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Trends In Optical Premises Networks

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Premises networks continue to be one of the most exciting and dynamic segments of IT and telecom networks today. Rapidly changing data management requirements, evolution of business applications, and growing traffic demands are continuing to push enterprise networks speeds. This growing bandwidth demand has driven innovation and standards activities in optical premises networks, resulting in new products and system classifications. These technology trends, both of the past few years and those that are likely to happen in the future, are highlighted in the sections that follow.

Enterprise Traffic Demand Continues to Grow

While it is true that no single “killer app” has emerged that approaches the dreams of the fiber optic community in the late 1990s, steady, sustained growth in the use of bandwidth-heavy applications continues to drive the need for more robust network infrastructure.

Drivers include, but are not limited to:

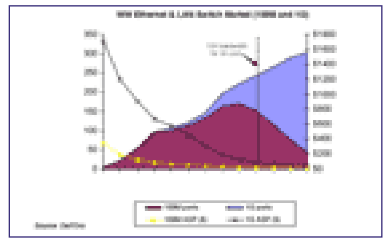
- Financial reporting:
  Significant changes in the way public companies must document their operational and financial activities drive the need for more thorough and careful data management. The Sarbanes-Oxley Act drives some of this activity, but generally, companies were increasing data management as more sophisticated tools came to market during the Internet revolution.
- Security:
  Carrying over from Y2K-related investments, an increasing spectre of security threats as more daily activity moves online, growth in wireless, and culminating with the terrorist attacks of 9/11, security, such as “mirror sites” for fault tolerance, is now commonly on the top of IT managers’ minds and driving off-site data backup.
- Online business activity:
  Enterprises continue to build stronger links in two directions: internally, connecting remote locations as the economy becomes more global; and externally, connecting to

their customers to conduct transactions and with their suppliers to drive efficiency in their supply chains. ERP, CRM, and other multi-site business software development continues to flourish.

- Others, including growth in digital media and document/medical imagery contribute to the steady increase in traffic demand.

Deployment Speeds Increase, 1G Becoming the Standard

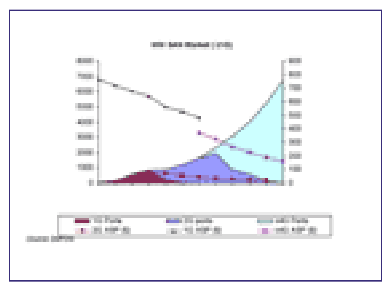
To handle the steady traffic growth, deployed enterprise system speeds continue to increase. As shown in Figure 1 and Figure 2, the shift towards Gigabit speeds as the standard horizontal enterprise deployment speed continues. It appears that the trend will follow the classic Ethernet “10X the speed for 3X the price” sometime in 2006/2007, at which time 1G will be the most common deployment speed.



(See Appendix A)
Fig 1: The worldwide Ethernet and LAN Switch Market (100M and 1G)

Additionally, an even more rapid change in speeds in datacenters and storage area networks has taken place. Continued growth in the requirements for data management and off-site disaster contingency planning are the major drivers. Innovation was occurring so fast that when ≥4G Fibre Channel ports started shipping in 2004, many were at price parity to 2G ports. This has led to an even more dramatic change in system capability growth.

Although the 1G IEEE optical standards were approved in 1998, the IEEE copper standard wasn’t completed until 1999. The requirements of the 1G copper application necessitated new copper cable specifications (CAT 5e) that included additional test requirements such as far end crosstalk. These developments paved the way for dramatic increases in deployed system capability.



(See Appendix B)
Fig 2: The worldwide SAN Market (1G)

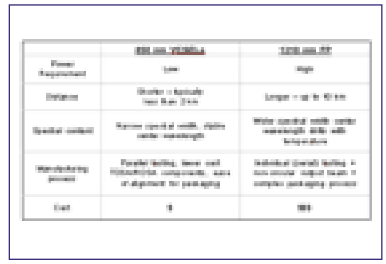
Lasers are Becoming the Standard Optical Transmission Source

Historically, for speeds below 1 Gb/s, light emitting diodes (LEDs) were the standard source for transmission modules in premise networks. Wider core multimode fibers allowed for significantly lower packaging tolerances. This, coupled with very low power requirements, led to low manufacturing costs. But data rates measured in the order of Mb/s are no longer enough. Now entering the era of 1 and 10 Gb/s, the market requires optical performance only possible with a laser.

There are two primary laser types used for ≥1G applications in premises networks today: 850 nm VCSELs (Vertical Cavity Surface-Emitting Lasers) optimized for multimode fibers and 1310 nm

Fabry-Perot originally developed for single-mode fibers. Some of the fundamental characteristics of each are listed in *Table 1.*

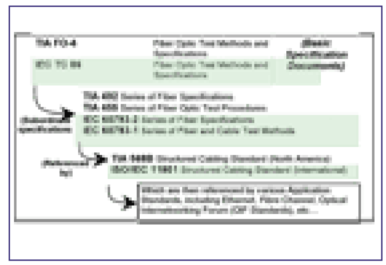
1 Gb/s 850 nm VCSEL module costs continue to decline dramatically, making it increasingly popular with end-users in the premises market. For the newest 10G VCSEL modules, manufacturers are having a hard time keeping up with demand, therefore stalling price declines. We continue to believe that low-cost 850 nm VCSELs for higher speeds (through 10G) will follow the 1G trend, and become the transceiver of choice for a majority of deployments.



(See Appendix C)
Table 1: Two primary laser types used today for 1G applications

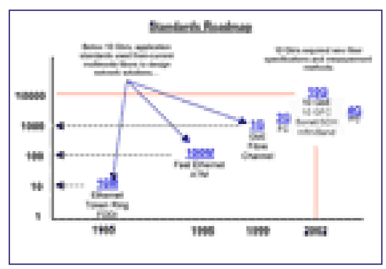
Standards Development Drives New Fiber Types and Measurement Methodologies

Figure 3 depicts the relationships between the different passive optical plant standards bodies, and how they feed into the application (software) processes. This includes TIA (U.S.) and IEC/ISO (International) bodies and subcommittees. Note that Ethernet and Fibre Channel are migrating to referencing IEC standards only, since they are international documents.



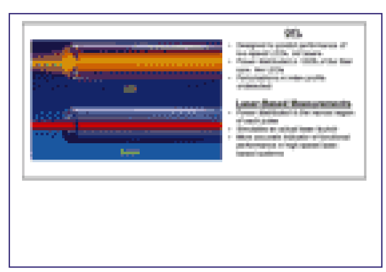
(See Appendix D)
Fig 3: The relationships between the different passive optical plant standards bodies

Traditionally, all application standards (Ethernet, Fibre Channel, etc.) were written around assumptions that they would be deployed on the current-technology passive plant. However, early in the standards development process for 10 Gb/s Ethernet, the major industry participants realized that the prevalent technologies for manufacturing and characterizing multimode fiber were not adequate to support 10 Gb/s transmission to 300 m. To support the burgeoning 10G standards, as shown in Figure 4, the fiber industry developed a new 50 µm laser-optimized multimode fiber standard. These new fibers were designed to provide significantly higher bandwidth and maximize performance with 850 nm lasers.



(See Appendix E)
Fig 4: Application standards roadmap

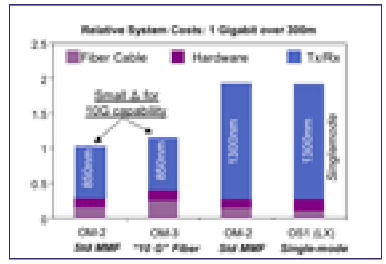
Additionally, the legacy bandwidth measurement metrics (designed for predicting performance with light emitting diodes, or LEDs) were not adequate to accurately characterize fiber performance at higher speeds with lasers. New measurement methods were developed and deployed in parallel with the new fiber standards. Overfilled Launch (OFL), which was developed in the 1980s to predict system performance, has given way to advanced laser-based bandwidth measurements (Restricted Mode Launch and Differential Mode Delay), see Figure 5.



(See Appendix F)
Fig 5: New measurement methods deployed with new fiber standards.

LOMMF (also known as OM3 or 10G) fiber is now the fastest growing segment of the market. As more consultants, system integrators, and end-users learn about the 10G standard, and increasingly deploy 1G to individual users, the need to ensure 10G-capable campus and building backbones drives increased acceptance. Corning now estimates that 10G fibers represent well over 10% of the worldwide multimode fiber market.

The economics of the decision to deploy advanced fibers are becoming increasingly accepted. As shown in Figure 6, for a very small incremental cost to the variable spend (total link costs minus switch chassis and labor), users can still enjoy significant savings over a single-mode solution, while also knowing that the newly installed network will support future network requirements.



(See Appendix G)
Fig 6:A comparison of relative system costs for 1 Gb over 300 m

Recently, fiber manufacturers have been offering even higher bandwidth fibers, extending the distance of 10G capability beyond 300 m at 850 nm. This trend further enhances the ability of end-users to take advantage of the significant cost savings by using 850 nm VCSELs. Additionally, enhanced bandwidth (beyond the standard required for 10G fibers), results in significant spare margin in the power budget. This spare margin can be counted on by the end-user to support additional passive connections in the initial installation or in the future. This additional margin is of particular interest to datacenter managers who typically do not need the higher bandwidth for link extension, but recognize its value as they deploy more robust and demanding systems. For a more detailed discussion on Engineered Links, see WP4253, The Evolution of 50/125 µm Fiber Since the Publication of IEEE 802.3ae on the Corning Optical Fiber website. As end-users continue to demand more of their networks, it is increasingly important to ensure the source of the fiber is consistent, reliable, capable and adheres to the highest measurement metrics recognized by standards.

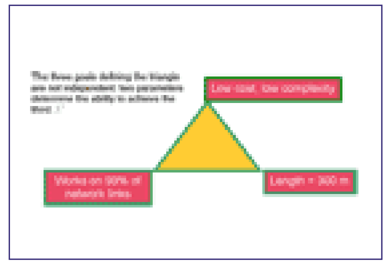
Single-mode fiber has made inroads into premises networks, primarily in campus backbones for links longer than 1000 m. Here the higher cost of multimode cable offsets the savings driven by low-cost optics. Some end-users like the idea of using single-mode fiber because of its simplicity and its theoretical “futureproofing”. LOMMF has full capability at 40G for all standardized deployment lengths, something that we expect IEEE to formally address some time in 2006/2007. Other end-users sometimes make the mistake of decoupling the purchase of their passive plant from purchases of the active electronics (transceivers). Certainly, when only accounting for cable costs, the single-mode fiber cable will typically be cheaper. However, as some find out only after laying their cable, this small cost differential is quickly dwarfed by expensive (anywhere between 2-4x pricing) single-mode transceiver modules. The most important lesson: end-users and their network planners need to consider the full cost of a network over at least 2-3 years before making decisions on cable type.

What’s Next?

The 10GBASE-LRM standard is scheduled for completion in 2006. The main drive of the LRM movement is to support 10G on the installed base of older, larger-core multimode fiber. The 10GBASE-LX4 standard is specified to support 300 m over the installed base of multimode fiber but is perceived to be complex, higher cost and may not support small form factor transceivers.

EDC (Electronic Dispersion Compensation) utilizes algorithms in the receive end of a transceiver set to clean up an otherwise unreadable signal (unreadable since it would be transmitted over fiber designed for 10M or 100M capability).

There are three competing forces (Figure 7) pulling at the core of the proposed standard: the solution must be relatively low cost (or otherwise there is no purpose for writing a new standard), the final solution should be capable to 300 m, and should work on 99% of the installed base. As of this publication, these three requirements are not possible, given the known defects on fibers deployed 10-20 years ago and longer.



(See Appendix H)
Fig 7: The three competing forces pulling at the core of the proposed standard.

Three options seem inevitable for the 10GBASE-LRM standard:

- LRM will be expensive (>LR)
- LRM link lengths will have to be de-rated below 300 m
- LRM will only support some portion of the installed base

Beyond 10G Ethernet: Although not a final answer, recent straw polls conducted in the Ethernet standards bodies point towards 40G (as opposed to 10G) as the next big effort (when and if LRM is completed). As stated above, we forecast that 10G fibers deployed today will be at least as capable (in regards to distance) as 40G. It is unclear what the final configuration of 40G solutions will be but the current generation of fibers will be capable.

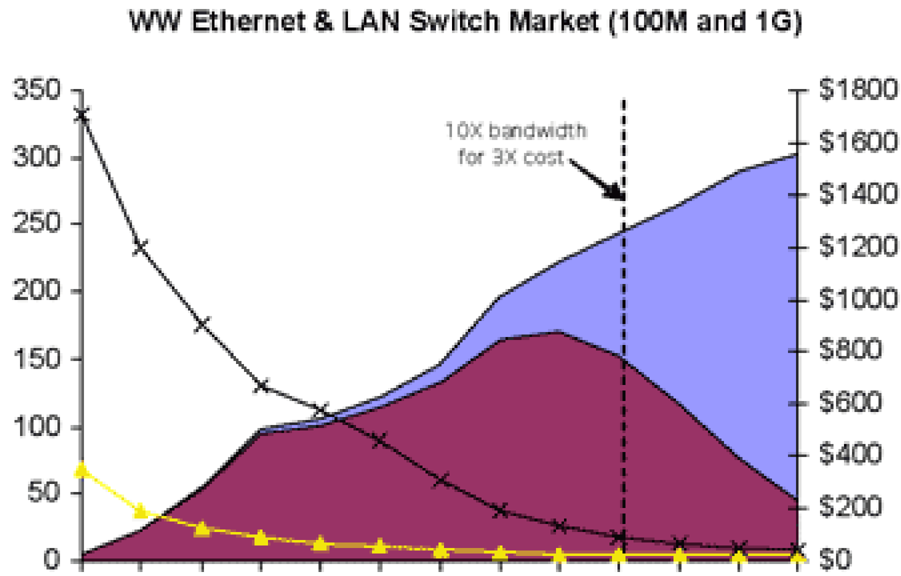
Multimode Fiber in Access: There has been a multimode fiber standard for access ever since the EFM (Ethernet in the first mile) standard was published. However, now that 1G has been widely deployed over multimode around the world, and has proven performance and significant cost advantage (over single-mode fiber), there is increasing interest in this solution from service providers and other FTTP players. Quite simply, if multimode provides such tremendous value (through 10G) in large commercial buildings, shouldn’t that value be reproducible in large residential buildings as well? We expect increased activity around this opportunity in the next 2-3 years, especially in regions with higher percentages of customers living in MDUs (multiple dwelling units).

10G Copper: The 10G copper standard is scheduled for completion in 2006, and some companies have been making pre-standard announcements of product availability for CAT-7 or augmented CAT-6 cables. New cables designed for 10G capability present significant challenges for manufactures and installers, including increased size, weight, power consumption, cooling requirements, and test procedures. Additionally, newer 10G copper connectors may reduce switch port densities, due to the size of the new connectors.

Summary

IT managers and premises network operators have always depended on multimode fiber to significantly lower network costs by choosing low-cost 850 nm VCSELs over higher priced single-mode lasers designed for metro/access applications. The multimode fiber industry continues to evolve with the increasing demands of enterprise networks. Advanced manufacturing processes and measurement/characterization techniques have enabled significant capability improvement, ensuring continued value creation for the 10G market and beyond.

Appendix A



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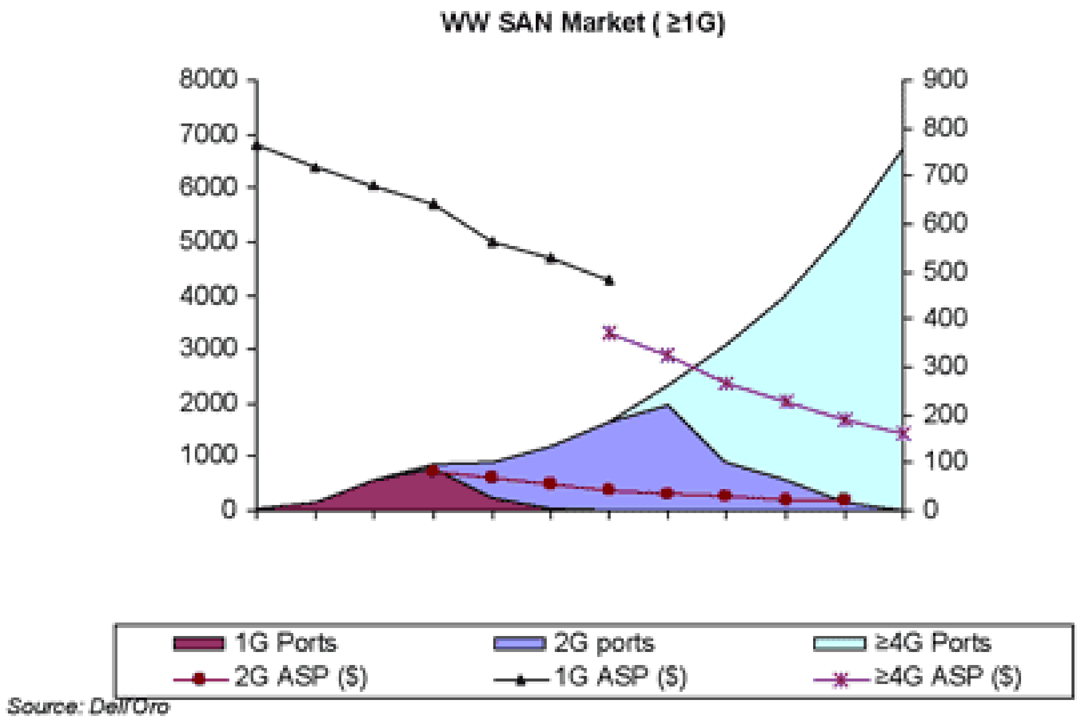

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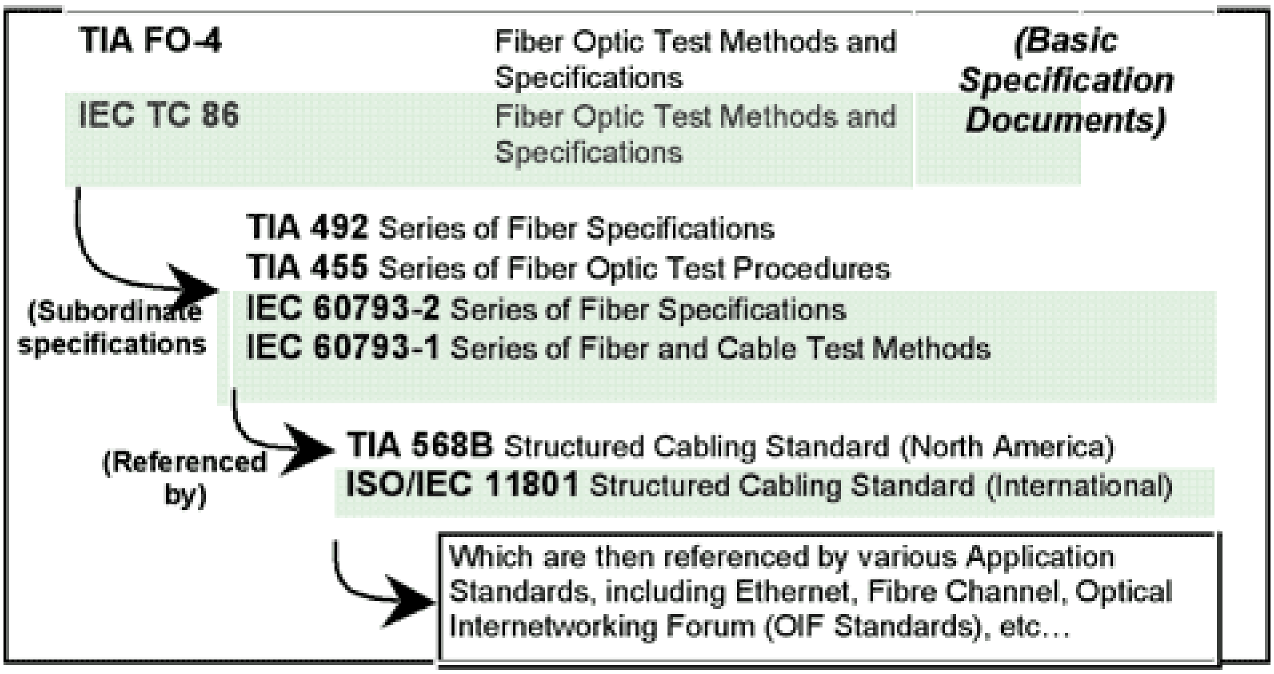
Appendix C

	850 nm VCSELs	1310 nm FP
Power Requirement	Low	High
Distance	Shorter – typically less than 2 km	Longer – up to 10 km
Spectral content	Narrow spectral width, stable center wavelength	Wider spectral width center wavelength drifts with temperature
Manufacturing process	Parallel testing, lower cost TOSA/ROSA components, ease of alignment for packaging	Individual (serial) testing + non-circular output beam = complex packaging process
Cost	$	$$$

Table 1: Two primary laser types used today for 1G applications

Appendix D



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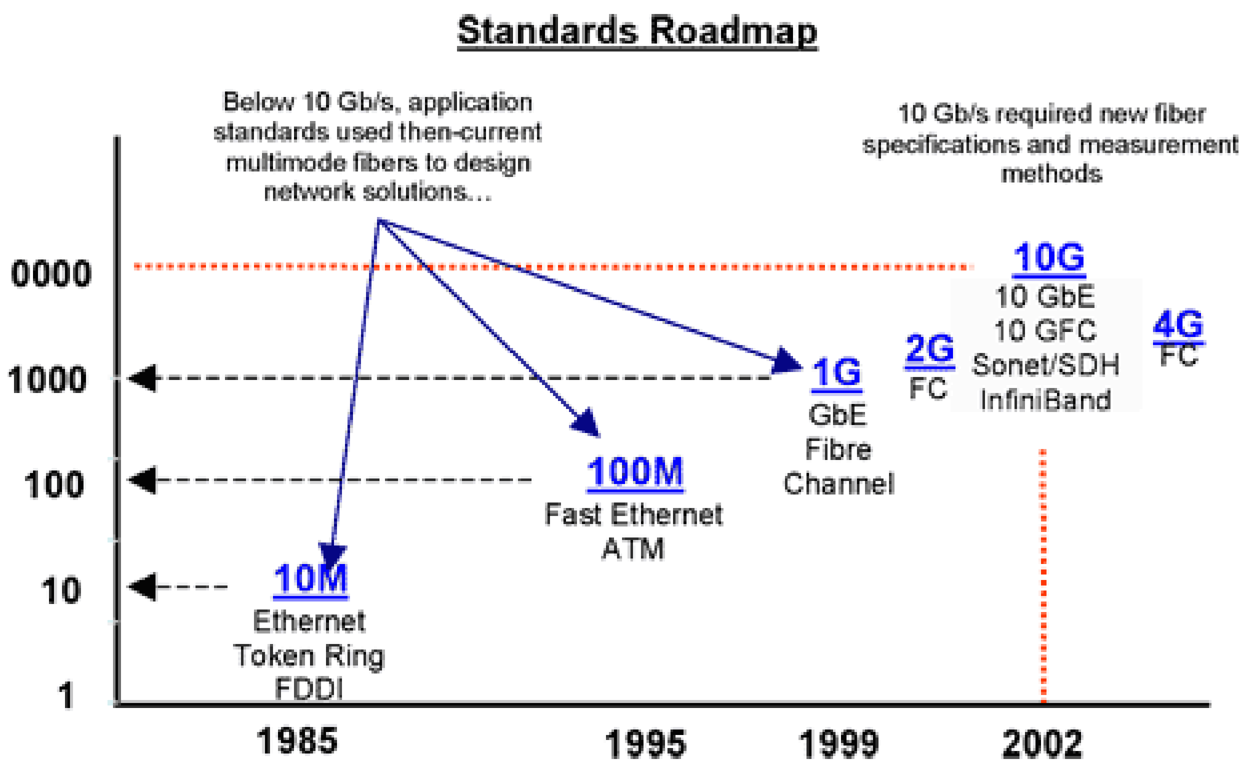
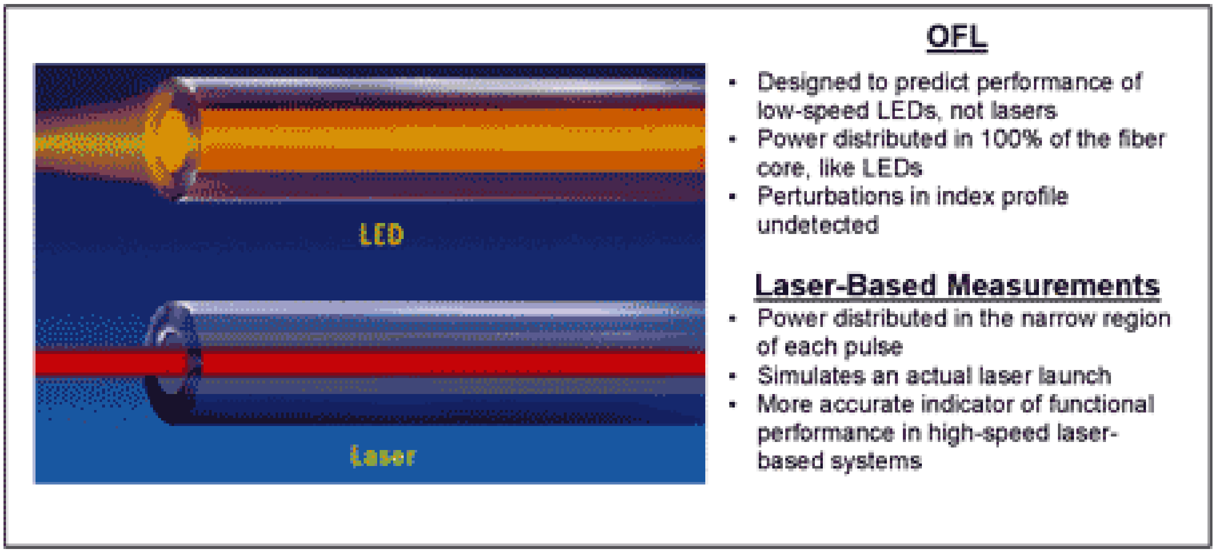


Figure 4: Application standards roadmap

Appendix F



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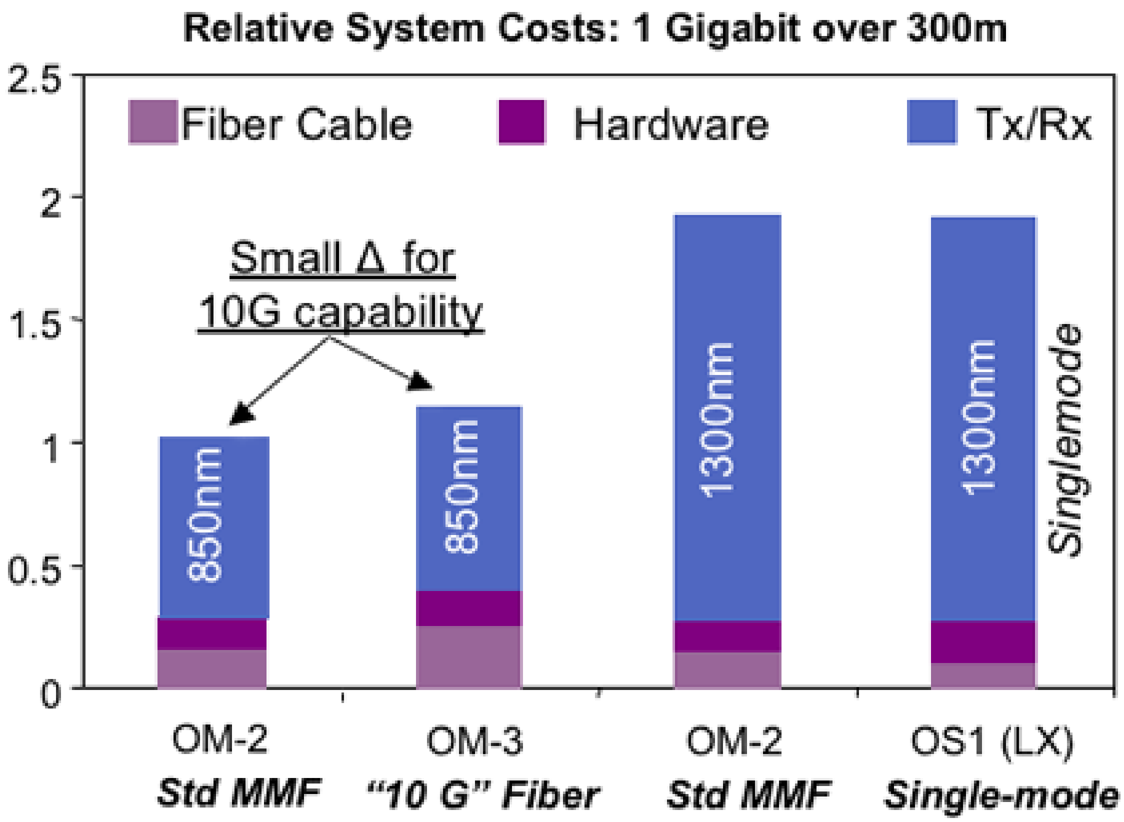
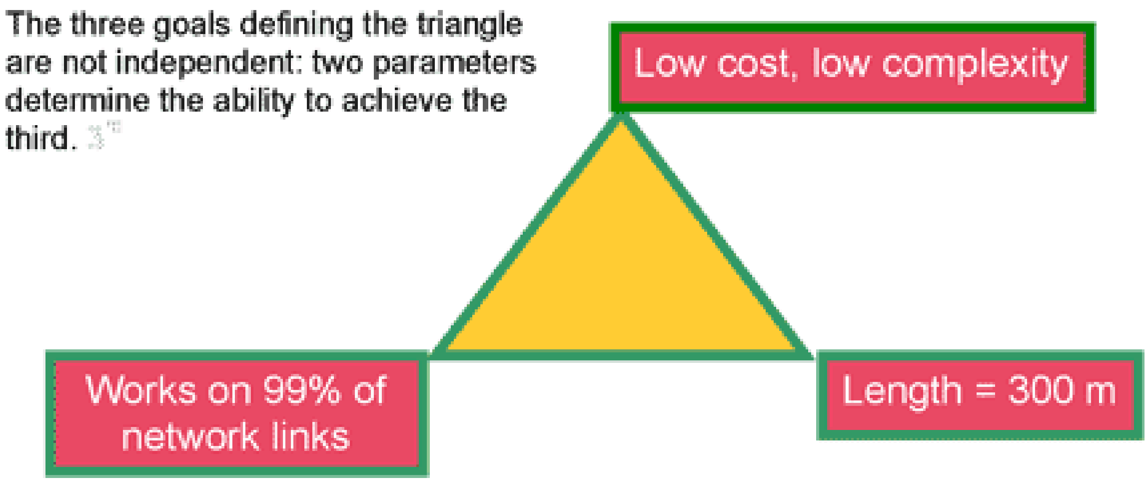


Figure 6: A comparison of relative system costs for 1 Gb over 300 m

Appendix H



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