WDM-the most needed Technology to Overcome Future Bandwidth Crisis in Data Communication

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ABSTRACT

This Paper discusses problems of bandwidth crisis for computer data communication as amount of flow of data in backbone network is increasing exponentially because of increasing use of text, audio, still & motion video data over long distance. The paper discusses about upcoming technique for economic solution to this problem to be adopted. Wavelength Division Multiplexing techniques is one of the economic solution to such bandwidth crisis problem. The paper also discusses about the problem of efficient implementation of such a technique. The problem is known as routing and wavelength assignment problem.

KEYWORDS : Wavelength Division Multiplexing, Optical fibres, Waveform, Switching

0. INTRODUCTION

For transmitting many different colours (wavelengths) of laser light down the same optical fibre at the same time, in order to increase the amount of information that can be transferred, WDM is used.

As an optical network consists of optical fibres carrying flashes of light from a laser, we can improve the speed of information transfer by increasing the number of laser light flashes per second (increasing the bit-rate).

In an optical network, we can increase the number of lasers and have them all sending their light down the optical fibre at the same time. However, there is a catch. All the different lasers must give out different colours (different wavelengths) of light so that their information can be separated at the other end of the network. The sending of many different wavelengths down the same optical fibre is known as Wavelength Division Multiplexing (WDM).

1. WAVELENGTH DIVISION MULTIPLEXING (WDM)

Modern networks in which individual lasers can transmit at 10 Gigabits per second can now have several different lasers each giving out 10 Gbit/s through the same fibre at the same time. The number of wavelengths is usually a power of 2 for some reason. So WDM systems will use two different wavelengths, or 4, 16, 32, 64, 128, etc. Systems being deployed at present will usually have no more than maybe 32 wavelengths, but technology advancements will continue to make a higher number of wavelengths possible.

The act of combining several different wavelengths on the same fibre is known as multiplexing. At the receiving end, these wavelengths need to be separated again, which is known, logically enough, as demultiplexing. Each wavelength will then need its own light detector to convert it back into useful information.

The exact wavelengths of light being used are usually around the 1550 nanometer region, the wavelength region in which optical fibre performs the best (it has very “low loss” or “low attenuation” at this wavelength). Each different wavelength will be separated by a multiple of 0.8nm (sometimes referred to as “100GHz spacing,” which is the frequency separation; or as the “ITU-Grid,” named after the standards body that set the figure). So if we have four wavelengths we may have them at 1549.2nm, 1550nm, 1550.8nm, and 1551.6nm. However, we could also separate each by 1.6nm, or even 2.4nm, as long as it is some multiple of 0.8nm. Newer designs that aim to cram even more wavelengths into an even tighter space, may even have half the regular spacing (0.4nm) or a quarter (0.2nm). There can be problems with wavelengths spreading out (known as dispersion) and affecting neighboring wavelengths; so this and other more complicated issues need to be considered carefully when designing a WDM system.

1.1 Increases capacity of optical fibres

Different wavelength lasers each transmitting at same time down same fibre 'Multiplexing' is combining wavelengths; 'demultiplexing' is splitting wavelengths Usually in powers of 2 — 2, 4, 8, 16, 32, 64, 128, etc. wavelengths Wavelengths separated by multiples of 0.8nm (100GHz) So an optical network just consists of incredibly thin strands of glass (similar in diameter to one of hair) that can be many hundreds or even thousands of miles long. They connect different locations that are part of the “optical network.” The optical fibre is packaged up and protected in a surrounding cable, and then usually laid underground or even underwater.

If we tried shining a flashlight down a short glass rod, very little light would actually make it to the other end. And so to make an optical network that can carry information over such huge distances there are two things to be improved. The glass that forms an optical fibre is specially designed to be able to transmit light for very long distances (it has “low loss” or “low attenuation”) and the light sent through the fibre is very high intensity laser light, capable of traveling much farther than regular light.

The laser light flashes on and off in a pattern that represents the information being sent. We can think of this as being similar to Morse code, where certain series of dots and dashes form information. The quicker the lasers can flash on and off, then the quicker the information can be transferred. The speed of transfer is known as “bit-rate” and is usually talked about in terms of bits per second — bps or bit/s (effectively the number of flashes possible per second). Modern networks can transmit 10 Gbit/s from one single laser — 10 Gigabits per second, which is 10 billion flashes per second. To put this into context, we could send the text of more than 1000 books in just one second.

At the other end of the optical fibre is a light detector that senses the on-off flashes of light and converts them back into regular information — whether that’s a sultry voice in a premium phone call or an image on a Web page.

The way that an optical network is generally used is that there will be optical fibre links between most large countries, between most large cities in a country, and then out from each of those cities to the smaller towns. However, electrical signals traveling down copper cables are usually still used for the relatively small amount of information that needs to be transmitted from our individual homes, although a larger business may have its own optical fibre link into the country's optical network.

1.2 One physical infrastructure

Aside from the enormous capacity gained through optical networking, the optical layer provides the only means for carriers to integrate the diverse technologies of their existing networks into one physical infrastructure. DWDM systems are bit-rate and format independent and can accept any combination of interface rates (e.g., synchronous, asynchronous, OC–3, –12, –48, or –192) on the same fibre at the same time. If a carrier operates both ATM and SONET networks, the ATM signal does not have to be multiplexed up to the SONET rate to be carried on the DWDM network. Because the optical layer carries signals without any additional multiplexing, carriers can quickly introduce ATM or IP without deploying an overlay network. An important benefit of optical networking is that it enables any type of cargo to be carried on the highway.

But DWDM is just the first step on the road to full optical networking and the realization of the optical layer. The concept of an all-optical network implies that the service provider will have optical access to traffic at various nodes in the network. Optical wavelength add/drop (OWAD) offers that capability, where wavelengths are added or dropped to or from a fibre. But ultimate bandwidth management flexibility will come with a cross-connect capability on the optical layer. Combined with OWAD and DWDM, the optical cross-connect (OXC) will offer service providers the ability to create a flexible, high-capacity, efficient optical network with full optical bandwidth management. These technologies are becoming essential to meet today's traffic demand.

Optical networking provides the backbone to support existing and emerging technologies with almost limitless amounts of bandwidth capacity. All-optical networking (not just point-to-point transport) enabled by optical cross-connects, optical programmable add/drop multiplexers, and optical switches provides a unified infrastructure capable of meeting the telecommunications demands of today and tomorrow. Transparently moving trillions of bits of information efficiently and cost-effectively will enable service providers to maximize their embedded infrastructure and position themselves for the capacity demand of the next millennium.

Support of aggregated bandwidth, low-latency requirements are extremely important for fast Internet access, video conferencing etc. Converting channel wavelength from one value to another is critical for wavelength routing. This conversion from one wavelength to another makes the system re-configurable. One way to achieve it is detecting the optical signal electrically and then modulating a laser at a different wavelength. This optic-electric and vice-versa conversion may cause problems in efficiency. An all-optical method is preferable and more efficient.

One of the most important device to do this is the tunable optical filter. The tunable optical filter is efficient in selectively adding or dropping particular wavelength channels from the multi-wavelength network. The most desirable features of a optical filter are:

Discrete waveforms form an orthogonal set of carriers that can be separated, routed and switched without interfering with each other. This holds as long as optical intensity is kept sufficiently low to prevent non-linearity as Brillourin scattering and four-wave mixing process.

Faced with the multifaceted challenge of increasing the rate of information transfer and efficiency, we need options to provide an economical solution. Laying more fibre can do this. For those networks where the cost of laying new fibre is minimal, this will prove the most economical solution. However, laying new fibre will not necessarily enable the optimum utilization or bandwidth management capability.

Another option could be Wavelength Division Multiplexing (WDM), which increases the capacity of embedded fibre by first assigning incoming optical signals to specific wavelength (l) within a designated wavelength band and then multiplexing the resulting signals out onto one fibre. WDM combines multiple optical signals so that they can be amplified as a group and transported over a single fibre to increase capacity.

Basic principle of WDM is that discrete waveforms form an orthogonal set of carriers that can be separated, routed and switched without interfering with each other. This holds as long as optical intensity is kept sufficiently low to prevent non-linearity as Brillourin scattering and four-wave mixing process.

1.3 Key system features of WDM

Increase in capacity:

Each wavelength supports an independent signal, and signals can be carried simultaneously, hence, the capacity of the fibre in increased.

Irrespective of format:

The transmission of the data is irrespective of the format of the data or the information in the data. Thus, different data types can be sent at the same time.

Wavelength routing:

Wavelength can be thought of as another dimension like time and space for communication system design.

Wavelength switching:

Reconfiguration of the optical layer can be done with efficiency.

Dense wavelength division multiplexing (DWDM) is a technology that puts data from different sources together on an optical fibre, with each signal carried on its own separate light wavelength. Using DWDM, up to 80 (and theoretically more) separate wavelengths or channels of data can be multiplexed into a lightstream transmitted on a single optical fibre. In a system with each channel carrying 2.5 Gbps (billion bits per second), up to 200 billion bits can be delivered a second by the optical fiber. DWDM is also sometimes called wave division multiplexing (WDM).

Since each channel is demultiplexed at the end of the transmission back into the original source, different data formats being transmitted at different data rates can be transmitted together. Specifically, Internet (IP) data, SONET data, and ATM data can all be travelling at the same time within the optical fibre.

One outstanding problem has never been solved:

How to regenerate multiple wavelength signals.

To recondition optical signals, it becomes necessary to decode their content and relaunch them. Thus signal regeneration, which is essential in long-haul networks, is still unavailable to DWDM.

Balancing this deficiency in very long transmissions is a new wave of all-optical switching elements that are able to add or remove a wavelength channel from a fibre.

These add-drop multiplexers offer a high-speed switching function that could not be duplicated with electronics, and have made metropolitan-area networks into a unique flexible, high-throughput communications medium.

Dealing with the high volumes of data that are coming off optical fibres will present a big challenge to electronics. Fortunately, wavelength-division multiplexing eases that task since each wavelength can be processed simultaneously by different circuits. Ultimately, electronics and optics technologies offer complementary abilities: "Optics is ideal for transporting data from point A to point B, but it is weak in the area of logic and switching, that is where we will need electronics."

New communication services, e.g., Internet, high-speed data, video, wireless, etc. have triggered a tremendous need for bandwidth that legacy communications networks are not being able to cope with. Presently voice traffic and data are increasing at a rate of 10% and 80%, respectively, per year. Among available choices, increasing the transportable bandwidth of an existing fibre is the most efficient way of meeting the demand.

There are two ways to increase bandwidth in a single fibre, either increasing the bit rate or increasing the number of wavelength (channels) in the same fibre. This second method is a viable solution that capitalizes on advances in solid-state and photonic technology. Several wavelengths, each transporting data at 10 or 40 Gbps would increase the transportable bandwidth by a factor as large as the number of wavelengths. Systems with 40, 80, and 128 wavelengths per fibre have been designed, and systems with more wavelengths are in planning or experimental phase.

1.4 Components of WDM

- Optical amplifiers (EDFA) with flat gain over a range of wavelengths and coupled in line with the transmitting fibre boost the optical signal, thus eliminating the need for regenerators.
- Integrated solid-state optical filters are compact and can be integrated with other optical components on the same substrate.
- Integrated solid-state laser sources and photodetectors offer compact designs.
- Optical multiplexers and demultiplexers are based on passive optical diffraction.
- Wavelength selectable (tunable) filters can be used as optical add-drop multiplexers.
- Optical add-drop multiplexer (OADM) components have made DWDM possible in MAN ring-type and long haul networks.
- Optical cross-connect (OXC) components, implemented with a variety of technologies (e.g., lithium-niobate), have made optical switching possible.

Inter-exchange carriers are seeing an aggregate doubling in bandwidth on their backbone networks every six to twelve months. Carriers are rebuilding their backbone networks once or twice per year. Wavelength routing technologies allow carriers to build networks that scale in capacity to meet the unprecedented rate of growth. These technologies provide fundamental data network architectures that are simple, low cost, and easy to manage. They meet the infrastructure-class reliability requirements of voice networks, while optimized for data. Conventional technologies and approaches, while well suited for voice and traffic aggregation, do not meet the benchmarks of scale, low cost, and reliability of wavelength-routed networks.

2. FUNDAMENTALS OF WAVELENGTH ROUTING

Wavelength routing technology builds on intelligent systems that are network-aware and can leverage optical internetworking in carrier networks. From an external view, these systems are managed using

Internet technologies that predominate computer networks today. They employ the most advanced object-oriented software designs and computing platforms, and they are modular in design. They flexibly allow technology upgrades of computing platforms and software without impacting the network. Wavelength routing systems can support client-server applications where applicable for operations, maintenance, and provisioning.

Wavelength routing elements use distributed intelligence in the system architecture as well as the network to provide a platform for rapid service provisioning and restoration. There are direct, established communication paths between wavelength routing systems such that each element knows the configuration of the network and its neighboring systems.

Wavelength routing elements are not dependent on legacy OSSs to provision and restore the network. Since the wavelength routing element is network-aware, it can route services through the network based only on source and destination routing. In the traditional approach, each system is provisioned at the circuit-pack level throughout the network. A sample network analysis shows this approach requires 24 steps to provision a single service, while a wavelength-routed network requires one. In addition, routing itself is traditionally performed using a centralized, manual method, adding significant cost and time to the process through an error-prone procedure. One carrier has estimated that their provisioning staff could be reduced by 80 percent by using wavelength routing technology. Clearly, the old-world approaches to provisioning will not scale to meet the exponential growth of a data network.

Since data aggregation and switching systems are also network aware, a wavelength routing system can communicate with these devices to provide a seamless, data-oriented architecture. The intelligence and ability to communicate, inherent in wavelength router systems, allows wavelength routers to share information with data aggregation systems (IP routers and ATM switches).

3. CONCLUSION

WDM is most needed technology to meet the huge demand of bandwidth of backbone network as amount of data traffic is increasing exponentially for increase of network user and application of multimedia. To make WDM more efficient we have to remove electronic components from the network as electronic components has speed limitation which may slow down the optical network. So the network is to be all optical network. But there is constraint which is known as Routing and wavelength assignment problem. Study is to be done to find out efficient method of routing and wavelength assignment in all optical network. The future holds many a challenges to the all-optical networks. But, the commercial implementations for WDM are not far away. It opens the pathway to Terabit networking and unleashes the enormous bandwidth potential of the silica fibre. The trend of WDM solutions over the last few years seems to have taken an exponential growth. WDM acts as the stepping stone towards a true optical networking era.

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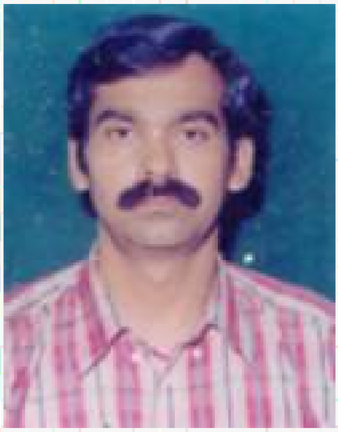

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