TECHNOLOGY WHITE PAPER

Fiber-to-the-User: The Ultimate Endgame

Fiber-to-the-user (FTTU) has been the ultimate endgame in access networks for a long time. Until recently, deploying FTTU was too expensive and complicated. Now, the creation of standards and reduced equipment and installation costs are making the technology more feasible to deploy. The regulatory environment originally discouraged ILECs from deploying FTTU. New providers, such as utilities companies, municipalities, competitive LECs and real estate developers, have started deploying community-based networks. This is leading to regulatory reforms that promote FTTU builds. Not only is FTTU a viable technology to deploy, it is becoming imperative for providers to build the infrastructure, in order to offer the services needed to stay ahead of their competitors.

ALCATEL

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Introduction

Network architects have recognized the potential for all-optical networks since they began the first fiber-to-the-home (FTTH) trials in the 1980s. However, heavily regulated market conditions and high costs overrode the advantages of fiber's high bandwidth and versatility.

While most of the core network is now fiber-based, the access network is still mostly copper-based. Today, nearly all residential and most business customers are connected to the network with copper wire. Telephone companies have traditionally used twisted pair copper wires, while cable multiple-service operators (MSOs) have relied on coaxial cable. In the past, networks were purpose-built to provide a single service — one network for telephone service, and a separate network for entertainment or cable TV.

The first FTTH technology trials were conducted with proprietary solutions from individual vendors. The Full Service Access Network (FSAN) group began to form technology standards for fiber access in the mid-1990s. The service provider community viewed establishing standards as the key to making the mass deployment of fiber viable in access networks.

The initial set of FSAN fiber access specifications for passive optical networks (PONs) was adopted by the ITU-T in 1998. Since then, products from multiple vendors have been introduced; however, deployment by the traditional, independent local exchange carriers (ILECs) has been limited. The ILECs were impeded by a regulatory environment that discouraged carriers from deploying fiber in access networks.

While traditional carriers were trying to meet the increasing demand for broadband services, new entities such as municipalities and utilities started building fiber access networks. Today, the market is characterized by comprehensive standards, a favorable regulatory market, reduced installation and equipment costs, growing demand for broadband services, and strong competition. Providing FTTU is fast becoming a requirement for service providers to stay competitive and retain customers.

Market Drivers

Decreasing Costs and a Maturing Technology

Extensive progress has been made in fiber access technology over the past ten years, reducing equipment and labor costs. Cost reductions and the maturity of the technology are the key drivers that have made fiber for access a viable network choice, now more than ever.

In the first FTTH trials in the 1980s, the capital cost per home connected was orders of magnitude higher than copper. Equipment was unreliable, and size and power consumption unsuitable for mass deployment. While considerable technological advances were made in fiber transmission in the 1980s, it was not until the late 1990s, coinciding with the formal standardization of the fiber access-technology by the ITU-T, when the most significant gains were made in performance and cost reduction.

Establishing standards is usually a pre-requisite for mass adoption of a technology. Standardization permits interoperability among vendors' equipment and creates an environment that encourages companies to compete in price and performance, and to develop a wider range of product features. This leads to further developments in the technology, and drives prices down.

Capital cost per home connected was still U.S. $7,500 in the early 1990s in the GTE Cerritos FTTH field trial, for example. But equipment costs have tumbled rapidly since the late 1990s. Capital cost per home connected is less than U.S. $1,500 today.

Impressive technological advances in fiber splicing, trenching, fiber ducts, connectors and enclosures have reduced installation costs significantly. These new technologies and processes make fiber installation easier and less time consuming, thereby reducing labor costs.

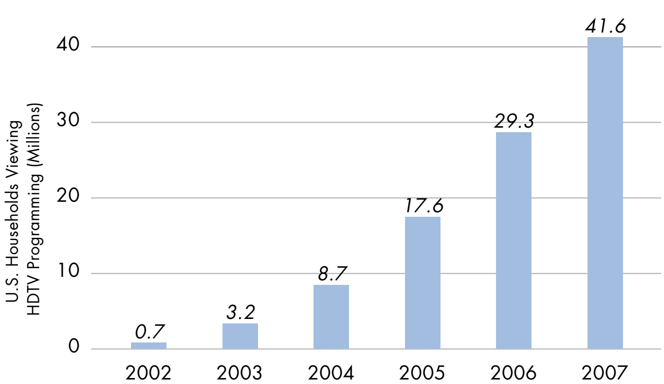
The Growing Demand for Broadband Services

The need for increased bandwidth has been consistently questioned by the skeptics. Not long ago, people asked who would need more than 64 kb/s bandwidth. But the demand for bandwidth is growing.

High speed Internet access over DSL or cable modem is approaching 40 percent in several countries and already exceeds 70 percent in South Korea. Peer-to-peer applications, video and audio streaming, and emails with large attachments dominate Internet traffic today.

In addition to data traffic, the video industry is going through revolutionary changes, such as the introduction of all-digital satellite TV with an integrated personal video recorder (PVR) that allows subscribers to watch broadcast TV programs on their own schedule. Cable operators are upgrading their networks to support digital TV and high definition TV (HDTV) in order to remain competitive, attract new service revenues, and meet changes in regulations (see Figure 1).

Figure 1 - Estimated Growth of HDTV Usage



Source: The Yankee Group, 2003

HDTV is expected to reach 41 million U.S. households by 2007, and will be mandated by the Federal Communications Commission (FCC) by 2006 under certain conditions. A host of other interactive TV applications are also expected to grow (see Figure 2). These applications are bandwidth intensive and best delivered over a fiber network.

Competition and the Changing Regulatory Environment

Increasing competition and the changing regulatory environment are making it imperative for service providers to offer FTTU.

Fiber networks are no longer the sole domain of telecommunications carriers. Traditional ILECs are being threatened by cable MSOs on one side, and by emerging carriers and community networks owned by municipalities, utilities and developers on the other. This competitive environment is forcing carriers to provide a suite of services. A network that supports a single service is no longer a viable business solution.

This new competitive landscape led the FCC to issue new regulatory guidelines for the wireline access network in its latest Triennial Review Ruling [Source: FCC Triennial Review, August 21, 2003]. The new rules allow ILECs to build optical access-networks without having to share them with competitors for new-build, or greenfield applications.

Offering multiple services provides several benefits, including:

> Increased revenue from additional services
> Lower costs to operate the network compared to costs of managing separate networks
> Lower costs for sales and marketing of services; a sales call for one service can be used to upsell other services
> The opportunity to bundle services to increase customer retention; increasing the number of services sold to a customer decreases the risk the customer will change service providers (see Table 1)

Table 1 - Bundled Services Reduce Customer Churn

	Cox Communications			Insight Communications		
Services in bundle	Churn	Life of sub (in months)	Life of sub (in years)	Churn	Life of sub (in months)	Life of sub (in years)
1	3.10%	32.26	2.69	3.20%	31.25	2.60
2	2.46%	40.65	3.39	2.80%	35.71	2.98
3	1.55%	64.52	5.38	1.20%	83.33	6.94

Source: UBS Investment Research, 22 September 2003, Page 6.

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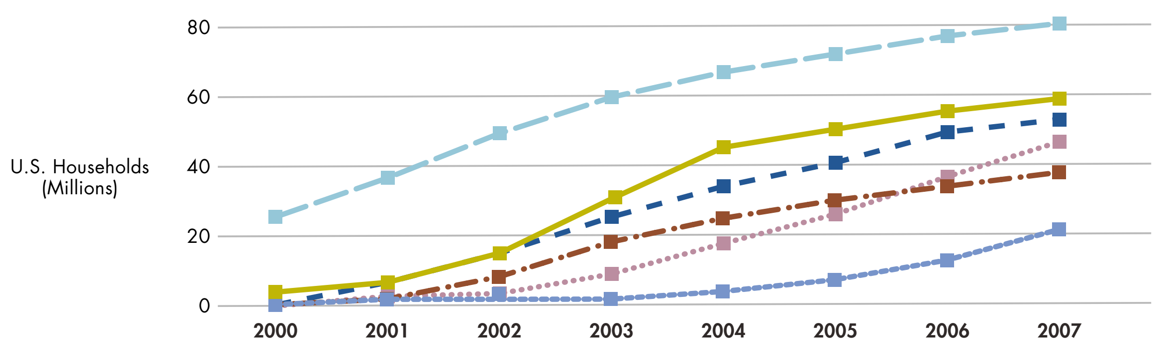
Reducing churn saves substantial costs associated with the acquisition of a new customer in a highly competitive environment. Acquiring a new customer often includes hundreds of dollars of up-front costs for free installation, customer premises equipment (CPE) and additional customer service. These expenses can jeopardize profitability unless the subscriber remains a long-term customer. Fiber offers the best guarantee that a network provider will have the infrastructure needed to deliver desired services, stay competitive, and retain customers.

Figure 2 - Growth of Interactive TV Applications



	2000	2001	2002	2003	2004	2005	2006	2007
IPG	24.9	35.9	47.1	57.0	63.4	68.8	73.3	76.4
Enhanced TV	3.4	7.5	14.6	30.1	43.9	48.8	53.5	58.0
Walled Garden/Virtual Channels	0.6	5.3	16.5	25.1	33.5	40.7	47.1	50.8
PVR*	0.3	0.9	3.3	9.4	17.2	26.0	35.8	45.7
VOD	0.4	2.9	8.5	18.1	24.3	29.2	32.9	36.7
Gateway	0.0	0.0	0.0	1.1	3.9	8.6	14.1	21.7

* In 2007, PVRs will reach more than half of U.S. households.

Source: Forrester Research Inc., 2002 report on Interactive TV

BPON Technology

There are many types of FTTU technologies; the most popular one is based on the concept of using a passive fiber distribution network, known as a passive optical network (PON). Broadband PON (BPON) is a set of standards that specify the service capabilities and network protocols for broadband services over fiber access. It is specified by the ITU-T, and published in the G.983.x series of ITU-T recommendations. There are several types of PONs, but BPON is the most mature and widely used.

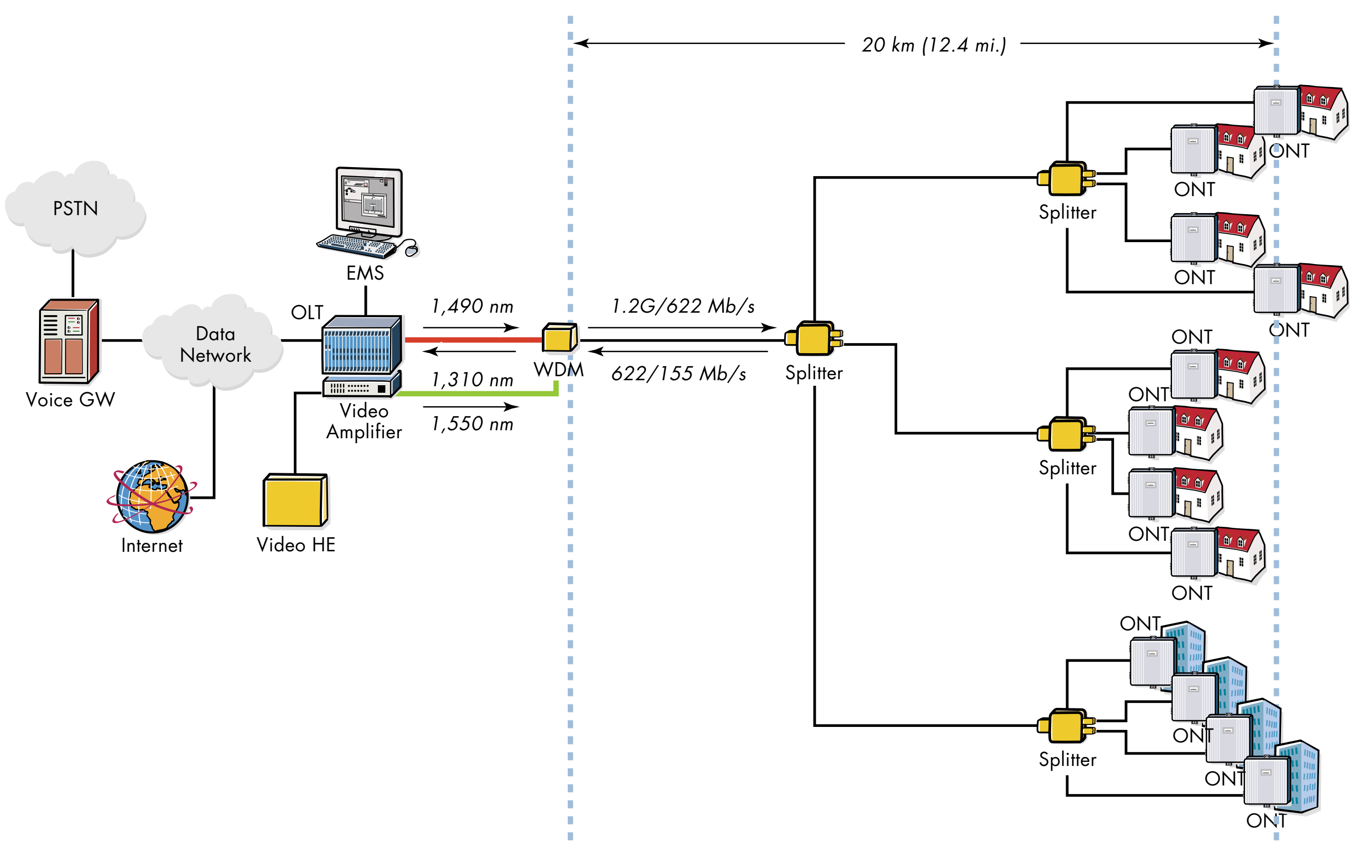
In a PON, the active optoelectronics are situated on either ends of the passive network (see Figure 3). An optical line termination (OLT) device is installed in the central office (CO), and an optical network termination (ONT) device is installed on the other end, in or near each home or business site. Fiber distribution is done using a tree-and-branch architecture. A single fiber connected to the OLT can be split up to 32 times and connected to multiple ONTs.

The ITU-T has improved BPON standards to provide the capability to meet emerging requirements for broadband services. Initially, BPON standards were specified at 622 Mb/s for downstream traffic and 155 Mb/s for upstream packet/data traffic. All services, including video, were expected to be encapsulated in data packets. Later, BPON standards were enhanced, first to add another wavelength for video services on the same fiber, and then to increase the downstream bandwidth to 1.2 Gb/s and upstream bandwidth to 622 Mb/s.

The wavelength 1550-1560 nm was added for two reasons. It was generally agreed that carrying a radio frequency (RF) signal over the same fiber offered the best solution for existing and emerging video services. It allowed the option to offer video distribution services as well as handle the growth of additional digital services in the future, and it enabled newer services such as HDTV, PVR and video on demand (VoD).

The downstream wavelengths of 1490 nm for data traffic and 1,550 nm for video traffic are coupled together using a coarse wavelength division multiplexing (CWDM) coupler and

Figure 3 - Broadband Passive Optical Network



transmitted over the same fiber. Upstream traffic is transmitted by the ONT using the 1,310 nm wavelength. The BPON standard offers bandwidth of up to 1.2 Gb/s for downstream and up to 622 Mb/s for upstream traffic. A separate dedicated wavelength is coupled for downstream video on the same fiber offering up to 6 Gb/s bandwidth. An external WDM device is used to couple the 1,550 nm wavelength dedicated for video on the same fiber. The ONT includes a highly sophisticated triplexer that allows transmission/reception of all three wavelengths on a single fiber.

The BPON access network is specified to operate effectively over a distance of 20 km. In typical network configurations, the video signal received from a video head end is amplified using erbium doped fiber amplifiers (EDFA) before it is transmitted over the fiber access network.

Downstream traffic is transmitted using time division multiplexing (TDM) and upstream traffic is transmitted with the time division multiple access (TDMA) protocol. Downstream cells destined for different ONTs are multiplexed using a single frame structure, and transmitted over the fiber network to all ONTs (see Figure 4). The ONTs rely on the cell addresses to filter the traffic appropriately. In the upstream direction, cells from different ONTs are transmitted based on time-slot access grants given by the OLT, where the whole transmission frame is terminated. The access grants can be administered based on provisioned bandwidth, or they can be dynamically allocated based on bandwidth availability and traffic load.

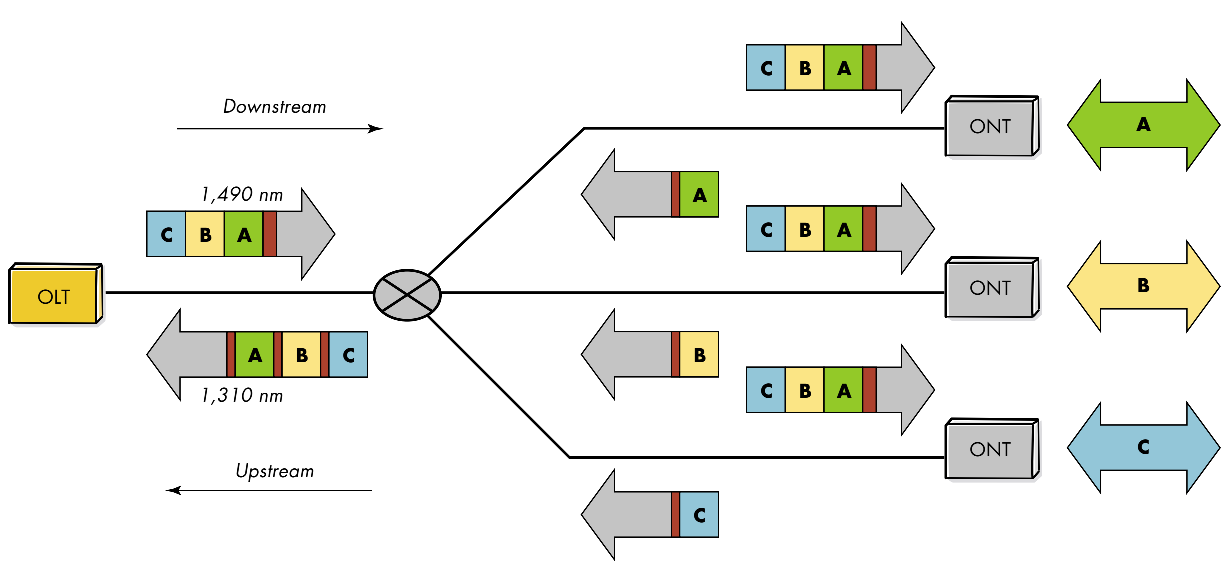
The BPON standard offers a number of key advantages compared to other technologies.

Because BPON is standards-based, it ensures product interoperability among vendors' equipment. This drives equipment manufacturers to compete for price and performance, and to develop new feature capabilities. This, in turn provides customers with the opportunity to choose from a variety of products most suited to their needs. The standard is comprehensive, ensuring products developed to meet BPON specifications are robust and reliable.

The BPON provides sufficient bandwidth for current and future applications. It offers bandwidth up to 1.2 Gb/s for downstream and up to 622 Mb/s for upstream traffic. The BPON standard includes quality of service (QoS) support for various types of services, including voice, data and video, using QoS capabilities in the ATM transport protocol.

No active components are installed in the outside plant, thereby reducing cost and maintenance issues in the PON. Passive optical splitters are used to build the tree-and-branch fiber distribution network. Optical splitters are inexpensive, highly reliable and require no power. Active elements in the outside plant require power, tend to be bigger (taking up more space), and are more complex to install. They have higher maintenance costs and more downtime.

Figure 4 - BPON Downstream and Upstream Traffic Flow



The BPONs are optimized for both high-speed data and video services (see Figure 5). They offer significantly more bandwidth compared to copper and other fiber access technologies because they use multiple wavelengths.

To evaluate the maximum bandwidth available in a BPON, add the downstream bandwidth in the 1,490 nm and 1,550 nm wavelengths. The downstream capacity approaches 6 Gb/s. Because the signal in the 1,550 nm wavelength is RF, its digital signal capability is calculated based on a given modulation scheme, such as QAM 64. QAM 64 is a typical modulation scheme used to carry digital video/data stream in RF channels.

The Emergence of Fiber-Based Community Networks

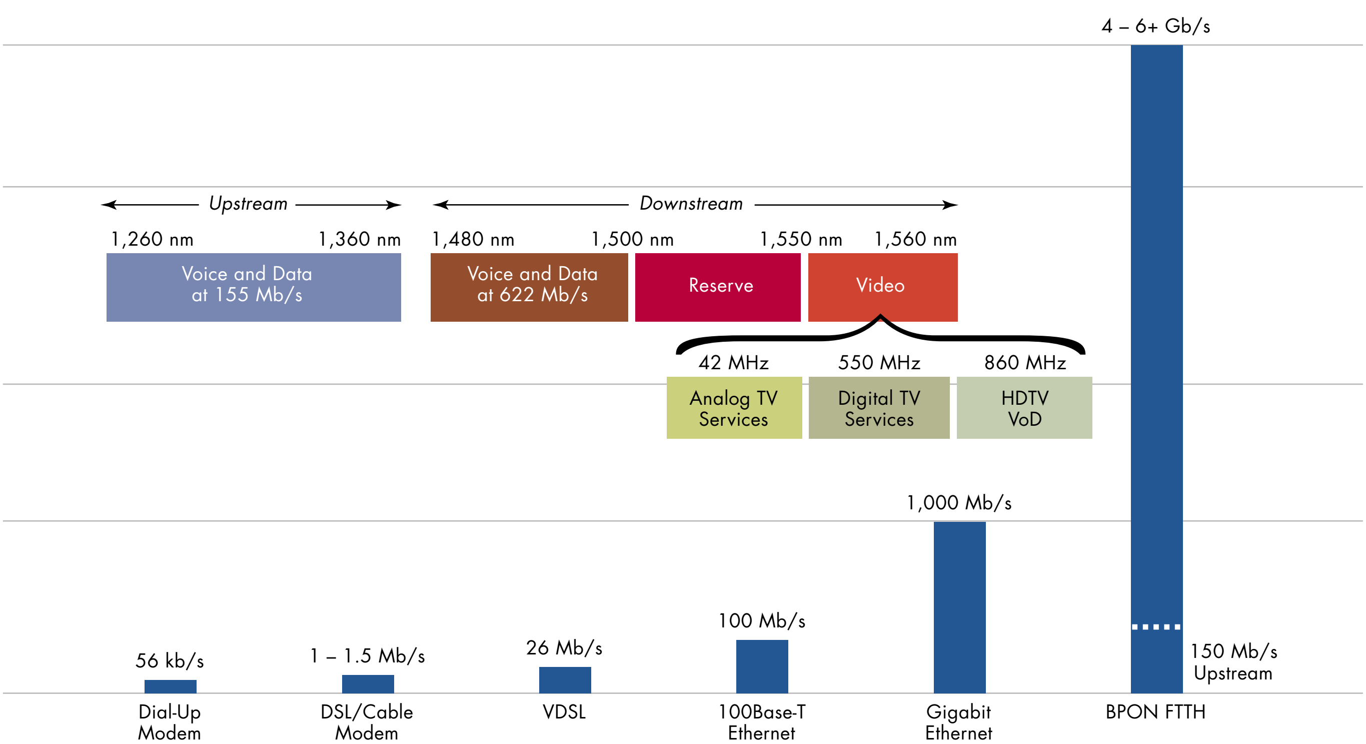
Municipalities and publicly owned utilities are starting to build fiber-based networks to serve their communities. There are currently 94 deployments of fiber-to-the-home and small businesses, in 26 states of the U.S. [Source: FTTH Council, General Session, October 9, 2003]. Most installations are deployed by municipalities, utilities and competitive local exchange carriers (CLECs) in small communities.

Fiber access networks can empower even sparsely populated and isolated communities, by reducing the disadvantages of distance and time. The role of a network that delivers broadband services is becoming increasingly important as the trend to live outside central, metropolitan areas increases, and people become more dispersed, not necessarily choosing to live close to their place of work.

These municipalities and utilities are generally motivated by the economic benefits and the potential for community development that a high-capacity communication network can provide. Many communities that have been under-served by their communication service providers consider building their own network as a viable alternative. Fiber-based, broadband networks provide the infrastructure a community needs to provide services, generate revenue and foster economic growth. They help attract home owners and businesses to areas, and offer access to services once available only in large metropolitan centers.

Several studies conducted over the last few years detail broadband's economic benefits. In July 2001, Robert Crandall and Charles Jackson estimated the benefits of broadband to

Figure 5 - BPON Bandwidth Allocation for Data and Video Services



be upwards of U.S. $500 billion per year within the next 15 to 20 years in the U.S. if broadband becomes nationally available [Source: Meredith Singer, "The Economic and Social Benefits of Broadband", Telecommunications Industry Association (TIA), August 27, 2002]. These rewards more than justify the capital expenses involved in building the networks. Now that there are many successful examples to follow, and the regulatory environment is becoming more favorable to new builds, with careful planning, services and revenue can be maximized, and deployments can be done cost effectively.

Building FTTU networks requires careful consideration and planning. In the initial stages, capital expenses are large, and finding the resources to finance the project is a critical concern. As the project progresses and services are turned up, operating expenses become the predominant issue. In an FTTU project with typical S-curve penetration of the customer base, capital expenses represent well over 90 percent of all expenses in the first year. But by Year Five, operating expenses comprise more than 50 percent of all expenses, and by Year Ten, operating expenses account for more than 75 percent of expenses. The long-term viability of a deployment depends more on how operating expenses are managed in relation to generated revenues than it does on the initial capital investments. It is not surprising, however, that the operational expenses dominate as the network buildout nears completion. What is important is that operational expenses are significantly lower for an FTTU network (up to 60 percent lower by some estimates) compared to existing copper networks.

A Community-Based FTTU Network

An American utilities company successfully installed a community-based fiber network in the U.S., and now provides voice, high-speed Internet and video services, in competition with the incumbent carriers. Demand for broadband services was high; the company's main challenge was keeping up with installation requests [Source: Ray Buzzard, "Triple play on PON", FTTH Council Session, October 7, 2003].

The penetration take rates have been phenomenal, greatly frustrating the incumbent service providers. Of the total customers served by the fiber network, 91 percent subscribe to video, 87 percent to voice, and 65 percent to data services. The company expects to be cash flow positive in less than two years of the initial service deployment, and to realize a full return on investment within seven years.

Community-based fiber networks also provide many indirect and qualitative benefits, including the potential to:

> Improve educational services for local schools
> Create white collar information industry jobs, as the local manufacturing industry base diminishes
> Gain access to remote, world-class healthcare resources
> Improve networks for other services such as monitoring the power distribution system, meter reading, and home monitoring
> Use the additional earnings from communication services to maintain low electricity rates
> Have local control of services, and be able to deliver services the local community wants

Alcatel's Fiber-to-the-User Solution

The Alcatel Fiber-to-the-User solution allows service providers to extend the core optical network all the way to the user, eliminating the bandwidth bottleneck in the last mile. The all-optical solution supports both residential and small business customers, offering unprecedented residential voice, video and data service over a single fiber.

Expanding on Alcatel's leading broadband access portfolio, the Alcatel FTTU solution helps service providers maximize revenues from the residential and business markets. It provides a superior platform for bundled services and serves a range of FTTU applications, including residential, SOHO, multiple dwelling unit, and business. With the Alcatel FTTU Solution, operators can offer any service mix with increased reliability and lower maintenance cost.

For more information about our complete FTTU portfolio, visit: www.alcatel.com/fttu

Conclusion

Municipalities, utilities and other community-based service providers are pioneering FTTU networks. They are demonstrating that FTTU is a viable alternative to traditional copper-based networks today. The technology based on the international BPON standards has matured and costs have decreased. Deployments are growing rapidly. Along with a changing regulatory and competitive environment, it is becoming imperative for all network providers to start planning to deploy fiber access-networks. Service providers that offer FTTU will have a strategic long-term advantage over their competitors.

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