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How Long is Long-Haul in a FTTH World?



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Fiber-to-the-home's newfound status as the preeminent wireline solution coupled with the emergence of IP video are driving higher bandwidth requirements into rural America. A seldom mentioned byproduct of these rural deployments is a need to link remote central office and hub locations over substantial distances. The capacity of those links will define the ability to deliver next-generation services in the last mile, and the distances those links support may introduce issues which were previously the exclusive domain of long-haul backbone providers. This paper examines those issues and defines the points where they come into play for a rural FTTH deployment.

There are a number of relevant factors that contribute to the success of any FTTH deployment. For the optical media itself, however, the most significant parameter between the central office and the home is attenuation. Attenuation is commonly understood by last-mile engineers, and is reasonably easy to both calculate and measure. However, a long link to a remote central office or hub site has the potential to introduce dispersion as a consideration. The amount of relevance that dispersion could have in that situation would be determined by a combination of both the distances involved and the amount of bandwidth being transported. Figure 1 illustrates where the limiting parameters begin to shift.

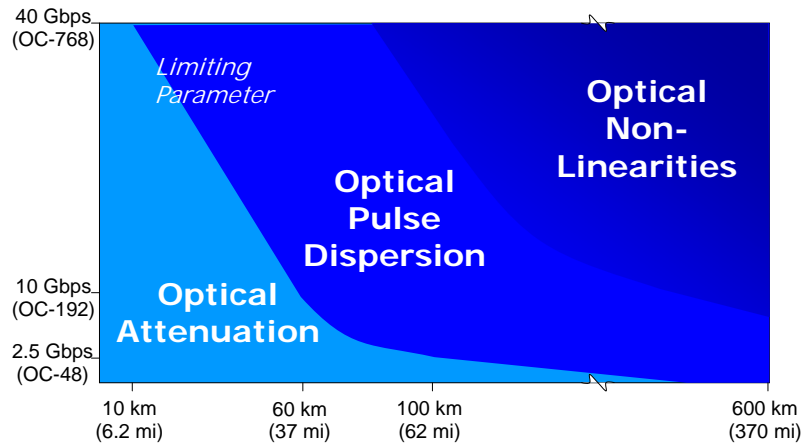


Figure 1

So, what exactly is dispersion? The answer to that question is, at varying levels, either very simple or quite complicated. On the simplest level, not all light travels through an optical fiber at the same speed. Like a plume of smoke from a stack that gets broader and harder to recognize as it travels farther from the stack, an optical pulse broadens as it travels down the fiber. In singlemode fiber most of the broadening is due to a property called chromatic dispersion. All wavelengths of light travel at different speeds in an optical fiber and, since transmitters have a finite spectral width; the light traveling down the fiber can spread. At 1310 nm, singlemode fiber has very little chromatic dispersion and thus this is not a problem. However, at the wavelengths used for longer distance transmission, such as 1550 nm, the dispersion can be significant when distances are over 60 kilometers and data rates are 10 Gb/s or faster.

There are three viable options for addressing dispersion concerns. The first is an improvement in laser transceiver technologies. The second is retrofit solutions for conventional single-mode in the form of dispersion compensating modules. And, the third is the use of optical fiber with modified dispersion characteristics. Improvements in laser technology are certainly a possibility and press releases from various vendors indicate that new solutions are on the near horizon. However, the price and availability of new transceivers are unknown variables. Therefore, we will limit our analysis to the known trade-offs between dispersion compensating modules and specialized fibers.

The dispersion compensating fiber (DCF) module contains a specially designed optical fiber that undoes the chromatic dispersion. These devices typically have an insertion loss of about 5-10 dB and remove the dispersion generated in about 50-100 kilometers of conventional singlemode fiber. Although relatively costly, DCF modules are convenient as they can be added after the optical cable has been deployed. The

logical current alternative to the DCF module is to deploy non-zero dispersion-shifted fiber (NZDF). Using NZDF fibers allows transmission of several hundreds of kilometers at 10 Gb/s with minimal chromatic dispersion. When an application calls for some level of dispersion mitigation, NZDF has two advantages. The first advantage is that NZDF fiber is less expensive than conventional fiber retrofitted with dispersion compensating modules. The second is that attenuation of the optical link with NZDF fiber is less than the attenuation of a conventional fiber with the DCF module. The second advantage also has a financial bearing since it greatly reduces the need for amplification.

The most immediately relevant dispersion-affected application for the rural independent communications provider is the 10 Gigabits-per-second and 60 kilometer crossover point. A distance of 60 kilometers between central offices or remote hubs is not uncommon for a rural carrier. And, a 10 gigabit backhaul upgrade is a rational expectation during the first few years of a FTTH deployment. As an example, Blue Ridge Mountain EMC is an electric cooperative deploying internet and IP video in rural North Georgia and Western North Carolina. Their architecture includes “node sites” where a router receives a backhaul connection and provisions the equipment that transports services via FTTH to subscribers. Those node sites are occasionally in excess of 60 kilometers from the primary equipment room, and Blue Ridge Mountain EMC needed to evaluate 10 gigabit upgrade options to the nodes before the first year had elapsed on their deployment.

The reason for the rapid upgrade to 10 gigabits stems from the current demands for support of IP video, the ever-increasing level of bandwidth usage among subscribers, and the low number of fibers used to support the remote routers. Historical trend lines indicate a growth in nominal data rate usage among internet subscribers at nearly 42% annually over the past several years. This growth rate may plateau in rural areas where there is relatively little competition among providers. Nevertheless, 10 gigabit backhaul requirements can materialize even under conditions of a much slower bandwidth growth when IP video drives a beginning nominal data rate of 30 megabits-per-second for new subscribers. So, in the circumstances of a rural provider such as Blue Ridge EMC, there are four fibers providing backhaul to a remote router at a node site. If the node site supports 1,000 subscribers at a nominal data rate of 30 megabits-per-second and at least 90% of all traffic routes through the backhaul fibers, then we begin with a need to support just under seven gigabits-per-second for each backhaul fiber during the first year. If a rural provider started under those circumstances and actually realized the historic 42% annual growth in the nominal data rate, the increase in capacity requirements for the backhaul would be resemble the bar graph in Figure 2.

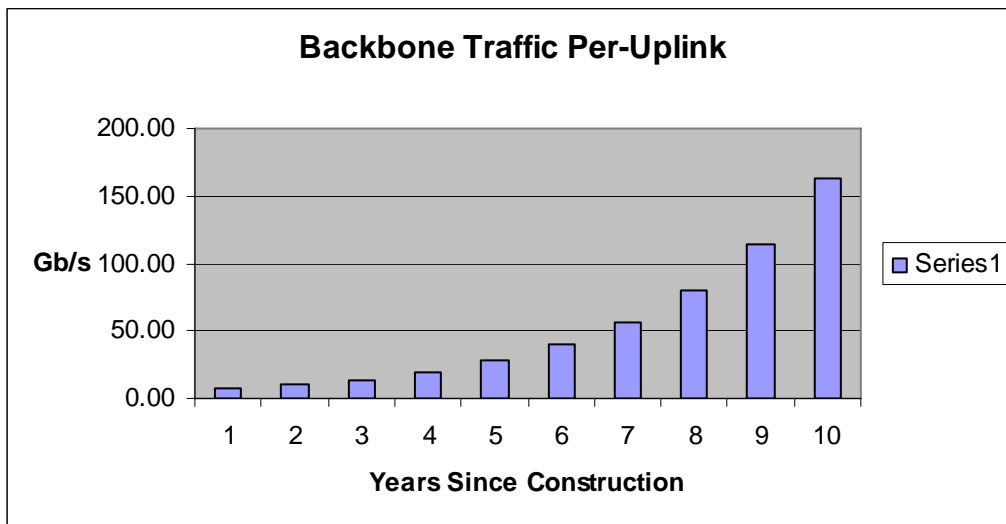


Figure 2

It may be unlikely that we will see serialized transmission of 150 gigabits-per-second in the near future. Most experts agree that such higher level data rates will be marked by a transition to CWDM or DWDM technologies. Nevertheless, outside plant infrastructure is deployed with the intention of supporting

operations for as long as 40 or 50 years. Certainly, therefore, we can expect 10 gigabit-per-second backhaul links to be ubiquitous in FTTH and perhaps 40 gigabit-per-second serialized transmission will be common before a backhaul fiber installed today exhausts its utility.

While a 10 gigabit-per-second link requires consideration for dispersion at 60 kilometers, a 40 gigabit-per-second link requires an awareness of dispersion at distances that encompass most backhaul links. It is entirely possible that 40 gigabit requirements will be met through CWDM or new laser technologies that circumvent the dispersion issue. Nevertheless, an awareness of dispersion will still be necessary for those charged with selecting the next upgrade technology. Therefore, some consideration for the cost trade-offs in the currently available technologies of NZDF fiber and DCF modules must be weighed into the analysis of any new capital investment in backhaul fiber links.

In most instances where dispersion is an issue from the beginning of a deployment, NZDF is a more cost-effective option than DCF modules and possible amplification. However, if the bandwidth requirements and distances just make dispersion mitigation a possibility on the horizon, DCF modules have the advantage of only being installed when needed. Thus, the DCF module approach allows for deferred expenditures until the day when the investment is absolutely needed. Finance 101 tells us that it is better to spend a dollar five years from now than a dollar today. Figure 3 illustrates a comparison of the present value of a standard single-mode solution with retrofit technologies (the G.652D graph) versus a NZDF solution for an actual application where the required rate of return on capital investments was 10%.

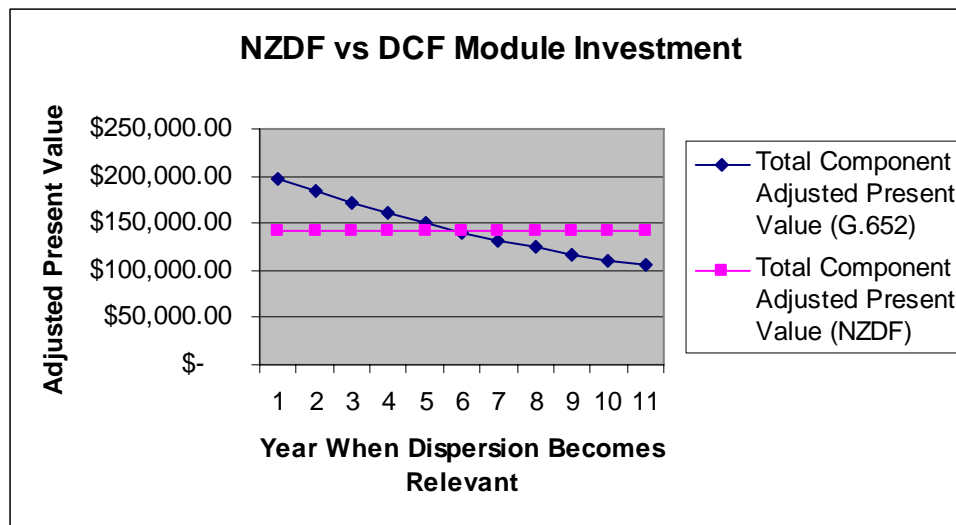


Figure 3

From the analysis in Figure 3, we would conclude that NZDF is a more cost-effective approach than DCF Modules if we expect to need dispersion control within the first five years of deployment. However, this particular model assumes no amplification – which is unlikely in most scenarios. It also uses 10 gigabits-per-second as the benchmark for bandwidth and follows the traditional long-haul model where all the fibers in a cable must either be NZDF or must be retrofitted with DCF Modules. In the case of a backhaul link to a remote central office to support FTTH, the latter assumption is probably incorrect.

In most circumstances, the number of fibers that will be used to support the remotely-located routers in a FTTH deployment will be very low: probably no more than four or six. Furthermore, the cable that houses those fibers will likely be required to perform additional duties of provisioning optical splitters or supporting drop locations for customers along the route. For those applications, a certain number of traditional G.652D fibers are not only desirable but mandatory. Thus, all of the costs associated with dispersion in the FTTH backhaul scenario are significantly lower than the costs reflected in a traditional long-haul deployment. After all, if we need NZDF fibers, we will only need a few of them. And, likewise, if dispersion compensation is required, it will only be for a very few fibers.

While the cost trade-offs and time value analysis of NZDF versus DCF modules is critically important, the issue of attenuation cannot be forgotten. As an example, Figure 4 compares two 50 mile optical links. One has conventional single-mode fiber with a DCF module and the second uses NZDF.

	Conventional Singlemode fiber	NZDF	
Distance miles	50	50	
Bit rate	10	10	Gb/s
Wavelength	1550	1550	nm
Fiber Dispersion	17.5	4.4	ps/nm*km
Compensation requirements	yes	none	
Dispersion compensator loss	5.3	0	dB
Attenuation at 1550	0.2	0.21	dB/km
Average Splice loss	0.1	0.15	dB
Approximate number of Splices	9	9	
fiber loss	16	16.8	dB
splice loss	0.9	1.35	dB
DCM	5.3	0	dB
Total loss	22.2	18.15	dB

Figure 4

Figure 4 clearly shows that the total loss for the NZDF link is 4 dB less. In many cases, this can result in fewer and less powerful optical amplifiers being deployed in the system which greatly reduces capital costs, operating costs, and engineering complexity. This impact of DCF module deployments on attenuation helps bolster the case for NZDF fiber where dispersion comes into play. The financial picture painted in Figure 3 becomes heavily skewed toward NZDF if amplification is added into the mix. And, realistically speaking, there are probably relatively few FTTH backhaul applications where a DCF module would be installed without amplification becoming necessary.

When backhaul bandwidth growth, a migration into rural applications, and the relative uncertainty of cost surrounding new high-bandwidth transmission technologies are considered, the case for a few NZDF fibers in a backhaul cable begins to look attractive. The typical backhaul cable being used for FTTH is a multi-purpose component and it is likely that less than 12 fibers in any cable would need to be NZDF in order to support a dispersion-impacted application. So, in the grand scheme of things, that relatively low number of fibers has a negligible impact on the overall cost of network construction, but can possibly mitigate a tremendous number of potential headaches. Rural FTTH carriers should give that option serious consideration whenever links reach the distances and bandwidths where dispersion could have an affect.