

Built to Last

The 40-Year FTTH Design

By Guy Swindell and Calvin Martin

FTTH is rapidly becoming the preferred wireline solution for access networks. The virtually unlimited services and bandwidth afforded by fiber optic cable relative to the alternatives is well documented. Presently, however, most of the content actually being delivered over FTTH networks could be supported by traditional metallic media. This reality does not impugn the value of an all-fiber network. It simply helps us recognize that today's FTTH deployments are driven by two key value propositions:

- The promise of a future-proof network through the ability to support virtually unlimited bandwidth.
- Cost-parity with other wireline solutions — which depends on reduced operating expenditures and the full realization of fiber's distance potential in the last mile.

The optimum phrases are “future-proof” and “cost-parity.” Carriers deploying FTTH must achieve a reasonable payback period with today's content and services. Meanwhile, they must engineer a last mile solution that can be expected to remain in service for a 40-year life span.

Exactly which elements of the FTTH network enable a 40-year life cycle? The last mile electronics represent a large portion of the overall cost, and therefore have a significant impact on “cost-parity.” However, those same electronics are typically depreciated on a 5- to 10-year schedule. The real value of our “future-proof” proposition is realized in the rather plain and ubiquitous elements of fiber, splitters and connectivity. Consequently, it is the outside plant designer who must operate with an eye toward the future.

Managing Attenuation Performance in Optical Fiber

If the outside plant designer's game plan focuses on enhancing the FTTH value propositions, the first order of business is to define metrics in outside plant performance which offer tangible support for those propositions. Since PON (Passive Optical Networks) is the prevalent FTTH architecture, and since attenuation is the primary limitation in most PON networks, the logical area for improvement is in attenuation performance.

Any improvement in attenuation performance can enhance the future-proof value proposition if it addresses loss characteristics across the full optical spectrum. Today's PON technology typically broadcasts one to two wavelengths (1,490 nm and 1,550 nm) downstream to subscribers, while supporting upstream traffic at the 1,310 nm wavelength. However, this type of PON technology is a “shared bandwidth” architecture. As such, it offers a dramatic improvement over metallic media in the last mile, but it still carries inherent bandwidth limitations. Early PON deployments have all followed some variation of this wavelength scheme. However, there is almost universal agreement that the ideal PON technology will provide a dedi-

cated wavelength to each subscriber, and thereby eliminate the shared bandwidth limitations of today's technologies. Technologies such as wavelength-division multiplexing (WDM) and coarse wavelength-division multiplexing (CWDM) are converging with PON in trial deployments. Without question, the ultimate PON solution will be economically viable long before the accountants stop depreciating a fiber infrastructure that is being deployed today.

Conventional single mode fiber is subject to a “water peak” defect in the optical spectrum where PON is likely to migrate. Water peak defects can create attenuation losses up to 1.2 dB per kilometer in spectrum supported by CWDM. Such losses constitute a deal-breaker for carriers contemplating next generation PON technologies. Most vendors now offer “low water peak” fibers that reduce this effect. However, even low water peak fiber can create an additional 2 dB worth of loss across the 20 km distance limit of most PON networks. Such a loss would be enough to require a reduction in the 1x32 split ratio, with a resulting dramatic increase in the cost per subscriber.

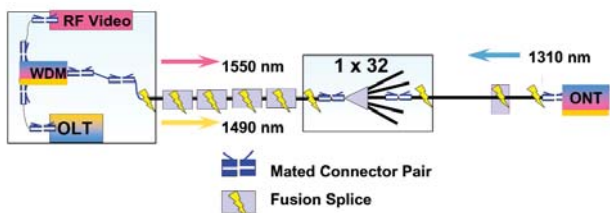
There are optimized fiber solutions for PON that address and virtually eliminate the water peak issue. However, the outside plant designer is advised to read the fine print. Water peak attenuation is not only a function of manufacturing, but also a function of aging (Chang, Flegal, 2005). Single mode fiber can be produced with minimal water peak defects, but still see increases in attenuation after prolonged exposure to the hydrocarbons found in most cable jackets and from various chemical reactions in the environment. The technology exists to manufacture fiber that is not subject to attenuation increases with aging, and network owners can require vendors to warranty against this age-related defect.

If the future-proof value proposition of PON is enabled by the long-term availability of a full optical spectrum, the cost-parity proposition can be enhanced by acknowledging the craft realities of the last mile. FTTH networks are subject to more splices per mile and more routing into compact fiber management systems. This increases the amount of loss from splicing, and the loss potential from craft errors such as macrobends. Also, the cost pressures in most FTTH deployments are substantial. Therefore, not only are there more splices and connection points per mile, but those connection points are usually created using less-sophisticated splicing equipment and less-experienced installation crews. Savvy network designers are aware of these realities and frequently budget up to a 2 to 3 dB attenuation “safety buffer” to accommodate the inevitable craft-induced losses.

The consequences of the “safety buffer” warrant the consideration of bend-insensitive fibers for distribution cables and assemblies. If an accounting of potential craft-induced losses requires a more conservative PON design, then the impact on attenuation budgets directly translates into an increased cost per subscriber. For example,

if a PON design is reaching the threshold of its optical loss budget, the logical design option is to reduce the split ratio one level from a 1x32 to a 1x16. The obvious downside to this option is that it leaves half of the central office equipment capacity unused. Since central office equipment averages \$250 per subscriber in a typical PON deployment, the loss of those sixteen potential connections translates into a \$4,000 penalty. If the use of a fiber with excellent splice capabilities and bend insensitivity can reduce the attenuation “safety buffer” by 1 to 2 dB, the cost savings achieved through complete utilization of PON capacity can be substantial.

On the subject of splicing: bend-insensitive fibers only have value in the last mile if they have full interoperability with other standards-compliant fibers on the market. Any savvy PON designer will seek to employ existing fiber infrastructure in their new build. Consequently, any fiber

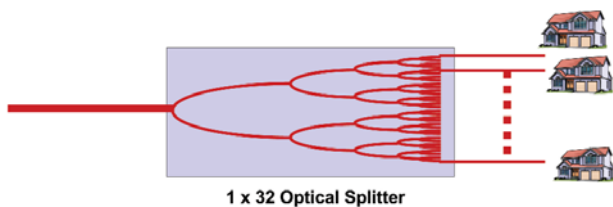


Example of the Potential Splices and Connected Pairs in a PON

technology for the last mile must be easily spliced or connected to existing single-mode plant with no loss penalty. Preferably, this can be accomplished without mandating the use of expensive core-alignment splicers and exotic splice programs.

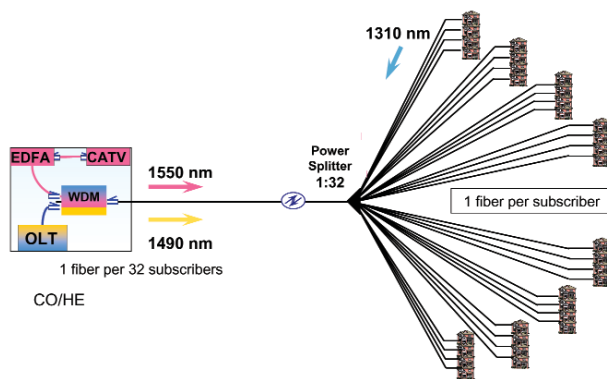
Optical Splitters and Connectivity

If benchmark attenuation performance across the full optical spectrum is key to achieving the long-term potential of FTTH, then it should be duly noted that optical splitters are the largest contributors to attenuation in PON. Low attenuation in today’s wavelengths is desirable for obvious reasons. However, much like the fiber itself, the optical splitter should be specified to operate across the full optical spectrum. Once again, such products are readily available. Also, once again, there are concerns relative to aging. In the case of optical splitters, higher split ratio products (1x4 to 1x32) are normally of the “PLC” variety. These splitters are



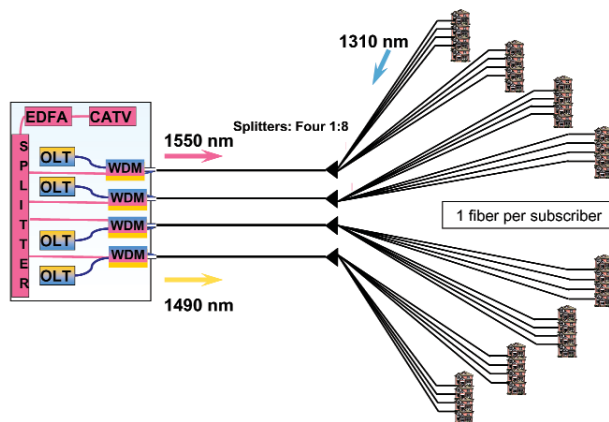
The Optical Splitter in a PON

manufactured using a chip technology. PLC’s have the desirable attributes of low attenuation and a small footprint. However, they occasionally have the quality of aggregating moisture over time — not at all desirable in an outside plant product. Network owners can do themselves a favor by requiring the use of PLC’s that are hermetically sealed during the manufacturing process.



Present Day Standard PON

What about connectors? Some suggest that PON should incorporate as many connectors as possible. The logic being that every connector pair represents a convenient access point for testing. However, connectors usually represent the long-term highest probability of failure in an outside plant link. Therefore, installing connectors only where necessary is probably a better guarantor of network longevity. Wherever connectors are installed, an option to minimize losses is to use a “tunable” product. Most SC and LC connectors can be offered in a tunable variety. The beauty of a tunable connector is that the position of the fiber in the connector ferrule can be optimized during assembly to maximize performance. Typical losses for “tunables” are often as low as .06 dB. A tunable product installed on a bend-insensitive singlemode fiber is a robust connectivity solution for PON.



Possible PON Upgrade Scenario to WDM-PON

Conclusion

The 40-year FTTH design gives equal billing to both cost-parity and future-proofing. Cost-parity is achieved by realizing the full distance potential of an all-fiber network, and by using any craft advantage available — including the availability of bend insensitive fibers. Future-proofing is achieved by using products that support the full optical spectrum and can sustain the rigors of aging. The real value of a FTTH deployment is lost or found in the commonplace elements of optical fiber, splitters, and connectors. Savvy owners and designers will plan accordingly.

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