FAST ETHERNET IN THE LAST MILE

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Abstract

Broadband HFC network operators in North America are uniquely positioned to serve the increasing needs for telecommunications services among small and medium size businesses. This paper analyzes the market potential for providing bandwidth and other telecommunications services to this telecommunications market segment. Near-term opportunities for HFC network operators as alternative bandwidth providers and longer-term opportunities as Layer 2 and Layer 3 service providers are also discussed. It describes several technology solutions that can be deployed in the HFC plant to support transport of bandwidth-intensive applications and services. The paper also includes a discussion on the requirements such business applications will place on an operator's network.

Finally, the paper describes how a solution based on Ethernet transport can also be deployed to support delivery of high-bandwidth residential services to MDUs/MTUs in high-density urban environments.

INTRODUCTION

Broadband HFC Advantage

Broadband HFC network operators in North America have a distinct advantage over their competitors in providing telecommunications services to small and medium size businesses. With the right selection of the technology, high quality service can be ensured at lower incremental cost than the cost incurred by the competitors for delivering equivalent service quality.

In the U.S., HFC network footprints already cover approximately 80% of all SMBs. As of 1999, 1 in 5 SMBs already subscribed to cable TV at their business location, primarily for customer entertainment.[i] In most of these cases, HFC networks are already within the last few hundred feet from potential business customers. This translates into lower incremental fiber construction costs in fiber-to-the-business (FTTB) architecture.

With fiber to the business, high-speed connectivity at 100 Mbps or 1 Gbps can be provided cost-effectively today. This high-speed access can be throttled back or aggregated depending on individual customer needs. Moreover, fiber to the business offers sustained full throughput in contrast to such alternative offerings as DSL or cable modem.

Ethernet Advantages

Several data communications systems have been developed and implemented to serve internal and external telecommunications needs of enterprises. Among them, Ethernet has gained the broadest acceptance. The following numbers clearly support this assessment:

1. 80+% of all data packets begin and end their lives as Ethernet packets.
2. There are 250 million Ethernet ports deployed worldwide.

3. 90% of transported business data begins and ends as Ethernet on LANs.

Ethernet is well understood by small, medium and large enterprises. It is manageable by small businesses without a dedicated IT staff. Moreover, it is supported by the dominant standard and represents mature technology. The IEEE 802.3 standard on Ethernet was released in 1980. It also proved to be extremely flexible and future proof as new developments (Gigabit Ethernet, 10 GigE) do not obsolete previous implementations.

Beside the fact that Ethernet technology is characterized by low maintenance cost, it is also relatively inexpensive to implement due to economies of scale from large installed base. It has shown excellent price/performance trend: 10x the performance of the preceding generation at 3x the cost.[ii]

Alternatives

The enterprises use almost all technologies available today to interconnect their internal organizations located at different locations and to secure connectivity with Internet. The following data[iii] (Table 1 and Figure 1) provide the distribution of deployment of different connectivity technologies for data communication services.

	Medium Size Businesses	Extended Medium Size Businesses
Dial Up	83%	84%
T1/T3	41%	61%
ISDN	36%	58%
Switched 56 kbps	19%	35%
Frame Relay	15%	21%
Satellite	6%	3%
ATM	2%	1%
ADSL	1%	1%

Table 1: Type of Connectivity for Data Communication Services

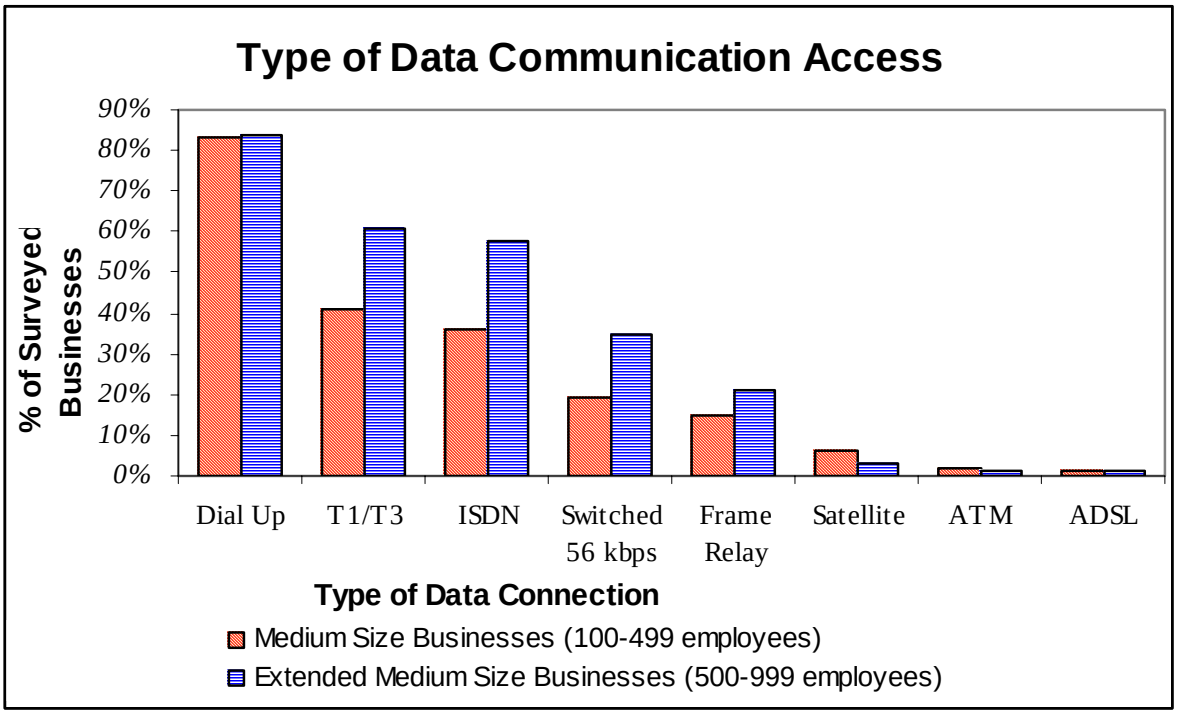

Figure 1: The Usage of Different Connectivity Technologies for Data Communications Services

OPPORTUNITY

Market Definition

There are many definitions of the small and medium size businesses. The following presents one of the accepted definitions with some characteristics of their communication needs and preferences:

1. Small size businesses:
   a. less than 50 employees,
   b. fastest growing segment,
   c. mostly ignored by local exchange carriers (LECs),
   d. highly receptive to competitive offerings,
   e. application and service needs: voice support for up to 24 POTS lines, Internet access (from 56 kbps to DSL speeds today) and IP management services,
   f. billing preferences: consolidated billing for voice and data (Internet) services.
2. Medium size businesses:
   a. up to 100 employees,
   b. multi-campus/branch offices, most often within a single metropolitan area,
   c. considered easiest target by many LECs,
   d. receptive to regional competitive offerings,
   e. application and service needs: voice support for digital PBX systems (requires fractional and full T-1 line provisioning), Internet access (high speed DSL today) and IP/WAN management services,
   f. billing preferences: consolidated billing for voice and data (Internet) services.
3. Large size businesses:
   a. in excess of 100 employees,
   b. multi-campus/branch offices,
   c. receptive to national/international offerings,
   d. application and service needs: voice and data networking (Intranet, private tandem switches, etc.), virtual private networking (today over frame relay and ATM networks).

Market Statistics and Opportunity

Based on the definitions presented above, the industry reports[iv] show that small and medium size businesses (SMBs) represent 95% of the entire U.S. business universe. They amount to 7.6 million entities approximately and this number is growing at approximately 2% annually. In 1998 alone, LAN penetration in SMBs grew by 10% to 36% while the percentage of LAN connected PCs grew by 24% to 13.4 million.

SMB spending on IT and telecom services is higher than $100 billion a year.

The costs and other characteristics of the alternative technologies for data connectivity today are presented below.

1. Low-speed T1 connections:
   a. typical installation times 30-45 days,
   b. installation costs range from $1,000 to $2,000,
   c. maximum symmetrical bandwidth of 1.5 Mbps,
   d. average monthly costs range from $400 to $1,200;
2. Low-speed, DSL connections:
   a. typical installation times 4-6 weeks,
   b. installation costs range from $200 to $300 plus CPE costs of $100-$400,
   c. 10+ DSL flavors results in complex pricing structure,

   d. maximum symmetrical bandwidth up to 1.5 Mbps in various increments,
   e. average monthly costs of $150 to $400 for symmetrical DSL service,
   f. must be close to central office (CO);
3. Cable modem connections:
   a. typical installation times less than a week,
   b. installation costs range from $0 (cost to the customer, non-zero cost to the service providers) to $150,
   c. average monthly costs range from $40 to $80,
   d. shared bandwidth perceived as a disadvantage for business applications;
4. Data carrier connections:
   a. Installation costs range from $3,500 to $7,500,
   b. Dedicated symmetrical bandwidth offering: 100BaseT to 1 Gbps Ethernet,
   c. Average monthly costs range from $1,000 to $4,000,
   d. Limited availability depending on market.

The data carrier connections can be quite expensive even in the access network. The following table presents pricing structure for Worldcom Ethernet service offerings.[v]

	Service	Customer Interfaces	Price/month
Metro and WAN Private Line	Corporate MAN links	50 Mbps, 150 Mbps, 622 Mbps	Similar to ATM and frame relay
Dedicated Internet	Enterprise access to Internet	1 Mbps to 500 Mbps	$1,200 to $200,000 per circuit
Enterprise private line/VPN	LAN to LAN and corporate network connections	1 Mbps to 100 Mbps	$630 to $20,000 per circuit

Table 2: Worldcom Ethernet Service Profiles

Market Requirements

There are several basic requirements specified by most businesses and some specific requirements dependant on the business size and type. Almost the same requirements are defined by service providers. The basis requirements can be summarized in the following points:

1. Service scalability
   a. Bandwidth offering scalable from 1 Mbps to 1 Gbps
   b. Symmetrical bandwidth preferable
2. Deployment cost scalability:
   a. Equipment to provide services can be deployed based on the service demand (number of customers and bandwidth requirements)
   b. Cost scales with the SLA requirements (for example, equipment and route redundancy can be implemented on a as-needed basis)
3. Deployment simplicity
4. Future proofing
   a. Future protocols do not render equipment providing connectivity obsolete

   b. Equipment upgrades are easy to accomplish at limited and demand driven locations
5. Acceptable service reliability and availability
6. Low maintenance costs

Some additional requirements from the following list may be critical dependant on business size and type:

1. Affordable and competitively priced
2. Security comparable to or better than provided by competitive technology and providers
3. Transparency to layer 2 and higher protocols:
   a. Allowing service providers (MSOs) and customers (SMBs) for leveraging the existing LAN/WAN hardware infrastructure
   b. Allowing for passing through Layer 2 and higher protocols, overlaying datacom protocols for robustness and security (e.g., CoS, QoS, IPSec)
4. Accessible to SMBs without a dedicated IT staff
5. Capable of supporting or transparent to critical business applications
   a. Transparent to voice, video and data applications
   b. Supporting:
      i. point-to-point LAN transport,
      ii. multipoint LAN interconnect and extension,
      iii. VLANs,
      iv. VPNs, and
      v. leased line replacement.
6. Low latency for latency-sensitive applications like VoIP and video streaming
7. Support for TDM (T1, E1, DS3) traffic and interfaces
8. Sustainable, non-degrading with distance performance (unlike various favors of DSL).

There are some requirements important to service providers:

1. ROI for equipment: in months
2. Clear network demarcation points
3. Compatible with existing HFC architecture and headend installation and equipment
4. Easy to install
   a. no additional active devices in the plant to install and manage
   b. capable of flexible connection topologies (point-to-point, ring, nested span, etc.)
5. Easy to manage
   a. SNMP compliant interfaces
   b. remote provisioning for new business customers
   c. upgradeable via software downloads.

TECHNOLGIES AVAILABLE TO BROADBAND HFC NETWORK OPERATORS[vi]

There are several data connectivity technologies that have been deployed in the past. This paper will concentrate on these that use Ethernet based interfaces. All of these technologies can be divided into two groups:

1. Technologies with network processing (intelligent) equipment distributed in the access plant.
2. Technologies with network processing equipment centralized in headends or main hubs.

Both groups require customer premise equipment. This equipment type and intelligence is mostly defined by medium type and internal LAN requirements. Both groups include several possible deployment scenarios and topologies.

Distributed Processing Equipment

Distributed equipment usually comprises IP switches/routers deployed in the field between headend (or CO) and the customer. Several architectures are being marketed by vendors:

1. FTTB/H EPON with:
    a. Switches and aggregation points in nodes and optical gateways on customer premises; or
    b. Switches at optical nodes and/or amplifiers and optical gateways on customer premises.
2. Hybrid fiber/copper pair architecture with:
    a. Switches and aggregation points at optical nodes,
    b. Switches in taps, and
    c. Cat6 copper pair physical layer mesh network between switches (Cat6 to homes).
3. Hybrid fiber/coax architecture with:
    a. Switches and aggregation points at optical nodes,
    b. Switches in taps,
    c. Coax drops to homes, and
    d. Coaxial physical layer with RF modulation and demodulation and up-and down- conversion at each switch location and at customer premises.

All the above technologies can be analyzed against the set of requirements presented previously. This detail analysis can be performed by the readers of this paper. Here are just few comments:

1. The history of IP and other higher layer protocols shows that the legacy equipment not always support and not always can be upgraded to support the new protocols and has to be replaced. This usually is not a problem when the legacy equipment is located at limited locations or on customer premises (demand-driven replacement) but may pose significant problems (cost, service disruption) if located in the access plant.
2. Addition of new switches and traffic aggregation points may lead to service disruptions for some architectures presented above. The service disruptions may affect data customers or any-service customers served by the HFC network.

Centralized Processing Equipment

Similarly to the distributed processing equipment solutions, the existing solutions for the centralized processing equipment offer several alternatives:

1. Ethernet over RF
    a. DOCSIS, a standard-based solution with:
        i. Steeply decreasing equipment prices
        ii. Improving performance (DOCSIS 2.0)
        iii. Limited total and per channel bandwidth (even with DOCSIS 2.0)
        iv. High maintenance cost of upstream HFC path
    b. Ethernet over RF based on proprietary solutions:
        i. Without bandwidth conversion or
        ii. With bandwidth up- and down-conversion.
2. Transparent Layer 1 pipe:
    a. Overlay systems with dedicated fiber or wavelength
    b. Integrated optical systems

The Ethernet over RF systems are comparable in performance. Proprietary systems may have advantage in delivering higher bandwidth, especially when combined with up- and down-conversion. However, the proprietary character of these solutions will most likely result in high equipment cost. Moreover, the coaxial shared medium is still

perceived by many businesses as less reliable than dedicated fiber and copper media.

The transparent pipe alternative in its overlay configuration has been available for as long as IP switches and routers exist. Several established transport and IP equipment manufacturers and some start-up companies provide equipment for point-to-point, point-to-multipoint and ring topologies. The equipment has several standard interfaces ranging from T1/E1 emulated TDM circuits through 1 GigE interfaces. This type of equipment competes with ATM, frame relay and (recently) SONET solutions. As described above, thanks to the Ethernet proliferation, it has cost and other advantages over the competing technologies. This technology is suitable for larger business and is a simple extension of metro-market topology into access plant. It does not offer a significant advantage to HFC network operators as any operator with a capability of installing or with already installed fibers to POPs located in proximity of large businesses could implement this data communications technology. Moreover, this market (large businesses) has been successfully addressed by ILECs, CLECs and other data carrier companies.

The integrated solutions are usually a hybrid approach (at least as long as FTTH for residential services is not deployed). Usually it can be integrated to the node location. From the node to the business, it is delivered on a dedicated fiber. At least one of the vendors offering this technology has also capability for flexible increase in capacity to 1 GigE and above. The integrated technology has been enabled in the last several years with the introduction of digitized technology in upstream HFC links supporting the legacy RF two-way communication. The figure below shows an example of the integrated Ethernet solution.

The integrated solutions can be modified to provide a full, dedicated connectivity to larger businesses in an evolutionary and scalable manner. This is supported by a significant progress in passive component technology (colorless and WDM), especially in their capability to perform under harsh outside plant conditions.

APPLICATIONS AND REVENUE OPPORTUNITY

Near-Term Opportunities

Near-term opportunities for HFC network operators as alternative bandwidth providers can materialize in the following areas:

1. T1 replacement with T1 interfaces for both data and voice services:
   a. lower cost (cost of T1: $400-1200/month with $1-2K installation cost for a maximum of 1.544 Mbps bandwidth)
   b. shorter than 30-45 day waiting period for T1 installation and activation
   c. service to
      i. small/medium/large businesses
      ii. wireless backhaul to the PSTN for cell towers
      iii. virtually any customer of T1 services today
2. DSL replacement for data communication and Internet access
   a. dedicated, guaranteed bandwidth, no degradation with distance
   b. higher capacity than DSL at similar or lower cost (cost of DSL: $150-400/month for symmetric DSL for 128 kbps—2 Mbps; $60-200/month for asymmetric DSL for 192 Kbps—1.5 Mbps)
   c. shorter waiting period
   d. service to small and medium businesses
3. VoIP

a. integration of voice with existing data services for small and medium size businesses
b. transport of T1 over Ethernet to support legacy PBX applications with integrated or off-the-shelves interfaces (T1 and E1 emulators)
c. secondary voice lines for the residential market (MDUs)

These services can be provided to the following market segments:

1. SOHOs/SMBs
2. MDUs
3. Multi-campus businesses
4. Businesses with telecommuters
5. Institutions:
6. Schools
7. Universities
8. R&D facilities
9. Hospitals
10. Military and Government facilities
11. Sports facilities

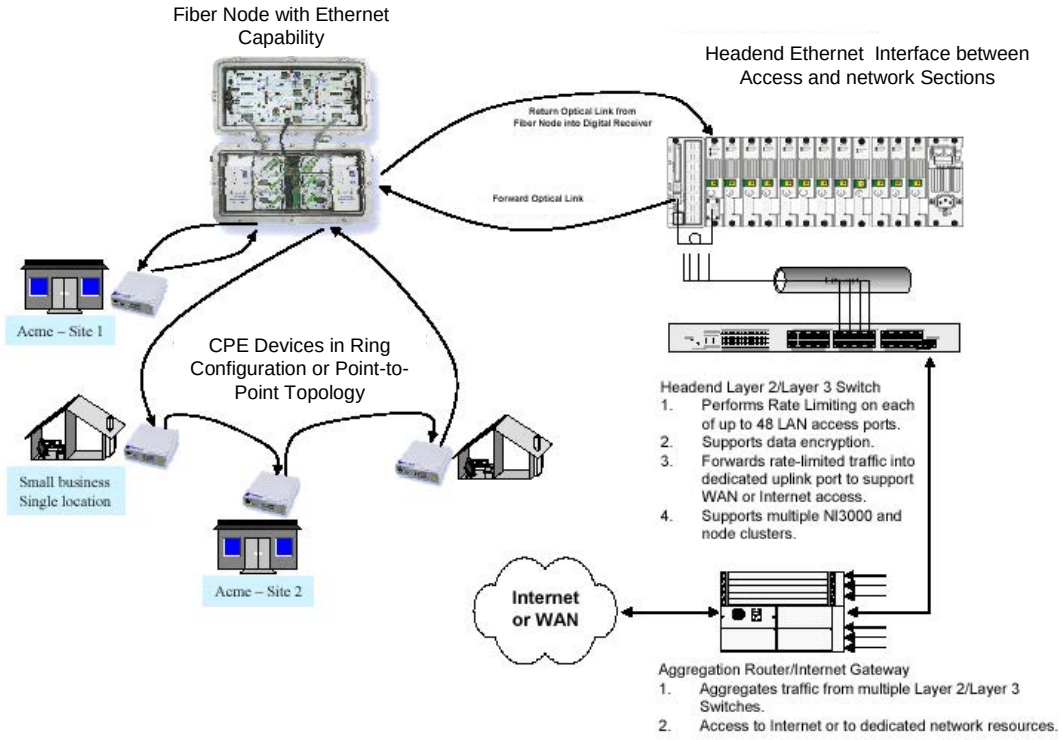

Figure 2: Integrated Ethernet over HFC Network – Example

Long-Term Opportunities

As the experience and familiarity with the networking technology grows, longer-term opportunities can be addressed and capitalized on. These include:

1. VLAN tunneling
2. Link aggregation
3. L2 and L3 Quality-of-Service (QoS) features
4. IP network services
5. Alternative high-speed ISP access
6. Alternative IP telephony services
7. Future services such as IP video streaming, etc.

Many MSO organizations have already expertise and staff to support these services to any businesses.

ETHERNET TO RESIDENCES

The integrated Ethernet approach can be easily extended to serve residences. This extension may happen selectively based on cost analysis. The residential Ethernet FTTH connections can take place initially in MDUs where the cost of CPEs and switches provisioning the service to individual suites can be shared among many tenants. This type of solution, besides minimizing network complexity, also allows freeing up valuable forward and return spectrum that can then be allocated to other services. Moreover, in most cases, it eliminates the need for costly coaxial cable rewiring in MDUs. With the development of lower cost CPEs with limited features, acting mostly as media converters, symmetrical Fast Ethernet (shared among several residences) can be also delivered to SFU residential areas. The figure below presents the evolution from FTTB to FTTH through intermediate step of deploying fiber to MDUs.

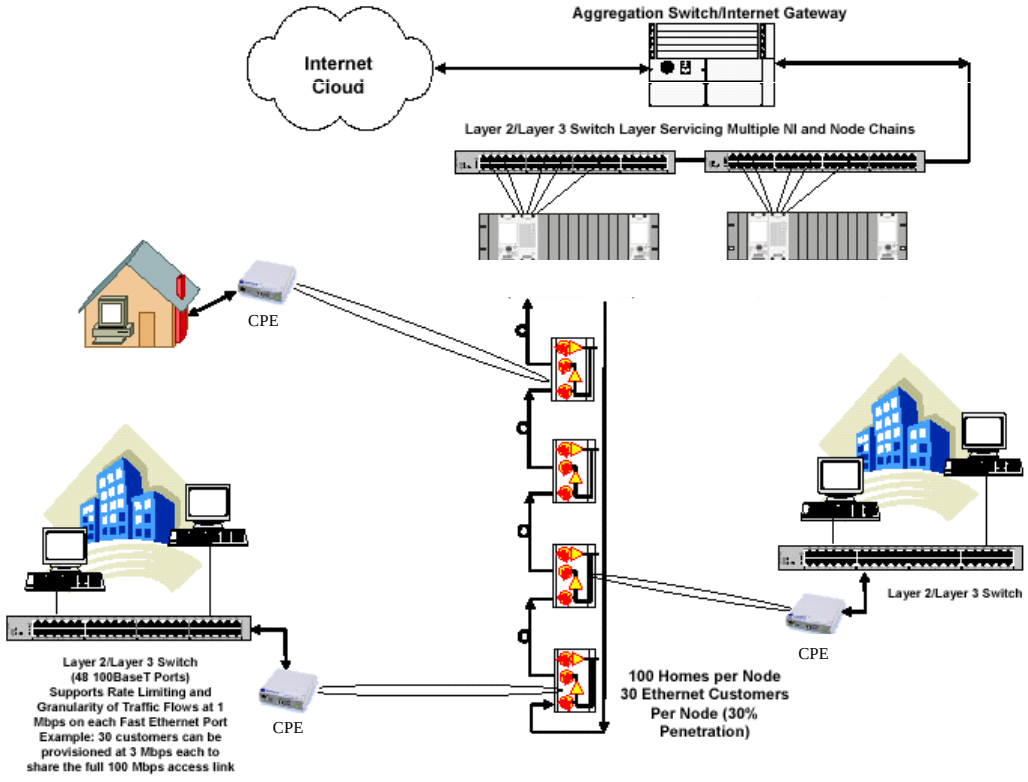

Figure 3: Evolution to FTTH Ethernet for Residential Areas

This evolution will be fueled by the trends[vii],[viii] reported in the industry summary reports:

1. 400,000 FTTH subscribers worldwide implemented by the end of 2002,
2. 50,000 (or 22,500 by others) FTTH subscribers in North America
3. 50 FTTH served communities in the USA
4. Trends:
   a. 300,000 FTTH subscribers in 2003
   800,000 FTTH subscribers in 2004 (1,400,000 by high projections for 2004)

SUMMARY

The demand for data communications and other telecommunications services from SMBs presents a lucrative opportunity for increased revenue. This increase can be achieved by leveraging MSOs' investment in broadband HFC networks.

Multiple choices of providing Ethernet to businesses are available to HFC network operators. These technologies and architectural choices should be evaluated against business and market (competition) requirements as well as against operator's objectives.

These solutions create an opportunity for HFC network operators to replace CLECs and ILECs as telecommunication service providers to SMBs. This market is dramatically underserved by the traditional telecommunication service providers.

Moreover, the technologies allow for competing with ILECs, CLECs and data carrier companies for large business market in a scalable and evolutionary manner.

FTTB applications can be readily and cost-effectively extended to the MDUs and MTUs today. Future price trends in the optical and digital technology may allow (and by some reports already allow) for cost-effective implementation of FTTH systems.

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[i] AMI-Partners

[ii] Metro Ethernet Forum

[iii] AMI-Partners

[iv] AMI-Partners' 2002 U.S. Small Business Market Opportunity Assessment Report

[v] Lightreading, May 2002

[vi] Information from web-sites and published documents of the following vendors:

- Advent
- Aurora
- Cisco
- Harmonic
- Jedai
- Narad
- SwitchPoint
- Wave7Optics
- Xtend

[vii] J. Baumgartner, Fiber-to-the-home blazes an evolutionary path, CED, February 2003

[viii] R. Pease, Fiber-to-home proponents speak out against negative deployment myths, Lightwave, February 2003.