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FOA Technical Bulletin

Guide To Fiber Optic Network Design

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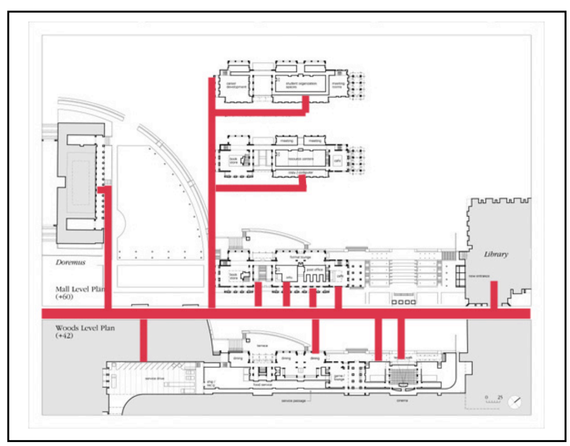
Part 1: Introduction



What is “fiber optic network design?” Fiber optic network design refers to the specialized processes leading to a successful installation and operation of a fiber optic network. It includes determining the type of communication system(s) which will be carried over the network, the geographic layout (premises, campus, outside plant (OSP, etc.), the transmission equipment required and the fiber network over which it will operate. Next we have to consider requirements for permits, easements, permissions and inspections. Once we get to that stage, we can consider actual component selection, placement, installation practices, testing, troubleshooting and network equipment installation and startup. Finally, we have to consider documentation, maintenance and planning for restoration in event of an outage.

Design requires working with higher level network engineers usually from IT (information technology) departments and cable plant designers such as the architects and engineers overseeing a major project, as well as contractors involved with building the projects. Other groups like engineers or designers involved in aspects of project design such as security, CATV or industrial system designers or specialized designers like BICSI RCDDs for premises cabling may also be overseeing various parts of the project that involves the design and installation of fiber optic cable plants and systems.

Designers should have an in-depth knowledge of fiber optic components and systems and installation processes as well as all applicable standards, codes and any other local regulations. They must also be familiar with most telecom technology (cabled or wireless), site surveys, local politics, codes and standards, and where to find experts in those fields when help is needed. Obviously, the fiber optic network designer must be familiar with electrical power systems, since the electronic hardware must be provided with high quality uninterruptible power at every location. And if they work for a contractor, estimating will be a very important issue, as that is where a profit or loss can be determined!

Those involved in fiber optic project design should already have some background in fiber optics, such as having completed a FOA CFOT certification course, and may have other training in the specialties of cable plant design such as electrical contracting apprenticeship, RCDD, SCTE or ISA training, etc. It's also very important to know how to find in-depth information, mostly on the web, about products, standards, codes and, for the OSP networks, how to use online mapping services like Google Maps. Experience with CAD systems is a definite plus.

References for the fiber optic designer's bookshelf include the FOA text, The Fiber Optic Technicians Manual, and the NECA/FOA-301 installation standard. When it comes to the NEC, I like Limited Energy Systems published by the NFPA. My own bookshelf has dozens of books on communications system design, but unfortunately, the fast pace of development in communications technologies means that many textbooks are hopelessly out of date unless it's updated frequently. Better to rely on the web, especially the websites of well-established manufacturers.

Getting trained specifically in fiber optic network design is becoming easier. This material is covered in part in some advanced fiber optic courses offered by the FOA-approved schools and by large manufacturers who help you understand how to build networks using their products. The FOA has developed a curriculum to allow more of our schools to offer a design specialty course and a new FOA design specialty certification. The bulk of the required material has been developed by a committee of experienced fiber installers and trainers working with the FOA.

Part 2: Getting Started

Before one can begin to design a fiber optic cable plant, one needs to establish with the end user or network owner where the network will be built and what communications signals it will carry. Most contractors are more familiar with premises networks, where computer networks (LANs or local area networks) and security systems use structured cabling systems built around well-defined industry standards. Once the cabling exits a building, even for short links for example in a campus or metropolitan network, requirements for fiber and cable types change. Long distance links for telecommunications, CATV or utility networks have other, more stringent requirements, necessary to support longer high speed links, that must be considered.

But while the contractor generally considers the cabling requirements first, the real design starts with the communications system requirements established by the end user. One must first look at the types of equipment required for the communications systems, the speed of the network and the distances to be covered before considering anything related to the cable plant. The communications equipment will determine if fiber is necessary or preferable and what type of fiber is required.

Premises cable systems are designed to carry computer networks based on Ethernet which currently may operate at speeds from 10 megabits per second to 10 gigabits per second. Other systems may carry security systems with digital or analog video, perimeter alarms or entry systems, which are usually low speeds, at least as far as fiber is concerned. Telephone systems can be carried on traditional twisted pair cables or as is becoming more common, utilize LAN cabling with voice over IP (VoIP) networks. Premises networks are usually short, often less than the 100 meters (about 330 feet) used as the limit for standardized structured cabling systems that allow twisted pair copper or fiber optic cabling, with backbones on campus networks used in industrial complexes or institutions as long as 500 m or more, requiring optical fiber.

Premises networks generally operate over multimode fiber. Multimode systems are less expensive than singlemode systems, not because the fiber is cheaper (it isn't) nor because cable is cheaper (the same), but because the large core of multimode fiber allows the use of cheaper LED or VCSEL sources in transmitters, making the electronics much cheaper. Astute designers and end users often include both multimode and singlemode fibers in their backbone cables (called hybrid cables) since singlemode fibers are very inexpensive and it provides a virtually unlimited ability to expand the systems.

Telephone networks are mainly outside plant (OSP) systems, connecting buildings over distances as short as a few hundred meters to hundreds or thousands of kilometers. Data rates for telecom are typically 2.5 to 10 gigabits per second using very high power lasers that operate exclusively over singlemode fibers. The big push for telecom is now taking fiber directly to a commercial building or the home, since the signals are now too fast for traditional twisted copper pairs.

CATV also uses singlemode fibers with systems that are either hybrid fiber-coax (HFC) or digital where the backbone is fiber and the connection to the home is on coax. Coax still works for CATV since it has very high bandwidth itself. Some CATV providers have discussed or even tried some fiber to the home, but have not seen the economics become attractive yet.

Besides telecom and CATV, there are many other OSP applications of fiber. Intelligent highways are dotted with security cameras and signs and/or signals connected on fiber. Security monitoring systems in large buildings like airports, government and commercial buildings, casinos, etc. are generally connected on fiber due to the long distances involved. Like other networks, premises applications are usually multimode while OSP is singlemode to support longer links.

Metropolitan networks owned and operated by cities can carry a variety of traffic, including telephone, LAN, security, traffic monitoring and control and sometimes even traffic for commercial interests using leased bandwidth or fibers. However, since most are designed to support longer links than premises or campus applications, singlemode is the fiber of choice.

For all except premises applications, fiber is the communications medium of choice, since its greater distance and bandwidth capabilities make it either the only choice or considerably less expensive than copper or wireless. Only inside buildings is there a choice to be made, and that choice is affected by economics, network architecture and the tradition of using copper inside buildings.

Part 3: Copper, Fiber or Wireless?

While discussions of which is better – copper, fiber or wireless – has enlivened cabling discussions for decades, it's becoming moot. Communications technology and the end user market, it seems, have already made decisions that generally dictate the media. The designer of cabling networks, especially fiber optic networks, and their customers today generally have a pretty easy task deciding which media to use once the communications systems are chosen.

Designing long distance or outside plant applications generally means choosing cabling containing singlemode (SM) fiber over all other media. Most of these systems are designed to be used over distances and speeds that preclude anything but SM fiber. Occasionally other options may be more cost effective, for example if a company has two buildings on opposite sides of a highway, a line-of-sight or radio optical wireless network may be easier to use since they have lower cost of installation and are easier to obtain relevant permits.

Other than some telco systems that still use copper for the final connection to the home, practically every cable in the telephone system is fiber optic. CATV companies use a high performance coax into the home, but it connects to a fiber optic backbone. The Internet is all fiber. Most commercial buildings in populous areas have direct fiber connections from communications suppliers. Cities use SM fiber to connect municipal buildings, surveillance cameras, traffic signals and sometimes offer commercial and residential connections, all over singlemode fiber. Even the cellular antenna towers you see along the highways and on tall buildings usually have fiber connections.

Premises cabling is where the fiber/copper/wireless arguments focus. A century and a half of experience with copper communications cabling gives most users a familiarity with copper that makes them skeptical about any other medium. And in many cases, copper has proven to be a valid choice. Most building management systems use proprietary copper cabling, for example thermostat wiring, as do paging/audio speaker systems. Security monitoring and entry systems, certainly the lower cost ones, still depend on copper, although high security facilities like government and military installations often pay the additional cost for fiber's more secure nature.

Surveillance systems are becoming more prevalent in buildings, especially governmental, banking, or other buildings that are considered possible security risks. While coax connections are common in short links and structured cabling advocates say you can run cameras limited distances on Cat 5E or Cat 6 UPT like computer networks, fiber has become a much more common choice. Besides offering greater flexibility in camera placement because of its distance capability, fiber optic cabling is much smaller and lightweight, allowing easier installation, especially in older facilities like airports or large buildings that may have available spaces already filled with many generations of copper cabling.

LAN cabling is often perceived as the big battleground of fiber versus copper, but the reality of the marketplace has begun to sink in for many users. The network user, formerly sitting at a desktop computer screen with cables connecting their computer to the corporate network and a phone connected with another cable, is becoming a relic of the past.

People now want to be mobile. Practically everybody uses a laptop, excepting engineers or graphic designers at workstations, and most of them will have a laptop as a second computer to carry, along with everybody else, to meetings where everybody brings their laptops and connects on WiFi. When was the last time you went to a meeting where you could connect with a cable?

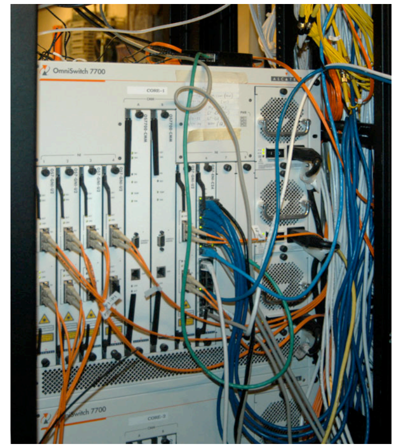
Besides laptops on WiFi, people use Blackberries and iPhones for wireless communications. Some new devices, like the iPhone, allow web browsing with connection over either the cellular network or a WiFi network. Some mobile phones are portable VoIP devices connecting over WiFi to make phone calls. While WiFi has had some growing pains and continual upgrades, at the 802.11n standard, it has become more reliable and offers what seems to be adequate bandwidth for most users.

The desire for mobility, along with the expansion of connected services, appears to lead to a new type of corporate network. Fiber optic backbone with copper to the desktop where people want direct connections and multiple wireless access points, more than is common in the past, for full coverage and maintaining a reasonable number of users per access point is the new norm for corporate networks.

What about fiber to the desk? Progressive users may opt for FTTD, as a complete fiber network can be a very cost effective solution, negating the requirement for telecom rooms full of switches, with data quality power and grounds, plus year-round air conditioning. Power users, like engineers, graphics designers and animators can use the bandwidth available with FTTD. Others go for a zone system, with fiber to local small-scale switches, close enough to users for those who want cable connectivity instead of wireless, to plug in with a short patchcord.

It's the job of the designer to understand not only the technology of communications cabling, but also the technology of communications, and to keep abreast of the latest developments in not only the technology but the applications of both.

Part 4: Choosing Transmission Equipment



Choosing transmission equipment is the next step in designing a fiber optic network. This step will usually be a cooperative venture involving the customer, who knows what kinds of data they need to communicate, the designer and installer, and the manufacturers of transmission equipment. Transmission equipment and the cable plant are tightly interrelated. The distance and bandwidth will help determine the fiber type necessary and that will dictate the optical interfaces on the cable plant. The ease of choosing equipment may depend on the type of communications equipment needed.

Telecom has been standardized on fiber optics for 30 years now, so they have plenty of experience building and installing equipment. Since most telecom equipment uses industry conventions, you can usually find equipment for telecom transmission that will be available for short links (usually metropolitan networks, maybe up to 20-30 km), long distance and then really long distance like undersea runs. All run on singlemode fiber, but may specify different types of singlemode.

Shorter telecom links will use 1310 nm lasers on regular singlemode fiber, often referred to as G.652 fiber, it’s international standard. Longer links will use a dispersion-shifted fiber optimized for operation with 1550 nm lasers (G.653. G.654 or G.655 for DWDM). For most applications, one of these will be used. Most telco equipment companies offer both options.

Most CATV links are AM (analog) systems based on special linear lasers called distributed feedback (DFB) lasers using either 1310 nm or 1550 nm operating on regular singlemode fibers. As CATV moves to digital transmission, it will use technology more like telecom, which is already all digital.

The choices become more complex when it comes to data and CCTV because the applications are so varied and standards may not exist. In addition, equipment may not be available with fiber optic transmission options, requiring conversion from copper ports to fiber using devices called media converters.

In computer networks, the Ethernet standards, created by the IEEE 802.3 committee, are fully standardized. You can read the standards and see how far each equipment option can transmit over different types of fiber, choosing the one that meets your needs. Most network hardware like switches or routers are available with optional fiber optic interfaces, but PCs generally only come with UTP copper interfaces that require media converters. An Internet search for “fiber optic media converters” will provide you with dozens of sources of these inexpensive devices. Media converters will also allow the choice of media appropriate for the customer application, allowing use with multimode or singlemode fiber and may even offer transceiver options for the distance that must be covered by the link.

CCTV is a similar application. More cameras now come with fiber interfaces since so many CCTV systems are in locations like big buildings, airports, or areas where the distances exceed the capability of coax transmission. If not, video media converters, usually available from the same vendors as the Ethernet media converters, are readily available and also inexpensive. Again, choose converters that meet the link requirements set by the customer application, which in the case of video, not only includes distance but also functions, as some video links carry control signals to the camera for camera pan, zoom and tilt in addition to video back to a central location.

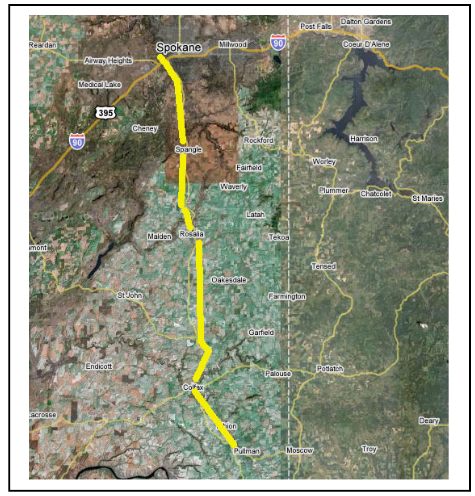
What about industrial data links? Many factories use fiber optics for its immunity to electromagnetic interference. But industrial links may use proprietary means to send data converted from old copper standards like RS-232, the ancient serial interface once available on every PC, SCADA popular in the utility industry, or even simple relay closures. Many companies that build these control links offer fiber optic interfaces themselves in response to customer requests. Some of these links have been available for decades, as industrial applications were some of the first premises uses of fiber optics, dating back to before 1980.

Whatever the application, it's important for the end user and the cabling contractor to discuss the actual application with the manufacturer of the transmission hardware to ensure getting the proper equipment. While the telecom and CATV applications are cut and dried and the data (Ethernet) applications covered by standards, it is our experience that not all manufacturers specify their products in exactly the same way.

I recently worked with one company in the industrial marketplace that offered about fifteen different fiber optic products, mainly media converters for their control equipment. However, those fifteen products had been designed by at least a dozen different engineers, not all of whom were familiar with fiber optics and especially fiber jargon and specifications. As a result, one could not compare the products to make a choice or design them into a network based on specifications. Until we trained their design, sales and applications engineers and created guidelines for product applications, they suffered from continual problems in customer application.

The only way to make sure you are choosing the proper transmission equipment is to make absolutely certain the customer and equipment vendor – and you – are communicating clearly what you are planning to do.

Part 5: Planning The Route



Having decided to use fiber optics and chosen equipment appropriate for the application, it's time to determine exactly where the cable plant and hardware will be located. One thing to remember – every installation will be unique. The actual placement of the cable plant will be determined by the physical locations along the route, local building codes or laws and other individuals involved in the designs. As usual, premises and outside plant installations are different so we will consider them separately.

Premises installations can be simpler since the physical area involved is smaller and the options fewer. Start with a good set of architectural drawings and, if possible, contact the architect, contractor and/or building manager. Having access to them means you have someone to ask for information and advice. Hopefully the drawings are available as CAD files so you can have a copy to do the network cabling design in your computer, which makes tweaking and documenting the design so much easier.

If the building is still in the design stage, you may have the opportunity to provide inputs on the needs of the cable plant. Ideally, that means you can use your experience as an electrical contractor to influence the location of equipment rooms, routing of cable trays and conduits, availability of adequate conditioned power and separate data grounds, sufficient air-conditioning and other needs of the network. For pre-existing buildings, detailed architectural drawings will provide you with the ability to route cabling and network equipment around the obstacles invariably in your way.

Sometimes you also have to work with other people who may influence the design. IT managers will usually have inputs on what their needs are now and in the future. Sometimes a structured cabling specialist may be involved who may or may not have experience with fiber, which is why you were brought in. Even company big shots may have an opinion, since many companies like to showcase their investment in fiber optics.

And as soon as possible, you must visit the site. For current buildings, you should inspect every nook and cranny to be absolutely certain you know what the building really looks like and then mark up drawings to reflect reality, especially all obstacles to running cabling and hardware and walls requiring firestopping that are not on the current drawings. Take pictures if you can. For buildings under construction, a site visit is still a good idea, just to get a feeling of what the final structure will be like and to get to know the construction managers you will be working with. They may be the best source of information on who the local authorities are who will be inspecting your work and what they expect.

Outside plant (OSP) cabling installations have enormous variety depending on the route the cable must take. The route may cross long lengths of open fields, run along paved rural or urban roads, cross roads, ravines, rivers or lakes, or, more likely, some combination of all of these. It could require buried cables, aerial cables or underwater cables. Cable may be in conduit, innerduct or direct buried, aerial cables may be self-supporting or lashed to a messenger. Longer runs often include crossing water, so the cable may be underwater or be lashed across a bridge with other cables.

With all those options on OSP installations, where do you start? With a good map. Not just a road map or a topographical map, but satellite images overlaid on roads is much better, like “Google Maps” can provide. Creating a route map is the first step, noting other utilities along the route on that map, and checking with groups that document the current utilities to prevent contractors from damaging currently installed pipes and cables.

Once you have marked up maps, the real “fun” begins: finding out whose permission you need to run your cabling. OSP installs are subject to approval by local, state and federal authorities who will influence heavily how your project is designed. Some cities, for example, ban aerial cables. Some have already buried conduit which you can use for specific routes. Since many municipalities have installed city-owned fiber networks, they may have fiber you can rent, rather than go through the hassle of installing your own.

Unless you are doing work for a utility that has someone who already has the contacts and hopefully easements needed, you may get to know a whole new set of people who have control over your activities. And you have to plan for adequate time to get approval from everyone who is involved.

For every project, you need to coordinate your work with facilities and electrical personnel to ensure you have proper space (size and AC) to install your terminal equipment and power – usually uninterruptible data-quality power and ground – available at each link end.

If all this sounds vague, it is. Every project is different and requires some careful analysis of the conditions before even beginning to choose fiber optic components and plan the actual installation. Experience is the best teacher.

Part 6: Choosing Components For Outside Plant Installations

The choice of outside plant fiber optic (OSP) components begins with Part 5's work, developing the route the cable plant will follow. Once the route is set, one knows where cables will be run, where splices are located and where the cables will be terminated. All that determines what choices must be made on cable type, hardware and sometimes installation methodology.

Most projects start with the choice of a cable. Since OSP applications often use significant lengths of cables, the cables can be made to order, allowing optimization for that particular installation. This usually allows saving costs but requiring more knowledge on the part of the user and more time to negotiate with several cable manufacturers.

To begin specifying the cable, one must know how many fibers of what type will be included in each cable. It's important to realize that fiber, especially singlemode fiber used in virtually all OSP installations, is cheap and installation is expensive. As one industry pundit described it, "Fiber is now cheaper than kite string or monofilament fishing line." Installation of an OSP cable may cost a hundred times the cost of the cable itself. Choosing a singlemode fiber is easy, with basic 1300 nm singlemode (called G.652 fiber) adequate for all but the longest links or those using wavelength-division multiplexing. Those may need special fiber optimized at 1500-1600 nm (G.653 or G.654). OM3 type laser optimized 50/125 multimode fiber is probably the best choice for any shorter multimode OSP runs, as its lower attenuation and higher bandwidth will make most networks work better.

Including more fibers in a cable will not increase the cable cost proportionally; the basic cost of making a cable is high but adding fibers will not increase the cost much at all. Choosing a standard design will help reduce costs too, as manufacturers may have the cable in stock or be able to make your cable at the same time as others of similar design. The only real cost for adding more fibers is additional splicing and termination costs, still small with respect to total installed cost. And remember that having additional fibers for future expansion, backup systems or in case of breaks involving individual fibers can save many future headaches.

Common traits of all outside plant cables include strength and water or moisture protection. The necessary strength of the cable will depend on the installation method (see below.) All cables installed outdoors must be rated for moisture and water resistance. Until recently, most people chose a gel-filled cable, but now dry-water blocked cables are widely available and preferred by many users. These cables use water-absorbing tape and power that expands and seals the cable if any water enters the cable. Installers especially prefer the dry cables as it does not require the messy, tedious removal of the gel used in many cables, greatly reducing cable preparation for splicing or termination.

OSP cable construction types are specifically designed for strength depending on where they are to be direct buried, buried in conduit, placed underwater or run aerially on poles. The proper type must be chosen for the cable runs. Some applications may even use several types of cable. Having good construction plans will help in working with cable manufacturers to find the appropriate cable types and ordering sufficient quantities. One must always order more cable than route lengths, to allow for service loops, preparation for termination and excess to save for possible restoration needs in the future.

Like cable types, cable plant hardware types are quite diverse and should be chosen to match the cable types being used. With so many choices in hardware, working with cable manufacturers is the most expeditious way to chose hardware and ensure compatibility. Besides cable compatibility, the hardware must be appropriate for the location, which can be outdoors, hung on poles, buried, underwater, inside pedestals, vaults or buildings, etc. Sometimes the hardware will need to be compatible with local zoning, for example in subdivisions or business parks. The time consumed in choosing this hardware can be lengthy, but is very important for the long term reliability of the cable plant.

Splicing and termination are the final category of components to be chosen. Most OSP singlemode fiber is fusion spliced for low loss, low reflectance and reliability. Multimode fiber, especially OM3, is also easily fusion spliced, but if only a few splices are necessary, mechanical splicing will provide adequate performance and reliability. If termination is done directly on multimode OSP cables, breakout kits will be necessary to sleeve fibers for reliability when connectors are directly attached. This takes more installation time than splicing pre-terminated pigtails on the cables, as is common with singlemode fiber cables, and may not save any costs. Even complete preterminated outside cable plant systems are becoming available, reducing the time necessary for termination and splicing. Talk to the cable manufactureres to determine feasibility of this option.

Part 7: Choosing Components For Premises Installations

Premises components are affected by several factors, including the choice of communications equipment, physical routing of the cable plant and building codes and regulations. If the design is a corporate network, the design will probably include a fiber optic backbone connecting wiring closets which house switches that convert the fiber backbone to UTP copper for cable connected desktops and either copper or fiber to wireless access points. Some desktops, especially in engineering or design departments, may require fiber to the desktop for it's greater bandwidth. Extra cables or fibers may be needed for security systems (alarms, access systems or CCTV cameras) also.

Design of the fiber optic cable plant requires coordinating with everyone who is involved in the network in any way, including IT personnel, company management, architects and engineers, etc. to ensure all fiber requirements are considered at one time, to allow sharing resources.

As in OSP design, consider the fiber choice first. Most premises networks use multimode fiber, although many astute users now install hybrid cables with singlemode fibers for future expansion. Recently there has been a change in fiber optic component choices. The 62.5/125 micron fiber (now designated OM1 fiber) that has been used for almost two decades has been superceded by the new 50/125 high bandwidth fibers. And of the three grades of 50/125 fiber, the higher bandwidth OM3/OM4 standard fiber is considered the best choice, as it offers substantial distance advantages over plain OM2 50/125 fiber. Virtually all equipment will operate over 50/125 OM3/OM4 fiber just as well as it did on 62.5/125 OM1 fiber, but it's always a good idea to check with the equipment manufacturers to be sure. Remember in the design documentation to include directions to mark all cables and patchpanels with aqua-colored tags, indicative of OM3/OM4 fiber.

As network speeds increase to 40 and 100 Gb/s, more users are looking at singlemode fiber. Passive optical LANs, based on FTTH PON architecture, are also gaining popularity and need singlemode fiber. Here two choices are available, OS1 and OS2. OS2, a low water peak fiber that allows for use in the complete range from 1300-1600 nm, ideal for wavelength division multiplexing, is becoming a more popular choice.

Cable choice in premises applications generally is made from either distribution or breakout cables. Distribution cables offer the ability to have more fibers with a smaller diameter cable, but require termination inside patch panels or wall mounted boxes. Breakout cables get bulky with high fiber count, but they allow direct connection without hardware, making them convenient for industrial use. Fiber count can be an issue, as backbone cables now have many fibers for current use, future expansion and spares, making distribution cables the more popular choice. The jacket should be fire-retardant per the NEC, generally OFNR-rated (Riser) unless the cable is run in air-handling areas above ceilings. Cable jackets for OM3/OM4 cables can be ordered in aqua for identification as both fiber optics and OM3 50/125 fibers.

If the cable is going to be run between buildings, indoor/outdoor designs are now available that have dry water-blocking and a double jacket. The outer jacket is moisture-resistent for outdoor use but can be easily stripped, leaving the fire-rated inner jacket for indoor runs.

Fiber optic connector choices are also changing. STs are becoming much less popular and even SCs are succumbing to the success of the smaller LC connector. Since most fast (gigabit and above) equipment uses LC connectors on the transceivers, using LCs in the cable plant means only one connector needs to be supported. The LC offers another big advantage for those users who already have 62.5/125 fiber installed but are upgrading to 50/125 fiber OM3/OM4. The LC connector is incompatible with the SC and ST connectors, so using it on 50/125 fiber cable plants prevents intermating 50 and 62.5 fiber with its high fiber mismatch losses.

Premises cables need to be run separately from copper cables to prevent crushing. Sometimes they are hung carefully below copper cable trays or pulled in indoor-rated innerduct. Using innerduct indoors can save installation time, since the duct (which can be purchased with pull tapes already inside) can be installed quickly without fear of damage and then the fiber optic cable pulled easily afterwards. Innerduct can be run with copper cables in cable trays too. Some applications may require installing fiber optic cables inside conduit, which requires being careful to provide intermediate pulls to minimize pulling force and sometimes using special fiber optic lubricants.

The hardware necessary for the installation will need to be chosen based on where the cables are terminated. Premises runs are generally point-to-point and are not spliced. Wherever possible, allow room for big radii in the patch panels or wall-mounted boxes to minimize stress on the fibers and choose hardware that is easy to enter for moves, adds and changes.

In premises applications, it's usually worth considering a perterminated system that uses backbone cables terminated in multifiber connectors and preterminated patch panel modules. If the facility layout is properly designed, the cable manufacturer can work with you to create a “plug and play” system that needs no on-site termination and the cost may be very competitive to a field-terminated system.

Part 8: The Link Power Budget

Once the basic design of the network is done, the next step is to do a "Link Loss Budget" which calculates the expected loss of the cable plant and checks to see if the chosen communications equipment will work on that cable plant link. Loss budget analysis is the verification of a fiber optic system's operating characteristics. This encompasses items such as routing, circuit length, fiber type, number of connectors and splices, wavelengths of operation and communications optoelectronics specifications.

Attenuation and multimode fiber bandwidth are the key parameters for cable plant loss budget analysis. Attenuation can be estimated based on manufacturer's component specifications and tested. Multimode bandwidth can be estimated based on specifications and the length of the cable plant but testing is generally unfeasible. Instead, communications system standards for multimode fiber call for a maximum length based on the type of fiber chosen (OM1, OM2, OM3 or OM4) so bandwidth can be confirmed by comparing the link lengths to the specifications of the system. (The FOA Tech Topics website has specifications for the most widely used fiber optic systems.)

Both the passive and active components of the circuit have to be included in the loss budget calculation. Passive loss is made up of fiber loss, connector loss, and splice loss. Also include any couplers or splitters in the link, as in passive optica LANs (POL) or FTTx PON networks. Active components specifications of interest are system wavelength, transmitter power, receiver sensitivity, and dynamic range – the difference between transmitter power and receiver sensitivity.

Since the idea of a loss budget is to ensure the network equipment will work over the installed fiber optic link, it is normal to be conservative on the specifications. Don't use the best possible specs for fiber attenuation or connector loss - give yourself some margin. Some standards like TIA-568 use very high connector loss, 0.75 dB, to allow prepolished splice connectors to meet the standard as well as adhesive/polish connectors which have typical losses of 0.3-0.5 dB. The standards are minimums for performance, so the user can specify a lower value, and they probably should if regular adhesive/polish connectors are being used.

The process of calculating the link loss budget is detailed on the FOA web site (Tech Topics). Follow those directions to calculate the estimated cable plant loss, compare it to the dynamic range of the communications equipment and ensure there is some system power margin. You need some margin for system degradation over time or environment, so include that (as much as 3dB) to get the loss budget for the link.

After installation and prior to system turn up, the installer will test the circuit with an OLTS and record loss data. That data should be compared to the loss calculated in the link loss budget analysis to ensure that it is within the loss budget.

NOTE: Many techs forget when doing a loss budget that the connectors on the end of the cable plant must be included in the loss budget. When the cable plant is tested, the reference cables will mate with those connectors and their loss will be included in the measurements.

Part 9: Documentation

Choosing the proper components for premises installations can take time, but is important for system operation. Once components are chosen, the materials lists are added to the documentation for estimating, purchase, installation and future reference. After installation, components are marked at access points for easy identification.

Documenting the fiber optic cable plant is a necessary part of the design and installation process for the fiber optic network. Documenting the installation properly as part of the planning process can save time and material in the installation and allow better planning for upgrading. During installation, it will speed the cable pulling and installation since the routing and terminations are already documented. After component installation, the documentation can be completed with test data for acceptance by the end user. If equipment is repositioned on a network, as is often the case, proper documentation will allow easier rerouting to the proper end points. And during troubleshooting, proper documentation is mandatory for tracing links and finding faults. Contractors should remember that proper documentation is often required for customer acceptance of the installation.

Documentation must begin with the cable plant path. OSP cables require documentation as to the overall route, but also details on exact location, e.g. on which side of streets, which cable on poles, where buried cables lay and even how deep or if markers or tracing tape is buried with the cable. Premises cables require similar details in order for the cable to be found at any location in the path.

Fiber optic cables, especially backbone cables, may contain many fibers that connect a number of different links which may not even be going to the same place. The fiber optic cable plant, therefore, must be documented as to the path of every fiber, connection and test.

Data which should be kept includes but is not limited to the following:

- Paths: where the cable plant is located and the link paths in every cable
- Cable: manufacturer, type, length, fiber type and size
- Splice and termination points (at distance markers, patch panels, etc.)
- Connections: types (splice or connectors and types), fibers connected, test data

Most of this data can be kept in CAD drawings and a database that stores component, connection and test data. Long links may also have OTDR traces which should be stored as printouts and possibly in special file formats for later viewing in case of problems (which works only if a computer set up for viewing is available. If the OTDR data is stored digitally, a database of data files should be kept to allow finding specific OTDR traces more easily. .

The Documentation Process

Before you start entering data, you should have a basic layout for the network finished. A sketch may work for a small building network but a large campus or metropolitan network will probably need a complex CAD layout. The best way to set up the preliminary data is to use a facility drawing showing the locations of all cables and connection points. Identify all the cables and closets/panels and then you are ready to transfer this data to a database.

You must know where all the cables go in the network and what every fiber will be connected to. You should know the specifications on every cable and fiber: what types of cable and fiber are being used, how many fibers, cable construction type, estimated length, and installation technique (buried, aerial, plenum, riser, etc.)

It will help to know what types of panels and closet hardware are being used, and what end equipment (if any) is to be connected. If you are installing a big campus cable plant with many dark (unused) fibers, some will probably be left open at the panels, and that must be documented also.. Whenever designing a network, it's a very good idea to have spare fibers and interconnection points in panels for future expansion, rerouting for repair or moving network equipment.

Documentation is more than records. All components should be labeled in accessible locations. Once a scheme of labeling fibers has been determined, each cable, accessible fiber and termination requires some labeling for identification. A simple scheme is preferred and if possible, explanations provided on patch panels or inside the cover of termination boxes.

Protecting Records

Cable plant documentation records are very important documents. Keep several backup copies of each document, whether it is stored in a computer or on paper, in different locations for safekeeping. If a copy is presented to the customer, the installer should maintain their own records for future work on the project. One complete set on paper should be kept with a “restoration kit” of appropriate components, tools directions in case of outages. Documentation needs to be kept up to date to be useful so that task should be assigned to one on-site person with instructions to inform all parties keeping copies of the records of updates needed. Access to modify records may be restricted to stop unauthorized changes to the documentation.

Part 10: Planning for the install

Final planning for the installation is a critical phase of any project as it involves coordinating activites of many people and companies. The best way to keep everything straight is probably to develop a checklist based on the design path:

Pre-install checklist:

- Main point of contact/project manager chosen
- Link communications requirements set
- Equipment requirements set and vendors chosen
- Link route chosen, permits obtained
- Cable plant components and vendors chosen
- Coordination with facilities and electrical personnel complete
- Documentation ready for installation, preliminary restoration plans ready
- Test plan complete
- Schedule and start date set for installation, all parties notified
- Components ordered and delivery date set, plans made for receiving materials (time, place,) arrange security if left outside or on construction site
- Contractor/installer chosen and start date set
- Link route tour with contractor(s)
- Construction plans reviewed with contractor(s)
- Components chosen reviewed with contractor(s)
- Schedule reviewed with contractor(s)
- Safety rules reviewed with contractor(s)
- Excess materials being kept for restoration reviewed with contractor(s)
- Test plan reviewed with contractor(s)

Before starting the install:

- All permits available for inspection
- Sites prepared, power available
- All components on site, inspected, security arranged if necessary
- Contractor available
- Relevant personnel notified

During install:

- Inspect workmanship
- Daily review of process, progress, test data
- Immediate notification and solution of problems, shortages, etc.

After completion of cable plant installation:

- Inspect workmanship
- Review test data on cable plant
- Set up and test communications system
- Update and complete documentation
- Update and complete restoration plan
- Store restoration plan, documentation, components, etc.

Facilities and Power/Ground issues

This document primarily focuses on the unique aspects of fiber optic cable plant design and installation, but this process cannot be done in a vacuum. Cable plants may require cooperation from other organizations to allow transit through their property and construction disruptions. Any communications system requires not only the cable plant but facilities for termination at each end, placing communications equipment, providing power (usually uninterruptible data quality power) and a separate data ground. Inside the facility, connections must be made to the end users of the link. The large number of options involved here make it impossible to summarize the issues in a few sentences, so let's just say you must consider the final, complete design to gain cooperation and coordinate the final installation.

Part 11: Developing A Test plan

Every installation requires confirmation that components are good and are installed properly. This entails testing to specifications which are created when a loss budget analysis is done.

The process of testing any fiber optic cable plant may require testing three times, testing cable before installation, testing each installed segment and testing complete end to end loss. Practical testing, however, usually means continuity testing each cable before installation to ensurethere has been no damage to the cable during shipment and testing each segment as it is terminated. Finally the entire cable run is tested for end-to-end loss.

One should require visual inspection of cable reels upon acceptance and, if visible damage is seen, testing the cable on the reel for continuity before installing it, to ensure no damage was done in shipment from the manufacturer to the job site. Since the cost of installation usually is high, often higher than the cost of materials, it only makes sense to ensure that one does not install bad cable. It is generally sufficient to just test continuity with a fiber tracer or visual fault locator. After installation and termination, each segment of the cable plant should be tested individually as it is installed, to ensure each connector and cable is good. Finally each end to end run (from equipment placed on the cable plant to equipment) should be tested for loss as required by all standards.

Testing the complete cable plant is done per standard test procedure OFSTP-14 for multimode or OFSTP-7 for singlemode. OFSTP-14 covers the problems of controlling mode power distribution in multimode fiber, which is also specified in some cabling and network testing standards. Outside plant cabling which included splices should be tested with an OTDR to verify splice performance and look for problems caused during installation.

For multimode fibers, testing is sometimes done at 850 nm and optionally 1300 nm, using LED sources with mode control. For singlemode fiber cables, testing is usually done at 1300 nm, but 1550 is sometimes required for long distance runs or WDM systems. The 1550 nm testing will show that the cable can support wavelength division multiplexing (WDM) at 1300 and 1550 nm for future service expansion. In addition, 1550 testing can show macrobending losses caused by installation that will not be obvious at 1300 nm, since the fibers are much more sensitive to bending losses at 1550 nm.

If cable plant end to end loss exceeds total allowable loss, the best solution is to retest each segment of the cable plant separately, checking suspect cables each way, since the most likely problem is a single bad connector or splice. If the cable plant is long enough, an OTDR may be used to find the problem. Bad cable segments need replacement and bad connectors must be repolished or replaced to get the loss within acceptable ranges.

The Test Plan should be coordinated with the documentation. The documentation shows what links need testing and the test data is incorporated into the documentation for acceptance of the installation and for reference in case of future problems requiring restoration.

Part 12: Planning For Restoration

The wise user designs a network with backup options. Telcos run dual links, one transmitting data and one on “hot back-up” ready to switch over in milliseconds. Electronics must be installed with duplicate links and all power must be backed up with batteries or fuel cells. Critical systems often add in geographic diversity, two links available running paths that are as widely separated as possible to ensure that if one suffers a failure due to damage to the fiber optic cable plant itself, the other can be switched in immediately. Even with backup, a failure requires immediate restoration, as one must never depend on a single link any longer than necessary.

Efficient fiber optic restoration depends on rapidly finding the problem, knowing how to fix it, having the right parts and getting the job done quickly and efficiently. Like any type of emergency, planning ahead will minimize the problems encountered.

The biggest single help in troubleshooting starts with producing good documentation during the installation and keeping it current. Documentation is the most helpful thing you can have when trying to troubleshoot a fiber network. Start with the manufacturer’s datasheets on every component you use: electronics, cables, connectors, hardware like patch panels, splice closures and even mounting hardware. Along with the data, one should have manufacturer’s “help line” contact information, which will be of immense value during restoration.

During installation, mark every fiber in every cable at every connection and keep records using cable plant documentation software or a simple spreadsheet of where every fiber goes. When tested, add loss data taken with an optical loss test set (OLTS) and optical time domain reflectometer (OTDR) data when available. Someone must be in charge of this data, including keeping it up to date if anything changes.

For the electronics, if possible one should have data on the optical power at transmitters and receivers. If that data is not taken during installation and setup, typical data should be available in the equipment manuals.

Outside plant cabling should have maps and photos detailing the routing of the cable, with GPS locations if possible. For premises cabling, drawings of the building noting all cable runs, again with photos if possible, are needed. One needs lists describing the types of cable, installation hardware and test data for restoration. Knowing where every cable goes will keep you from blindly searching for the cables when you try to locate problems. Having original test data will make it much easier to find bad cables.

Next you must have available basic test equipment. An OLTS should have a power meter to use to test the power of the signal in the transmission link to determine if the problem is in the electronics or cable plant. Total failure of all fibers in the cable plant usually means a break or cut in the cable. For premises cables, finding the location is often simple if you have a visual fault locator or VFL, which is a bright red laser coupled into the optical fiber that allows testing continuity, tracing fibers or finding bad connectors at patch panels.

For longer cables, an OTDR will be useful. Outside plant networks should use the OTDR to document the cable plant during installation, so during restoration a simple comparison of installation documentation with current traces will usually find problems. OTDRs generally do not have adequate resolution for short cables, say less than 30-50 meters, so a VFL will be needed. OTDRs can also find non-catastrophic problems, for example when a cable is kinked or stressed, so it only has higher loss, which can also cause network problems. Remember that OTDRs measure fiber length, not cable length, which is usually 1-2% shorter due to the excess fiber in the cable.

Once you find the problem, you have to repair it. Repair requires having the right tools, supplies and trained personnel available. Besides the test equipment needed for troubleshooting, you need tools for splicing and termination, which may include a fusion splicer for outside plant cables. You also need matching components. For every installation, a reasonable amount of excess cable and installation hardware should be set aside in storage for restoration. Some users store the restoration supplies along with documentation in a sealed container ready for use. Remember that the fiber optic patchcords that connect the electronics to the cable plant can be damaged also, but are not considered repairable. Just keep replacements available.

One big problem is pulling the two cable ends close enough to allow splicing them together. You need about 1 meter of cable on each end to strip the cable, splice the fibers and place them in a splice closure. Designing the cable plant with local service loops is recommended. If the cable ends are too short , you have to splice in a new section of cable, which should be kept from the leftovers after installation.

What else besides cables and cable plant hardware should be in a restoration kit? You should have a termination or mechanical splice kit and proper supplies. For splices, you need splice closures with adequate space for a number of splices equal to the fiber count in the cable. All these should be placed in a clearly marked box with a copy of the cable plant documentation and stored in a safe place where those who will eventually need it can find it fast.

Personnel must be properly trained to use this equipment and do the troubleshooting and restoration. And, of course, they must be available on a moments notice. The biggest delay in restoring a fiber optic communications link is often the chaos that ensues while personnel figure out what to do. Having a plan that is known to the responsible personnel is the most important issue.

Major users of fiber optics have restoration plans in place, personnel trained and kits of supplies ready for use. It's doubtful that most premises users are ready for such contingencies. Users may find that the cost of owning all this expensive equipment is not economic. It may be preferable to keep an inexpensive test set consisting of a VFL and OLTS at each end of the link and having an experienced contractor on call for restoration.

Part 13: Choosing A Contractor

Customers for fiber optic installation should expect the contractor/installer to be more knowledgeable about and experienced with fiber optics than they are. That's not just because most users are new to fiber optics or rarely contract for fiber optic installations, but because they have other things to worry about, like running an large computer network, security system or just their own business. They look for someone that will not only do a fiber optic installation, but can guide them through the process, providing support before, during and after installation, in a way that inspires confidence.

The competent fiber optic contractor will be able to work with the customer in each installation through six stages: design, installation, testing, troubleshooting, documentation and restoration. Each stage has its own requirements for knowledge and skills.

Design

One should be able to rely the contractors to not only do the installation but to assist in the design of the network and help choose components and vendors. If a contractor can show the customer design options such as how an all-fiber LAN cabling system can sometimes actually be less expensive than a fiber-backbone with copper to the desktop or all copper network using aids like the TIA Fiber Optic LAN Section's fiber vs. copper comparison model (www.FOLS.org), it can affect the customer's decision on how the network should be designed and often make for a better design.

Once the contractor has the assignment, they should be able to help the customer choose the right kinds of cables, connectors and hardware for the installation. The contractor should know which components meet industry standards which will ensure interoperability and future expandability. Unlike copper cabling, within the standards there are many options on what kinds of fiber optic cable to choose, which fibers make sense and what connector types and termination methods to use. For example, two types of 50/125 micron multimode fiber are now available in addition to the 62.5/125 fiber that has been used for over 15 years. Choosing one of these new 50/125 fibers will allow networks to work at today's gigabit rates and be upgraded to 10 gigabits in the future, a perfect example how a contractor that stays up to date on fiber optic technology can gain the confidence of and enhance the company's appeal to customers.

The customer probably doesn't do many fiber optic installations, so the experienced contractor also should help in the choice of vendors. Experience with particular product types and vendors will allow the contractor to not only assist the customer, but also to choose products that make the installation faster and easier.

The design is critical to the whole installation, so a complete design must cover the rest of the phases of the job also, as will be noted below. It's worth mentioning that experience has led us to be wary of architects and engineers when it comes to fiber optics. Many learned about fiber optics twenty years ago and never took a refresher course. A knowledgeable contractor armed with the latest standards should not be shy in reminding the customer and their other vendors that fiber optics is a dynamic business that demands users stay current.

Installation

The actual installation process can involve more than just putting in cable and terminating it. If the contractor is knowledgeable, the user will sometimes ask the contractor to purchase, receive, inspect and bring components to the work site also, which can be another good source of revenue for the contractor. Having full control of the materials process can also make life easier for the contractor, as they have a better chance to keep on schedule rather than depending on a customer who has many other priorities. Plus, they can choose components they are familiar with, facilitating the actual installation process.

The installation itself should be easy for an properly experienced contractor to do. The customer wants the job done quickly and with as little disruption to their business as possible. Sometimes working outside the customer's usual business hours is an issue, as it minimizes distractions to their workforce and disruptions to their processes. Some data processing companies demand installs be done during off hours to prevent inadvertent problems affecting their usual business operations.

Of course, the customer expects the installation to be done in a "neat and workmanlike manner." NECA and The Fiber Optic Association (FOA) have cooperated in creating a standard that defines what that means in fiber optic installations. NECA 301-2004, Installing And Testing Fiber Optic Cables, is available from NECA. This document is a good reference for both the contractor and the user, as it covers all aspects of the installation, including the topics we cover here, and is designed as a reference standard for contracts on installation jobs.

Testing

Testing provides the customer with proof that the contractor did the job as specified, so it is important to make sure the design phase covers how to test the installation. It is rare that a customer understands fiber optic testing, so reference to the NECA 301 standard is a good practice. The biggest concern is that the user know what is relevant for testing. It's not unusual to find a user calling for OTDR testing on short premises or campus cables, which is rarely appropriate or done properly and extremely expensive. We even know contractors who did OTDR testing because it was called for in the customer specification, but the data was misinterpreted and the installation rejected erroneously. The customer should be given references to standards that show insertion loss is the test required for all networks.

Troubleshooting

It's not unusual to have a few problems in an installation; customers expect that. Some can be avoided by proper planning at the design stage, for example, if the customer wants 36 fibers in the backbone, purchasing a cable with a few extra (and inexpensive) fibers allows for damage to a fiber or two at splice or termination points without causing major rework and installation delays or cost overruns. Plan during the bid stage to purchase extra connectors to replace those which require retermination during the installation. Site inspections can pinpoint potential problem areas and supervisors and installers should be briefed on plans to prevent difficulties with the installation. Crews doing the testing should be quick to respond if a problem crops up, as they are usually the only ones who can assess the damage and find an immediate solution.

Documentation

Documentation is what the customer expects to get as proof the job was done correctly and will speed up the process of payment to the contractor. Documentation includes drawings of cable runs, tables of connection data and test data on every fiber in the cable plant. Documentation is expensive! The contractor must provide exactly what the customer expects and be prepared to provide it in a format they can understand. Remember to include it as a line item in your bid. Use the TIA 606 documentation standard for premises cabling or the software provided by some tester manufacturers if that is agreeable with the customer.

Remember the usefulness of documentation goes beyond proving the installation was done correctly. It is needed for moves, adds and changes (MACs) and restoration. If the customer agrees, you should keep a copy for your records (adding photos if possible) to use if you are ever called on to work on the same installation again.

Restoration

Most customers don't expect to have problems or to have you help them fix them, but it's only an oversight on their part. Consider during the design phase that problems can occur and planning ahead can alleviate the pain of restoration. Purchasing excess cable, saving leftovers from the installation and storing it onsite to replace broken or cut cables or to splice into long runs after a cable cut should be part of the contractor's job.

Keeping a file on the installation detailing all the components used and the complete documentation can help both you and them. They will know who to call for assistance and you will have the information you need to promptly troubleshoot the problem and implement a fix.

Experience and Certifications

When evaluating contractors for a fiber optic installation, what users are looking for is someone with knowledge and experience in similar jobs. Look for references from previous customers and to ask if you can use them as a reference. Look for experience with components like your cable plant is using, for example, contractors installing singlemode cable plants should be experienced with singlemode fiber, especially splicing and testing techniques. If you are using a specific type of connector, it's wise to find a contractor with experience with that type to ensure that their experience is relevant. Customers also want to feel confident that the actual workers are competent, so certifications like the FOA CFOT (see www.thefoa.org) reasonable to expect.

Part 14: Managing The Project

Managing a fiber optic project can be the easiest part if the design and planning has been done thoroughly and completely, or, if not, the hardest. But even assuming everything has been done right, things will still probably go wrong. Here are some guidelines for managing the project that can minimize the problems.

First, someone has to be in charge, and during the project, they must be readily available for consultation and updates. While this may sound obvious, sometimes the user's representative has other responsibilities and may not be able or willing to direct full attention to the project. Whoever is assigned the task of managing the project must be involved full time. If necessary, delegate responsibility to the contracting construction supervisor with requirements for daily reports and personal updates.

Make certain that everyone responsible for parts of the project have copies and have reviewed the install plan. Everyone should have toured the relevant sites and be familiar with locations. They must also know who to contact about questions on the sites. Everyone needs to have contact information for each other (cell phones usually, email may be too slow, instant messaging will probably not be available to field workers.)

Locations of components, tools and supplies should be known to all personnel. On larger jobs, managing materials may be a full time job. Special equipment, like splicing trailers or bucket trucks, should be scheduled as needed. Outside plant installs may require local authorities to provide personnel for protecting installation personnel on public sites, so they become involved in the scheduling.

If the project is large enough to last several days or more, daily meetings to review the day's progress are advisable. At a minimum, it should involve the on site construction supervisor and the user's person in charge of the project. As long as things are going well, such a meeting should be short.

What if things go bad? Here judgement calls are important. If (or when) something happens, obviously it is the responsibility of the onsite supervisor to decide quickly if they can take care of it, or, if not, who needs to be brought in and who needs to be notified. By reviewing progress regularly, disruptions can be minimized. Equipment failures (e.g. a fusion spplicer) can slow progress, but cable laying can continue, with splicing resumed as soon as replacement equipment is available. Problems with termination should be reviewed by an installer with lots of experience and the cure may require new supplies or turning termination over to more experienced personnel.

Following the completion of the install, all relevant personnel should meet, review the project results, provide data for the documentation and decide if anything else needs to be done before closing the project.

Part 15: Maintaining The Network

Some people have suggested that fiber optic networks need periodic inspection of connectors, mating adapters, and even testing or taking OTDR traces. That advice is misguided. It could hurt you or get you sued by an irate network owner whose network you bring down or cable plant you damage.

Do you think the telcos have crews out checking fiber networks to see if the connectors and splices are OK? How about the military on tactical systems in Iraq? Or is there a Captain Nemo in the Nautilus checking submarine cables? Of course not.

Fiber systems are designed to be installed and never touched unless something damages them – the infamous “backhoe fade” of buried outside plant cables. In the early days of fiber optics (when I was in the test equipment business), some network owners tried building automatic monitoring systems to keep tabs on the loss of the cable plant. That idea faded when fiber proved to be much more reliable than copper cabling and the network communications manufacturers built into their equipment monitors for data transmission, a more reliable indicator of problems.

Let me give you some reasons why you do not want to try to do maintenance on any fiber optic network:

Most inspection procedures require bringing the network down, unacceptable in almost every instance. Telcos have backup links running alongside operational links and the equipment will switch over to the backup if it senses high errors on the main link. Do you know any premises networks set up like that? Want to bring down a gigabit LAN backbone fast? Unplug a fiber optic connector to inspect it with a microscope. See how long it takes the network manager to find you.

Most harm to installed fiber optic systems (and copper also) is done during handling by unskilled or clumsy personnel. I heard of one network that crashed when a executive of a company disconnected a fiber connector to show it to a visitor they were escorting around the facility. I know of workers accidentally backing into patch panels and breaking cables at the junction to the connector. I’ve seen connectors dropped on the floor breaking the ceramic ferrule. I’ve helped troubleshoot broken fibers in splice closures caused during repairs of other fibers.

It's easy to get dirt into mating adapters or on connectors whenever they are exposed to the air. Fiber technicians are taught to keep connections clean after termination, cover connector ferrules and mating adapters with dust caps and clean the ferrule end whenever it is opened to the air. If dirt is such a big problem (and airborne dirt is the size of the core of singlemode fiber), why risk contaminating operating connectors by exposing them to the air to see if they are dirty?

Mating and unmating may wear the connector interfaces, affecting optical performance. Ferrule endfaces rubbing against the mating connector and the outside of the ferrule scraping materials off the alignment sleeve in the mating adapter, especially with adapters using cheap plastic alignment bushings which are good for only a few mating cycles, can cause higher loss.

Links operating at gigabit and higher speeds generally use 850 nm VCSELs, which are relatively high power lasers at a wavelength near the high end of human eye sensitivity, still visible to some people. Using a high power microscope, like a 400X, concentrates the light into the eye, increasing the risk of eye damage, especially if you are not able to see this wavelength. Should a link being inspected be “hot,” the consequences could be bad. Anyway, a 400X microscope is overkill – it’s the maximum magnification you would use to inspect singlemode connectors during termination; 100-200X is generally considered the maximum for connector inspection.

The fiber link loss may be different when a link is reassembled after inspection, especially with connectors that have spring loaded ferrules like STs. Inspecting a connection could lead to higher loss than initially measured and potentially affecting data transfer on systems like Gigabit Ethernet and 10G Ethernet where loss margins are very low.

As for testing with an OTDR for maintenance inspection, well, some telcos do that automatically on spare fibers in outside plant cables that run tens or hundreds of kilometers through desolate regions. An ORDR is inappropriate for most premises systems under any circumstances (as we have discussed in several columns this year) and often causes more problems that it solves.

Finally, if you have a problem with dust in a telecom closet, room or data center, you have a poorly designed facility that should be fixed with proper sealing, filtration and air conditioning. You should not try to fix it with a feather duster.

So one more time: What periodic maintenance should be done on fiber optic networks? NONE!

Part 16: Use of Cabling Standards

Many documents relating to cable plant design focus on industry standards. But these standards are not written for users or installers. At a TIA standards meeting, the FOA brought up the topic of why standards such as TIA-568 are so expensive and so hard for most people to understand. The reason for the question, we explained, was that we get many inquiries regarding what standards apply to situations or what they mean. Users and installers could not justify buying the expensive standards when they only needed to know what a few paragraphs said.

At the meeting, the FOA suggested the TIA make the standards available for free or a nominal cost to encourage their use or publish books for contractors, installers and end users on what the standards mean and how to install compliant systems.

We were told that contractors, installers and end users have no reason to be interested in the standards, since they were not written for them. The standards were written for the manufacturers who send personnel to the meetings to negotiate what the standards say. As a friend who headed one of the standards committees once said, standards are "mutually agreed upon specifications for product development." They ensure that various manufacturers' products work together properly. Their primary intent is not educating the installers or end users – that's the job of the manufacturers of standards-compliant products.

Standards make little sense to the end user, but lots of sense to manufacturers of components who are concerned about the performance of individual components themselves and the performance of complete cabling systems built from these components. The very wording of these standards include nuances that only the standards writers understand; the subtle differences between "shall" and "should," the options available to those who can read between the lines – or have spent many days sitting in meetings filled with detailed technical presentations – to produce products "better" than the standards for competitive markets.

Those manufacturers who wrote those standards and build products that comply with them are only too happy to educate you and your customers. Every structured cabling manufacturer has a section in the back of their catalog or on their website that explains the relevant standards in simple words and clear pictures that you can actually understand. They tell you what systems should look like, what components are used to build them and how they should be tested. Take advantage of these companies, they want you to, that's why they attend those boring standards meetings and write all those catalog pages or websites, hoping you will come to them for education – and products.

Grab a vendor catalog or download a file from a website to learn what you need to know about the standards. You will get the information directly from the people writing the standards who have a vested interest in making certain you know what you need to know. No more, no less.

References:

There are other FOA Technical Bulletins that should be used as references for the design and planning of the network. These documents can be downloaded from the FOA Tech Topics website. In addition to those, we recommend:

The FOA Reference Guide to Fiber Optics, by Jim Hayes, published by the FOA.

The FOA Reference Guide to Premises Cabling, by Jim Hayes, published by the FOA.

The FOA Reference Guide to Outside Plant Fiber Optics, by Jim Hayes, published by the FOA.

FOA Online Reference Guide, FOA website, www.thefoa.org

NECA/FOA-301 Standard For Installing And Testing Fiber Optic Cables (NECA/FOA-301), NECA Codes and Standards, 3 Bethesda Metro Center, Bethesda, MD 20814 *Download from FOA website*

FOA Tech Bulletins (Printable Reference Documents)
Designing and manufacturing fiber optic communications products for manufacturers of products using fiber optics . (PDF, 0.2 Mb)
Choosing, installing and using fiber optic products for communications network users. (PDF, 0.1 Mb) (this document)
Designing Fiber Optic Networks - for contractors, designers, installers and users and the reference for the FOA CFOS/D Design Certification (PDF, 1.3 MB).
Installing Fiber Optic Cable Plants. (PDF, 0.2 Mb)
Troubleshooting fiber optic cable plants and communications systems. (PDF, 0.1 Mb)
Fiber Optic Restoration - how to plan ahead and restore networks quickly. (PDF, 0.1 Mb)

Note: This information is provided by The Fiber Optic Association, Inc. as a benefit to those interested in designing, manufacturing, selling, installing or using fiber optic communications systems or networks. It is intended to be used as a overview and guideline and in no way should be considered to be complete or comprehensive. These guidelines are strictly the opinion of the FOA and the reader is expected to use them as a basis for creating their own documentation, specifications, etc. The FOA assumes no liability for their use.

Fiber Optic Network Design
Do you have comments on this technical bulletin, corrections or information to add to it to make it more complete. Please send them to the FOA at info@thefoa.org.

The Fiber Optic Association, the professional society of fiber optics, has available on its website, www.thefoa.org, guides for end users on fiber optic network design and installation. The FOA has certified 24,000 technicians through over 200 approved schools to create a pool of trained, experienced and certified techs who can install and restore networks. You can search for techs or contractors with appropriate experience throughout the world using the FOA's free online database on its website.

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