FTTH for this Century:

How to build networks that last and survive future requirements

by Daniel Daems, CommScope

The optical fibre 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 1260nm to 1625nm for data transmission and up to 1650nm for network monitoring is necessary in all portions of the optical network, including the access portion of FTTH network deployments.

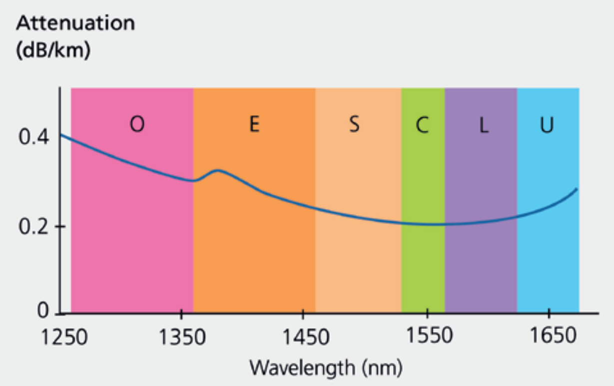
Introduction

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 fibre/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 fibre access networks are built?

Today's situation

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

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



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 fibres over different ITU-T transmission bands

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

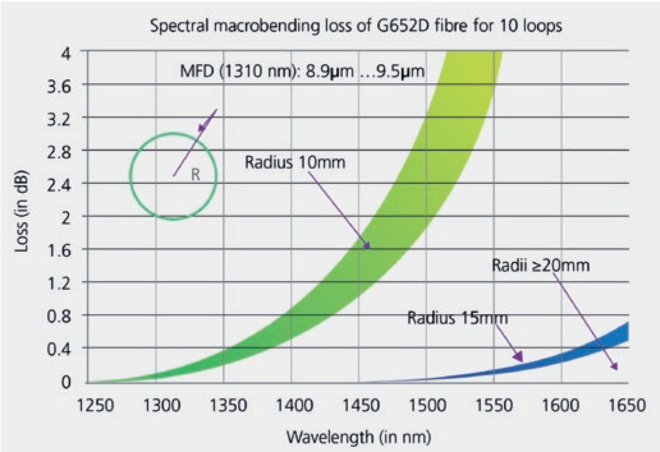


Figure 2: Wavelength dependent attenuation caused by macrobending

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

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

When ITU-T G.657 bend insensitive fibres were introduced in FTTH roll outs, attention to installation quality and management of fibres and cables seemed to disappear. At the time, it was assumed that using bend insensitive fibres in FTTH PON architectures using wavelengths up to 1550nm maximum, meant that relaxed patch cord specifications and less fibre 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 fibre handling skills. Less-skilled crews, however, mean even greater attention must be given to selection of materials and to network architecture.

For example, proper fibre splicing requires skill, training and experience. And fully-trained splice technicians are expensive and increasingly rare. A network architecture that minimises 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 1310nm and 1550nm only) of optical fibre cables and optical connectors and reduced attention to installation practices (uncontrolled bends in stored fibres).

This trend can soon become a costly issue since the current networks might not be able to deal with systems operating at wavelengths above 1550nm. 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.

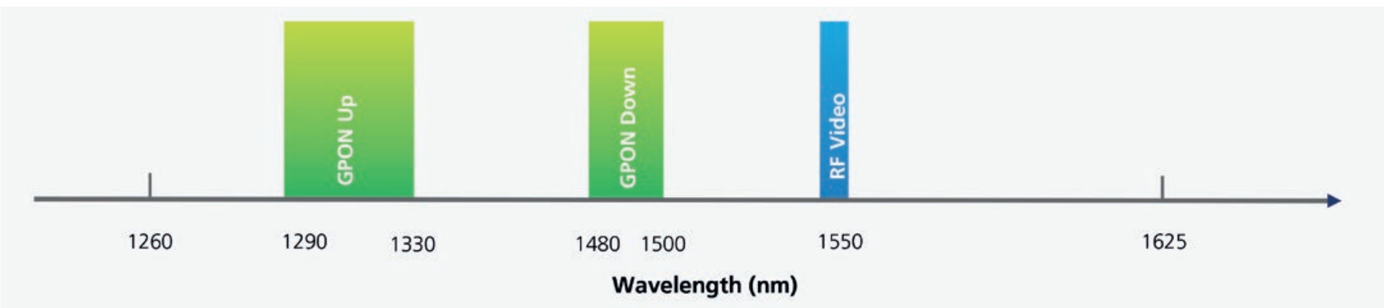


Figure 3: GPON transmission wavelength bands + RF video overlay

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 ingnored during fibre access/FTTH network builds.

Let's consider how use of G.657 bend insensitive fibres impact CAPEX and OPEX. Although optical performance of macrobending improved greatly, the fibres' mechanical reliability remained the same as for G.652D fibres. 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 fibres and patch-cords depending on the following five parameters:

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

As shown in Figure 4, the expected reliability of the fibre lines depends on the type of network. In core, metro and long haul fibre 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.

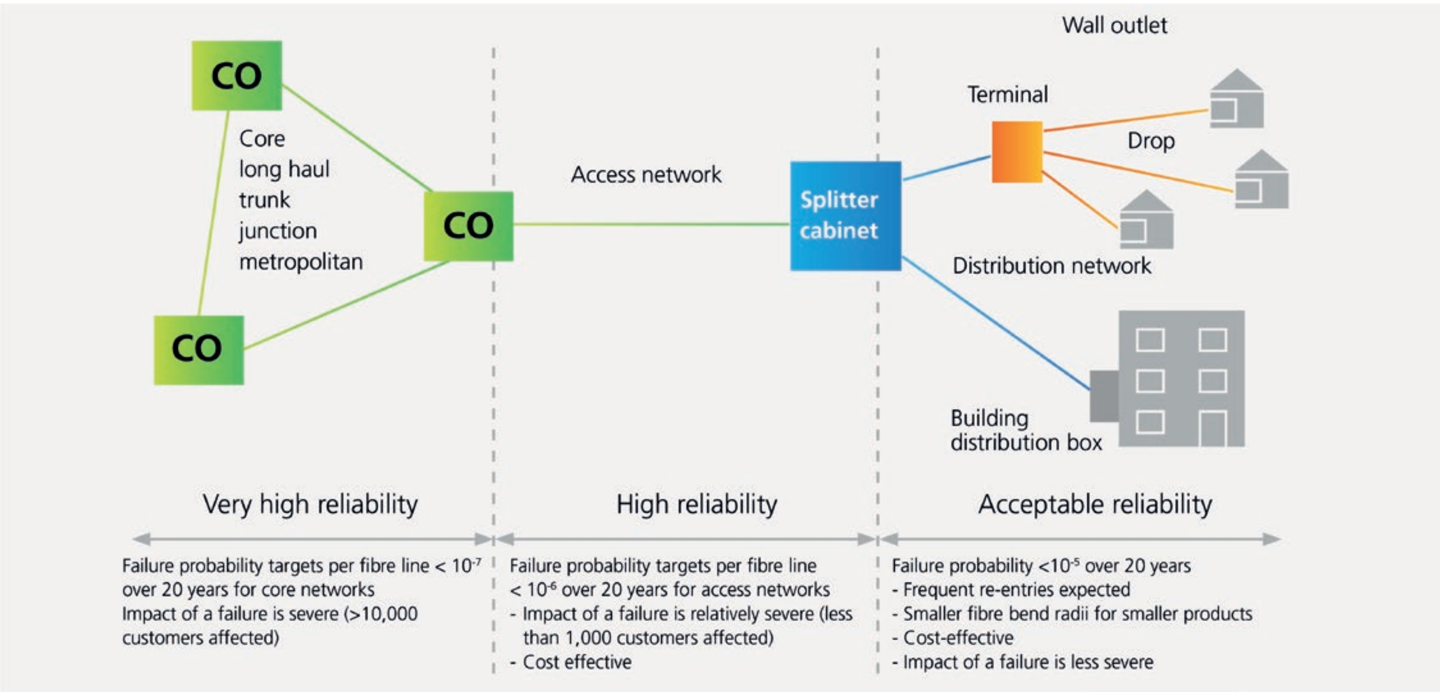


Figure 4: Expected mechanical reliability in various optical networks

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

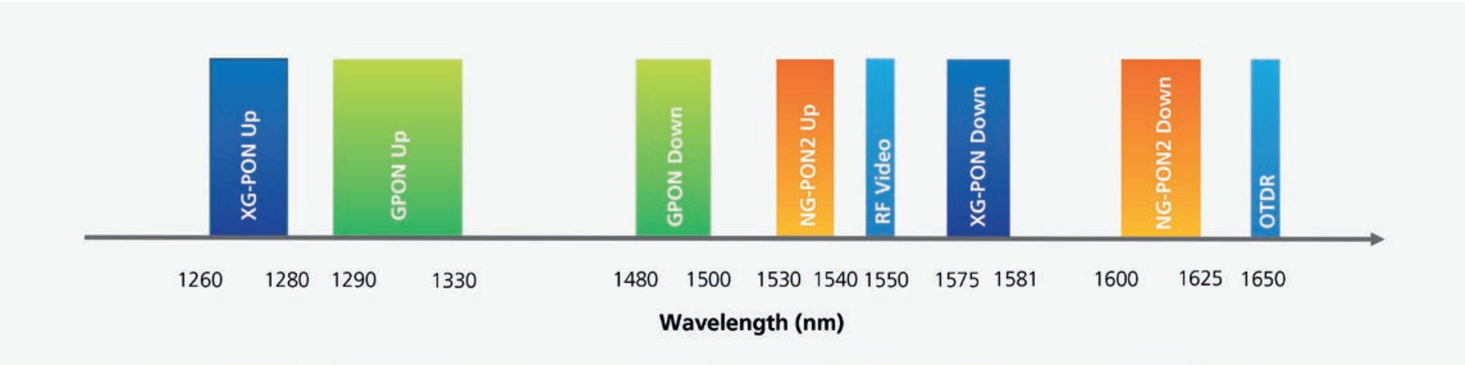


Figure 5: Wavelength allocation of various PON transmission protocols

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 fibre 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 fibre with more connected customers or sharing networks with multiple operators. The new NG-PON2 standards, using transmission wavelengths from 1260nm to 1625nm, employ more of the same fibre 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?

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

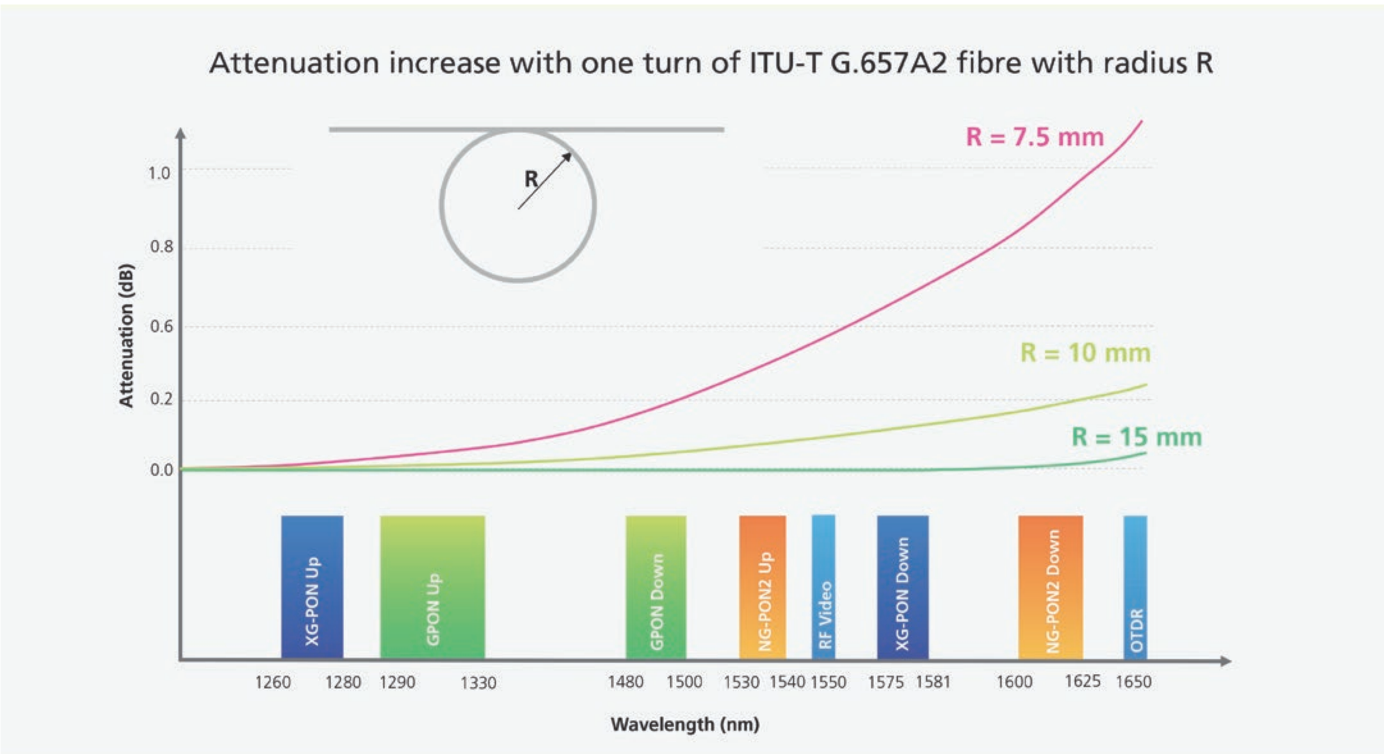


Figure 6: Macrobending attenuation for ITU-T G.657 A2 fibre

"Downtime affecting residential customers was historically not the highest priority for network operators but times, and customer expectations, have changed."

IEC and ITU performance standards for various network components				
Network component	**1310nm**	**1550nm**	**1625nm**	
Fibres	✓	✓	✓	ITU-T G.65x series IEC 60793 series
Cables	✓	✓	✓	IEC 60794 series
Splices	✓	✓	✓	IEC 61753-131 series ITU-T L.400/L.12
Connectors	✓	✓	✓	IEC 61753-021 series ITU-T L.402/L.36
Splitters	✓	✓	✓	IEC 61753-031 series ITU-T L.403/L.37
WDM	✓	✓	some	IEC 61753-08x series
Fibre Management Systems	✓	✓	✓	IEC 61753-101 series ITU-T L.200/L.51
Enclosures	✓	✓	✓	IEC 61753-111 series ITU-T L.201/L.13

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

revisions were planned these wavelengths were added (Table 1). For future-proof networks, all network components should be specified for use from 1260nm to 1625nm.

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 fibre 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 have increased, technology has to evolve. In recent years, standards and technologies have opened a wider portion of the fibre 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 fibre/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 1625nm is a certainty.

Lessons from the past—training crews to handle fibre 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.

For more information, see www.commscope.com