

## Introduction

Several developments in the telecommunication environment in South Africa and the surrounding region are expected to boost the development of Information and Communication Technology (ICT) infrastructure, boost bandwidth usage and improve access networks to the end users.

The liberalization of the Industry includes the licensing of a second network operator, Neotel, and the imminent conversion of some Value Added Network Services licenses (VANS) to Electronic Communication Network Services (ECNS) licenses. ECNS licensees are expected to “self provision” or deploy their own telecommunication infrastructure, thereby providing the much anticipated competition against the incumbent telecommunication companies. Any access networks that will by-pass Telkom’s network will result in price pressure on Telkom’s ADSL (Asymmetric Digital Subscriber Lines) services which are currently the most expensive in the world. In the next couple of years, more South African premises are expected to have access to less expensive broadband services, including data and Voice over Internet Protocol (VoIP). Furthermore, several planned undersea projects such as the East Africa Submarine System (EASSy) and The East Africa Marine Systems (TEAMS) will provide competition to SAT-3 and result in lower cost of International bandwidth which is currently among the highest and beyond the reach of most service providers.

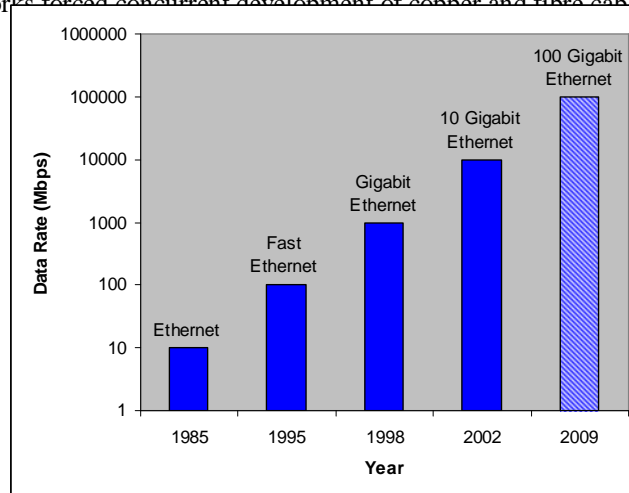
For those considering deploying or upgrading premises networks such as in office parks, multi-dwelling units and gated communities it is imperative to deploy technologies today that will be commensurate with tomorrow’s bandwidth requirements. Optical telecommunication has proved to be the most future proof technology for increasing bandwidth demands. It has been demonstrated in more developed parts of the world, that 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 light of these changes, optical networks are becoming the most suitable technologies for growing bandwidth requirements.

Tomorrow, increasingly higher performance from the premises network will be demanded, but at the same time simple installation, reduced installation costs, and a long network lifecycle will be required. This article will explore the performance and cost advantages of optical fibre relative to copper in relation to modern premises network applications.

## Modern networks are expected to support higher data rates

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

In the 12 years from 1994 to 2006, the Ethernet revolution drove the progressive development of higher bandwidth Ethernet standards from 10 Mb/s to 10 Gb/s and now 100 Gb/s solutions are being developed with a standard expected in approximately late 2009 as shown in Figure 1. The associated consumer demand for increasingly higher bandwidth premises networks forced concurrent development of copper and fibre cabling bandwidth capability.

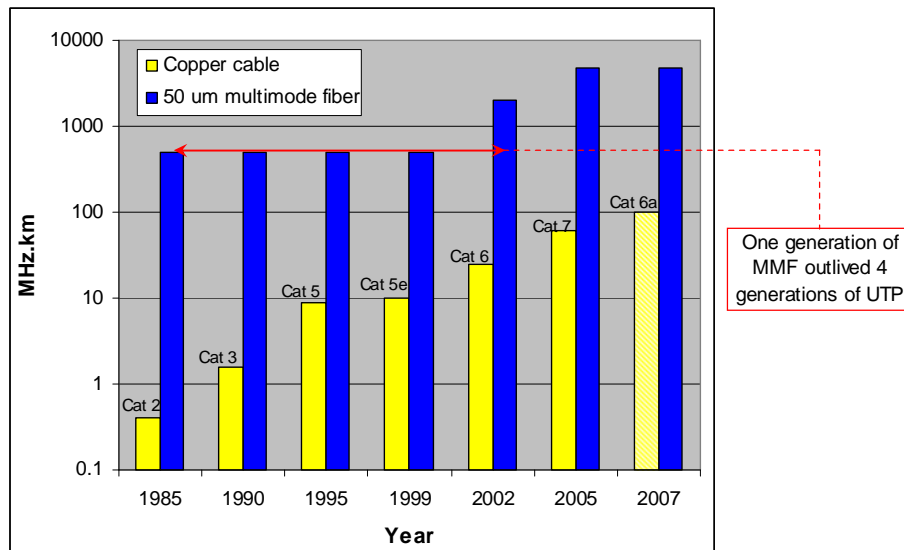


**Figure 1: During the years from 1994 to 2006 the Ethernet revolution drove bandwidth requirements for premises networks from 10 Mb/s to 10 Gb/s.**

## Modern networks require higher bandwidths

### *Higher bandwidth: multimode optical fibre outlived 4 generations of copper cable*

Despite numerous upgrades to unshielded twisted pair (UTP) copper cable, fibre bandwidth and reach capability has always remained significantly ahead of copper. In order to compare the relative performance of copper and fibre as transmission media for premises network, we consider the bandwidth-distance product, given in MHz.km. Figure 2 shows that in 1985, 50 µm multimode optical fibre could support up to 500 MHz.km, which supports 1Gb/s over 550m. UTP copper cabling of that era (Cat 2) could support 4 Mb/s over a maximum distance of < 100 m, or < 1 MHz.km. This comparison continues into 2007 with the proposed and as yet non-standardized fifth upgrade of UTP (Cat 6a). Cat 7 is a bulkier, shielded twisted pair (STP) copper cable that is available today and provides marginally greater bandwidth-distance capability than Cat 6 UTP cable but otherwise experiences many of the same problems as UTP cable. Figure 2 shows that one generation of multimode fibre continues to outlive all generations of UTP copper cable despite the introduction of higher bandwidth OM3 fiber for multi-Gigabit/s applications.



**Figure 2: Relative performance evolution (in log scale) of copper cable vs. 50 µm multimode fibre.<sup>1</sup>**

## We still expect simple installation of the network

### *Optical fibre installation is now a simple “plug and play” procedure*

Newer categories of UTP cable are becoming increasingly more difficult to install and test. In order to pass certification, electrical cross-talk and noise from neighboring cabling must be minimized. Cat 5e and Cat 6 installations need greater care and attention to routing with increased cable separation and avoidance of tight bends, both of which result in the need for more space. Care must also be taken not to use excessive pulling force causing the stranded wires to untwist, which must be maintained to within 13 mm of the termination point to prevent transmission degradation. Considerable attention must also be paid to the compatibility of cable sections, connectors

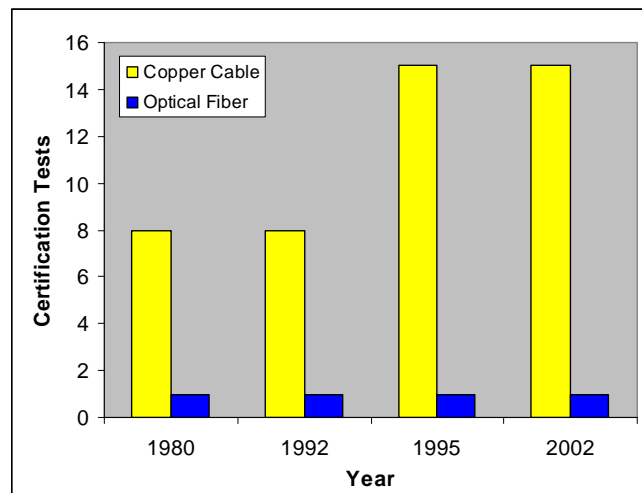
<sup>1</sup> After Cat3, copper cabling underwent four significant upgrades (Cat 5, Cat 5e, Cat 6 and Cat 7) from 1994 to 2005, and a fifth upgrade (Cat 6a) is now under consideration. During the same time, optical fibre underwent only one upgrade, when in the year 2002, MMF upgraded from LED optimized to laser optimized fibre which now offers a bandwidth of 10 Gb/s over up to 550m or up to 4.7 Gb/s over 1km (4700 MHz.km). Cat 6, the nearest approved UTP competitor to laser optimized MMF, provides performance up to 250 MHz over a maximum distance of 100 m.

and termination components in order to avoid impedance mismatches. This increased complexity often leads to longer installation times and higher costs.

As optical technology has matured and installation experience has increased, the termination of premises optical networks is now a simple “plug and play” procedure. New optical connectors like the Duplex LC, which terminates two fibres (send and receive) simultaneously in a connector that clicks into position like an RJ-45 phone jack, are replacing the traditional SC-type connectors. Duplex LC connectors are more user friendly, and being half the size of an SC connector, have doubled the port density capability of optical fibre systems. There are also higher density multiple termination push-on (MTP or MPO) connectors that provide connectivity for ribbon type fibres ranging in count from 2 to 72 fibres, offering even simpler and faster installation.

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

Optical fibre networks have, since their introduction in the 1980s, only been required to conform to one simple installation test procedure - link insertion loss. Even in 1990, Cat 3 copper cables were required to pass 8 different test procedures before full certification. As data rates have increased, the limited bandwidth capability of copper cable technology means that installations are more sensitive to sources of electrical interference and noise because the signal impedance of copper cables increases rapidly at higher frequencies. This has led to further complexity in copper cable test certification. Cat 5, Cat 5e and Cat 6 cables require 15 separate test procedures in order to achieve system certification. By contrast, optical fibre networks of all types (single-mode and all grades of multimode) still only need to conform to one simple installation test procedure. This leads to far shorter testing times, resulting in correspondingly reduced installation costs.

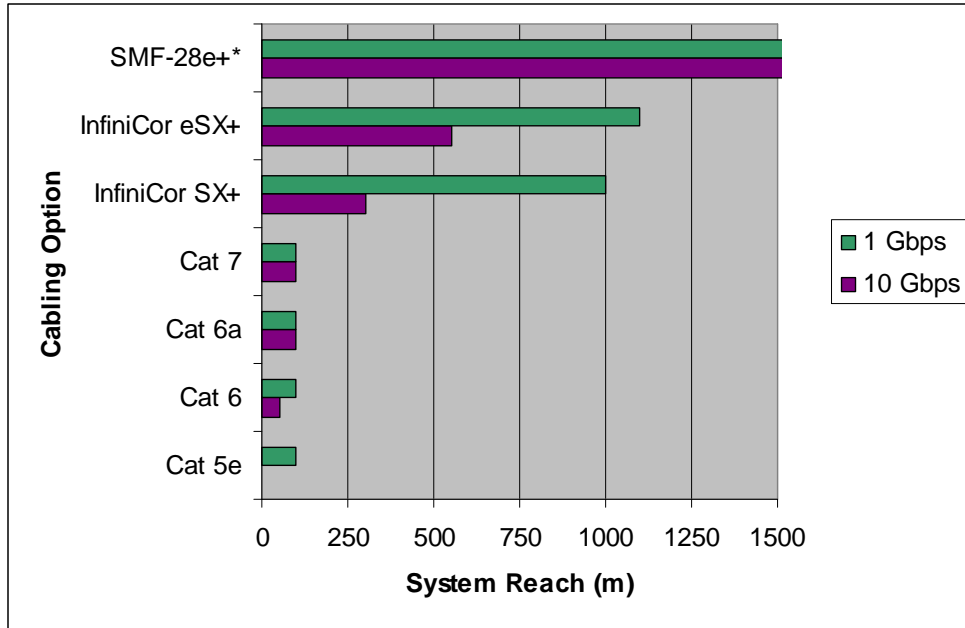


**Figure 3 Copper networks require significantly more post-installation tests than optical networks.**

## **Modern premises networks must be flexible and future-proof**

### ***Superior reach and flexibility with fibre***

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 fibre translates into a greater distance capability for any given data rate. Laser-optimized fibres, such as Corning’s InfiniCor® SX+ fibre and InfiniCor® eSX+ fibre, 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 (TIA/EIA-568-B) provides for only 55 m reach at 10 Gb/s.



\* Corning® SMF-28e+™ fiber can provide a system reach of between 2 km and 140 km, depending upon the transceiver used

**Figure 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 °C) distort electrical properties such as insertion loss (attenuation due to increased electrical resistance). By contrast, laser-optimized optical fibre 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 telecommunications rooms (TR) that are required to increase the system reach. This further reduces the flexibility of high data rate copper network architectures.

### **Modern networks demand high reliability and high security**

Network reliability and security is of utmost importance in modern telecommunication systems. System downtime must be avoided as this not only adds to network maintenance costs but also results in lost business transactions for data centers and other private networks. Network security must be guaranteed, as increasing levels of sensitive information are transferred over intranets and the internet and may also be subject to legislative requirements for data protection.

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

It is estimated that sixty percent of all copper-based network outages are caused by faults in cabling and cabling related products. Copper transceivers, unlike fibre, are not dielectrically connected and so can conduct stray electrical currents caused by lightning strikes or power surges which can damage sensitive electronic digital signal processing (DSP) components. Susceptibility to electro-magnetic interference (EMI), cross-talk and impedance mismatching are other major factors which 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 or far-end cross talk). This interference is especially pronounced when full duplex traffic is being carried, as is the case in practically all gigabit Ethernet (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, 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 needed to overcome the high impedance at high frequencies in the cables means that alien crosstalk becomes a significant issue. Optical fibre carries light rather than electricity and so it is not affected by EMI, cross-talk or impedance mismatching. Optical fibre 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, or areas close to power lines or fluorescent lights.

#### ***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 detected 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 fibres cannot be tapped without interrupting the transmitted signal and therefore offer much greater levels of security.

#### **For optical fibre networks this equals 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
  - 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
  - Energy costs, power supply and environmental control
  - Downtime; including costs to repair and cost of impact on productivity
  - Network management: including costs of network changes
  - Re-cabling 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 additional cost of optical transceivers and media converters (for optical to electronic conversion) was prohibitively high, often making copper networks a more attractive solution. Advances in fibre technology and the economies of scale associated with higher fibre and photonic component production volumes have pushed the cost of fibre and its associated system components down to new competitive pricing levels. In the interim, optical fibre systems have been demonstrated to require less office space and have lower power requirements. Copper systems require power of 10-15 watts/port vs. the 1-2 watts/port required for optical systems. Because of the increased power requirements for copper systems, port densities are limited to 4-6 ports/card as compared to 48 ports/card for SFP+ transceiver optical systems. 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 fibre 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 and ten gigabit Ethernet premises networks place a great strain on the performance capabilities of UTP copper cabling, resulting in higher UTP cable manufacture costs and lengthy installation test procedures. As a result, UTP cable and installation costs have risen such that the cost of installation of modern high bandwidth copper based premises networks is now at parity with the cost of installing an equivalent optical fibre network.

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

Optical fibre systems need less environmental control in the duct space and due to their superior reach, need less equipment located in the TR. As a consequence, optical systems enable significantly reduced power consumption and lower energy use. In contrast, the high impedance of copper cables, particularly at 10 Gb/s when DSP is also required, means that the transmitted signal power levels needed to communicate are much greater than those of fibre, which has significantly lower attenuation. In high density applications, this power usage is significant, not

only in consumption but also in the generation of heat, which requires cooling to protect transmission equipment from rising temperatures. More power consumption requires greater cooling and humidity control which increases running costs and overhead costs of un-interruptible power supply (UPS) systems and back-up power supplies. The increased port density capabilities available with fibre systems also result in decreased space requirements, which can be a significant operational cost, particularly for data centers located in regions with expensive lease rates. In addition, the higher reliability of optical networks, gained through their dielectric properties and associated EMI immunity, yields further significant operational savings.

### ***Optical fibre 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 minimum delay. The cables carrying optical fibre are so slim that during initial installation many surplus fibres can be provisioned in order to facilitate rapid future network changes with congesting cable pathways and preserving greater airflow for cooling of electronics.

Network upgrades are the most significant operating cost. As illustrated in Figure 2, the lifecycle of optical fibre is far greater than that of copper networks. Over the years this feature has yielded great cost savings for premises optical fibre network managers as fibre performance has kept pace with the bandwidth requirements of the Ethernet revolution, while at the same time copper networks have required numerous stages of re-cabling 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 fibre is much less than that of copper. Further, more detailed information on the relative costs of fibre and copper networks is given in the cost model prepared by the Fibre Optic 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 fibre premises networks offer much greater bandwidth and reach capabilities over UTP copper alternatives. In this paper we have illustrated that the enhanced performance capabilities of optical fibre 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.