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Fiber Optic Conıınunication System

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ABSTRACT

in fiber optie communication systems engineering covering basic aspects of mo~ fiber-optic communication systems that includes sources and receivers, optical fibers, optical amplifiers and current system architectures. The principles of operation and properties of optoelectronic components, as well as signal guiding characteristics of glass fibers are discussed, System design issues include underwater links, terrestrial point-to-point optical links and wavelength division multiplexing (WDM) fiber..optic networks. From this project you will obtain the knowledge needed to perform basic fiber-optic commıınication systems engineering calculations, and apply this knowledge to modem fiber optic systems. This will enable you to evaluate real systems, communicate effectively with colleagues, and understand the most recent literature in the field of fiber-optic communications,

Fiber-based networks form a key part of international comnıunications systems. This project introduces the physical principles of optical fibers, and details their use in sensor technology and modem optical communication systems. The authors begin by setting out the basic propagation characteristics of single mode and multimode optical fibers. in later chapters they cover optical sources, optical detectors, and fiber-optic commnnication system design, They also treat a wide variety of related topics such as doped fiber amplifiers, dispersion compensation, fiber sensors, and measurement techniques for the characterization of optical fibers. Throughout the book, physical and engineering aspects of the subject are interwoven, and many worked examples and exercises are included, it will be an ideal textbook for undergraduate or graduate students taking projects in optical fiber communications, photonics, or optoelectronics.

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INTRODUCTION

In this project optical fiber transmission system is studied with intensive care and an application of this unique system is shown. Optical Fiber transmission system is anew technologies which have a large impact in telecommunication feature, telecommunication networks as well as videos transmission, reciever, transmitter and computer interconnections,

It provides several major advantages over conventional electronic transmission system, This includes immunity to electromagnetic interference, thinner and lighter cables, lower transmission losses and wider bandwidths. Optical fiber are vital in an information society, it is a threadlike structure capable of handling the transportation of a large volume of information traffic. We need it as the building block of our information highway system to help us in managing our energy resources, transportation and communications; delivering health care and community services; strengthening our military defense; developing business and providing materials for our entertainment and education. Here in this project I will discuss in four chapters the functions, the aims of the fiber optic and how we can use it in the network and communication .

First Chapter about the Fiber Optic Data Communications Link, End-to-End,

Second Chapter represent the transmission medium of fiber optic witch contain the transmitter, receiver and connectors with the process of placing information onto an information carrier.

Third Chapter represents the Sharing the Transmission Medium, Time Division Multiplexing (TDM). Wavelength Division Multiplexing (WDM) With Fiber Optic Cable and .Comparing Multiplexing Techniques for.the Premises environment on the hasis of link design flexibility.

Fourth Chapter about Brief History of Local Area Networks and Transmission Media Used To Implement An Ethernet LAN, Examining the Distance Constraint, also I will give some examples of LAN Extenders Shown In Typical Applications, Model 375 lOOBase~T to Fiber Transceiver for Fast Ethernet, Model 377 Series Single-Mode lOOBase-T/FMedia Converter.

CHAPTERONE

THE FiBER OPTIC DATA COMMUNICATIONS LiNK FOR THE PREMISES ENVIRONMENT

1.1 Overview

in this chapter we consider the simple fiber optic data link for the premises environment. And also we will represent the fiber optic cable,

1.2 Th.e Fiber Optic Data Cômmunications Link, End-to-End

This is the basic building block for a fiber optic based network. A model of this simple link is shown in Figure 1-1.

The illustration indicates the Source-User pair, Transmitter and Receiver. It also clearly shows the fiber optic cable constituting the Transmission Mediiım as well as the coımectors that provide the interface of the Transmitter to the Transmissioıı Medium and the Transmission Medium to the Receiver.

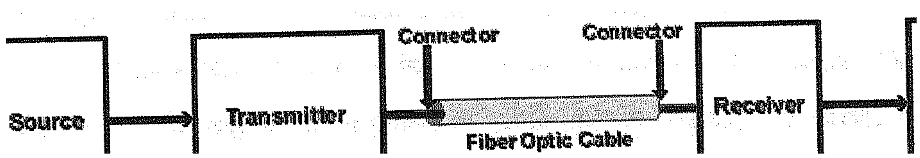


Figure 1-1: Model of"simple" fiber optic data link

All of these are components of the simple fiber optic data link. Each will be discussed. Wewill conclude bytaking up the question ofhow to analyze theperformance ofthe simple fiber optic data link.

1.3 Fiber Optie Cable

We begin by asking just what is a fiber optic cable? A fiber optic cable is a cylindrical pipe. It may be made out of glass or plastic or a combination of glass and plastic. it is fabricated in such a way that this pipe can guide light from one end of it to the other. The idea of having light guided through bent glass is not new or high tech. The author was once informed that Leonardo DaVinci actually mentioned such a means for guiding light in one of his notebooks. However, he has not been able to verify this assertion. What is known for certain is that total internal reflection of light in a beam of water - essentially guided light - was 'demonstrated by the physicist John Tyndall [1820-1893] in either 1854 or 1870 - dependiıg upon which reference you consult.

Tyndall showed that light could be bent around a corner while it traveled through a jet of pouring water.Using light for comınunications came after this. Alexander Graham Bell [1847-1922] invented .the photo-phone around 1880. Bell demonstrated that a membrane in response to sound could modulate an optical signal, light. But, this was a free space transmission system. The light was not guided. Guided optical comınunications had to wait for the 20th century, The first patent on guided optical comınunications over glass was obtained by AT &T in 1934. However, at that time there were really no materials to fabricate a glass (or other type of transparent material) fiber optic cable with sufficiently low attenuation to make guided optical communications practical. This had to wait for about thirty years, During the 1960's researchers working at a number of different academic, industrial. and g<>vernment laboratories obtained a mııch berter understanding of the loss mechanisms inglass fiber optic cable. Between 1968 and 1970 the attenuation of glass fiber optic ca~le dropped from over 1000 dB/km to less than 20 dB/km. Corning patented its fabrication process for the cable.

The continued decrease in attemıation through the 1970's allowed practical guided light communications using 'glass fiber optic cable to take off. in the late 1980'$ and 1990's this momentum increased with the evenlower cost plastic. fiber optic cable and Plastic Clad Silica (PCS).Basically, a fiber optic cable is composed of two concentric layers termed the core and the cladding, These ate showri ön the right side of Figure 1-2. The core and cladding have different indices of refraction with the core having n_1 and the cladding n_1. Light is piped through the core,

A fiber optic cable has an additional coating around the cladding ealled the jacket. Core, cladding and jacket are all shown in the three dimensional view on the left side of Figure l-Z. The jacket usually consists of one or more layers of polymer. lts role is to protect the core and cladding from shocks that might affect their optical or physical properties. It aots as a shoek absorber. The jacket also provides protection from abrasions, solvents and other contaminants. The jacket does not have any optical properties that might affect the propagation of Iight within the fiber optic cable. The illustration on the left Side of Figure 1-2 is somewhat simplistic.·In aetuality, there may be a strength member added to the fiber optic cable so that it can be pulled during installation.

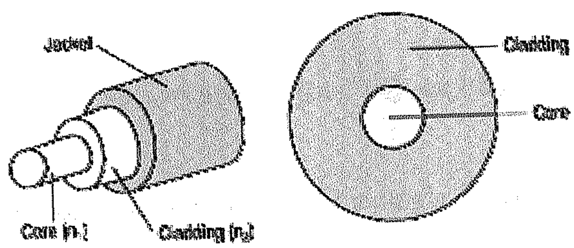


Figure 1-2: Fiber Optic Cable, 3 dimensional view and basic cross section

This would be added just inside the jacket. There may be a buffer between the strength member and the cladding, This protects the core and cladding from damage and allows the fiber optic cable to be bundled with other fiber optic cables.How is light guided down the fiber optic cable in the core? This oecurs beeaııse the core and cladding have different indices of refraction with the index of the core, n_1, always being greater than the index of the cladding, n_2. Flgure 1·3 shows how this is employed-to effect the propagation of light down the fiber optic cable. As illustrated a light ray is injected into the fiber optic cable on the right. If the light ray is injected and strikes the core-to-cladding interface at an angle greater than an entity .called the critical angle then i! is reflected back into the core. Since the angle of incidence is always equal to the angle of reflection the reflected light will again be reflected. Light can be guided down the fiber optic cable if it enters at lessthan the critical angle. This angle is fixed by the indices of refraction ofthe core and cladding and is given by the formula:

4>c= are eoslae (n2 /n1).

The critical angle is measured from the cylindrical axis ofthe core. By way of example, if nı = 1.446 and n2= 1.430 then a quick computation will show that the critical angle is 8.53 degrees, a fairly small angle.

Ofcourse, it must be noted that a light ray enters the core from the air outside, to the left ofFigure 1-3. The refractive index ofthe air must be taken into account in order to assure that a light ray in the core will be at an angle less than the critical angle. This can be done fairly simply. The following basic rule then applies. Suppose a light ray enters the core from the air at an angle less than an entity called the extemal acceptance angle - <I>ext it will be guided down the core. Here

CI>ext = are sin [(nı/ no) sin (4>c)]

With nO being the index of refractlon of air. This angle is, likewise, measured from the cylindrical axis of the core, In the example above a computation shows it to be 12.4 degrees - again a fairly small angle.

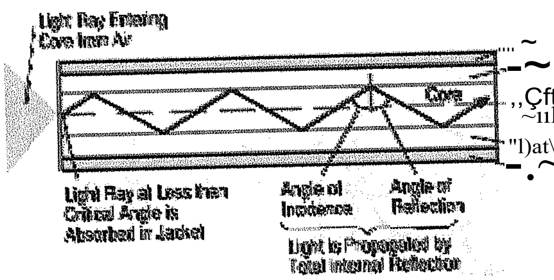
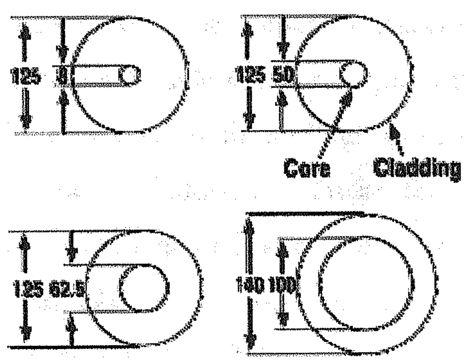


Figure 1-3: Propagation ofa light ray down a fiber optic cable

1.3.1 Fiber optie dada performance

Fiber optic data link performance is a subject that will be discussed in full at the end of this chapter. However, let's jump the gun just a little. In considering the performance of a fiber optic data link the network architect is interested in the effect that the fiber optic cable has on overall link performance. The more light that can be coupled into the core the more light will reach the Receiver and the lower the BER. The lower the attenuation in propagating down the core the more light reaches the Receiver and the lower the BER. The answers to these questions depend upon many factors. The major factors are the size of the fiber, the composition of the fiber. and the mode of propagation, When it comes to size, fiber. optic cables have exceedingly small diameters, Figure 1-4 illustrates the cross sections of the core and cladding diameters of four commonly used fiber optic cables, .The diameter sizes shown are in microns, 10-6 m. To get some feeling for how small these sizes actually are; understand that a human hair has a diameter of 100 microns. Fiber. optic cable sizes are usually expressed by first giving the core size followedby.the cladding size. Consequently, 50/125 indicates a core diameter of 50 microns and a cladding diameter of 125 microns; 100/140 indicates a core diameter of 100 microns anda cladding diameter of 140 microns.

The larger the core the more light can be coupled into it from external acceptance angle cone; However, larger diameter cores may actually allow too much light in and too much light may cause Receiver saturation problems. The left most cable shown in Figure 1-4, the 125/8 cable, is often found when a.fiber optic data link.operates with single-mode propagation, The cable that is second from the right in Figure 1-4, the 62.5/125 cable, is eften found in a fiber optic data link that operates with multi-mode propagation.



Figu.re 1-4: Typieal core and cladding diameters -Sizes are in microns

1.4 Types of fiber optie eable

When it comes to composition or material makeup fiber optic cables are of three types: glass, plastic and Plastic Clad Silica (PCS). These three candidate types differ with respect to attemıation and cost. We will describe these in detail. Attenuation and cost will first be mentioned only qualitatively. Later, toward the end of this sub-ehapter the candidates will be compared quantitatively. By the way, 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 attenuatiorı 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.

1.4.1 Glass fiber optie cable

Glass fiber optic cable has the lowest attenuation and coınes at the highest cost. A pure glass fiber optic cable has a glass core and a glass cladding. This candidate has, by far; the ınost wide spread use. It has been the most popular with link installers and it is-the candidate with which installers have the ınost experienee. Tlıe glass employed in a fiber optic cable is ultra pure, ultra transparent, silicon dioxide or fused quartz, Onereference put this in perspective by noting that "if seawater were as clear as this type of fiber optic cable then you would be able to see to the bottom of the deepest trench in the Pacific Ocean." During the glass fiber optic cable fabrication process impurities are purposely added to the pure glass so as to obtain the desired indices of refraction needed to guide light, Germanium or phosphorous are added to increase the index of refraction, Boron or fhıorine is added to decrease the index of refraction, Other impurities may somehow remain in the glass cable after fabrication. These residual impurities may increase the attenuation by either scattering or absorbing light.

1.4.2 Plastic fiber optle eable

Plastic fiber optic cable has the highest attenüation, but comes at the lowest cost, Plastic fiber optic cable has a plastic core and plastic cladding. This fiber optic cable is quite thick, .Typical dimensions are 480/500, 735/750 and 980/1000. The core generally consists of PMMA (polym.ethylmethacrylate) coated with a flııropolymer. Plastic fiber optic cable was pioneered in Japan principally for use in the automotive industry. it is just beginning to gain attention in the premises <lata communications market in the United States, The increased interest is due to two .reasons, First, the higher attenuation relative to glass may not be a serious obstacle with the short cable runs often required in premise networks. Secondly; the cost advantage sparks interest when network archltects are faced with budget decisions, Plastic fiber optic cable does have a problem with flammability. Because of this, it may not be appropriate for certain environments and care has to be given when it is run through a plenum. Otherwise, plastic fiber is considered extremely rugged with a tight bend radius and 'the ability to withstand abuse.

1.4.3 Plastie Clad Silica (PCS) fiber opüe eable

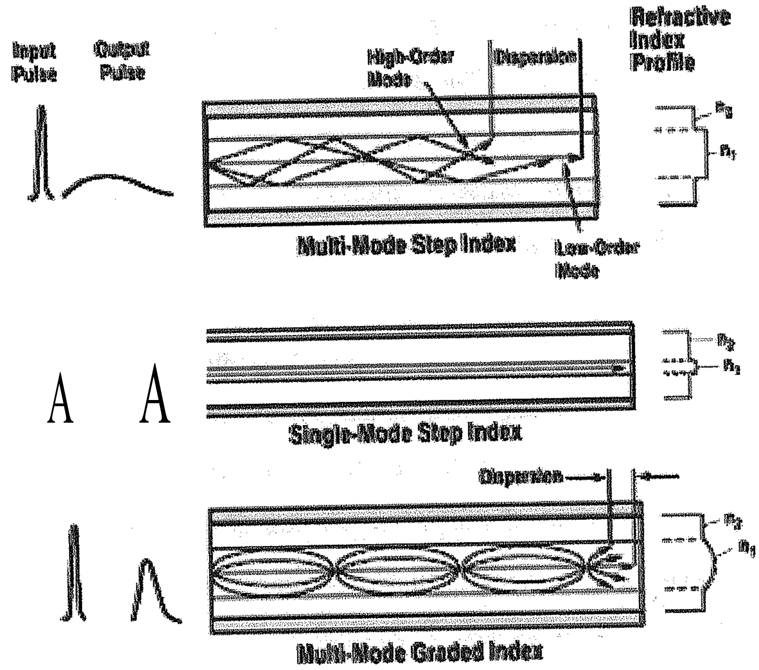
Plastic Clad Silica (PCS) fiber optic cable has an ~ttenuation that liesbetween glass and plastic and a cost that lies between their costs as well. Plastic Clad Silica (PCS) fiber optic cable has a glass core which is often vitreous silica while the cladding is plastic - usually a silicone elastomer with a lower refraetive index. In 1984 the IEC standardized PCS fiber optic cable to have the following dimensions: core 200 microns, silicone elastomer cladding 380 microns, jacket 600 microns, PCS fabrieated with a silicone elastomer cladding .suffers from three major defects, It has considerable plasticity, This makes connector application difficult. .Adhesive bonding is not possible and it is practically insoluble in organic solvents. All of this makes this type of fiber optic cable not particularly popular with link installers, However, there have been some im.provementsin it in recent years.

1.5 The single-mode fiber optie eable

A propagation fiber.optic eable can be one of two types, multi-mode or single.mode. These provide different performance with respect to both attenuation and time dispersion. The single-mode fiber optic cable provides the better performance at, of course, a higher cost, in order to understand the difference in these types an explanation must be given of what is meant by mode of propagation, Light has a dual nature and can be viewed as either a wave phenomenon or a particle phenomenon (photons).

For the present purposes consider it asa wave. When this wave is guided down a fiber optic cable, It exhibits certain modes. These are variations in the intensity of the light, both over the cable cross-section and down the cable length. These modes are actually mımbered :from lowest to highest. In a very simple sense each of these modes can be thought of as a ray of light. Alıhough, it should be noted that the term ray of light is a hold over :from classical physics and does not really deseribe the true nature of light. In any case, view the modes as. rays of light. For a given fiber optic cables the number of modes that exist depend upon the dimensions of the cable and the variation of the indices of refraction of both core and cladding across the cross section, There are three principal possibilities. These are illustrated in Figure 1-5. Consider the top. ilhıstration in Figure 1-5. This diagram correspondsto·multi-mode propagation with a refractive index profile that is called step index, As can be seen the diameter of the core is fairly large relative to the cladding. There is also a sharp discontinuity in the index of refraction as you go from core to cladding. As a result, when light enters the fiber optic cable on the right it propagates down toward the left in mıltiple rays or multiple modes.

This yields the designation mıılti-mode. As indicated the lowest order mode travels straight down the center. It travels along the cylindrical axis of the core. The higher modes represented by rays, bounce back and forth, going down the cable to the left;The higher the mode the more bounces per unit distance down to the left. Over to-the left of this top illustration are shown a candidate inputpulse and the resulting .outputpulse. Note thar the output pulse is significantlyattenuated relative to .the input pulse>It also suffers significanttime dispersion, The reasons for this are as follows. The hiğher order modes, the bouncing rays, tend to leak into the cladding as they propagate down the fiber optic cable. They lose some of their energy into heat. This results in an attenuated output signal, The input pulse is split among the different rays that traeel down the fiber optic cable. The bouncing rays and the lowest order mode, traveling down the center axis, are all traversing paths of different lengths from input to output. Consequently, they do not all reach the right end of the fiber optic cable at the same time. When the output pulse is constructed :from these separate ray components the result is time dispersion.



Figu:re 1..5: Types ofmode propagation in fiber optic cable (Courtesy of AMP

1.6 Multi-mode Propagation

Fiber optic cable that exhibits multi-mode propagation with a step index profile is thereby characterized as having higher attenuation and more time dispersion than the other propagation candidates have. However, it is also the least costly and in the premises environment the most widely used. It is especially attractive for link lengths up to 5 km. Usually; it hasa core diameter that ranges from 100 microns to 970 microns. it can be fabricated either from glass, plastic or PCS. Consider the middle ilhıstration in Figure 1-5. This diagram corresponds to single.mode propagaıiôn with a refractive index profile that is called step index, As can be seen the diameter of the core is fairly small relative to the cladding. Typically, the cladding is ten times thicker than the core. Because of this when ligbr enters the fiber optic cable on the rigbt it propagates down toward the left in just a single ray, a single-mode, and the lowest order mode. in extremely simple terms this lowest order mode is confined to a thin cylinder around the axis of'the core. (in actuality it is a little more complex).

The higher order modes are absent. Consequently, there is no energy lost to heat by having these modes leak into the cladding. They simply are not present. All energy is confined to this single, lowest order, mode. Since the higher order mode energy is not lost, attenuation is not significant. Also, since the input signal is con:fined to a single ray patlı, that of the lowest order mode, there is little time dispersion, only that due to propagation through the non-zero diameter, single mode eylinder. Single mode propagation exists only above a certain specific wavelength called the cutoff wavelength. To the left of this middle illustration is shown a candidate input pulse and the resulting output pulse, Comparing the output pulse and the input pulse note that there is little attenuation and time dispersion.

Fiber optic cable that exhibits single-mode propagation is thereby characterized as having lower attemıation and less time dispersion than the other propagation candidates have. Less time dispersion of course means higher bandwidth and .this is in the 50 to 100 GHz/ km range. However, single mode fiber optic cable is also the most costly in the premises environment. For this reason, .it has been used more with Wide Area Networks than with premises data communications. It is attractive more for link lengths go all the way up to 100 km. Nonetheless; siiıgie-mode fiber optie ..cable has been getting increased attention as Local Area Networks have been extended to .greater distances over corporate campuses, The core diameter for this type of fiber optic cable is exceedingly small ranging from 5 microns to 10 microns. The standard cladding diameter is 125 microns.

Single-mode fiber optic cable is fabrieated :from glass. Becaııse of the thickness of the core, plastic cannot be used to fabricate single-mode fiber optic cable, The author is unaware of PCS being used to fabricate it. it should be noted that not all single-mode fibers use a step index profile.

Some use more complex profiles to optimize performance at a particular wavelength. Consider the bottom illustration in<Figure 1-5. This corresponds to multi-mode propagation with a refractive, index profile that is called graded index. Here the variation of the index of re:fraction is gradual as it extends out :from the axis of the core through the core to the cladding. There is no sharp discontinuity in the indices of refraction between core and cladding. The core here is much larger than in the single-mode step index case discussed above.

Mnlti-mode prôpagation exists with a graded index. However, as illııstrated the paths of the higher order modes are somewhat confined. They appear to follow a series of ellipses. Because the higher mode paths are con:finedthe attenııation through them due to leakage is more limited than with a step index, The time dispersion is more limited than with a step index, therefore, attenuation and time dispersion are present, just limited.

To the left of this bottom illustration is.shown a candidate input pulse and the resulting output pulse. When comparing the output pulse and the input pulse, note that there is some attenuation and time dispersion, but not nearly as great as with multi-möde step index fiber optic cable.

Fiber optic cable that exhibits melti-mode propagation with a graded index profile is thereby characterized as having attenuation and time dispersion properties somewhere between the other two candidates. Likewise its cost is somewhere between the other two candidates, Popular graded index fiber optic cables have core diameters of 50, 62.5 and 85 microns. They have a cladding diameter of 125 microns - the same as single-mode fiber optic cables. This type of fiber optic cable is extremely popular in premise data communications applications. In particular, the 62.5/125 fiber optie cable is the most popular and most widely used in these applications.

Glass is generally used to fabricate multi-mode graded index fiber optic cable. However, there has been some work at fabricating it with plastic. The illustration Figure 1-6 provides a three dimensional view of multi-mode and single-mode propagation down a fiber optic cable. Table 1-1 provides the attenuation and bandwidth characteristics of the different fiber optic cable candidates. This table is far from being all inclusive; however, the common types are represented,

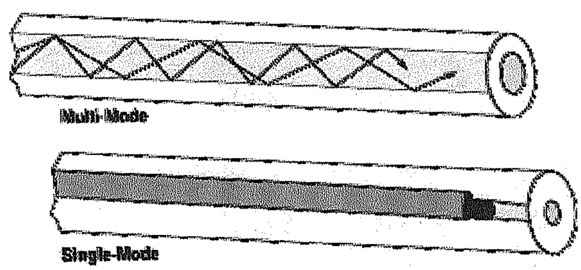


Figure 1-6: Three dimensional view, optical power in multi-mode and single-mode fibers

Table 1~1: Attenuation and Bandwidth characteristics of different fiber optic cable candidates

·---------,~-----

Mode	jMaterial	Index jRefradion Profile	mierens	Size l(microns)	IAtten. dB/km	IBandwidth MHz/km
Multi-mode	Glass	Step	800	62.5/125	5.0	6
Multi-mode	Glass	Step	850	62.5/125	4.0	6
Multi-mode	Glass	Graded	850	62.5/125	3.3	200
Multi-mode	Glass	Graded	850	50/125	2.7	600
Multi-mode	Glass	Graded	1300	62.5/125	0.9	800
Multi-mode	Glass	Graded	1300	50/125	0.7	1500
Multi-mode	Glass	Graded	850	85/125	2.8	200
Multi-mode	Glass	Graded	1300	85/125	0.7	400
Multi-mode	Glass	Graded	1550	85/125	0.4	500
Multi-mode	Glass	Graded	850	100/140	3.5	300
Multi-mode	Glass	Graded	1300	100/140	1.5	500
Multi-mode	Glass	Graded	1550	100/140	0.9	500
Multi-	Plastic	Step	650	485/500	240	5 @ 680

mode						
Multi-mode	Plastic	Step	650	735/750	230	5 @ 680
Multi-mode	Plastic	Step	650	980/1000	220	5 @ 680
Multi-mode	PCS	Step	790	200/350	10	20
Single-mode	Glass	Step	650	3.7/80 or 125	10	600
Single-mode	Glass	Step	850	5/80 or 125	2.3	1000
Single-mode	Glass	Step	1300	9.3/125	0.5	*
Single-mode	Glass	Step	1550	8.1/125	0.2	*

* Too high to.measure accurately. Effectivelyinfinite,

Figure 1-7 illustrates the variation of attenuation with wavelength taken over an ensemble of fiber optic cable material types. The three principal windows of operation, propagation through a cable, are indicated. These correspond to wavelength regions where attenuation is low and matched to the ability of a Transmitter to generate Iight efficientlyand a Receiver to carry out detection. The 'OH' symbols indicate that at these particular wavelengths the presence of Hydroxyl radicals in the cable material cause a bump up in attenuation. These radicals result from the presence ofwater. They enter the fiber optic cable material through either a chemical reaction in the manııfacturing process or as hıımidity in the environment. The illıstration Figure 1~8 shows the variation ofattenııation with wavelength for, standard, single-mode fiber optic cable.

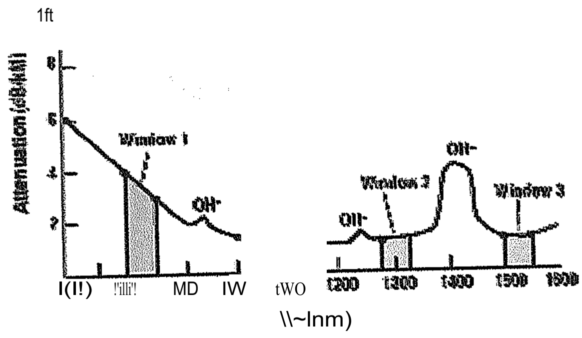


Figure 1-7: Attenuation vs. Wavelength

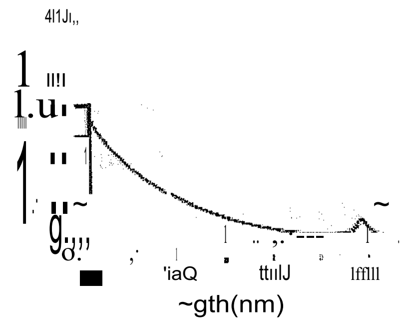


Figure 1-8: Attenuation spectrum of standard single-mode fiber

CHAPTERTWO

THE TRANSMITIONDEVICESOF FiBER OPTIC CABLES

2.1 Overview

In this chapter we will represent the transmission medium of fiber optic witclt corifaın the transmitter, receiver and connectors with the process of placing information onto an information carrier.

2.2 'I'ransmitter

The Transmitter component serves two functions. First, it must be a source of the light coupled into the fiber optic cable. Secondly, it niustmodiılate this light so as to represent the binary data that it is receiving froınfhe Source, With the first of these functions it is merely a light emittefor a source ôflight. With the second ofthese functions it is a valve, generally operatilig by vacyin.ğthe intensity of'the Iight fhatitis emitting and coupling into 'the fiber. Within the côıitext of interest in this book the Source provides the data to the Transmitter assônıe digital electrical signal, The Traıismitter can then be thoughfôf as Electro-Optical (EO) transducer, First some hisfory. At the dawn of fiber optic data comniunicaıion» twenty-five years ago,there was no such thing as a commercially available Transmitter, The network a:fchitect putting together a fiber optic data link hadto design the Transmitter himself. Everything was custômized.

The Transmitter was typically designed using discrete electrical and Blectro-optical devices, This very quick:ly gave way to designs based upon hybrid modules containing integrated circuits, discrete components (resistors and capaciters) and optical source diodes (light emitting diodes-LED's or laser diodes), The modulation function was generally performed using separate integrated circuits and everything was placed on the same printed circuit board. By the 1980's higher and higher data transmission speeds were becoming of interest to the data link architect, The design of the Transmitter while stili generally customized became more complex to acoommodate these hiğher.speeds. A greater part of the Transmitter was implemented using VLSI circuits and attention was given to minimizing the number of board interconnects, Intense research efforts were undertaken to integrate the optical source diode and the transistor level circuits needed fer modulation on a common integrated circuit substrate, without compromising performance. At present, the Transmitter continues to be primarily designed as a hybrid unit, containing both discrete components and integrated circuits in a single package, By the late 1980's commercially available Transmitter's became available. Asa result, .the link design could be kept separate :from the Transmitter design,

The link architect was relieved frem the need to do high-speed circuit design or .to design proper bias circuits for optical diodes.

The Transmitter could generally be Iooked at as a black box selected to satis:fy certain requirements relative to power, wavelength, data rate, bandwidth, ete. This is where the situation remains today. To do a proper selection of a commercially available Transmitter you have to be able to know what you need in ordeı' .to match your other link requirements, You have to be able to understand the differenees between Transmitter candidates. There are many. We cannot begin to approach this in total. However, we can look atthis in a limited way. Ttansmitter candidates can be compared on the hasis oftwo characteristics. Transmitter candidates can be compared on the hasis of the optical source component employed andthe method of modulation.Let us deal with the optical source componeııtoffheTransmitter first. This has to meet a number of requirements,These are delineated below:

First, its physical dimensions must be compatible with the size of the fiber optic cable being used. This means it must emit light in a cone with cross sectional diameter 8-100 microns, ot it cannot be coupled into the fiber optic cable.

Secondly, the optieal source must be able to generate enough optical power so that the desired BER can be met.

Thirdly, there should be high efficiency in coupling the light generated by the optical source into the fiber optic cable.

Fourthly, the optical source should have sufficient linearity to prevent the generation of harmonics and intermediations distortion. If such interference is generated it is extremely difficult to remove. This would cancel the interference resistance benefits of the fiber optic cable.

Fifthly, the optical source must be easily modulated with an electrical signal and must be capable of high-speed modulation-or else the bandwidth benefits of the fiber optic cable are lost.

Finally, there are the usual.requirements of small.size, low weight; low cost and high reliability. The light emitting junction diode stands out as matching these requirements, it can be modulated at the needed speeds. The proper selection of semiconductor materials and processing techniques results in high optical power and efficient coupling of it to the fiber optic cable. These optical sources are easily manufactured using standard integrated circuit processing. This leads to low cost and-high reliability, There are two types of light emitting junction diodes that can be used as thesoptieal source of the Transmitter, These are the light emitting diode (LED) and 'the laser diode (LD). This is not the place to discuss the physics of their operation, LED's are .simpler and generate incoherent, lower power, light. LD's are more complex and generate coherent, higher power light. Figure 2-1 illustrates the optical power output, P, from each of'these devices asa function of the electrical current inplıt,I, fromthe modulation circuitry, As the figure hıdicates the LED has a relatively linear p..I ic:haracteristicwhile the LD has a strong non..linearity or threshold effect, The LD may also be prone to kinks where the power actually decreases with inereasing bandwidth, With minor exceptions, LDs have advantages over LED's inthefollowing·ways:

- They can be modulated at very high speeds,
- They produce greater optical power,
- They have higher coupling efficiencyto the fiber optic cable.

LED's have advantages over LD's because they have

- Higher reliability
- Better Iinearity
- Lower cost

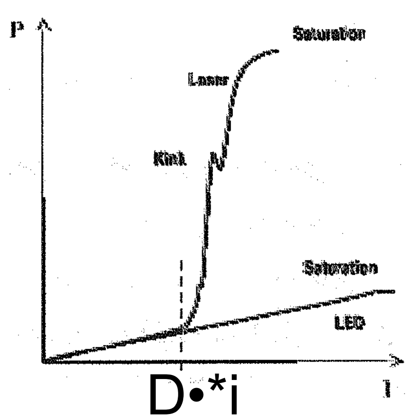


Figure 2-kLED and laser diodes: P-I characteristics

Both the LED and LD generate an optical beam with such dimensions that it .can be coupled into a fiber optic cable. However, the LD produces an output beam with mnch less spatial width than an LED. This gives it greater coupling efficiency. Each can be modulated with .a digital electrical signal. For very high-speed data rates the link architeet is generally driven to a Transmitter having a LD. When cost is a major issue the link architect is generally driven to a Transmitter having an LED. A key di:fference in the optical output of an LED and a LD is the wavelength spread over which the optical power is distributed. The spectral width is 3 dB optical power·width (measured in nm or microns). The spectral width impacts .the effective transmitted signal bandwidth. A larger spectral widthtakes.up a larger portion ofthe fiber optic cable link bandwidth. Figure 2-2 illustrates the spectral width of the two devices. The optical power generated by each device is the area under the, curve. The spectral width is the half-power spread. A LD will always have a smaller spectral width than a LED. The specific value of the spectral width depends on the. details of the diode structure and the semiconductor material. However. typical vahıes. for. a LED are .around 40 nm for operation at 850 nm and 80 nm at 1310 nm, Typical values for a LD are 1 nm for operation at 850 nm and 3 nm at 1310 nm,

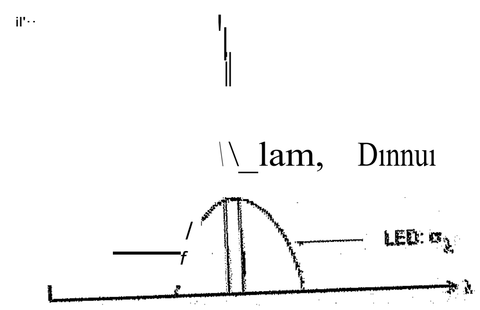


Figure 2-2: LED and laser spectral widths

Once a Transmitter is selected on .the hasis of being either an LED or a LD. additi<.)llal concern should be considered in reviewing ithe specifications of the candidates. Jhese concems include packaging, environmental sensitivity .of .device characteristics, h.e.ı:tt sinking and reliability. With either an LED or LD the Transmitter package mııst have .a transparent window to transmit light into the fiber optic cable. lt may be packaged with either a fiber optic cable pigtail or with a transparent plastic or glass window. Some vendors supply the Transmitter with a package having a small hemispherical lens to help focus the light .into the fiber optic cable, Packaging must also address the thermal coupling for the LED or LD. A complete Transmitter module may consume over 1 W- significant power consumption in a small package. Attention has to be paid to the heat sinking capabilities. Plastic packages can be used for lower speed. and lower reliability applications, However, for high speed and high reliability look for the Transmitter to be in ametal package with built-in fins for heat sinking,

2.2.1 The Modulator Componeat of the Transmitter

Let us now deal with the modulator component of the Transmitter. There are several different schemes for carrying out the modulation :function. These are respectively: Intensity Modulation, Frequency Shift Keying, Phase Shift Keying and Polarization Modulation. Within the context of a premise fiber optic data link the only one really employed is Intensity Modulation. This is the only one that will be described.

Intensity Modulation also is referred to as Amplitude Shift Keying (ASK) and On-Off Keying (OOK). This is the simplest method for modulating the carrier generated by the optical source. The resulting modulated optical carrier is given by:

$$E_s(t) = E_o\, m(t) \cos(2\Phi f_s t)$$

Within the context ofa premises fiber optic data link the modulating signal m (t), the Information, assumes only the values of '0' and 'I.' The parameter ':tl' is the optical carrier frequency. This is an incoherent modulation scheme, This means that the carrier does not have to exhibit stability. The demodulation :functionin the Receiver will just be looking for the presence or absence of energy durinğ a bit titne inte:rval.

2.2.2 Iatensity Medulatlon

Intensity Modulaıion is .employed universally for premises fiber optic data .links because it is well matched to the operation of both LED's and LD's. The carrier .that e.ach of these sources produce is easy to modulate with this technique, Passing current through them operates both of these devices. The amount ofpower that they radiate (sometimes referred to as the radiance) is proportional to this current. in this way the optical power takes the shape of the input current. If the input current is the waveform m (t) representing the binary information stream then the resulting optical signal will look like bursts of optical signal when m (t) represents a '1' and the absence of optical signal when m(t) represents a '0.' The situation is illustrated in Figure 2-11 and Figure 2-12. The first of these figures shows the essential Transmitter circuitry för modulating either an LED or LD with Intensity Modulation. The second of these figures illustrates the input current representing the Iiinformation and the resulting optical signal generated and provided to the fiber optic cable.

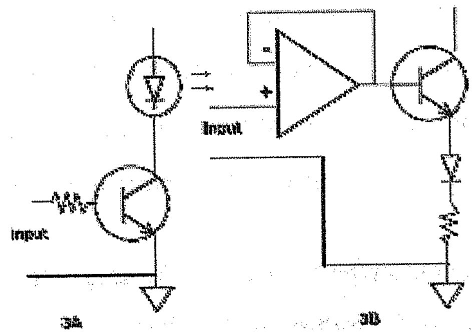


Figure 2-3: Two methods for modulating LEDs or LDs

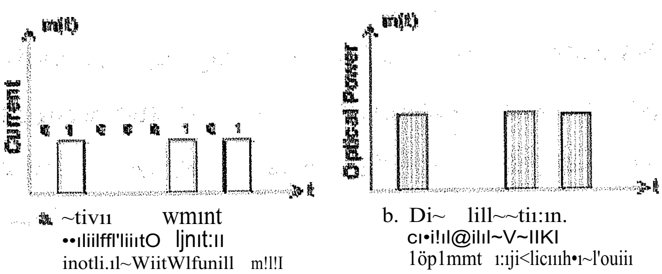


Figure 2-4: a. Input current representing modulation wavefôrm, in(t); b. Output optical signal representing m(t). Vertical cross hatches indicate optieal carrier

It mııst be noted that one reason for the popularity of .Intensity Modulation is its suitability för operation with LED's. An LED can only produce incoherent optical power, Since Intensity Modulation does not require coherenee it can be used with an LED.

2.3 Reeeiver

First, it must sense or detect the light coupled out ofthe.fiber optic cable then convert the light into an electrical signal. Secondly, it must demodulate this light to determine the identity ofthe binary data that it represents. In total, it must detect light and then measure the relevant Information bearing light wave parameters in the premises fiber optic data link context intensity in order to retrieve the Source's binary data.
Within the realm of interest in this book the fiber optic cable provides the data to the Receiver as an optical signal. The Receiver then translates it to its best estimates of the binary data, It then provides this data to the User in the form of an electrical signal,

The Receiver canthenbe thoughtofasanElectro-Optical (EO) transducer.
A Receiver is generally designed with a. Traı:ısmitter~ Both are modules within the same package. The very heart of'the Receiver is the means for sensing the light output ofthe fiber optic cable. Light is detected arı.d then conVirted to an electrical' signal, The demodulation decisionprocess is caıfied out ontbe resulting electrical signal. The light detection is carried outby a photodiode. This seııseslight and converts it into an electricalcurrent. However, the optical signal from the fiber optic cable and the resulting electrical current will have small amplitudes. Consequently, the photodiode circuitty must be followed by one or more amplificatiort stages. There may even be filters and equalizers to shape and improve the Information hearing electrical signal,

Allofthisactive circııitry inthe Receiver presents a source ofnoise. This is a source of noise whose origin is not the clean fiber optic cable. Yet, this noise can affect the de:ı:nodulation process. The very heart of the Receiver is. This shows a photodiode, bias resistor anda low noise pre-amp. The output ofthe pre-ariıpis aıı.electrical waveform version of'the original Information out the source- Tothe right of this pre-amp would be additiotıal amplifica.tion, fihers 'and equalizers. All of these components may be on 'a single integrated clrcuit, hybrid or even a printed circuit board.

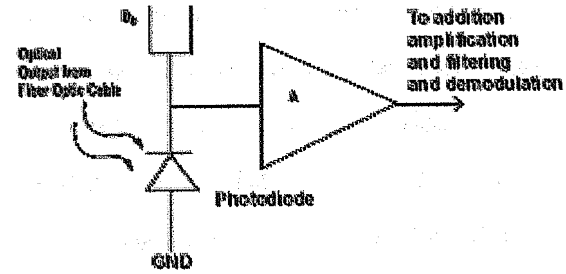


Figure 2-5: Example of Receiver block diagram - first stage

The complete Receivermay incorporate a number of other functions. If the data link is supporting synchfonous communications this will inchıde clock recovery. Other functions may include decoding (e.g. 4B75B ericoded information), error detection and recovery,

The complete Receiver mııst have hiğh detectability, high bandwidth and low noise. It must have high detectability so that if can detectlôw-level optical signals coming out of the fiber optic cable, The hiğher the sensitivity, the more aitenuated siğnals it can detect, it must have high bandwidth or fast rise time so that it can respond fast enough and demodulate, high speed, digital data. it rnust have low noise so that it does not significantly impact the BER of the link and counter the interference-resistanee .of the fiber optic cable Transmission Medium,

2.3.1 The Photodlode Struetures

There are two types of photodiode structures; Positive Intrinsic Negative (PiN) and the Avalanche Photo Diode (APD). in most premises applications the PiN is the preferred element in the Receiver, This is mainly due, to .fact that it can be operated from a standard power supply; typically between 5. ınıd 15 V. APD devices have much better sensitivity. in fact it has 5 to 10 dB more sensiıivity. They also have twice the bandwidth. However, they cannot be used on a 5V printed circuit board. They also require a stable power supply. This makes cost higher. APD devices are usually found in long haul commıınications links.

2.3.2 The Demodulation Performanee

The demodıılation performance of the Receiver is characterized by the BER that it delivers to the User. This is determined by the modulation scheme - in premise applications - Intensity modulation, the received optical signal power, the noise in the Receiver and the processing bandwidth, Considering the Receiver performance is generally characterized by a parameter called the sensitivi.ty,this is usually a curve indicating the minimum optical power that the Receiver can detect versus the data rate, in order to achieve a particular BER. The sensitivity curve varies from Receiver to Receiver, It subsumes within it the signal-to-noise ratio parameter that generally drives all communicatioııs link performance. The sensitivity depends upon the type of photodiode employed and the wavelength of operation, Typical examples of sensitivity curves are ilhıstrated in Figure 2-6. in examining the .specificationof any Receiver you need to look at .the sensitivity parameter.Tbe curve designated Quantum Limit in Figure 2-6 is a reference. in a sense it represents optimum performance on the part of the photodiode in the Receiver, That is, performance where there is 100% efficiency in converting light :from the fiber-optic eable into an electric current for demodulation,

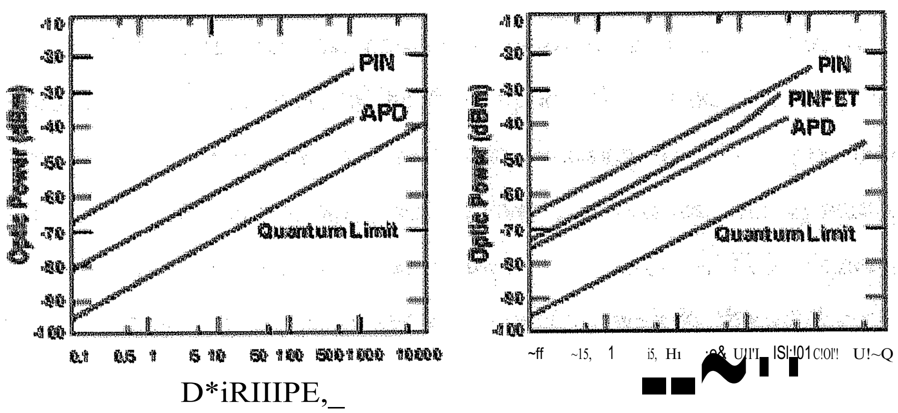


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Figure 2-6: Receiver sensitivities forBER = 10·9, with differentdeviees,

2.4 Conneetors

The Connector is a mechanical device mounted on the end of a fiber optic cable, light source, Receiver or housing. It allows it to be mated to a similar device. The Transmitter provides the Information bearing light to .the fiber optic cable through a connector. The Receiver gets the Information bearing light from the fiber optic cable through a connector. The connector must direct light and collect light. it must also be easily attached and detached from equipment, This is akey point.. The côm.iectoris disconnect able. With this feature it is different than' a splice which wın·.1,e 'discussed in the next sub-chapter,

A connector marks a place in the premises fiber optic data link where signal power can be lost and the BER can be affected>If marks a place in the premises fiber optic data link where reliability can be· affecteijI by a nıechanical connectiön, There are many different connector types. The ones for glass :fiber optiô cable are briefly described below and put in perspective. This is föllowed by discussion of cönnectors for plastic fiber optic cable. However, it must be noted that the ST connector is the most widely used eonnector for premise da.taco:rrimuhlcations.

Connectors to be used with glass fiber optic cable are listed below in alphabetical order. Bionic - One of the earliest connector types used in fiber optic data links. It has a tapered sleeve that is fixed to the fiber optic cable, When this plug is inserted into its receptacle the tapered end is a means for locating the fiber optic cable in the proper position. With this connector, caps fit over the ferrules, rest againsf guided rings and screw onto the threaded sleeve to secure the connection. This connectör is in' liftle use today.D4 - It is very similar to the FC connector with its threaded coııpling, keying and PC end finish, The maili difference is its 2.0mm diameter fetmle; Designed originally by the Nippon Electric Corp. FC/PC - Used for single-mode fiber optic cable, it offers extremely precise positioning of the single-mode fiber optic cable with respect to the Transmitter's optical source emitter and the Receiver's optical detector. it features a position locatable notch and a threaded receptacle. ünce installed the position is maintained with absolute accuracy.SC - Used primarily with single-mode fiber optic cables, it offers low cost, simplicity and durability. It provides for accurate alignment via its ceramic ferrule, it is a push on-pull off connector with a Iocking tab, SMA - The predecessor ofthe ST connector. it features a threaded cap and housing. The use ofthis connector has decreased markedly in recent years being replaced by ST and SC connectors. ST - A keyed bayonet type similar to a BNC connector. It is used for both mıılti-mode and single-mode fiber optic cables. Its use is wide spread. It has the ability both to be inserted into and removed :from a fiber optic cable both quickly and easily. Method of location is also easy, There are two versions ST and ST-U. These are keyed and spring loaded. They are push-in and twist types, Photographs of several of these connectors are provided in Figure 2-7.

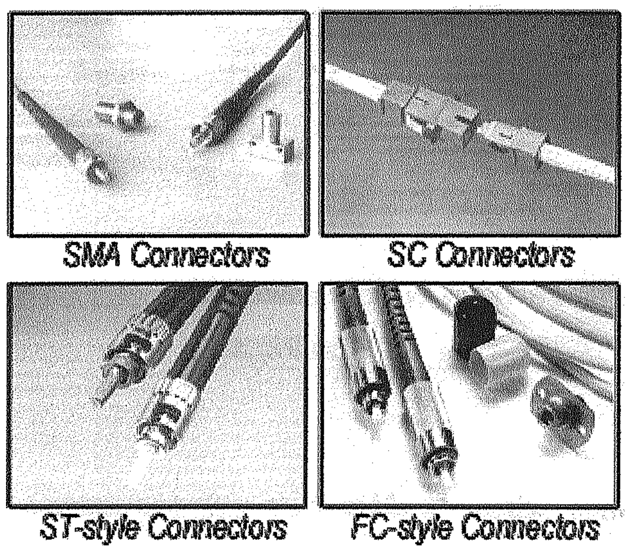


Figure 2-7: Common connectors fot glass fiber optic cable (C01.:ırtesy of A.MP Incorporated)

Plastic Fiber Optic Cable Cöimectors - Cennectors that are exclusively used)f'öt plastic fiber optic cable sttess very'İow cost aııd easy applicatfon. Ofteri used in applicatiöl1S with no polishing or epöxy. Figure 2.:8 illustrates such a connectOr. CoııneetOrs for plastic fiber optic cable include both proprietafy desiğtıs and staııdard designs, Connectors used for glass fiber optic cable, such as ST or SMA are also available for use with plastic fiber optic cable, As plastic fiber ôptic cable gains in popularity in the data communications world there will be undoubtedly greater standardization.

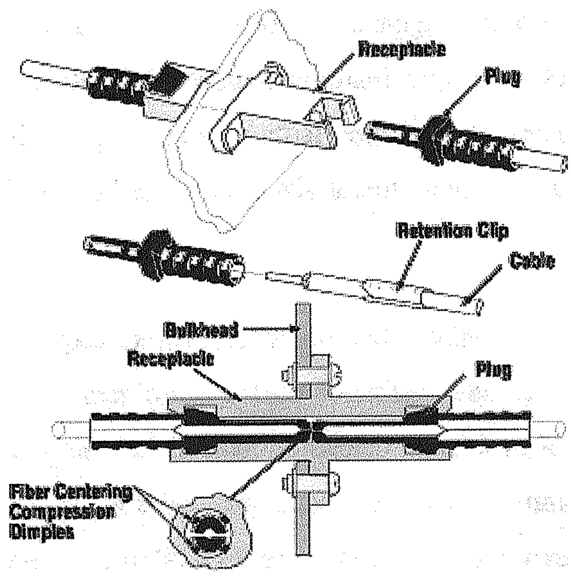


Figure 2;;.8: Plastic fiber optic cable'cönnector (Illustration courtesy of AMP Incorporated)

2.5 Splicing

A splice is a device to conrıect oı:ıe fiber optiô cable to another perrnanently.Jt is dıe attribute of permanence tha.t distinguishes a splice fronı con.rtectors.Noııetheless, Sôme vendors o:ffer spİicesthat can be dıscônnected tha.tarehotpennanent so thaftheycanbe disconnected for repairs or tearrangements. The ternıinology can get cô.rifusmğ. Fiber optic cables may have tô be splicedtogether for any of a numbef of feasôfıs. One reasorr is to realize a link ofa particular lerigth. The networkınsta.fiet lllıiy hav~ iıı his inventory severalfiber ôptic cables but none long enôuğhtô satis:cy th.e required link Iength, This may ea.sily arise Since cable manufacturers o:ffer cables in limited lengths - usually 1 to 6 km. If a link of 10 km has to be installed this can be done by splicing several together, The installer may then satisfy the distance requirement and not have to buy a new fiber optic cable, Splices may be required at building entrances, wiring closets, couplers and literally any intermediary point between Transmitter and Receiver. At first glance you may think that splicing two fiber optic cables together is like connecting two wires, To the contrary, the requirements fora fiber-optic connection and a wire connection are.very di:fferent. Two copper connectors can be joined by solder or by connectors that have been crimped or soldered to the wires, The purpose is to create an intimate contact between the mated halves in order to have a low resistanee patlı across a junction, On the other hand, connecting two fiber optic cables requires precise alignment of the mated fiber cores or spots in a single-mode fiber optic cable, This is demanded so thar nearly all of.the light is coupled from one fiber optic cable across a junction to the other fiberoptic.cable. Actual .contaet.between.the fiber optic cables is not even mandatory, The need for precise alignment creates a challenge to a designer of a splice,

There are two principal types of'splices: fusion and mechanical, Fusion splices - uses an electric arc to weld two fiber optic cables together, The splices offer sophisticated, computer controlled alignment of fiber optic cables to achieve losses as low as 0.05 dB. This comes at a high cost. Mechanical-splices all share common elements, They are easily applied in the field, reqüire little or no toolin.g and offer losses of about 0.2 dB.

2.6 Analy:ıing Performaaee of a Link

You have a tentative design for a fiber optic d~tıı lin.k of the type that is being dealt with in this ehapter, You want to know whether-this .tentative design will satisfy .your performance requirements. You characterize your' performance requirements by BER. This generally'depends upoılthe specific Source-User applicatiQn. This could be asfügh as 10"3 for applications like digitized voice or as low as 10·10 for scientific data. The tendeney though has been to require lower and lower BERs. The question the:ıi<is will the tentative fiber optic link design provide the required BER? The answeritothis question hinges on the sensitivity of the Receiver that you have chosen for··yôut fiber optic data link design, This indicates how much received optical power must appear at the Receiver in order to deliver the required BER

To determine whether your tentative fiber optic link design can meet the sensitivity you must analyze it. You must determine how much power does reach the Receiver, This is done with a fiber optic data link power budget. A power budget for a particular example is presented in Table 2-1 below and is then discussed. This example corresponds to the design ofa fiber optic data link with the following attributes:

1. Data Rate of 50 MBPS.
2. BER of 10-9.
3. Link length of 5 km (premises distances).

4. Multi-mode, step index, glass fiber optic cable having dimensions 62.5/125.Transmitter uses LED at850 nm,
5. Receiver uses PiN and has sensitivity of -40 dBm at 50 MBPS.
6. Fiber optic cable has 1 splice,

Table 2-1: Example Power Budget for a fiber optic data link

LINK ELEMENT	VALUE	COMMENTS
Transmitter LED output power	3 dBm	Specified value by vendor
Source coupling loss	-5 dB	Accounts for reflections, area mismatch etc.
Transmitter to fiber optic cable connector loss	-1 dB	Transmitter to fiber optic cable with ST connector. Loss accounts for misalignment
Splice loss	-0.25 dB	Mechanical splice
Fiber Optic Cable Attenuation	-20 dB	Line 2 of Table 2-1 applied to 5 km
Fiber optic cable to receiver connector loss	-1 dB	Fiber optic cable to Receiver with ST connector. Loss Accounts for misalignment
Optical Power Delivered at Receiver	-24.25 dB	
Receiver Sensitivity	-40 dBm	Specified in link design, Conslstem with Figure 2-14
LOSSMARGIN	15.75 dB	

The entries in Table 2-1 are more or less self-explanatory, Clearly, the optical power at the Receiver is greater than that required by the sensitivity of the PiN to give the required BER. What is important to note is the entry termed Loss Margin? This specifies the amount by which the received optical power exceeds the required sensitivity, in this example it is 15.75 dB. Good design practice requires it to be at least 10 dB. Why? Because no matter how careful the power budget is put together, entries are always forgotten, are too .optimisticor vendor specificationsare not aecurate.

CHAPTER THREE

EXPLOITING THE BANDWIDTH OF FIBER·OPTI(JCABLE-EMPLOYMENT BY MULTIPLE USERS

3.1 Overvlew

in this chapter, I will represent the Sharing the Transmission Medium, Time Divisio:n Multiplexing (TDM). Wavelength Division Mıltiplexing (WDM) With Fiber Optic Cable and Comparing Multiplexing Techniques för the Premises envirerıment on the hasis of'link design flexibility,

3.2 Sharing the Transmissfon Medium

You are the network manager ofa co:mpany.Y'<>u have a Source..User link requirement given to you, in response you install a premises fiber optic data link. The situation is just like that illustrated in Figure 2-1. However, the bandwidth required by the particular Source-User pair, the bandwidthto accommodate the Source-User speed requirementsls much, much, Iess than is· available from the fiber optic data Iinking, The tremendous bandwidth ofthe installed fiber optic cable is being wasted, On the face of it, this is not an economically efficient Installation,

You would like tojustify the installation oftheJink to the Co:n.t:roller of you:r côrnpany, the person who reviews your budget. The Controller doesn'tJ.ındetstand the attemıation benefits of fiber optic cable, The Controller doesn't understand the ihterfereıce benefits of fiber optic cable, The Controller hates waste. He just wants to see most of the bandwidth of the fiber optic cable used not wasted, There is a solution to this problem. Don't just dedicate the tremendous bandwidth of the fiber optic cable to a single, particular, Source-User communication requirement. Instead, allow it to be shared by a multiplicity of Souree-User requirements, it allows it to carve a rmıltiplicity of fiber optic data links out ofthe same fiber optic cable. The technique used to bring aboııt this sharing of the fiber optic cable among a multiplicity of Source-User transmission requirements is called mıltiplexing. it is not partieular to fiber optic cable, it occurs with any transmission medium e.g. wire, microwave, etc., where the available bandwidth far surpasses any individual Source-User requirement. However, multiplexing is particularly attractive when the transmission medium is fiber optic cable. Why? Because the tremendous bandwidth presented by fiber optic .cable presents the greatest opportunity, for sharing between different Source-User pairs. Conceptually, multiplexing is illustrated in Figure 3-1. The figure shows 'N' Source-User pairs indexed as 1, 2. There is a multiplexer provided at each erid ofthe:fibefoptic cable. The multiplexer on the left takes the data provided by each of the Sôurces. It combines these data streams together and sends the resultant stream out on the fiber optic cable, In this way the individual Source generated data streams share the fiber optic cable. The multiplexer on the left performs what is called a multiplexing or combining function, The multiplexer on the right takes the combined stream put out by the fiber optic cable. It separates the combined stream int9 the individual Source streams composing it. It directs each of these component streams jo .the corresponding User. The multiplexer on the right performs what is called a demultiplexing funetion, A few things should be noted about this ilhıstration shown in Figure 3-1.

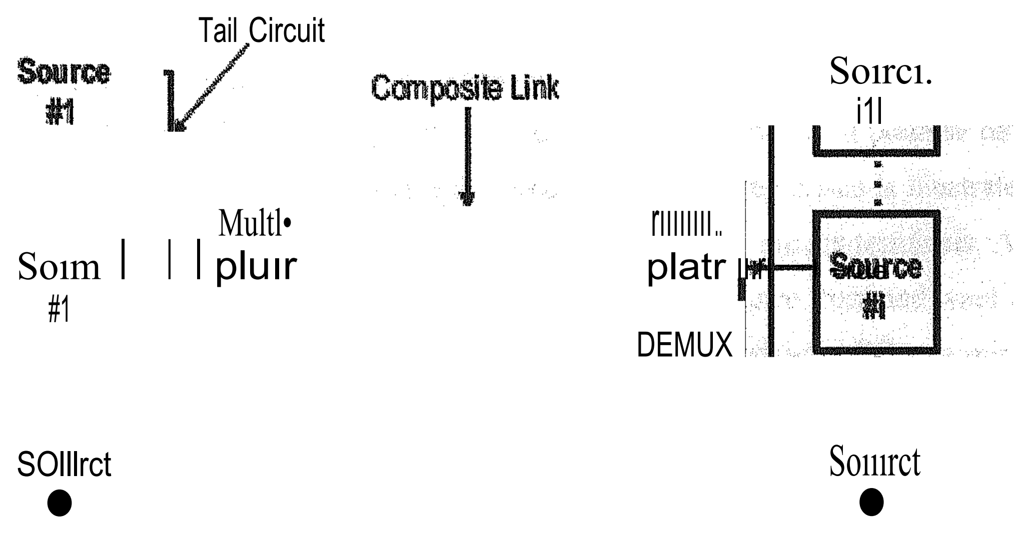


Figure 3-1: Conceptual view of'Multiplexing. A single fiber optic cable is "carved" into a multiplicity of fiber optic data links,

First, the Transmitter and Receiver are stili present even though they are not shown. The Transmitter is considered part of the multiplexer on the left and the Receiver is considered part ofthe multiplexer on the right.

Secondly, the Sources and Users are shown close to the multiplexer, For multiplexing to make sense this is usually' the case. The connection from Source-to-multiplexer and mıltiplexer-to-User is called a tail circuit. If the tail circuit is too long a separate data link may be needed just tô bring data :from the Source to the multiplexer or :from the multiplexer to the User. The cost of this separate data link nıay counter any savings effected by multiplexing.

Thirdly, the link between the multiplexer, the link in this case realized by the fiber optic cable, is termed the composite link. This is the link where traffic is composed of ali the separate Source streams.

Finally, separaıe Users are shown in Figure 3-1. However.It may be that there is just one User with separate ports and ali Sources are coıfununicating with this common user, There may be variations upon this; The Source-User pairs need not be all of the sanı.e type. They may be totally different types of data equipment serving differertt applications and with different speed requirements. Within the context of premise data communications a typical situation where the need for multiplexing arises is illustrated in Figure 3-2. This shows a cluster of terminals, in this case there are.six.te~als -..All of these term.inals are fairly close to one another, All are at a distance :from and want to communicate with a multi-user computer. This may be either a multi-use PC ora mini-computer. This situation may arise when all ofthe terminals are co-located on the same :floor of an office building and the multi-user computer is in a computer room on another :floor of the building.

The communication connection of each of these terminals could be effected by the approach illustrated in Figure 3-3. Here each of the terminals is connected to a dedicated port at the computer by a separate cable. The cable could be a twisted pair cable,

Figure .3.,2: Terminal eluster isolated from multi-user computer

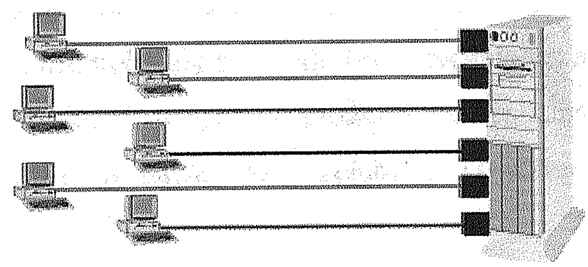


Figure 3-3: Terminals in cluster, Each connected by dedicated cablestô n:ıultilüser :
cômputer

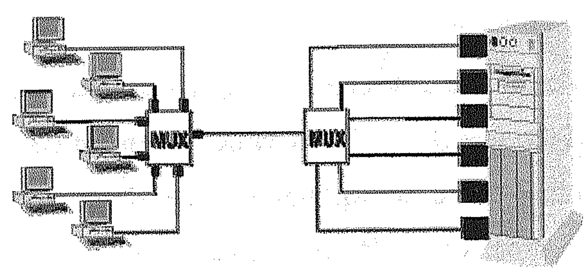


Figure 3-4: Terminals sharing a single cable to multi-user computer by multiplexing

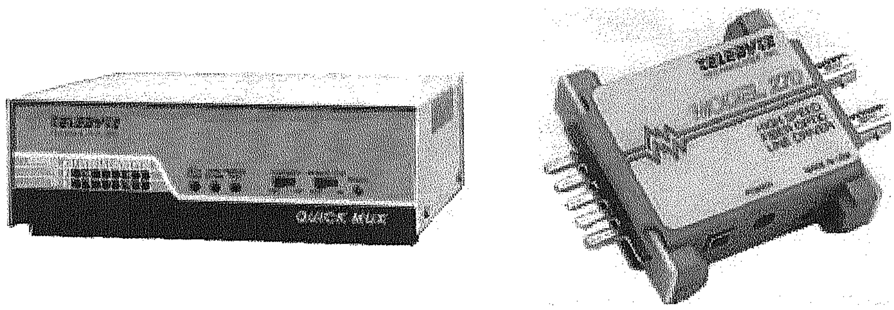
A more economically efficient wayofrealizing the communication.conneetionis shown in Figure 3-4. Here each of the six terminals is conneeted to .a multiplexer .. The data streams from .these terminals are collected by the .multiplexerx The streams are combined and then sent on a single cable to another multiplexer located neatthe multi-user computer. This second multiplexer separates out .the .individual terminal .<:lata streams and provides each to its dedicated port.The connecjion going from the. çompu.ter to the terminals is similarly handled. The six cables shown in Figure 3-3 has been replaced by the single composite link cable shown in Figure 3-4. Cable cost has been significantly reduced. Of course, this comes at the cost of two multiplexers. Yet, if the terminals are in a cluster the tradeoff is in the direction of a 11.et·decreasein cost. There are two techru.qÜesfor cartying out nıtıltiplexing on .fiber öptic eable in the premise environment. These .two techniques are Time Divisiöıı Multiplexiııg (TDM) and Wavelength Division Mültiplexinği(WDM). "Ihese tecİmiqueşCarede~cri@d in the sequel, Examples are introduced of specific products for realizing these techniques, These products are readily available from Telebyte, TDM and WDM are then compared.

3.3 Time Dlvision Multiplexing (TDM) with Fiber Optic Cable

With TDM a multiplicity of communication .links, each for a given Soµrçe..l.Jş~r(pair, share the same fiber optic cable on the. hasis of time. The multiplexer(s)./set. up Jı continuous sequence of time slots using clocks, The duration of the time slöts 4epends upon a number of different engineering design factors; ymost. notably the needed transmission speeds for the different links,

Each communication link is assigned a specific time slot, a TDM channel, during which it is allowed to send its data from the Source end to the User end. During this time slot no other link is permitted to send data, The multiplexer at the Source endtakes in data from the Sources connected to it. It thel1 loads the data from each Source iıtô its corresponding TDM channel, The multiplexer at the User end unloads ·the dafa froriı each channel and sends it to the corresponding User.

The Telebyte Model 570 Quick Mux is an excellent example of a TDM based multiplexer that can exploit the bandwidth of fiber optic cables for premises data communications, The Telebyte Model 570 Quick Mux can actually carry out multiplexing in the premise environment when Unshielded Twisted Pair (UTP) cable is being employed. However, this unit can be adapted for transmission ovee a fi°Qer optic cable, This is accomplished simply by using the Telebyte Model 270:Hiğh..Speed Fiber Optic Line Driver, This attaches to the output port.fbr.the-cemposite linkoftheTelebyte Model 570 Quick Mux and is then used for transmitting and receiving over aifibetoptic cable. Both the Telebyte Model 570 Quick Mux and the Model 270 are pictured in Figure 3-5



Figımre 3-5: Model 570 TDM Multiplexer with Model 270 Fiber Optic Line Driver

The Telebyte Model 570 Quick Mux has eight (8) input ports. This tıfilt can accommodate Source-to-User;~tunicati~~that ~tsynchronous and fullduplex at any data speed up to 19.2 KBPS. Each input p<>rt canalso take in the bi-directional control signals DTR and DCD/ffhe·\fiber optic da.ta lirik<betweenthe Sourceiand User multiplexers can be as long as 2 km. The unit hasa status display. The unit can easily accommodate different port speeds, Source-User transriiissiôıı speeds, The true advantage of the Telebyte Model 570 Quick Mux is its versatility that is its ability to be used with both fiber optic cable and UTP transmission media, The illustration Figare 3-6 shows an application of'the 'Telebyte Model 570 Quick Mux with the Telebyte Model 270. On the right side of the figure are eight (8) different data devices, There are all different types, i.e., PCs, a plotter and 2 printers. All of these data devices need to communicate with the UNiX Server shown on the left side. Each data device is assiğn.ed a dedicated port atthe UNiX Server. The two (2) Model 570's and two {2)Model 270's effect the communicaıiön from/to all these devices by using just one (1) fiber optie cable, When-the transmission medium is fiber optic cable the data devices can be as far

as 2 km from the UNIX Server. The Telebyte Model 273 Four Channel Fiber Optic Multiplexer is another excellent example ofa TDM based multiplexer that can exploit the bandwidth ofa fiber optic cable for premises data communications. A photograph of this unit is shown in Figure 3-7. Unlike the Model 570 Quick Mux,the 'Felebyte Model 273 Four Channel Fiber Optic Multiplexer only operates with a fiber optic cable,

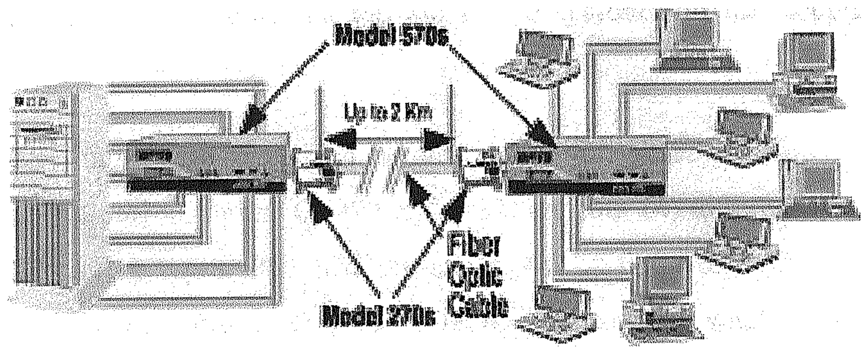


Figure 3-6: Model 570 TDM Multiplexer with Model 270 realizing time division multiplexed data communications all to a UNIX server.

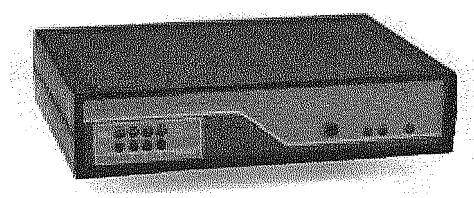
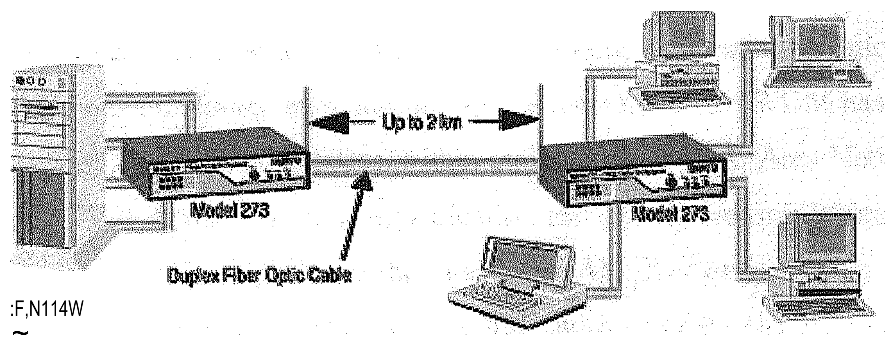


Figure 3-7: Model 273 Four channel fiber optic TDM Multiplexer

The Telebyte Model 273 Four Channel Fiber Optic Multiplexer has four {4)input ports and can accommodate Source-to-User communication that is asynchronous and full duplex at any data speed up to 64 KBPS. This is much higher than the Model 570 Quick Mux, On each input port it can also take in a bi-directional control signal e.g. DTR/DCD. Control signals can be transmitted at a speed up to 16 KBPS. A jumper option allows upgrading TDM channel 1 of the Telebyte Model 273 Four Channel Fiber Optic Multiplexer to 128 KBPS while reducing the number of total channels from 4 to 3. The fiber optic data link between the Source and User multiplexers can be aslong as 2 km. The Telebyte Model 273 Four Channel Fiber .Optic Multiplexer has a status display. Transmit and Receive data are indicated för each TDM channel; As a further aid to installation and <verificatiön of· fiber optie data link performancetheTelebyteModel 273 Four ChannelFiber Optic Multiplexetiseq_uipped with a front panel TEST switch. The switch on one Multiplexer, say thı;, one rieartthe Sources sends a test pattern to the remote Model 273. This caııses the remote Môdel273 to go into loop..backwhiletheoriginating Model·273searches forthe receptio:tfofthe test'pattern,

The illustration Figure 3-8 shows an application of the Telebyte..Model 273 Four Channel Fiber Optic Multiplexer. On the right side are four (4)different data devices. These are of different types, PCs and terminals. All of these data devices need to communicate with a main frame computer. This is not shown but what is shown on the left is the Front End Processor (FEP) ofthis main frame computer. All communication to/from the mainframe computer is through ports of the FEP. Each 'data..ğevice is assigned a dedicated port at the FEP. The two Model 273's effect the coımnunic~{iop. from/to all these devices by using just one fiber optic cable that can be as long as 2. krı:ı.



Figu.re 3-8: Model 273 realizing time division mıltiplexed,data commımications to a mainframe computer through its FEP.

3.4 Wavelength Division Multiplexing (WDM) With Fiber Optle Cable

With WDM a multiplicity of conmiuriicaiion1llil<s?eachfofa givenŞpurce-User pair, share the same fiber optic cable ol'.lthebasis.ofwayeleııgth. The<iaJijştream from each Source is assigned an optical wavelength; ihe :multiplexerhas within it the modulation and transmission processing circuitry, The multiplexer modulates each data stream from each Source. A:fter the modulatien process the resultinğ optical signal generated for each Source data stream is placed on its assigned wavelength, The multiplexer then couples the totality of optical signals generated for all Source data streams into the fiber optic cable. These different wavelength optical signals propagate simultaneously. This is in contrast to TDM.The fiber optic cable is thereby carved into a mııltiplicity of'data links - each data link corresponding to a different one of these optical wavelengths assigned to the Sources, At the User end the multiplexer receives these simultaneous optical signals, it separates these signals out according to their different wavelengths l)y using prisms. This constitutes the demultiplexing operation. The separated signals correspond to the different Source-User data streams. These are further dem.ôdula.ted. The resulting separated data streams are then provided to the respective lJsers. At this point a slight digression is necessary,

The focus of this project is on premise data communications, data commuıiicatiöMi.11 the local area environment. Notwithstanding, it must be mentioned that WDM<hasbeen receiving a tremendous amount of attention within the context ofWide Area Netwôrks (WANs). Both CATV systems aridtelecommunication carriers aremfilcınğiireatel'and greater use of it to expand the capacity of the installed WAN fiber öptic cabliıığ plant. Within the Wide Area Networking environment the multiplicity of channels carved from a single fiber has increased tremendously using WDM. The increase has led to the term Dense Wavelength Division Multiplexing (DWI)M) to describe the newer \\TDMs employed. Now, back to our main topic. The Telebyte Model 381 2 Channel WDM - Wavelength Division Multiplexer is an excellent example ofa WDM based multiplexer that can exploit the bandwidth ofa fiber optic eable'for premises data communications, A photograph ofthis unit is shown in Figure 3-9.

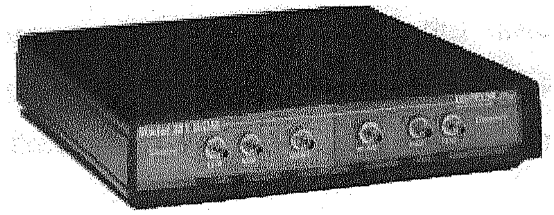


Figure 3-9: Model 3812 ChaıiliefWDM

The Telebyte Model 381 2 Channel WDM-Wavelength l)i"i~ion Multiplexer is totally passive. It employs wavelength division multiplexing with Acsiı.ıgle-mode output. This essentially doubles the data carrying capacity of a fiber optic cable. it carves oıit two channels out of the fiber optic cable. The Telebyte Model 3.~1.>2 Channel WDM-Wavelength Division Multiplexet allows the combining and s~pat'ating of.iı.ıdiyidual wavelengths allowing the two individual channels to be ırarısmitted slınultaneotıslyiover the same fiber optic cable. The Telebyte Model $81 2 Channel(WDM - Wa.v~l~n.gt:h Division Multiplexer requires the attached data <l.eyices, the Sources, to. prqyi.de 411.e necessary wavelengths for operation. The wavelengths being multiplexed are 1310 nnı and 1550 nm. Consequently, each Source must have a Transmitter that provideSthe necessary optical signal to this unit. Similarly, each User must have a Receiverto-take the corresponding opticalsignal from this unit. The Telebyte Model 381 2 Channel WDM - Wavelength Division Multiplexer is completely protocol ~~)>speed independent, Both analog and digital a.pplications canpe transmitf~dsin:ıµl\~eöusly on the same fiber. Within the premise environment' the u:rüt can multiplex aııdithereby merge the optical transmissions of daıa, voföe, video and other types of inforırriatiön on a single fiber optic cable.

Furthermore, the unit can be employed for inter-office service channel monitoring and perform out ofband network management.Because the Telebyte Model 381 2 Channel WDM - Wavelength Division Multiplexer is passive it has high reliability. Also, with respect to the type of data traffic it can multiplex, it has mııch greater flexibilitytharithe TDM based products described above. The TDM based products essentially handle oıily digital traffic, Tlıe Telebyte Model 381 2 Channel WDM - Waveieıງgtlı IJi\iision Multiplexer is a stand-alone unit. However; there is a rack-mounted version of it, the Model 2381. This is hosted in Telebyte's Model 2200 Card cage. Both units utilize a fused biconic taper concept to effect the mııltiplexing of the individu.al channels, This allows for high isolation, low insertion loss and back reflectance over a wide range of temperature and mechanical stresses, High isolation means that there will be little interference between the two channels being multiplexed, effectively low cross talk. Low insertion loss and back reflectance mean greater optical signal levels delivered to the User end of the cable,

This all works to a lower BER. The ilhıstration showed in Figure 3-10 shows an application of the Telebyte Model 381 2 . Channel WDM - Wavelength Division Multiplexer. This is an application in the office building facility ofa company. On the left side of the figure are two different data devices, the Ethernet Server and a digital leased Tl line. The Ethernet.Server is at the hub ofthe companys LAN. The leased-TI line brings in voice traffic from some ofthe company's remote-locations. For purposes of this example these are the .Sources, Within .the office building facility the Ethernet Server needs to eommunicate to the Ethemet Switch shown on the right side öfthe figure. The.leased-Tl line needs to be connected-te-the-company's diğitahPBX sothat these. voice conversations can be routed inthe buildfug to the appropriate personnel, The Ethernet Switch and the PBX are tbe Users in this example,

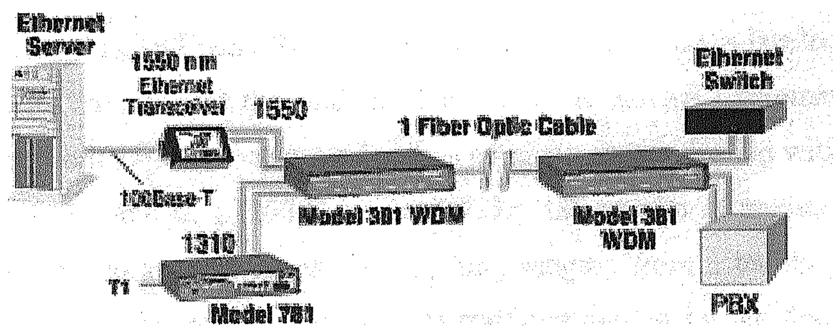


Figure 3-10: Model 381 realizing wavelengih division multiplexed data communications, Application also employs Model 376 and Model 781.

This application requires two Sources to be connected to two Users by a single fiber optic cable. The fiber optic cable has to be shared-multiplexed, As shown in Figiıre 3-10 the Telebyte Model 381 2 Channel WDM - Wavelength Division Multiplexer aided by two other Telebyte products realizes the needed connection on the single fiber optic cable, The Ethemet Server on the left is generating lOBase-T LAN data traffic, it supplies this traffic to the Telebyte Model 376 lOBase-T to single mode transceiver.

This essentially acts as the Transmitter for the Ethernet Server Source, it puts the 1OBase-T data traffic on a single-mode optical signal at a 1550 nm wavelength, The leased Tl line on the left supplies its digital voice traffic to the Telebyte Model 781 Fiber Optic Modem. This acts asa Transmitter for-the Tl traffic, It puts the Tl traffic ona single-mode optical signal ata 1310 nm wavelength. Both of'these wavelengths are compatible with Telebyte Model 381 2 ChannelWDM - Wavelength Division Multiplexer. Both of these optical signals are taken by the Telebyte Model 381 2 Channel WDM - Wavelength Division Multiplexer and.coupled into the single fiber optic cable and transmitted simultaneously.

On the right side you will see that the Telebyte Model 381 2 Channel WDM - Wavelength Division takes the combined signal out of the single fiber optic cable. It separates it according to wavelengths. The unit then provides the respective Source traffic to the respective Users. The illustration Figüre 3-11 shows another application of the Telebyte Model 381 2 Channel WDM - Wavelength DivisionMultiplexeriand)its companion produets the Model 2381 and Model 2200.

This application is concerned with testing ofa fiber optic cable based communica.tiorts network. It concerns the testing of the fiber optic links from some central net"7prk location to individual customers, in Figure 3-11 the central network location is label.ed Service Provider Optical Terminal and the individual customer is labeled ~~s,on:ı~r Optical Terminal. The network could be one provided by a common carrier dealing with digital comrmınications or it could be a CATV service. Within the context öfpremise data communications -the rıetwork could be almost anything ranğing from aFbuilding security network to a LAN. In this application the data traffic is cartied by the fiber optic cable basednetwork ata wavelength of 1310:nın..This isclearly·shown at the Service Provider Optical'Terminal and at the Customer Optieal-terminal; The network manager would Iike to test the contimııty of the fiber optic cable connections out to individual eustomers by doing Ioop back tests, The network manager would like to do this by sending a test signal out from the .Service:Provider OpticalTerminal to each Customer Optical Terminal and then detecting the signal's return to the Service Provider Optical Terminal The network manager wouldlike·to do this withôuf disturbingthe traffic being carried at 1310 nm, In otherwords the network manager<warttstô perform out of band-loop back testing.

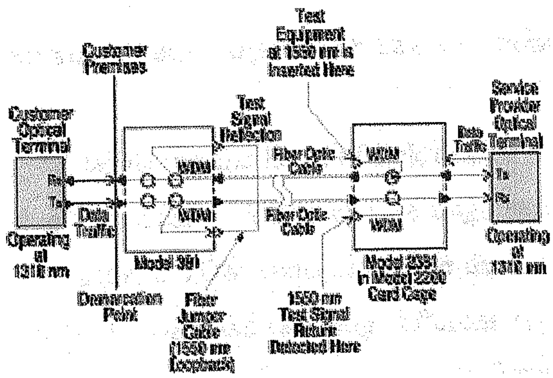


Figure 3-11: Typical application of'out-of-band loop access and testing using "\VD1\ı1's

Figure 3-11 shows how this can be done with' WDM. First of all, as the lllustration shows at the Service Provider Öptical Terminal there is a Model 2200 Card Cage populated with Model 2381 rack mounted cards. this. is a convenient way 'tô package the needed WDMs so that loôp baek testing can. be performed simultaneouslyôri a multiplicity of Service Provider Optical Terminal-to-Customer Optical Terrrııirı~Ffiber optic links. Only one' such' link· is shown but imagine that the testing is going on vvith multiple Iinks, Each rack-mounted eard will correspond to each one oftheselmks. Consider a specific one oftbese.Iinke.

Atthe Service~rovider• Optical Terminal end the traffic (~~ta or ?fh~r}atl '!10 nm intended för this link is provided to a Model 2381 WDM. It is multiplexed with an optical test slgnal ğenerated ata wavelength of 1550 ıını. The cônıbined optical signal is then sent over a fiber optic cable to the Customer Optical Terminal end, The stand alone Model 381 at the Customer Optical Terminal end separates the traffic (data or other) fromthe·injectedtestsiğnal·o1 1the basisofwavele1 1gth.. It :forwards.Üıe traffic at the 1310 nm wavelerıgth to the Customer Optical Terminal. However, it takes the 1550 11.tll wavelength test signal and comblıies it withtraffic coming from the Custômeröptical Terminal and intended for the Service Prövider Opticaf Terminal. The test signal'and this traffic are multiplexed and sent back along another fiber optic cable to the Service Provider Optical Cable, When this combined traffic stream reachesthe Model 2200 Card Cağe/it is separated by a Model 2381 again on llie hasis of wavelength, The traffic (data or other) on the 1310 nm wavelengthis forwardedto th~Service Provider Optical Terminal. The test signal on the 1550 nm wavelength is detected for completion of the loop back test. If the test signal is not received backthe loop back test fails.

3.5 Comparing Multiplexing Techniqu.es fôtthe Premisesenvirônment

It is best to compare TDM and WDM on the basis oflinkdesign flexibility, speed and impact on BER. Link Design Flexibility - TDM can be engineered to accoın:modate di:fferentlink types, in other words, a TDM scheme can be designed to carve a given fiber optic cable into a multiplicity of links earrying different types of traffic and at di:fferenttransmission rates.. TDM can also be engineered to have different time slot assignment strategies. Slots may be permanently.assigned, Slots may be assigned .up◇ll demand (Demand Assignment Multiple Access - DAMA).·Slots .may vary depending upon the type of link being configured, Slots may even be dispensed with a.ltogether with data instead being encapsulated in a packet with Source and User· addresses (statistical multiplexing). However, within the context of premises environmeıt;d,ı~ı-~is strong anecdotal evidence that TDM works best when it is .ıısed to coııfigµre a. multiplicity of links all ofthe same traffic type, withtime slots all ofthe sameidutati()n and permanently assigned. This simplest version of TDM is easiest to d~sign<aml manage in premise data communications.

The more complex versions are really meant for tbe WAN environment, Onithe ôther hand, in the premises environment WDM, generally, has much grea.fol'flexibilitylWinJ is essentially an analog technique. As a result, with WDM it is mu.eheasie:r to carve a fiber optic cable into a multiplicity of links of quite dif.feren.ttypes.Theicha:facterofthe traffic and the data rates can be quite different and not:pose any rea.ldifficillties for WDM. You can mix 1OBase-T Ethemet LAN traffic wıth 100:Base~T Etherııet' LAN traffic with digital video and with out ofband testing signals and so on. With WDM it is mııch easier to accommodate analog traffic. it is n:ıucheasier to add new links o:rftô an existing architecture. With TDM the addition of new links with different fraffic requirements may require revisiting the design of all the time slots, a major e:ffort. With respect to flexibility the one drawback that WDM has relative to TDM in. tbe p:remises environment is in the number of simultaneous links it can handle. This is uswıllYmııch smaller with WDM than with TDM. Nonetheless, advances in DWDM for the WAN environment may :filter down to the premise environment and reverse this drawback.

Speed - Design ofTDM implicitly depends upondigital components. Digital circuitry is required to take data in from the various Sources, Digital components ate needed to store the data. Digital components are needed to load the data into cörresponding time slots, unload it and deliver it to the respective Users, How fast musr these digital components operete? Roughly, they must operete at-the speed of the cômpôsite link of the multiplexer. With a fiber optic cable transmission medium, depending upôh cable length, a eomposite link of multiple GBPS could be accoımnodated. However, commercially available, electricallybased, digital logic speeds today are ofthe 6rder of 1 billion operations per second,

This can and probably will. change in the future as device/ techn<>logy contin~s .to progress, But, let us talk in terms oftoday, TDM is really speed limited when itçoınes to fiber optic cable. it can notprovide a composite link speed toJake full advanta.ge qf the tremendous bandwidth presented by fiber optic cable. This is notjust particµlflfto the premises environrnent it also applies to the WAN environment. .On the.ether hand, WDM does not have this .speed constraint. it is an. analog technique. Its operati9n.~oes not depend upon the speed of digital circuitry. it can provide composite link speeds t}mt are in line with the enormous bandwidth presented by fiber optic cable. Impact on BER - Both TDM and WDM, carve a multiplicity of links from a given fiber optic cable, However, there may be cross talk between the links created, This cross talk ··is interference that can impact the BER and affect the performaiıce of the applica.fiôn underlying the need för communication. With TDM cross-talk arises whellsôme ôfthe data assigned to one time slot slides into an adjacent time slot. Hôw does this bapperi? TDM depends upon accurate clocking, The ınultiplexer at the Sôürce en.d depertds upon time slot boundaries being where they are supposed to be so thatthe correcİSource data is loaded into the correct time slot. The multiplexer at the User end depends upon time slot boundaries being where they are supposed to be so that the correct User gets data from the correct time slot, Accurate clocks are supposed to indicate to the multiplexer where the time slot boundaries are. However, clocks drift, chiefly in response to variations in environmental conditions like temperature. What is more, the entire transmitted data streams, the composite link, may shift small amounts back and forth in time, an effect called jitter. This may make it difficult for the multiplexer at the User end to place time slot boundaries accurately.

Protection against TDM cross-talk is achieved by puttiııg guard times in the slots. Data is not packed end-to-end in a time slot. Rather, there is either a dead space, or dummy bits or some other mechanism built into the TDM protocolsôtfüıt ifdata slides from one slot tô anôther its impact on BER is minimal.. With WDM btôss·tallfarises becaııse the optical signal spectrum for a given link placed upon one particıılar (center) wavelength is not bounded in wavelength (equivalently frequency). *i* This is a consequence of it being a physical signal that can actually be generated, The optical signal spectrum will spill over onto the optical signalspectııımför another lilikplooed at another (center) wavelength.

The amount of spillage depends, upon how close .the \\'avelell.~M ıı.re and how ınuch opticalfiltering is built into the WDM to buffer it. The protectio.ri'.~gaiµst cross4@<'~ere is measured by a parameter called isolation. This. is the attemıafigtı(dB) of the optica.l signal placed at one (center) wavelength as ıneaşured at another {çenter) wavelength. The greater the attenuation the less effective spillage and the less impact on BER. At the present time, clock stability for digital circuitry is such that TDM cross-talk presents no real impact on BER in the context of premises data communications and at .the composite link speeds that can be accommodated.

The TDM cross-talk situation may be different when corisidetirig WANs. However~this is the case in the premise environment. The situation is not as. ğôôd for WIJM.'iflere, depending upon the specific WDM design, the amount of isolation may'vtfr)f:6:ôına'löW vahıe of 16 dB allthe way to 50 dB. A. low value of isolatıöıı füeanstJ:iafthiiıtıpruSt upon BER could be<sigriificant. In such situafions WIJlvfis lımitedlô côınınüiıcatiôııs applications that can tôlera.te a high BER. Digital vöice a.ııd videô wôuld be in this group, However, LAN traffic would not be in this gtôup/Frôın.theperspective ofBER generated by cross-talk TDM is more favorable than. WIJM.

CHAPTER FOUR

EXPLOITING THE DEL.AY PROPERTIES OF FIBER .OPTIC CABLE FOR LOCAL AREA NETWORK (LAN) EXTENSlON

4.1 Overview

Our chapterit will speakabout Brief History of Local Area Networks and Transmissicn Media Used to Implement an Ethernet LAN, Examining the Distance Constraint, also l will give some examples of LAN Extenders Shown in Typical Applieations, Model 375 1OOBase-T to Fiber Transceiver for Fast Ethernet, Model 377 Series Single-Mode 1OOBase-T*IF* Media Converter. Fiber optic cable provides a way for extending reach of Local Area Networks (LANs). lf you are well versed on the subject ofLANs you are welcome to jump right into this subject and skip the next two subchapters. However, if you have not been initiated into LAN technology then you will find the subjects covered in these next two subehapters worthwhile reading.

4~2 Brief History ofLeeel Area Networks

Two full generations ago, in the early days of the data revohıtion, each computer served only a single user. in the computer room (or at that time 'the building') of an installation there was I CPU, I keyboard, 1 card'reader, (maybe) I magnetic tape reader, 1 printer, I keypunch machine ete. From a usage pôint of view this was highly inefficient. Most data processing managers were concerned that this highly expensive equipment spent möst of the time waiting för users to ·employ it. Most data processing managers knew this looked bad to the Controllers of their organizations. This led to the pioneering development of time-sharing operating systems by MiT with Project MAC.

Time-sharing opened up computational equipment to more than one user. Whole departments, companies, schools ete. began making use of'the expensive computational equipment. A key element in time-sharing systems concerned the keyboard. A computer terminal replaced it. The multiple terminals were connected to the CPU by data communicatlons links. There was a marriage of computation and data communicatiorıs.

in particular, the data cornmünications was mostly (though not exclusively) premises data communicaılons, Throughout the years time-sharing led to distribute computation. The idea of distributed computation being that applications programs would reside on one central computer called the Server. Applications users would reside at PCs. When an applications user wanted to run a program a copy of it would be downloaded .to hittılher. in this way multiple users could wôrk with the same program sinıultaneously. This was much more efficient than the original itime sharing. Distributed computation required a data communications network totie the Server to the PCs and peripherals, This netvvotk was called a Local Area Network (LAN). This network had to have high bandwidth, in fact, it had to accommodate speeds that were orders of magnitude greater than the original time-sharing networks. Entire applications programs had to be downloaded to multiple users. Files, the results of running applications programs, had to be uploaded to be stored in central memory.

LANs first came on the scene in a noticeable sense in the late 1970's. From that time until the present many flavors ofLANs have been offered in the marketplace. There are still a mımber of different flavors each with its group of advocates and cult following. However, some time around the late 1980's the market place began to recognize Ethernet as the flavor of choice. All of the discussion in the sequel will concern only Ethernet.

The Ethe:met LAN archit~foture had its origins in work done at Xerox Palo"Alto Research Center (PARC)by Robert Metcalfin the early' 1970's. Metcalflater went on to become the foundefof3COM.·XeroxWas later joined-by DECand Intel in promoting Ethernet as the coming 'LAN standard. In .the developinent of the Etheriıet LAN architecture Metcalf built upon previous research funded by the Advanced Research Projects Agency (ARPA) at the University of Hawaii. This ARPA· program was coneerned with an asynchronous mıltiple aceess data communiöations technique called ALOHA.

The basic operation of anEthernet LAN can be briefly explained with the'.aid offi~e 4-1. This illustration indicates various data equipment that all need to conırrıunicatewith eaôb öther. The data equipınent constitute the users oftheLAN. EachIs a Source and User Within the contexr ofthe discussion ofChaptei' 1. The location on the LAN of each data equipment unit is termed the station.

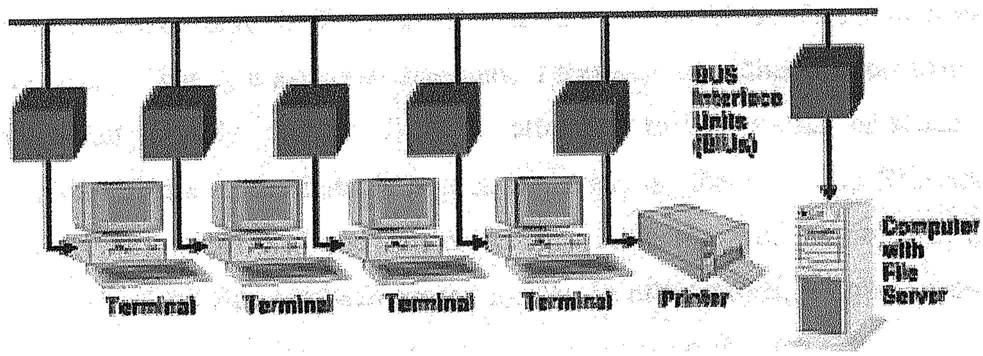


Figure 4-1: EthernetBus architectıre

The communication between the data equipmenr is accomplished by having all the data equipment tap onto a Transmission Mediıım, Eaeh station taps onto the Transmissien Medium, The Transmission Medium is typically some type of eable.. As showtr in Figure 4-1 it is labeled Broadcast Channel - The Ethernet Bus. The Bus Interfa.ce l.Jrıits (BIUs) provide the essential interfacingat a ·station between the data equipınetıtan.dthe Broadcast Channel, That is, they provide the transmiı/receive capability and aU)ıeeded intelligence.

It is an essential feature of the Ethernet LAN architecture that any. dara equipment\cari transmit to any other data equipment and any data equipment' can>listeıCto<a.11 transmissions on the Broadcast Channel, whether intended for it or'for, some .füner cliıta. equipment user, Implicitly, the Ethernet architecture assumes › that<thete is no coordination in the transmissioıs of 'the different data equipmeıtr ,This is quite a bit different from the sharing ofa Transmission Medium by TDM where coordination is essential, Transmitted data only goes in its assigned slot.Now how does an Ethernet LAN operate? It operates by making use ofthree>esse:ntial items. First, it employs a Carrier Sense Multiple Access/Collision Detection

(CSMA/CD) protocol, Secondly, data to be conl.nl.unicated is enveloped in packets that have the addresses of the data equipment units communicating. The paeket has the address of the equipment sending data (the origin) and the data eq_uipmentthat is the intended recipient (the destination). Thirdly, the Ethernet Bus - the Transmission Medium - is taken as passive and supports broadcast type transmissions, The way in which the Ethernet LAN architecture uses these items is explained briefly, Consider a specific data equipment unit at its station, This will be our data equipment unit, station and BIU of interest. For the sake of an example, .suppose it is. a PC wanting to communicate with the Computer with File Server at its station. Before attempting to transmit a data packet onto the Ethernet Bus our terminal's BIU first listensto d,etermine if the Bus is idle, That is,' it listens to determine if there are any other packets :&om other data equipment already on the Bus. it attempts to sense the presence <of a communication signal represeoting it ·packet, a carrier/tm the Bus, Our BIU ruidiruiy BIU have circuitry to perform this Carrier Sensing. .An active BIU transitiits its packet on 'the Bus only if the Bus has'been sensed as idle. in other words, it only trru:ısıilits iıs packet ifit has determined that no other packet is already on the Bus - carrier is absent. If the Bus is sensed, as busy- earrier is present-' then the Bil Tclefers its transıilissidn urttil the Bus is sensed as idle again, This procedure allows the varföus data eqtiiprlient to operate asynebronouslyyet avoid interferingwith'ene another's cfünımunications. However, it ınay be that a carrier has not sensed an existing packet' is already'ô:ıiithe Bus, Transmission ofa packet by the BIU of intetest begins but there are Stili pr9blems, There ate propagatlon delays and carrier detection processing delays. Because ôftlıese; it may be that the packet. from our PC's BIU stili interfetes with, or collide§ Witjta packet transmitted by another equipment's BIU. This interfering packet is one tnat(.h.as not yet reached our BIU by the end of the interval ili.Whichithru:l perfotıned the<catrier sensing, A BIU monitors the transmission of the packet it is sending outto dete:rımfie if it does collide with another packet, To do .this it makes use·ofthe broa.dcıısfruıturecıôf the transmission medium, A BIU can monitör whatit has put on the Ethem.et Btis•and also any other traffic on the Ethemet Bus. Our BIU and anjtBIU<lıils<circüitcy/tô perform Collision Detection, The BlU that transmitted the füterfering packet alscfhas circuitry to perform Collision Detection,

When both BIUs sense a collisiônthey cease ttansmittmg. EachBIUthenwaits a random amount <of time before >re-transmitting .• >that is sensing for carrier a:nd transmitting the packet onto the bus. If anothe:rcollision occurs thert this randöm. time wait is repeated but increased. In fact, it is increased at an exponential rete untiLthe collision event disappears, This approach to getting out of collisiôris is icalled exponential back off

4.3 Transmission Media Used To Implement An EthernetLAN

Early implementations of Ethernet LANs employed thick coaxial cable, Actually, it was thick yellow coaxial oable - the original recipe Ethernet cable. The cable was defined by the lOBase-5 standard, This' implementation was called Thiek net. It could deliver a BER of 10^{-8}. It supported adata rate of 10 MBPS. The rtıaximum LAN cable segment length was 500 meters, Unfortunately, the thick coaxiaFcable was difficult to .work with. As a result, second wave impl~ınentations of<l$tlıemet LANs employed thin coaxial cable.

The cable was RG58 A/U coaxial cable - sometimes ca.lled~e!;:i::0et. This cable was defined by the lOBase-2 standard. Theimplementation was call~d'I'liliıried. It supported a data rate of 10 MBPS. But, it had a BER somewhat degraded relative to 'fhlcket .Thinnet ultimately gave way to the replacement of coaxial cable with l.Jnshielded Twisted Pair cable (UTP). This came about through an interesting m.ergmg öfthe Ethemet LAN architecture with another LAN. fın:v~r StarLAN was based uporı whaf a Telco, a phone company, normally does .for. busiııesses that is, proyiçl~ y~i9~ commıınications.

The Transmission Medium a Telco uses within a facility. for voice conmı1.l11.icıaj:io~ iş Unshielded Twisted Pair cable (UTP). it provides voice commUllicatio11S /wjtlıiıı a. facility and to the outside world by connecting all of the phones, the hall~s~ts, fllı:~~ğlıa telephone closet or wiring closet. The distance from Iıandset toJ~leBJ:ı.9tıt} çl9s~tis relatively limited, maybe 250 meters, The StarLAN idea was to ta,k~tlıişl,asicapproach for voice and use it fora LAN. The LAN stations would be connectedthrough acloset, The existing UTP cable present in a facility for voice would I,e usedfortheLAN data traffic, However, in 1990 aspects ofStarLAN werefakeri-and mergedwith the Ethernet LAN architecture. This resulted in a new EthemetLAN based upon UTP and defined by the 1OBase-T standard, It was with this UTP approach .that Ethernet really took off in the market place. Ethernet under the 10:Llase-T standard has a hub<and spoke architecture. This is illustrated in Figure 4-2.

The various data equipment units, .the statiöns; iare all connected **to a central** point called a Multipoint Repeater or Hub, The corin.ections iare by **UTP cable.** This architecture does support the Broadcast Channel-Ethernet Bus, This occurs because all data equipment units can broadcast to all öther data equipmerit units through the Hub. Likewise, all data equipment units can listen to the transmissions from all other data equipment units as they are received via the UTP cable connection to the Hub. The Hub takes the plaee of the telephone closet. The Hub may be strictly passive or it may perform signal restoration functions,

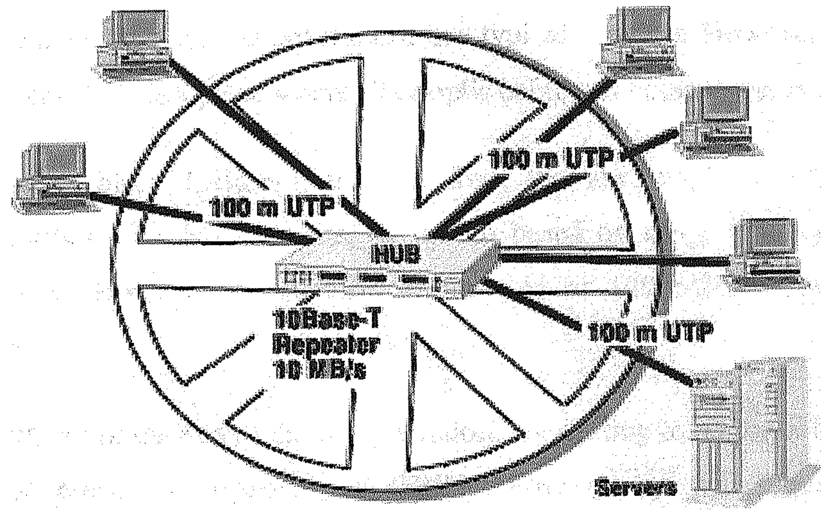


Figure 4-2: lOBase-T hub-and.•spoke architecture

The illustration Figure 4-3 indicates how the lOBase..T topology may actuallylôökinan office set-up at some facility. Here the data equiptrıefü units are aU'.PCs. One>s~tv~s\.is the file server; The illustratio:ı.ıshows vvhat is usually referred to asa. l0Base-T.W6rk Group, it may serve one specific department in a company. By f()tl.1l:ect·iµ·'·$.it0; e)~~'r these work groups Ethernet :LANs may be extended. This is açconlpli~Jı~4 LhY connecting hubs using LAN network elements called bridges, routers and switches. A description ef tbeir öperation is'beyondthe focus of the present-discüsslon,

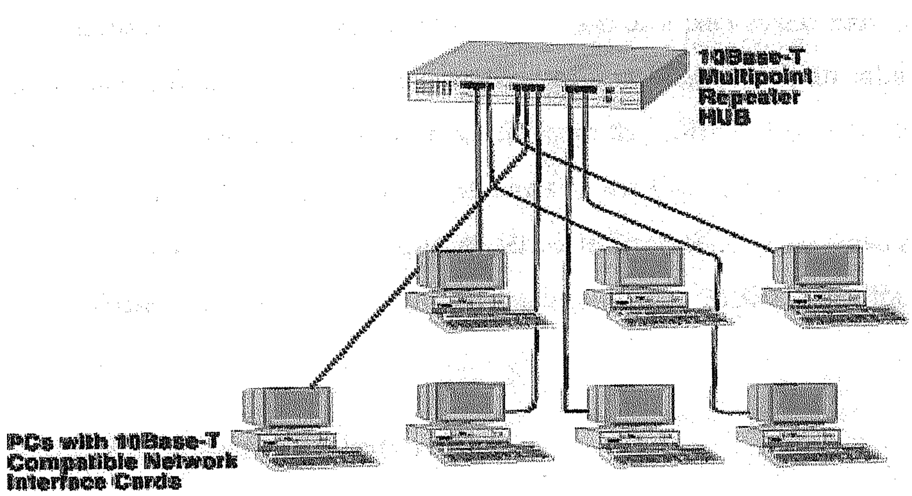


Figure 4..3: Etheriıef öperating as a 1OBase-T wôrkgroup

But, let us get back to lOBase-T. It supports adata rate of 10 MBPS. It hasa BER comparable to Thinned. However, the LAN segment length is reduced even further. With 1OBase-T the LAN segment .length is only 100 m - a short distance but a 'distance that is tolerable for many data equipment stations in a typical business, However, itmay be too short for others, This is aplace where fiber optic cable·can come to the rescue.

For the LAN market place lOBase-T was far from the .Jast word, It Ied to the development of lOOBase-T - Fast Ethemet. It is also based on using UTP cable for transmission medium. However, it supports a data rate .nf>JOO MBPS over cable segments of 100 m,

FastEtherııet, itself is not the end of'the road. Veııdors are statting to promote Giga Bit Ethernet which is capable of süppörting 1 GBPS. However, will stop at Fast Ethernet and the ptôblem thar bôth. it 'and lOBase-T ha.Ve - tbe sh.()rt cable s~ğnıent <>f 100m.

Before continuing it will be worthwhile to define two terms that come up in discussing Ethernet characteristics, These are 1) Network Diameter and 2) Slot Time.

The Network Diameter is simply the maximum end-to-end distanee betweeıı>dafü equipment users, stations, in an Ethernet network-It is reallywhat.has beellrefer1'~dfö

above as the cable segment. The Network Diaıneter is the saıne :~: ~~t~JPB~e-'f and lOOBase-T, 100 m.After a BIU has begun the transmission ofa packetthe Slot Time is the time interval that a BIU Iistens for the presence of a collision with an interfering packet, The Slot Time cannot be infinite. It is set for bothfhe lOBase-T and lOOBase-T Ethernet architectures. It is defined for both standards as the füne dtıration of 512 bits. With a lOBase-T Ethemet network.operating .atlO MBPS the Slot Time translatesıto 51.2sec. With a lOOBase-T Ethernet netwo*.J:)~rating at ·100· MBPS.the.Slot Time translates to 5.12sec.

4.4 Examining the Distance Constralnt

The distanceconstraint ofan EtherııetLAN isthe Network Diameter. As rloted above this is 100 m for both the lOBase-T and lOOBase-Timplementations'. This rrıay not be

enough for all potential users ofan Ethemet LAN. Now how do you support LAN users that are separated by more than this lOO·m constraint? To deal with this question it is important to understand where this constreint comes from and what is driving it.
Many people believe that the Network Diameter is. set strictly by the attenuation properties of the UTP copper cable connecting data equipment to the Hub, This is erroneous. .Atteruation does .affect .the Network Diameter, but it is not the dominant influence. However, if it were, you would be able to see the immediate possibilities of improving it by using fiber optic cable rather than UTP eopper cable. The significantly less attenuation of fiber optic cable would boost the NetworkDiameter. No, it is not attenuation but instead the Slot Time that really sets the Network Diameter. The Slot Time is related to the amount of time delay between a transmitting BIU and the furthermost receiving BIU. The diagram showed iıfFigure 4-3 illustrates the Slot Time issues to be discussed now. Here we show two data equipmenf users of an E!lj.eruet LAN - either lOBase-T or 100Base-T • it doesn't matter. These ate labeled Js/b~t:a Terminal Equipment Unit A and Data Terminal Equipment lJnit B. Fö'.rbrevitytheywi.11 be referred to as Unit A and Unit B.. The BIU's are taken as subsumed in the ova.Is.

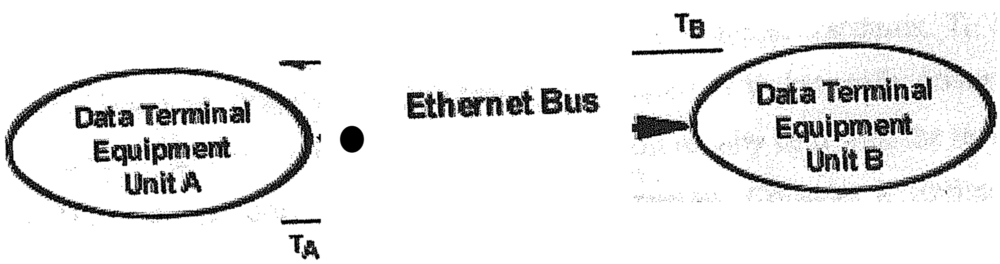


Figure 4-4: 2 Stations communicating on an Ethemet Bus, Delays shown.

Suppose Unit A transmits a data packet over the Ethemet Bus to Unit B.. The transmitted data packet travels along the .Ethernet Bus, It takes a time inte.rval of TA seconds to reach Unit B. In the meantime, llnit B has performed cm.'l'ier sensin.ğ and has determlned, from its perspective, that the Ethemet Bus is not busy and so it also begins to transmit adata packet. From a collision detection point ofviewtlıe worst case occurs when Unit B begins to transmit its data packet just before the data paeket from Unit A arrives in front of it. Why is this worst case? When the Unit Adata packet arrives at

Unit B, Unit B immediately knows that a collision has occurred and can begin **recovery** operations. However, Unit A will not know that .there has been any collision problem until the data packet from Unit B arrives in front of it. This packet from Unit B takes a time interval of T_B seconds to arrive at Unit A. Putting this .1ogether Unit A has to wait at least $T_A + T_B$ seconds before it can detect the presence/absence of a collision. There is some additionaltime needed to sense the presence/absence .of-a collision at both Unit A and Unit B. The collision deteedon processing time is den.oted as Tc. For lOOBase-T networks atypical value.for this is 1.12 0sec. TheSlotTimeisthe sum TA +Ta+ Tc.TA and T_B usually can be taken as equal and denoted as t. Putting these together brings:

$$4 >= (\text{Slot Time} - Tc) / 2$$

The one-way delay (t) is equal to the distance between Unit A and. UiiitB divided bythe velocity oftransmission between Units Aand/B.. The maximum distatıceis ofü;oursethe Network Diameter.. The velocity oftransmissiônwillbe denotedby 'VJ,this isthespeed ofan electromagnetic wave on the Ethemet Bus, Applying these brings:

$$\text{Network Diameter} = (V/2)(\text{Slot Time} - Tc)$$

The Slot Time is fixed by the lOBase-T and 1OOBas~-T Ethernet stl:1.lidarqs. 'J:'c/is a function of BIU design, It is evident then that it is the value ofVth;freatiy~fi~~~the Network Diameter. in characterizing the Ethernet Bus you usually deal with the inverse of V. For UfP copper cable v'' is approximately, ~ .~;,,_ ç<mSı;;; : ~OÔ~ T Bthernet LAN. Applying this vahıe for V'1 above brings a valiıe of 250 m for the Network Diameter.

On the face of it this is quite a bit better than thelOQ ...m allotted for the Network Diameter by the standard, 'The differeace is accounted for by a number ofdela.y items that were excluded :from the example, These were excluded in order to bring out the principle pomt • the dependence ofNet~~ ~ on v''. Tbir~ is taken up by margin allotted for other processing functions, These functions include the detay through the Hub, They inchıde proces~ing delays in software at the interface betvveen the data equipment and its BIU. The margin is also allotted for deleterious properties of cable.

However, the essential point remains. The achievable Network Diameter is determined by the delay through the transmission medium, The speed ofV"1 throııgh UTP copper cable results in a Network Diameter of 100 m.Consider a fiber optic cable. Typically, the vahıe ofV"1 is 5 nsec/m for muiti-mode fiber optic cable, This is almost 50% lower than for UTP copper cabl~·/Apfly~gt~s Yjlue ~i]~~~ve example would bring a Network Diameter of 40Q/1.n;.quitç a bitmore tlı,angsp m;By using a fiber optic cable you can connect data equipment stations to the LAN that are much further apart than the 100 m distanee allowed for by the assUllled UTP copper cable in 1OBase-T or 1OOBase-T LANs. You can do this because the velocity oflight through a fiber optic cable is much faster than the group velocity of electromagnetic waves in copper cable- the speed of current in copper cable. You can do this because the transmission delay, v', of a packet traversing a fiber optic cable is about 50% lower tban it is for UTP copper cable,

How would you do it? How would you exploit a fiber Ôptic cable tô bring distan.t users into a UTP copper cable based Ethemet LAN? How wcmlcl. you aceomn:ıôdate tea.lly distant stations to a 1OBase-T or 100:Base-T Etherııet LAN, stations iriuch futllieftlılı:n the Network Diameter?Iıı ordef to do tbis you need to côl111ect them to the Hub using a fiber optic cable. This may beeither a multi-mode or single-mode fiber optic cable. However, neither the Ethernet Hub nor the BIU at the distant dat~ eqüipınent user knows anything about signaling ona fiber optic cable Ttansınissioll Mediuın Sô, atthe Hub you need some type of equipment that will take the ·töBase-f ôf tôôBase-t packets, in their electrical format, ancfcôııvert it to light toprôpa.ğa.tedôwnafi.bel'ôptfo cable, You need the same equipmeiit at the dist:fuıt cıata ecıüii,nıent:'s BIU for transmission toward the Hub; Similatly, you need this device to be<a.ble to take the Iight wave representations ofa packet coming out oftlıe fiber Ôpt:ic c~'ble aiıd côrıverfit to an electrical format recognizable by the Hub or the BIO. 'fhis is called a. LAN Extender, By using a LAN Extender you get a distance beneiit. In additioıi, ôıı the particular LAN link you get the other bene:fits·available with fi.berôptic cable, These inchıde protectiôn :from ground loops, power surges and lightnıng.

4.5 E:ıamples of LANExtenders Shown InTypical.Applicatiôııs

Telebyte offers a. variety ofLAN Extenders, These are now descriped. Model 10Base-T to Multi-Mode Fiber Optic Converter This unit is pictured jn Figure 4-5. It extends the distance ofa lOBase-T Ethernet LAN to over 2 km. The Model 373 10Base-T to Multi-

Mode Fiber Optic Converter takes lOBase-T Ethemet .signalsand converts them to/from optical signalsthat are transmitted/received frem-rmıltimode fiber optic cable.

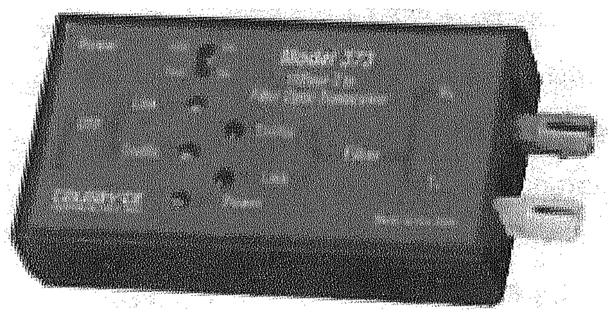


Figure 4-5: Model 3731 OBase-Tto Multi-l\1odeFibeij()pticConverter

The Model 373 hasa group of 5 LED's. These indicate the pfesence of the fiber optic link, traffic going back and forth in both directions, the presence ofa collision and power, The unit evert includes a Link Test switch. This assures compatibility between older and newer Ethernet adapters. allows the enabling/disabling of the Link Test heart beat option, The Model 373 uses ST connectors for the fiber optic cable. it is designed for transmission/reception over 62.5/125 mılti-mode fiber optic cables, On the 10Base-T port side the Model 373 is in full compliance with the IEEE 802.3 specificatien. The Model 373 is also in full compliance with the Ethernet lOBase-FL standard. This is the standard for using multi-mode fiber optic cable to extend the Network Diameter of a 10Base-T Ethernet LAN. The Model 373 is illustrated, in a typical application in Figure 4-.6. This shows the stations ofa 1OBase-TEthernet LAN in a typiçal business environment. Most of the stations of the LAN are .locateduear one another in the same building. This is Building A. All ofthe stationsin Building A.are within 100 m of one another, For purposes of this example, these people atthesç stations may all be in the company's Accounting pepartment. They can all be co1lp.eçte4 to the LAN through the Hub located in Buil4ing using the UTP. c<>pper ç~ble ordinary building block ofa lOBase-T LAN. They are all within the1QO-ın N"etvvotk Diameter for a UTP copper cable based 1OBase-T network. However, th~re is one remote station of this LAN that is not in Building A. This may be the station of the mamıtaetunng manager, His officeis in Building B- the productionfacility. BuildingB is located some distance away :from the front office ofBuilding A. In fact, Building B is about 1 km away from Building A. The manufacturing manager needs to be tied into the

Accounting Department LAN so that he can update the Controller with inventory and purchasing information. As Figure4"'.6 indicatesthe. manufacturing manager in Building B can easily be tied into the L~. This is acföomplished>by placing a Model 373 at the Hnb in Building A. A multi-modefibetoptic cı:ıbletoanother Model 373 in Building B then connects the Model 373. Thesecönd:Môd.~137},isçonnected to the manufacturing manager's work station. The pair of Model 373's and the fiber optic cable will be completely transparent to all stations of the LAN, both the .,ı\.ccounting Department stations in Building A and the remote station of the manufacturing manager in Building B.

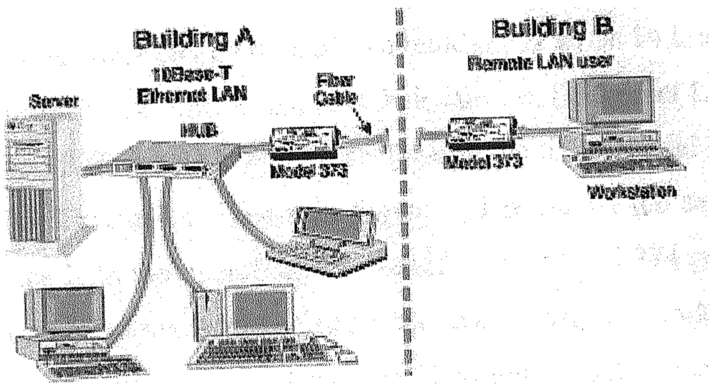


Figure 4-6: Model 373 shown in a typical applicafion

Model 374 lOBase-T to Single-Môôe :Fiber Opti6 C611Verter. This unit is pictured in Figure 4-7. It is the almost the same as the Model 373 except that its fiber optic eomponents are adapted for sirıgle..mode transmission. Because single mode fiber optic cable has much lower attemıation this allows ıfsignificarilextension of distance. In fact, the Model 374 10Base-T to Single-Mode Fiber Optic Converter extends 'the distance of a 10Base-T Ethemet LAN to over 14 km. The ability to achieve the extendeddistaiice is due to full duplex transmission. Full-Duplex has one important advantage. Since there are separate transmit and receive paths, DTE's can transmit and receive at the same time. Collisions are tberefore eliminated. Full Duplex Ethemet is a collision free

environment. For single-mode fiber optic cable transmission there is no 'Standard comparable to 1OBase-FL.

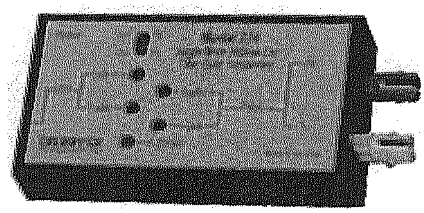


Figure 4-7: Model 374 LAN Spreader - lOBase-T to Single-Mode Fiber Optic Converter

The application illustrated in Figure 4-6 also applies to the Model 374. However, rıow our manufacturing manager can be located in a building as far as 14 km away from the Accounting Department and still betied into theirlOBase'-TEthernetLAN.

Model 376 lOBase-T to Single-Mode Fiber Transceiver. The Môdel 376 lOBase-T to Single Mode Fiber Transceiver shown in Figure 4-8 is .almost füe same as the Model 374. The difference is in the operating wavelen.ğth. The Model 374 generates .a single-' mode opticatoutput at awavelength of 1310 nm. Incontrast, the Model 376 generates a single-mode optical output at a wavelength of 1550 nm, Single-mode fiber optic cable has significantly Iess attenuation at the higher wavelength. This allows the Model 376tö extend a lOBase-T Ethernet LAN to a distance of38 km, quite a bit more than the 14 km of the Model 374. It achieves this distance by using a laser diode in its transmitter.The application illustrated in Figure 4-6 also .applies to the Model 376. However, now our nıaııı.ıfacturingmaruıgercan belocated in a building as far as 38 km away from the Accounrin.ğ OepartmeıiLand still be tied in.to their 1OBase-T Ethernet LAN. The Model374 puts out lOBase-T data packets on an optical signal at a wavelength of 1310 nm, 'The Model 376 puts out lOBase·"fdata packets on an optical signal ata wavelength ofl550 nm, This allowsth~~ptica}olitputsofboth units to be multiplexed on the same single-mode>fiber optic Ca'.6le: This caii be accomplished by employing the Telebyte Model 381 2 ChanneF WOM ... Wavelength Division Multiplexer. The Model 381 was discussed in.Chaptef 3.

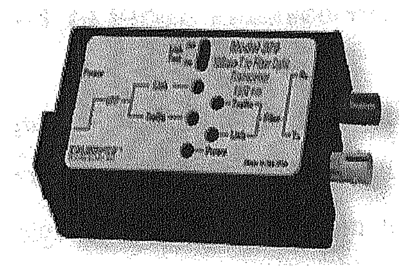


Figure 4-8: Model 376 lOBase-T to Single..Md~eFibber Transceiver

The application illustrated in Figure 4-9 shows this. i 'I'fı.is>is an extension.<ôf the application provided in Figure 4-6. Two 10Base-T EthernetL.l\:Nslôcated.inBtı.ilding A are shown on the left of'this illustration. The top one; L.AN.#1 is the 011.e thatbeldn.gS tö the Aecounting Department. lt needs to tie in User #1, the ınanuJa~t~~g~a~~f!f"!~: is located remotely in Building B. The bottom one, LAN #2 is the onethatbeloıigsto the Engineering Department. it needs to tie in User #2, the :rriatiufactörn:ıg'<,test teehnician, who is located with his boss in Building B. The.•trafficftôfü eacfü~l'carı be placed on an appropriate optical wavelength for the Model 381 WDM. Tb.is\is accomplished by using the Model 374 asa LAN Extender for LAN #1 and usirığfhe Model 376 as a LAN Extender for LAN #2. At the .remôte, Building B side, the traftfo can be demultiplexed and provided to the appropriate Users,

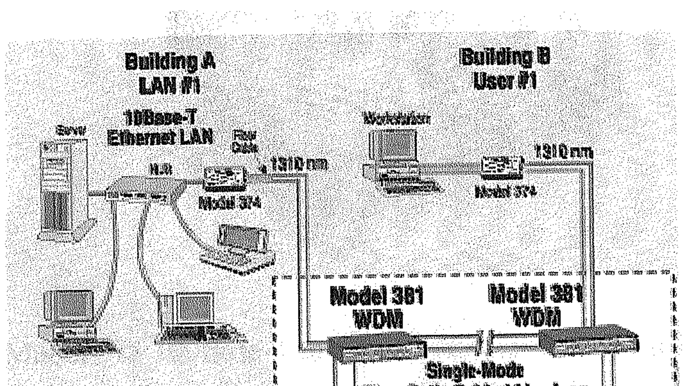


Figure 4-9: Model 374, Model 376 and Model 381 employed to sem:I traffiö from two 10Base-T Ethernet LANs to two remote users

4.6 Model 375 100Base-T to Fiber Transceivet for Fast Ethernet

This unit is pictured in Figure 4-10. It extends the distance ofa lOOBase-T Ethernet LAN to over 2 km. In other words, it is aFastEthernetLAN Extender. The Model 375 takes 1OOBase-T Ethernet signals and converts them to/from optical signals that are transmitted/received from multi-mode fiber optic cable.

The Model 375 lOOBase-T to Fiber Transceiver for FasfEthernet has a group of 3 LED's. These report if the 1OOBase-T. port and fiber optic port are active and powered, This unit allows any two 1OOBase-T compliant ports to be connected by mılti-mode, 62.5.125 fiber optic cable. A modified version can bfl•• obtained for single-mode operation,

The Model 375 assures that collision information is preserved and translated from one segment to the other. The Model 375 is compatible With the Fast Etherııefstaridatd fôr fiber optic transmission, 1OOBase-FX. Far end fault detection is possible with the Model 375.

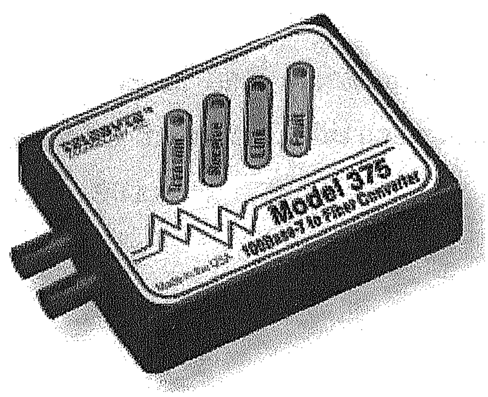


Figure 4-10: Model 375 lOOBase-T to Fiber Transceiver for Fast Ethernet

The application illustrated in Figure 4-6 applies to the Model 375.

You merely have to substitute a Fast Ethernet, lOOBase-T Ethernet LAN, for the lOBase-T Ethernet LAN and substitute a Model 375 for the Model 373.

4.7 Model 377 Series Single-Mode 100Base-T/F Media Converter

This is a series ofunits. One version is pictured in Figure 4-11. The Model 377 series of media converters are designed to convert 1OOBase-T, Fast Ethemet, signals meant for UTP copper cable transmissionto light pulses.

The resulting optical signal is apprôpfüıte for single-nıô<ietransmission.

The Model 377 series support füll tlμ.plex: ôpetation. I>etailed discussion of this is really beyond our scope. However, full auple~öperati6,nYallows greater LAN throuğhput. Explained very simply, this is accomplished bybeing able to transmit .while carrying out collision sensing.

The Model 377 series presents this as a major innovation. It gteatly iınpföves the response time over a LAN as compared to half duplex operation.

The Model 377SC and the Model 377ST employ a Fabry-Perot Laser Diôde;.<l,D-transmitter.

These units can achieve 1OOBase-T Ethemet LAN extension to 33 km. The Model 377ST-l uses an even more powerful LD transmitter. This unit can achieve lOOBase-T Ethemet LAN extension to an amazing 90 km.

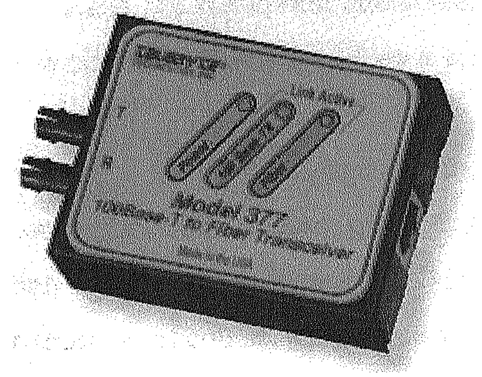


Figure 4-11: Model 377 100Base-T/F Media Converter

CONCLUSION

The fiber optic is small, flexible, .strong, and<[ightvveight,i it has· a large information carrying and low loss and special properties. Fiber ôptic cableis fabricated from glass or plastic. Glass fiber optic cable has th~ 1<:>vv~stattenuatfon and comes at the highest cost, plastic fiber optic cable has the highestattenuation it is a cylindrical pipe.

As we discussed when it comestö n:ıode ofpropagation fiber optic cable can be one of two types, multi-mode or slngle-mode. These provide different performance with respect to both attennation and time dispersion, The single-mode fiber optic cable provides tlie berter performance at, of course, a higher cost.

The Transmitter component serves two functions. First, it must be a source of the light coupled into the fiber optic cable. Secondly, it must modulate this light so as to represent the binary data that it is receiving from the Source

The Receiver component serves two functions. First, it must sense or detect the light coupled out of the fiber optic cable then convert the Ught into an electrical signal. Secondly, it must demodulate this light to determine the identity ofthe binary data that it represents,

There is a multiplexer provided at each end of the fiber optic cable, Time Division Multiplexing, Wavelength Divisioıl\ıfültiplexing.The cortırntınication between the data equipment is accomplished by having a:llthe da.ta. equiprn.eıfta.p onto a Transmission Medium

The Model 373 uses ST connectors for the fiber optic cable. is designed for transmission/reception over 62.5/125 mıılti-mode fiber optic cabl

The Model 373 is illustrated in 'a typical application Moctei 374 10Base-T to Single-Mode Fiber Optie Converter extends the distance ofa 1OBase-T Ethemet LAN to over 14km.

Finally.d achieved my aims after this project and the best thing for [illegible] cables the fiber optic

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