Enabling New Services through Fiber to the Premises

White Paper

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Abstract

Recently, Local Exchange Carriers (LECs) in the U.S. announced plans for large-scale deployments of Fiber to the Premises (FTTP) for residential customers and small and medium businesses. However, FTTP will only be successful if LECs develop and offer services that leapfrog the competition and grow the revenue stream. In addition, LECs will have to evolve every part of the network, not just the access. This paper describes some network challenges that must be met to support what is called the triple play of services (voice, data, and video). It looks at the evolution of services and the changes required in the network to support those services. It also shows that new services, not FTTP alone, will be the driver for significant evolutionary changes in the network, including optical core networks, service elements, and signaling and control

Introduction

In the past, numerous Local Exchange Carriers (LECs) have explored the feasibility and economic viability of deploying fiber to the premises (FTTP), although fiber access facilities have generally only been provided to large businesses. Recently, however, LECs in the U.S. have started expressing their commitment to large scale deployments of FTTP for residential customers and small and medium businesses. There are several reasons why the time is right for FTTP deployments:

- **Regulatory landscape:** Recent FCC decisions stemming from the latest triennial review imply more
- **Technology readiness:** Numerous proven passive optical networking solutions for FTTP are now commercially available.
- **Costs:** Capital expenditures associated with fiber systems have come down substantially, reaching the economically required threshold of $1200 per connected user.
- **Competitive necessity:** Competitive conditions in the LEC market provided by aggressive cable company moves require sweeping measures as opposed to incremental improvements.
- **New commercial drivers:** There is a renewed emphasis on video delivery, invigorated by the commercial availability of HDTV products priced for the mass market.

As evidence of the growing acceptance that the time is right for the deployment of FTTP in the U.S., in May, 2003, three incumbent LECs, BellSouth, SBC, and Verizon, announced the adoption of a common set of technical requirements for FTTP and issued a joint request for proposals for equipment suppliers. More recently, Verizon and SBC announced the selection of its vendors for the FTTP rollout; and Verizon stated its goals of 1 million homes passed by year end 2004 and 60% revenue coverage within 5 years.

If the time is right for FTTP, it will only be successful if LECs develop and offer services that would make it attractive to customers. Thus LECs will have to create a services strategy to leapfrog the competition and grow the revenue stream with services that extend beyond those that just offer a bigger pipe. New service offerings must take advantage of the capabilities that FTTP offers, and service bundles should be designed to retain customers. In addition, LECs would have to make evolutionary changes in nearly every part of their networks.

Evolution of Video and Entertainment Services

The most obvious choice for new services is video, a service not readily available to LEC customers with today’s limited access bandwidths. As LECs deploy FTTP, they will also undertake a series of evolutionary changes to their service portfolios. The first is to offer video services to residential customers. Figure 1 shows the initial architecture, with the LEC establishing a relationship with a video service provider (VSP) to deliver those services to customers, in much the same way a cable TV company would. In offering this service, the LEC provides transport for the video broadcast signals, and the consumer selects the videos through a set-top box. This arrangement can support all the services offered today by cable TV companies, including analog and digital broadcasts, pay-per-view, and video-on demand because any signaling and control are done between the set-top box and the VSP.

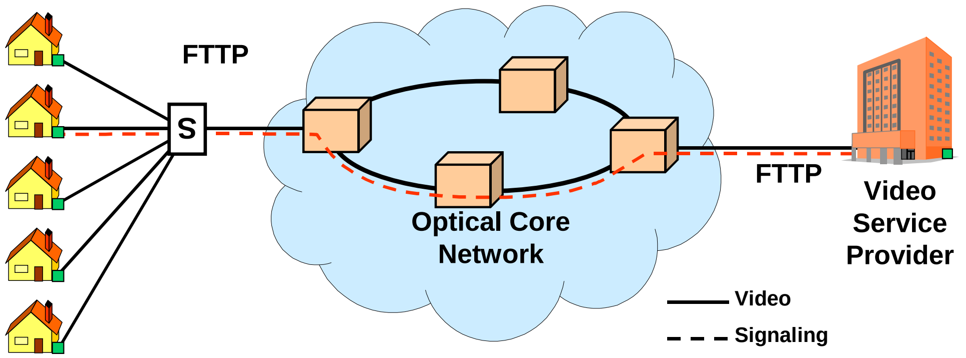

Figure 1. Basic Video Services

The next step in the service evolution is to permit customers to access more than one VSP, a service that no cable TV company offers today. To provide such a service, the LEC must provide a mechanism to permit the customer to select VSPs. This can be done with a Service Gateway, which is a network-based application that works in conjunction with a user interface application in a customer's set-top box. Figure 2 depicts a high-level architecture view of this service.

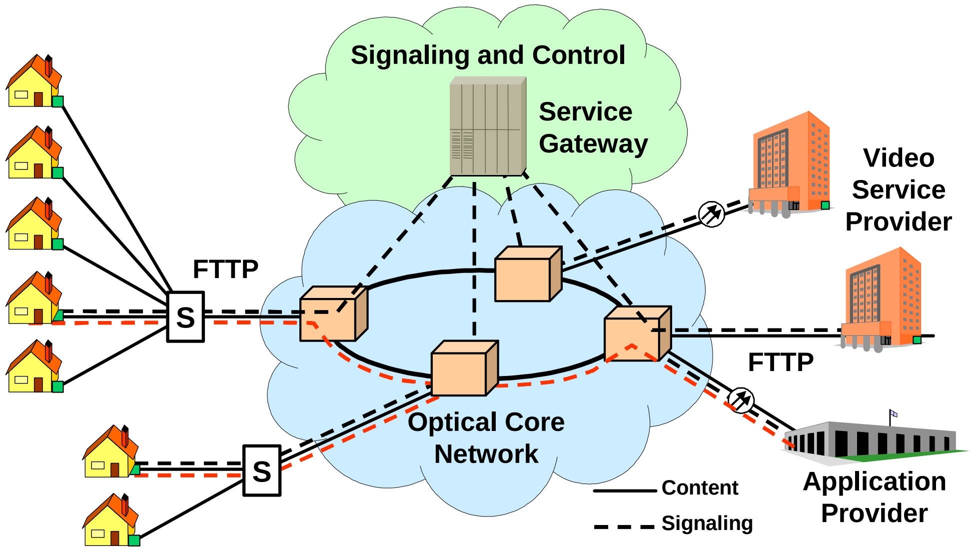

Figure 2. Advanced Video Services

It is also important that the LEC offer access and value-added services to the video service providers. Besides providing broadband transport to their customers, the LEC can also provide local caching of videos. Through the use of storage area networking (SAN) technology, the LEC can store, in each local office, a copy of the most popular on-demand videos. When a customer requests one of these videos, it is played from the local office. This will save transport costs through the network and processing costs at the VSP, which will still handle the customer's original request and bill appropriately.

The next step in the service evolution is to expand the functionality of the Service Gateway to interface with more devices at the customer's premises, such as personal computers and electronic game devices. As shown in Figure 2, the customer will be able to select among many different types of service providers, both VSPs and other applications providers. Once the connections through the network are established, the customer will interact directly with the provider shown on the right side of the figure.

Network Evolution to Support FTTP and Services

Just as LECs have built optical networking infrastructures to provide high bandwidths needed for services and to integrate the core service-providing networks together, LECs will use FTTP in a similar role in the access network. In addition, FTTP will provide other benefits by removing much of the distinction between core and access networks, thus permitting further integration of the operations and management. This section describes the network architectures and evolution required to support FTTP and the associated services.

A. Service Elements

The services provided in an FTTP environment require new service-providing elements in the network.

Network Overview

Figure 3 shows a generic network model, with an LEC's core network in the middle, FTTP on the left, and other service providers on the right, including full-service providers (e.g., competitive LECs and interexchange carriers) and application and content providers. In the LEC's network, an optical core network supports high-layer networks, such as IP and ATM, and a set of service elements. The core network will evolve to an all-IP network to facilitate offering new services over FTTP.

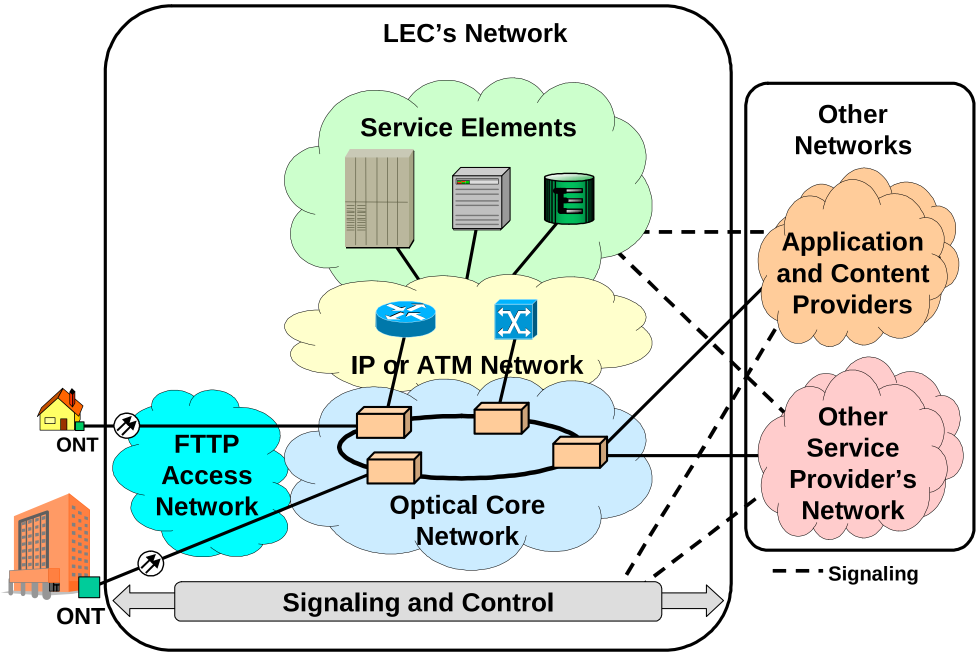

Figure 3. Physical Model of FTTP and Service Elements.

Not all services use the LEC's application-layer service elements; for example, data transport services may be provided entirely by the optical network or by the IP or ATM network. Further, another service provider (on the right side of Figure 3) may have a role in providing an advanced service to an end user, with the LEC's network providing only transport. Some of the key service elements and the network evolution challenges to provide these new services are described below.

1. Service Gateway

With so many services available, a Service Gateway is needed to provide users with a way to select, use, and control the services that they want at a particular time. The Service Gateway, one of the service elements shown in Figure 3, is a network-based application that works in conjunction with a user application in customer premises equipment and will give customers an increased capability for self-service and management.

The Service Gateway will display a list of services, such as shown in Figure 4. Using the gateway would be analogous in the PSTN world to picking up a telephone handset and getting a dial tone, then instructing the network to establish a connection by dialing a number. With PSTN voice services, of course, bandwidth and service quality are already fixed. The Service Gateway will accept the user’s request and establish an instance of the service. The display of the services available depends on the particular device the customer is using. A personal computer might display a window like that shown in Figure 4, while a set-top box might display only a list of video service providers. The devices themselves would also set some of the service parameters; for example, HDTVs and music players would each set the bandwidth appropriate for the particular use. For more complex services, the Service Gateway would allow the user to select other parameter choices appropriate to the type of service being requested and the type of device that the user wants to connect. The ultimate challenge is to have a Service Gateway that keeps the establishment of a service as simple as possible.

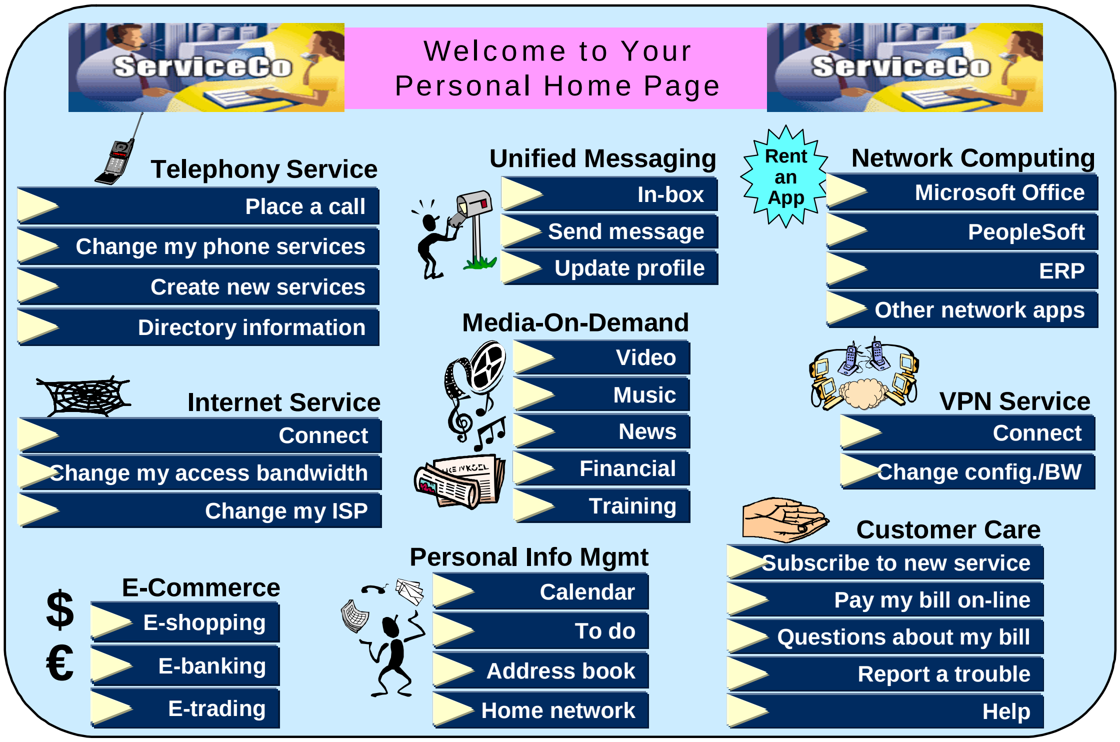

Figure 4. Example of Screen from Service Gateway.

2. Residential Gateway

A residential gateway is needed to provide some of the new services that the LECs would offer with FTTP. Initially the residential gateway would interact with a softswitch to set up a connection for a VoIP call. The residential gateway would provide capabilities such as echo cancellation and would support QoS through the IP network. Although some work has been done to address network evolution from legacy PSTN service to VoIP, the issue of how to integrate VoIP into FTTP needs exploration.

3. Multimedia Communications Manager

As LECs start offering communications services beyond VoIP, such as supporting video phones and multimedia devices, the communications and service elements will have to evolve. The softswitch will have to be enhanced with a Multimedia Communications Manager (MCM) to provide session control capabilities; and the residential gateway will have to be enhanced to provide multimedia connection control, including enhanced compression, encoding, codec selections, and signaling to the MCM for adding or changing connections within a session. In addition, the MCM will have to interact with the Service Gateway. The evolution paths that customer premises equipment (e.g., residential gateways and set-top boxes) take remains to be determined. Within the network, another evolutionary challenge is to determine the relationships and evolution paths for the softswitch, the MCM, and the Service Gateway.

4. Video and Entertainment Service Elements

A key element for video and entertainment services will be personal video recorder capabilities. These can be provided either in the network (like voice mail) or as customer premises equipment (like an answering machine). Network-based video servers will be accessed by the user for viewing previously recorded videos after the user selected the programs to be recorded through the Service Gateway. The user will use the Service Gateway to access and view the program.

B. Access Networks

At this point in time, Passive Optical Networks (PONs) appear to be the most effective FTTP technology. PONs offer point-to-point and point-to-multipoint connections using splitters that require no power, thus providing significant savings on the maintenance of the distribution facility and extended lifetimes of the access network [1].

As shown in Figure 5, a PON consists of three major components:

- Optical Line Terminal (OLT) in the central office that interfaces the optical fiber on the access side with the core network.
- Optical Network Terminal (ONT) that terminates the optical access fiber at the customer’s premises and provides customer interfaces for voice (RJ-11), data (RJ-45 Ethernet), and video (coaxial cable F connector). The residential gateway plugs into the ONT.
- Optical Distribution Network (ODN) that consists of optical fibers and optical splitters. A single fiber connects the OLT and a splitter, using two different wavelengths, one for upstream and one for downstream. A third wavelength or another fiber might be used for broadcast video; and an ODN can have multiple splitters, although distance and power limitations must be considered in the design.

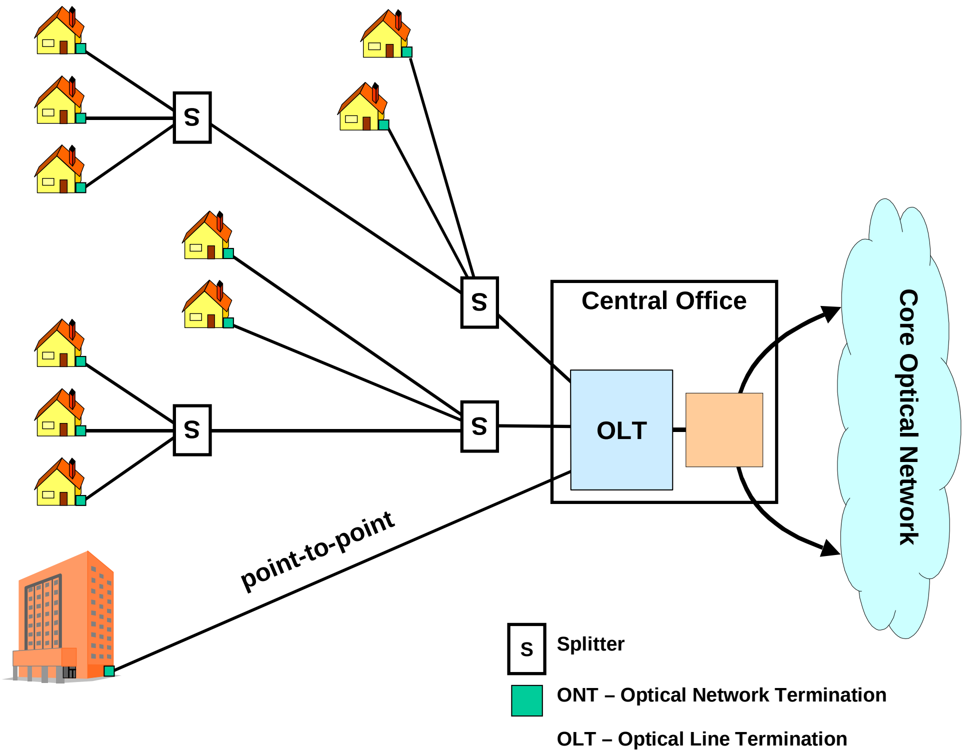

Figure 5. PON Architecture.

Although several types of PONs exist, all of them share the same basic network architecture and optical transmission characteristics. The differences are in the higher layer protocols used, such as ATM and Ethernet. The types of PONS are as follows:

- BPON (Broadband PON), standardized in ITU-T Recommendation G.983, is the most mature of the PON technologies. It uses fixed time slots (TDM) to broadcast information downstream and time-division multiple access (TDMA) to receive upstream information from users [2]. Because BPON uses ATM as a layer-2 technology, the system is service-independent and can transport other protocols, such as IP, Ethernet, and T1.
- EPON (Ethernet PON), from IEEE 802.3, supports Ethernet services over FTTP. EPON also relies on TDMA for upstream traffic and fixed-length frames for downstream traffic because the OLT is required to maintain synchronization of the ONTs; however, the OLT uses variable-length packets (Ethernet) within those frames [3].
- GPON (Gigabit PON) is an effort to increase the bandwidth of BPON to over 1 Gb/s from 155 Mb/s. GPON will have strong operations and management capabilities, offering end–to-end service management and protocol-level security for downstream traffic needed by the multicast nature of the PON.

For delivering services over FTTP, a LEC will need to make some technology choices, including the type of PON and the transport protocols to be used. Although it is possible to match an FTTP technology to a particular service (e.g., BPON for TDM services and EPON for IP-based services), it is not possible to customize entire FTTP systems that serve many different customers with different demands. Thus any FTTP technology will have to meet the demands of all services, including those offered today and those that can be envisioned for the future.

C. Core Networks

The core network consists of an integrated optical core network that supports various service-providing networks on top of it, including the PSTN, ATM, and IP. There are many types of technologies available for the optical core network. Some, such as SONET, can carry many different types of traffic, while others, such as packet over SONET, are better suited for IP traffic. As LECs start to offer a wider variety of services over FTTP, it is important that the right core networking technologies are used to support those services. As IP networking becomes the technology of choice, and services migrate to IP, including voice over IP and video over IP, it will be appropriate to migrate the core network to a technology that carries IP traffic with efficiency, reliability, quality, and other attributes that the LECs deem important.

In the central office, where the access and core networks meet, it is important to plan the interface properly. The ONT at the customers' premises and the OLT in the central office multiplex the diverse traffic together over FTTP. The traffic diversity is due to the different types of services provided to customers, from voice and data to video. Within the central office, traffic has to be multiplexed and demultiplexed to pass it to the appropriate network elements there. Figure 6 shows a typical central office arrangement. The traffic from the different service-providing networks is multiplexed in the optical core network and demultiplexed for the individual network elements.

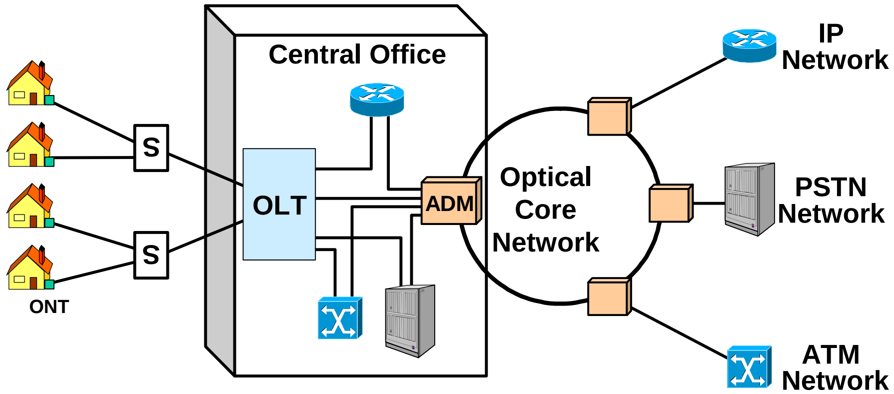

Figure 6. Typical Central Office Configuration.

As long as customers subtending a central office need TDM and ATM, SONET is the best choice for the optical core; however, this is quickly changing. Wavelength division multiplexing allows the optical core network to be a set of individual overlay networks using a common optical infrastructure. In Figure 6, for example, the add-drop multiplexer (ADM) can be replaced by an optical ADM so that the PSTN traffic is placed on one wavelength, the ATM traffic on another, the IP traffic on a third, and the TDM traffic on a fourth. Such an arrangement permits different transport technologies to be used together. The wavelength carrying IP traffic could use packet over SONET, while the other wavelengths might use just SONET.

FTTP will bring about a more radical evolution of network architectures. Today, service-providing network elements tend to be deployed in central offices where they are needed. If all the customers subtending a central office are on FTTP, however, it will be possible to move the service-providing network elements to another office. Figure 7 shows a central office on the left with all the customers connected by FTTP. In this arrangement, the OLT has a multiplexing-demultiplexing function and does not have to separate the service-specific traffic. Instead, it can transmit all the traffic over an optical line to the ADM, and the optical core network will backhaul the traffic to a central office that houses the service-providing network elements. Although a LEC will not want to put all its service elements into a single location, FTTP will give the LEC another degree of freedom for making economical and business decisions. The arrangement shown in Figure 7, for example, simplifies both the OLT and the ADM in the FTTP central office; and it consolidates the operations for services and equipment into fewer locations.

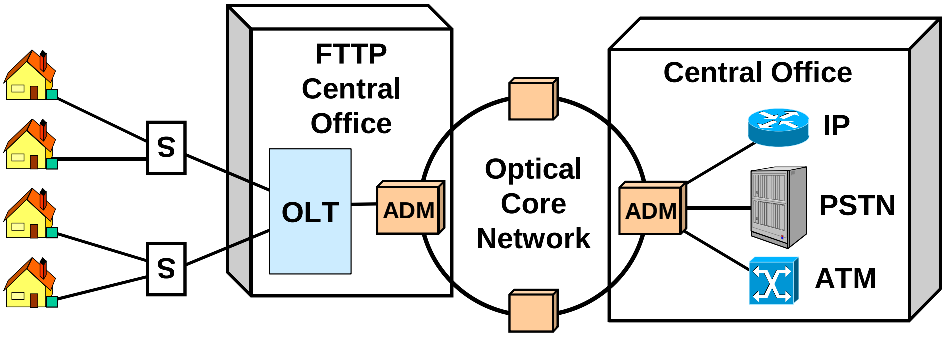

Figure 7. Evolution of the Network with FTTP.

As high-bandwidth services become more commonplace, FTTP will have to be deployed in greater numbers, and the capacity of the core network will have to be increased to carry the additional traffic. As this happens, a number of technology and design decisions will have to be made to accommodate the changing nature of the services being offered. For example, as more services become IP based, at some point voice traffic should be moved from the PSTN to VoIP. Such a migration will not only help simplify the network by moving towards an all-IP network, but it will accommodate new services built upon PSTN, including simultaneous imaging (as can be done with mobile camera phones today) and video calls. The network, both the core and the FTTP access, will have to be designed end-to-end to meet the requirements of the services at a reasonable cost for providing them. Some of the considerations include:

- Managing the quality of service for different services
- End-to-end compatibility of equipment, from the customer's equipment to that of other service providers who have interconnection arrangements with the LEC
- Technology choices and evolution, considering the range of services offered, the maturity of the technologies, and their costs.

One example of a decision to be made is the handling of broadcast video. One solution is to provide an additional fiber or wavelength in the FTTP system to carry the analog or digital broadcast traffic because there is insufficient bandwidth in either BPON or EPON to carry it. Another option is to move toward switched digital video, in which only the selected video channels are carried over FTTP. Thus, rather than the channel being switched at the set-top box, it is switched in the central office.

D. Signaling and Control

For the LECs to offer a full range of services, a number of new signaling and control capabilities are needed, including mechanisms for media control, connection and session control, bandwidth management, content navigation, and quality-of-service management. Although there have been significant efforts in standards bodies to define protocols and coding schemes to enable the deployment of such services, more needs to be done in the overall signaling and control architectures. As mentioned above, a Service Gateway is needed to provide users with a way to select, use, and control the services that they want at a particular time. The Service Gateway requires signaling and control mechanisms that allow customers to select and manage their services.

In optical networking, technologies aim to exploit the existing infrastructure to offer new services while lowering operational costs. The optical control plane strives to automate provisioning through one overarching scheme, a significant departure from today's processes in which each layer has its unique management system and communication protocol. Both the Automatically Switched Transport Networks (ASON), in ITU-T Recommendation G.8080, and the Generalized Multi-Protocol Label Switching (GMPLS), by the IETF, address control and signaling in the control plane. The Optical Internetworking

Forum (OIF) has specified the optical UNI (O-UNI) to allow customer premises equipment to signal a request for connectivity across the optical network.

Many of the services that are described in this paper require more functionality than what the optical control plane alone can support. Additional work is needed to address end-to-end services to determine how the concepts of the Service Gateway and the optical control plane fit together to give end users a means of selection and control over service and communications parameters.

It is clear that a signaling channel is needed between the user's premises and the Service Gateway. Besides being used to select and establish a service, the signaling channel will also be used to disconnect a service at the end of a session; and it may be used to modify a service during a session (e.g., to increase the bandwidth or create a real-time video connection during a collaborative session). In addition, some services may require a signaling channel to be established between the end user and the service provider.

Conclusions and Paths Forward

To make wide-scale deployment of FTTP successful, LECs will not only have to introduce new services, but will have to evolve every part of the network, not just the access. Examples of network evolutionary changes include:

New service elements, including:

- Service Gateway to permit customers to access multiple video, entertainment, and applications service providers
  - Residential Gateway to provide some of the new voice and eventually multimedia services that the LECs would offer with FTTP
  - Other advanced customer premises equipment, such as advanced set-top boxes, personal computers, and electronic game devices, to establish the appropriate communications services.
  - VoIP softswitch, which will evolve to become a Multimedia Communications Manager for multimedia connection control
  - Local caching in central offices for the most popular videos
  - Personal Video Recorders for viewing previously recorded videos
- Passive Optical Networks (PONs), which will still require technology choices to be made, including the type of PON and the transport protocols to be used, to meet the demands of all services, including alternatives for handling broadcast video on additional fibers or on additional wavelengths
- Evolution of the core network to IP, including optimization of the optical core network to meet traffic demands. As the traffic mix evolves, DWDM will allow LECs to easily overlay different transport protocols.
- Evolution of signaling and control mechanisms among service elements, network equipment, and content and service providers' equipment to:
  - Manage QoS for different services
  - Establish the right communications sessions between customer premises equipment and content and application providers
- In addition, relationships between the Service Gateway, other service elements, and the optical control plane will have to be defined.
- Migration of service-providing network elements from local central offices to more central locations, thereby eliminating the distinction between core and access networks and permitting end-to-end integration of much of the operations and management.

Finally, as the LECs evolve their networks to take advantage of FTTP and the services that can be offered, there are several other challenges that they have to meet:

- Access network planning and engineering for multi-tenant buildings and areas with buried cable.
- Upgrading the core network to meet the demand for higher bandwidths and to meet quality-of-service requirements.
- Planning for new services, such as video and information services, that FTTP enables.
- Developing new signaling and control features that make services easy to use.
- Interconnection with many new classes of service providers, such as VSPs, to support end-to-end services with strict quality-of-service requirements.
- End-to-end service and network operations, including service subscriptions, billing, and security.

References

[1] See the PON Forum website to technical details: http://www.ponforum.org/technology/default.asp

[2] F. J. Effenberger, H. Ichibangase, and H. Yamashita, „Advances in Broadband Passive Optical Networking Technologies, " *IEEE Communications Magazine*, December, 2001, pp. 118-124.

[3] G. Kramer and G. Pesavento, "Ethernet Passive Optical Network (EPON): Building a Next-Generation Optical Access Network," *IEEE Communications Magazine*, February, 2002, pp. 66-73.

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