Laying the Fiber:

A Detailed Cost Analysis

Plan to reuse and adapt infrastructure as fiber evolves to the home

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Carriers and consumers alike are being bombarded by messages that tout the benefits of fiber. All eyes are on the telcos, especially RBOCs Verizon, SBC, and BellSouth, as they pursue somewhat divergent paths toward a fiber optic future. What remains unclear are the relative merits of the various fiber deployment strategies and how RBOCs and other telcos can reach widespread deployment in the most business-savvy manner. This climate of uncertainty has even prompted some observers to question whether FTTP means "Fiber to the Premises" or "Fiber to the Press." In other words, is the goal really to drive optical cable to subscriber households or is it an exercise to impress Wall Street?

If Fiber-to-the-Premises (FTTP) is the endgame carriers should be positioning themselves for, how can Fiber-to-the-Node (FTTN) and Fiber-to-the-Curb (FTTC) deployments complement this strategy? Is the entirety of the installed copper infrastructure no longer of any use or can it still be leveraged to the carriers' advantage? What is the real business case for fiber as carriers drive fiber deeper into the access network?

The ultimate goal for carriers is to provide new broadband service sets to consumers that will be better than the service sets offered by their competitors. In order to do this, an access network has to have two fundamental attributes:

- Physical bandwidth capacity right to the user's home.
- Architecture that can organize and control the bandwidth, to streamline and simplify the service view across the network.

This article will focus mainly on the first attribute, discussing how physical bandwidth capacity can be added to existing neighborhoods to enable a competitive suite of broadband services. I will try to convince you that there is no immediate need to push fiber to the premise. Very high subscriber bandwidths that can deliver an excellent set of multimedia services can be achieved by using a hybrid copper-fiber strategy today.

Existing Neighborhoods

The best medium for physical bandwidth is definitely fiber-optic cable. Fiber-optic cable can carry many orders of magnitude more data than traditional telephony twisted-pair copper. In greenfield applications, it is generally accepted that fiber-optic cable can be economically placed in the open trench to the home, either as a fiber-only cable or as a fiber/copper composite cable.

Existing neighborhoods are tougher to analyze. Because the copper cable is

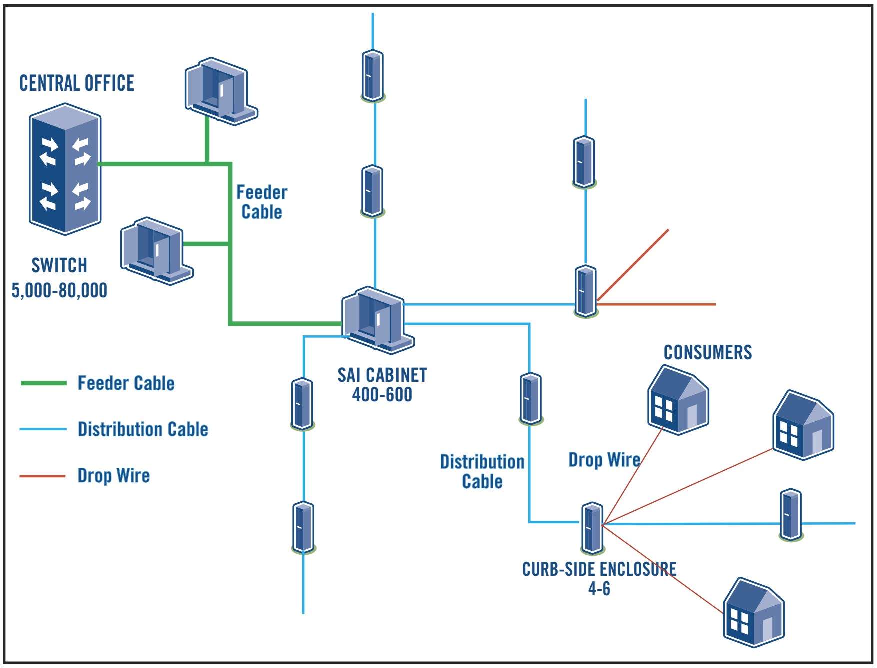

Figure 1. A model subscriber distribution network.

already in the ground, there is no opportunity for installation personnel to "kill two birds with one stone" and install fiber to the home instead of, or along with, twisted-pair copper. In addition, because the neighborhood is established, it is very expensive to dig an open trench, bore a direction hole, or use a compact trencher to place the additional fiber.

In fact, the existence of sidewalks, fences, other utilities, roadways, and home owners' landscaping and structures means that some fiber simply cannot be placed without excessive cost. Typically, in alleys or next to sidewalks there is a municipal right-of-way (or easement) that is reserved for utility companies' use, but on private property there is no control of what obstacles might be present. Thus, the problem gets worse as you get deeper into the neighborhood.

The Outside Broadband Plant

The structure of most of the copper outside plant/access network in North America today has followed a common set of design rules laid out by standards bodies in the U.S. and Canada. Generally, outside plant falls into two categories: Aerial and underground. In particular, most of the urban and suburban outside plant built since the late 1960s and early 1970s is underground, and shares many common characteristics.

There are three distinct copper cable sections in the outside plant: The feeder cable, the distribution cable, and the drop wire (see Figure 1, from D.E. Dodds' *Analog and Digital Telephony*). Each cable section is either underground or aerial. At the junction of two cable sections, a simple cabinet is placed to house weatherproof cross-connect blocks that allow the cable sections to be connected so that each active customer has a direct connection to the Central Office.

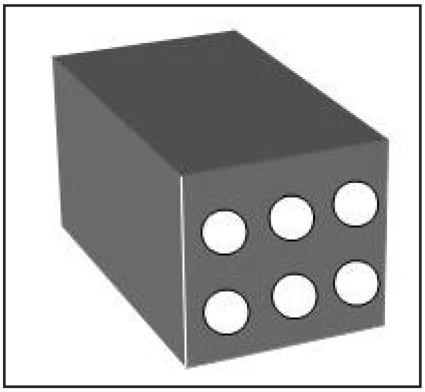

Figure 2. Underground concrete structure with 3" ducts.

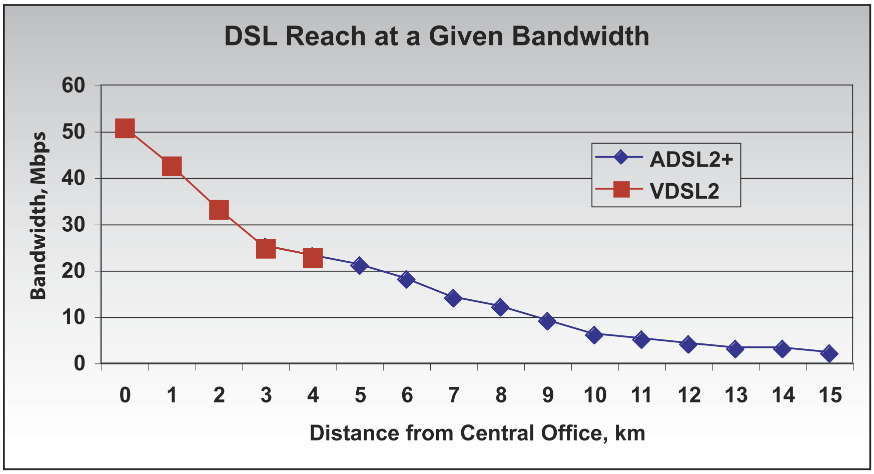

Figure 3. Reduction of DSL bandwidth capacity (Mbps) with respect to reach.

In existing neighborhoods it is typically more cost-effective to install new fiber in existing copper cable rights-of-way than along new routes; ducts usually exist to pull the fiber.

The feeder cable section carries the large cables outward from the Central Office. The feeder cable is typically housed in an underground duct structure that runs beneath an arterial street in the city. The duct structure is used so that the cabling can be reinforced and changed without trenching or digging, as illustrated in Figure 2.

In today's world of copper, the feeder cable meets the distribution cable at a cabinet that can be referred to by several different names:

- SAC box - Serving Area Concept
- JWI - Jumper Wire Interface
- SAI - Serving Area Interface

This cabinet typically serves about 400 subscribers. According to Millennium Marketing, the majority of U.S. homes are serviced from these cabinets and of these homes, approximately 90 percent are within 5,000 feet of the cabinet, making the cabinet an ideal site from which to deliver a 20-Mbps ADSL2+ service set.

The distribution wire typically radiates out from the SAI cabinet in four to six distribution bundles. Each distribution bundle has several curbside enclosures along its length. The curbside enclosure is a small cabinet where the distribution wires meet the drop wires. The distribution wires are typically direct-buried in trenches without ductwork, although some companies may have ducted the distribution runs.

The drop wires radiate out from the curbside enclosure in individual multipair cables destined for a single home, and are also usually buried without ductwork.

Service Name	Deployment Method	Minimum Bandwidth	Multicast Video	Video on Demand (VOD)	VoIP	HSIA (minimum)
Broadcast TV	ADSL2+ from SAI	15 Mbps	3xSD or 1HD + 1SD	-	-	1.5 Mbps
Broadcast TV+	ADSL2+ from SAI	15 Mbps	B3xSD or 1 HD + 1 SD	Push to STB	3 calls	1.2 Mbps
Multi-HD	VDSL2 from curbside	35 Mbps	3xHD or 8 SD or Mix	1 channel network VOD	3 calls	5 Mbps
Multi-HD+	VDSL2 from curbside	35 Mbps	3xHD or 8 SD or Mix	1 channel network VOD	3 calls	5 Mbps
Full New-Generation Network	FTTH (active Ethernet)	100 Mbps	6 HD	6 channels network VOD	10 calls	20 Mbps

Figure 4. Service description.

Assumptions and Acronyms for Figure 4:
- Standard Definition (SD) - 3 Mbps, MPEG4 or VC-1.
- High Definition (HD) - 8 Mbps, MPEG4 or VC-1.
- 20% overhead (ATM, Electronic Programming Guide (EPG)...).
- Video on Demand (VOD) stream replaces one of the broadcast streams.
- VOD and Voice over IP (VoIP)...can be offered on High Speed Internet Access (HSIA).
- VoIP, 128 kbps per simultaneous conversation; VoIP adapters usually reserve the bandwidth whether it is being used or not.

How Much Fiber is Enough?

Based on the outside-plant infrastructure of today, in existing neighborhoods it is typically more cost-effective to install new fiber in existing copper cable rights-of-way than along new routes. The fiber cable will eventually be converted to copper cable; copper is what the typical subscriber sees inside his or her home. But the demarcation doesn't have to be at the home's outer wall. There are three distinct, opportunistic locations where the fiber-copper transition can occur:

- At the demarcation point on the outside of the home (FTTP).
- At the curb-side enclosure or drop-distribution interface (FTTC).
- At the SAI or distribution-feeder interface (FTTN).

As the fiber is pushed deeper into the network, the costs increase because more fiber and construction is required. However, the closer the fiber is pushed toward the home, the greater the bandwidth that can be achieved.

In the U.S., last October's FCC order 04-248, which promotes deep fiber strategies by providing immunity from loop unbundling for any hybrid fiber/copper installation in which the optical networking unit (ONU) is deployed within 500 feet of the houses it serves, has reinforced the telcos' desire to address deep fiber deployments.

But let's be clear. In addition to the regulatory change, consumer demand for high bandwidth services has also helped drive deep-fiber deployments. Figure 4 shows a number of service sets that are being considered and their bandwidth requirements. The question therefore is not only how much fiber is enough, but which deployment method should be used.

Deployment Costs

Knowing the bandwidth requirements for the new service sets, it is important to consider the cost of various deployment options. The predominant cost factor will be the length of fiber that needs to be installed. However, there are several other factors that affect the cost of fiber deployments:

1. There is typically ducting to the SAI but not to the curbside enclosure, therefore, pulling fiber to the SAI is significantly less in $/ft than trenching or boring fiber to a curbside enclosure.
2. The amortization that can be gained

SAI deployment	Non-hardened remote DSLAM	Hardened remote DSLAM
Maximum copper length	5,400 ft	5,400 ft
Minimum estimated bandwidth	16 Mbps	16 Mbps
Assumed take rate	30%	30%
Cost per Subscriber	***$668***	***$496***
Cost per Subscriber, home passed	***$169***	***$114***

Figure 5. SAI deployment installation costs.

Curb-side deployment	Non-hardened remote DSLAM	Hardened remote DSLAM
Maximum copper length	900 ft	900 ft
Minimum estimated bandwidth	35 Mbps	35 Mbps
Assumed take rate	50%	50%
Cost per Subscriber	***$2,382***	***$1,778***
Cost per Subscriber, home passed	***$953***	***$758***

Figure 6. Curbside deployment installation costs.

FTTP deployment	Passive Optical Network	Active Optical Network
Maximum copper length	0 ft	0 ft
Minimum estimated bandwidth	62.5 Mbps	62.5 Mbps
Assumed take rate	50%	50%
Cost per Subscriber	***$7,104***	***$3,970***
Cost per Subscriber, home passed	***$2,802***	***$1,782***

Figure 7. FTTP deployment installation costs.

by multiplexing several users onto one fiber pair provides a significant savings, and this savings is a function of how many subscribers are collected at the multiplexing point. This means that the per-subscriber fiber costs of FTTP are significantly more expensive than FTTC costs, which are more expensive than FTTN costs.

3. The type of electronics that are placed in the field will yield dramatically different total costs of deployment. Electronics that are derived from traditional rack-mount Central Office designs will require environmental cabinets to ensure that moisture and corrosive particles do not come in contact with the circuit boards and to ensure that a fan drives sufficient airflow past the circuit boards. Conversely, sealed, passively cooled electronics that have been designed for the outside plant do not need any environmental control components. This reduces total installed costs and time to deploy, while increasing reliability.

4. Powering of outside-plant electronics can be through local AC power or through power sources in the Central Office that express power out to the remote site over existing spare copper pairs. Express powering saves installation costs because the central power supply is more cost-efficient (no trenching to remote locations) and battery backup and conversion can be done in one central location. Central power also has higher reliability because it is located indoors.

Figures 5 to 7 compare total cost of deployment for the various fiber options based on a model that uses an average North American topology. There is assumed to be 384 customers in the area with four curbside links off the SAI. The scenarios considered are bringing fiber to the SAI, to the curbside enclosure, and to the home. We also compare a rack-mount DSLAM design that requires an environmental sub-system, to a hardened outside-plant DSLAM that requires no environmental design. The variance in the cost of deployment for each scenario is quite apparent as you move from FTTN to FTTC to FTTP. As costs-

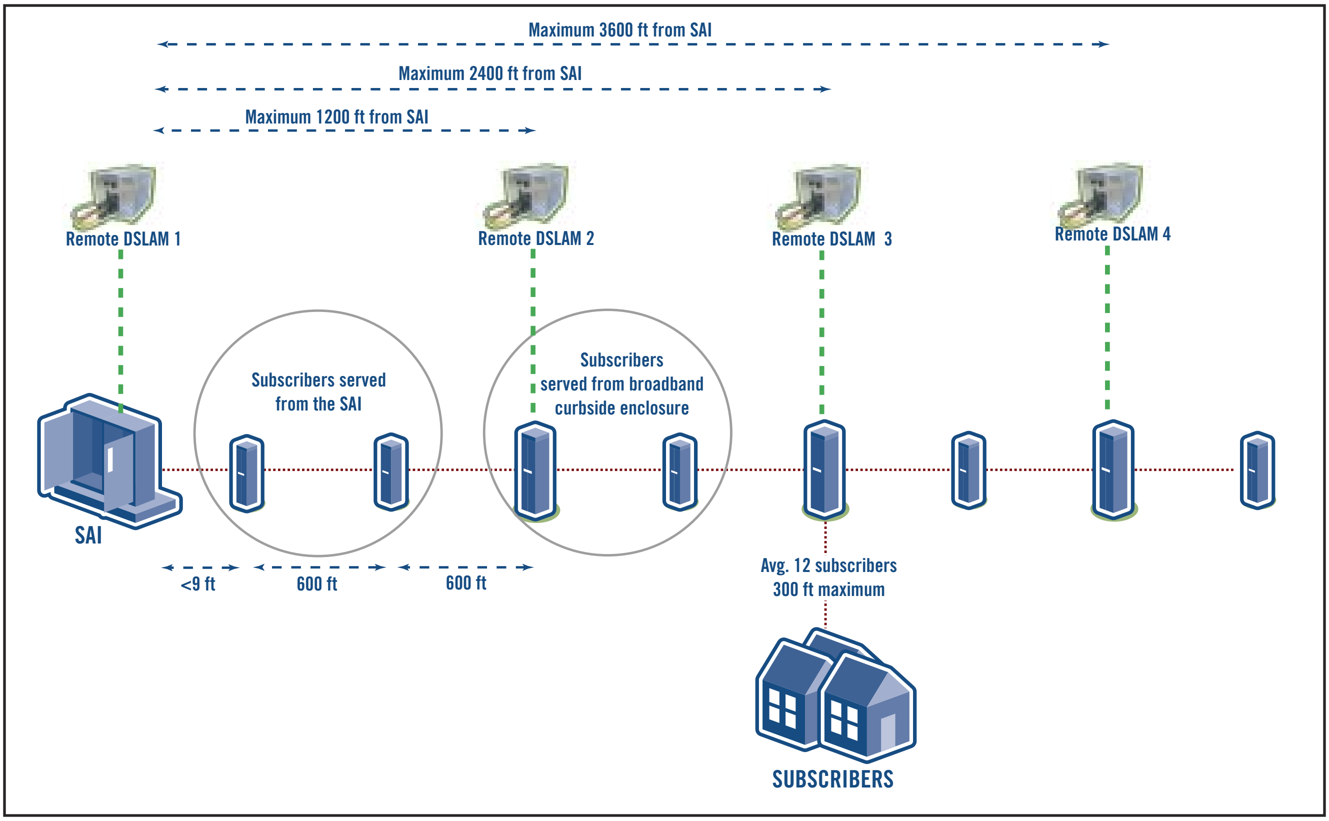

Figure 8. FTTC deployment scenarios.

Let's be clear. In addition to the Fall 2004 FCC regulatory change, consumer demand for high bandwidth services has also helped drive deep-fiber deployments in the United States.

per-subscriber increase dramatically per fiber deployment type, the need for increased revenue realization is obvious.

The FTTC scenario in Figure 8 assumes that not every curbside enclosure will be turned into a broadband curbside enclosure. By taking advantage of the fact that distribution cable bundles carry the pairs for all the homes in the distribution length, the network planner can pick the optimal curbside enclosures to turn into broadband curbside enclosures. The tradeoff is higher costs to broadband-enable more curbside enclosures versus the shorter loop lengths achieved when more curbside enclosures are broadband-enabled.

For the FTTP scenario, a Passive Optical Network (PON) approach is compared to an active approach where a hardened product would be located at the broadband curbside enclosures to terminate 100 Mbps optics and aggregate users back to the SAI with gigabit Ethernet (GigE) optics. This approach means more electronics in the loop, but it provides significantly lower fiber costs because of the additional fiber muxing point at the curbside cabinet. I firmly believe that by using proper outside-plant design techniques, all active optical network devices can achieve Mean-Time-Between-Failure (MTBF) rates in the range of PON devices.

The FTTN scenario has one DSLAM port for every active subscriber. However, the FTTC and FTTP scenarios have all homes connected to the network at all times. This eliminates all service add/drop truck rolls and it allows for self-serve service provisioning as well as for temporary service and service previewing. Thus, FTTC and FTTP lower marketing costs as well as servicing costs, and increase marketing flexibility.

An Evolutionary Approach

For brownfield installations in existing neighborhoods, therefore, a reasonable strategy for those carriers

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wanting to deliver new-generation services but not willing to spend the FTTP upfront costs, would be to push fiber to the SAI now and deliver a 20-Mbps ADSL2+ service set. As consumer demand for bandwidth increases, the fiber could be pushed to the broadband curbside enclosures and a 35-Mbps VDSL2 service can easily be achieved.

Pushing the fiber to the premises and re-using the broadband curbside enclosures for an optical-to-optical aggregator can achieve a cost-effective 100 Mbps bandwidth.

If the active optical network approach is used, the entire infrastructure is re-used in each evolutionary step, allowing the incremental costs to be significantly less. FTTN and FTTC deployment options can become a migration strategy in a carrier's arsenal to counter competitive threats from cable providers and to provide new-generation broadband services to their consumers immediately.

This evolutionary approach provides the lowest capital risk and the quickest time-to-market. Providing carriers with immediate revenue sources and the time to consider how to budget for their eventual FTTP deployment, FTTN and FTTC are viable growth solutions for carriers wanting to realize new broadband revenues while leveraging their existing network infrastructure.

Of course, if their vision includes new bandwidth-devouring services in the very near future, immediate FTTP makes sense - but only if the money and the construction crews can be found to deploy it fast enough! ◆

About the Author

Mark Labbé is CTO at Critical Telecom. Mr. Labbé was previously at Sci-Tec Instruments and has worked at both Bell Northern Research and Nortel Networks. He is named as inventor on three patents with Critical Telecom and two with previous employers.