

FTTH for this Century: How to build networks that last and survive future requirements

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Abstract

The optical fiber network infrastructures installed today will typically see four generations of transmission systems over the network's expected lifetime. As recent history has shown, the amount of data traffic these networks will carry will increase dramatically and continuously.

In order to cope with this increasing growth, a completely open spectral transmission window from 1260 nm to 1625 nm for data transmission and up to 1650 nm for network monitoring is necessary in all portions of the optical network, including the access portion of FTTH network deployments.

Introduction

Networks are built to last for decades, and they need to support, without interruption or failure, increasingly heavy traffic at higher bandwidths. Factors that contribute to the network's reliability and longevity, such as the need for good fiber/cable management and highly reliable connections throughout the network, have been accepted as necessary. In addition to meeting today's needs, operators need to build networks with an eye to future requirements. These have long been standard considerations for long-haul, core and metro networks. What happens when FTTH fiber access networks are built?

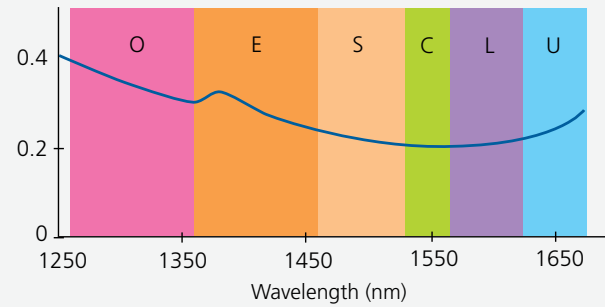
Today's situation

New standards and new technologies in the development of fiber optic cabling and connectivity directly impact operators' network considerations.

Single-mode optical fibers are designed to operate with wavelengths ranging from 1260 nm up to 1650 nm. Below 1260 nm, the fiber behaves as a multi-mode fiber, while above 1675 nm the fiber glass material starts to absorb the light. **Figure 1** shows a typical attenuation curve.

Bends in the fiber cause an attenuation increase at longer wavelengths (above 1550 nm). As shown in **Figure 2**, standard ITU-T G.652D fiber will typically show the following

Attenuation
(dB/km)



ITU-T has defined the following transmission bands:

• O-band (Original)	1260 nm to 1360 nm
• E-band (Extended)	1360 nm to 1460 nm
• S-band (Short wavelength)	1460 nm to 1530 nm
• C-band (Conventional)	1530 nm to 1565 nm
• L-band (Long wavelength)	1565 nm to 1625 nm
• U-band (Ultra long wavelength)	1625 nm to 1675 nm (used for monitoring only)

Figure 1: Spectral attenuation of single-mode fibers over different ITU-T transmission bands

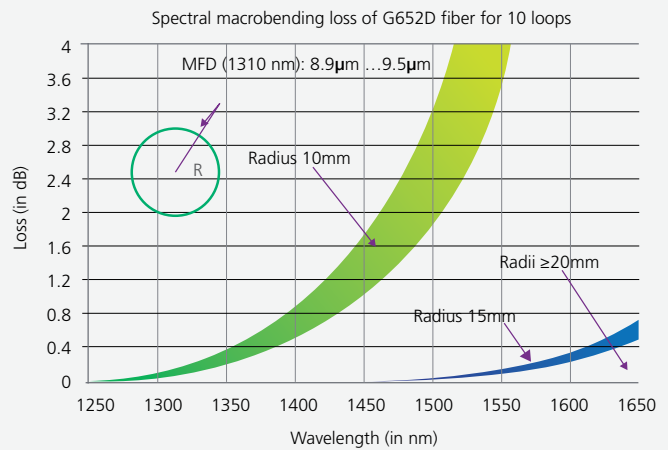


Figure 2: Wavelength dependent attenuation caused by macrobending

wavelength-dependent attenuation increase when making 10 turns on fiber with a certain diameter.

Figure 2 indicates that a minimum bend radius of 20 mm can be accepted for ITU-T G.652D fibers. However, when installing fiber at customer premises, this minimum installation radius is not at all practical. ITU-T G.657 bend insensitive fibers were introduced as a solution. For G.657 A2 fibers stored with a bend radius of 10 mm, the macrobending loss is about 10 to 20 times lower than that of G.652D fibers with the same bend radius. Also note that for the same fiber with the same bend radius, the bend loss at 1625 nm will be about 2 to 2.5 times higher than that at 1550 nm.

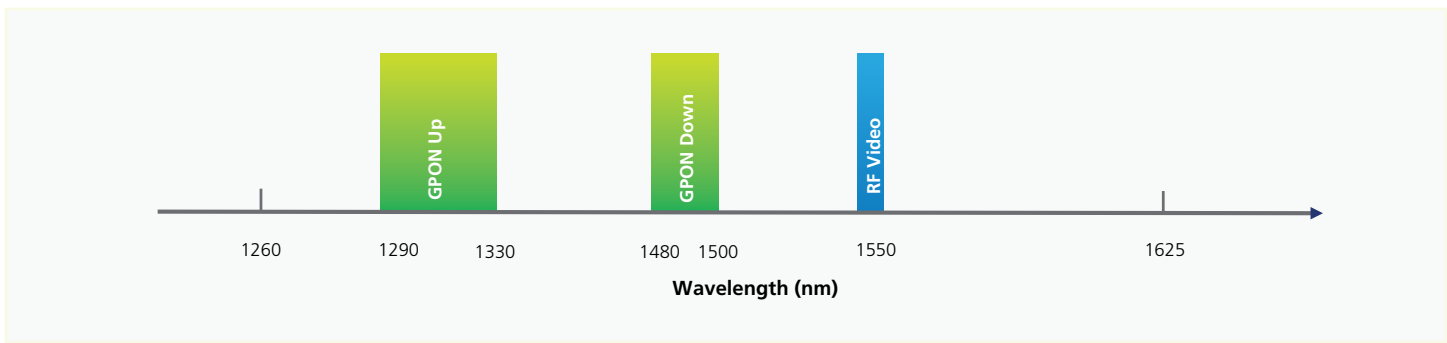


Figure 3: GPON transmission wavelength bands + RF video overlay

When ITU-T G.657 bend insensitive fibers were introduced in FTTH roll outs, attention to installation quality and management of fibers and cables seemed to disappear. At the time, it was assumed that using bend insensitive fibers in FTTH PON architectures using wavelengths up to 1550 nm maximum, meant that relaxed patch cord specifications and less fiber management were permissible (Figure 3).

Having “looser” specifications allowed operators to employ crews with lower technical skills in building out their FTTH network. Access and FTTH networks are very large and training the vast number of people required to build them is time consuming and costly. To reduce costs, to save time and meet commitments to various stakeholders, and to match the realities of the competitive landscape, operators have employed installation crews with limited fiber handling skills. Less-skilled crews, however, mean even greater attention must be given to selection of materials and to network architecture. For example, proper fiber splicing requires skill, training and experience. And fully-trained splice technicians are expensive and increasingly rare. A network architecture that minimizes the number of splice locations, concentrating them and increasing their individual splice density, can help reduce costs but must be planned in from the beginning of the network’s design.

On top of that, many FTTH network business cases were calculated to have pay-back in shorter timeframes and focused primarily on initial costs. This resulted in reduced specifications (at 1310 nm and 1550 nm only) of optical fiber cables and optical connectors and reduced attention to installation practices (uncontrolled bends in stored fibers).

This trend can soon become a costly issue since the current networks might not be able to deal with systems operating at wavelengths above 1550 nm. Should network deployment decisions be based on financial CAPEX calculations without considering the long-term effects of these decisions and ignoring related OPEX costs? It is tempting to implement savings on the quality of material used, on training installation crews and assuring that specifications meet the

real needs, although the relative cost for this quality is typically a very small part of the network’s complete total cost of ownership.

We should remember that the initial CAPEX of an FTTH deployment consists mainly of civil costs (about 70 percent), cost of actives (about 23 percent) and civil hardware (cables, connectors, closures, distribution frames (about 7 percent)¹. So the passive equipment, which in general sees long service lives sometimes in the harshest conditions, is a relatively small cost of the overall installation. However, their impact on later OPEX, due to the costs involved in replacing them, can be huge. OPEX costs (assumed to be around 15 percent of CAPEX, but occurring annually) impact the network business case only later on and for that reason seem to be ignored during fiber access/FTTH network builds.

¹ Percentages are averages and vary depending on construction types—buried, aerial, facade, etc.

Let’s consider how use of G.657 bend insensitive fibers impact CAPEX and OPEX. Although optical performance of macrobending improved greatly, the fibers’ mechanical reliability remained the same as for G.652D fibers. By allowing smaller bend radii, the probability of mechanical failure also increases, without an “optical attenuation” warning. The careful reader might have seen that in the ITU-T G657 document, a failure probability of 10^{-5} is considered acceptable for FTTH applications. For long haul networks, a much lower failure probability is requested as one failure could affect the transmission of several thousand customers. The standard IEC 61756-1 Ed2 provides guidance on the minimum allowed bend radius of stored fibers and patch-cords depending on the following five parameters:

- Location in the network (allowed maximum failure probability)
- Length of stored fiber
- Fiber type (657.A1, A2 or B3)
- Longest wavelength of transmission (1550 nm or 1625 nm)
- Maximum allowed attenuation increase by storing the fibers or patch-cords

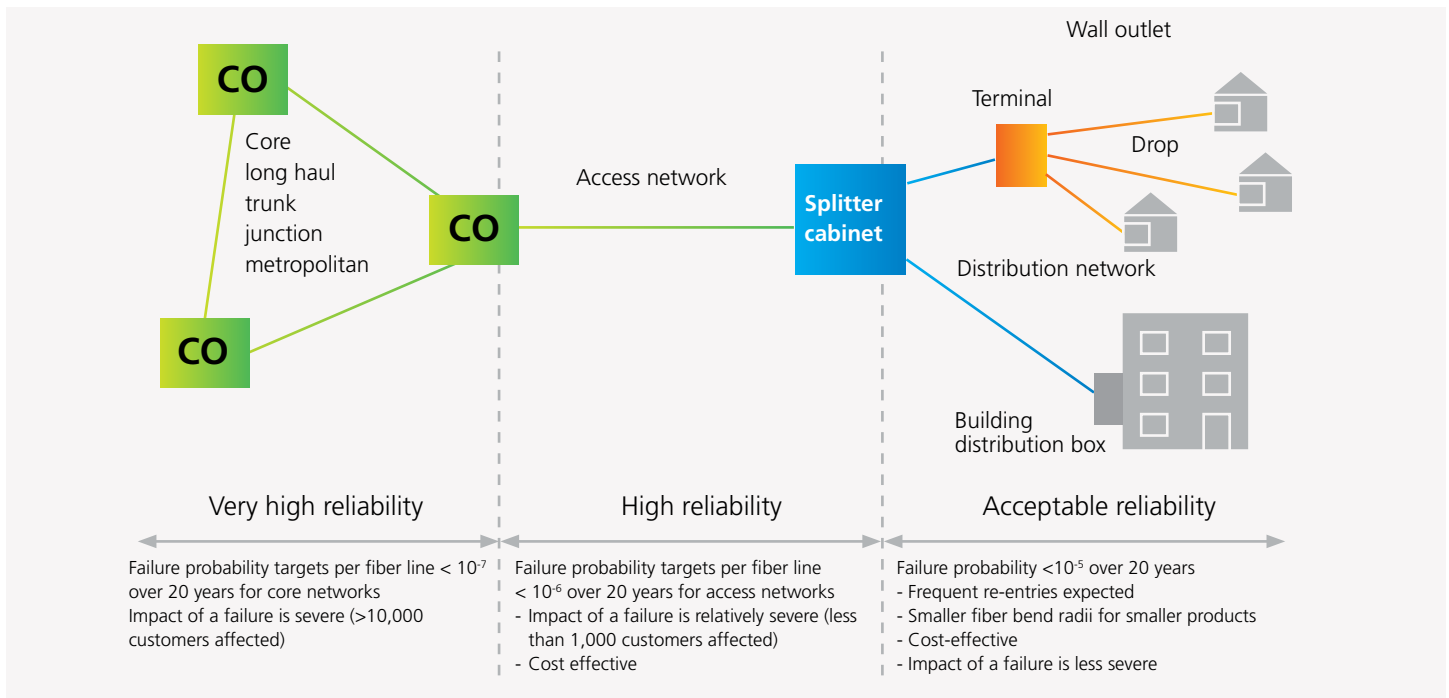


Figure 4: Expected mechanical reliability in various optical networks

As shown in Figure 4, the expected reliability of the fiber lines depends on the type of network. In core, metro and long haul fiber networks, attention has traditionally been paid to the deployed network's long-term reliability. Networks have been built to last for decades, and have had to support, without interruption or failure, increasingly heavy traffic at higher and higher bandwidths.

Reduced network quality inevitably leads to increased downtimes. Downtime affecting residential customers was historically not the highest priority for network operators but times, and customer expectations, have changed. One network operator executive described the change of customer contacts at downtimes as an increasing 'drama effect.' Customer calls are much more emotional than in the past as people are almost continuously on line.

Fortunately, as pressure and expectations from both business and residential customers has increased, technology has evolved. In

recent years, standards and technologies have opened a wider portion of the fiber spectrum to assure that expensively deployed networks are built to last.

Requirements for future transmission systems

The new NG-PON2 transmission standards that are under discussion at ITU-T allow operators to increase the FTTH networks' bandwidth capacities and reduce deployment cost by sharing the same fiber with more connected customers or sharing networks with multiple operators. The new NG-PON2 standards, using transmission wavelengths from 1260 nm to 1625 nm, employ more of the same fiber deployed and allow seamless overlays of new services to existing GPON networks (Figure 5). With both a wider spectrum, and a less forgiving customer base, are we still willing to introduce components with reduced specifications today into future-generation access networks?

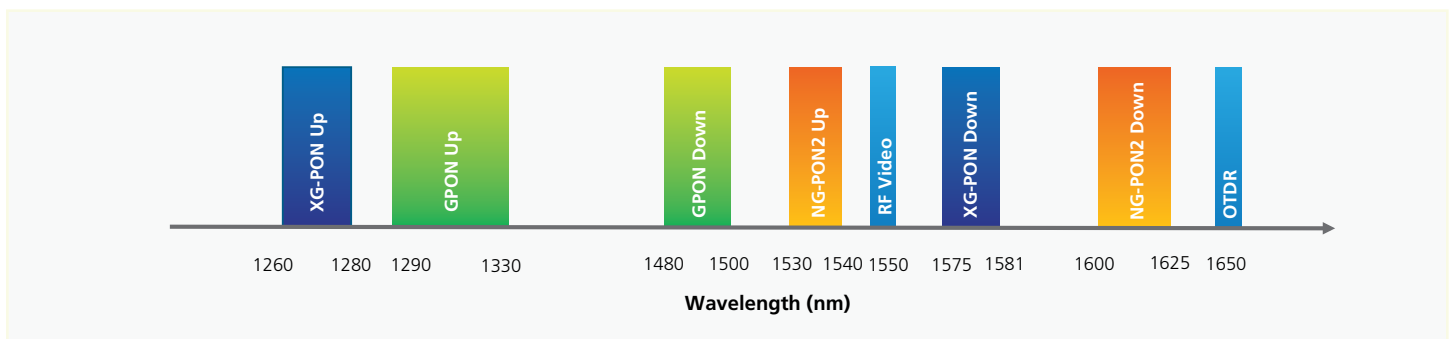


Figure 5: Wavelength allocation of various PON transmission protocols

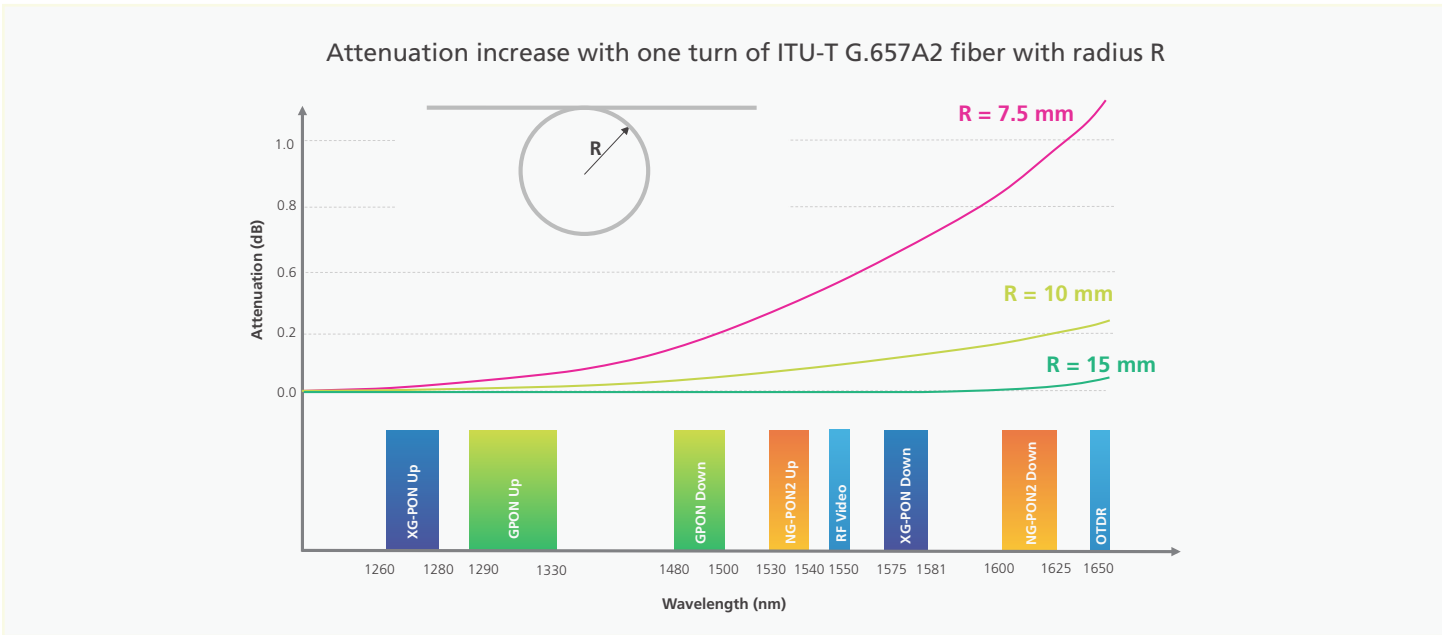


Figure 6: Macrobanding attenuation for ITU-T G.657 A2 fiber

The NG-PON2 downstream channels will operate in the wavelength band between 1600 nm and 1625 nm. These are the transmission wavelengths most sensitive for bending of the fiber (Figure 6).

A few years ago, the published IEC performance standards for cables and connectors did not always reflect these requirements for the future transmission wavelengths. When revisions were planned these wavelengths were added (Table 1). For future-proof networks, all network components should be specified for use from 1260 nm to 1625 nm.

IEC and ITU performance standards for various network components			
Network component	1310 nm	1550 nm	1625 nm
Fibers	✓	✓	✓
Cables	✓	✓	✓
Splices	✓	✓	✓
Connectors	✓	✓	✓
Splitters	✓	✓	✓
WDM	✓	✓	some
Fiber Management Systems	✓	✓	✓
Enclosures	✓	✓	✓

Table 1: IEC and ITU performance standards for various network components

In the past, operators replaced connectivity components in the core network when they started to use longer wavelengths in order to increase the capacity of their fiber builds. For FTTH networks the impact of such rework would obviously be multiplied as the number of connectivity points is huge compared to those in core networks.

Conclusion

As pressure and expectations from both business and residential customers has increased, technology has to evolve. In recent years, standards and technologies have opened a wider portion of the fiber transmission spectrum to assure that expensively deployed networks are built to last, even when new transmission equipment or systems are added to the line.

Factors that contribute to reliability and longevity, such as the need for reliable connections and good fiber/cable management systems throughout the network, are necessary. To survive and grow, operators need to build networks with an eye to future requirements—change will happen, that is certain. What form the change will take is less clear, but future use of wavelengths up to 1625 nm is a certainty.

Lessons from the past—training crews to handle fiber properly, using solutions supporting correct cable management, using connectors with the right performance specification—provide both short- and long-term benefits to operators and customers alike.



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