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Novel technologies used in the development of optic fiber networking components and its advances

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Abstract—The work presented in this paper gives a brief review about the optical networking technologies & the applications. Further, a novel method of improving the capability of the optical networking is also presented. The work done in this paper shows the efficacy of the methods developed. This is a brief survey paper on optic fiber networks.

***Keywords* —** Optical networks, TCP IP, VPN.

INTRODUCTION

The transmission of IP data is becoming more and more important for Telecom operators. Recently proposed new solutions like IP over WDM need to be analysed and tested. Networking and management aspects of using IP technology on an Optical Network were studied in the EURESCOM project P918. Project P1014 TWIN ('Testing WDM IP Networks') set out to experimentally test different protocol stack solutions, compare and evaluate them against each other and prove that they work as described. A key focal area of P1014 TWIN is the interoperability between the different protocols, and also between different vendor realisations. The project restricts its study to the 3 IP over WDM network scenarios found the most promising by the study

1. IP over SDH over WDM, whereby SDH is used for point to point connection;

2. IP over DPT over WDM, in which Dynamic Packet Transport DPT is a new layer 2 switching proposed by Cisco for a flexible IP transport network;

3. IP over Gigabit Ethernet over WDM – in this scenario a new end to end Ethernet solution is considered.

Expected results of P1014 TWIN should give EURESCOM shareholders guidelines and network engineering rules for near and medium term IP/WDM network deployments.

OPTICAL NETWORKS

In today's telecommunication networks, there is a strong movement towards transport of high capacity, high bitrate, and increasingly dense data traffic over the Internet. According to a Berkeley study [1], the yearly growth of digital information is 50%. Thus, the Internet growth is not limited to number of users; the quantity of information transmitted is also increasing rapidly. As a reaction, leading carriers and several service providers have deployed optical technology to increase capacity in long-distance networks and in a variety of enterprise networks. Furthermore, new systems to be implemented offer not only more bandwidth but also support other than voice telephony technologies, like Ethernet, ATM and Internet Protocol (IP). IP is widely described as the chosen protocol to deliver tomorrow's services over optical networks, like Voice over IP

(VOIP) OR IP VIRTUAL PRIVATE NETWORKS (VPN)

Their capacity demands range from several kbps to many Mbps. IP over ATM/SDH/WDM is widely used in today's backbone networks. ATM is based on well-established standards. It supports rich traffic engineering functionality and is able to provide CoS and QoS. However, ATM's features do not seem to satisfy upcoming requirements on backbone networks. ATM's high complexity and the price tag coming with it, the cell tax, the limited scalability in terms of interface bandwidth and the high level of functionality redundancy that requires close co-ordination between the layers (e.g. protection & restoration) are all critical issues. Reducing the number of protocol layers and removing functionality in intermediate layers is expected to solve many problems and reduce costs. This comes partly at the expense of granularity, flexibility, and bandwidth manageability.

OVERVIEW OF THREE TECHNOLOGIES TO TRANSPORT IP TRAFFIC - PACKET OVER SDH/SONET (POS)

Packet over SDH/SONET is a standard based (RFC 2615 [5] and 1662 [6]) transmission method that enables to send native IP packets across standard SONET/SDH transmission equipment. Packet over SDH/SONET (POS) uses standardized mapping of IP into SDH using point-to-point protocol (PPP) and high-level data link control (HDLC) as defined by IETF. The main function of HDLC is to delineate the PPP-encapsulated IP datagrams across the synchronous transport link.

POS does not use the multiplexing function of SDH. Linking multiple containers together results in a single container into which the payload is mapped, providing higher interface rates. This mapping is also referred to as a "concatenated" SDH payload (e.g. STM-4-4c). Packet over SDH/SONET provides a point-to-point full duplex connection between two router interfaces, using SDH framing. Scalability is not a problem: interworking between SDH and WDM system is excellent and there is no intrinsic limit to the number of nodes. POS is a sound solution for realising efficient high-speed router connections. Based on SDH, POS may be

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seamlessly integrated in existing backbone networks, since there are no interworking issues with physical interfaces. In terms of signal processing within SDH nodes, POS signals are different from nonconcatenated SDH frames. If the POS signal is processed by SDH nodes (for instance DXCs) not capable to handle concatenated signals, the operator will face interworking issues. POS seems especially attractive in combination with Multi-Protocol Label Switching (MPLS).

GIGABIT ETHERNET (GBE) & 10 GB ETHERNET (10 GBE)

Gigabit Ethernet [7] utilizes the same frame format as 10 Mbit/s Ethernet and 100 Mbit/s Fast Ethernet. In an IP backbone only full-duplex operation with flow control is relevant. As 8/10B encoding is used, the link rate for Gigabit Ethernet is 1.25 Gbit/s. Switching and forwarding of frames between all types of Ethernet networks are simplified because no fields in the frame need to be changed. In an optical/WDM transport network, Gigabit Ethernet is only used for framing on point-to-point connections between IP routers with Gigabit Ethernet interfaces. Gigabit Ethernet was developed and is highly suitable for high-speed LAN environments.

The main driver for Gigabit Ethernet is its low cost. Gigabit Ethernet line cards are cheaper than equivalent SDH line cards. Gigabit Ethernet's weak point is its high overhead. However, if we also consider availability and cost, Gigabit Ethernet framing seems very interesting for WAN environments as well. Gigabit Ethernet used for framing combined with layer 3 routing may be a cost-effective solution for high-speed router interconnections in backbones. With the new 10 Gigabit Ethernet technology, bandwidth can be scaled from one to ten gigabits per second without sacrificing any of the intelligent network services.

These services can be delivered at line rates over the Ethernet network and supported over all network physical infrastructures in the LAN, MAN, and WAN. 10 Gigabit Ethernet uses the IEEE 802.3 Ethernet media access control (MAC) protocol, the IEEE 802.3 Ethernet frame format, and the IEEE 802.3 frame size. It is full duplex, just like full-duplex Fast Ethernet and Gigabit Ethernet; therefore, it has no inherent distance limitations.

It also minimizes the user's learning curve by maintaining the same management tools and architecture, in the case of teams which have already Ethernet experience. An optional interface has been specified that delivers Ethernet data at a rate compatible with SDH/SONET. This WAN physical layer interface enables the attachment of packet-based IP/Ethernet switches to SDH/SONET access equipment.

DYNAMIC PACKET TRANSPORT (DPT)

Dynamic Packet Transport (DPT) [8] is a Cisco proprietary transport technology intended for transporting IP packets over ring networks. DPT networks consist of two counter-rotating rings. In future versions of DPT, several rings may be interconnected, for instance, access rings to backbone rings, or multi-operator backbone rings.

The DPT network is composed of two levels:

• SRP (Spatial Reuse Protocol) level

• IPS (Intelligent Protection Switching) level

The SRP is a MAC layer that provides switching functionality similar to Ethernet. SRP frames encapsulate IP packets. A fairness algorithm (SRP-fa) governs the nodes' access to the ring. The IPS provides protection and restoration functionality. SRP distinguishes two different priority classes for packets. Though SRP itself is media independent, SDH is the first medium it is provided for. It can run transparently over dark fiber, WDM, and SDH point-to-point links and rings.

DPT interfaces are initially available for STM-4. The single-mode DPT interface is specified for up to 40 km. For applications with longer inter-nodal distance, DPT nodes will be integrated with IP regenerators and third party SDH regeneration equipment. Cisco states that DPT does not require extensive station management or lengthy manual procedures for configuration and provisioning. On the contrary, DPT capabilities should provide automatic configuration.

The bandwidth on the DPT ring has to be divided among the nodes on the ring. DPT has two traffic classes and only the traffic of the low priority class is regulated. DPT's ring concept shows good functionality and is quite usable in local and MAN networks. However, DPT does not seem to be suitable as backbone technology. Its shortcomings are in the area of interoperability and missing MPLS support.

Cisco has submitted the Spatial Reuse Protocol (SRP) to the IEEE 802.17 Resilient Packet Ring (RPR) Working Group for consideration as the industry standard. Currently the Resilient Packet Ring (RPR) standardization is going further and this new protocol, successor of DPT, will probably overcome DPT in the metro area networks in the next years.

CONCLUSION ABOUT THE THREE TECHNOLOGIES STUDY

None of these protocol architectures for IP over WDM has a clear technical advantage over the others. They all have their merits and shortcomings. Ultimately, it is the decision of the individual operators, which solution they adopt. This decision largely depends on the particular situation of the operator (legacy solutions in its network, targeted market segment, evolution vision and strategy). Experiments and field trials can provide valuable information, in the form of practical experience to support such a decision. That is where P1014 will contribute to refine the picture:

- Evaluation of the performance and demonstration of functionality in a realistic environment;
- testing interoperability (between equipment, between solutions and between suppliers)

Today's challenge for long distance operators consists in optimising the core network architecture beyond a "green field" study or a theoretical comparison. Network planners and managers have to handle several trade-offs in the design of large bandwidth transport networks:

- there is a trend to simplify the protocol stack in the network in order to simplify the architecture and minimise the number of pieces of equipment. On the other hand, customers are demanding an ever-increasing

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variety of services (client signal formats) and network functions;

- compatibility with technologies already deployed versus network evolution towards higher bitrates and network intelligence;
- Existing equipment and need for interconnection versus network performance. There is a need for interoperability at the equipment level (multi-vendor interoperability). The interoperability between different architectures is also an issue in case of an interconnection between operators. In this realistic scenario, the network management is likely to be limited and complex.

CONFORMANCE AND CONCEPT VALIDATION RESULTS

Basic functionality was verified for all three technologies in the four test beds. All three solutions passed the conformance tests, which mean that all of them are viable. There are minor differences, in the sense that some solutions are easier to implement:

- POS is easy to implement, because the SDH-compatibility reduces required engineering work and the necessary engineering is similar to the already deployed network (if the network operator already has an SDH network),
- On the customer side, it is easy to interface Gigabit Ethernet connecting the already existing

LANs to a Gigabit Ethernet switch, but generally, experience in engineering is lacking on traditional operators. This means that extra effort needs to be invested in the transport engineering until sufficient experience is gained. Until then, there might be some unexpected technical problems.

COMPARING PACKET OVER SDH & GIGABIT ETHERNET

SDH and SONET systems were the techniques of choice until very recently, even though they were designed primarily for voice traffic and were often said to be an inefficient mechanism to carry data traffic. However, the development of WDM and DWDM coupled with the emerging all-optical technologies is going to make a distinct change in the way optical networks of the future will be considered and designed.

From a reliability point of view, traditional voice networks have used SDH/SONET technologies to achieve an availability of 99.999 percent as an industry norm. This corresponds to around five minutes downtime per year. In contrast, in Internet systems best effort is considered as the usual norm. Tomorrow's networks need to deliver the most important IP services with similar reliability as we had in the past.

Currently, two major standards initiatives are underway that should provide a major leap forward in resiliency and QoS issues:

- Resilient Packet Ring (RPR) aims to give Ethernet SONET-level protection and reliability with a data link layer optimized for packet traffic in the LAN, MAN, and WAN;
- The ITU X.86 standard that maps Ethernet packets to SONET transmission links.
- The current telecommunication operators look for a more flexible high-speed network that responds cheaply and quickly to changing customer usage patterns.

DIFFERENCES BETWEEN POS AND GIGABIT ETHERNET

Using Gigabit Ethernet in the WAN cannot be equal to an SDH/SONET network. SDH/SONET is a synchronous protocol, which means it preserves the time slots used, an essential feature for any TDM traffic. Thus, Gigabit Ethernet could be used for services like Internet access, which usually has a dedicated access line not shared with voice. The advantages of using only Gigabit Ethernet in the MAN and the WAN are low cost, easily provisioned, highly granular bandwidth (frame size), simpler, centralised management and less network equipment required, the ability to easily upgrade network routers or nodes and big pipes that make the WAN look like the LAN to an end user.

Some downsides are lack of reliability, and marginal QoS capabilities. The major differences between POS and Gigabit Ethernet are in terms of engineering. Network Division staff is already trained to deal with SDH equipment and SDH services, in the case of the traditional operators. Gigabit Ethernet, while being a new technology in the access, metro and backbone, is on the other hand based on the well-known LAN Ethernet technology. POS requires more hands-on management while GbE is more self-configurable and needs less human intervention.

In economical terms, GbE interfaces are cheaper. However, when comparing the transport cost (which is the operator's main concern), both solutions appear almost equivalent. In terms of management functionality, many operators will prefer the POS solution because of its standard management capability. This is confirmed by our experience in the field trial. In terms of bandwidth utilization, the operator will also prefer the POS solution since it uses the full wavelength capacity of its WDM system while only 1 Gbit/s of the client's signal is put on a potential 2.5 Gbit/s channel in the native Gigabit Ethernet solution.

However, there exist concepts to multiplex several GbE streams into one channel of higher capacity. When looking at those arguments, it seems there is a dilemma between the clients' needs (would like the cheaper Gigabit Ethernet interfaces) and the operators' preferred solution (POS). We predict that the challenge for transporting native GbE over a wavelength will be efficiently solved in this context (moving to 10Gigabit Ethernet in the WAN or with Ethernet over SDH with virtual concatenated formats). Our experience emphasizes on management functionalities that are missing on today's systems.

Our study was carried out in the context of Gigabit Ethernet against 2.5 Gbit/s POS. The short-term evolution towards 10GbE will significantly change this comparison. In this case the overhead will be lower with respect to the case of Gigabit Ethernet. We believe that some clients will require transparent transport of their 10GbE streams. Then the balance

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between the two scenarios changes, in particular since the argument of better bandwidth utilization is no longer true.

RULES FOR THE OPTICAL TRANSPORT LAYER

The Optical Channel layer is not really managed in the actual equipment. Current management of long distance WDM systems do not support as extensive management for Gigabit Ethernet as for SDH/SONET over an optical channel. In the backbone, optical equipment is generally based on SDH technology. For instance, the management system assumes that SDH bytes are analysed by the transponders at the regeneration sites. Reduced management functionality was experienced when 2R transponders were used to regenerate GbE over a single wavelength.

Another important lesson learned from the interconnection is that the absence of protection could be a nightmare in case of failure. Being a client of the backbone for testing did not protect us from failures. On the contrary, the likelihood of failure increases because our fibres and signals were not standard clients. We did not control the whole path, so in case of failure we could not identify by ourselves where the source of the problem was. Paying clients are expected to ask for this type of control. Such a service could be called “client managed optical transmission”, which could be in demand from important enterprises with networking resources of their own.

It is current practice to offer a non-protected service to customers, but high capacity connections need protection, because in case of failure huge amounts of data are not transmitted. A likely consequence is frustration and a bad image for the networking service supplier. But this issue has to be defined in the Service Level Agreements (SLAs). Even if the client is not willing to pay for protection, the network operator could be prepared to rapidly restore traffic to fulfill availability agreements (if there enough available resources in the network). This restoration could be on the order of minutes rather than milliseconds.

Optical transmission problems such as crosstalk or non-linearities should be taken into account. Power should be kept low enough because of the non-linear issues in the fibre. A maximum value of +13 dBm is advisable. In case many optical channels are transmitted over the same fibre engineering should take care of crosstalk. Ideally, crosstalk should be less than -45 dB.

ASYNCHRONOUS AND SYNCHRONOUS TRANSPONDERS

A transponder performs three consecutive actions – and thus can be considered as three stages connected in series:

1. O/E conversion of the input optical signal,
2. Regeneration of the electrical signal;
3. Selection of the output laser or the tuning of it to the desired wavelength and modulating it with the regenerated electrical signal.

There are three possible levels of signal regeneration:

1. Re-amplification (1R),
2. Re-amplification + reshaping (2R), and
3. Re-amplification + reshaping + re-timing (3R). This also requires and includes a clock recovery circuit.

An optical channel regenerator is a transponder, where the input and output wavelengths are the same. Transponders impact on the cost of link-establishment can be quite important, due to the fact that different suppliers ask to use transponders to ensure signal quality and correct power levels when connecting their equipment to other suppliers' equipment. Then the decision of taking 2R or 3R transponders has to be made. The cost is not the same for asynchronous and synchronous transponders; the latter are more expensive (for the same bitrate characteristics). On the physical transmission level the asynchronous transponder can have jitter limitations since it does not retime the signal. Over long distances and with protocols sensible to jitter it is better to choose 3R transponders to ensure a proper transmission. Naturally, each engineering decision should be made after a careful study of link-feasibility using either solutions (or even a mix of the two).

APPLICATIONS ASPECTS

To identify bottlenecks is not an easy task: an improved network does not automatically improve performance of applications. Many parameters have an impact on the performance of applications: full duplex transmission, buffer sizes, timeout values, VLAN configurations, delays due to overall network load, motherboard buses, hard disk drive read/write speeds, operating systems and transport protocol parameters (e.g. TCP).

Our tests have shown that performance of PC based applications have a number of limiting factors beyond pure transmission limitations. Using Fast Ethernet connections, the maximum bitrate we could obtain with PCs was surprisingly low, much less than the full link speed even when deducting link protocol overhead. The multitude of parameters to set and configure to run applications correctly is also a problem.

From our experience, it is necessary to use professional equipment for real time communication (good sound and video cards if a PC is used, good and fast audio and video codecs and equipment with echo cancellation). Overall link traffic should be kept below 95% (especially if traffic is bursty). If this is not possible then prioritize real time traffic, for example by using different VLANs. In conclusion, the user experience with an application is in most cases limited by performance of the PC that runs the application, rather than by the transport network.

TYPES OF FIBRES

The core is the highly refractive central region of an optical fiber through which light is transmitted. The standard telecommunications core diameter in use with SMF is between 8 m and 10 m, whereas the standard core diameter in use with MMF is between 50 m and 62.5 m. Figure 3-4 shows the core diameter for SMF and MMF cable. The diameter of the cladding surrounding each of these cores is 125 m. Core sizes of 85 m and 100 m were used in early applications, but are not typically used today. The core and cladding are manufactured together as a single solid component of glass

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with slightly different compositions and refractive indices. The third section of an optical fiber is the outer protective coating known as the coating. The coating is typically an ultraviolet (UV) light-cured acrylate applied during the manufacturing process to provide physical and environmental protection for the fiber. The buffer coating could also be constructed out of one or more layers of polymer, nonporous hard elastomers or high-performance PVC materials. The coating does not have any optical properties that might affect the propagation of light within the fiber-optic cable. During the installation process, this coating is stripped away from the cladding to allow proper termination to an optical transmission system. The coating size can vary, but the standard sizes are 250 m and 900 m. The 250- m coating takes less space in larger outdoor cables. The 900- m coating is larger and more suitable for smaller indoor cables.

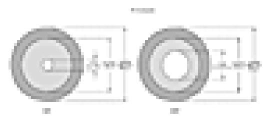

Fig. 1 : Optical-Cable Construction

Fiber-optic cable sizes are usually expressed by first giving the core size followed by the cladding size. Consequently, 50/125 indicates a core diameter of 50 microns and a cladding diameter of 125 microns, and 8/125 indicates a core diameter of 8 microns and a cladding diameter of 125 microns. The larger the core, the more light can be coupled into it from the external acceptance angle cone. However, larger-diameter cores can actually allow in too much light, which can cause receiver saturation problems. The 8/125 cable is often used when a fiber-optic data link operates with single-mode propagation, whereas the 62.5/125 cable is often used in a fiber-optic data link that operates with multimode propagation. Three types of material make up fiber-optic cables:

- Glass
- Plastic
- Plastic-clad silica (PCS)

These three cable types differ with respect to attenuation. Attenuation is principally caused by two physical effects: absorption and scattering. Absorption removes signal energy in the interaction between the propagating light (photons) and molecules in the core. Scattering redirects light out of the core to the cladding. When attenuation for a fiber-optic cable is dealt with quantitatively, it is referenced for operation at a particular optical wavelength, a window, where it is minimized. The most common peak wavelengths are 780 nm, 850 nm, 1310 nm, 1550 nm, and 1625 nm. The 850-nm region is referred to as the first window (as it was used initially because it supported the original LED and detector technology). The 1310-nm region is referred to as the second window, and the 1550-nm region is referred to as the third window.

A. Glass Fiber-Optic Cable

Glass fiber-optic cable has the lowest attenuation. A pure-glass, fiber-optic cable has a glass core and a glass cladding. This cable type has, by far, the most widespread use. It has been the most popular with link installers, and it is the type of cable with which installers have the most experience. The glass used in a fiber-optic cable is ultra-pure, ultra-transparent, silicon dioxide, or fused quartz. During the glass fiber-optic cable fabrication process, impurities are purposely added to the pure glass to obtain the desired indices of refraction needed to guide light. Germanium, titanium, or phosphorous is added to increase the index of refraction. Boron or fluorine is added to decrease the index of refraction. Other impurities might somehow remain in the glass cable after fabrication. These residual impurities can increase the attenuation by either scattering or absorbing light.

B. Plastic Fiber-Optic Cable

Plastic fiber-optic cable has the highest attenuation among the three types of cable. Plastic fiber-optic cable has a plastic core and cladding. This fiber-optic cable is quite thick. Typical dimensions are 480/500, 735/750, and 980/1000. The core generally consists of polymethylmethacrylate (PMMA) coated with a fluropolymer. Plastic fiber-optic cable was pioneered principally for use in the automotive industry. The higher attenuation relative to glass might not be a serious obstacle with the short cable runs often required in premise data networks. The cost advantage of plastic fiber-optic cable is of interest to network architects when they are faced with budget decisions. Plastic fiber-optic cable does have a problem with flammability. Because of this, it might not be appropriate for certain environments and care has to be taken when it is run through a plenum. Otherwise, plastic fiber is considered extremely rugged with a tight bend radius and the capability to withstand abuse.

C. Plastic-Clad Silica (PCS) Fiber-Optic Cable

The attenuation of PCS fiber-optic cable falls between that of glass and plastic. PCS fiber-optic cable has a glass core, which is often vitreous silica, and the cladding is plastic, usually a silicone elastomer with a lower refractive index. PCS fabricated with a silicone elastomer cladding suffers from three major defects. First, it has considerable plasticity, which makes connector application difficult. Second, adhesive bonding is not possible. And third, it is practically insoluble in organic solvents. These three factors keep this type of fiber-optic cable from being particularly popular with link installers. However, some improvements have been made in recent years. Please note that for data center premise cables, the jacket color depends on the fiber type in the cable. For cables containing SMFs, the jacket color is typically yellow, whereas for cables containing MMFs, the jacket color is typically orange. For outside plant cables, the standard jacket color is typically black.

D. Multifiber Cable Systems

Multifiber systems are constructed with strength members that resist crushing during cable pulling and bends. The outer cable jackets are OFNR (riser rated), OFNP (plenum rated), or LSZH (low-smoke, zero-halogen rated). The OFNR outer jackets are composed of flame-retardant PVC or fluoropolymers. The OFNP jackets are composed of plenum PVC, whereas the LSZH jackets are halogen-free and constructed out of polyolefin compounds. Figure 3-5 shows a

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multiribbon, 24-fiber, ribbon-cable system. Ribbon cables are extensively used for inside plant and datacenter applications. Individual ribbon subunit cables use the MTP/MPO connector assemblies. Ribbon cables have a flat ribbon-like structure that enables installers to save conduit space as they install more cables in a particular conduit.

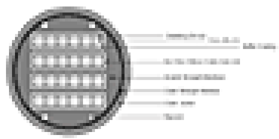

Fig. 2 : Inside Plant Ribbon-Cable System

Figure 3 shows a typical six-fiber, inside-plant cable system. The central core is composed of a dielectric strength member with a dielectric jacket. The individual fibers are positioned around the dielectric strength member. The individual fibers have a strippable buffer coating. Typically, the strippable buffer is a 900- m tight buffer. Each individual coated fiber is surrounded with a subunit jacket. Aramid yarn strength members surround the individual subunits. Some cable systems have an outer strength member that provides protection to the entire enclosed fiber system. Kevlar is a typical material used for constructing the outer strength member for premise cable systems. The outer jacket is OFNP, OFNR, or LSZH.

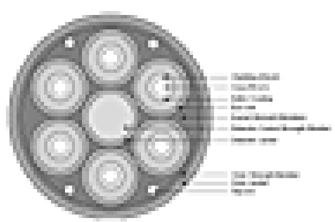

Fig. 4: Cross Section of Inside-Plant Cables

Figure 4 shows a typical armored outside-plant cable system. The central core is composed of a dielectric with a dielectric jacket or steel strength member. The individual gel-filled subunit buffer tubes are positioned around the central strength member. Within the subunit buffer tube, six fibers are positioned around an optional dielectric strength member. The individual fibers have a strippable buffer coating. All six subunit buffer tubes are enclosed within a binder that contains an interstitial filling or water-blocking compound. An outer strength member, typically constructed of aramid Kevlar strength members encloses the binder. The outer strength member is surrounded by an inner medium-density polyethylene (MDPE) jacket. The corrugated steel armor layer between the outer high-density polyethylene (HDPE) jacket, and the inner MDPE jacket acts as an external strength member and provides physical protection. Conventional deep-water submarine cables use dual armor and a special hermetically sealed copper tube to protect the fibers from the effects of deep-water environments. However, shallow-water applications use cables similar to those shown in Figure 3 with an asphalt compound interstitial filling.

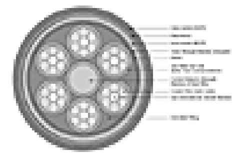

Fig. 5: Cross Section of an Armored Outside-Plant Cable

II. GRAPHENE

The use of graphene in telecommunications could dramatically accelerate internet speeds by up to a hundred times, according to new research by scientists in our Department of Physics. In a paper published in Physical Review Letters, researchers from the Centre for Graphene Science at the Universities of Bath and Exeter have demonstrated for the first time incredibly short optical response rates using graphene, which could pave the way for a revolution in telecommunications. Every day large amounts of information is transmitted and processed through optoelectronic devices such as optical fibres, photodetectors and lasers. Signals are sent by photons at infrared wavelengths and processed using optical switches, which convert signals into a series of light pulses.

Ordinarily optical switches respond at rate of a few picoseconds—around a trillionth of a second. Through this study physicists have observed the response rate of an optical switch using ‘few layer graphene’ to be around one hundred femtoseconds—nearly a hundred times quicker than current materials. Graphene is just one atom thick, but remarkably strong. Scientists have suggested that it would take an elephant, balanced on a pencil to break through a single sheet. Already dubbed a miracle material due to its strength, lightness, flexibility, conductivity and low cost, it could now enter the market to dramatically improve telecommunications.

Commenting on the report’s main findings, lead researcher Dr. Enrico Da Como said: “We’ve seen an ultrafast optical response rate, using ‘few-layer graphene’, which has exciting applications for the development of high speed optoelectronic components based on graphene. This fast response is in the infrared part of the electromagnetic spectrum, where many applications in telecommunications, security and also medicine are currently developing and affecting our society.” Co-Director of the Centre for Graphene Science at Bath, Professor Simon Bending added: “The more we find out about graphene the more remarkable its properties seem to be. This research shows that it also has unique optical properties which could find important new applications.” In the long term this research could also lead to the development of quantum cascade lasers based on graphene. Quantum cascade lasers are semiconductor lasers used in pollution monitoring, security and spectroscopy. Few-layer graphene could emerge as a unique platform for this interesting application.

CONCLUSION

WE are moving toward a society which requires that we have access to information at our fingertips when we need it, where we need it, and in whatever format we need it. The information is provided to us through our global mesh of

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communication networks, whose current implementations, e.g., today's Internet and asynchronous transfer mode (ATM) networks, do not have the capacity to support the foreseeable bandwidth demands. (WDM) is an approach that can exploit the huge opto-electronic bandwidth mismatch by requiring that each end-user's equipment operate only at electronic rate, but multiple WDM channels from different end-users may be multiplexed on the same fiber. Under WDM, the optical transmission spectrum is carved up into a number of non-overlapping wavelength (or frequency) bands, with each wavelength supporting a single communication channel operating at whatever rate one desires, e.g., peak electronic speed.

Thus, by allowing multiple WDM channels to coexist on a single fiber, one can tap into the huge fiber bandwidth, with the corresponding challenges being the design and development of appropriate network architectures, protocols, and algorithms. In conclusion, the user experience with an application is in most cases limited by performance of the PC that runs the application, rather than by the transport network. Also, WDM devices are easier to implement since, generally, all components in a WDM device need to operate only at electronic speed; as a result, several WDM devices are available in the marketplace today, and more are emerging. WAVELENGTH division multiplexing (WDM) is about to play a major role in the expansion of photonic networks. One of the main reasons is that WDM has the advantage of not forcing the end-users to run at the aggregate data rate, and does not require any synchronization between channels. It is also the only multiplexing technique which allows the full use of the low-attenuation bandwidth regions of an optical fiber.

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