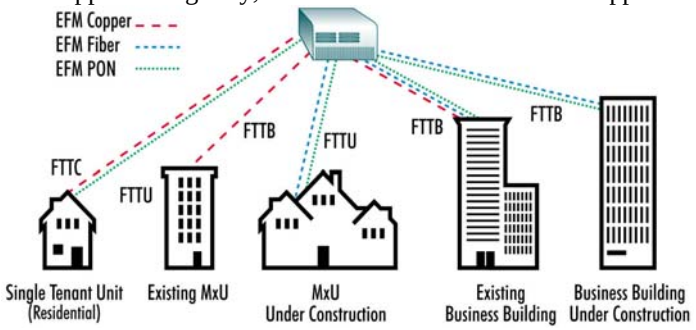
Flexible Deployment

The three EFM topologies are complementary. Network operators can deploy EFM solutions to a diverse user community and within a variety of first mile infrastructures. In urban areas, where fiber networks are plentiful, EFMC or EFMF may be the optimal solution. An EFMF solution is well-suited to newly-built office parks)with fiber installed inside and outside the buildings), as well as for new residential subdivisions with fiber to the home.

Ethernet over copper wire (EFMC) is probably be the best fit for existing neighborhoods and business parks where a voice-grade copper infrastructure exists. This also holds true for multi-tenant units (MTUs) or multi-dwelling units (MDUs), collectively called MxUs. MxUs include apartments, hotels and office buildings. However, there may be a mix of EFM service feeds into or between buildings, and within larger buildings.

In some cases, a combination of technologies will exist in the first mile. For example, in a new “greenfield” build-out, or in a rehabilitation effort where new water, electrical, sewer or gas infrastructure is being installed, fiber cable can be laid into open trenches. However, the existing buildings may still have copper wiring. In these deployments, known as fiber to the building (FTTB) or fiber to the curb (FTTC), the network operator can supply a hybrid fiber and copper EFM solution (EFMH).

The flexibility of EFM deployments will allow service providers and network operators to market their EFM access solutions to a broad base of users, whether those users have fiber to their homes and business offices, copper wiring only, or a combination of fiber and copper.



Future-Proof Application Delivery

EFM enables data, video and voice applications and services to be delivered to end-users. Two factors are critical for such a converged access network: quality of service (QoS) and bandwidth.

While Ethernet was originally developed as a data-oriented protocol, it has evolved to support a full range of services, including voice and video, across the enterprise network and WAN. A number of existing and future IEEE standards focusing on prioritization, Virtual LAN (VLAN) tagging, traffic shaping, bandwidth management, and resource reservation will enable network operators to provide guarantees for time-sensitive packet delivery on the EFM network.

In addition to QoS, Ethernet will provide the bandwidth that voice, video and high-speed data access requires. Offering speeds up to 1 Gbps, EFM will significantly improve connectivity speed over current "broadband" access technologies, such as DSL and cable.

As the following table shows, EFM will be a "future-proof" access technology for transport of all applications and services.

Application	Implementation over EFM
Digital Video	MPEG 2 or 4; encoded digital video for DVD quality video-on-demand services all the way up to High Definition TV (HDTV) streams
Digital Voice	Packetized voice over IP
Data	High-speed Internet access; Transparent LAN Services; Virtual Private Networks (VPNs); remote data storage; e-commerce; customer support

By eliminating multi-protocol conversions and low bandwidth links, and by creating a universal technology, EFM is future-proof for any application. There will soon be a wide selection of interoperable and inexpensive equipment, and flat network designs will enable more services at lower deployment costs. And by specifying a

simple OAM approach, EFM reduces network management complexity, so there is less need for constant changes and upgrades to integrate mixed services.

Conclusion

EFM will revolutionize the subscriber access network by making universal broadband access a reality. For network operators, equipment and component manufacturers, and ultimately for subscribers, Ethernet will deliver universal broadband access with a universal set of interoperable components. All stakeholders will experience the most effective infrastructure for data services, future-proof transport for data, video and voice applications, and a simple global standard that will ensure interoperability.

Appendix

Terminology

Term	Definition
Access Node	The network side of the first mile where an operator's access equipment is located. Options exist to deploy the Access Node in a Central Office (Telephony Local Exchange) or remotely at the curbside or in a building.
Ethernet	A packet-based protocol that is used universally in local area networks and strong candidate for cost efficient deployment in access and metropolitan networks.
EFMC	Ethernet in First Mile topology for voice-grade copper.
EFMF	Ethernet in First Mile using Point-to-Point Fiber topology
EFMP	Etehrnet in First Mile using Point-to-Multipoint topology, based on Passive Optical Networks (PONs).
EFMA	Ethernet in First Mile Alliance. An alliance of companies whose goal is to focus the necessary resources to make IEEE 802.3ah a successful industry standard. In 2004, the EFMA became part of the Metro Ethernet Forum
First Mile	Also called the last mile, the subscriber access network or the local loop, the first mile is the communications infrastructure of the business park or the neighborhood.
IEEE	Institute of Electrical and Electronics Engineers. A standards setting body responsible for many telecom and computing standards, including the Ethernet in the First Mile standard, IEEE 802.3ah.
MDU	Multi-dwelling unit, such as an apartment house or hotel.
MTU	Multi-tenant units, such as an apartment house or office building.
MXU	The collective name for MDUs and MTUs.
OAM	The specification for managing EFM.
Network operator	Also called service providers and local exchange carriers, they provide access network services to subscribers.
PON	Passive Optical Network. A single, shared optical fiber that has inexpensive optical splitters located near the subscribers.
PSTN	Public Switched Telephone Network.

References and Resources

Reference	Description
IEEE 802.3-2002	"CSMA/CD Access Method and Physical Layer Specifications", http://standards.ieee.org/reading/ieee/std/lanman/restricted/802.3-2002.pdf
IEEE 802.1Q	"Virtual Bridged Local Area Networks", http://standards.ieee.org/reading/ieee/std/lanman/802.1Q-1998.pdf
MEF 10	MEF Technical Specification "Ethernet Service Attributes, Phase 1", http://www.metroethernetforum.org/PDFs/Standards/MEF10.pdf
MEN Technical Overview	" Metro Ethernet Networks – A Technical Overview", http://www.metroethernetforum.org/PDFs/WhitePapers/metro-ethernet-networks.pdf

Disclaimer

This paper reflects ongoing work within the MEF captured in a series of technical specifications which are a work in progress. The official MEF specifications are available at www.metroethernetforum.com/techspec. These represent a 75% member majority consensus as voted by members of the MEF Technical Committee at the time of their adoption.

This paper will be updated as new work emerges from the MEF Technical Committee. Updates versions are available at http://www.metroethernetforum.org

About the Metro Ethernet Forum

The Metro Ethernet Forum (MEF) is a non-profit organization dedicated to accelerating the adoption of optical Ethernet as the technology of choice in metro networks worldwide.

The Forum is comprised of leading service providers, major incumbent local exchange carriers, top network equipment vendors and other prominent networking companies that share an interest in metro Ethernet. As of December 2005, the MEF had over 70 members.