A White Paper from the Experts in Business-Critical Continuity

Powering the fiber information network

EMERSON
Network Power

The future of voice, data and video transmission is fiber, but electronics will still be required to translate sounds and images into pulses of light for transmission and back again to electronics for hearing and viewing. And electronics require sources of DC power.

The question facing telcos today is "Who will provide this power, and where will it be located?"

Traditionally, the telco has maintained an "active" copper network, providing 48V DC power with battery backup to energize copper transmission lines in the Central Office (CO) and at other points along the network to overcome resistance in the copper. Pulses of light carried by fiber optic cables do not require power to overcome resistance.

Ultimately, fiber will reach all the way from the CO to the home or premise in "passive networks," with no power needed between the optical switch in the CO and the Optical Network Terminal (ONT) installed at each subscriber's location.

As this migration from copper to fiber has progressed, a variety of sometimes-confusing acronyms has arisen: FITL (Fiber In The Loop), FTTN (Fiber To The Node), FTTC (Fiber To The Curb), FTTP (Fiber To The Premise), or FTTH (Fiber To The Home). While nearly every telco has utilized one or more of these topologies in portions of its network, the bulk of the network is still copper, and traditional DC power solutions will continue to be required for years to come.

These power solutions may change shapes, they may change voltages, and they may change sizes. They may be located in cabinets on pads, on poles, on rooftops, in basements or on your inside garage wall, but they will still be there.

Whether you have begun to roll out your fiber network, or haven't yet decided what your future network will look like, it is important that you understand the differences between the various FTT(x) topologies, how the fiber network is being powered today and how it will be powered in the future.

Switch Switch

Changes in powering and topology of the distribution network are readily seen in the CO. There have been steady declines in the total number of subscriber lines and changes in switching topologies and switch power needs. Class 5 and Class 4 switches that did circuit-to-circuit or other types of digital switching are being replaced with "soft switch" or packet technology that puts everything on an optical backbone. These switches also reduce space requirements, manpower needs and maintenance costs. Such savings may make it possible to reduce the number of COs while still allowing the telco to service new developments.

With "soft" or optical switching, optical signals are brought into the switch and all the switching is done through software. The switch output is optical, so, instead of dedicated trunks of actual Cat. 5 or other wiring, there are trunks of optical fiber leaving the switch, with hundreds and thousands of drivers per optical line.

The ultimate long-term goal is to abandon the copper in the ground and replace it with fiber. However, since fiber does not yet reach all the way to most subscribers, at some point, conversion is required from optical to electronic so that it can be carried "the final mile" on existing copper.

Triple Play Players

Telcos have traditionally been extremely strong in voice communication, are getting better in data, but are historically weak in video. Cable companies, on the other hand, have been extremely strong in video, fairly strong in data and very weak in voice. Both are now competing tooth-and-nail to improve all their offerings and capture new customers.

To compensate for the decrease in land lines and to stave off the cable companies, telcos are extending fiber deeper into their networks, replacing portions of their traditional “Home Run” CO-based copper architectures so that they can to offer these “triple play” services requiring high bandwidth (voice, data, high-definition video).

Home Run copper architecture provides a copper line you can trace directly to a CO and you always have power and signal on that line (figure 1). However, copper is limited in the amount of bandwidth it can carry for more than short distances. Also, much of the copper has been in the ground for 50 or 60 years and is losing the battle with corrosion.

The cable network, on the other hand, was originally built with large sections of fiber, with the final segments to the subscriber carried on coaxial cable. At present, the cable companies are committed to maintaining their network as it stands and are looking for new technologies (like Voice Over Internet Protocol [VOIP]) that will allow them to improve their offering of triple play services.

In this race for subscribers, both telcos and cable companies are offering bundled services, where, for a flat rate, they will offer all three services at a significant savings compared to a separate phone line, an internet connection and cable or dish video service.

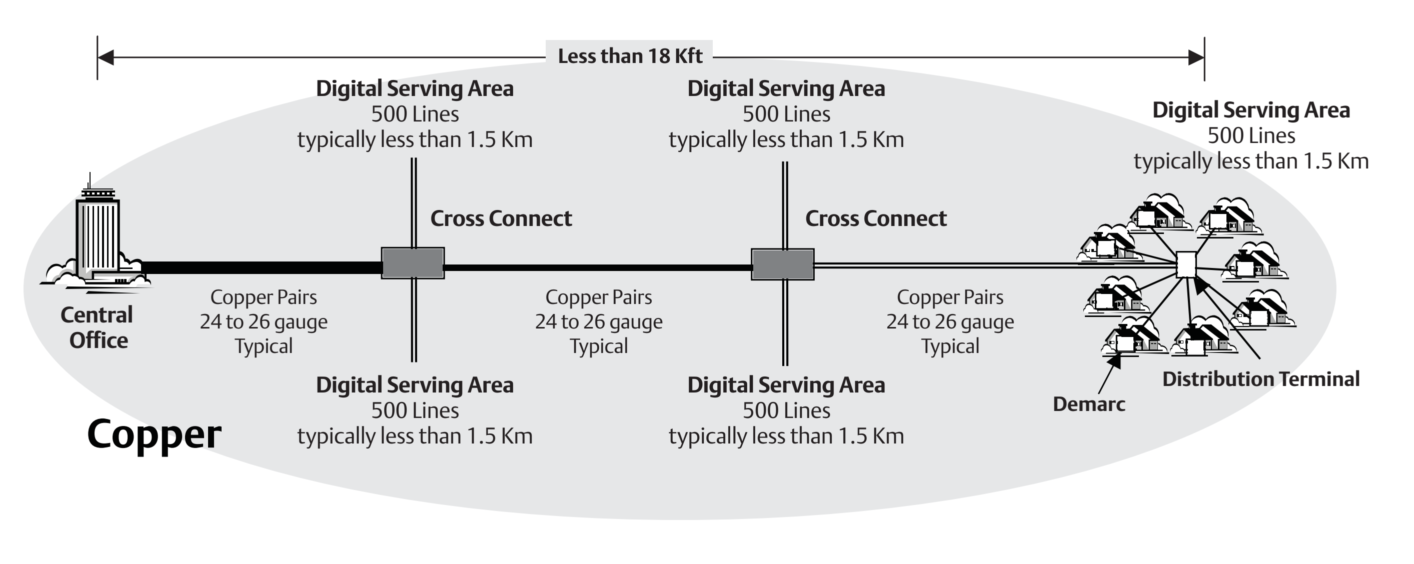
The telcos may contend VOIP is not dependable, but the proliferation of cell phones has accustomed a large part of the market to an occasional dropped call, and the convenience of bundling has considerable appeal. So at the end of the day, it becomes a pricing issue.

Breaking the loop

FITL —Fiber In The Loop —was one of the earliest fiber topologies and has been used for years. It deployed fiber by building a 5 to 10-mile fiber ring around a service area, with cabinets at various junction points. From these points, the network branched out to serve subscribers with other fiber topologies such as Fiber To The Curb (See Below). Power solutions to convert optical signals to electronic were installed at various points throughout the network.

The advantage of FITL is that, if the fiber loop is broken at one place, service can still be delivered from the other direction. Fiber loops are still used for concentrations of commercial subscribers. However, to satisfy today’s greater bandwidth demands, no more than 1,000 feet of copper can be used in the network, and the newer FTT(x) topologies get fiber much, much closer to the premise.

Figure 1



Copper under glass

Fiber To The Node—FTTN—topology is implemented by overlaying the portion of the traditional Home Run copper network closest to the Central office with fiber (figure 2). The initial strategy was to extend fiber to a “node” close enough (1000 to 3000 ft.) to concentrations of customers to be able to deliver the desired massive amounts of bandwidth over existing copper, without the cost of extending the fiber all the way to the premise.

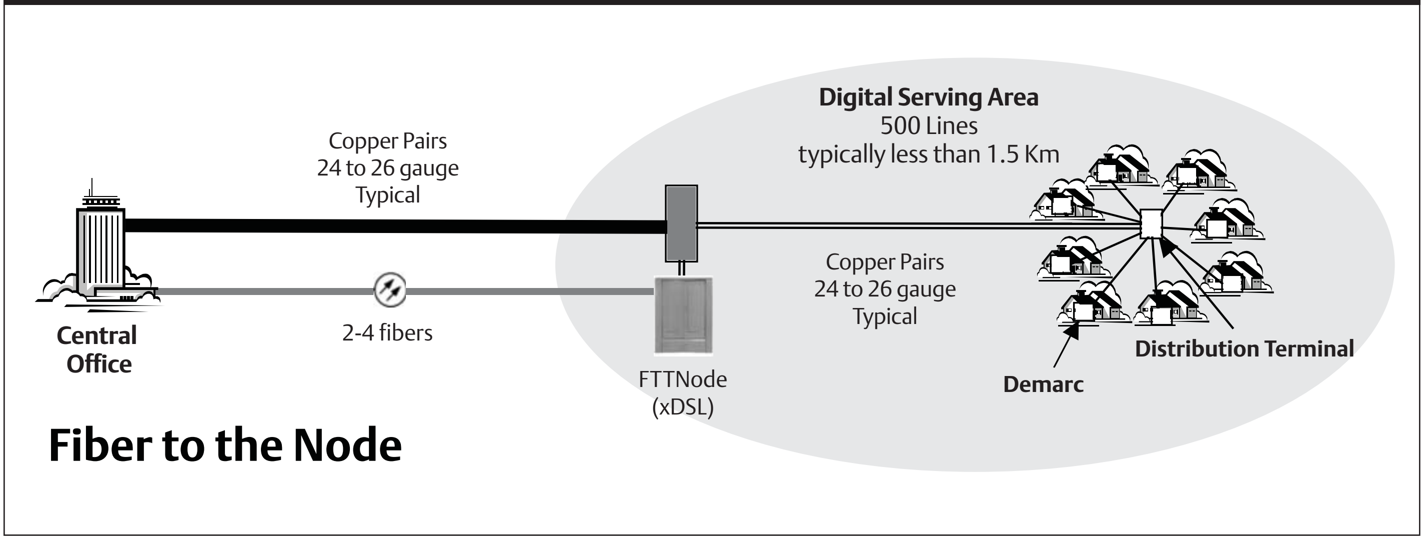
At the node, which includes a dedicated power solution, the optical signals are converted to electrical signals and transmitted the rest of the way to subscribers over the existing copper network. Massive amounts of bandwidth can be carried on copper pairs for very short distances. FTTN allows you provide a Digital Subscriber Line (DSL) with all-digital voice, from 1.5 to 5 mbs bandwidth for data and a certain amount of broadcast television over an existing twisted pair line to the subscriber’s premise. (The old copper from the CO to the node location is left to “die in the ground.”)

However, there are limitations to FTTN, depending on the actual distance from the node to the subscriber. Broadcasting capability for high definition signals over copper pairs is always being challenged. How many high-definition signals can you transmit over one copper pair, and are they true high-definition 1080 interlaced signal, or will they be 720 signals?

At first, nodes were being located an average of 2800 to 3000 feet from the premise. Now, telcos are bringing that number down closer to 1500 feet because they are realizing that they can’t get the number of high definition signals to the subscribers that they want down the road. Once a subscriber gets used to a high-definition signal, the subscriber normally wants high-definition service for all the sets in the premise. Three or four high-definition signals, along with the other triple play services, are hard to deliver over more than 1500 feet of copper. Also, the condition of the copper affects its bandwidth delivery capability.

Perhaps some kind of yet-to-be-developed compression technology will be able to extend the capacity of copper. However, it will take a massive implementation effort and coordination between the broadcasting franchises, the television networks at the core offices and the manufacturers of the set-top boxes that would be required at each location.

Figure 2



Almost there

Fiber To The Curb —FTTC —is similar to FTTN, except that instead of dropping fiber from the CO into a node which is a few thousand feet from the subscriber, the fiber is brought to a High Density Terminal (HDT) located at what is referred to as the “curb,” typically near an existing copper cross connect, 500 feet away from an office, building or home (figure 3). The HDT includes equipment to translate optical signals to electronics and a dedicated power solution (utility power pedestal, battery backup and monitoring provisions) that carries electronic signals to the subscriber.

That last 500 feet can be covered with copper pairs, or, where bandwidth demands are great or the existing copper is too corroded, with fiber directly to the premise. Essentially, it is a hybrid architecture that blends together FTTN with Fiber To The Premise —FTTP (See Below).

FTTC gets deployed where you have a mix of business and residential subscribers (particularly Multiple Dwelling Units [MDUs]) within the same service area, as well as in “greenfield” areas. Many businesses and MDUs are going to have bandwidth needs much higher than a single family residence, so the telco can take dedicated fiber from the HDT located on the street corner, straight to the larger businesses and MDUs, and twisted pairs to the smaller businesses and private residences.

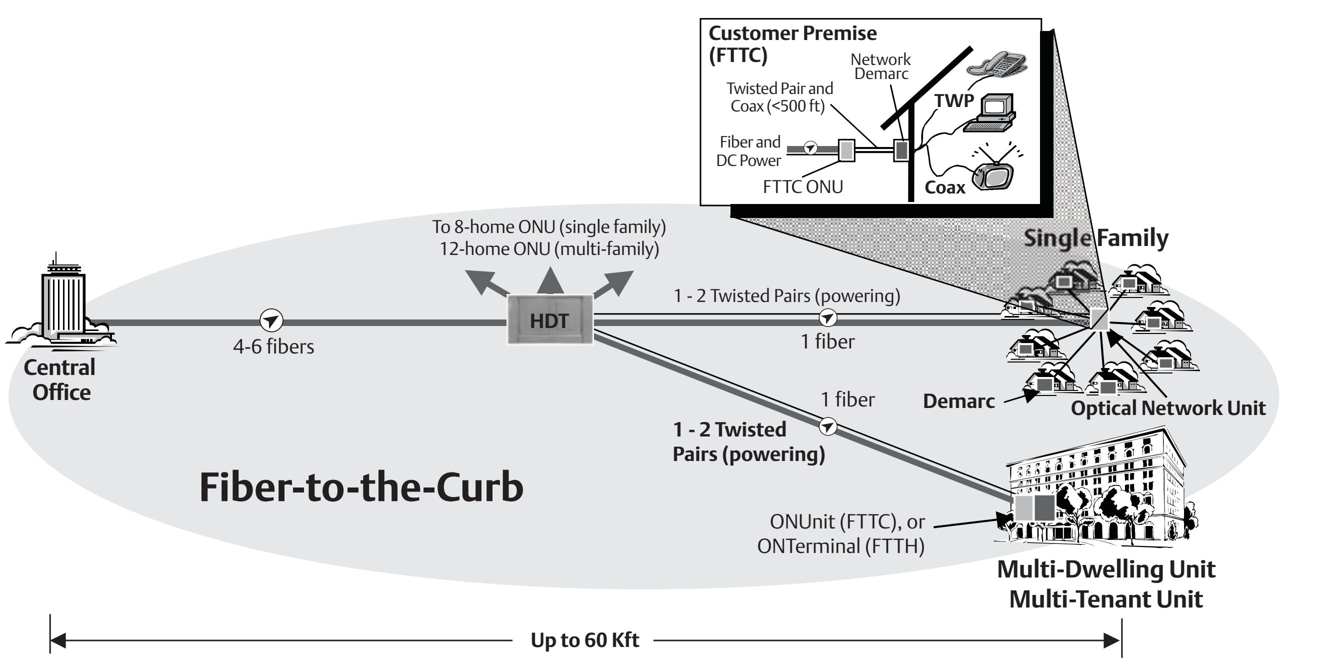
When the fiber goes all the way to the premise, the optical-to-electrical translation occurs at an Optical Network Unit serving single subscribers or an Optical Network Terminal (ONT) serving multiple subscribers-instead of at the HDT. When the telco is responsible for powering the ONU or ONT, “SPAN” power is often used to “bridge” the power gap between the dedicated power solution in the HDT and the optical network translator at the subscriber’s premise.

With SPAN power, you utilize existing twisted pairs to carry the required electrical energy. It is necessary to raise the voltage of the power from the normal 48V up to 190V to overcome resistance in the copper pair. (A more detailed discussion of SPAN power follows, below.)

This is the big difference between FTTN and FTTC. The FTTN node does not output anything higher than about 48V. The HDT will output 48 or 190V power or optical signals to serve the differing needs of the service area.

HDT power consumption is about twice the rate of the FTTN node cabinet. HDT boxes are significantly bigger than FTTN nodes: 6’ high and 4’ x 6’ wide vs. 4’ high or less and 2.5' x 2.5' square. The size reflects the amount of electronics and power conversion equipment inside.

Figure 3



Home Run Fiber

Just as copper once provided an electrical path all the way from the CO to the subscriber, FTTP/H —Fiber To The Premise/Home —will provide a totally optical path, particularly in "greenfield" and "brownfield" areas where there is no existing copper network to "save." (figure 4)

Verizon is selling this architecture on the basis that it delivers essentially unlimited bandwidth. It will carry, perhaps, up to 10 high-definition video signals, as much data as the subscriber wants to buy, and doesn't have the "health" limitations of copper. Bandwidth, they claim, is only limited by what the CO is going to broadcast out.

They propose to eventually overlay their entire distribution network —along existing copper routes where they already have right-of-way —with overhead fiber, and, ultimately, cut over all subscribers to fiber. In greenfield developments, they will trench only fiber, leaving subscribers no alternative other than cable providers.

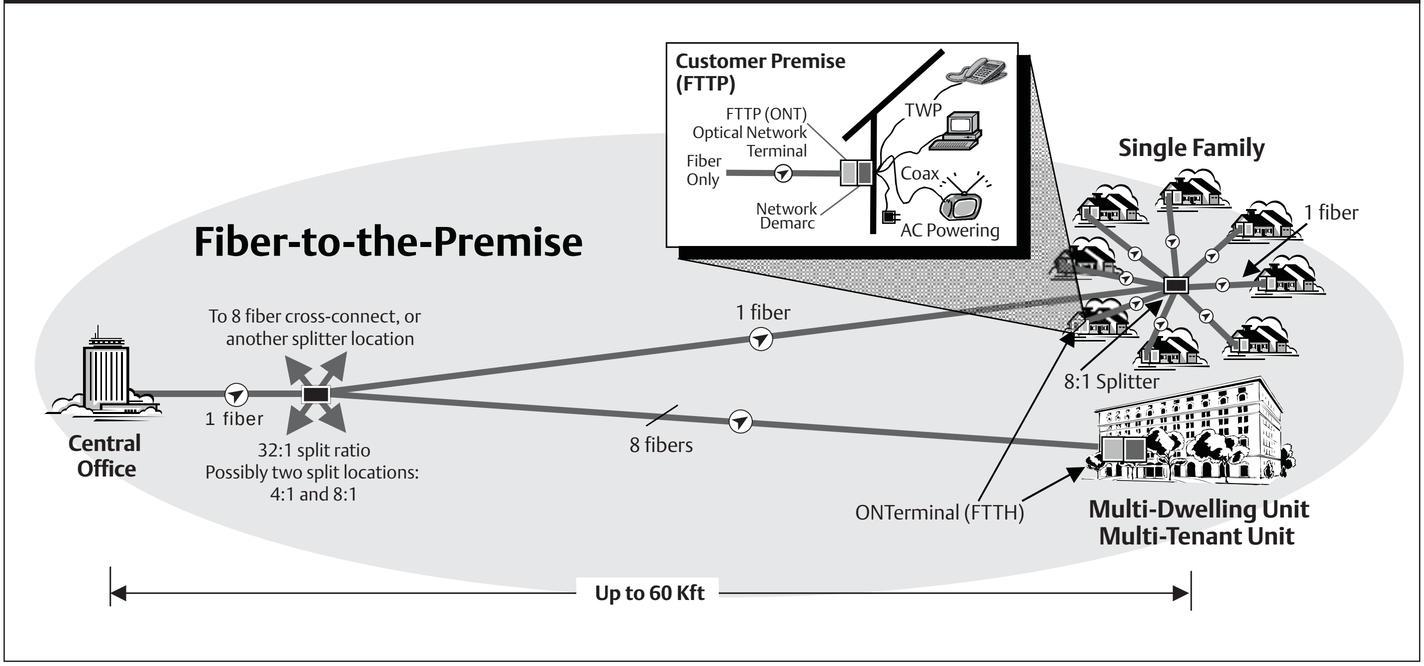
An FTTP network should be much easier to maintain, without a large number of cabinets, electronics, and batteries to service. There will be far fewer problems with lightning strikes, floods and storms because most of the deployment is aerial, optics don't draw electricity, they're not grounded, and glass doesn't attract lightning.

FTTP is a "passive" optical network. Once the light signal leaves the CO on an optical cable, it passes through a series of optical cross connects and splitters, but there is no power conversion or amplification until it gets to the end user.

While this topology eliminates the need for conventional Outside Plant (OSP) power solutions, transmission needs at the CO will remain, and a lot of new power gear is being deployed in COs as they migrate from legacy equipment to new power technology. Also, the optical signal still must be converted back to electronics at the subscriber, requiring a DC power source.

Several companies are making optical translation equipment (ONUs, ONTs) containing power conversion cards and DC-powered electronics that will normally operate on 110V utility power provided by the subscriber. Since the fiber will carry lifeline (911) services, the "lighting" of the fiber at the CO will be protected by battery backup. However, to utilize these lifelines during utility power outages, the ONUs and ONTs must also incorporate 48V or 12V battery backup.

Figure 4



Great Debate

This has resulted in a great debate that is yet to be resolved. Who is responsible for battery backup? Some telcos have promised to keep the optical fiber lit at the CO and claim that is where their accountability ends. They maintain that this is no different than a homeowner providing battery backup for a security system.

Other telcos have agreed to share responsibility for the battery by adding alarm features to the ONU or ONT that will send signals back to the subscriber over the optics saying that the battery is dead and should be replaced. The terminal may also include warning lights alerting the subscriber to a dead battery. If the ONU/T is mounted on the outside of the premise giving the telco 24/7 access, the telco can assume responsibility. If it is mounted inside the subscriber's garage, for example, it will be up to the homeowner to provide an AC outlet and maintain the battery.

During utility power outages, the system may cut off your video to reduce the power draw, allowing the battery to support voice and data service for longer periods. A small 12V battery, the type most likely to be used in an ONT, will keep the electronics powered up for 6-12 hours during a power outage, depending on what services shut off. It may be possible to run up to four hours with everything on and 24 hours with just voice. The actual times depend on the battery condition, the ambient temperature, etc.

Muddy MDU Picture

Getting fiber optics all the way to tenants in Multiple Dwelling Units is not nearly as neat and clean as delivering it to single dwelling units. While getting the optical signal to the subscriber isn't much different than running twisted copper pairs, it's converting the signal back into electronics that is the challenge.

There may be a powered main community Fiber Distribution Hub (FDH) somewhere in the building that converts the optical signal to electronics. The telco may decide to locate it in the basement and bring coax or Cat. 5 cable up through conduits to the individual subscribers. Or they may bring the optics up from the basement and then have individual conversion boxes (ONTs) inside each apartment or attached to the side of each condo. Deployment will be extremely variable, depending on the physical structure and number of units.

If you have 500 residences in a building, and you are going to put the electronics in the basement, you won't just need a 300W power supply; you will need a small DC plant in the building that the telco will have to maintain in the basement. This means the telco will need to have rights and access to the basement, 24/7. There are all kinds of tenant rights and ownership rights involved.

Some buildings have basements, some don't; some have closets, some don't. It might be necessary to put an FDH on the roof and drop Cat. 5 or coax down somewhere. How do you bring this fiber technology to New York City, for example? Getting the fiber to the individual apartments and having each dwelling unit provide a power supply with battery backup would be the obvious solution, but some buildings don't allow you to have batteries in the building because of fire codes.

With service providers, subscribers, building owners, landlords, local governing bodies, trades and other factions all involved, there is no clear picture of MDU deployment.

Figure 5

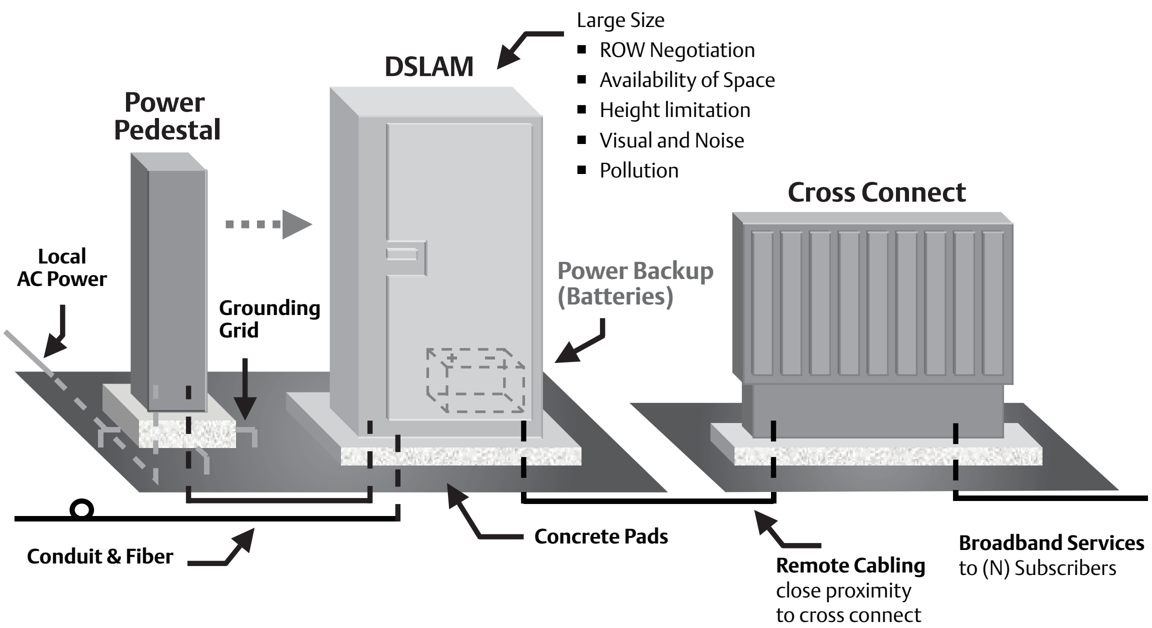
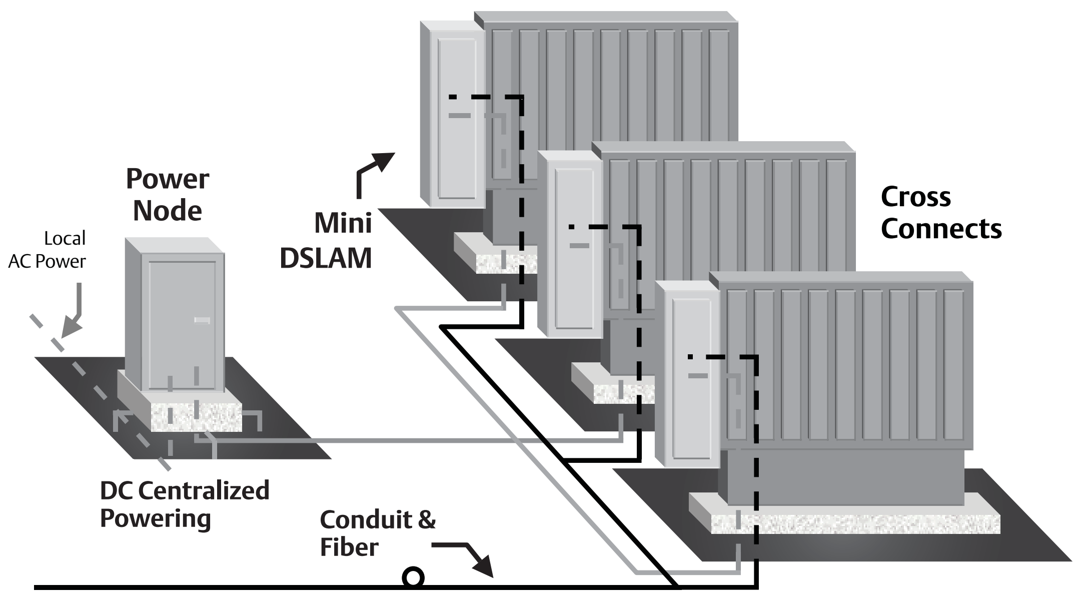


Figure 6



Where to put the power

As we have seen, telco distribution network power needs range from power everywhere (Home Run CO based copper) to power almost nowhere (FTTP/H). While the power picture is changing, there still are a large number of power opportunities and issues to face, particularly because AT&T is advocating and deploying FTTN with the same enthusiasm as Verizon is pushing FTTP/H.

Traditional DSL Deployment

In the traditional Digital Subscriber Line deployment (figure 5), the Digital Subscriber Line Asynchronous Multiplexer (DSLAM) is deployed in close proximity to an existing copper cross connect in the Digital Service Area (DSA) and fiber is run from the CO to the DSLAM. To power the translation electronics in the DSLAM and carry the electronic signals over twisted pairs to nearby subscribers, a power pedestal is installed and connected to local AC power. In addition to the translation electronics, the DSLAM houses battery backup. Copper cable connects the DSLAM to the cross connect.

While relatively simple, this deployment usually requires additional space, may involve Right-Of-Way (ROW) negotiations, may be subjected to height limitations and can be considered a source of visual and noise pollution, particularly in residential neighborhoods.

FTTN/C Power Deployment

Fiber To The Node and Fiber To The Curb deployments are similar to DSL deployments, which is why a lot of people are comfortable with them. There may already be a DSL cabinet on a pad and, to upgrade the network, they may only have to put another cabinet (Node or High Density Terminal) alongside of it. If the neighborhood is used to looking at one cabinet, what's one more?

If there are several cross connects in a highly populated area, the telco may deploy one large power node with battery backup and trunk the power to each of the cross connects, onto which they have hung mini DSLAMs (conversion electronics) (figure 6). The fiber in the ground goes directly to each cross connect/mini DSLAM. This architecture is not getting used extensively, except in highly populated areas.

While the mini DSLAM eliminates the need for an additional pad, ROW issues may arise over the "air rights" to the space occupied by the overhanging mini DSLAM.

FTTP/H Power Deployment, Single Residences

When fiber is trenched in, it will come into a service entrance and have an ONU (with an integrated power solution and battery backup) (figure 7). The subscriber will be responsible for powering the ONU and

Figure 7

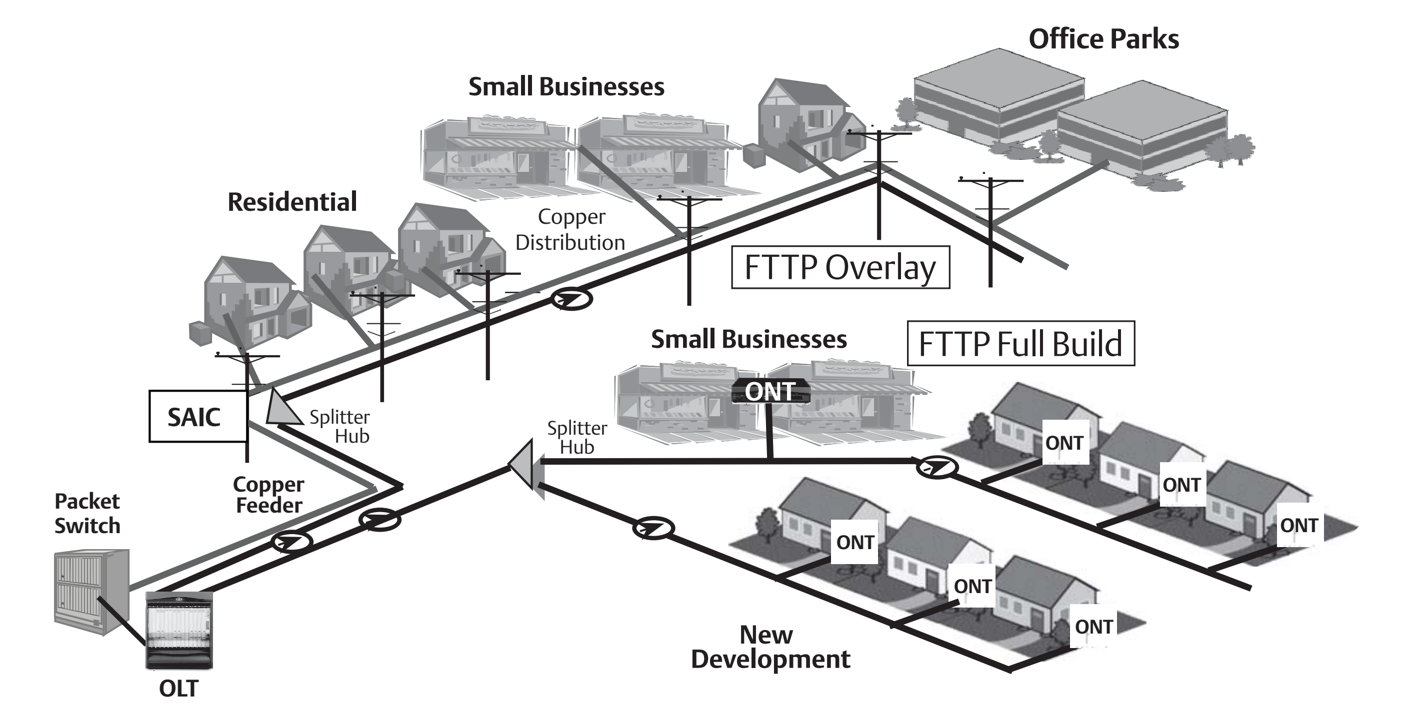
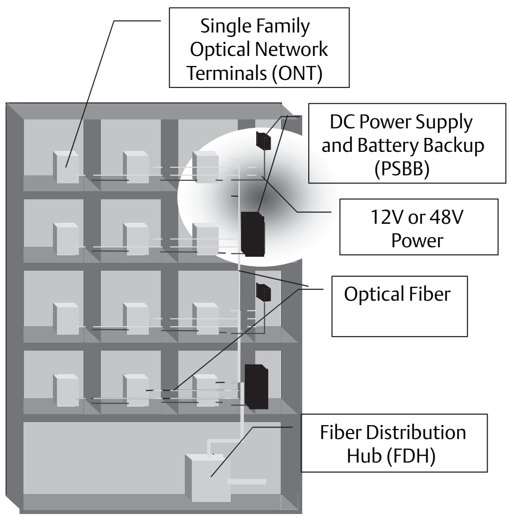


Figure 8



maintaining a battery capable of 4-16 hour backup. Where fiber is transmitted overhead, optical nodes will be hung onto wire and serve multiple homes (6-10), as long as the nodes are very close to the residence (500 ft. or less). The telco be responsible for providing the power in this situation, along with 8-40 hour battery backup.

FTTP/H Power Deployment, Multiple Dwelling Units

As previously discussed, powering FTTP/H in MDUs will entail multiple options, depending on local laws, owner preferences, physical structure limitations and other factors (figure 8). With 30-40 million MDUs in the US alone, any number of powering schemes and arrangements will be tried and developed by the time fiber reaches all the MDU subscribers who want or need it.

SPANing the Power Gap

SPAN power is a strategy for transmitting electrical power for longer distances (12,000 to 15,000 feet) and overcoming resistance in copper pairs, some of which may have deteriorated after having been in the ground for up to 60 years.

It is an in-between solution for service providers who haven't yet committed to deploying fiber all the way to the premise, or who, like Bell South, have a mix of rural and city subscribers and operate in a high-humidity/salt/corrosion environment. SPAN allows them to transmit power between a single power node and multiple mini DSLAM/cross connects and provide DSL services to subscribers located greater distances from the DSLAM.

SPAN power uses some of the twisted pairs in an existing copper cable bundle to carry power. However, these conductors were meant only to carry 48V signals over relatively short distances, to 48V apparatus. To achieve the benefits of SPAN power it is necessary understand and overcome the physical limitations of copper conductors.

A certain portion of the power passed along a copper conductor is lost in overcoming the resistance of the conductor. If the line is too long (too much resistance), there may be no power left to power the load (such as optical-to-electronic translators).

The formula for Power losses (watts) in a copper conductor is $P_{losses} = I^2 \times R$, where I is the current (amperes) and R is the resistance (ohms) (figure 9). The only way to reduce the power loss is to reduce the current or reduce the resistance (which is fixed, since the copper is already in the ground).

The formula for DC current is $I = P/V$, where P, again, is the power and V is the Voltage. To reduce the current, and thus minimize transmission losses, the Voltage must be increased, commonly from 48V to 190V, using either a bulk-power conversion configuration or an individual-converter configuration. When the power reaches the DSLAM or ONU, a step-down converter is used to reduce the Voltage back to 48V.

The benefits of SPAN power transmitted over existing copper cable include deployment savings, centralization of battery backup (savings on provisioning and protecting AC, savings on maintenance and battery life) and reduced size of access enclosures (savings on pad and placement, savings on right-of-way negotiations).

However, while increasing Voltage from 48V to 190V greatly reduces power losses and allows power transmission up to as far as 14,000 feet on common cable conductors, too much power (high voltage and high amperage) leads to safety hazards with the potential for serious injury or death. As a result, NEC, Telecordia, IEC and other organizations have established safety standards for exposure to various power levels.

For a more detailed discussion of SPAN power, view a copy of "Span Power can Reduce the Cost of Powering the Broadband Network" from Emerson Network Power.

Keeping Ahead of the Curve

A lot of attention has been paid to fiber topologies because of media coverage and the major players associated with the various configurations. But a lot of people haven't paid much attention to the power issue. Whether you are in the process of rolling out your fiber distribution network or are still considering your options, sooner or later you will be faced with new power needs in different locations than you ever encountered with your copper network.

You may initially decide to cut off your fiber feed somewhere short of the subscriber's premise as a stop-gap measure to keep subscribers from defecting to cable companies and to utilize existing copper where possible. However, many suspect that these topologies (FTTN, FTTC) will be abandoned in 5-10 years and telcos will be forced to install fiber cross connects and fiber splitters to finally bring fiber within 500 feet or less of every subscriber's ONU or ONT.

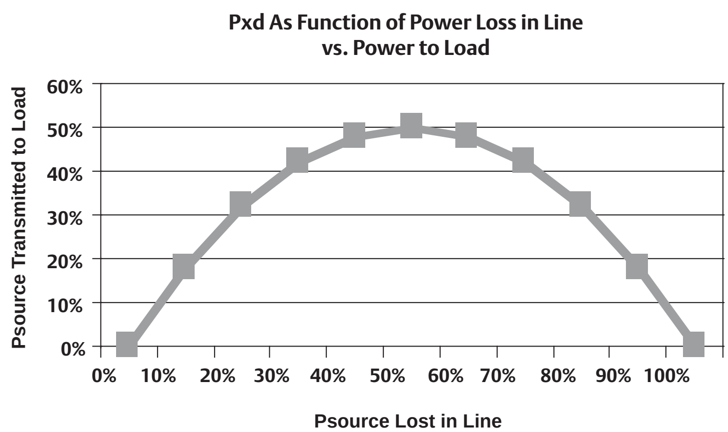
The demand for high-definition TV may well be what signals the end for FTTN and FTTC. Once a subscriber gets one high-definition signal, it will only be a matter of time before the subscriber wants high-definition for each of the 4-6 TVs on the premise. This, in combination with data and voice, will be more than the limitations of copper will allow.

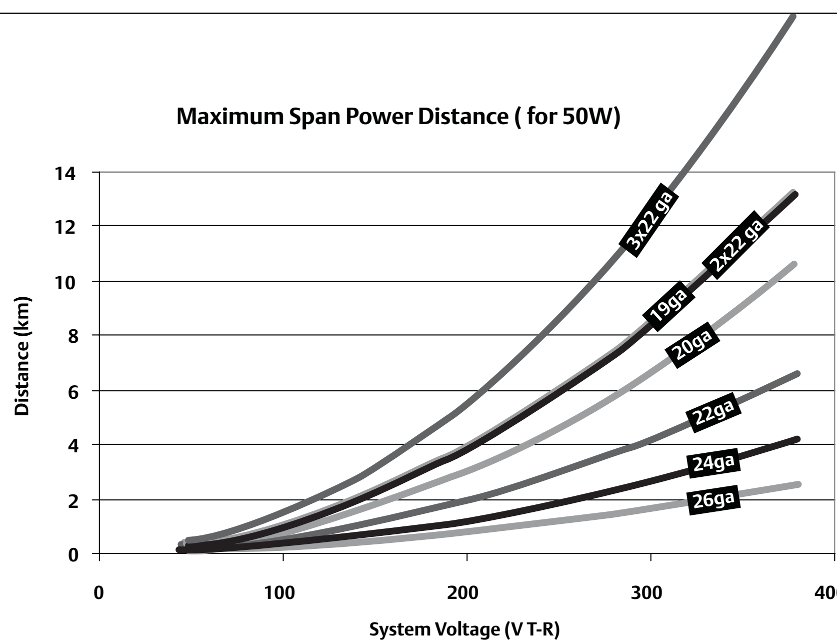
Cable companies already run fiber deep into their networks and say that coax can handle the broadband demand now. But by 2015, the demand may well exceed the capacity of the coax portions of their networks and the cable companies will be forced to run fiber all the way as well, further blurring the distinction between the phone company and the cable company.

The need for power in each FTT(x) scenario is clear. It's just a question of which one will win out, and how you will stay ahead of the power curve. As you look at the different architectures, DC system requirements to power the electronics don't go away, they just change shapes. They may even change voltages, they may change size or how they are applied, they may be on rooftops, they may be pole mounts, but they are still there. And the battery is still there, whether it is a small 12V battery or a large monobloc cell.

You may need some smarter electronics to monitor all these power solutions, but, at the end of the day, it's just very small chunks of the power you used to provide in the CO that are now getting dispersed throughout the network.

Figure 9





Emerson Network Power
Energy Systems, North America
1122 F Street, Lorain, OH 44052
Toll Free: 800-800-1280 (USA and Canada)
Telephone: 440-246-6999 **Fax:** 440-246-4876
Web: EmersonNetworkPower.com/EnergySystems

Emerson Network Power.
The global leader in enabling business-critical continuity.

EmersonNetworkPower.com

- AC Power
- Connectivity
- **DC Power**
- Embedded Computing
- Embedded Power
- Monitoring
- Outside Plant
- Power Switching & Controls
- Precision Cooling
- Racks & Integrated Cabinets
- Site Monitoring
- Surge Protection

Code: PWP-FTTx-078

August 2007