Spliced versus factory pre-terminated solutions

A comparison of architectures

by Jan Vandenbroeck, FTTH Business Development Manager

Introduction

Every network operator planning to deploy a next generation fiber network has to determine how to build a flexible, reliable and long-lasting infrastructure at the lowest possible cost. Therefore, he needs to make critical decisions. One of the most important decisions is whether to use splices or connectors when creating junctions or joints in the network.

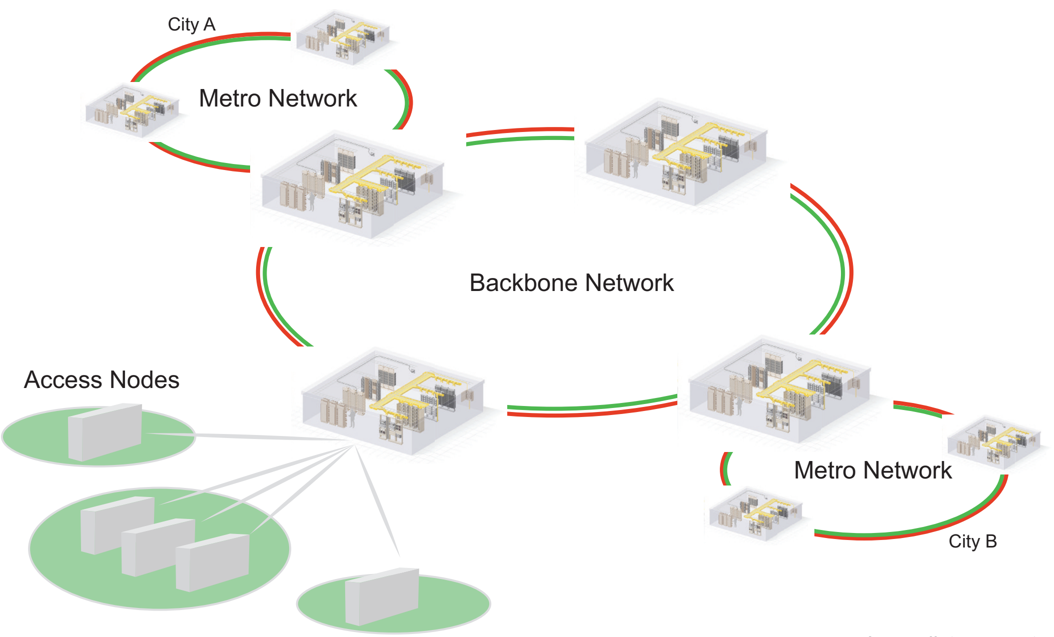
Operators began to build the first commercial fiber links in 1978, entirely focused on the long distance segment of the network. Standard practices to create connections that were developed then, were repeated in the fiber access network. However, when starting large volume deployment in the access network, the legacy practices did not always turn out to be the best strategy.

In the access network, connections are needed on average about every 250m to 300m, resulting in six times more connections than in a typical long distance network. This means that connectivity in the next generation fiber access network is driving -to a large extent- the OPEX cost for the operator, especially in terms of labor.

Market situation and trends

Long distance network versus access network

A long distance network can best be described as an "install and forget" cable junction between two centers with optoelectronic equipment. The standard practice is to use connectors inside the central office and fusion splices in the external plant closures used as track or spur joints.
Connectors provide the flexibility for churn in optoelectronic equipment (with a shorter lifetime), for network troubleshooting and for simple addition of equipment as traffic volume and routes grow. A cross-connect topology linking external cables to optoelectronic equipment is the most common format providing adequate registration capability of optical links.
Optical connections in external plant closures are almost entirely based on fusion splices. During network construction, all splices are made at the same moment in a controlled environment to obtain highly reliable connections with the lowest optical loss. The time and cost of set-up, creating a controlled environment and cable preparation are acceptable as they can be spread over a large number of fibers.



Long distance network

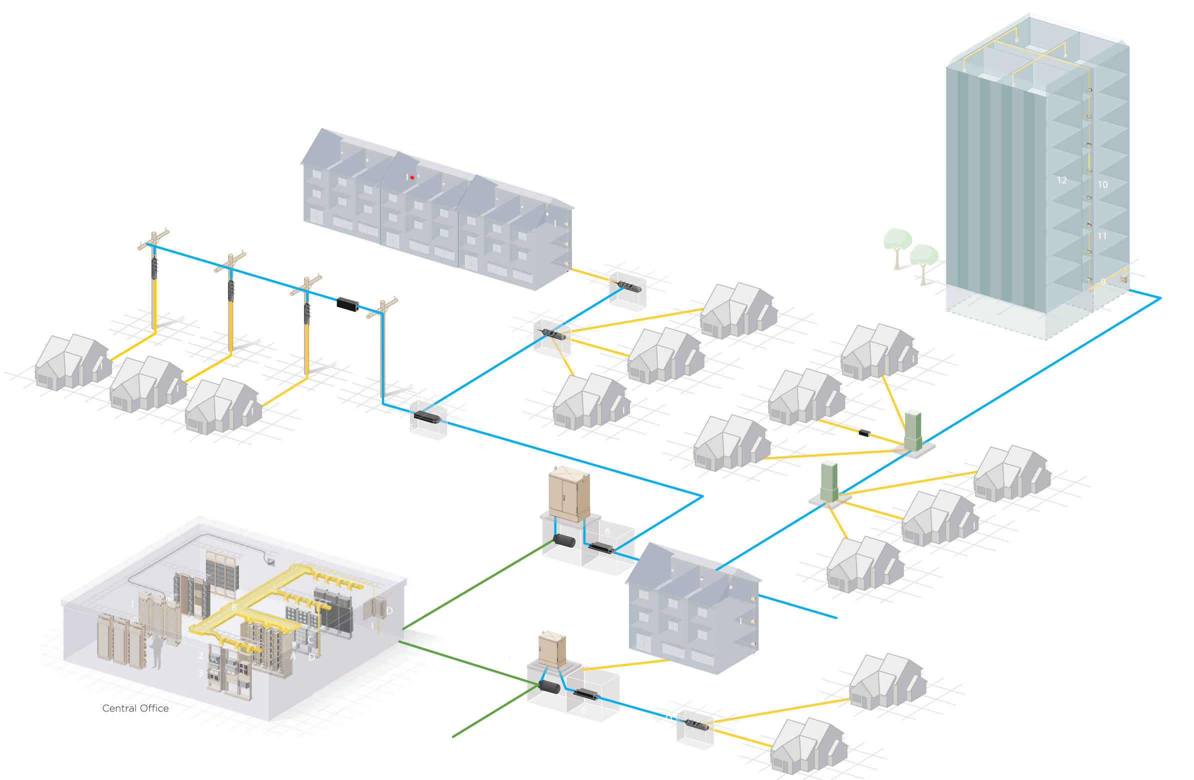
Until 2004, operators copied this practice in FTTH network trials and deployments. Today, many are still using an all-fusion spliced approach from the central office to the subscriber's premises.

Their primary objections to connectorization in the external plant are:

- Capital expense (CAPEX) savings of a fusion-spliced approach outweigh the operational expense (OPEX) savings of connectorization;
- Extra connection points can affect the optical loss budget and create additional points of failure in the network;
- The number of network failures may not be large enough to require the additional test access points connectorization provides;
- Network elements with splices and connectorization require more real estate that is costly or not necessarily available in the access segment.

These objections, relevant for the long distance network, are not necessarily a concern for all points in the access network.

Although next generation access networks are constructed in a wide range of topologies, they can all be represented by a series of network elements, closures and access points, between a service center and the customer premises.



Access network

In contrast with the long distance network, 50% of the optical connections in the access network are made during the construction phase and 50% during the operational phase. This is irrespective of brownfield or greenfield deployment and Single Family Units (SFU) or Multiple Dwelling Units (MDU) deployment, because an operator confronted with competition for access to broadband pipes will delay the provisioning cost until the customer asks for the service. Moreover, the customer base can change over time and create churn in joints.
The access network is also the most sensitive to quality issues, e.g. cable cuts, requiring maintenance and testing. To test a fiber, a technician needs to access the connectivity points using optical connectors. For maintenance or the operational phase, the connectivity is located in access points (e.g. cabinets, closures, boxes, ...).

Connectivity characteristics in the access points

Five connectivity characteristics need to be considered when selecting the appropriate connectivity method for the access points:

- Mating and de-mating
- Sensitivity to environmental conditions
- Impact on labor (skill level + installation time)
- Optical performance
- Identification and organization

Mating and de-mating

Fibers and cables going to the customer premises (outgoing fibers) are entered in the access points during construction, stored in a “parking lot” or added to the network element at the day of provisioning. In all cases, the optical connection is executed at the day of provisioning with typically one joint per provisioning job in a specific network element.

Moreover, a well-known study in the USA[1] revealed that, on an annual basis, about 1/3 of the copper access lines require at least one truck roll for churn, repair, troubleshooting or planned maintenance purposes. Even

1 Fiber: Revolutionizing the Bells’ Telecom Networks, A joint Bernstein-Telcordia Research Study, May 2004 though there is not yet enough historical data and experience with the next generation fiber access networks, leading operators start to recognize the importance of de-mating points for simplified churn and network testing as fiber networks become larger with higher take-rates offering connected customers additional value-added services.

Sensitivity to environmental conditions

Provisioning, churn, troubleshooting and repair are all unplanned activities when compared to construction and long distance networks. In order to service the customer, the jobs need to be done on top of a pole, on a ladder against the wall, in a humid manhole, in a dusty environment, inside a building under construction, etc., independent of weather conditions or physical situation of the location (like presence of dust or condensation). Moreover, potential tools should not be susceptible to changing conditions (e.g. warm van to cold installation site) when moving from one access point to another. Creating a controlled environment for these typically single joint jobs would be far too expensive. Therefore, the selection process of the most appropriate connectivity system for a given access point should take all these elements into account.

Impact on labor

Beside the objective to reduce OPEX to a minimum, the jobs also have to be done in the shortest time possible for two main reasons:

1. Next generation access networks need to reach a minimum service level, of which the speed of provisioning and repair can deliver a strong competitive advantage.
2. Faster provisioning or repair can reduce the number of provisioning and repair crews.

This brings us to potentially the most important reason to carefully consider all options: labor.

Leading operators installing next generation access networks experienced massive problems in the step from field trial to volume deployment. Speed of implementation was seriously impacted by the shortage of qualified people for handling fiber and creating fiber joints. In the European Union, with 210 million households, the objective to connect 40% of the households in an eight-year time frame would require about 30 times the quantity of installation crews present today when using standard practices. The choice for faster solutions can lower the need for more crews, but cannot solve it. Therefore, it is absolutely necessary to reduce the required skill levels, widening the pool of potential candidates and increasing the quality of work.

Optical performance

The current conditions (e.g. optical budget) of an access network allow us to consider a wide range of connectivity technologies for the following reasons:

- High optical losses did not meet the stringent optical budget requirements for a long distance network, but access networks are only short distance;
- Optical connectivity technology has improved substantially in optical performance over the past decade;
- Higher optical losses were associated with less reliable connections when standard practices were used.That is no longer the case with the current technology if it complies with international standards defining different grades;
- Fibers, lasers, detectors and splitters all improved in performance allowing more optical budget for the connections.

Identification and organization

Last but not least, the access network requires adequate and simple identification systems for registration purposes and access to individual lines without disturbing other service links. The more compact the system deployed can be while not limiting access to and handling of the fibers, the better it will fit the limited real estate typically available in the distribution, drop and MDU section of the network. Compactness is often associated with more aesthetic design, another important parameter when obtaining a license for construction and approval from the customer. The ability to achieve these goals will depend on the connectivity and fiber organizer system.

Understanding the connectivity characteristics of the access points makes it clear that the legacy practices are often not optimal. Since the European market is very fragmented with a wide variety of business models to be supported, a high degree of flexibility in the physical layer is required, stressing the importance of selecting the right type of connectivity.

Connectivity technique options for next generation access

Fusion splicing

Fusion splicing is the technology for joining fibers since the late seventies. Over the past years, it has been adapted from core alignment to cladding alignment, software has been added to simplify some of the installation steps, and tools have been reduced in weight and size, making them more compatible with the specific needs of the access network.

Advantage

- Typical average optical losses of 0.05dB or lower

Disadvantages for access points

- Not de-mateable
- Special installation skills needed
- Tools sensitive to the environment
- Relatively long installation time
- Standard organizer techniques required

A fusion splice is environmentally and mechanically protected with a sleeve. For reconfiguration or testing purposes, a technician will cut out this splice with its sleeve and take the incoming and outgoing fiber out of the organizer. Depending on the type of organizer, it can require all other fibers in that tray to be taken out with the risk of fiber breakage or transmission issues in these lines. Each splice cut takes about four centimeters of fiber away on both sides. Over the lifetime of a network, that may be a limiting factor or require longer lengths of fiber to be stored in an organizer system.

The process of fiber organization and fiber splicing demands very specific skills. Making a splice goes beyond pushing a button, especially for the fiber preparation with removal and cleaning of coatings, whereas cleaving is also very sensitive to tools and skills; skills that can only be acquired by extensive training and field experience. Moreover, this field experience and training need to be a continuous process because fibers, tools and coatings are constantly changing.

During provisioning, the process involves an extra step to prepare the cable. Fiber access field trials and deployments have shown that splicing a fiber drop cable to a distribution fiber, ready to be spliced, takes about 20 minutes if the tools are ready for installation and not affected by humidity or dust. Although this is likely to be the case, experience shows that there are many exceptions. Since ubiquity is a goal for volume deployment and competitiveness, its sensitivity to environmental changes makes the fusion alignment and arcing system less appropriate for the access network.

Mechanical splicing

Mechanical splicing is the technology for joining fibers introduced in the early 1980s. However, it has never been really successful and remained limited to fast repair jobs. Over the past years, this technology has been enhanced from straight cleave installation to angled cleave installation. The cleaving mechanism and fiber installation system to create physical contact is integrated in one tool. The cleaving blade automatically progresses to a new position and has an automatic end of life. This mechanism makes it more compatible with the specific needs of the access network.

Advantages

- Typical average optical losses of 0.1dB or lower
- Insensitive to environmental conditions

Disadvantages

- Not fully de-mateable
- Special installation skills required
- Relatively long installation time
- Standard organizer techniques

A technician cannot simply mate and de-mate the fiber ends the way connector technology would do. The mechanical splice can be opened and the fiber removed. The latter can be done separately for the incoming or outgoing fiber, depending on the one that needs to be replaced or requires access. The fibers and the splice need to be taken out of the organizer like for fusion splices. The process of fiber organization and fiber splicing requires specialists with very specific skills, although for making the splice, the special skills are limited to accurate coating removal and adequate cleaning. The mechanical splice is not sensitive to the fiber type and the quality cleave is guaranteed by the tool features. The installation time of mechanical splices is almost the same as with fusion splices, but the set-up time is about 30% shorter, especially if there is no cable preparation required. Even more time can be saved in exceptional environmental conditions, because the installation tool is insensitive to them.

Factory pre-termination

Factory pre-termination is the third alternative. Cables and fibers are terminated to a connector in the factory. When carefully planned, splicing jobs for specialized technicians can be limited to the network construction phase. With connectors, a de-mateable product is available at the access points.

Advantages
- Typical losses of 0.15dB or less
- Fully de-mateable
- No special installation skills required
- Reduced installation time
- Very simple organizer systems
- Insensitive to environmental conditions

Provisioning, churn and network testing can be performed by technicians without specific fiber skills, because the organizers can be very simple. For some of the applications, the pre-termination can be hardened to eliminate the organizer. Connectors are accessible on the outside of the network element, reducing the need to access a product and the risk of disturbing other lines.

This design, based on standard SC connector technology, was introduced in the USA in 2004. The latest design, especially interesting for the European market, is more compact and provides environmental sealing, also when the mechanical connection is not adequately tightened. Compatibility with the original hardened connector can be guaranteed with a simple converter.

With pre-connectorized products, the connection time is reduced from 20 to less than 5 minutes, including the connector cleaning step. When connecting fibers with connector technology, there is no issue of environmental sensitivity.

Factory pre-termination is also compatible with optical budget requirements by selecting the appropriate grade as defined by the international IEC standards. When properly planned, pre-connectorized products do not add extra connectivity points, thus eliminating extra optical loss or reflections. The market shows a trend towards B grade APC style connectors providing typical losses of 0.15dB or less.

Conclusions

When comparing next generation access network requirements with connectivity technology features, we could conclude that the deployment of factory pre-terminated solutions provides by far the best fit. The trend in Europe is to go for a hybrid solution, being pre-terminated at one end and spliced at the other. Truly plug-and-play solutions would indeed be faster and not require specialized technicians, but can logistically result in unwanted burdens. To make factory pre-termination fit the physical civil structure, detailed engineering of the site is required, since connectors may not fit ducts or wall passings. As there are no two identical situations and unplanned situations may occur, some standard lengths need to be agreed upon and made available. Inventory levels are considerably higher than for planned splices. In most cases, some overlength will need to be stored somewhere. Although the industry has created some innovative products to facilitate storage, it may not always be an accepted solution. The hybrid approach resolves these issues: the least accessible or difficult end (wall or pole mounted, in manholes etc.) is pre-terminated and the other side is spliced in the field.
Coming from an all fusion spliced situation in the external plant, today about one third of the homes connected use factory pre-termination and one third use mechanical splicing. Innovation will further improve the solutions and each network will have slightly different parameters making a one size fits all solution unlikely. Many have recently tried field installable connectors, but without conclusive results, because the accuracy needed during installation is hard to obtain in the field. Maybe tomorrow, the industry will find an adequate field installable and de-mateable connectivity solution to resolve this issue.

	De-mating	Environmental sensitivity	Skill level	Installation time	Optical performance	Organiser complexity	Total
Fusion splicing	0	0	0	0	10	0	10
Mechanical splicing	5	10	5	0	10	0	30
Factory pre-termination	10	10	10	10	5	10	55
Fusion field installable connectors	10	0	0	0	5	10	25
Mechanical field installable connectors	10	10	0	0	5	10	35

10 Excellent
0 Not adequate
Labor

Jan Vandenbroeck

Jan Vandenbroeck is FTTH Business Development Manager at TE Connectivity. He has over 30 years of experience in tele- and datacommunications.

Since 1985, Jan Vandenbroeck has held product management positions in Europe and North America where he introduced several new product lines for the long distance, metro and access fiber networks. He currently focuses on fiber connectivity systems.

WHITE PAPER

Contact us:
Tyco Electronics Raychem bvba
Diestsesteenweg 692
3010 Kessel-Lo, Belgium
Tel: 32-16-351 011
Fax: 32-16-351 697

www.te.com
www.telecomnetworks.com

or your local sales representative

TC 001/WP/1 02/12