



# WHY FIBER IN PREMISES NETWORKS?

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Over recent years, optical telecommunication technology has matured, while the performance requirements for premises networks have increased dramatically. The ever-increasing bandwidth requirements have driven significant increases in the cost of copper network systems, while technological maturity has led to relative declines in the cost of optical systems. In the light of these changes, the historical economic arguments against using fiber in the premises should be reexamined.

These days we demand increasingly higher performance from the premises network, but at the same time we expect “plug and play” installation, declining installation costs, and an increasing network lifecycle. Today the performance and cost advantages of optical fiber relative to copper technology in relation to modern premises networks applications are evident.

## Modern Networks Must Support Higher Data Rates

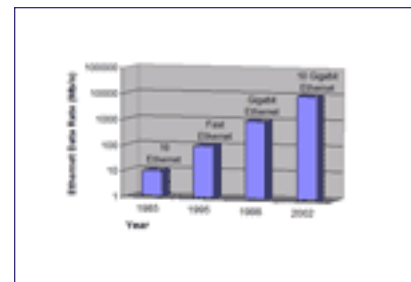
### *The Ethernet example: higher data rates*

In the 11 years from 1994 to 2005, the Ethernet revolution drove the progressive development of higher bandwidth Ethernet standards from 10 Mb/s to 10 Gb/s, as shown in *Figure 1*. The associated consumer demand for increasingly higher bandwidth premises networks forced concurrent development of copper and fiber cabling bandwidth capability.

## Modern Networks Must Have Higher Bandwidths

### *Higher bandwidth: multimode optical fiber has outlived four generations of copper cable*

Despite numerous upgrades to UTP copper cable, fiber bandwidth and reach capability have always remained significantly ahead of copper. In order to compare the relative capabilities of copper and fiber as transmission media, we must consider the bandwidth-distance product, given in MHz.km. *Figure 2* shows that in 1985, 50  $\mu$ m multimode optical fiber could support up to 500 MHz.km, which was equivalent to 500 Mb/s over a distance of 1000 m. UTP copper cabling of that era (Cat 3) could support less than 10 Mb/s over a maximum distance of 100 m, or 1 MHz.km. This comparison continues through 2005 with the proposed fourth upgrade of UTP



(See Appendix A)

**Figure 1:** During the years from 1994 to 2005, the Ethernet revolution drove bandwidth requirements for premises networks from 10 Mb/s to 10 Gb/s

(Cat 7). Very significantly, *Figure 2* shows (on a logarithmic scale) that one generation of multimode fiber has outlived four generations of UTP copper cabling.

## We Still Expect Simple Installation of the Network

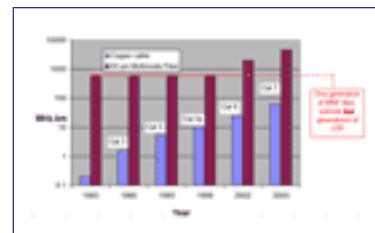
### *Certification testing of fiber is short and simple*

Optical fiber networks have, since their introduction in the 1980s, only been required to conform to one simple installation test procedure; link attenuation. Even in 1990, Cat 3 copper cables required four different test procedures before certification. As the bandwidth requirements have increased, certification testing of copper cabled networks has become more involved and more time-consuming. As shown in *Figure 3*, the new higher bandwidth Cat 5, Cat 5e and Cat 6 cables require 15 separate test procedures in order to achieve system certification. By contrast, optical fiber networks continue to need only to conform to one simple installation test procedure. Clearly this leads to far shorter testing times, and installation costs will be reduced accordingly.

### *Optical fiber installation is becoming a simple “plug and play” procedure*

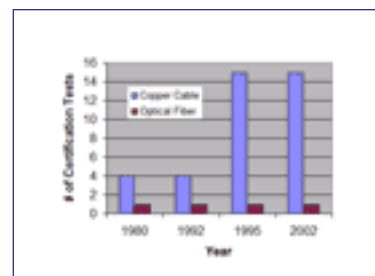
The new high bandwidth categories of UTP cable are becoming increasingly more difficult to terminate. In order to pass certification testing and to suppress noise from electrical cross-talk, Cat 5e and Cat 6 cabling now require the twists to be maintained to within 13 mm of the termination point. Considerable attention must also be paid to the compatibility of cable sections, connectors and termination components in order to avoid impedance mismatches.

As optical technology has matured and installation experience has increased, the termination of premises optical networks is becoming a simple “plug and play” procedure. New optical terminators like the Duplex LC, which terminates two fibers in a connector that snaps in like an RJ-45 phone jack, are replacing the traditional SC-type connectors. The Duplex LC is more user friendly, and being half the size of a SC connector while providing simple termination for two fibers, has doubled the port density of optical fiber systems. There are also higher density MPO connectors that provide connectivity for an array of 1 x 12 fibers.



(See Appendix B)

**Fig 2:** Comparison of evolution of relative bandwidth-reach (MHz.km) performance of copper cabling versus 50 µm multimode optical fiber over time.<sup>1</sup>



(See Appendix C)

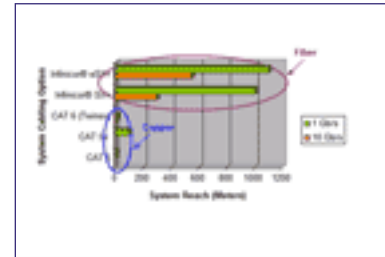
**Fig 3:** Copper networks require a far greater number of post-installation tests than optical networks. High data rate copper networks now require 15 separate tests to achieve system certification.

1. After Cat 3, copper cabling underwent four upgrades (Cat 5, Cat 5e, Cat 6 and Cat 6e) from 1994 to 2005, and a fourth upgrade (Cat 7) is now under consideration. During the same time, optical fiber underwent only one upgrade, when in the year 2002, MMF upgraded from LED-optimized to laser-optimized fiber, which now offers a bandwidth of 10 Gb/s over up to 550 m or up to 4.7 Gb/s over 1 km (4700 MHz.km). Cat 6e, the nearest competitor to laser-optimized MMF, can only offer 10 Gb/s over 100 m or ~500 MHz.km.

## Modern Premises Networks Must be Flexible and Future-proof

### *Superior reach and flexibility*

The premises network of today must have the flexibility to provide for current network needs while having the capability to facilitate the upgrades and extensions that may be required in the future, without re-cabling. *Figure 4* illustrates that for 1 Gb/s and 10 Gb/s systems, copper cabling can severely restrict the distance capabilities of a premises network. The greater-bandwidth reach capability of optical fiber translates into a greater distance capability for any given data rate. Laser-optimized fibers will provide premises network connectivity at 1 Gb/s and 10 Gb/s out to 1100 m and 550 m, respectively. The Cat 5 standards for UTP copper-based premises cable systems (TIA/EIA-568-A) provide for a maximum of 100 m reach at 1 Gb/s and Cat 6 provides for only 5 m reach at 10 Gb/s. In addition, the cable for the 10 Gb/s copper solution cannot be easily field terminated.



(See Appendix D)

**Fig 4:** Premises network reach limitation as a function of cable selection and data rate

When installed in non-environmentally controlled areas, the distance capability of copper cables can be further reduced, as elevated temperatures ( $>20^{\circ}\text{C}$ ) distort electrical properties such as insertion loss (attenuation due to increased electrical resistance). By contrast, laser optimized optical fiber systems are relatively temperature insensitive and hence have the flexibility to be installed in such adverse environments.

For many office blocks, the distance from the main equipment room to individual work stations will exceed a copper network's upper distance limit of 100 m. Consequently, copper cabling systems will need extra office space and power to locate and drive the electronics in the additional TR rooms required to increase the system reach. This further reduces the flexibility of high data rate copper network architectures.

## Modern Networks Must Have High Reliability and High Security

Network reliability and security is of utmost importance in modern telecommunication systems. System downtime must be avoided as network maintenance increases the operating costs (OPEX). Network security must be guaranteed, as increasing levels of sensitive information are transferred over intranets and the Internet.

### *Dielectric properties and EMI immunity provide high reliability*

It is estimated that 60 percent of all copper-based network outages are caused by faults in cabling and cabling-related products. Copper facilities, unlike fiber, are not dielectric and so can conduct stray electrical currents and lightning strikes that can damage sensitive electronic transmission equipment. Susceptibility to electro-magnetic interference (EMI), cross-talk and impedance mismatching are other major factors that cause noise and errors in copper systems. EMI radiating from power, radio and microwave sources can couple into copper cables, creating network errors that

result in downtime. Cross-talk originates from EMI. The signal-carrying copper cables themselves radiate electromagnetic energy, which, when picked by adjacent copper cable, results in cross-talk (also known as alien cross-talk). Copper connectors can also introduce cross-talk — near-end cross talk (NEXT) or far-end cross talk (FEXT). This interference is especially pronounced when full duplex traffic is being carried, as is the case in practically all GBE over copper applications. Impedance mismatching occurs mainly at patch panels and telecommunications outlets and results in a significant portion of the signal being reflected back to the receiver and resulting in severe signal attenuation. EMI, cross-talk and impedance mismatching are factors that are often exacerbated by poor installation, but their effects can also be augmented by changing environmental conditions or cable disturbance. For copper cables carrying 10 GBE signals, the high power levels in the cables mean that alien crosstalk becomes a significant issue. Optical fiber carries light rather than electricity and so it is not affected by EMI, cross-talk or impedance mismatching. Optical fiber cable therefore offers much greater reliability and, in addition, has the capability to operate without concern at 10 Gb/s and also in adverse environments where there are high levels of electrical noise, such as factory floors, close to power lines or fluorescent lights. While copper cable will be designed to offset these factors, users will lose design flexibility and “real estate” in the more dense areas of the network.

#### *EMI immunity provides high network security*

The electromagnetic properties of copper cabling can also have an adverse impact on the security of UTP copper networks. In this increasingly data-driven world, the security of information is of prime concern for the private individual as well as for large corporations. The electromagnetic energy inherently radiated by copper cables can be picked up in a metal-based conductor without any interference to the transmitted signal. Hence, with the appropriate technology, unprotected UTP cables can be tapped and therefore present a security risk. By contrast optical fibers cannot be tapped without interrupting the transmitted signal and therefore offer much greater levels of security.

### **For Optical Fiber Networks This All Leads to Network Cost Savings**

Over the lifetime of a premises network the inherent costs that need to be considered include both the installation costs and the lifetime running costs of the network as detailed below:

- Capital expenditure (Capex)
  - Cabling and components, such as wall outlets, patch panels, patch cords & connectors
  - Electronic equipment, including switches, routers and network interface cards
  - Office space for equipment location
  - Labor costs for installation and testing the system
- Operating expenditure (Opex)
  - Power supply and environmental control
  - Downtime, including costs to repair and cost of impact on productivity
  - Network management, including costs of network changes
  - Recabling associated with network upgrades to enable higher bandwidth

### *Installation costs of high-data-rate optical and copper networks are reaching parity*

In the early days of optical premises networks, the cost of optical-to-electronic (O-E-O) conversion was prohibitively high, often making copper networks a more attractive solution. Advances in fiber technology and the economies of scale associated with higher fiber and photonic component production volumes have pushed the cost of fiber and its associated system components down to new competitive pricing levels. In the interim, optical fiber systems have been demonstrated to require less office space and have lower power requirements. Concurrently, premises network data rate requirements have increased from 10 Mb/s to 10 Gb/s in the years since 1995. In the 1980s, when commercial optical fiber-based premises network systems first became available, copper systems could readily deliver the necessary bandwidth and distance capabilities. By contrast, the new higher bandwidth demands of today's gigabit Ethernet (GbE) and 10 gigabit Ethernet (10 GbE) premises networks place a great strain on the performance capabilities of unshielded twisted pair (UTP) copper cabling, resulting in higher UTP cable manufacturing costs and lengthy installation test procedures. As a result, UTP cable and installation costs have risen significantly, such that the cost of installation of modern high bandwidth copper-based premises networks are now at parity with the cost of installing an equivalent optical fiber network.

### *Optical fiber networks enable much lower operational costs than copper networks*

Optical fiber systems need less environmental control in the duct space and — due to their superior reach — need less equipment located in the telecommunications room. As a consequence, optical systems enable significantly reduced power consumption. In addition, the higher reliability of optical networks gained through their dielectric properties and associated EMI immunity yields further significant operational savings.

### *Optical fiber networks facilitate lower cost network management*

Flexibility is the key to the design of modern data centers, and enhanced flexibility enables savings in network management time. Data centers need to rapidly adapt to changing network requirements, facilitating higher data rates, enabling new connections, and bringing servers online or off-line with the minimum of delay. The cables carrying optical fiber are so slim that during initial installation many surplus fibers can be provisioned in order to facilitate rapid future network changes.

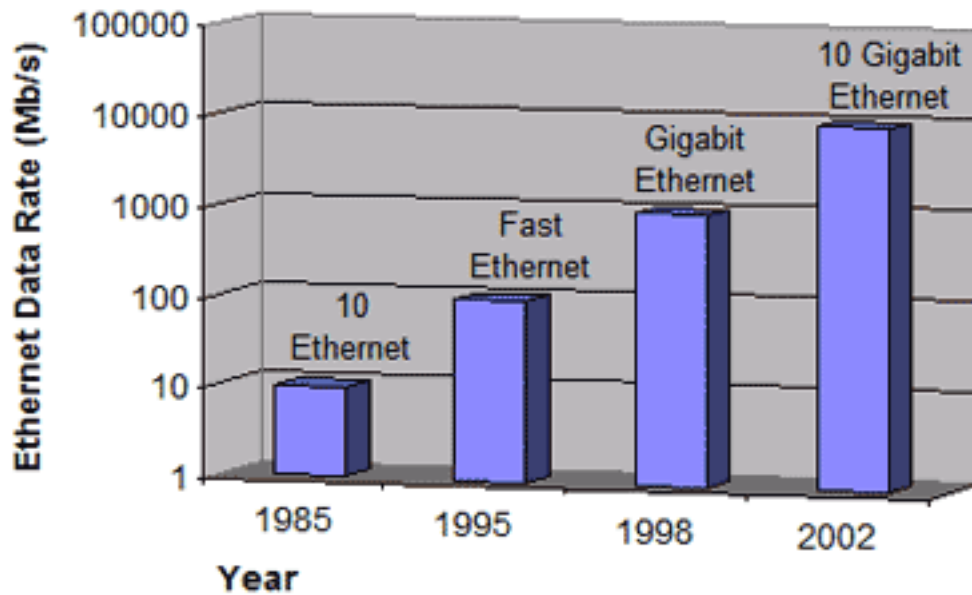
Network upgrades are the most significant operating cost. As illustrated in *Figure 2*, the lifecycle of optical fiber is far greater than that of copper networks. Over the years this feature has yielded great cost savings for premises optical fiber network managers as fiber performance has kept pace with the bandwidth requirements of the Ethernet revolution, while copper networks have required numerous stages of recabling in order to enable increasing data rates.

If we consider operating costs as well as the capital expenditure associated with initial network installation, the total installed lifetime cost of fiber will be much less than that of copper. Further, more detailed, information on the relative costs of fiber and copper networks is given in the cost model prepared by the Fiber Optics LAN Section (FOLS) of the Telecommunications Industry Association (TIA) ([www.fols.org/resources](http://www.fols.org/resources)).

## Conclusion

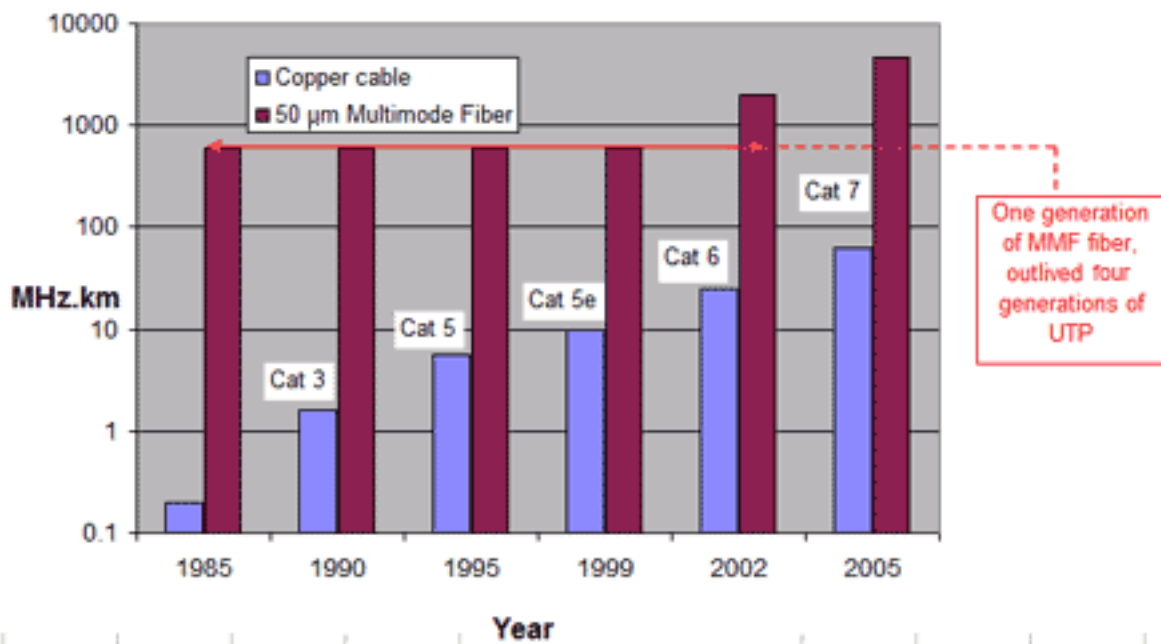
It is widely accepted that optical fiber premises networks offer much greater bandwidth and reach capabilities over UTP copper alternatives. There are several examples that illustrate the enhanced performance capabilities of optical fiber lead to network cost savings in terms of reduced installation and operating costs. As the relentlessly rising bandwidth demands of the Ethernet revolution continue, the installation and maintenance costs of UTP cabling have increased significantly, such that it has become more cost-effective to deploy optical rather than copper networks in high data rate premises systems.

## Appendix A



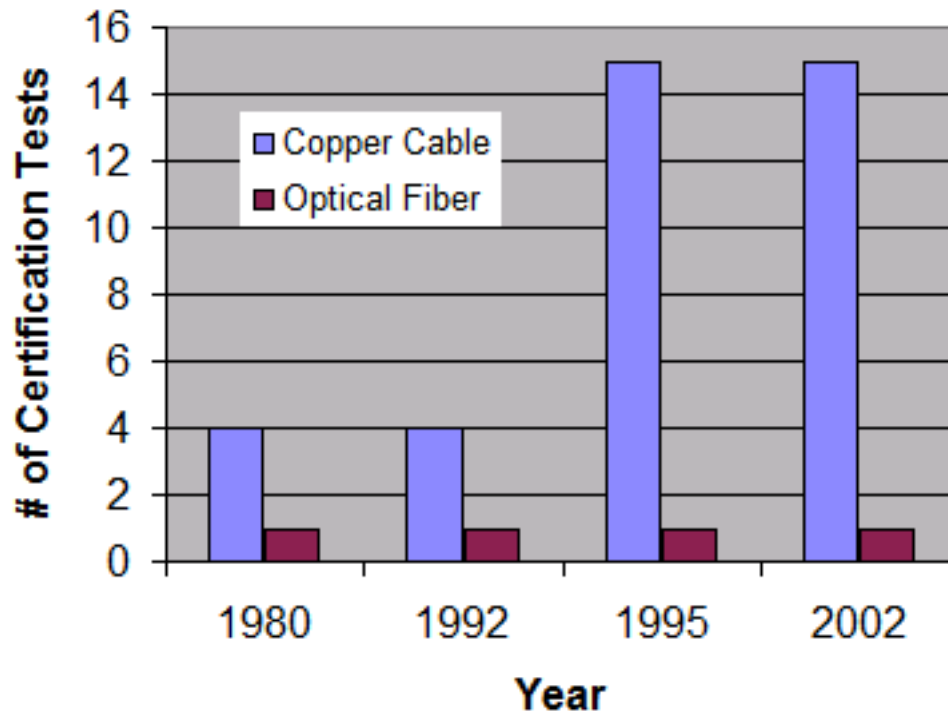
**Figure 1:** During the years from 1994 to 2005, the Ethernet revolution drove bandwidth requirements for premises networks from 10 Mb/s to 10 Gb/s

## Appendix B



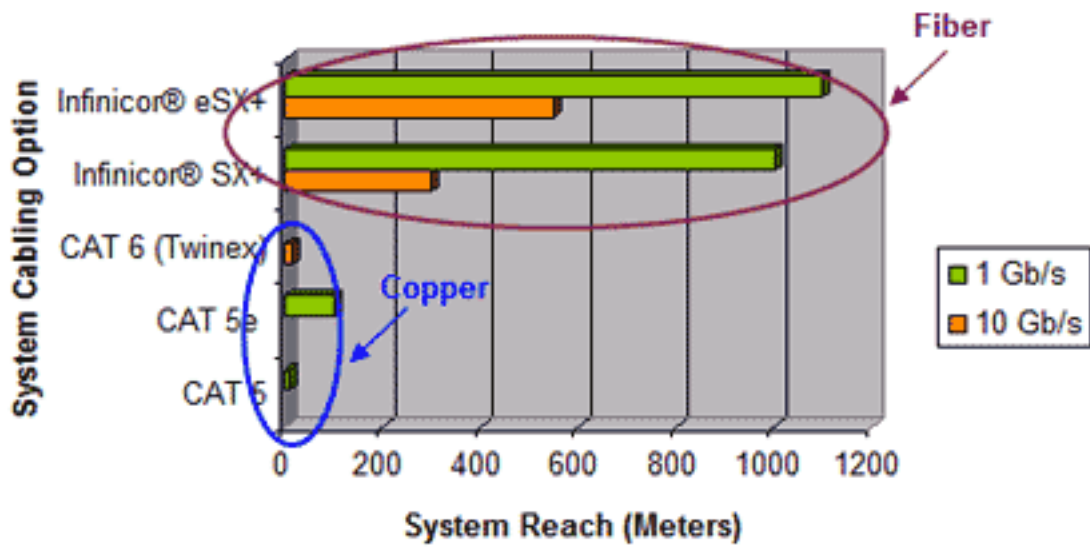
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## Appendix C



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## Appendix D



**Fig 4:** Premises network reach limitation as a function of cable selection and data rate.