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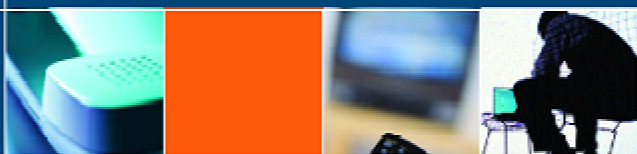


FTTx: Selecting the Best Architecture for the Access Network

Fiber Drivers in Today's Access Networks

Since the late 1980s, telecommunications providers have dreamed of an all-fiber network. And, for good reason. Fiber provides substantially more bandwidth, carries signals farther, is more reliable and secure, and has a longer life span than any other transmission medium. Additionally, providers view fiber's bandwidth capacity as a competitive weapon, particularly in the access network.

Never before has the access network been as important to telecommunications providers as they look for ways to deliver new high-bandwidth services to their subscribers—services that generate new revenues, help them retain existing customers, attract new ones and increase profits. Fiber is seen as the preeminent long-term alternative to today's broadband access technologies, one that not only allows providers to generate new services, but also provides them with significant and sustainable reductions in operating expenses and shifts their capital spending from older technologies to newer, less costly technologies.

The single greatest driver for fiber in the access network is "triple play" services, the opportunity to offer subscribers high-speed data, voice, and video as one of a variety of potential bundled services. The subscriber market for Triple Play is large and growing and includes both residences and businesses. The Confluence Research Group expects 6.6 million houses will be fiber-connected by 2008. Businesses need more bandwidth and many of the advanced services that only fiber can deliver, and Triple Play offers homeowners the convenience of voice, data and video from a single vendor and on a single bill.

With Triple Play as their goal, local telcos are exploring the best way to move fiber closer to the subscriber. All view Triple Play as a strong competitive service offering now and into the future and are looking at fiber as the way to deliver not only Triple Play but other new services such as distance learning, interactive gaming and telemedicine. As traditional telecommunications providers explore their fiber network options, many municipalities and utilities are taking the lead, building greenfield fiber networks to serve their communities and to attract new business.

Today, fiber networks come in many varieties, depending on the termination point: premise (FTTP), home (FTTH), curb (FTTC) or node (FTTN). For simplicity, most people have begun to refer to the fiber network as FTTx, in which x stands for the termination point.

As telecommunications providers consider the best method for delivering fiber to their subscribers, they have a variety of FTTx architectures to consider. Currently, there is not a one-size-solves-all architecture, so providers must make a series of technology decisions based on their service goals. A primary consideration for providers is to decide whether to deploy an active (point-to-point) or passive (point-to-multipoint) fiber network.

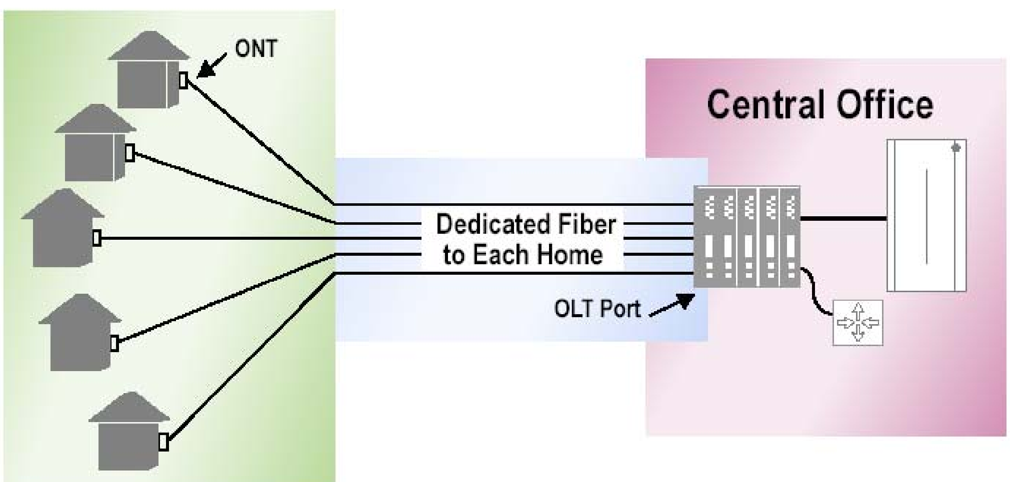
An Architectural Comparison: Active vs. Passive

When deciding which architecture to select a provider has many things to consider including the existing outside plant, network location, the cost of deploying the network, subscriber density and the return on investment (ROI). Active architectures, sometimes referred to as Home Run Fiber and/or Active Star Ethernet, and passive architectures, which include Passive Optical Networks (PONs), are the current choices. Each has its own pros and cons, and the final selection will depend on the provider's unique requirements.

Home Run Fiber (Point-to-Point)

A Home Run Fiber architecture is one in which a dedicated fiber from an Optical Line Terminal (OLT) unit located in the Central Office (CO) connects to an Optical Network Terminal (ONT) at each premise. Both OLTs and ONTs are active, or powered, devices, and each is equipped with an optical laser. Subscribers can be located as far away from the CO or OLT as 80km, and each subscriber is provided a dedicated "pipe" that provides full bi-directional bandwidth. Over the long term Home Run Fiber is the most flexible architecture; however, it may be less attractive when the physical layer costs are considered. Because a dedicated fiber is deployed to each premise, Home Run Fiber requires the installation of much more fiber than other options, with each fiber running the entire distance between the subscriber and the CO. The fiber cost and size of the fiber bundle at the OLT can make this network expensive and inconvenient in many service areas. In their recent paper, *Towards Technologically and Competitively Neutral Fiber to the Home (FTTH) Infrastructure,* Anupam Banerjee and Marvin Sirbu of Carnegie Mellon Institute, estimate that the total cost of terminating 728 fibers at the CO is $22,600.

Figure 1. Home Run Fiber Architecture



Active Star Ethernet (Point-to-Point)

An Active Star Ethernet (ASE) architecture is a point-to-point architecture in which multiple premises share one feeder fiber through a remote node located between the CO and the served premises. Environmentally hardened optical Ethernet electronics—switches or Broadband Loop Carriers—are installed at the remote node to provide fiber access aggregation. The remote node can be shared between four to a thousand homes via dedicated distribution links from the remote node. Like Home Run Fiber, subscribers can be located as far away from the remote node as 80km, and each subscriber is provided a dedicated "pipe" that provides full bi-directional bandwidth. Active Star Ethernet reduces the amount of fiber deployed; lowering costs through the sharing of fiber. This architecture is very similar to current telco copper architectures and is likely to be more readily accepted by current network planners. ASE also offers the benefits of standard optical Ethernet technology, much simpler network topologies and supports a wide range of CPE solutions. And, most importantly, it provides broad flexibility for future growth. Active Star Ethernet is a popular choice for independent ILECs, cable operators and municipal utility districts.

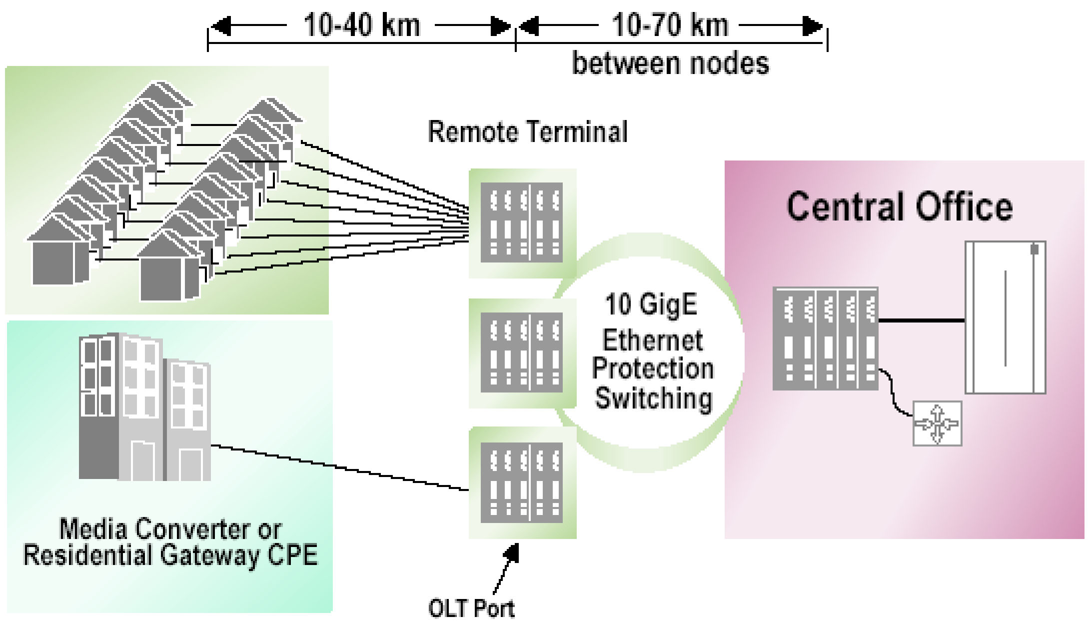


Figure 2. Active Star Ethernet Architecture

Passive Optical Network (Point-to-Multipoint)
Passive Optical Networks are shared media, or point-to-multipoint, networks in which multiple users share the same bandwidth. In this network architecture, passive optical splitters are used to divide the bandwidth from a single fiber among up to 64 users over a maximum distance of 10-20km. In a PON, a CO-located OLT connects to customer-premise-located ONTs to terminate the fiber. Both the OLT and the ONT are powered. The architecture is called passive because all splitters and intermediate equipment located between the CO and the ONT is passive; that is, it has no active electronics and therefore does not need separate power.

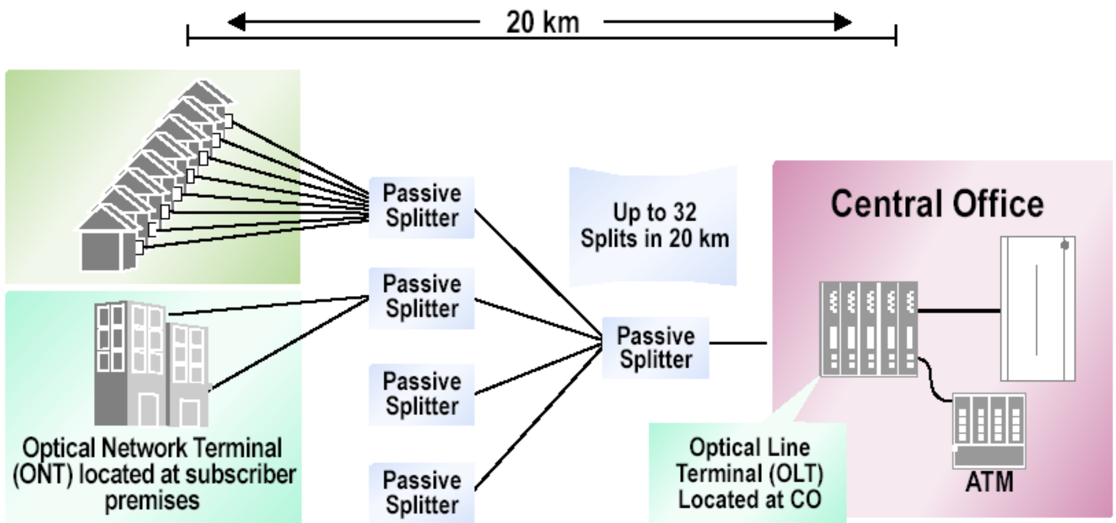


Figure 3. Passive Optical Network Architecture

There are several types of PON networks from which to choose, including:

	Layer 1-2	ONUs per ONT	Upstream	Downstream	Mbps/ONT
APON	ATM	32	622Mbps	1.2Gbps	37.5Mbps
EPON	Ethernet	32	1.25Gbps	1.25Gbps	78.1Mbps
GPON	Gigabit Ethernet	32 64	155Mbps 622Mbps 1.25Gbps 2.5Gbps	1.25Gbps 2.5Gbps	19.5Mbps 39.0Mbps

Architectural Strengths and Weaknesses

As mentioned earlier, there are currently no one-size-solves-all architectures. When comparing an active versus a passive architecture there are a number of points to consider.

ACTIVE ARCHITECTURE	
Strengths	Weaknesses
▪ Leverages standard Ethernet technologies ▪ Dedicated fiber ▪ Maximum bandwidth ▪ Maximum flexibility ▪ Synchronous bandwidth ▪ Uses low-priced, IEEE-standard components ▪ Intelligent network electronics installed at the subscriber network edge simplifies network troubleshooting ▪ Operates at distances up to 80km, regardless of the number of subscribers ▪ Can be built on a pay-as-you-grow basis ▪ More economical in low density subscriber areas ▪ Predictable cost of new customer acquisition ▪ Does not require complex preplanning for large service areas ▪ Low incremental subscriber cost, regardless of subscriber location ▪ Deployed capital begins generating revenue immediately ▪ Supports up to 1Gbps per customer ▪ Greater service flexibility	▪ Requires many long fiber runs ▪ Requires longer distance lasers ▪ Does not share OLT or port optics ▪ Requires right of way (ROW) and power for cabinets ▪ Powered electronics distributed in the access network

PASSIVE ARCHITECTURE	
Strengths	Weaknesses
▪ No active electronics in the access network ▪ Providers can share the costs of fiber, installation and CO equipment among multiple customers since multiple users share a single strand ▪ Reduces OSP capital expense and associated operational costs ▪ Upgrades or new services can be accomplished with equipment changes at the network ends and on a per customer basis	▪ Not interoperable with other types of PON networks ▪ More customers affected by link failure ▪ Shared bandwidth limits bandwidth to each subscriber ▪ Limited coverage area: 20km maximum depending on the total number of splits (more splits = less distance) ▪ Unpredictable incremental next customer costs ▪ High first subscriber costs - OLT ports become economical only when serving 26 ONUS (81% of total)[1] ▪ When new OLT is needed, cost per subscriber goes up until OLT ports are fully subscribed ▪ Non-intelligent passive splitters are unmanageable ▪ Less flexibility ▪ Asynchronous ▪ Capacity planning difficult for business applications

[1] XChange Online, "Battling for Access: Active Ethernet vs. PON", September 13, 2004

Selecting the Right Architecture

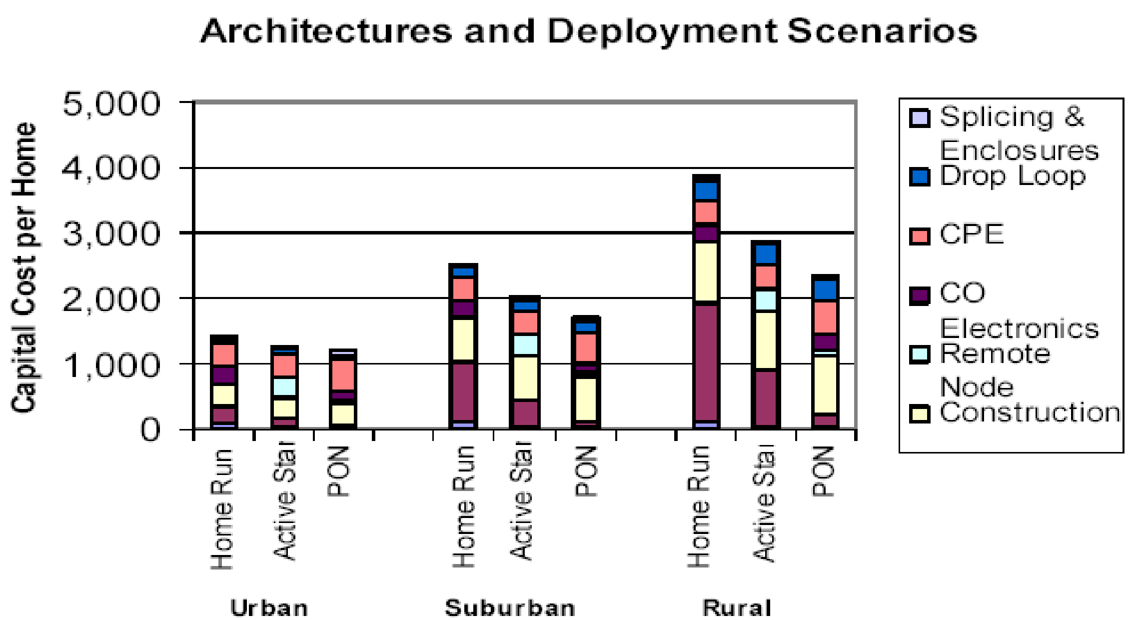
A telecommunications provider must consider many factors when selecting a fiber architecture, but none is more important than subscriber density.

Subscriber Density: The Key Consideration

Subscriber density plays a key economic role when selecting the right architecture for a provider. Because Active Star Ethernet operates over longer distances, it is much more economical in low density subscriber areas. And, with an ASE architecture, since fiber can be deployed on an as-needed basis it also lowers first subscriber costs.

In high density subscriber service areas, the distances between premises are shorter and a PON architecture can be more economical. However, it is important to remember that with PON there can be a high fixed cost incurred when a new subscriber signs up in each splitter farm. Each OLT supports up to 32 subscriber OLTs. When more than 32 subscribers request service, a new, high-cost OLT port must be added to service a single subscriber, which results in a very high cost for that incremental subscriber.

Banerjee and Sirbu developed the following chart that compares the economics of deploying the three types of networks in urban, suburban and rural areas. In this chart, they clearly point out that the cost of deploying a fiber network is driven more by subscriber density than which technology a provider chooses. Low density service areas are more expensive to serve than high density service areas where the sheer number of subscribers makes it easier for a telco to recover capital investments more quickly.



Source: Carnegie Mellon University

Figure 4. Breakdown of Capital Costs per Home for FTTx Architectures

For a more detailed analysis of the economic differences among the network architectures please refer to *Towards Technologically and Competitively Neutral Fiber to the Home (FTTH) Infrastructure* at http://itc.mit.edu/itel/docs/2003/banerjee_sirbu.pdf

Other Important Considerations

Once a carrier has determined or considered its subscriber density based on its particular mix of service areas, there are a series of secondary questions that must be asked when selecting a fiber architecture — considerations such as type of deployment, degree to which legacy infrastructure will be incorporated, stages of deployment and planned and potential services.

Is it a greenfield deployment or an overbuild of an existing network?
In greenfield developments such as business parks, campuses, or new homes it costs nearly the same to install fiber as copper, so most forward looking providers select fiber. Obviously, it is more efficient to install fiber during construction than to retrofit a neighborhood. If a provider chooses to deploy a PON in this scenario, there are drawbacks. PONs utilize strict architectures that require careful planning to maximize the provider's investment. Because subscriber density will be low initially, the result is often high first subscriber costs and a slow return on the capital invested in the network. Many municipalities, utilities, and smaller service providers are choosing Active Star Ethernet for their greenfield deployments to overcome these drawbacks and for other reasons such as cost, scalability and interoperability.

In a community already served by copper and coaxial cable, deploying fiber as an overbuild of the existing network is the most practical and cost-effective solution. According to Michael Render, principal analyst at Render Vanderslice & Associates, "From a pure cost standpoint, there's more of an argument for overbuilds versus greenfields." For the majority of independent operating companies (IOCs), an overbuild from the CO using an Active Star Ethernet architecture provides a more practical solution than either Home Run Fiber or PON. With ASE, an IOC can deploy fiber on an as-needed basis with minimal future network planning complexities. If the provider already has a remote terminal or node network infrastructure in place, it isn't necessary to invest excess capital that it may not recover for months. The provider can leverage its existing infrastructure to deliver fiber-based services.

How much Legacy Infrastructure will be reused?
Only an Active Star Ethernet architecture enables providers to leverage legacy access infrastructure and to add fiber to an existing Remote Terminal or Node at a lower incremental cost than PON since the cabinet, power, chassis, etc. already exist and there is no need to obtain additional Right of Way authority.

Can the network be deployed in stages, and if so how?
According to Tom Starr, chairman of The DSL Forum, most local companies have a short-term copper strategy and a long term-fiber strategy. There are many enhanced copper systems capable of delivering Triple Play services to residences, and, according to Vertical System Group, there are over 600,000 buildings in the United States still connected by copper. An ASE architecture enables providers to leverage these existing access network facilities to deliver today's high-bandwidth applications while deploying fiber on an as-needed or an as economically justified basis. Providers can deploy fiber on a pay-as-you-grow basis to small groups of homes or buildings, realizing immediate income from their capital investment.

PON networks can also be deployed in stages, although the minimum stage is a geographic service area. PON also requires that a long-term plan be in place for fiber growth to understand capacity requirements for COs and fiber feeder conduits into the CO.

What current and future services are you planning offer and what are the corresponding bandwidth requirements?

The trend over the next few years indicates that bandwidth requirements will continue to increase as home users request services such as video on demand, interactive gaming and HDTV. Network architects must plan for the anticipated bandwidth demand over the life of the network to ensure that the access infrastructure can support the high-bandwidth, revenue generating services that maximize return on investment. With PON, shared bandwidth limits the amount of bandwidth available to each subscriber—the more subscribers per PON, the less bandwidth a provider can deliver to a user. Active Star Ethernet can provide up to 1Gbps per subscriber regardless of the number of subscribers; more than enough bandwidth for today's and future advanced services.

	2000	2004	2008
Typical Data Requirements	56kbps dial-up modem to 128k DSL	4-8 Mbps broadband	20-30 Mbps broadband
Broadcast TV Requirements	40 channels analog 2 TVs per home	150 channels digital 3.8 Mbps per TV 2 TVs per home	250 channels digital 10-20 Mbps per HDTV 3 TVs per home
On-Demand Requirements	None	Music downloads; Online gaming	TBD
Bandwidth Requirements per Home	128k + Cable TV	10-20 Mbps	100-120 Mbps

Table 1. Future Service and Bandwidth Requirements

Occam and FTTx

Occam believes that Ethernet is the key technology for networks that will deliver FTTx. It is a mature, well-understood technology that offers low equipment cost and low operations and management costs. And, its enormous, highly scalable bandwidth means greater network efficiency that translates into higher customer satisfaction.

Whether Home Run Fiber or Active Star Ethernet, an active Ethernet architecture offers telecommunications providers a number of distinct advantages when deploying a fiber network. This is particularly true for IOCs serving suburban and rural areas because the architecture is very cost-effective in medium-to-low density subscriber areas. To serve these markets the company is developing a fiber solution for the Occam BLC 6000 Platform that offers providers a building block approach to delivering fiber to the end user while creating maximum network flexibility.

Occam can help you deliver a competitive FTTx solution from the BLC 6000 platform, enabling you to extend an IP/Ethernet architecture further into your network. Fiber capabilities are fully integrated within the BLC and the BLC cabinet. Providers will find that they have more flexibility in designing and deploying their fiber network since the BLC is environmentally hardened. Using the BLC 6000 to deploy an Active Ethernet architecture enables a provider to leverage its existing infrastructure in the CO, the remote node and fiber access network since the BLC typically works with whatever equipment the telco has installed. Additionally, the BLC platform offers a provider the flexibility to upgrade to fiber neighborhood-by-neighborhood.

An Active architecture built with Occam products is fully compatible with existing Occam cabinets, access rings and central office terminals (COTs). The BLC uses existing cables, COTs and Ethernet Protection Switching (EPS) rings to reduce costs and to utilize and enhance existing copper facilities, which are still viable competitively.

While Occam believes that Active Star Ethernet is the most scalable, cost-effective, and flexible fiber network architecture, it realizes that a provider's unique requirements will dictate its final selection. Because of this reality Occam offers providers the flexibility to choose the right architecture. The BLC 6000 System can be used to build either active Ethernet networks — Home Run Fiber or Active Star Ethernet—from a single platform.

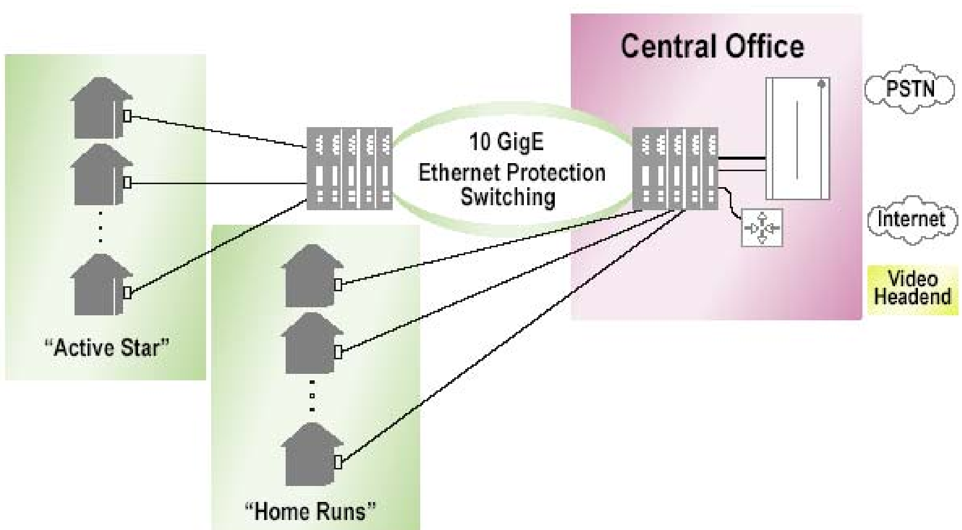


Figure 5. Residential FTTP Topologies with Active Ethernet

Summary

The benefits of a fiber network are obvious: a high-quality bandwidth transmission medium that will take service providers through the 21st century. The best solution for deploying these networks is less obvious and depends on a myriad of factors unique to each service provider investigating its options. Clearly, there are many factors to consider. Smart providers are looking for architectural options that offer low-cost implementation and operation, scalable bandwidth, greater network efficiency, seamless integration into existing network architectures and greater flexibility as the move from copper to fiber.

Occam Networks was founded on the principle that the simplest solution to a problem is typically the best solution. At Occam that means developing products that provide the greatest flexibility, scalability and efficiency at a cost that enables telcos to upgrade their networks without having to wait years for a return on their investment. The Occam BLC 6000 System is the industry's most cost-effective access platform for the deployment of advanced services whether a carrier's infrastructure is copper- or fiber-based. Designed to integrate seamlessly into a telco's network, the BLC has is a superior platform for the deployment of Ethernet-based FTTx networks, particularly Active Star Ethernet.

In this paper we have discussed many of the issues telcos face when deploying FTTx. As noted, every carrier faces its own unique network issues when deciding to deploy FTTx. Occam welcomes the opportunity to discuss those issues and to help you solve the particular problems you face as begin planning your fiber network.

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