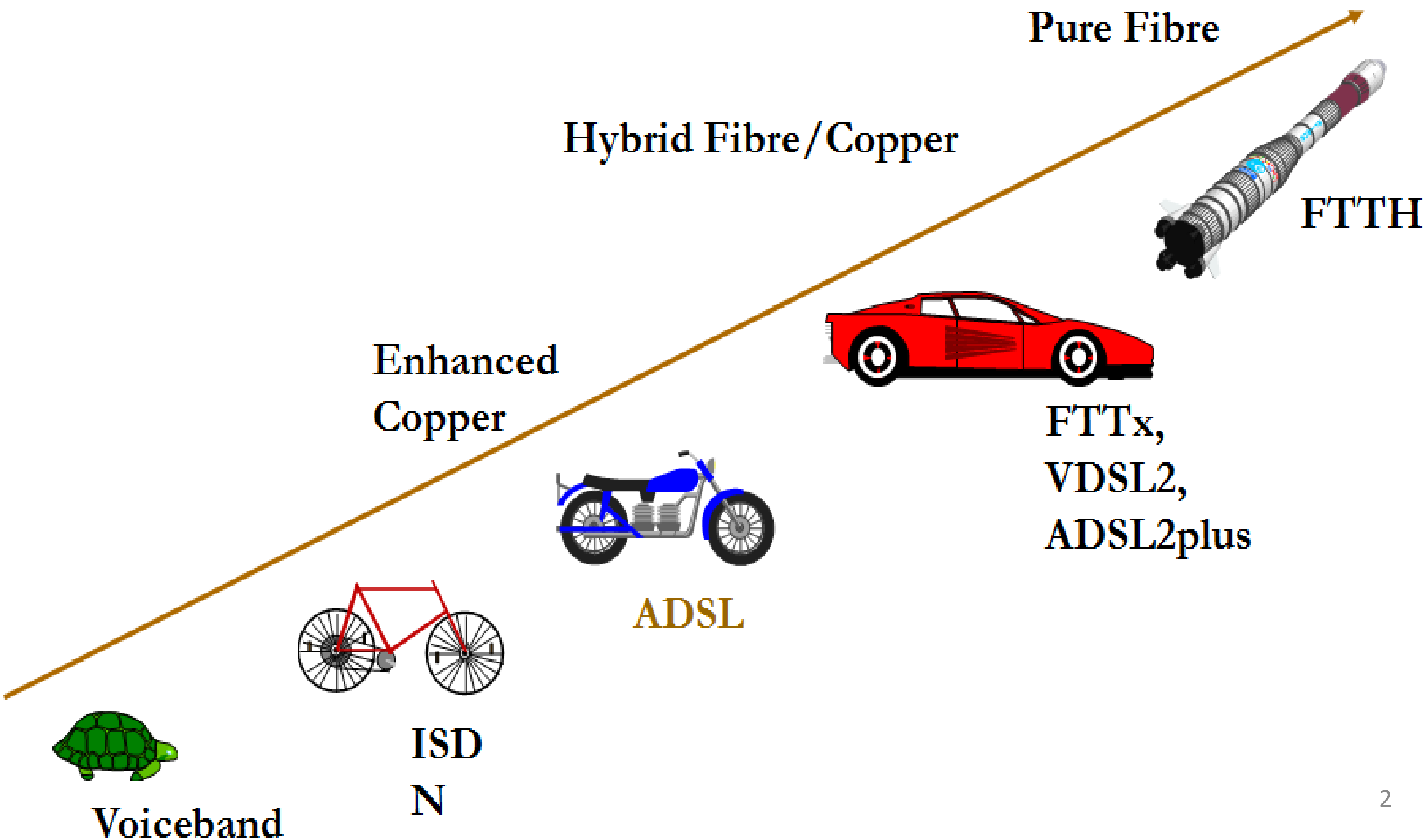
Asymmetrical Digital Subscriber Line

- What Is ADSL ?
- What Can ADSL Do ?
- How Does It Work ?
- Architectural Options
- Status of the Technology
- The Future

“Evolution of Digital Access”



ADSL Applications

- *Internet Access & File Sharing*
- *Video*
  - *Broadcast TV*
  - *Video On Demand*
- *Voice over IP via DSL*
- *Teleworking*
- *Online Education & Shopping*
- *Telemedicine*
- *Online Gaming*

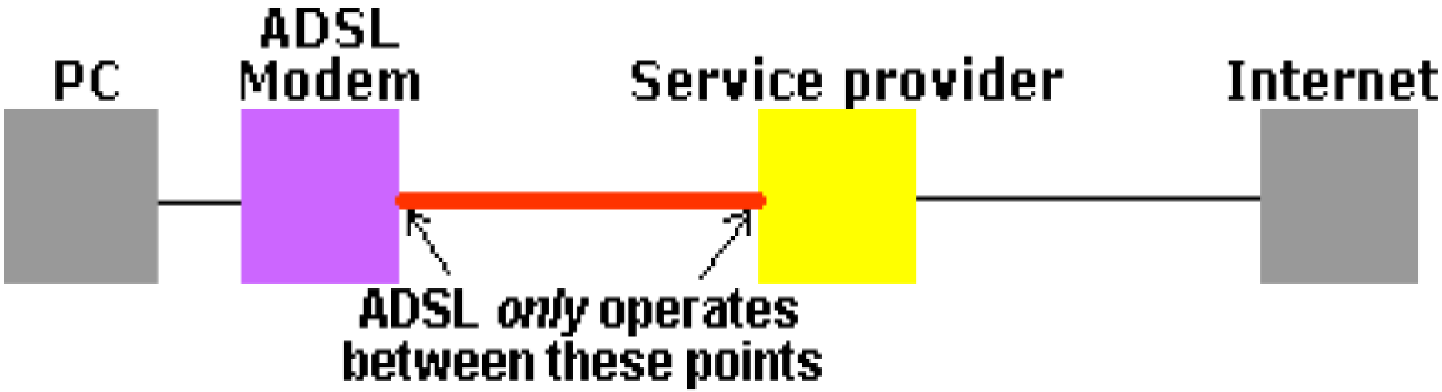
What is ADSL?

- ADSL stands for Asymmetrical Digital Subscriber Line
- ADSL is a new broadband communication technology that creates high-speed access to the Internet and remote networks using the phone lines that are already present in your home.
- ADSL is superior to analog modems in many respects.

What does ADSL do?

ADSL defines how data can be transmitted between a user's premises (home or office) and the local telephone exchange over the normal telephone wiring. The telephone companies call this telephone wiring 'the local loop'.

Getting data to and from the local telephone exchange is not in itself of much use. The purpose of ADSL services is to enable high-speed access to the Internet, so discussions of ADSL (including this one) generally include how the data connection is extended to an Internet Service Provider, and therefore, to the Internet.

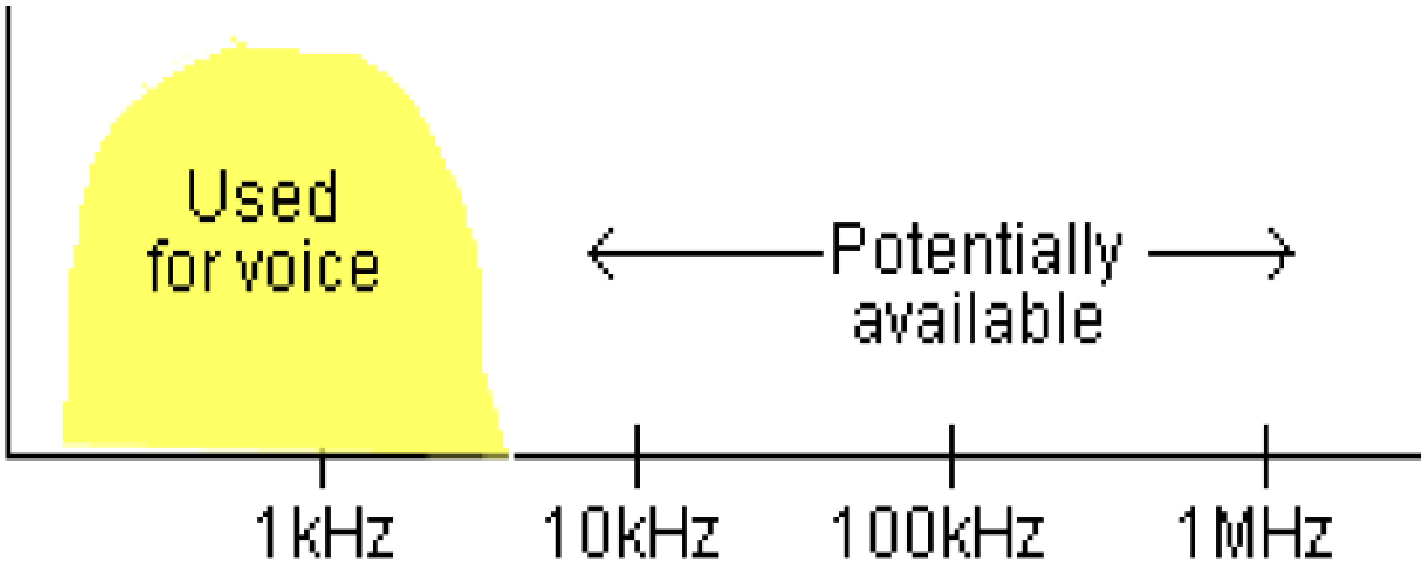


So although we assume that ADSL is used to carry data using Internet protocols, how this is done is not in fact part of the ADSL specification. This gives rise to some of the variations that occur in practical implementations of ADSL.

ADSL was originally devised as a way of delivering digital television over telephone wires and this may be a significant application in the future. For now, the main use of ADSL is Internet access.

How does ADSL work?

ADSL exploits the **unused analogue bandwidth** that is potentially available in the wires that run from the user premises to the local exchange. This wiring was designed to carry that portion of the frequency spectrum that is occupied by normal speech. The wires can, however, carry frequencies above this rather limited spectrum. This is the portion that ADSL uses.



The diagram above is approximate - voice typically uses the range 300Hz to 3,400Hz.

We can now see how voice and ADSL data can share the same telephone line - in fact, splitters are used to ensure that the data and voice do not interfere with each other.

The frequencies that the local loop can carry - and hence, the amount of data transmission capacity that is available - depend on a number of factors such as:

- the distance from the local exchange
- the type and thickness of wires used
- the number and type of joins in the wire
- the proximity of the wire to other wires carrying ADSL, ISDN and other non-voice signals
- the proximity of the wires to radio transmitters.

ADSL: A comparison with PSTN & ISDN

So, what are the inherent differences between ADSL and 'traditional' dial-up modems and ISDN?

- PSTN and ISDN are dial-up technologies
  - **ADSL is 'always-on'**
  - **ADSL is un-metered and charged at a flat-rate**

- PSTN and ISDN allow you to use fax, data, voice, data to the Internet, data to other devices
  - **ADSL is just about data to the Internet**

- PSTN and ISDN allow you to choose the Internet Service Provider you want to use
  - **ADSL connects you to a pre-defined ISP**

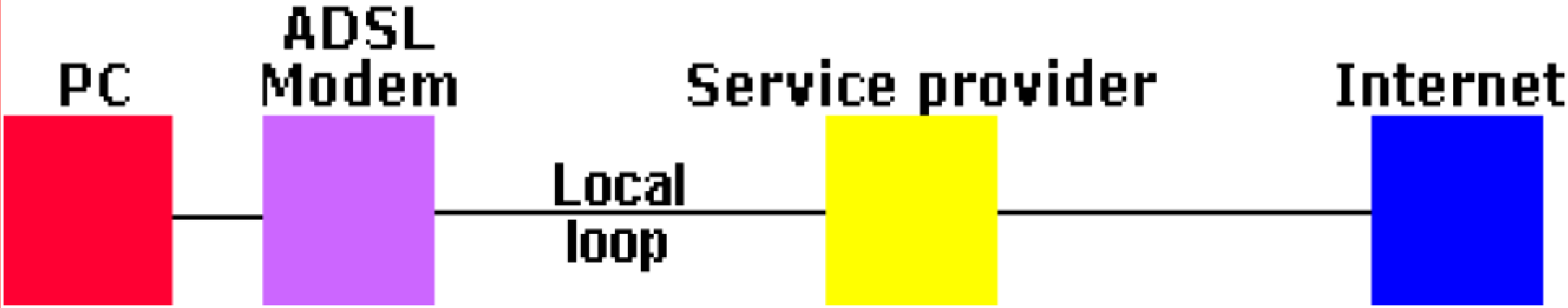
- ISDN runs at 64kbps or 128kbps
  - **ADSL can potentially download at 8Mbps**
  - **Many home ADSL services are provided at around 512kbps**

- PSTN stops you using your phone
    - **ADSL allows you to surf and phone at the same time**

Notes:

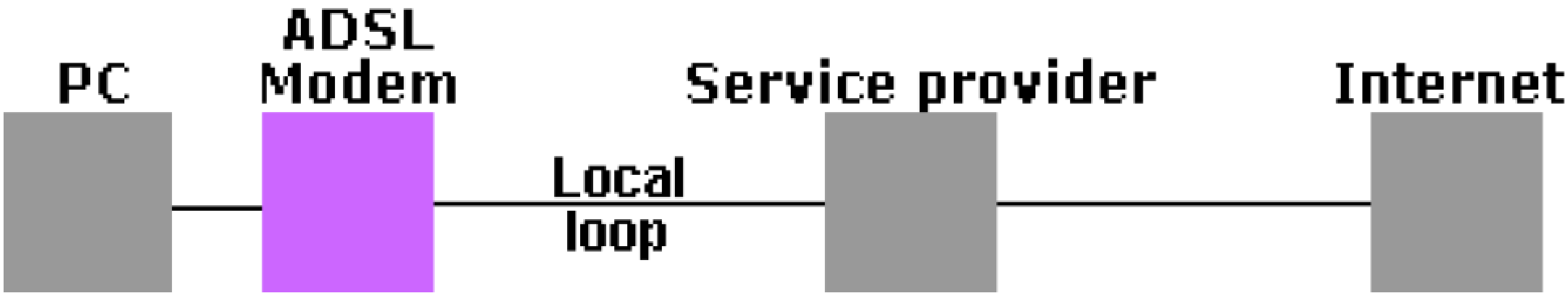
1. While your ADSL modem is permanently connected, it may be necessary to take action on your PC to make the connection to the Internet.
2. Services like fax and voice can be provided over the ADSL data connection to the Internet.
3. In practice, a typical download speed on a home ADSL service will be up to 400kbps

ADSL Components: Introduction



In this section we will describe in turn the function of each component that connects you to the Internet, starting from the ADSL Modem.
We will also look inside the 'Service provider' box and examine the main components that they use to provide your ADSL service.

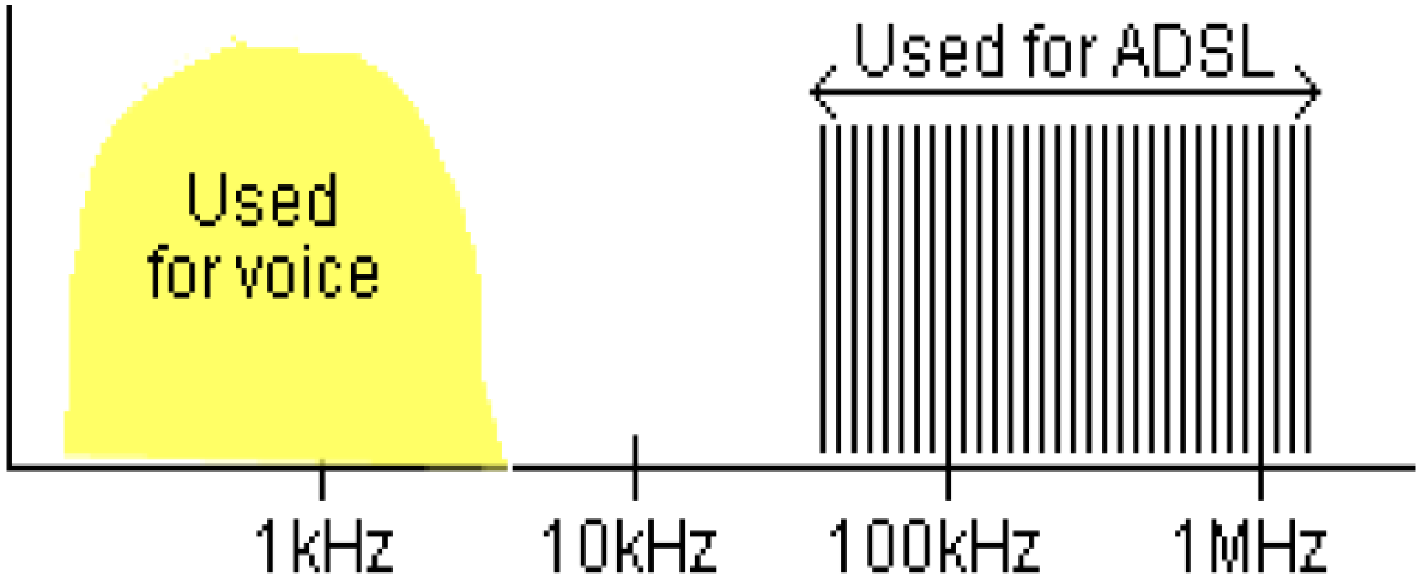
What is an ADSL Modem?



Your ADSL modem is connected to the telephone wiring (called the 'local loop') that connects you to the local exchange equipment.
The ADSL modem uses a combination of several advanced signal processing techniques in order to achieve the required throughput speeds on ordinary telephone wiring at distances up to several miles from the local exchange.

How does an ADSL Modem work?

ADSL works by implementing many modems in parallel, each of which uses its own slice of the available bandwidth.

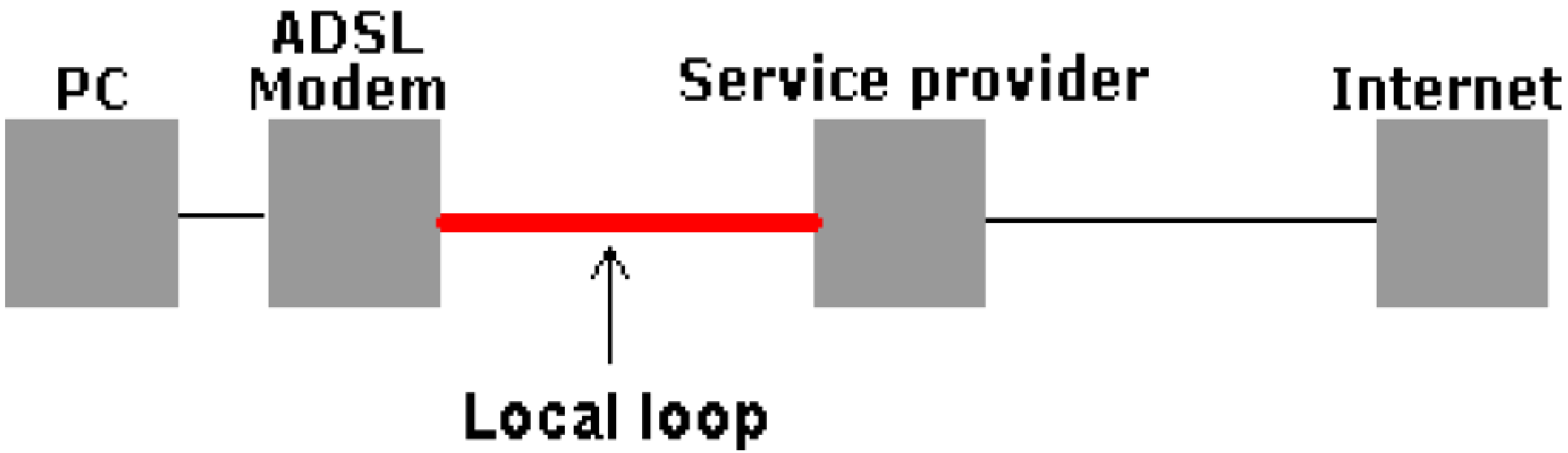


The diagram above is approximate, and shows how **ADSL uses many individual modems working in parallel** to exploit maximum bandwidth and deliver very high speed.

Each black bar represents a modem operating at a different frequency. In fact there are as many as 255 modems operating on an ADSL line. ADSL typically uses the frequency range 26kHz to 1.1MHz. All of the 255 modems are implemented on a single chip. Advances in electronics technology that make this level of integration possible are critical to ADSL.

The amount of data that can be transmitted by each modem depends on the characteristics of the line at the frequency allocated to that modem. Some modems may not work at all because of interference from an outside source such as another local loop or a radio station. Modems at the higher frequencies typically transmit less data than the others because attenuation (losses) are greater at higher frequencies, especially over long distances.

What is the Local Loop?

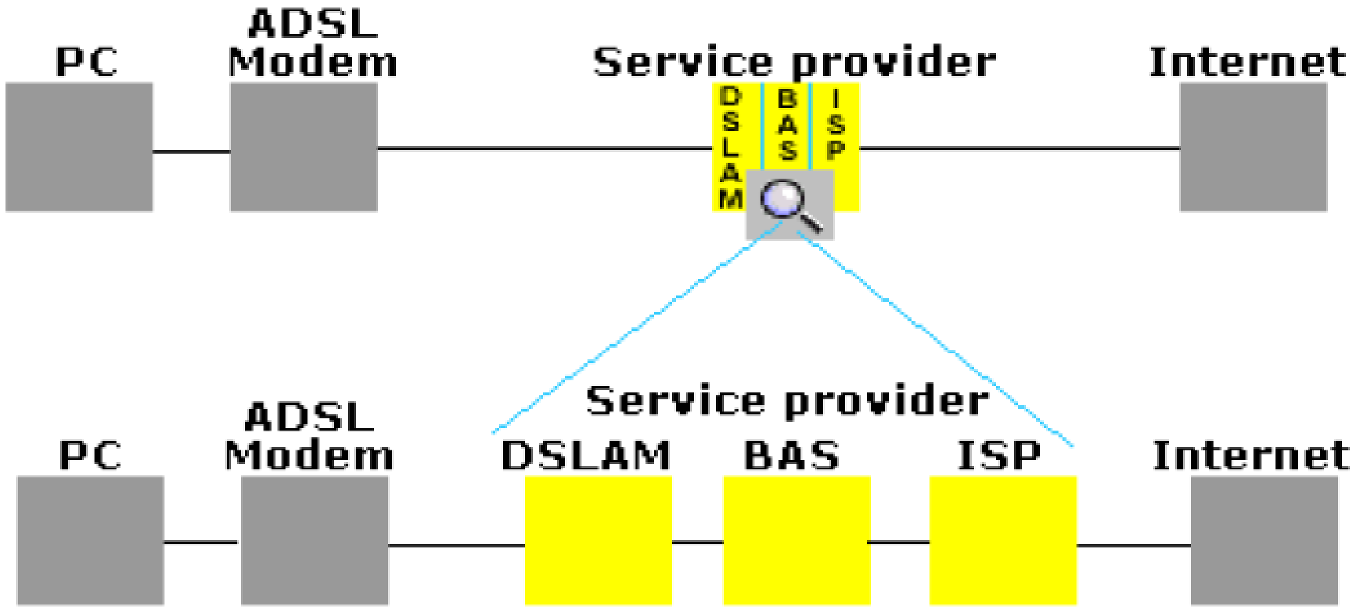


'Local loop' is the term applied to the **ordinary telephone wires** that go from a user's premises to the telephone company. It is only on the local loop that ADSL communications actually take place.

The reason for the term local loop: the telephone receiver is connected across the two wires, causing them to appear as a loop when viewed from the local exchange.

ADSL Components - Service provider

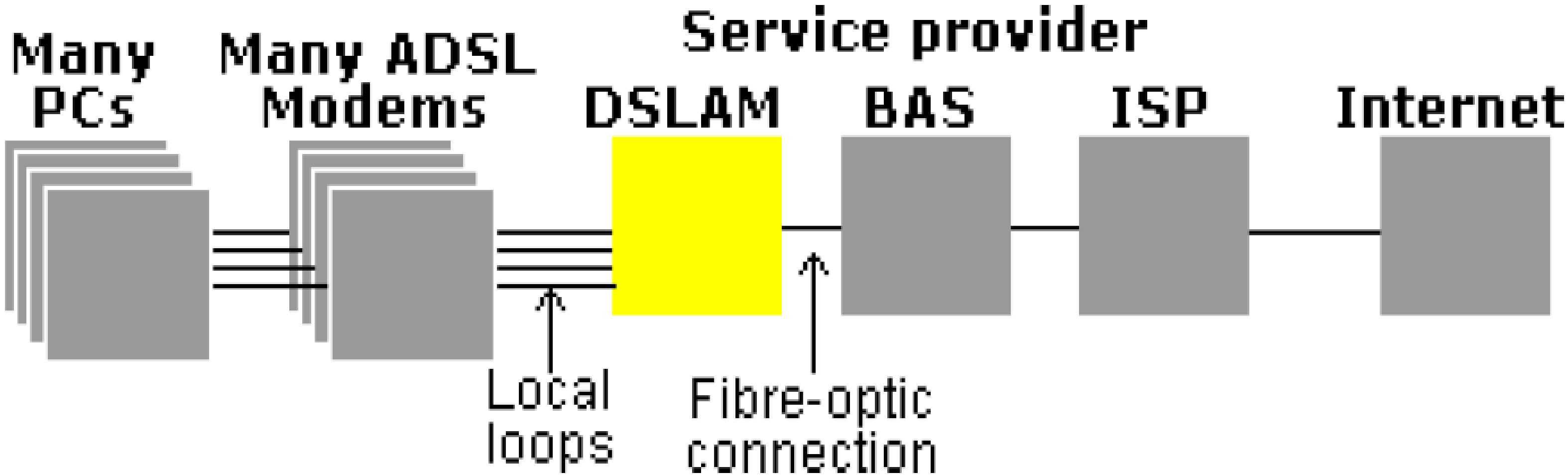
We now need to look more closely at how the Service provider implements ADSL.



Within the block that was previously identified simply as 'Service provider', there are three important components:

- **DSLAM** - **D**SL **A**ccess **M**ultiplexer
- **BAS** - **B**roadband **A**ccess **S**erver
- **ISP** - **I**nternet **S**ervice **P**rovider

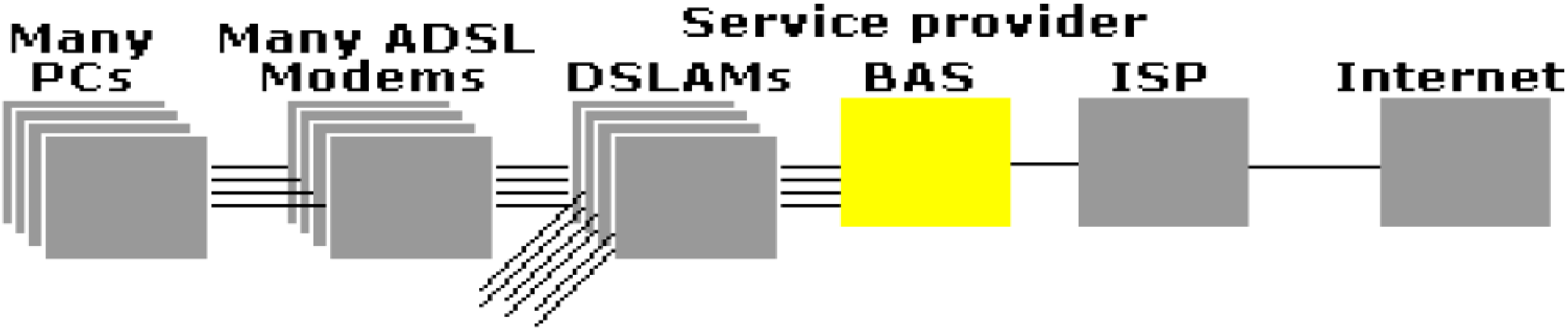
What is a DSLAM?



The DSLAM is the piece of equipment at your local exchange that is at the other end of your ADSL connection. It houses a bank of ADSL modems on one side and has a single fibre-optic data connection on the other.

The DSLAM consolidates a number of ADSL user connections - perhaps as many as several hundred - onto a single fibre connection. This fibre will normally be connected to a Broadband Access Server or BAS, but it may not be a direct connection; the BAS can be located anywhere.

What is a BAS?

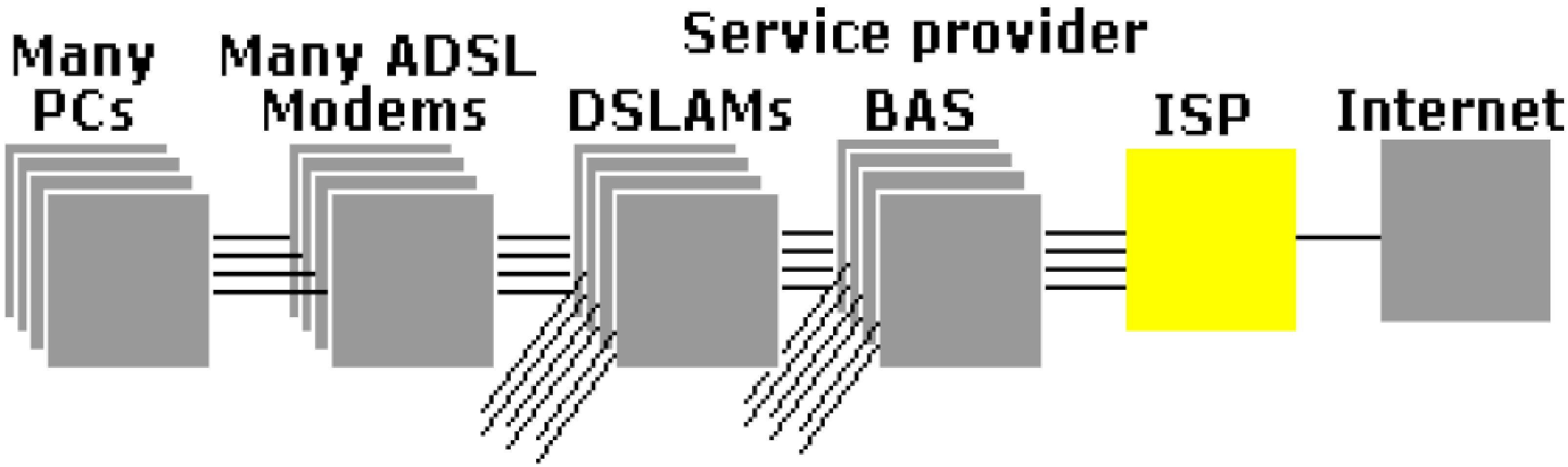


The **Broadband Access Server (BAS)** is the piece of equipment that sits between the DSLAM at the telephone exchange and the ISP that connects you to the Internet. It may be in your local exchange or it may be elsewhere in your service provider's network. A single BAS will probably handle connections from several DSLAMs.

The purpose of the BAS is to unwrap the various protocols inside which your data travels over the ADSL connection. It also makes your connection to the ISP appear exactly as if you had connected using a dial-up modem or ISDN.

As we noted before, ADSL does not specify the protocols that are used to construct the connection to the Internet. The result of this is that there are at least five different ways in which the data can be carried between the PC and the BAS. The method used by the PC and the modem **must** be the same as that used by the BAS for the connection to work.

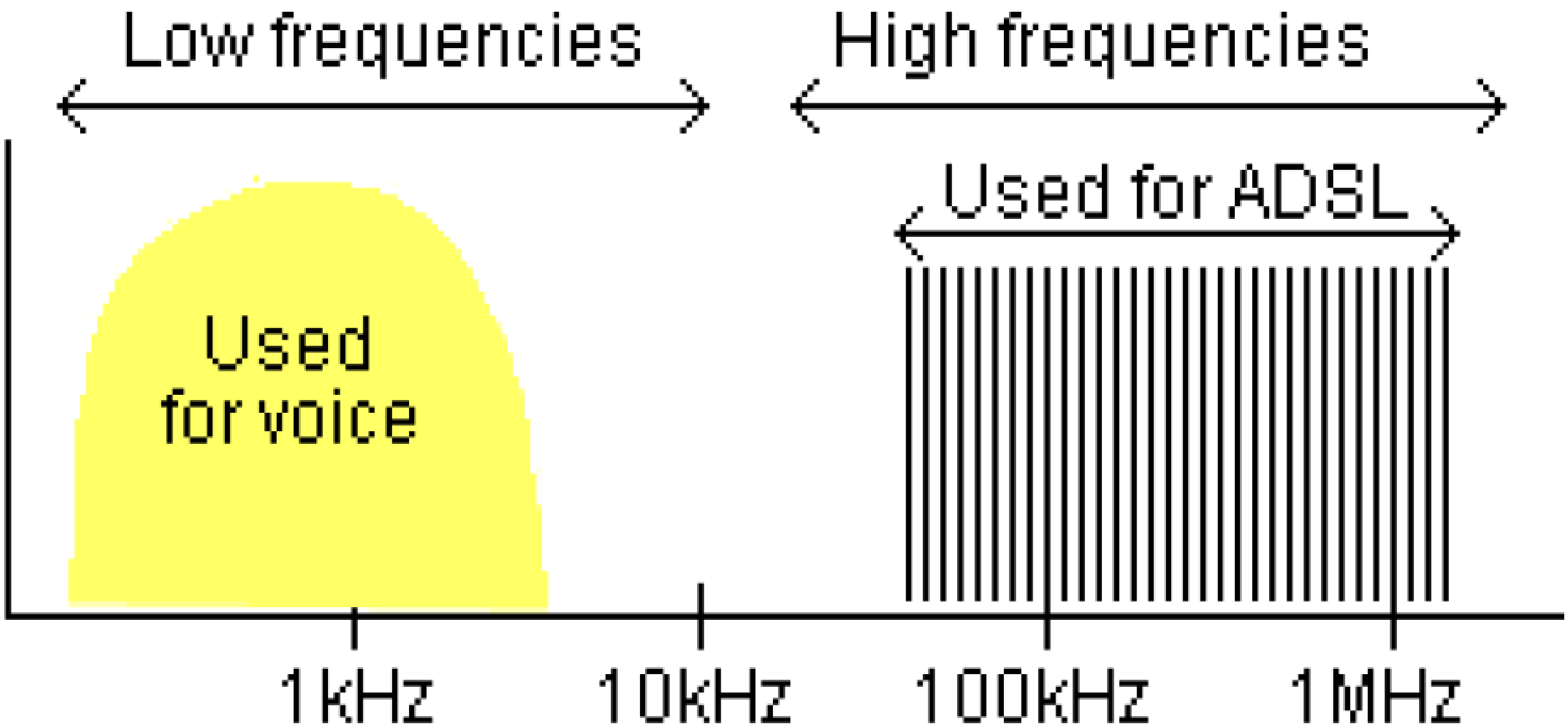
What does the ISP do?



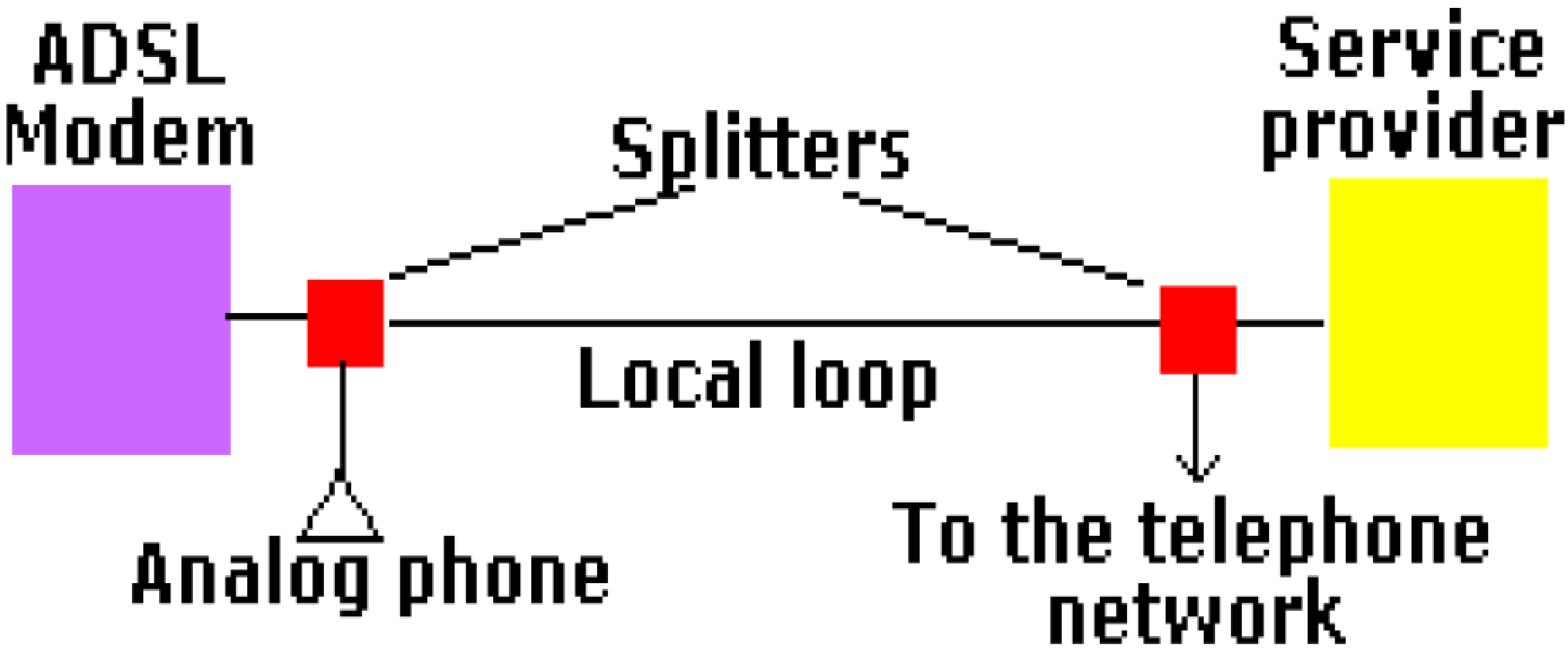
The Broadband Access Servers are connected to an Internet Service Provider or ISP. This is the place where your connection to the Internet is made.
The ISP usually provides other services like mail and news servers, and may cache frequently-used pages from the Internet so that you can access them more quickly.
The ISP treats ADSL connections exactly the same as connections made using ordinary dial-up modems or ISDN.

How do voice and data co-exist in ADSL?

If you are surfing the Internet using an ADSL modem, then a telephone call can still be made on the same line.
Splitters that separate the high frequencies used by ADSL from the low frequencies used by voice are situated at each end of the local loop.

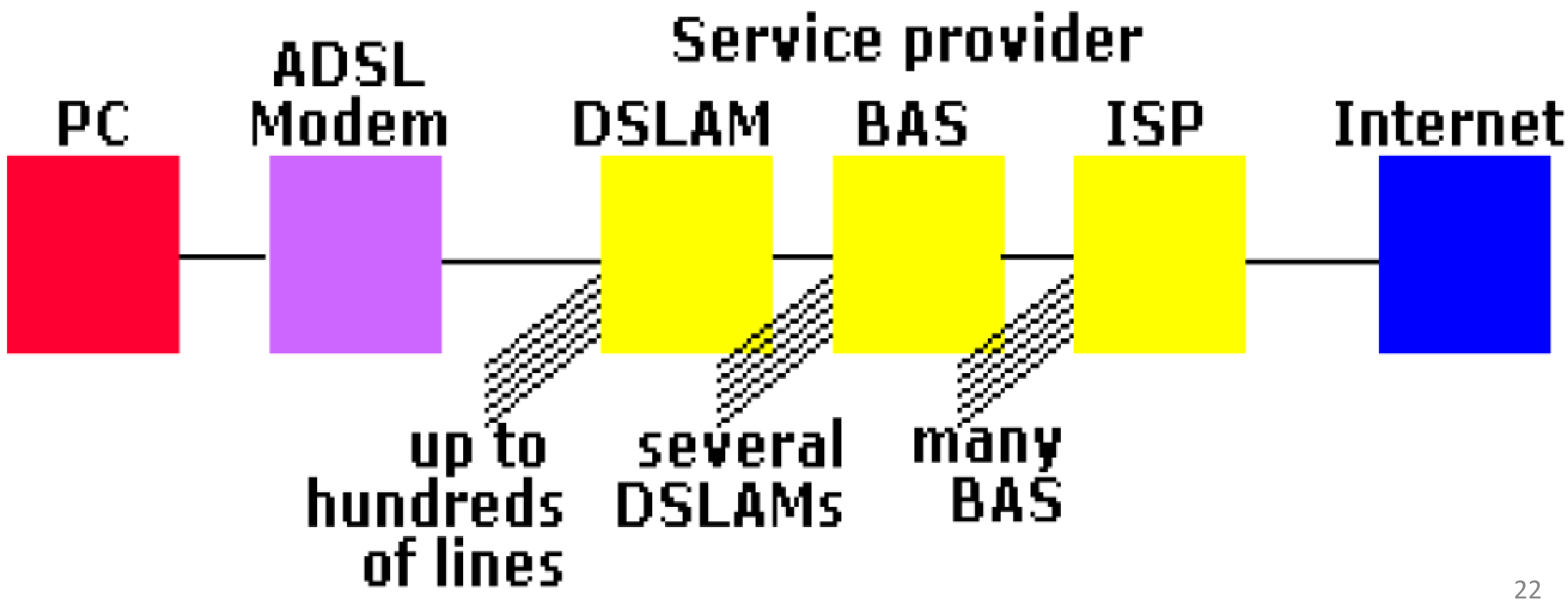


At your end of the connection, the low frequencies go to your phone and the high frequencies go to your ADSL modem. At the local exchange, the low frequencies go to the normal telephone network while the high frequencies go to the service provider.



Speed can be variable

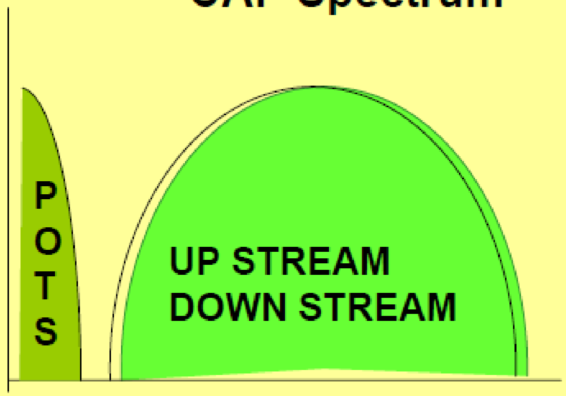
The speed of the connection achieved between your ADSL modem and the DSLAM depends on how far you are from the DSLAM, and the maximum allowed speed for your connection configured in the DSLAM. The speed of your connection to the Internet depends on many more variables.



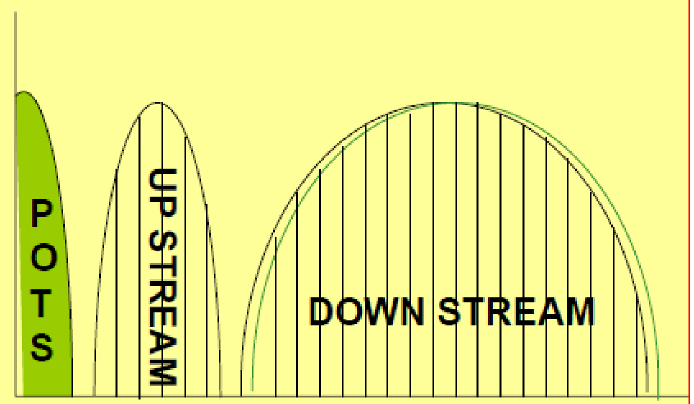
1. The number of other users connected to the same DSLAM and how many of these users are actively using their connections now
2. The speed of the connection between the DSLAM and BAS
3. How many other DSLAMs are connected to the same BAS as you and how many of these users are active
4. The speed of the connection between the BAS and the ISP
5. How many other BAS are connected to the same ISP as you and how many of these users are active
6. The speed of the ISP's connection to the Internet
7. How many of the other users of the ISP (using dial-up modems and ISDN as well as ADSL) are active.
8. Whether the ISP already has the information you requested cached so that it is not necessary to get the data from the Internet.

CAP and DMT

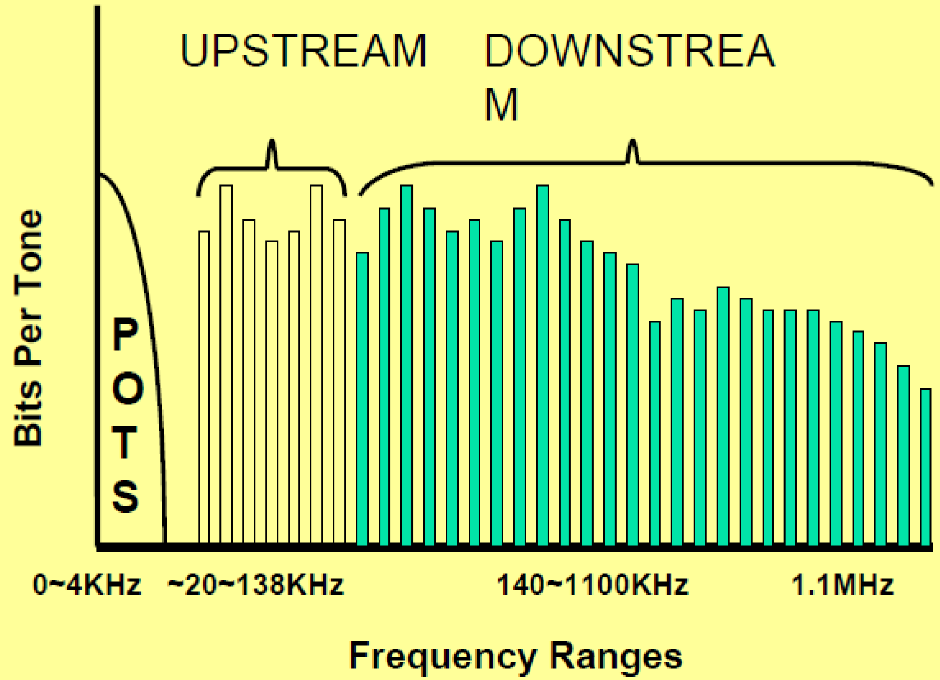
CAP Spectrum



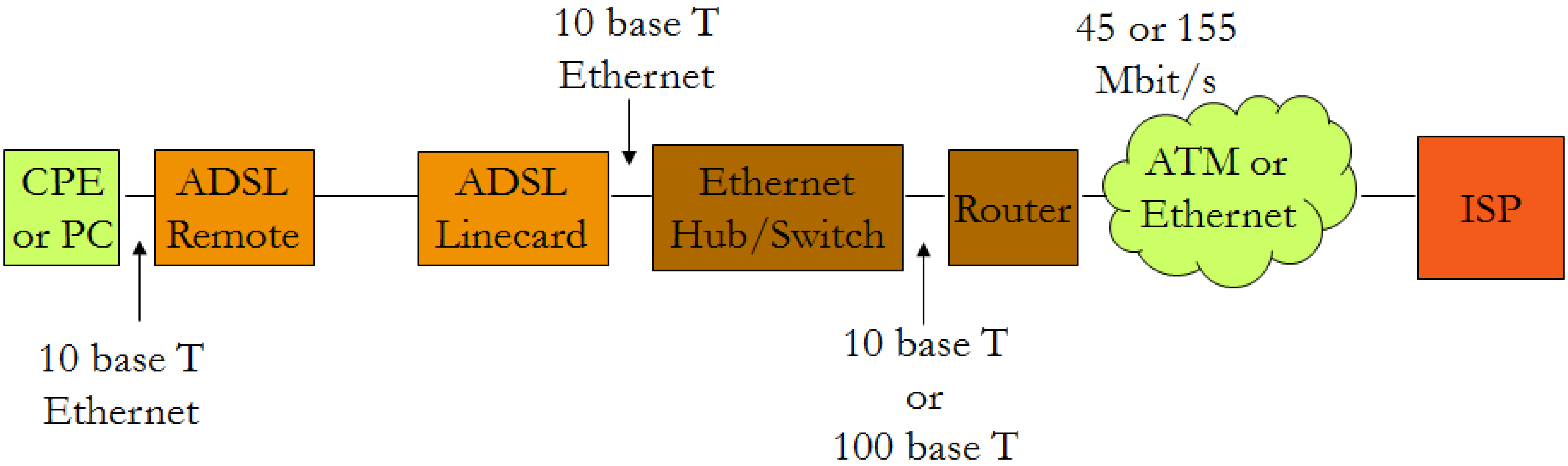
DMT Spectrum



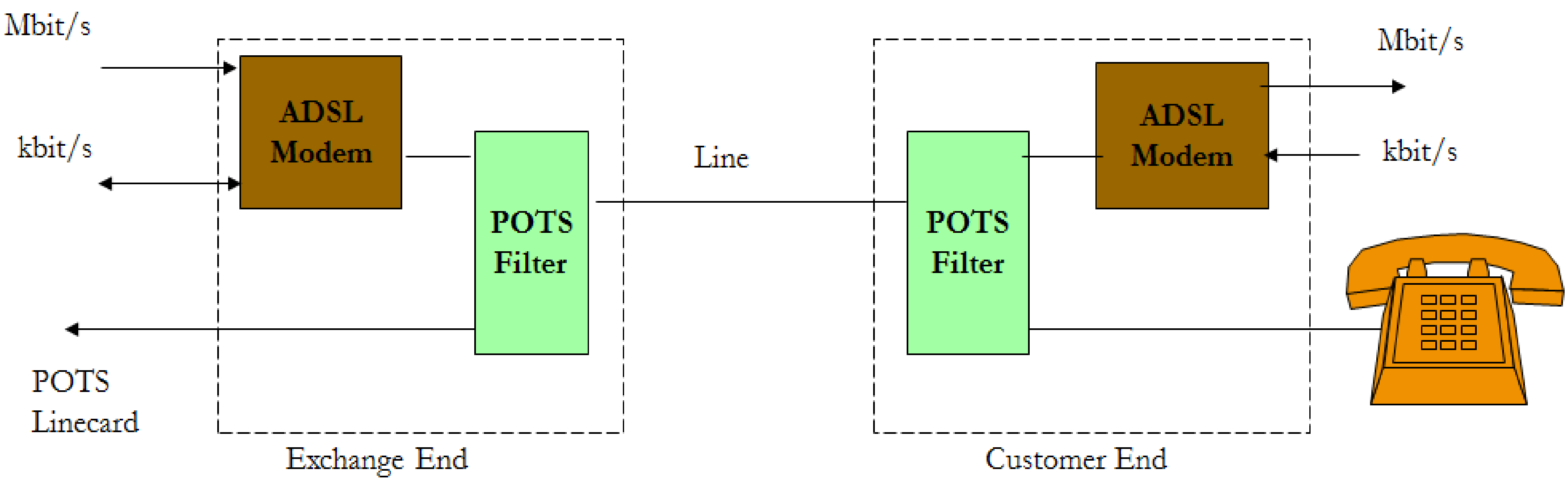
DMT Frequency Spectrum



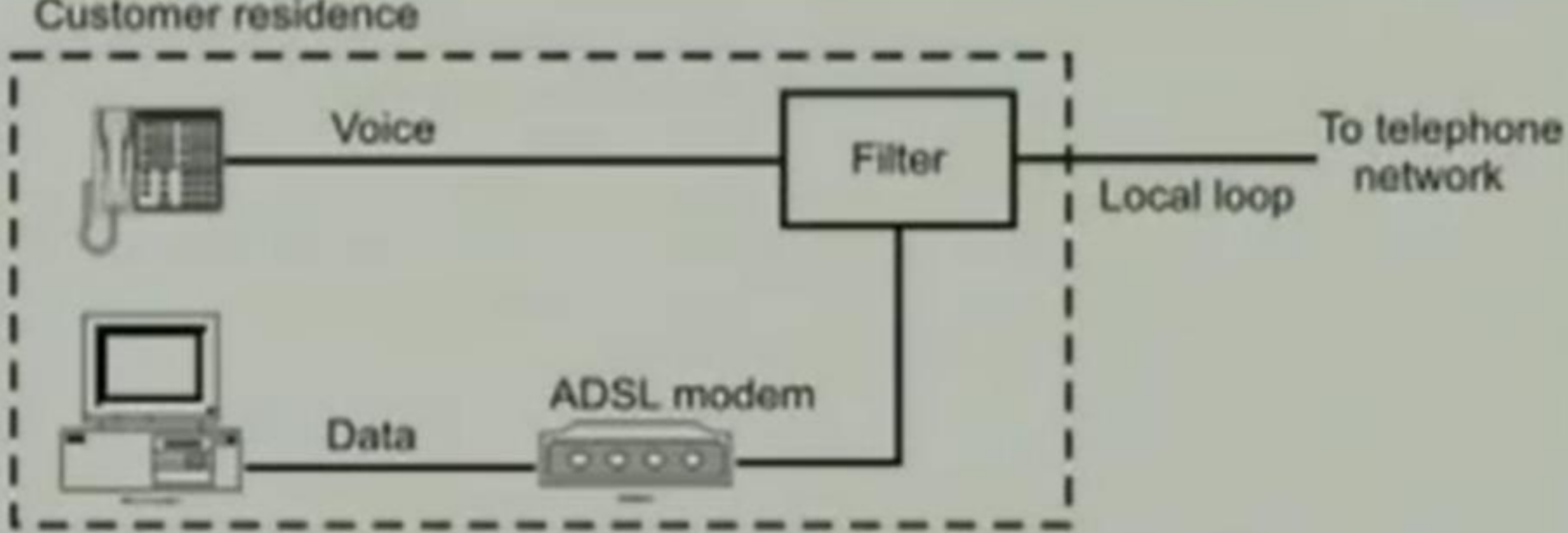
Basic Architecture

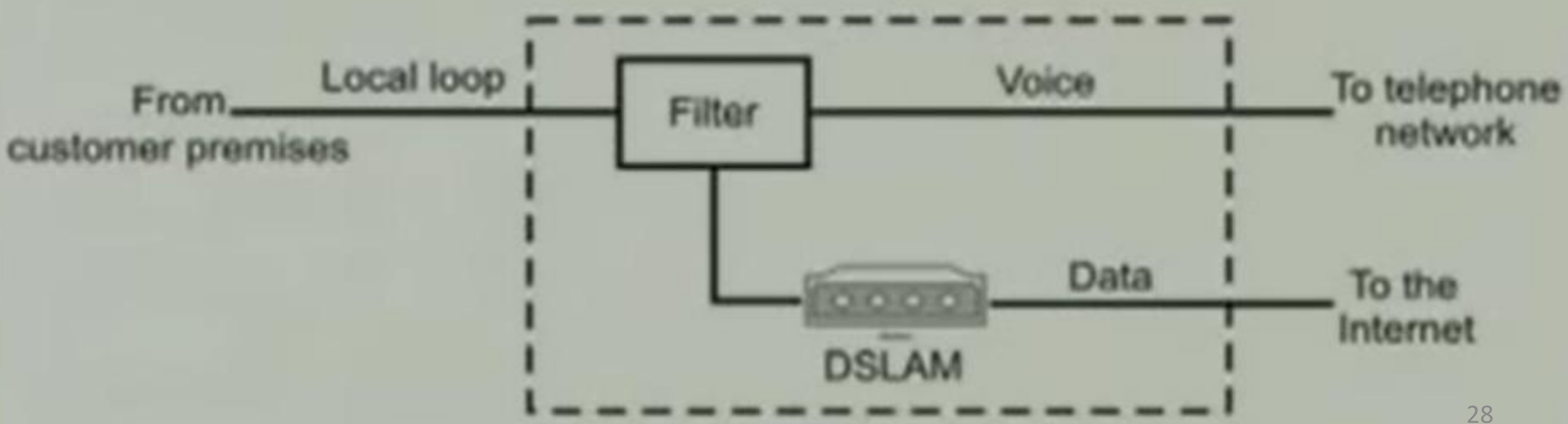


ADSL Modem Structure

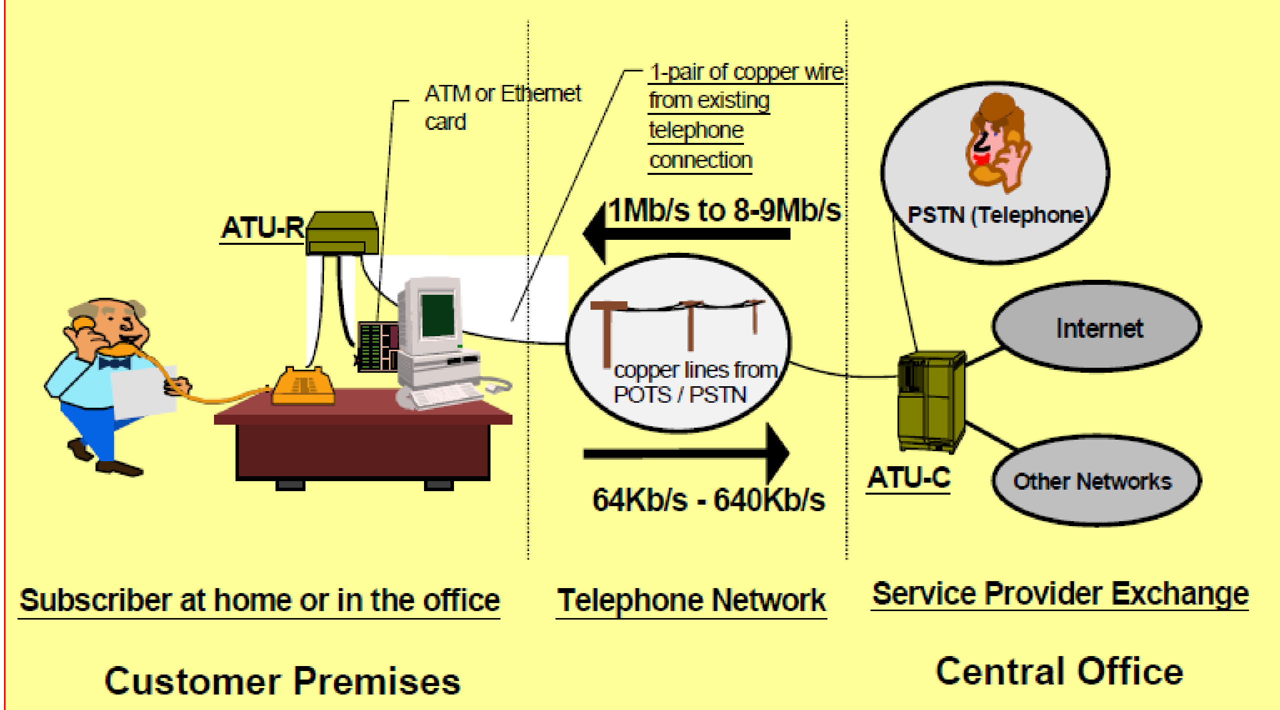


Equipments used in ADSL

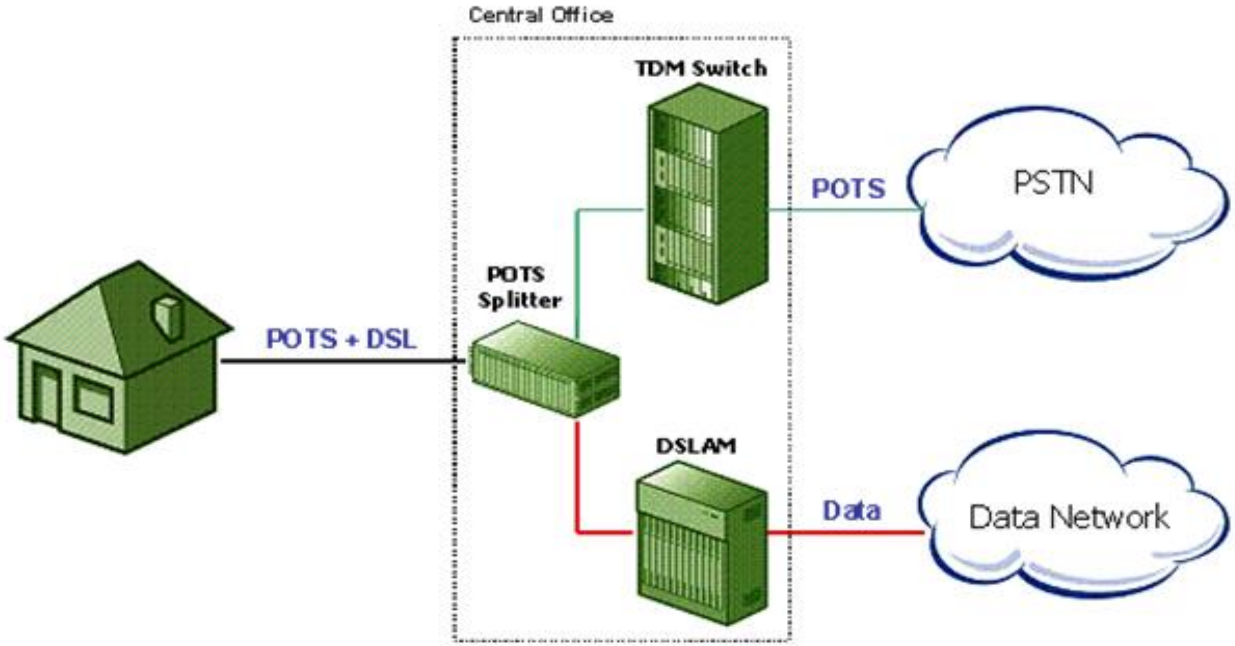




ADSL Network Components

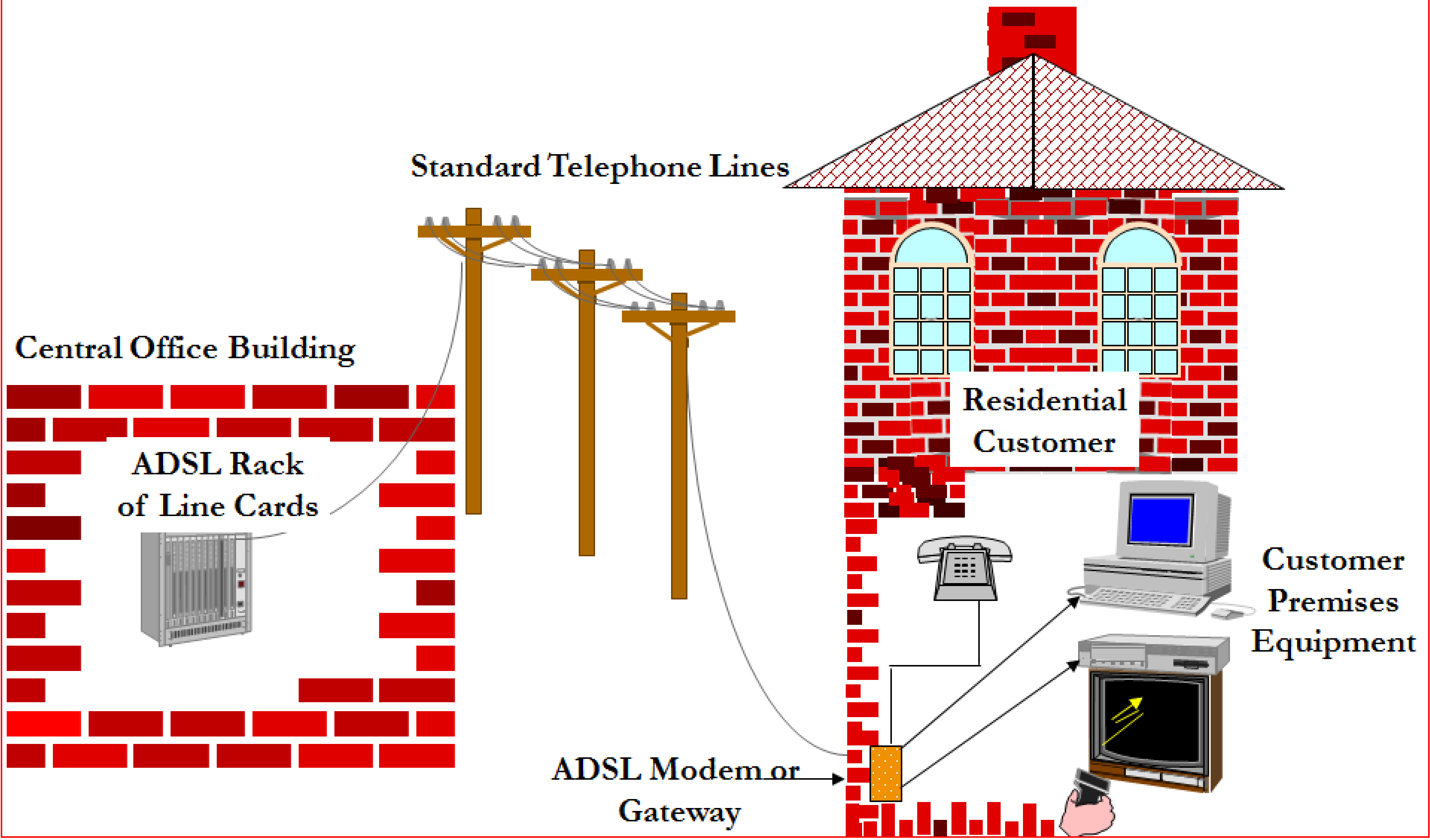


Simple overview of ADSL in the phone network

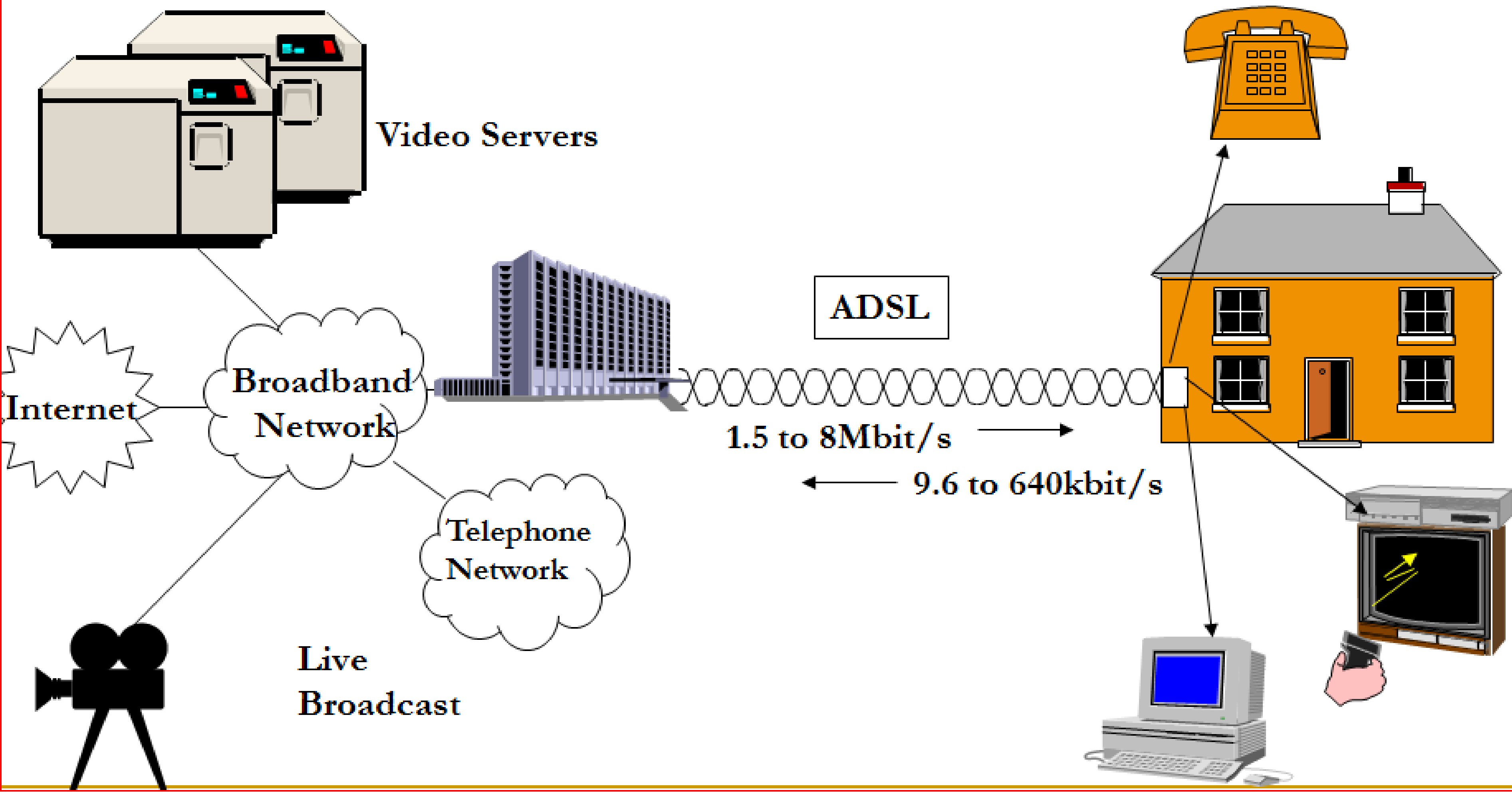


POTS- Plain Old Telephone Service

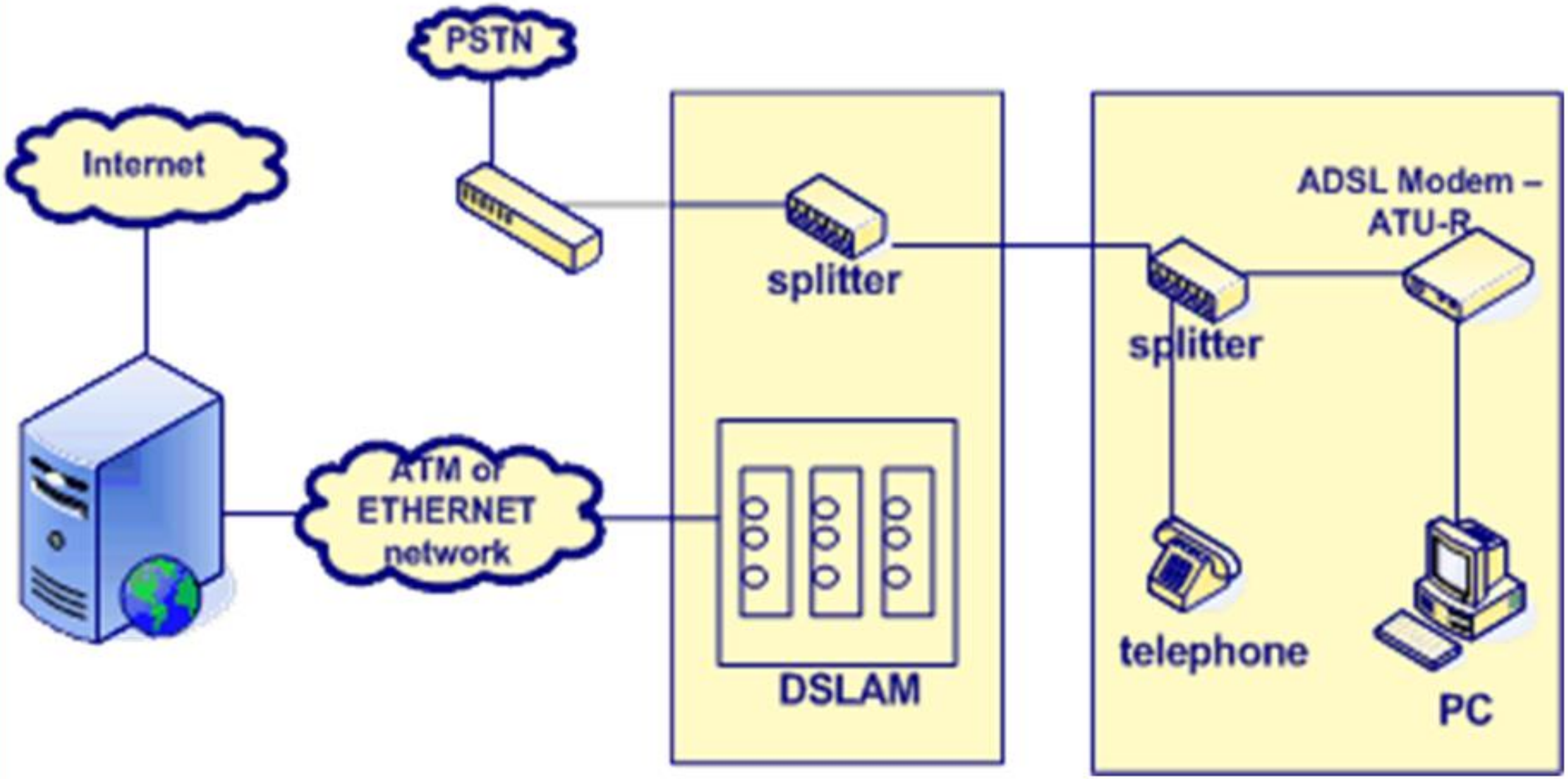
ADSL Equipment



"Today's Typical Network" : ADSL



ADSL Loop Architecture



ADSL standards :

Standard name	Common name	Downstream rate	Upstream rate
ITU G.992.1	ADSL (G.DMT)	8 Mbit/s	1.0 Mbit/s
ITU G.992.2	ADSL Lite (G.Lite)	1.5 Mbit/s	0.5 Mbit/s
ITU G.992.3/4	ADSL2	12 Mbit/s	1.0 Mbit/s
ITU G.992.3/4 Annex J	ADSL2	12 Mbit/s	3.5 Mbit/s
ITU G.992.3/4 Annex L	RE-ADSL2	5 Mbit/s	0.8 Mbit/s
ITU G.992.5	ADSL2+	24 Mbit/s	1.0 Mbit/s
ITU G.992.5 Annex L	RE-ADSL2+	24 Mbit/s	1.0 Mbit/s
ITU G.992.5 Annex M	ADSL2+	28 Mbit/s	3.5 Mbit/s

Today there are various

DSL Technology Options

Family	ITU	Name	Ratified	Maximum Speed capabilities
ADSL	G.992.1	G.dmt	1999	7 Mbps down, 800 kbps up
ADSL2	G.992.3	G.dmt.bis	2002	8 Mb/s down, 1 Mbps up
ADSL2plus	G.992.5	ADSL2plus	2003	24 Mbps down, 1 Mbps up
ADSL2-RE	G.992.3	Reach Extended	2003	8 Mbps down 1 Mbps up
SHDSL	G.991.2	G.SHDSL	2001	5.6 Mbps up/down
VDSL	G.993.1	Very-high-data-rate DSL	2004	55 Mbps down, 15 Mbps up
VDSL2	G.993.2	Very-high-data-rate DSL 2	2005	100 Mbps up/down

ADSL Range

- In general, the maximum range for DSL without a repeater is 5.5 km
- As distance decreases toward the telephone company office, the data rate increases

Data Rate	Wire gauge	Wire size	Distance
1.5 or 2 Mbps	24 AWG	0.5 mm	5.5 km
1.5 or 2 Mbps	26 AWG	0.4 mm	4.6 km
6.1 Mbps	24 AWG	0.5 mm	3.7 km
1.5 or 2 Mbps	26 AWG	0.4 mm	2.7

- For larger distances, you may be able to have DSL if your phone company has extended the local loop with optical fiber cable

ADSL Speed Depending on Distance and Wire Diameter of copper wire

Value Networking

Data Rate	Wire Gauge	Distance	Wire Size	Distance
1.5 or 2 Mbps	24 AWG	18,000 ft	0.5 mm	5.5 km
1.5 or 2 Mbps	26 AWG	15,000 ft	0.4 mm	4.6 km
6.1 Mbps	24 AWG	12,000 ft	0.5 mm	3.7 km
6.1 Mbps	26 AWG	9,000 ft	0.4 mm	2.7 km

Comparing DSL Types

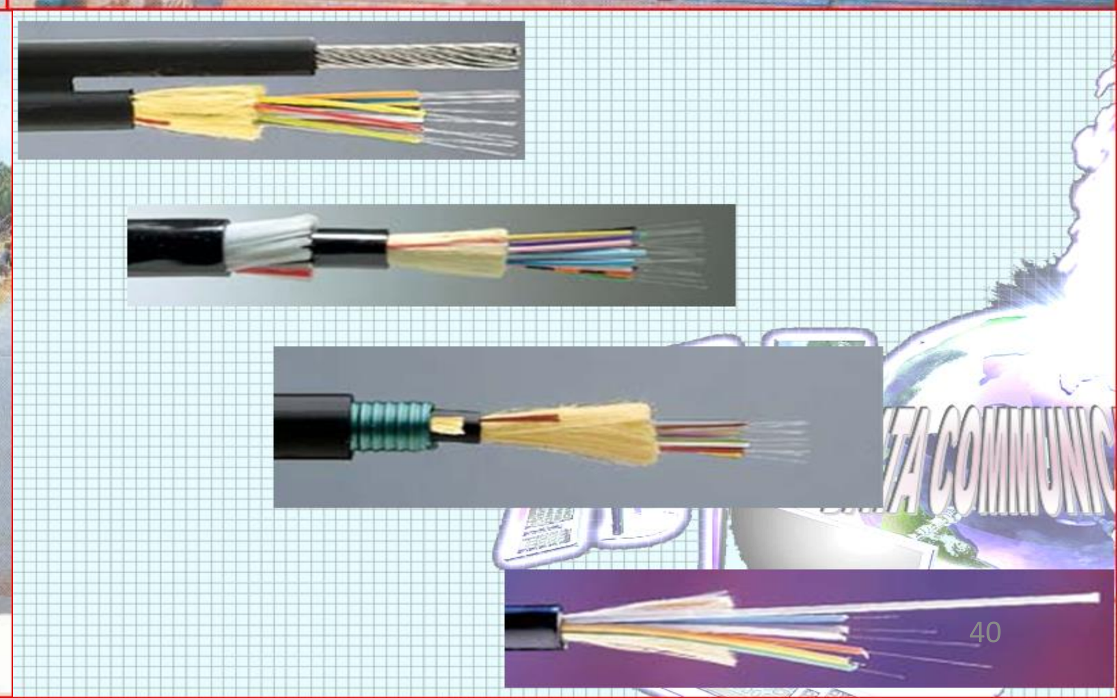
TYPE	Meaning	Rate	Duplex mode	Application
DSL	Digital Subscriber Line	160 Kbps	Duplex	ISDN,Voice and Data
HDSL	High Bit rate Digital	1.544Mbps 2.048Mbps	Duplex Duplex	T1/E1, WAN,LAN
SDSL	Symmetric Digital Subscriber Line	1.544Mbps 2.048Mbps	Duplex Duplex	T1/E1, WAN, LAN Symmetric Service
ADSL	Asymmetric Digital Subscriber Line	1.5 to 8Mbps	Down Up	Internet,VOD,Multimedia, Remote Education Asymmetric Service
VDSL	Very High data rate Digital	13 to 52Mbps	Down Up	Internet,VOD,Multimedia,Remote Education and HDTV Asymmetric Service

ADSL benefits

- You can talk on the phone and use the Internet at the same time on a single phone line
- You can connect to the Internet at up to 140 times faster than analog modems
- Your connection to the Internet is always on
- Your home has its own dedicated connection
- Your connection is highly reliability
- Your connection is highly secure

Fiber Optic

សកម្មភាពនៃការភ្ជួរកប់ខ្សែកាប្លិដោយប្រើគ្រឿងចក្រ



BRIEF OVER VIEW OF FIBER OPTIC CABLE ADVANTAGES OVER COPPER:

SPEED

Fiber optic networks operate at high speeds up into the gigabits

BANDWIDTH

Large carrying capacity

DISTANCE

Signals can be transmitted further without
needing to be "refreshed" or strengthened.

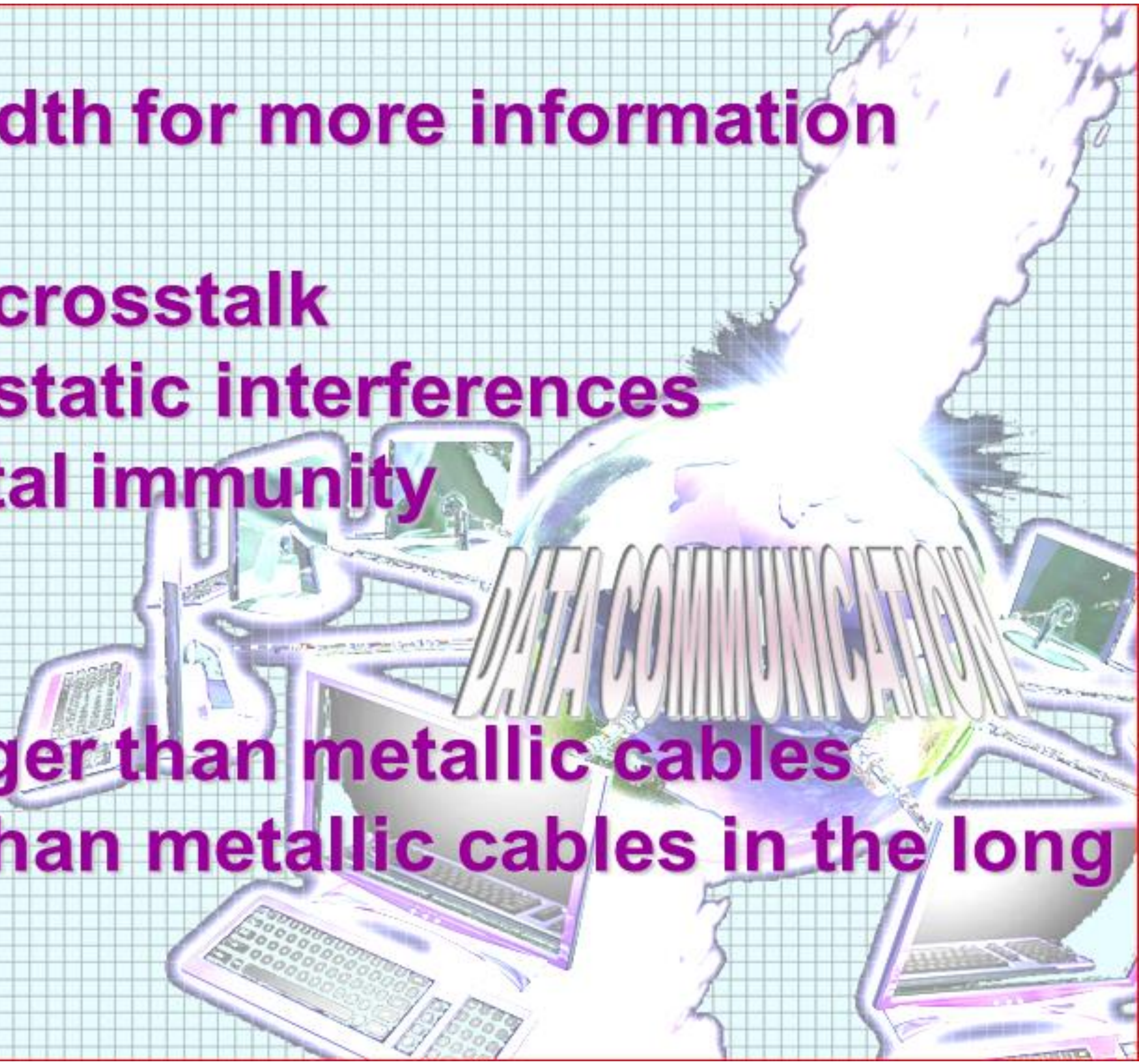
RESISTANCE

Greater resistance to electromagnetic noise such as radios, motors or other nearby cables.

MAINTENANCE

Fiber optic cables costs much less to maintain.

1. High bandwidth for more information capacity
2. Immunity to crosstalk
3. Immunity to static interferences
4. Environmental immunity
5. Safety
6. Security
7. May last longer than metallic cables
8. Lower cost than metallic cables in the long run



ADVANTAGES OF OPTICAL FIBERS

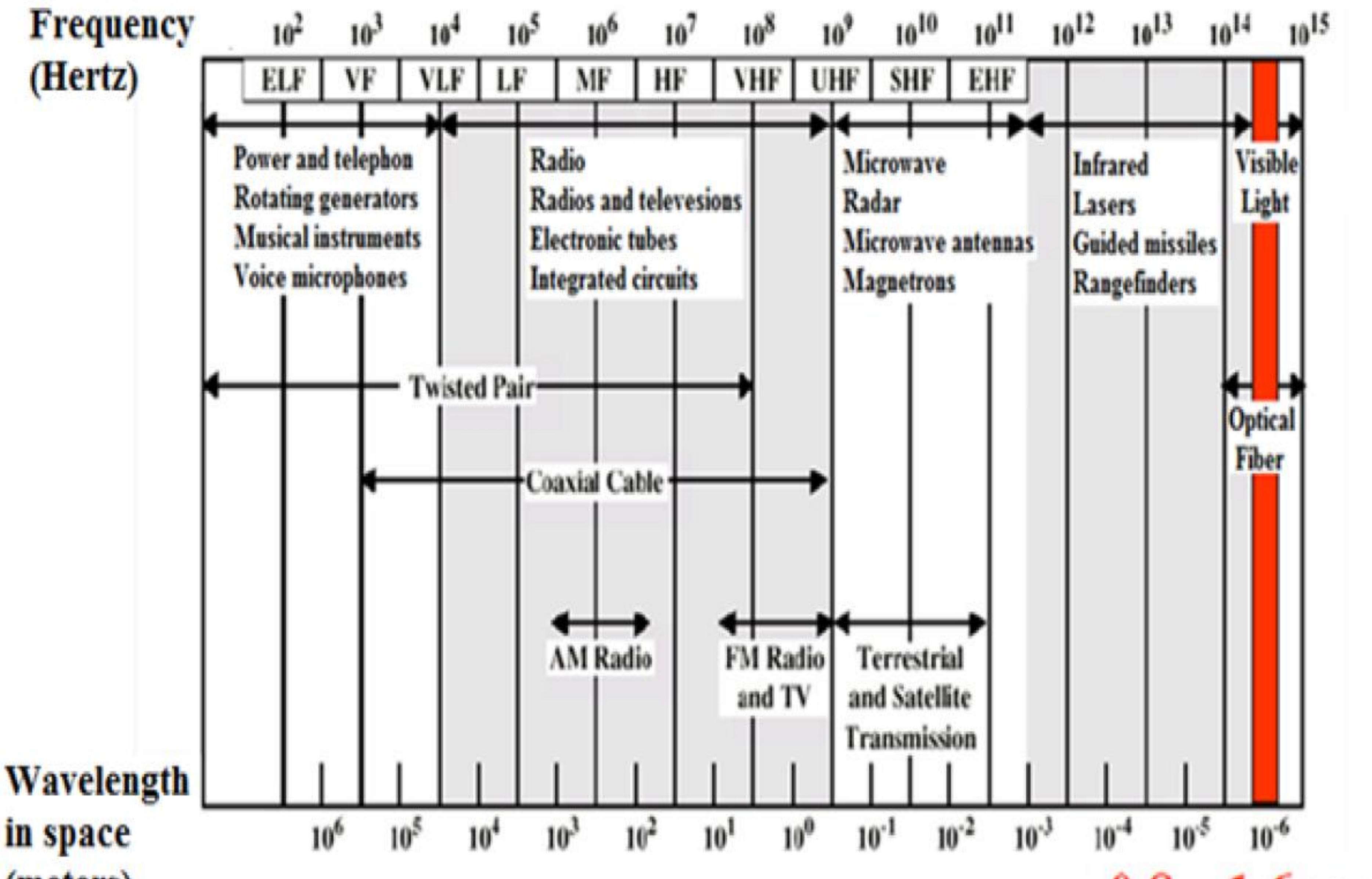
It is a very high information carrying capacity.

1. Less attenuation (order of 0.2 db/km)
2. Small in diameter and size & light weight
3. Low cost as compared to copper (as glass is made from sand ...the raw material used to make optical fiber is free….)
4. Greater safety and immune to EMI & RFI, moisture & corrosion
5. Flexible and easy to install in tight conducts
6. Zero resale value (so theft is less)
7. Is dielectric in nature so can be laid in eclectically sensitive surroundings
8. Difficult to tap fibers, so secure
9. No cross talk and disturbances

DISADVANTAGES OF OPTICAL FIBERS…

1. The terminating equipment is still costly as compared to copper equipment.
2. Of is delicate so has to be handled carefully.
3. Last mile is still not totally fiber-ised due to costly subscriber premises equipment.
4. Communication is not totally in optical domain, so repeated electric –optical – electrical conversion is needed.
5. Optical amplifiers, splitters, MUX-DEMUX are still in development stages.
6. Tapping is not possible. Specialized equipment is needed to tap a fiber.
7. Optical fiber splicing is a specialized technique and needs expertly trained manpower.
8. The splicing and testing equipments are very expensive as compared to copper equipments.

Electromagnetic spectrum and communication services:



0.8 – 1.6 μm

II. What is an optical fiber communication system?

Transmission of information using light over an optical fiber;

The main parts of the optical fiber communication system are,

1- The transmitter. (The heart of a transmitter is a light source usually *LEDs* or laser lights (*LDs*)).
2- The fiber. (The transparent flexible filament that guides light from a transmitter to a receiver)
3- The receiver. (The key component of an optical receiver is its *photo-detector*).

<u>Basic Optical Link Design</u>

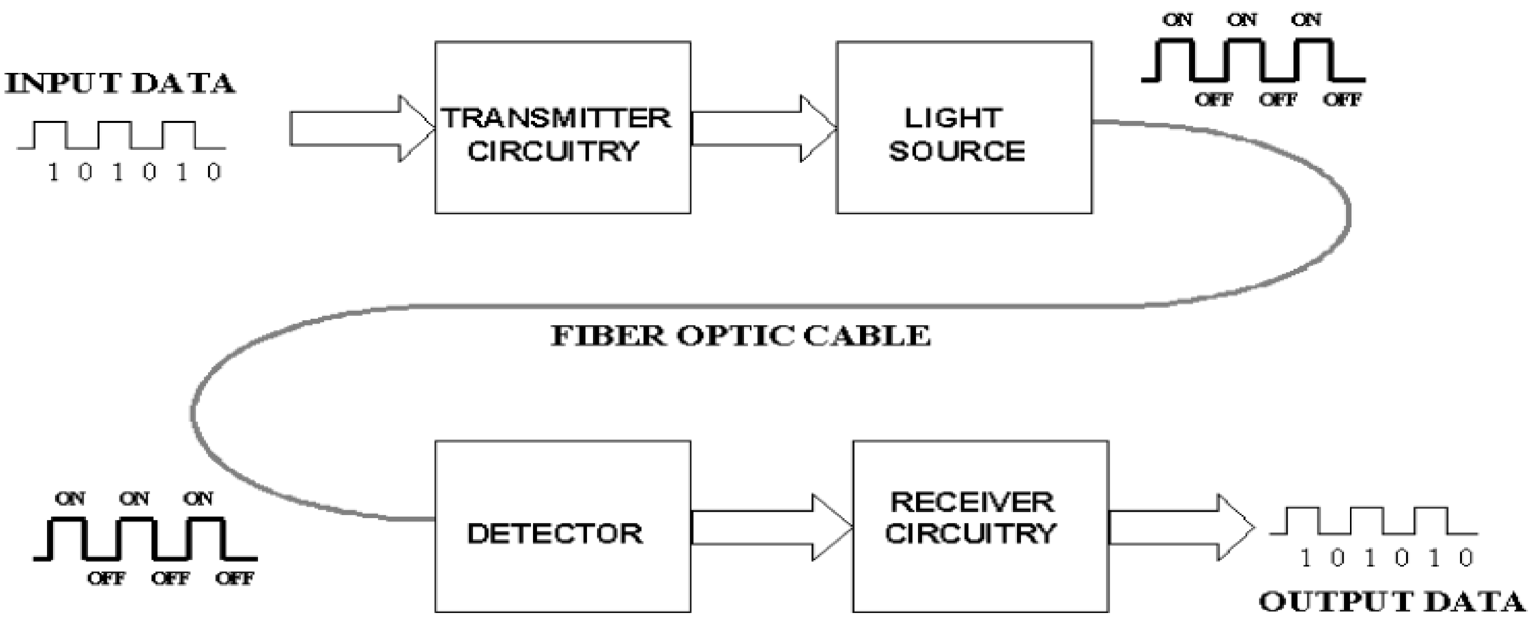


Fig.3 Basic fiber optic communication System

V. Types of Fiber

Three basic types of fiber optic cable are used in communication systems:

1. Step-index multimode

2, Step-index single mode

3, Graded-index, this is illustrated in Figure 5.

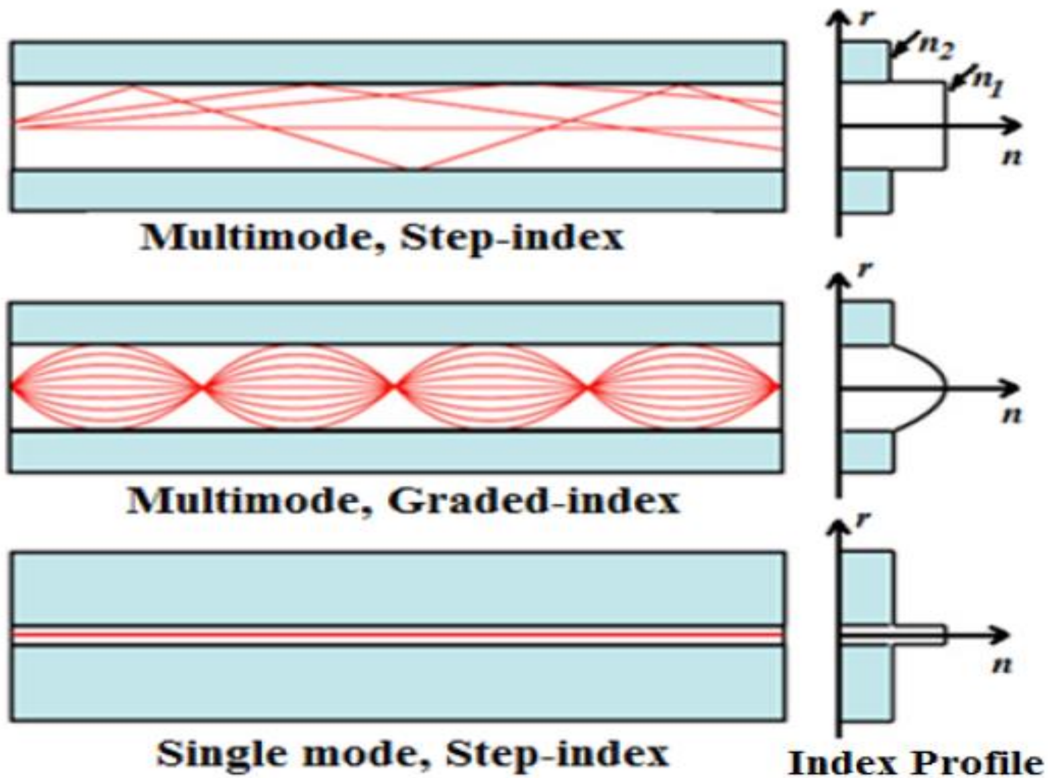


Fig.5 Index profile of various optical waveguides

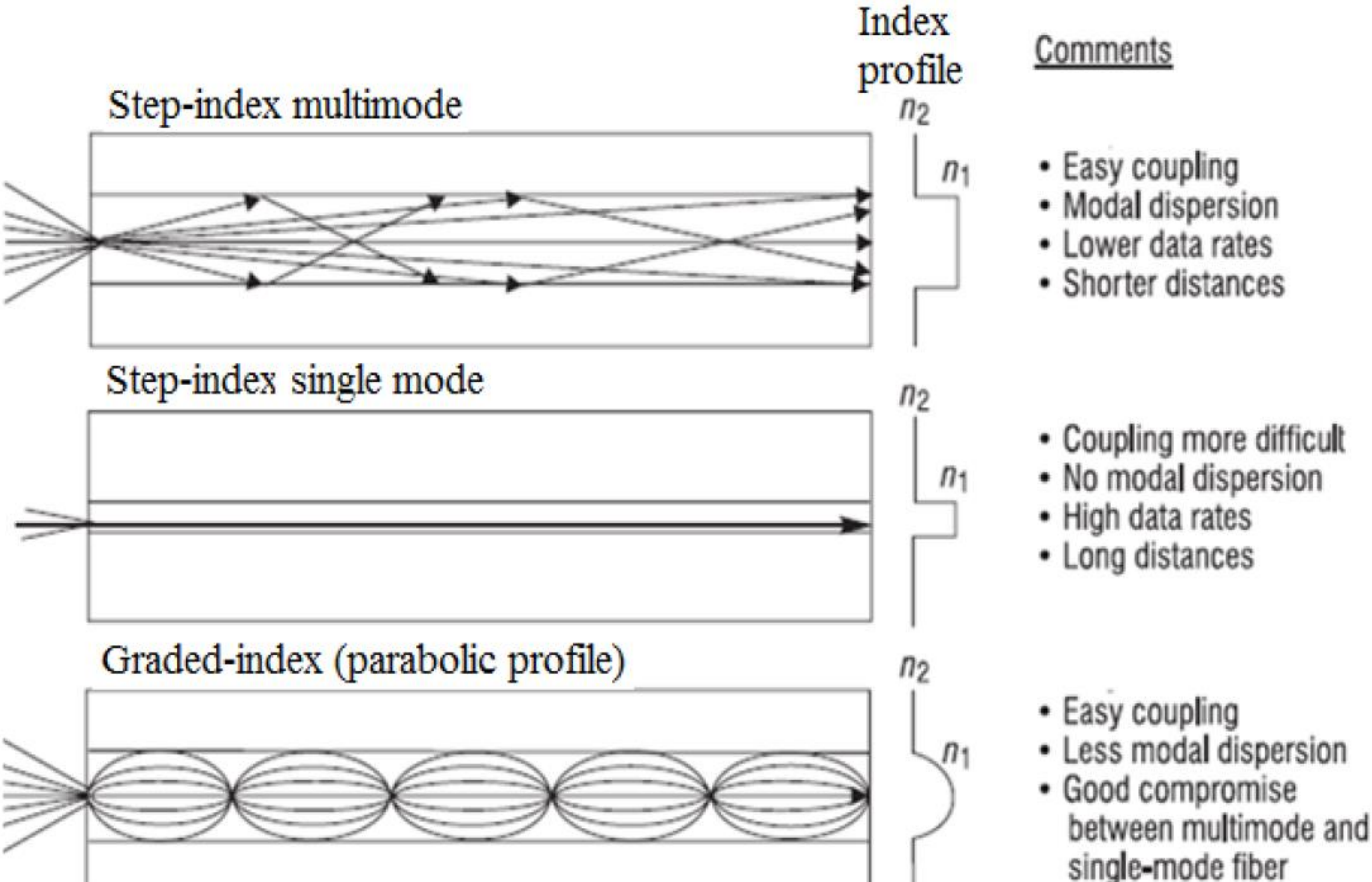


Fig.6 Types of fiber

<u>Step-index multimode</u>: fiber has an index of refraction profile that "steps" from low to high to low as measured from cladding to core to cladding. Relatively large core diameter and numerical aperture characterizes this fiber. The core/cladding diameter of a typical multimode fiber used for telecommunication is 62.5/125 μm (about the size of a human hair). The term "multimode" refers to the fact that multiple *modes* or *paths* through the fiber are possible. Step index multimode fiber is used in applications that require high bandwidth (< 1 GHz) over relatively short distances (< 3 km) such as a local area network or a campus network backbone.

The major benefits of multimode fiber are: (1) it is relatively easy to work with; (2) because ofits larger core size, light is easily coupled to and from it; (3) it can be used with both lasers and LEDs as sources; and (4) coupling losses are less than those of the single-mode fiber. The drawback is that because many modes are allowed to propagate (a function of core diameter, wavelength, and numerical aperture) it suffers from *modal dispersion*. The result of modal dispersion is bandwidth limitation, which translates into lower data rates.

Single-mode step-index: fiber allows for only one path, or mode, for light to travel within the fiber. In a multimode step-index fiber, the number of modes M_n propagating can be approximated by

$$M_n = \frac{V^2}{2} \tag{5}$$

Here V is known as the normalized frequency, or the ***V*-number**, which relates the fiber size (a), the refractive index (n), and the wavelength (λ). The V- number is given by Equation (6)

$$V = \left[\frac{2\pi a}{\lambda}\right] \times N.A. \tag{6}$$

or by,

$$V = \frac{2\pi a}{\lambda} \times n_1 \times (2 \times \Delta)^{\frac{1}{2}}$$

In either equation, a is the fiber core radius, $\lambda$is the operating wavelength, N.A. is the numerical aperture, n_1 is the core index, and $\Delta$is the relative refractive index difference between core and cladding.

The analysis of how the V-number is derived is beyond the scope of under graduate, but it can be shown that by ***reducing*** the diameter of the fiber to a point at which the V-number is ***less*** than **2.405**, higher-order modes are effectively extinguished and single-mode operation is possible.

LED in Fiber Optics

The type of LED used in fiber optic systems are top emitting heterojunction types which is either the planar heterojunction type or the burrus etched-well. These types provide larger power output and more efficient light transmission

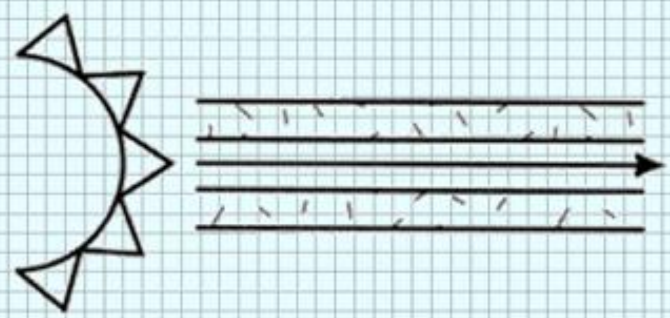
THREE TYPES OF FIBER OPTIC CABLE

single mode

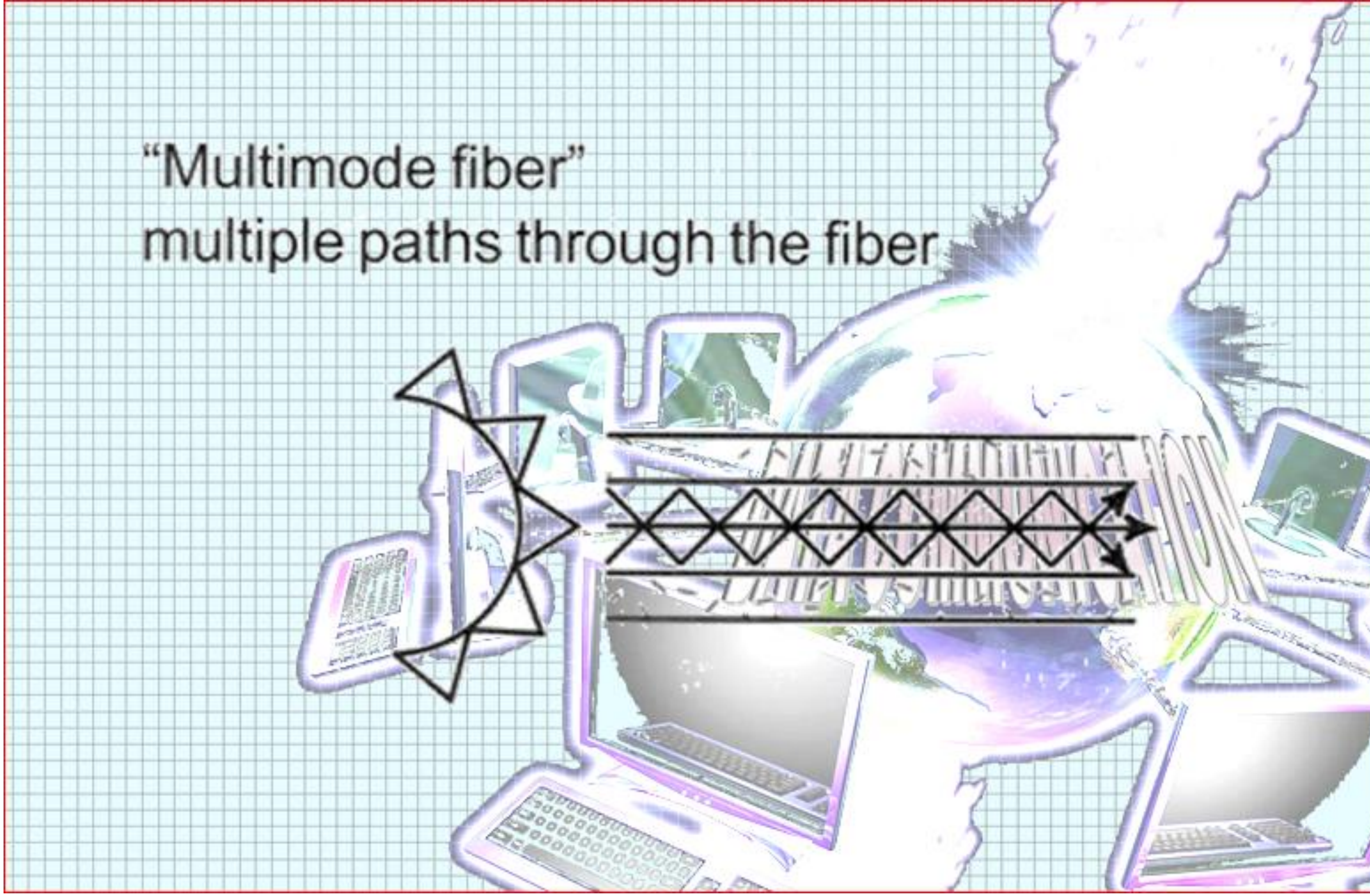
multimode

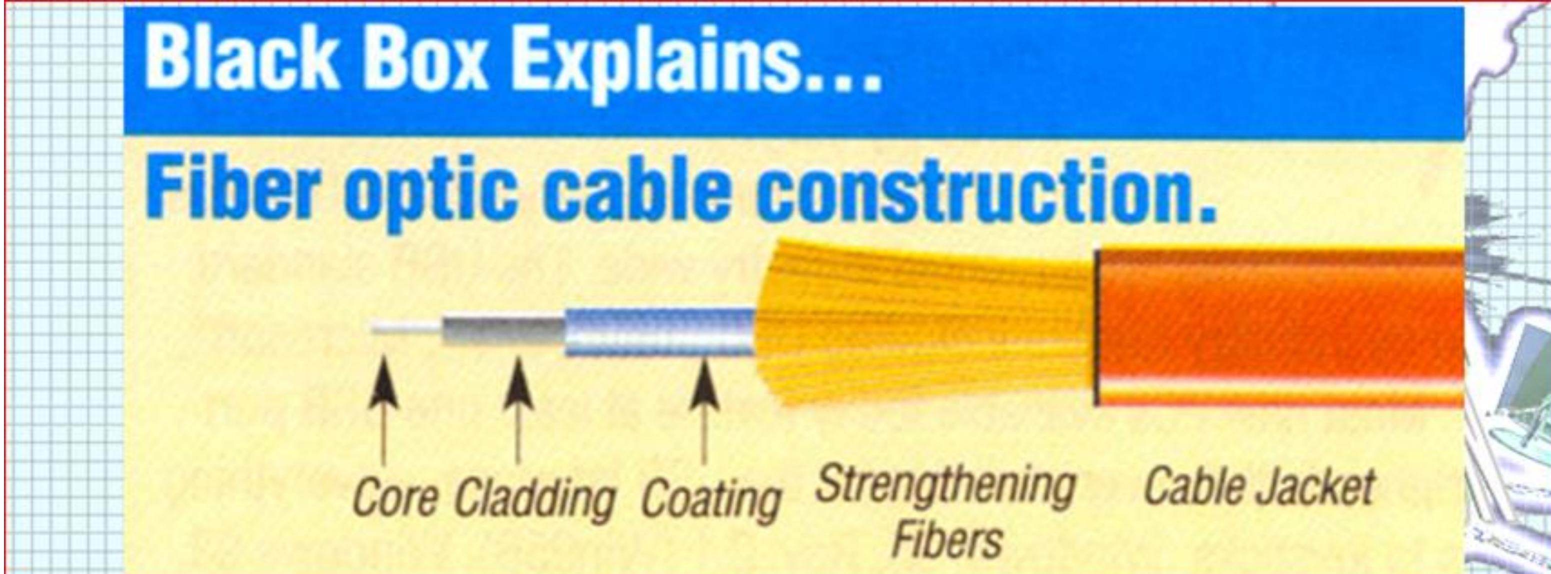
plastic optical fiber (POF).

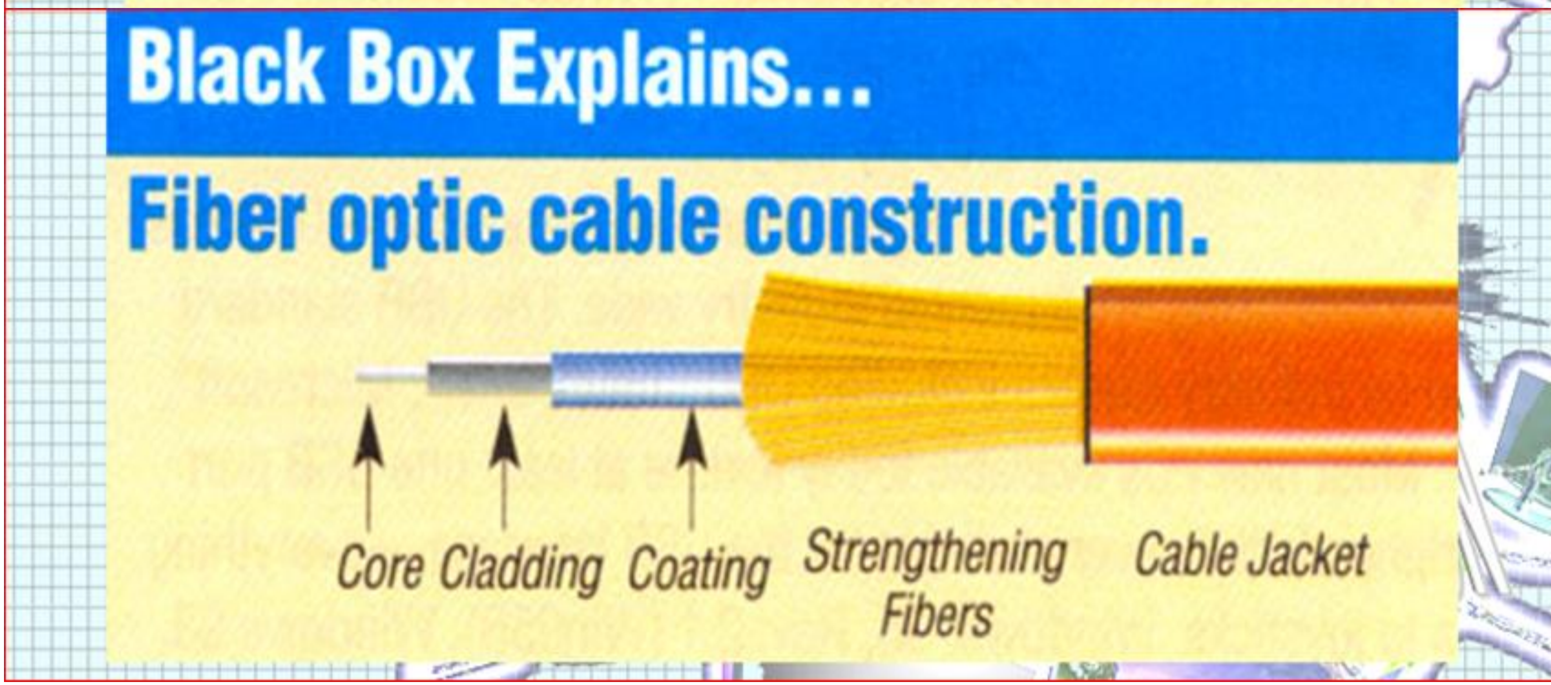
"Single mode fiber"
single path through the fiber



Is a single stand of glass fiber with a diameter of 8.3 to 10 microns that has one mode of transmission. Single Mode Fiber with a relatively narrow diameter, through which only one mode will propagate typically 1310 or 1550nm. Carries higher bandwidth Single-mode fiber gives you a higher transmission rate and up to 50 times more distance than multimodeThe small core and single light-wave virtually eliminate any distortion that could result from overlapping light pulses, providing the least signal attenuation and the highest transmission speeds of any fiber cable type.


"Multimode fiber"
multiple paths through the fiber


Black Box Explains...
Fiber optic cable construction.
Core
Cladding
Coating
Strengthening Fibers
Cable Jacket


Black Box Explains...
Fiber optic cable construction.
Core
Cladding
Coating
Strengthening Fibers
Cable Jacket

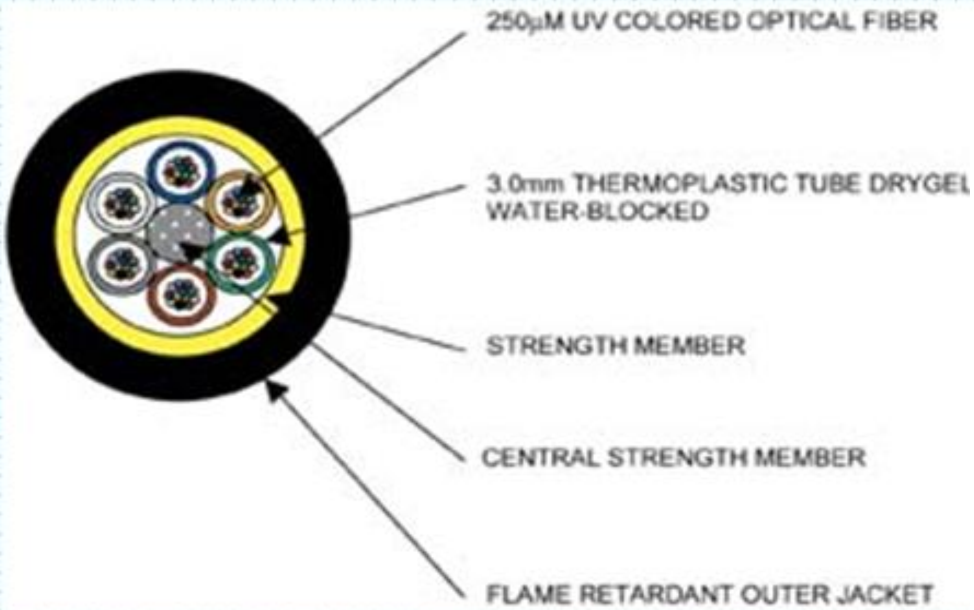
Optical fibers consist of three essential parts:

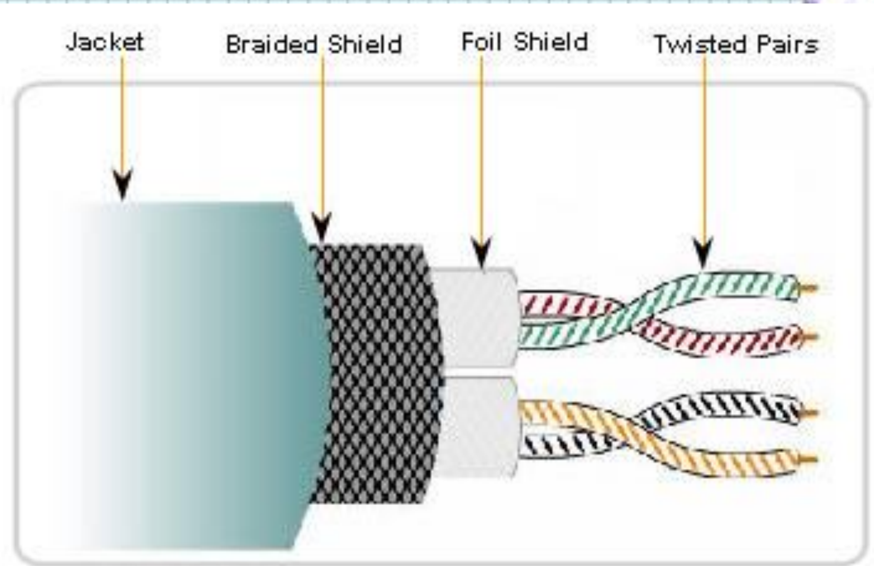
- **The CORE**
- **The CLADDING**
- **The COATING/ COVER/ Jacket**

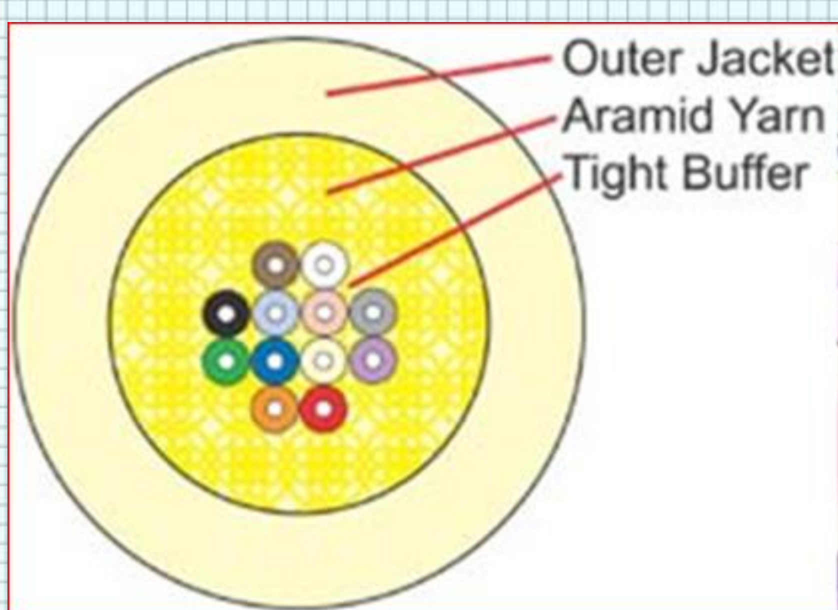
The **core** is the transmission area of the fiber which is a cylinder of transparent material with a certain refractive index (n1)

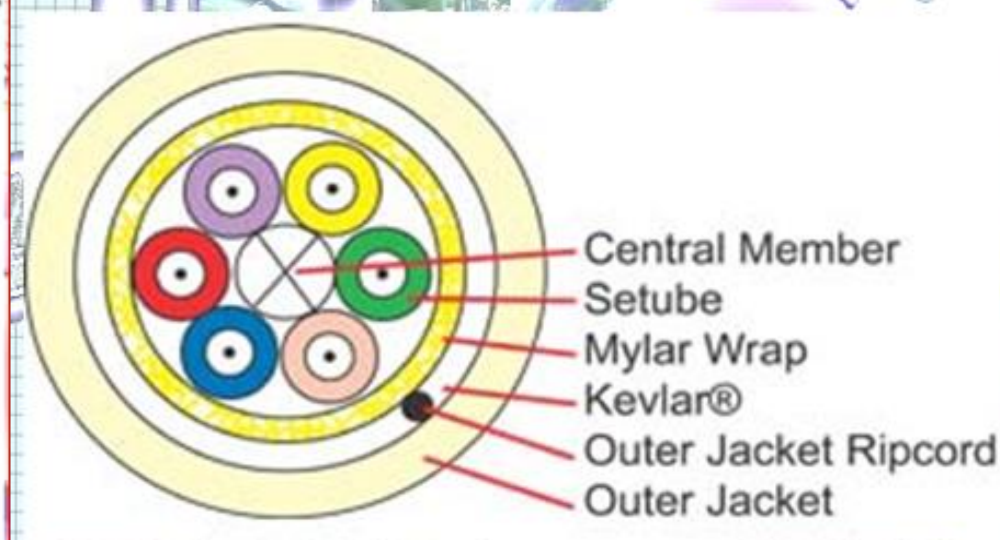
The **cladding** is the layer next to the core which is another transparent layer with a different refractive index (n2). Its main function is to confine the light inside the core similar to what the walls of a pipe do to contain the fluid within the pipe to prevent any leakage.

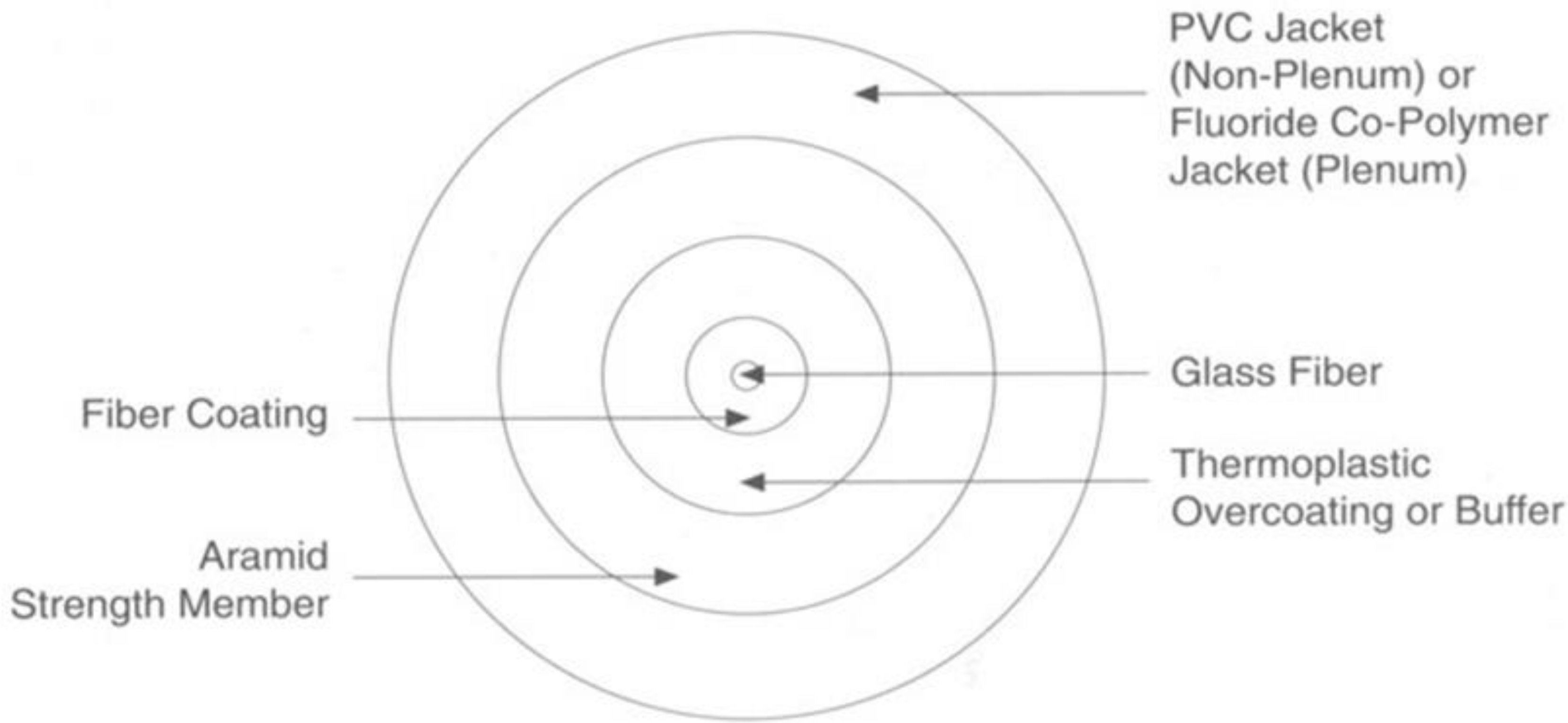
The coating is a specially formulated plastic coating that provides first level shock and abrasion resistance to the fiber. It also provides mechanical and tensile strength to the fiber. Coating may be of several layers of materials like epoxy plastic resin, yarn (kevlar), and other plastic materials which is generally called buffers


250µM UV COLORED OPTICAL FIBER
3.0mm THERMOPLASTIC TUBE DRYGEL WATER-BLOCKED
STRENGTH MEMBER
CENTRAL STRENGTH MEMBER
FLAME RETARDANT OUTER JACKET

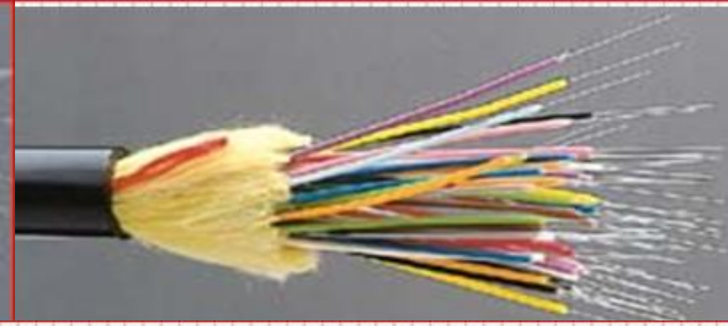

Jacket
Braided Shield
Foil Shield
Twisted Pairs


Outer Jacket
Aramid Yarn
Tight Buffer

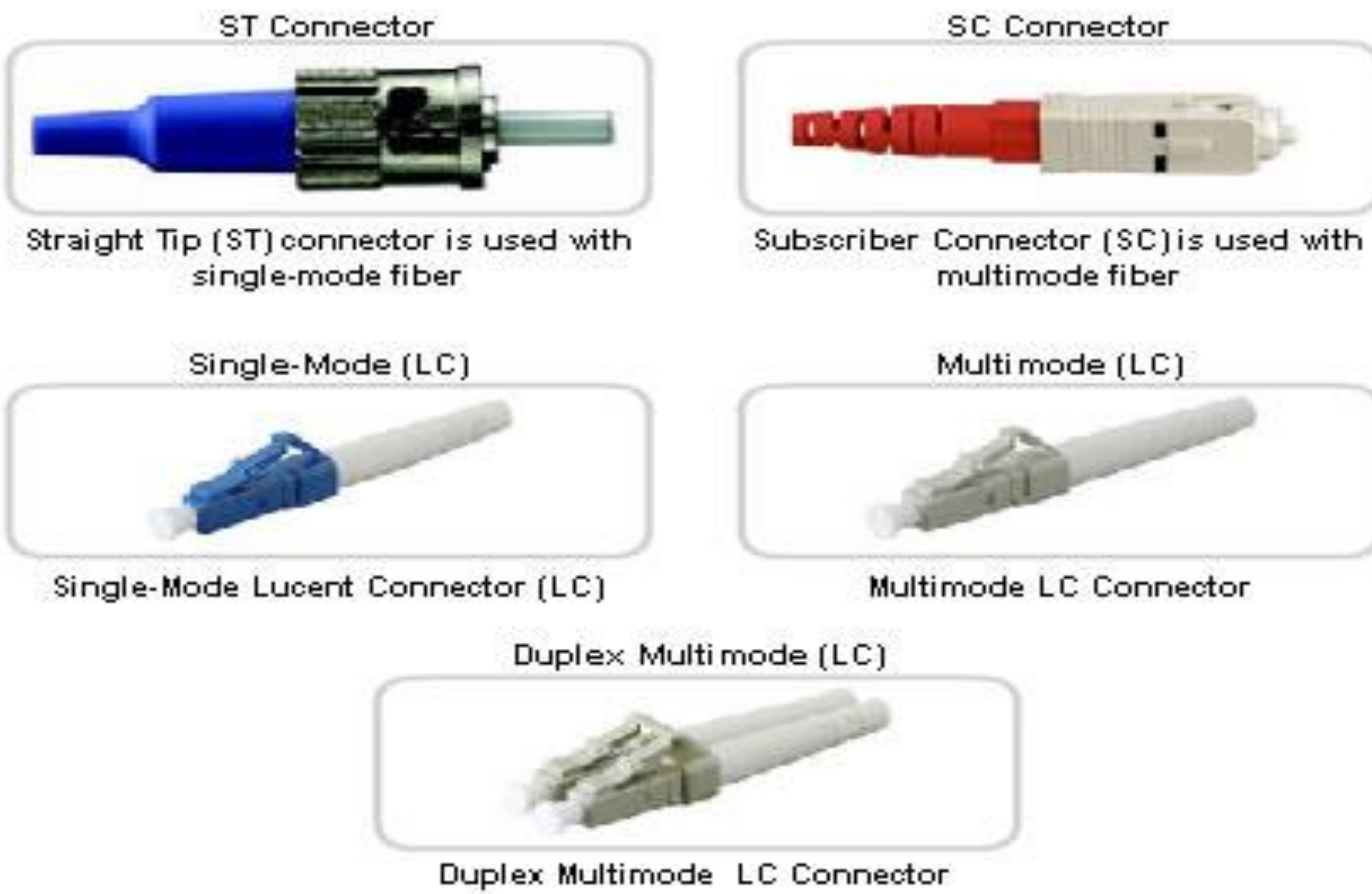

Central Member
Setube
Mylar Wrap
Kevlar®
Outer Jacket Ripcord
Outer Jacket



Tight-Buffered Cable

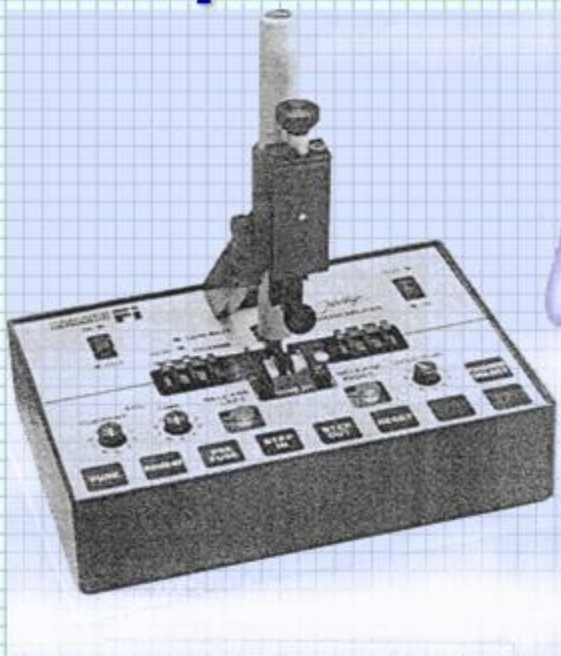


Media Connector – for fiber optics

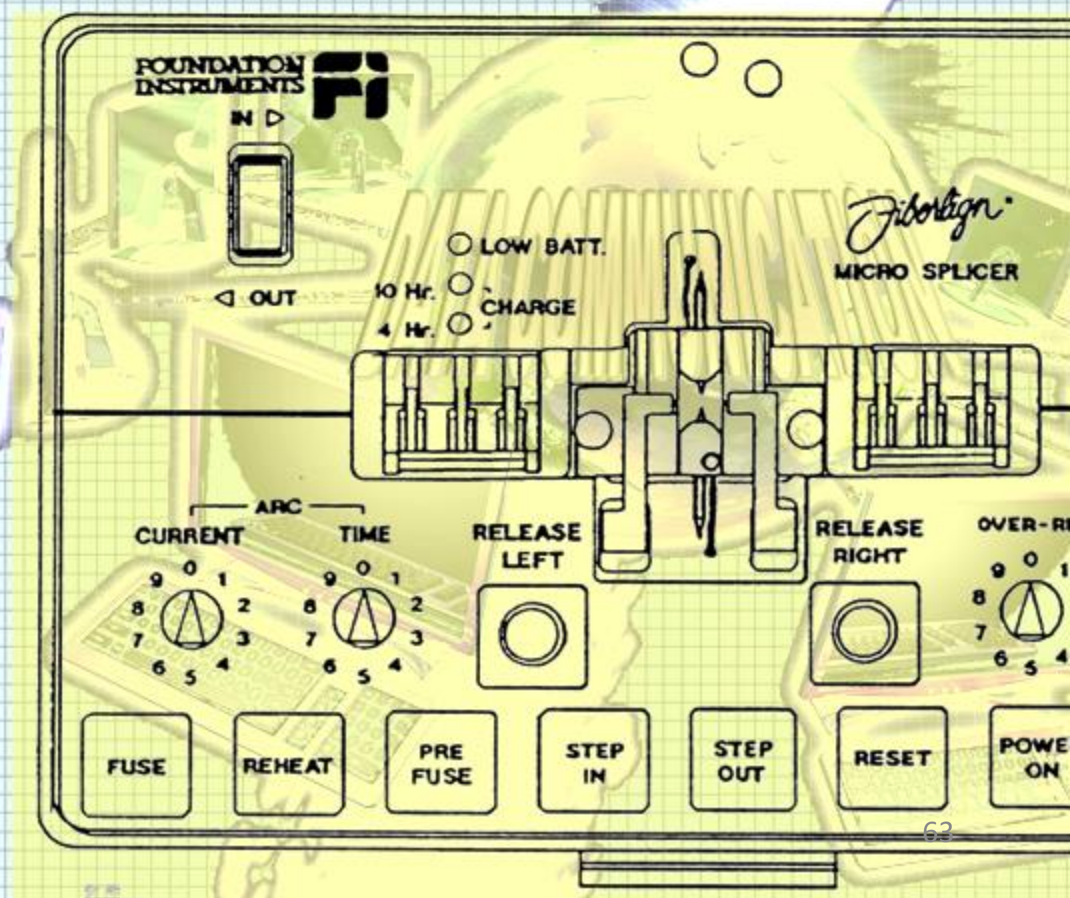


Disadvantages of Optical fibers

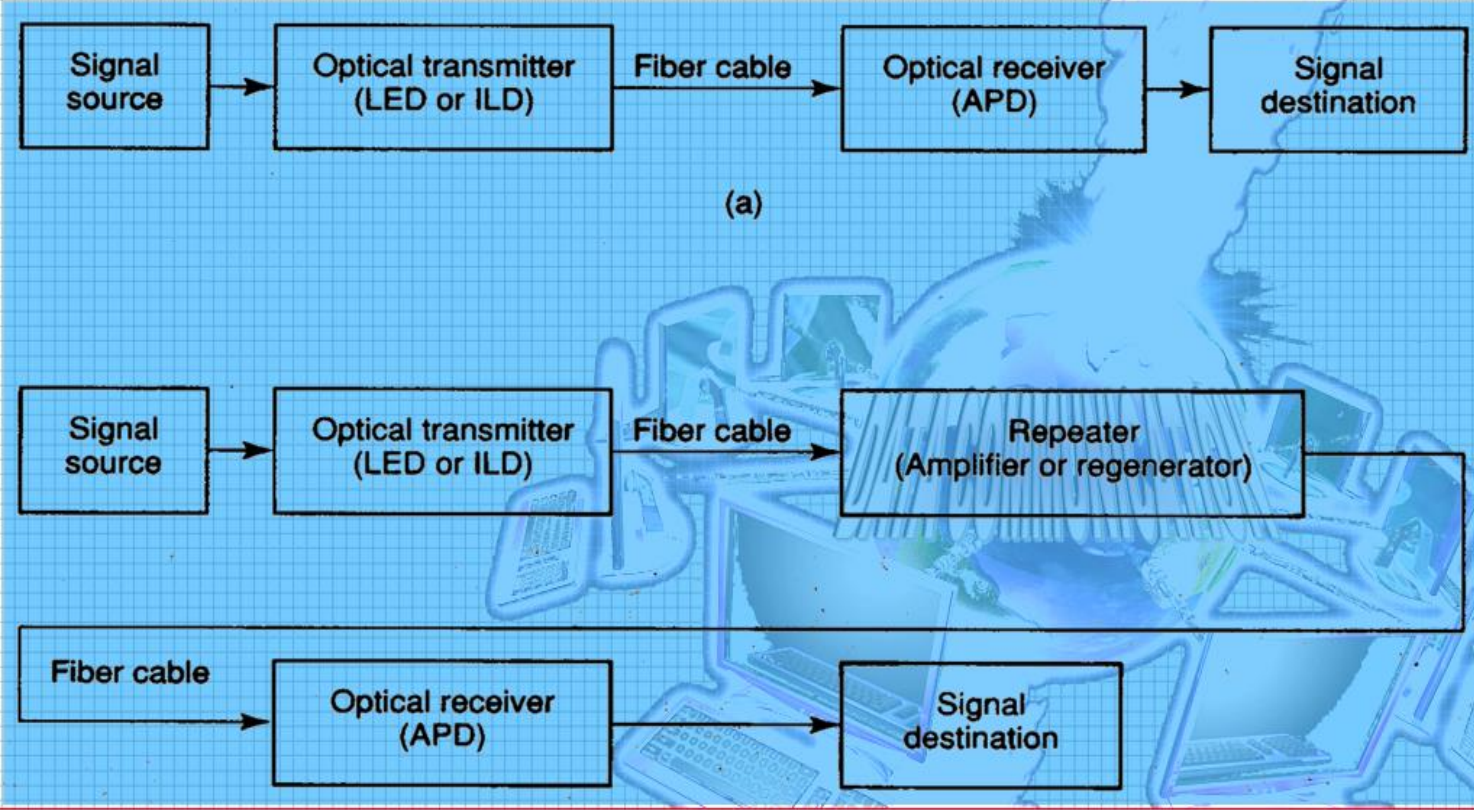
4. ***Need specialized tools, equipment, a***
   training
5. ***Unproven***

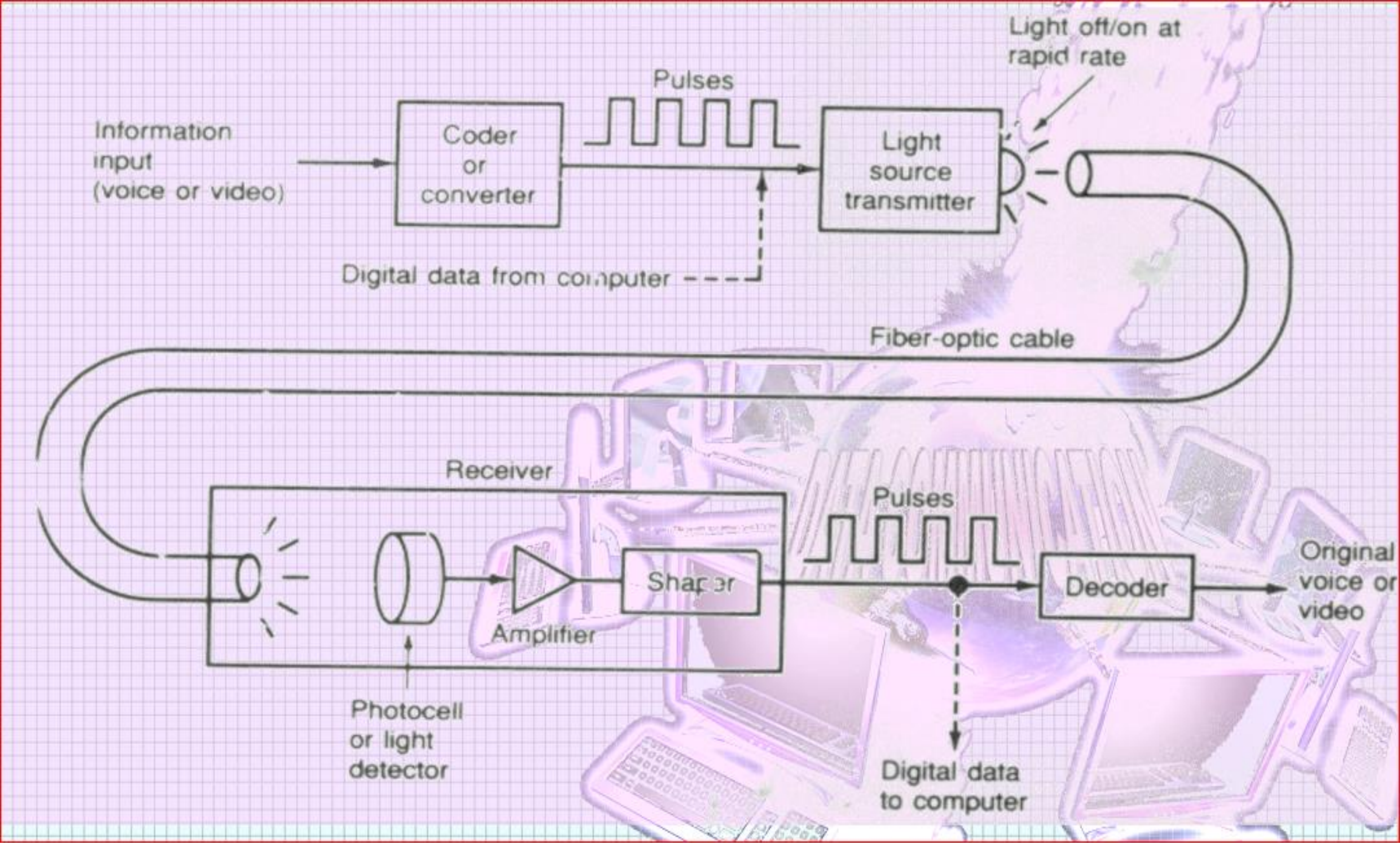


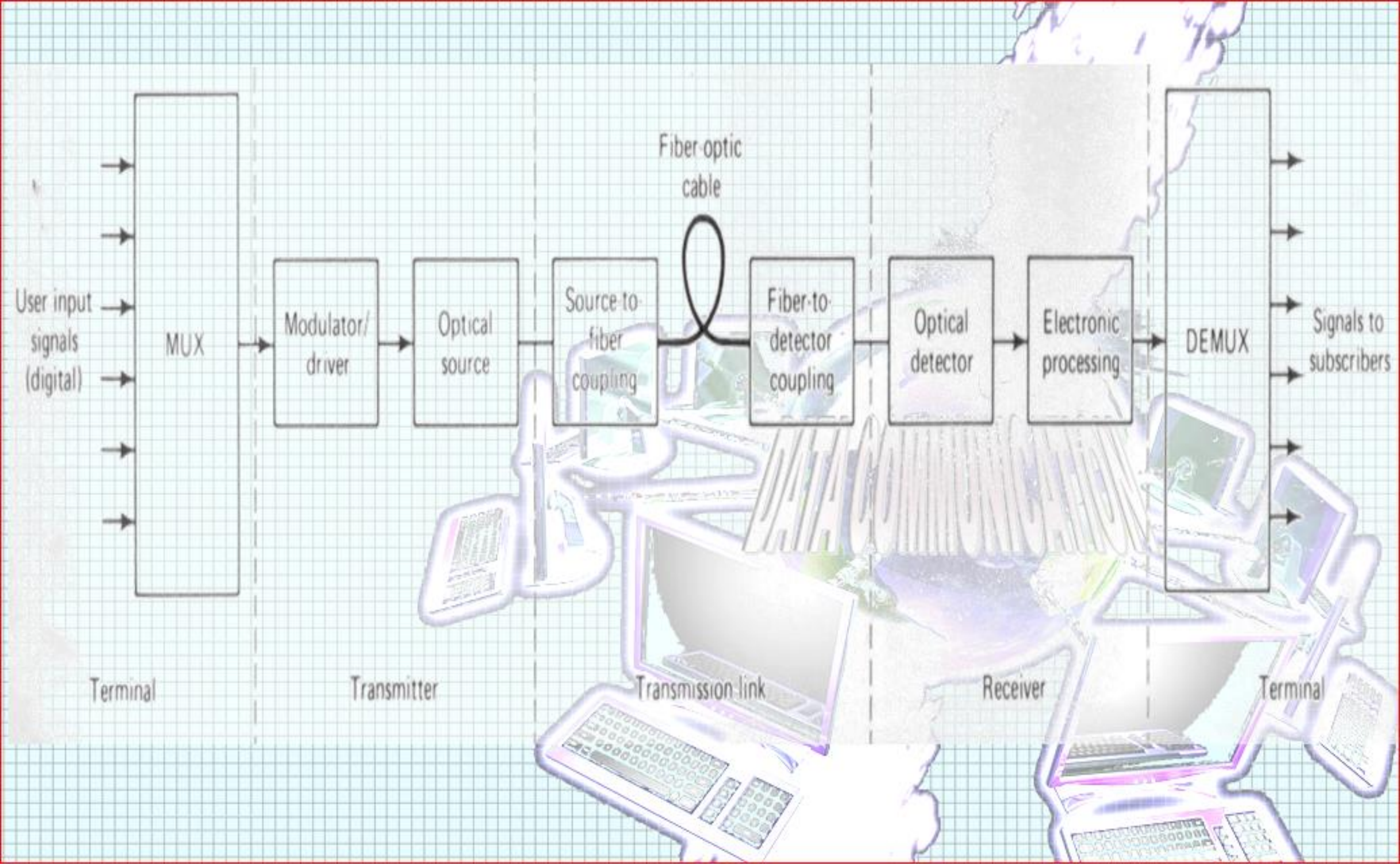
FIBERLIGN® MICRO FUSION SPLICER



Evaluating the Fiber Optic link




Light off/on at
rapid rate
Pulses
Information
input
(voice or video)
Coder
or
converter
Light
source
transmitter
Digital data from computer
Fiber-optic cable
Receiver
Pulses
Shaper
Amplifier
Decoder
Original
voice or
video
Photocell
or light
detector
Digital data
to computer


Fiber-optic cable
User input signals (digital)
MUX
Modulator/ driver
Optical source
Source-to-fiber coupling
Fiber-to-detector coupling
Optical detector
Electronic processing
DEMUX
Signals to subscribers
Terminal
Transmitter
Transmission link
Receiver
Terminal

Check Fiber mode

#sh int G0/1

Media type: 1000 Base SX SFP……. MM connect to fiber or ODF 200-550 m

100 Base CX SFP ……… MM short cable from switch to switch (Twinaxia Cableing 25 m)

GBIC: SX/SH …. MM 300 m …. Orange

LX/LH ……. SM 2km Yellow

LX…. MM 550 m

LX….. SM 5 km

LX10 ….SM 1.130 nm ….. 10 km

EX … SM 1.310 nm 40 km

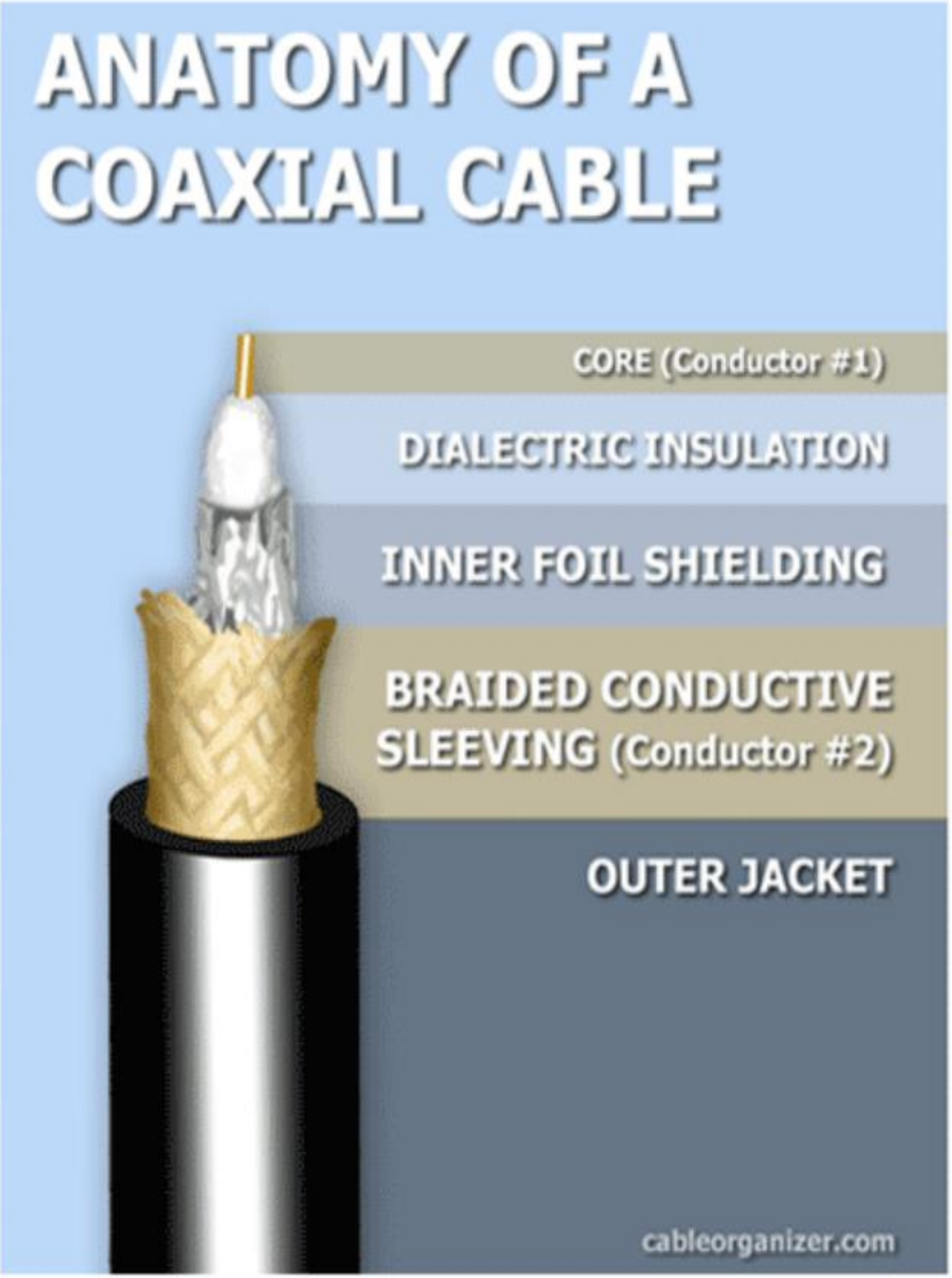
ZX … SM 1.550 nm 70 km

BX10 …. SM 1.490 downstream and 1310 nm upstream 10 km

 # sh cdp neighbors

 # sh int …..

Cable TV Network



What is Coaxial Cable?

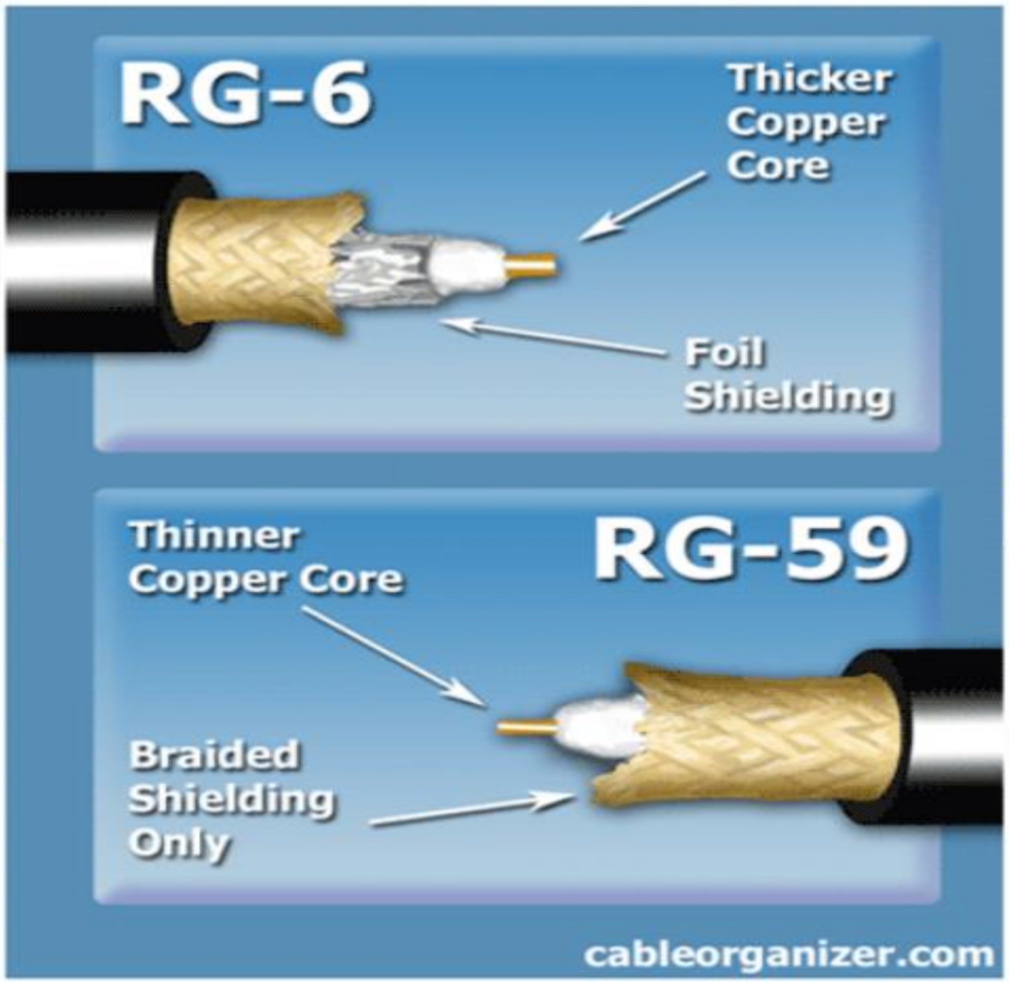
Everyone's heard of coaxial cable, right? Or maybe you've heard it by its hip nickname: "coax" (that's two syllables, co + ax…not the word that means "to draw forth"). It's a fairly common type of shielded data transmission cable, which is made up of two conductors that are coaxially oriented (hence the name), but separated by a layer of insulation. The make-up of your typical coax is as follows: the core consists of a metal wire (conductor #1), which is then surrounded by a layer of nonconductive dielectric insulation, which is itself covered in metallic mesh, foil and/or braid (conductor #2), and then whole shebang is wrapped in a protective outer sheathing, or jacket, which holds everything together and locks out moisture and impurities (sorry Phil Collins, a jacket is required…if you don't get that reference, ask an old person about the 80's).

What is Coaxial Cable Used For?

Good question! Coax is designed to carry high-frequency signals, and to protect those signals against electromagnetic interference (EMI) from external sources. Most people probably associate it with their cable television (CATV) service, and probably have not-so-fond memories of squeezing behind the TV to try and thread the end of the cable onto the wall outlet and/or the back of the TV set. But you'll find these cables in lots of other applications, including commercial radio communications, ham radio, undersea cable systems, closed-circuit television (CCTV), home video equipment, and broadband Ethernet application.

Back

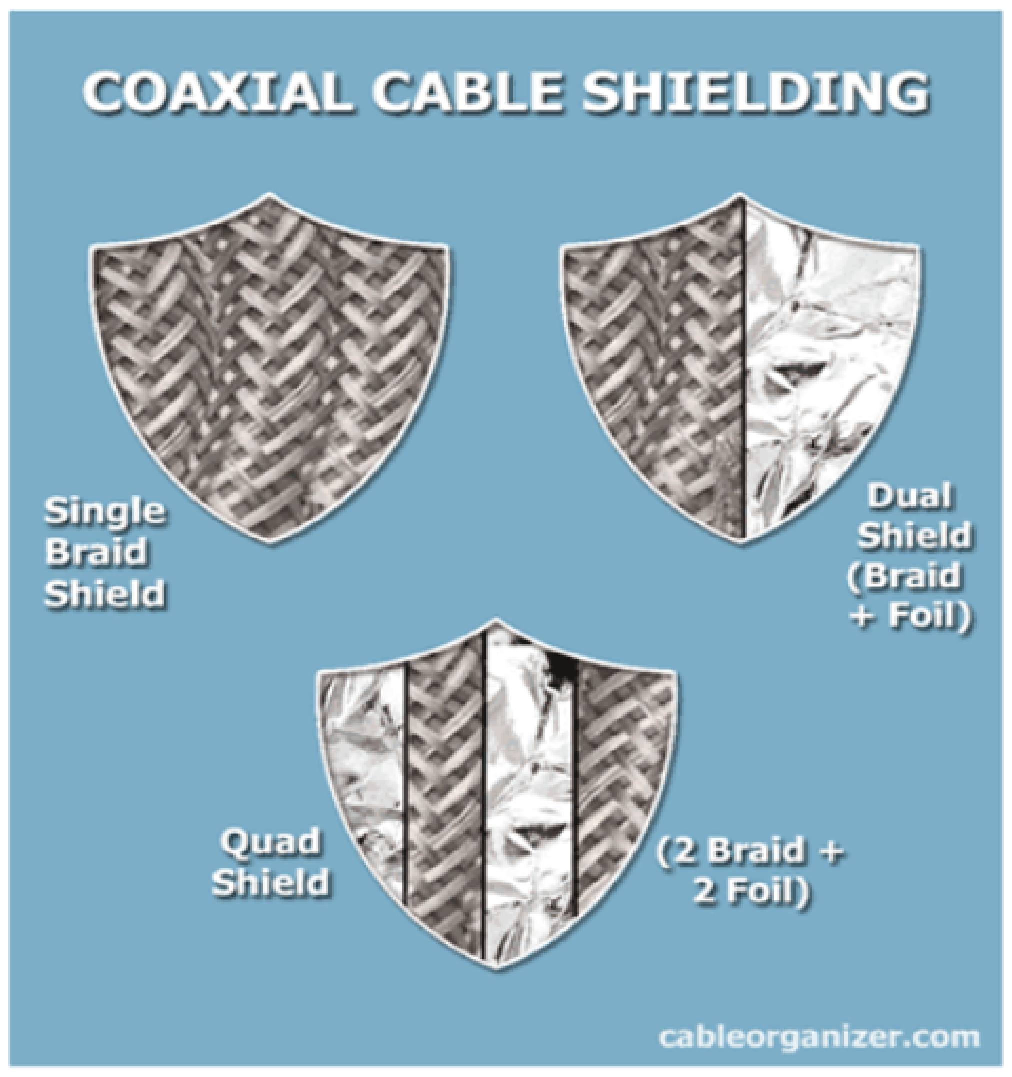
Next



What Does the "RG" in Coaxial Cable Types Like "RG-6" and "RG-59" Stand For?

Really Good? Rapid Growth? Rockstar Groupies? No silly, none of those. It turns out, the "RG" is short for "Radio Guide", a term that dates back to the World War II era, when the military made heavy use of coax, and developed a set of standards to specify different grades and their applications. Even though us civilians still refer to coaxial cables by their original RG numbers today, these standards are now obsolete in the actual military, which now uses the umbrella specification of MIL-C-17.

There are dozens of RG specifications, but there's no real rhyme or reason to the numbers they're assigned; it's actually pretty random. When it comes to the most commonly utilized specifications, both RG-6 and RG-59 cables are widely used in residential settings, especially when it comes to TV. The difference is found in the specific signals they're used for: RG-59 is the norm for standard Cable (CATV), while RG-6 is the coax that handles digital video signals and satellite TV. When you compare the two types side by side, RG-6 has a larger core conductor, thicker dielectric insulation, and anywhere from 2 to 4 layers of shielding, versus RG-59's one. These physical differences make RG-59 best suited to low-frequency transmissions and short cable runs, and RG-6 the ideal choice to carry high frequency signals over long distances. So basically; 6 rules, 59 drools. However, the shielding used by both respective types is typically tailored to their use, which means RG-59 is better for short-range, “baseband” applications (video projectors, component video, etc.), and 6 is geared toward long-range, satellite and cable feeds.

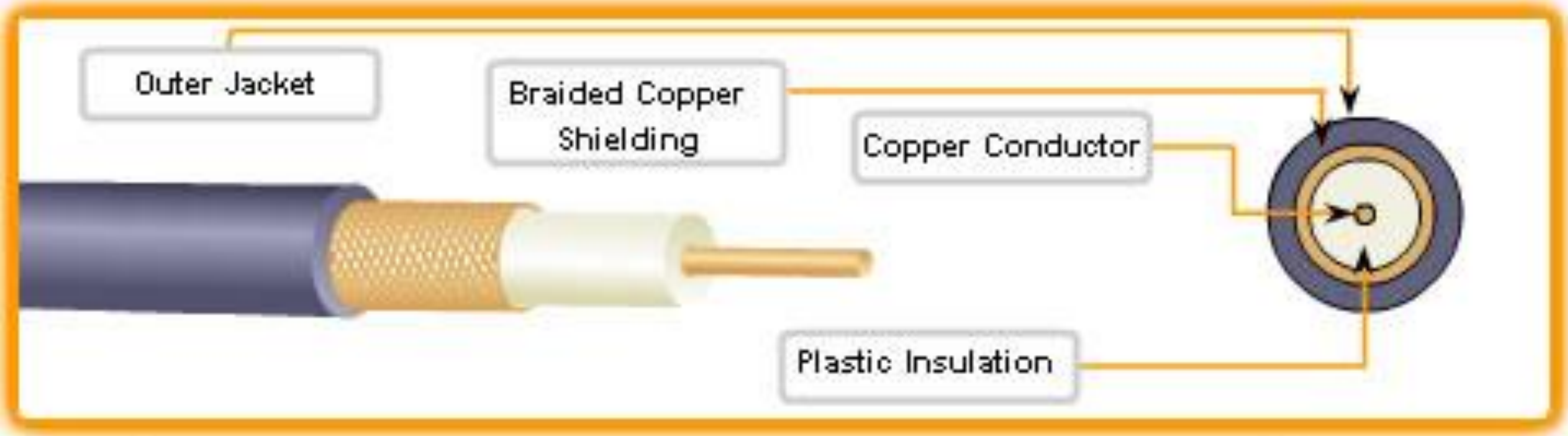


What Makes One Cable Better than Another?

In the coax world, better shielding equals less signal interference, so that's one good way to measure a cable's quality. Types of shielding can vary greatly, as can the amount present from one cable to next – coax typically has anywhere from one to four layers. The best coaxial shields are the ones that offer the highest density, or percentage of cover. Tightly-woven metal braid makes an excellent choice – not only is it highly conductive, it can provide as much as 95% coverage. To deal with that extra pesky 5%, some manufacturers combine braid with an additional layer or two of metallic foil (like a coaxial baked potato!), which helps to block small amounts of EMI that often manage to seep into the cable through tiny holes found in the braid.

When it comes to cable quality, conductor materials can be a controversial topic that's sure to stir up debate. While some manufacturers and A/V enthusiasts will tout the benefits of silver and oxygen-free copper (OFC), the truth is that – used as core conductors – these metals generally don't perform any better than standard or tinned copper. They do, however, sound really fancy, and are often used to justify obscene price mark-ups on what is, essentially, the same cable. In the end, we'd recommend trusting a cable's specifications over hoity-toity labeling.

So, now that you're up to speed, why not head over and check out our coaxial cables?


Outer Jacket
Braided Copper Shielding
Copper Conductor
Plastic Insulation


Coaxial Connectors
BNC
N type
F type

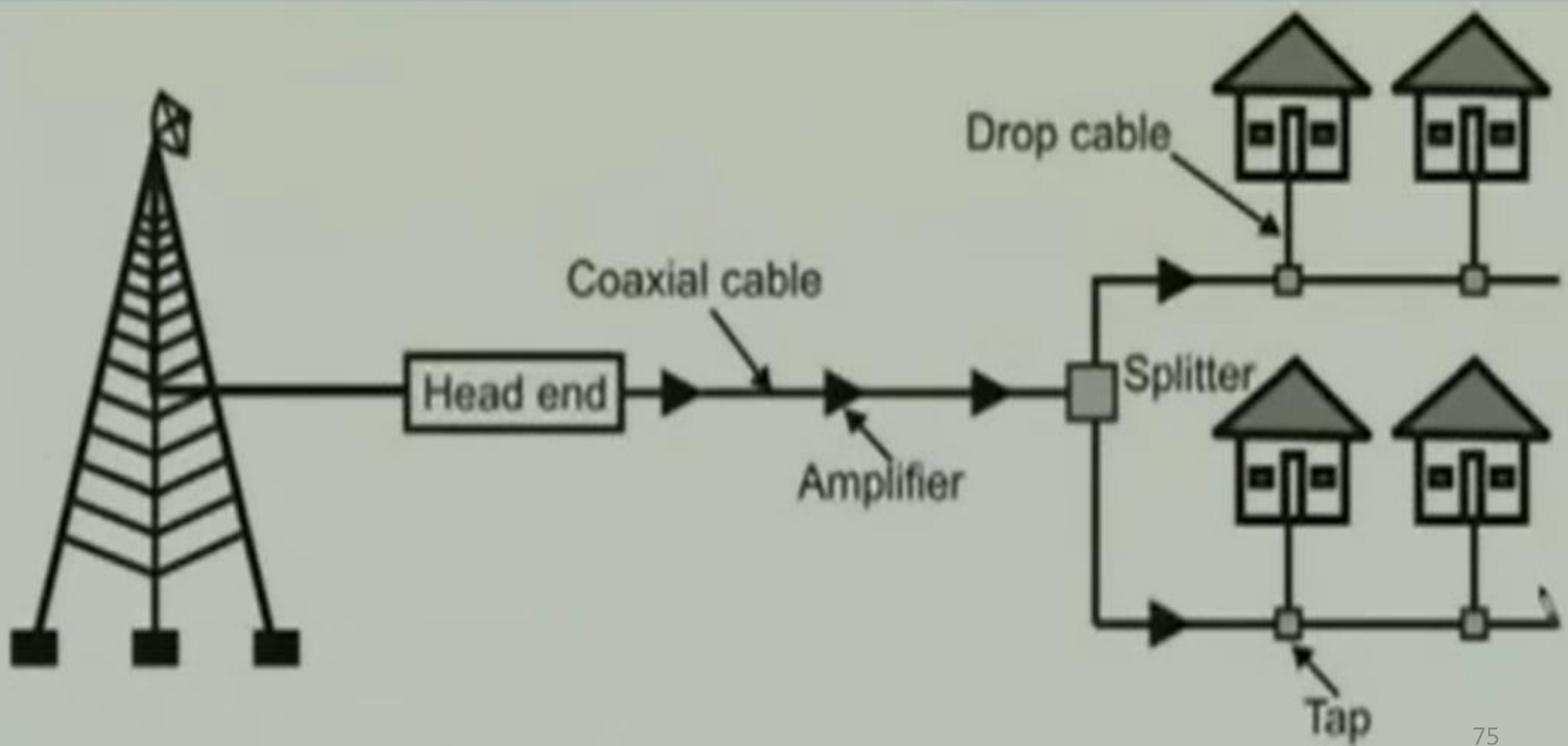
Common Applications

- Used in a variety of applications:
  - Television distribution (cable TV)
  - Long-distance telephone transmission (10,000 voice channels per cable)
  - Local Area Networks

Category	Impedance	Use
RG-59	75Ω	Cable TV
RG-58	50Ω	Thin Ethernet
RG-11	50Ω	Thick Ethernet

Cable TV System

- Traditional Community Antenna TV (CATV) distributes broadcasted video signals to residences.



Cable TV System

- **Transmission Media**: The widest use of coaxial cable is in cable TV system. Coaxial cable provides much better immunity to interference and crosstalk compared to twisted-pair used in ~~cable modem~~ DSL Network

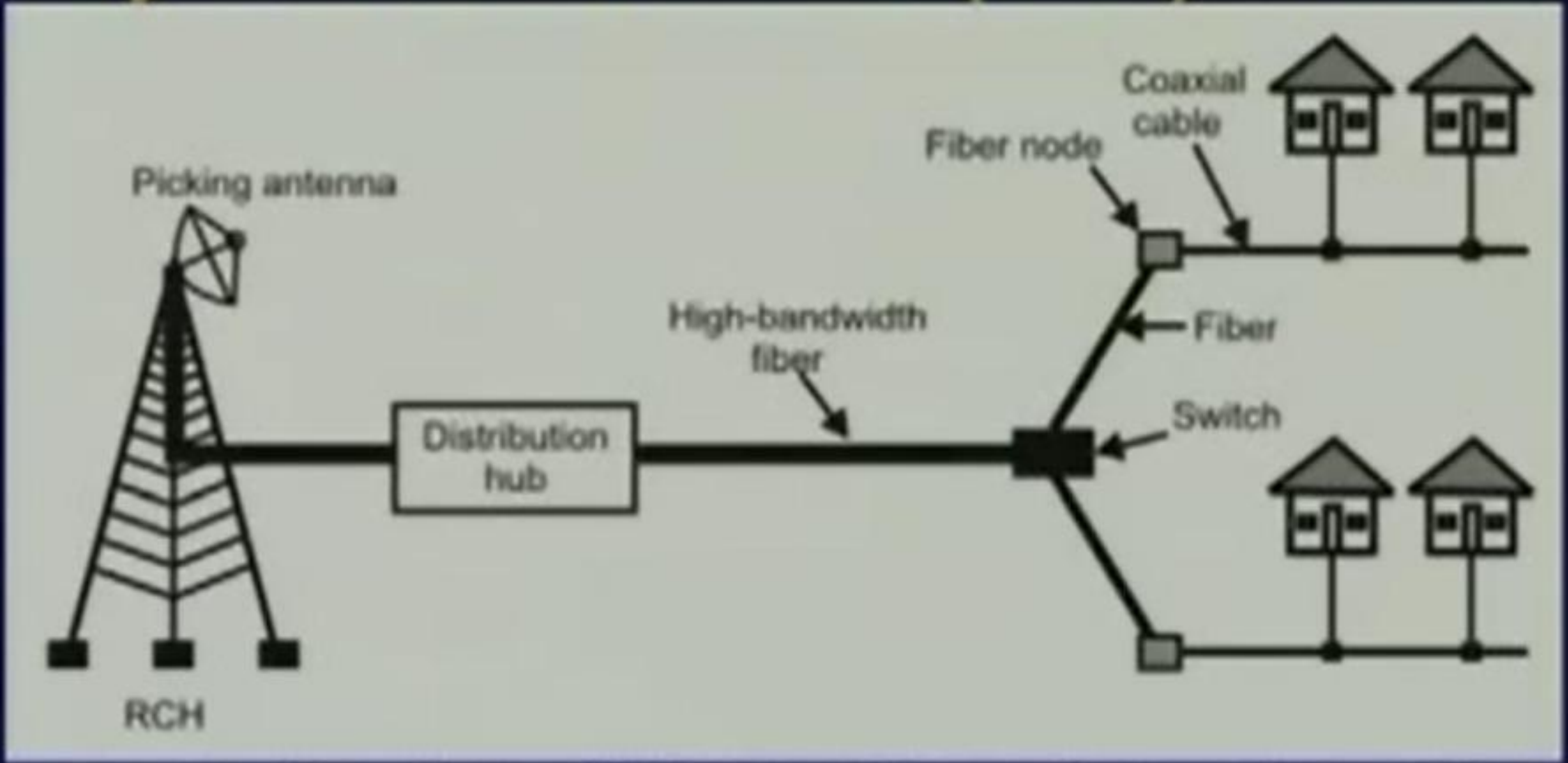
- **Bandwidth**: Cable TV systems use the frequency range from 54 to 500 MHz

- **NTSC** (National Television Standards Committee) and **PAL** (Phase Alteration by Line) standards use 6 MHz and 8 MHz bands, respectively to send analog TV signals, providing 50 to 70 channels.

Cable TV Devices

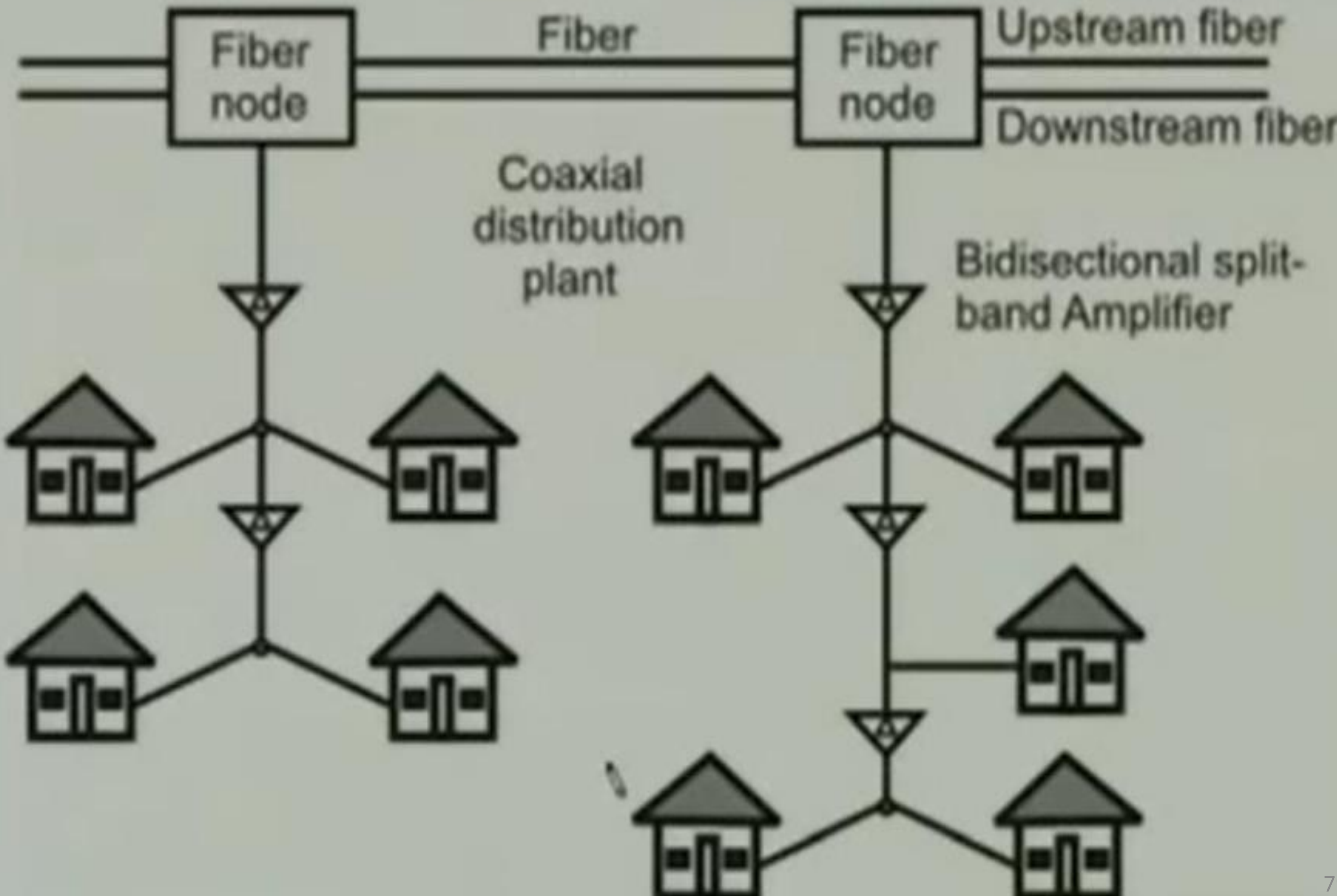
- **Head end**: The head end receives video signals from broadcasting stations with the help of an antenna installed at the top of a tall building
- **Amplifiers**: Amplifiers are used to boost the signal levels. Up to 35 amplifiers may be used between the head end and subscriber premises
- **Splitters**: Splitters are used to split distribution of signals into branches and **drop cables** are used to take signal to subscriber premises
- Because of large attenuation and the use of large number of amplifiers, the communication is **unidirectional** (downstream) in nature

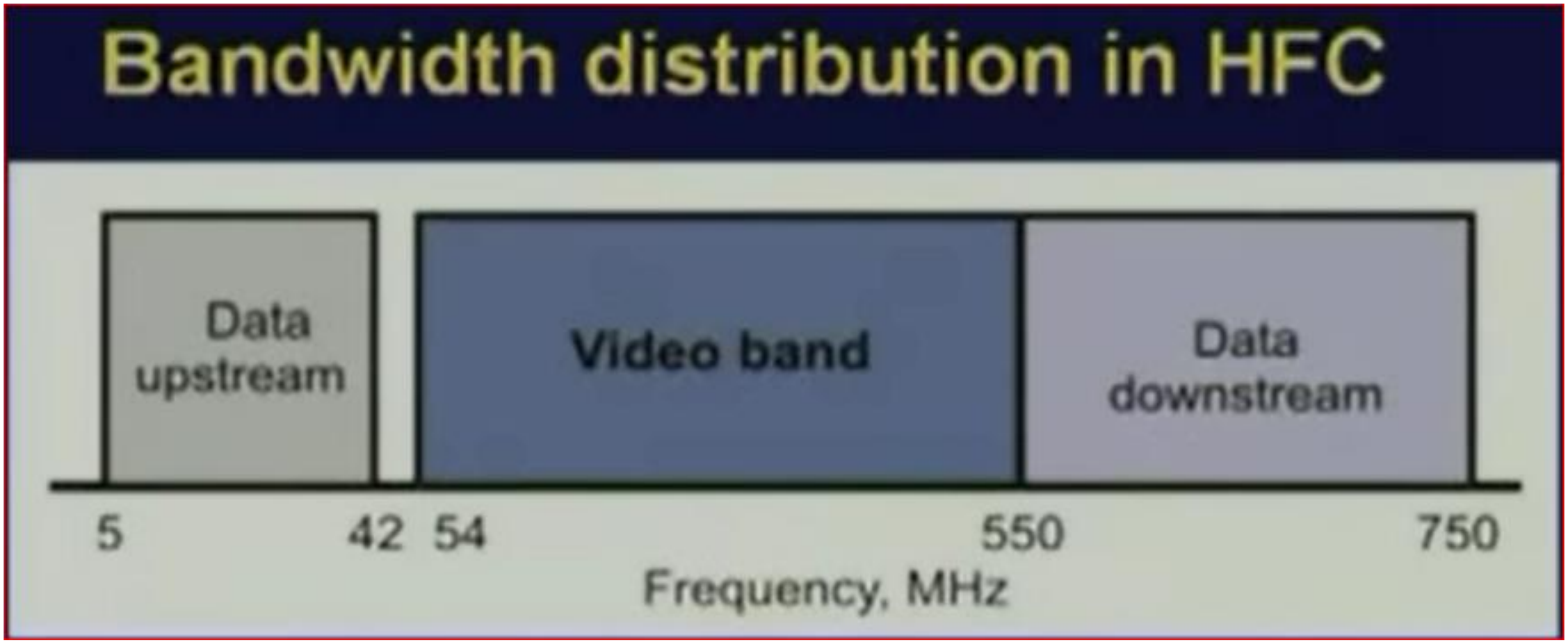
Hybrid Fiber-Coaxial (HFC) network



- Uses a combination of fiber-optic and coaxial cable
- HFC network facilitates bidirectional communication
- RCH can serve as many as 400,000 users, distribution hubs can serve 40, 000 users, each coaxial cable can serve 1000 users

Hybrid Fiber-Coaxial (HFC) network




Bandwidth distribution in HFC
Data upstream
Video band
Data downstream
5
42
54
550
750
Frequency, MHz

Bandwidth distribution in HFC

- **Upstream data band**: Occupies the lower band from 5 to 42 MHz, divided into 6-MHz channels.
  - As it is more susceptible to noise, **QPSK** is used instead of QAM
  - Theoretical data rate is **12 Mbps**

6 channels

- **Video band**: Downstream only
From 54 to 550 MHz, accommodates 80 channels

6 MHz

- **Downstream data band**: Occupies the band from 550 to 750 MHz, divided into 6-MHz channels. Can support up to ~~80~~ channels
  - **64-QAM** is used for modulation
- As one bit is used for upward error detection, theoretical data rate is **30 Mbps** (actual 10Mbps)

33 channels

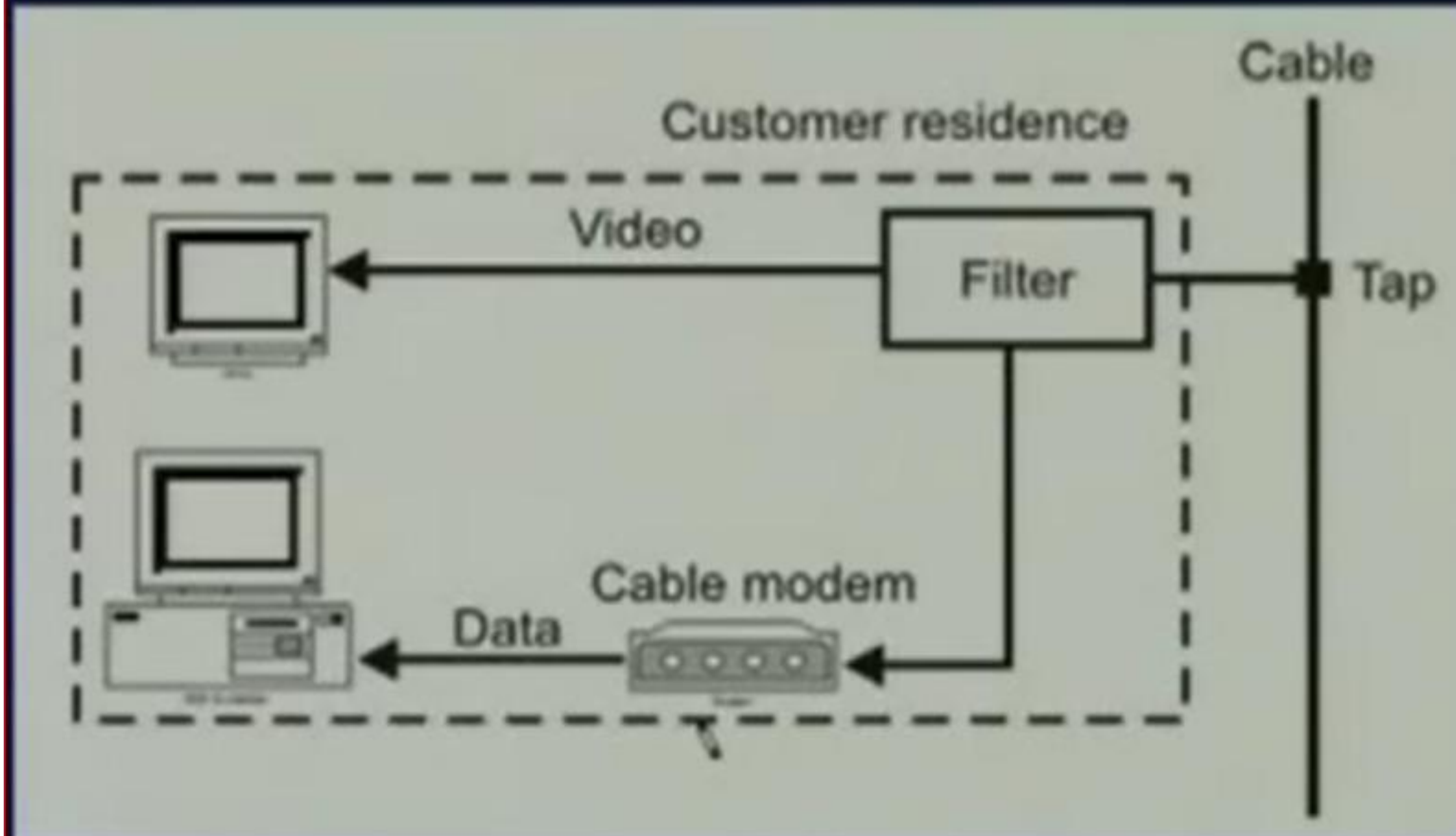
Sharing of Bandwidth

- The subscribers share both upstream and downstream bandwidths.

Upstream sharing: As the upstream bandwidth is only 37 MHz, these are divided in to six 6-MHz channels using FDM, which are shared by users. One channel is allocated to a group of users statically or dynamically.

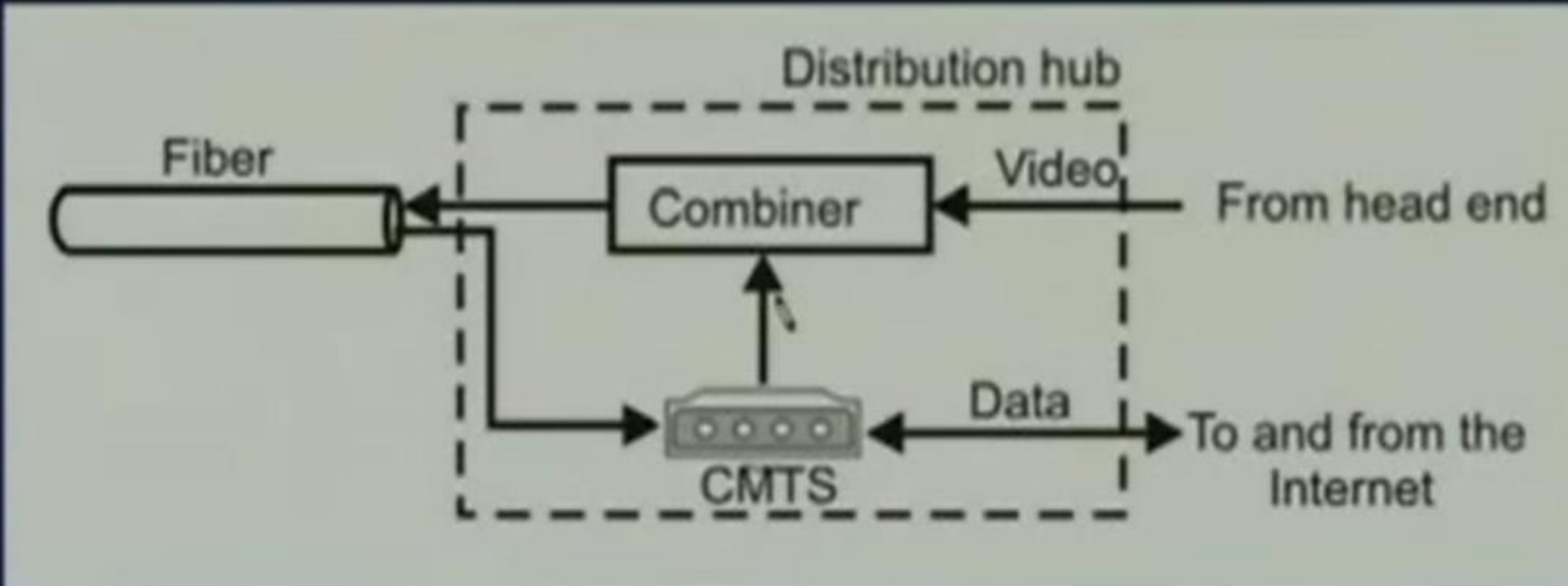
Downstream sharing: Downstream band has 33 channels of 6 MHz each, which are shared by all the users. Here multicasting is done based on matching of address.

Cable Modem Devices



CM is similar to ADSL modem

Cable Modem Devices



- Cable Modem Transmission System (CMTS) is installed in the distribution hub of the cable company.
- CMTS receives data from the internet and sends them to the combiner. It also receives data from the subscriber and passes them to the internet

Data Transmission Schemes

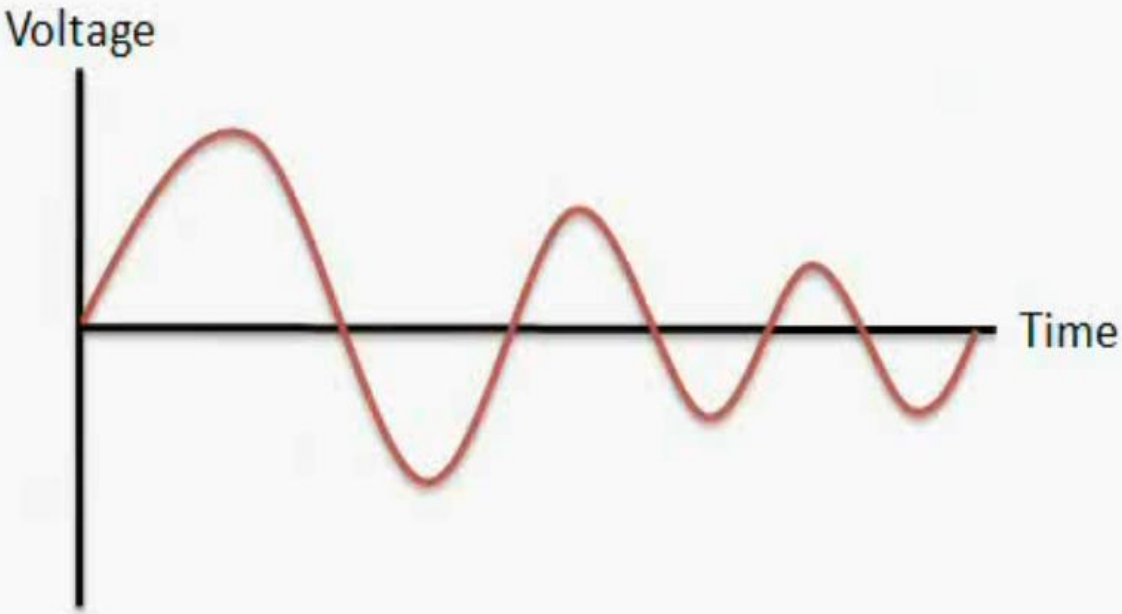
- Data Over Cable System Interface Specification (DOCSIS) devised by Multimedia Cable Network Systems (MCNS)
- DOCSIS defines all the protocol necessary to transport data from a CMTS to a CM. Timesharing is allowed for upstream data
- A CM must listen for packets destined to it on an assigned downstream channel
- The CMs must contend to obtain time slots to transmit their information in an assigned channel in the upstream direction
- The CMTS sends packet with the address of the receiving CM in the downstream direction without contention

Multiplexer

PDH: Plesiochronous Digital Hierarchy

- Multiplex levels:
  - 2.048 Mbit/s
  - 8.448 Mbit/s
  - 34.368 Mbit/s
  - 139.264 Mbit/s
- Uses Positive justification to adapt frequency differences
- Overheads: CRC
- Defects: LOS, LOF, AIS

PROPERTIES OF ELECTRICITY

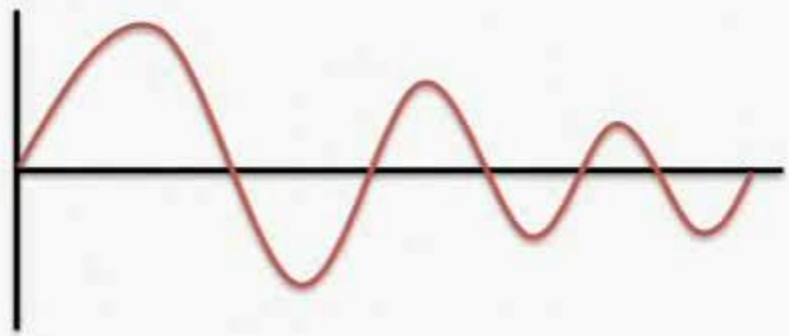


- AS YOU SPEAK INTO AN ANALOG PHONE, YOUR VOICE IS CONVERTED INTO ELECTRICITY

- THE PROPERTIES OF THE ELECTRICITY ARE USED TO CONVEY THE PROPERTIES OF YOUR VOICE

Digitizing Voice

Step 1. Sample the Signal



- The famed Dr. Nyquist formula:
- If you sample at twice the highest frequency, you can accurately reconstruct a signal digitally
- Common Frequencies:

  -Human Ear: 20 - 20,000Hz
  -Human Speech: 200 - 9,000Hz
  -Nyquist Theorum: 300 - 4,000Hz

Reviewing the Digital Conversion Process

- The Nyquist Theorem:

  "If you sample a signal in regular intervals of at least twice the highest channel frequency, the samples will contain enough information to accurately reconstruct the signal"

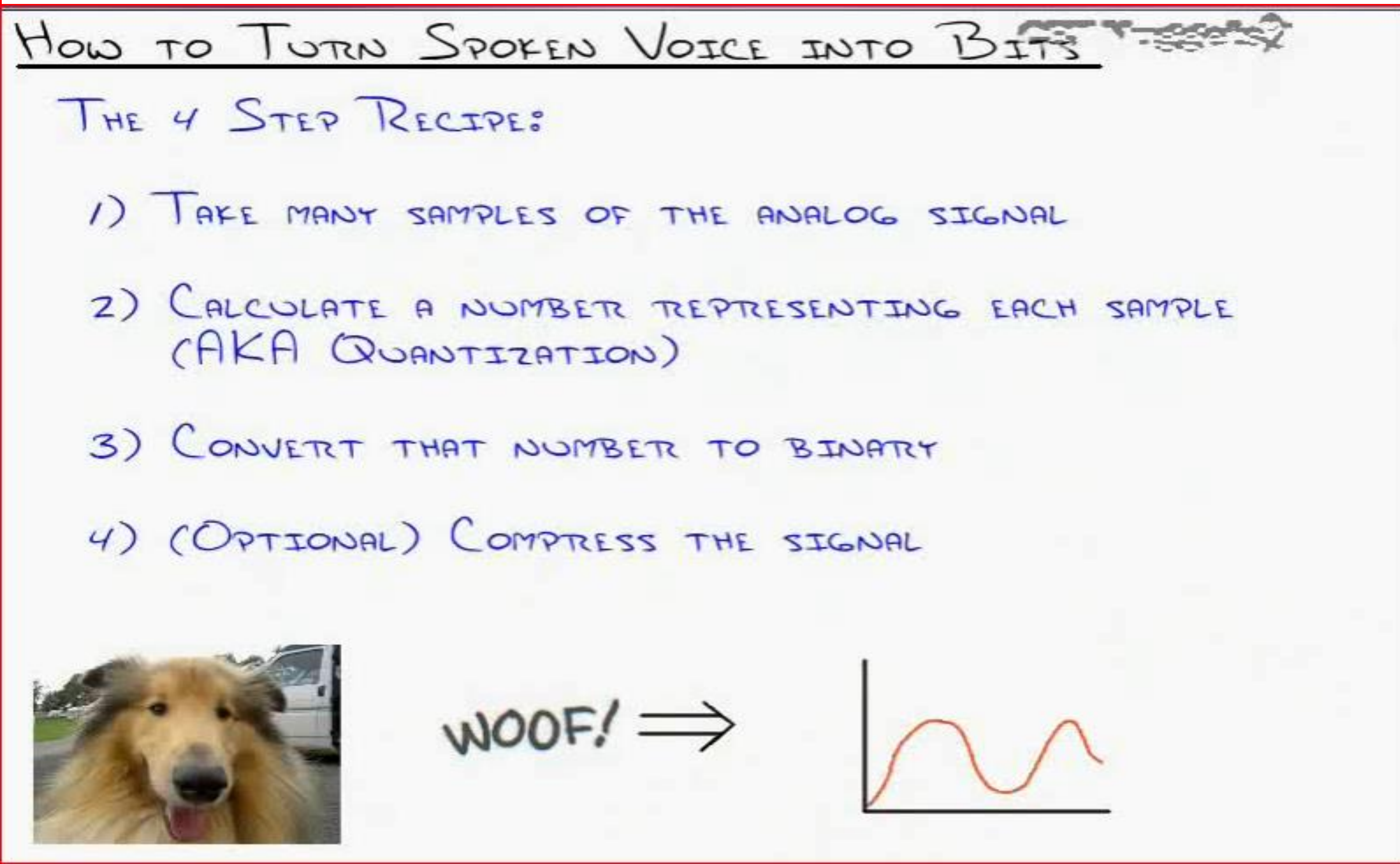
  -Jeremy's Paraphrase

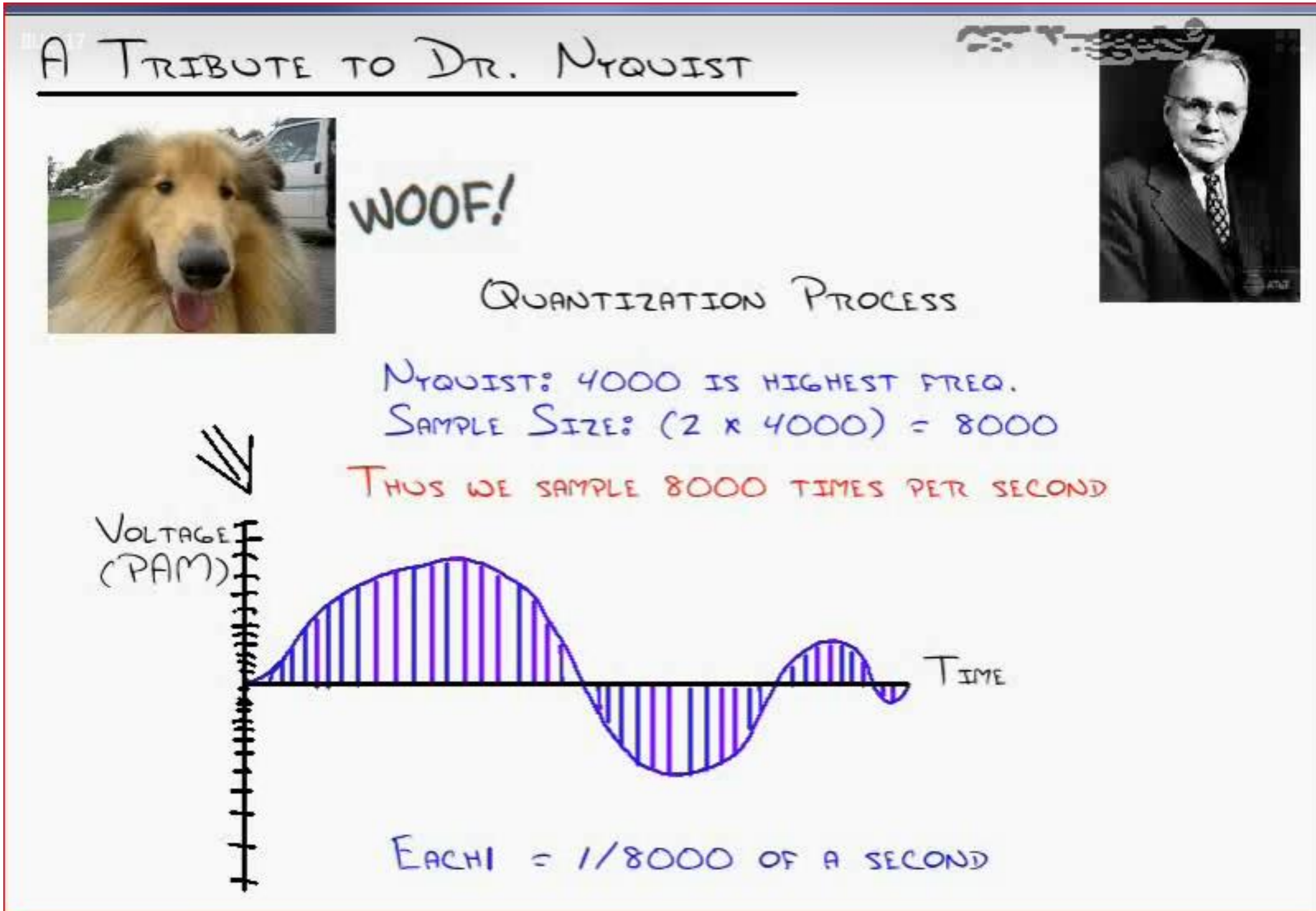
- Some Important Frequencies:

  The human ear: 20 - 20,000 Hz
  Human Speech: 200 - 9,000 Hz
  Telephone Channel: 300 - 3,400 Hz
  Nyquist Theorem: 300 - 4,000 Hz

To convert an analog signal into digital format, the converting device goes through a four-step process:

1. Sample the signal.
2. Quantize the signal.
3. Encode the quantized value into binary format.
4. Optionally compress the sample to save bandwidth.




A Tribute to Dr. Nyquist
WOOF!
Quantization Process
Nyquist: 4000 is highest freq.
Sample Size: (2 x 4000) = 8000
Thus we sample 8000 times per second
Voltage (PAM)
Time
Each | = 1/8000 of a second

Analog Versus Digital Signaling

- Analog signals require one set of wires (2 or 4) per call
- Digital signals require <= 64 kbps
- Higher quality/speed line can carry up to 1.544/2.048 Mbps (T1/E1)
- Digital uses time-division multiplexing (TDM) for more efficient transmission

* Multiplex and Framing.

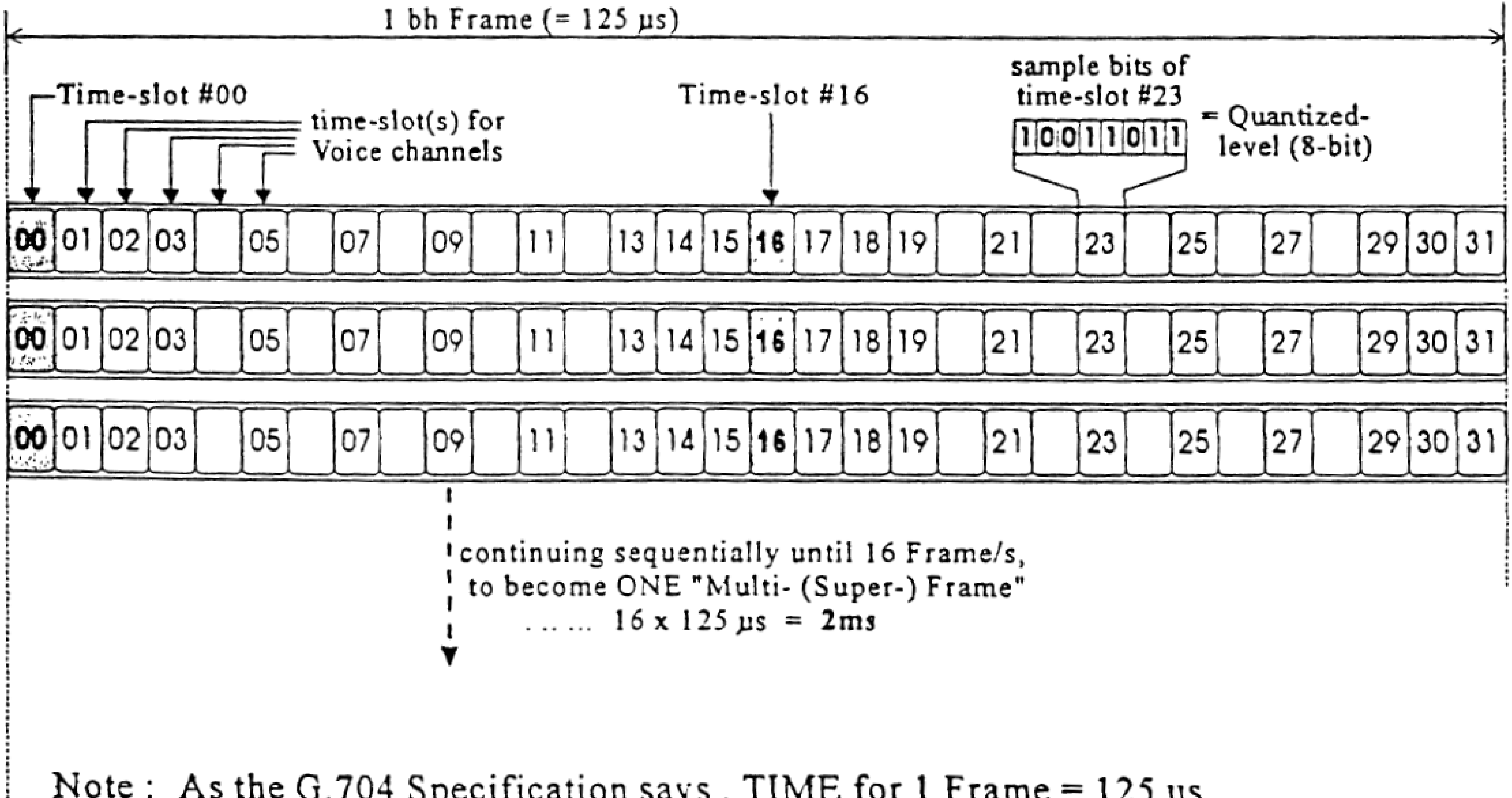
• As we know already in PCM system :
With "sampling-rate" = 8000 per second . ... . then "quantized" to become code of level/s, which are "8-bit" digital words.
Therefore : 1 digitised Voice Chnl needs Bit-Rate of (8000 X 8=) 64 kbps.

The PCM EnCoding for that 1 Voice-Chnl is for the purpose of "starting" of combining/grouping process of many, many Voice-Channels, to become a bundle or something like a packet or "Trunk", thus easier for Transmission.

Because all Channel/s are "digital" , thus the easy packaging/grouping (=Multipxing) system applied is Time Division Multiplexing (=TDM).
The PCM-Multiplexing utilised most is the European Standard (=CEPT), where a "Frame" duration must be 125 uS , containing 32 Time-slots , each with 8 bits (CCITT G.704 Specification) namely :

* 1 special Time-slot #00 , alocated for Frame Alignment (Synchronisation), also for link management/householding and Alarm indications ;
* 30 Time-slots , namely #01 ... #15 and #17 ... #31 for Voice/Data Chnls;
  Note : Voice Chnl number = 01 . .. ... 15, then continue 16 . .. ... 30 (!).
* 1 Time-slot #16 , specially alocated for (Voice) Channel Signalling.

Drawing below will help us see more about the "framing" process and standard :



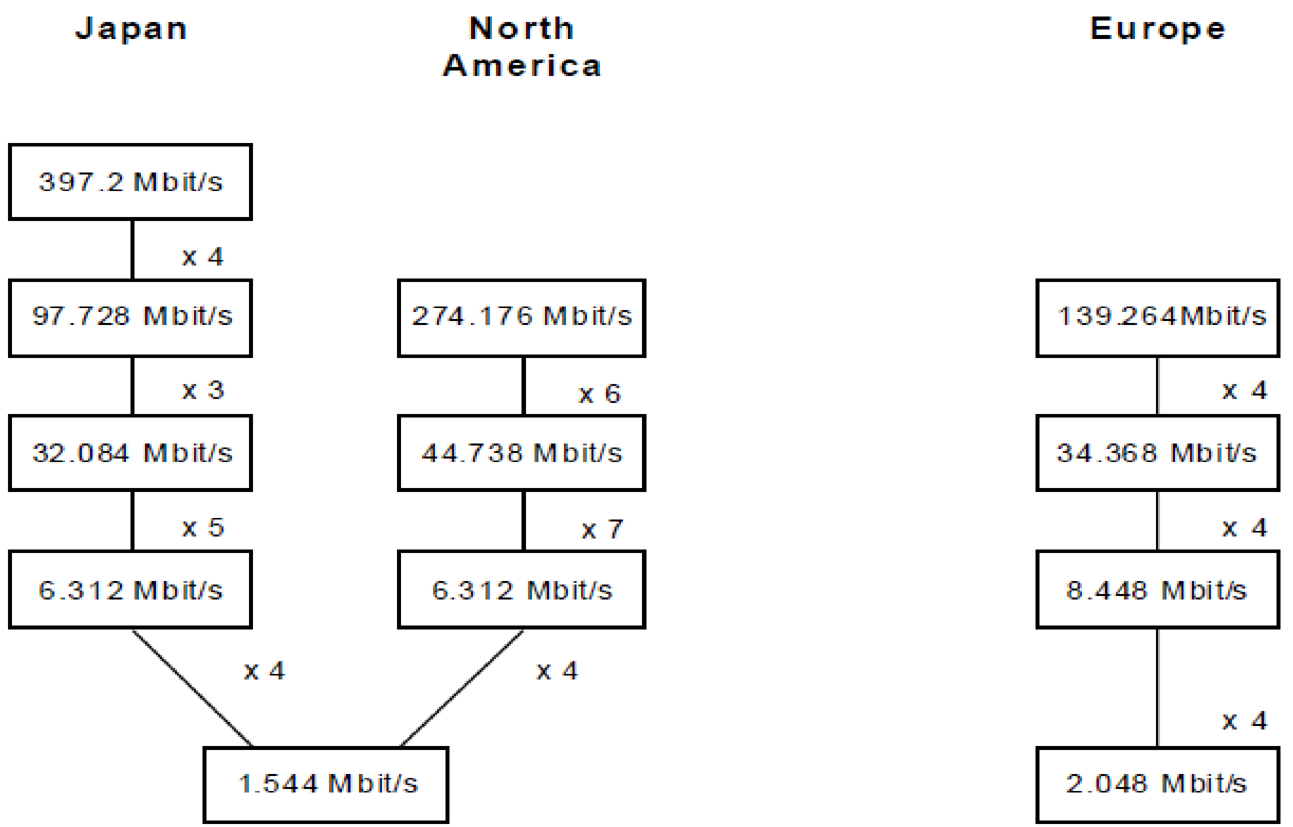
Note : As the G.704 Specification says , TIME for 1 Frame = 125 µs.
Therefore within 1 sec. (= 1000 ms or = 1000000 µs) we will find a total of 8000 Frames , each containing 32 X 8-bits ;
In other words : 32 x 8 x 8000 bits per sec., or = 2 048 000 bps ; in Telecom language usually is named : E-1 Rate, or (PCM) Trunk Rate = 2.048 Mbps.
Above Chnl grouping/trunking is also called : First Order Multiplex.

Plesiochronous Multiplexing

- Before SDH transmission networks were based on the PDH hierarchy.
- Plesiochronous means nearly synchronous.
- 2 Mbit/s service signals are multiplexed to 140 Mbit/s for transmission over optical fiber or radio.
- Multiplexing of 2 Mbit/s to 140 Mbit/s requires two intermediate multiplexing stages of 8 Mbit/s and 34 Mbit/s.
- Multiplexing of 2 Mbit/s to 140 Mbit/s requires multiplex equipment known as 2, 3 and 4 DME.
- Alarm and performance management requires separate equipment in PDH.

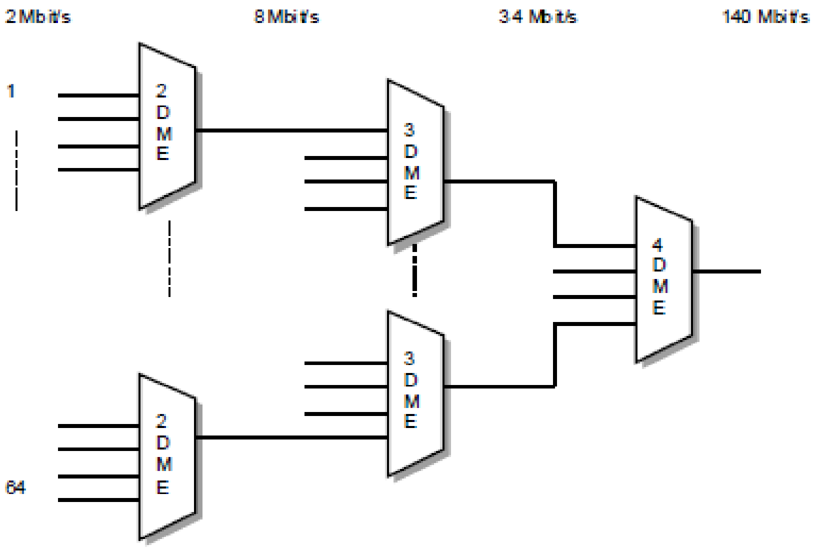
PDH vs. SDH Hierarchy

- PDH transmission rates:
- SDH is designed to unify all transmission rates into a single Mapping hierarchy



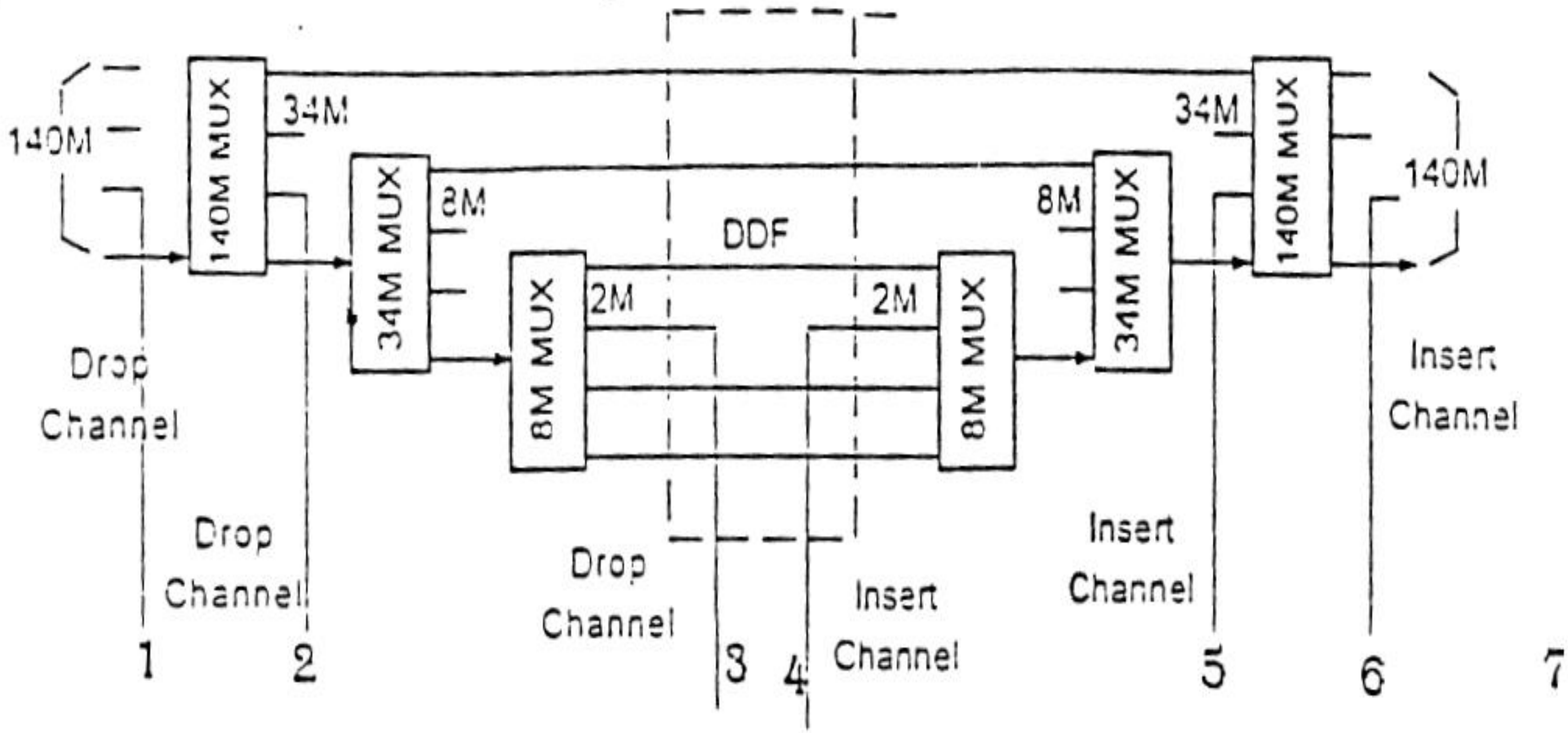
PDH Multiplexing

- PDH Multiplexing of 2 Mbit/s to 140 Mbit/s requires 22 PDH multiplexers:
  - 16 x 2DME
  - 4 x 3DME
  - 1 x 4DME
- Also a total of 106 cables required.



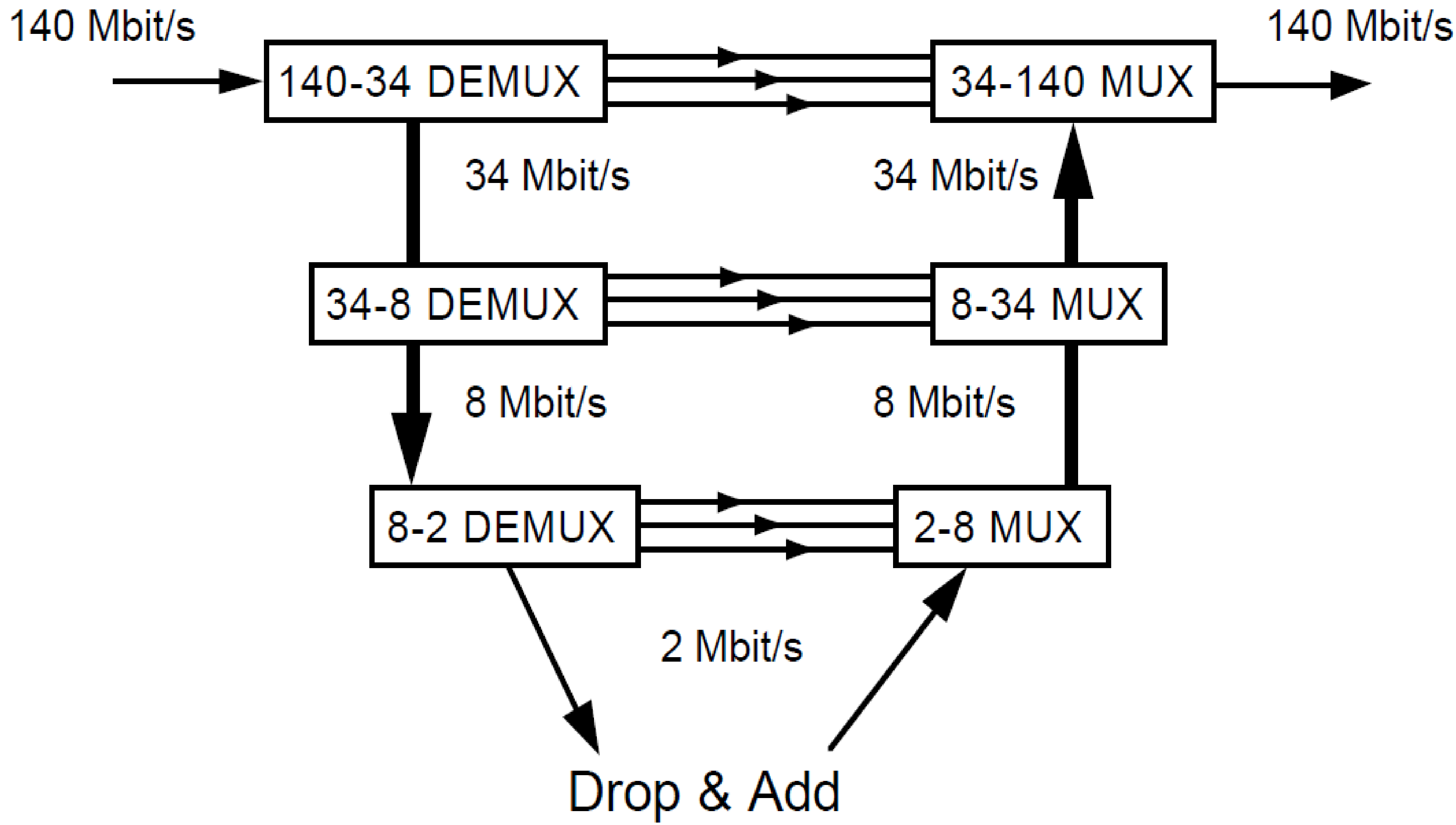
Simple Access to Tributary

a) PDH Connection Block Diagram



Add/drop of constituent signals;

A back-to-back multiplexer arrangement is applied in order to achieve add/drop function for th.. PDH networks. This example indicates that a 140M signals carrier four 34M signals. If one or more 34M signals need to be added afterwards, the 140M signal must be demultiplexed by one equipment, and then must be multiplexed by another equipment for performing the drop/add functionality.



▶ ***Figure 1.*** *PDH multiplexing by steps, showing add/drop function.*

What is SDH?

- The basis of Synchronous Digital Hierarchy (SDH) is synchronous multiplexing - data from multiple tributary sources is byte interleaved.
- In SDH the multiplexed channels are in fixed locations relative to the framing byte.
- Demultiplexing is achieved by gating out the required bytes from the digital stream.
- This allows a single channel to be 'dropped' from the data stream without demultiplexing intermediate rates as is required in PDH.

SDH Rates

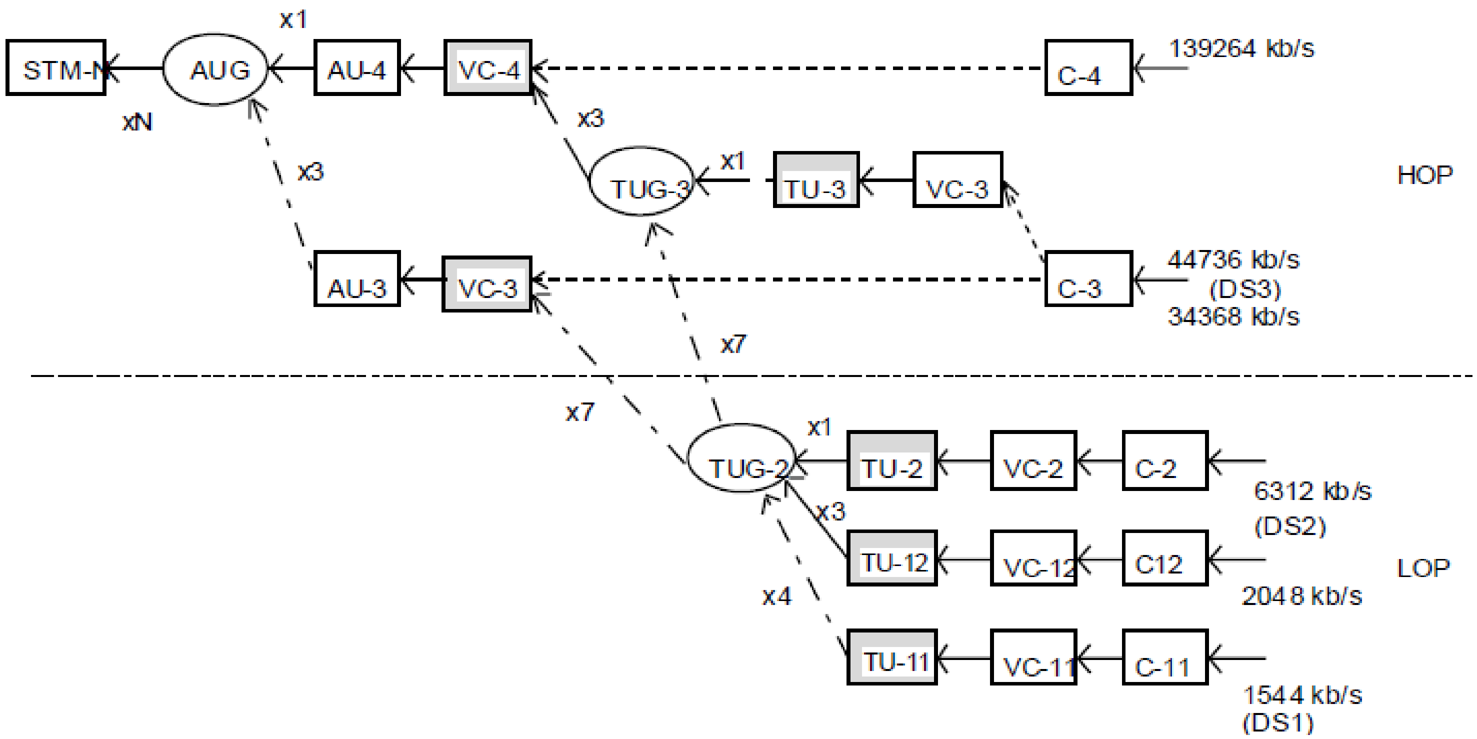
- SDH is a transport hierarchy based on multiples of 155.52 Mbit/s
- The basic unit of SDH is STM-1:

STM-1	=	155.52 Mbit/s
STM-4	=	622.08 Mbit/s
STM-16	=	2588.32 Mbit/s
STM-64	=	9953.28 Mbit/s

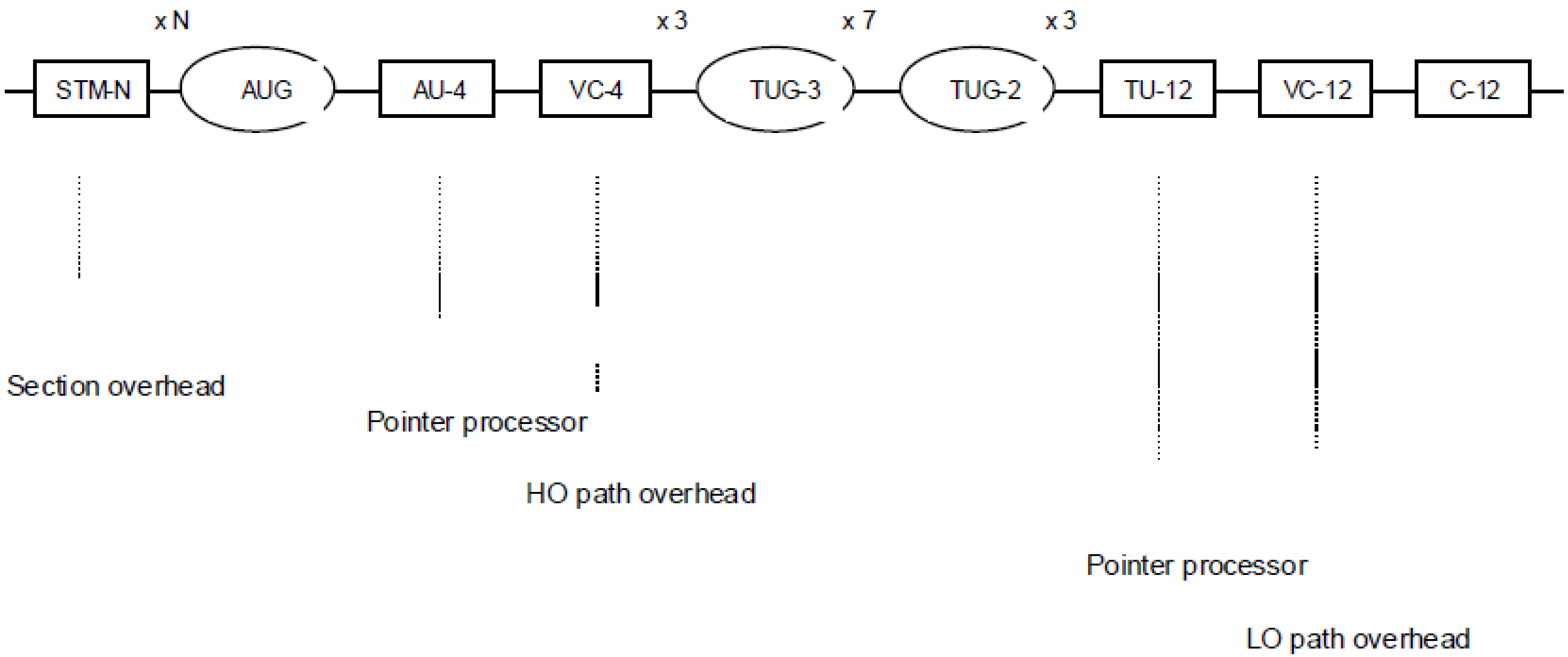
- Each rate is an exact multiple of the lower rate therefore the hierarchy is synchronous.

SDH Hierarchy

- SDH defines a multiplexing hierarchy that allows all existing PDH rates to be transported synchronously.
- The following diagram shows these multiplexing paths:



Example: Multiplex path for the E1

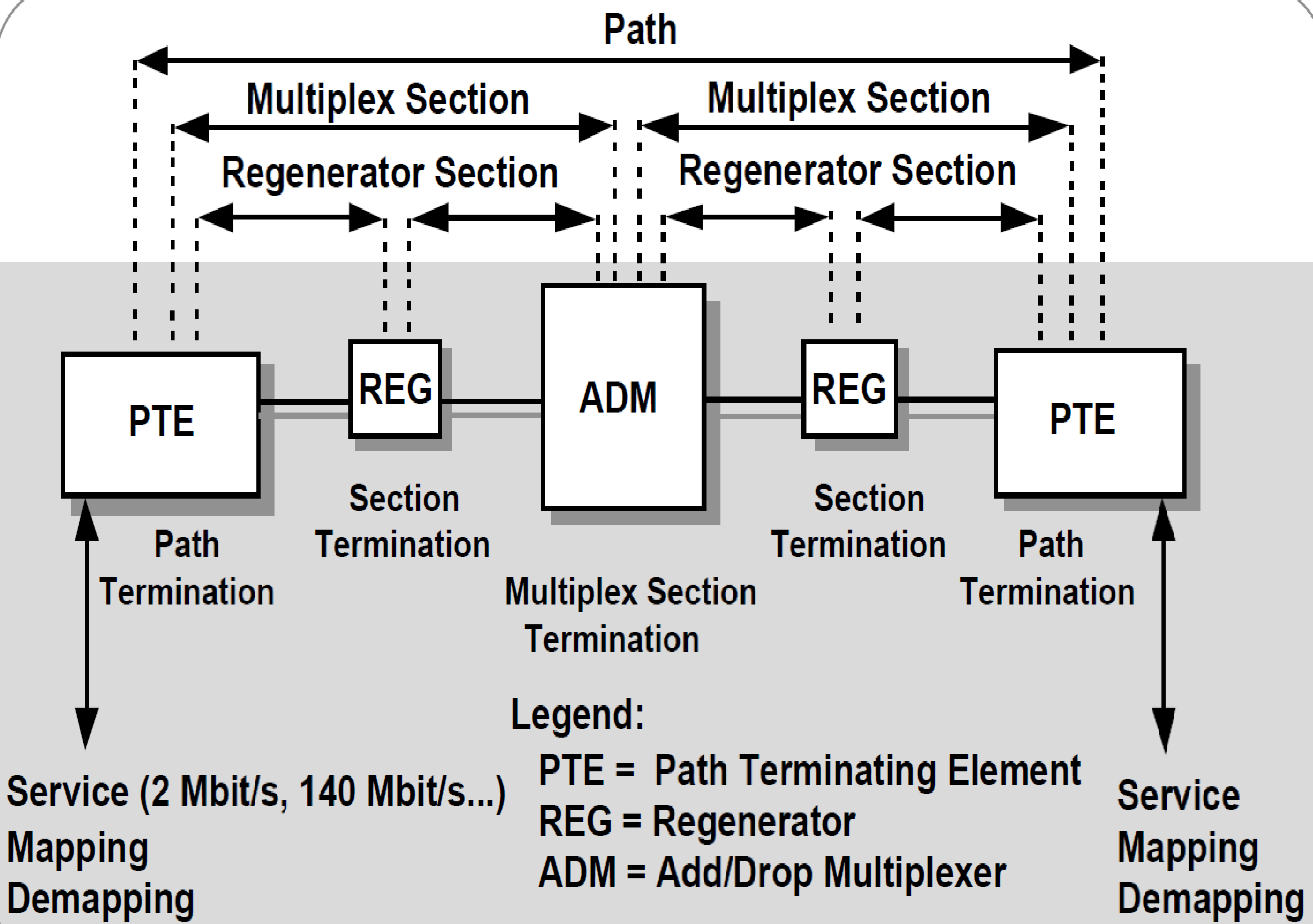


Transport of PDH payloads

- SDH is essentially a transport mechanism for carrying a large number of PDH payloads.
- A mechanism is required to map PDH rates into the STM frame.
- This function is performed by the container (C).
- A PDH channel must be synchronised before it can be mapped into a container.
- The synchroniser adapts the rate of an incoming PDH signal to SDH rate.

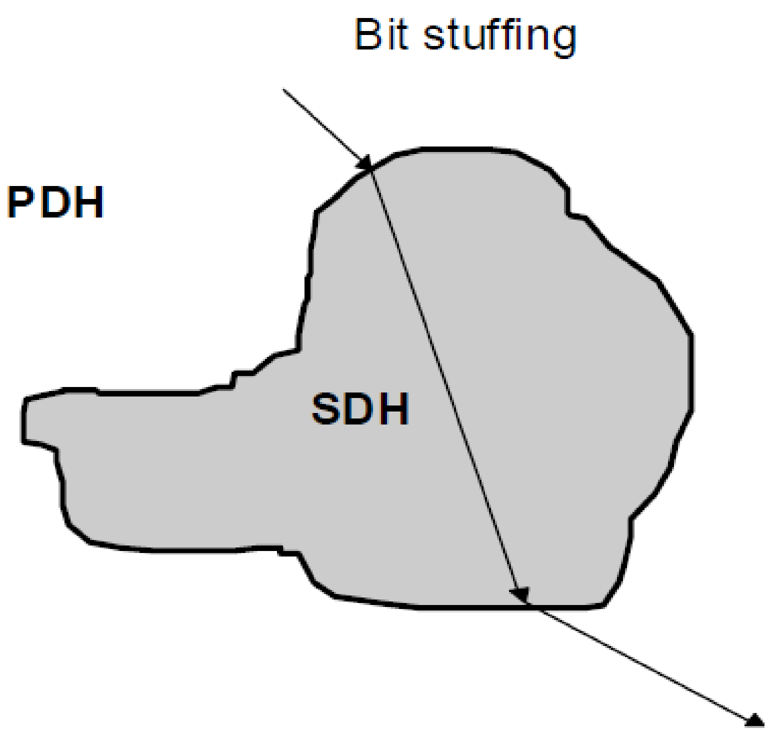
SDH virtual Containers

- Once a container has been created, path overhead byte are added to create a virtual container.
- Path overheads contain alarm, performance and other management information.
- A path through an SDH network exists from the point where a PDH signal is put into a container to where the signal is recovered from the container.
- The path overheads travel with the container over the path.

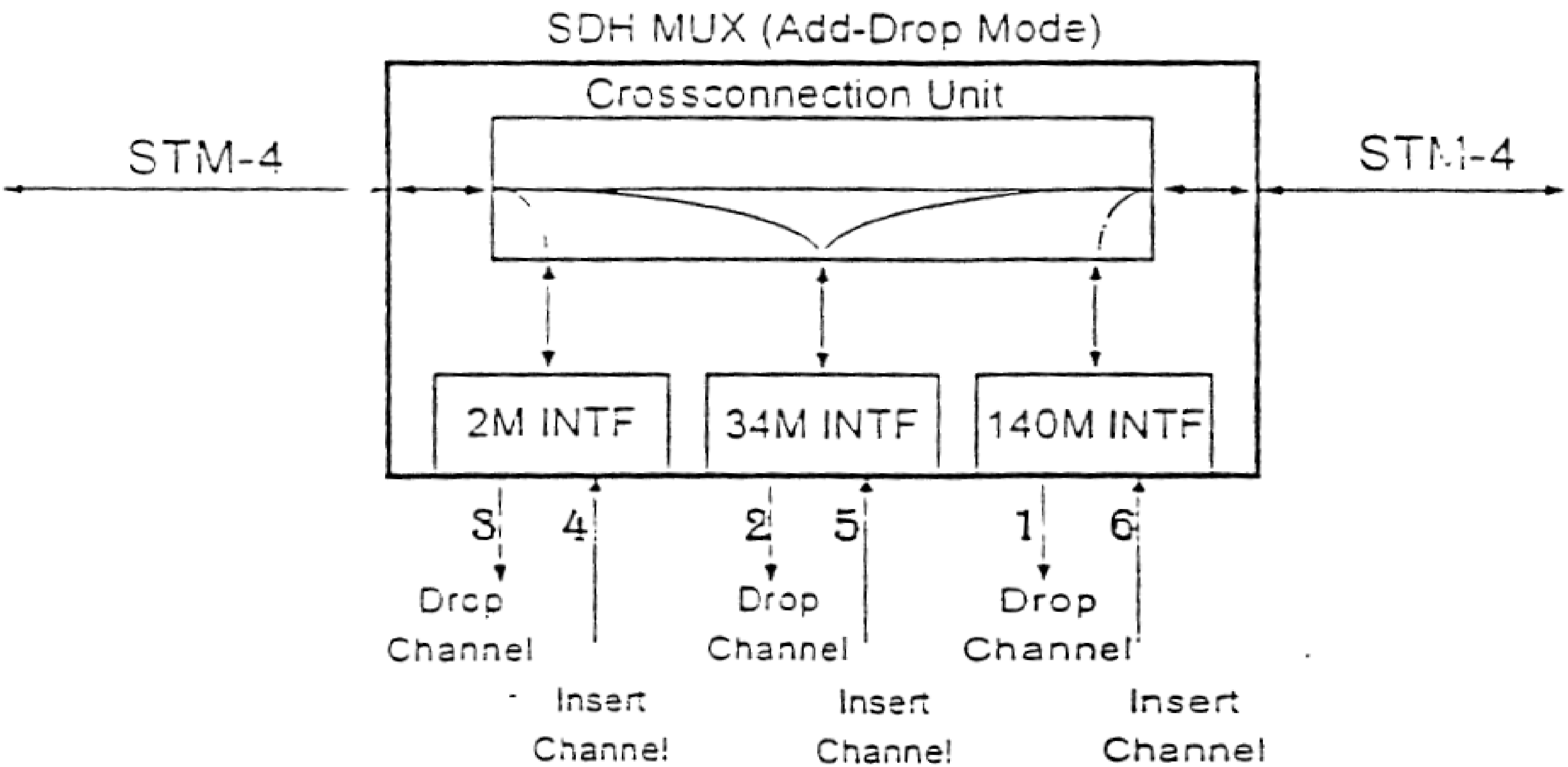

Path
Multiplex Section
Multiplex Section
Regenerator Section
Regenerator Section
PTE
REG
ADM
REG
PTE
Section
Termination
Section
Termination
Path
Termination
Multiplex Section
Termination
Path
Termination
Legend:
PTE = Path Terminating Element
REG = Regenerator
ADM = Add/Drop Multiplexer
Service (2 Mbit/s, 140 Mbit/s...)
Mapping
Demapping
Service
Mapping
Demapping

SDH and non-synchronous signals

- At the PDH/SDH boundary Bit stuffing is performed when the PDH signal is mapped into its container.



b) SDH Connection Block Diagram (Add-Drop Mode)



SDH multiplexer can perform add/drop functionality without the need of suing back-to-back multiplexer arrangement as shown in figure below.

Note:-

Plesiochronous digital hierarchies(PDH)

Synchronous Digital Hierarchy(SDH)

Synchronous Transfer Module Level One (STM-1)

The figures in each box indicates bit rates in kbit/s

Table 10. SDH Multiplexing Structure

Term	Contents	User
C-N	N = 1 to 4	Payload at lowest multiplexing level
VC-N	N = 1, 2 (Lower-Order)	Single C-n plus VC POH
VC-N	N = 3, 4 (Higher-Order)	C-N, TUG-2s, or TUG-3s, plus POH for the specific level
TU-N	N = 1 to 3	VC-N plus tributary unit pointer
TUG-2	1, 3 or 4 (TU-N)	Multiplex of various TU-Ns
TUG-3	TU-3 or 7 TUG-2s	TU-3 or multiplex of 7 TUG-2s
AU-N	N = 3, 4	VC-N plus AU pointer
AUG	1, 3 (AU-n)	Either 1 AU-4 or multiplex of 3 AU-3s
STM-N	N = 1, 4, 16, 64 AUGs	N synchronously-multiplexed STM-1 signals

POH = Path Overhead

C = Container

TU = Tributary Unit

AU = Administrative Unit

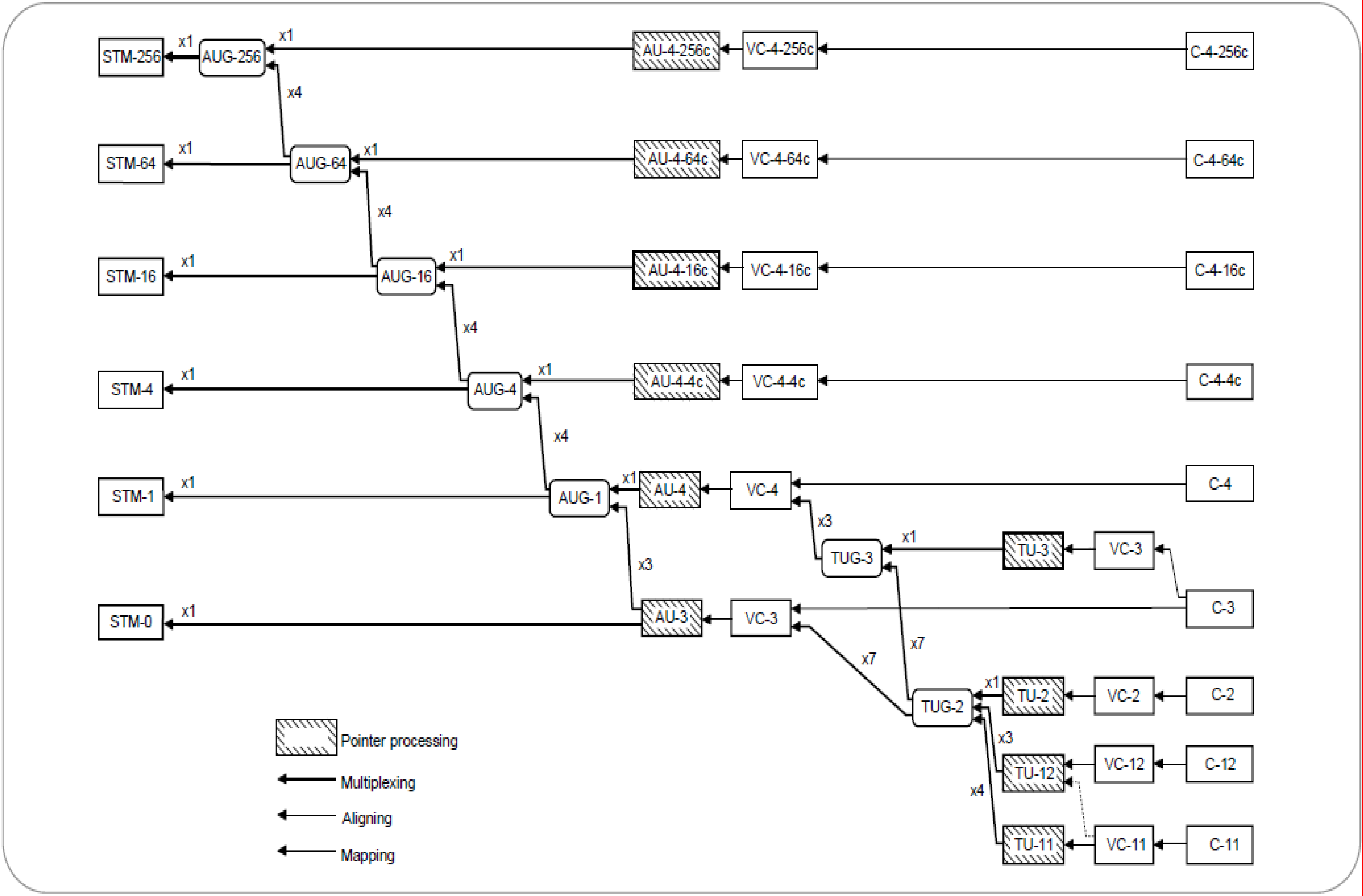
VC = Virtual Container

TUG = Tributary Unit Group

STM = Synchronous Transport Module

Table 3. Virtual Containers (VC)

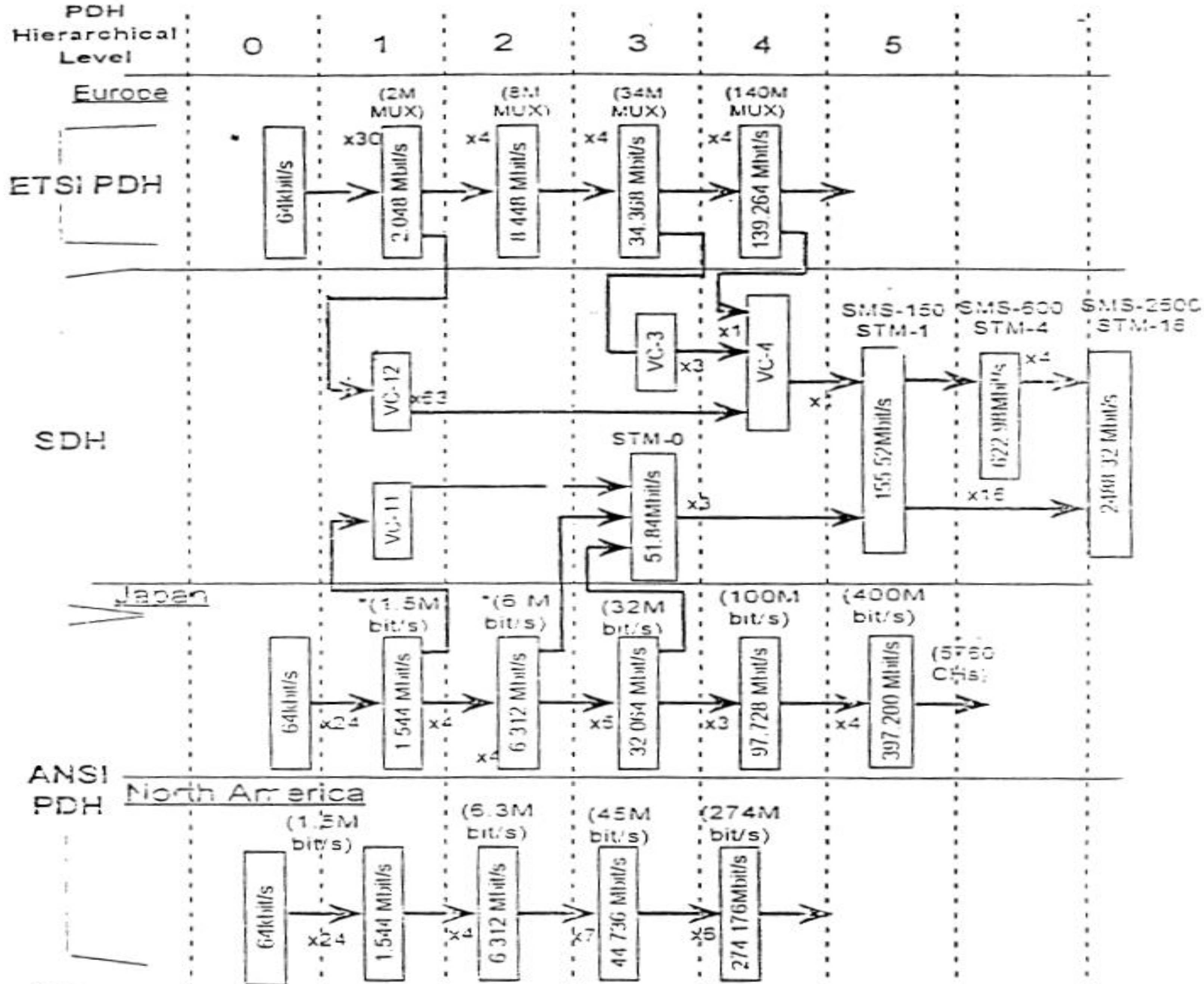
SDH	Digital Bit Rate	Size of VC
VC-11	1.728 Mbit/s	9 rows, 3 columns
VC-12	2.304 Mbit/s	9 rows, 4 columns
VC-2	6.912 Mbit/s	9 rows, 12 columns
VC-3	48.960 Mbit/s	9 rows, 85 columns
VC-4	150.336 Mbit/s	9 rows, 261 columns



▶ ***Figure 12.*** *SDH multiplexing structure.*

PDH & SDH Digital Hierarchy

a) PDH Three Digital & SDH Digital Hierarchy



b) SDH Bit Rate (N = 1, 4, 16 & 64)

Synchronous digital hierarchy Level	Hierarchical bit rate kbit/s	Total 64 bit/s Channels	
		30 TS	32 TS
STM - 0	51 840	630 CHs	672 CHs
STM - 1	155 520	1890 CHs	2016 CHs
STM - 4	622 080	7560 CHs	8064 CHs
STM - 16	2 488 320	30240 CHs	32256 CHs
STM - 64	9 953 280	120960 CHs	129024 CHs

STM

: Synchronous Transfer Mode

30 CH/trib x 63 CHs

= 1890 CHs

32 CH/trib x 63 CHs

= 2016 CHs

a) The first level of the synchronous digital hierarchy shall be 155.520 Mbit/s.

b) Higher synchronous digital hierarchy levels should be obtained as integer multiplexes of the first level bit rate.

Rate of an STM-N signal = N x Rate an STM-1 Signal

= N x 155.520 Mbit/s

c) Higher synchronous digital hierarchy levels should be denoted by the corresponding multiplications factor of the first level rate.

d) This specification of levels than 64 requires further study.

e) SMS stands for " Synchronous Multiplexing System ".

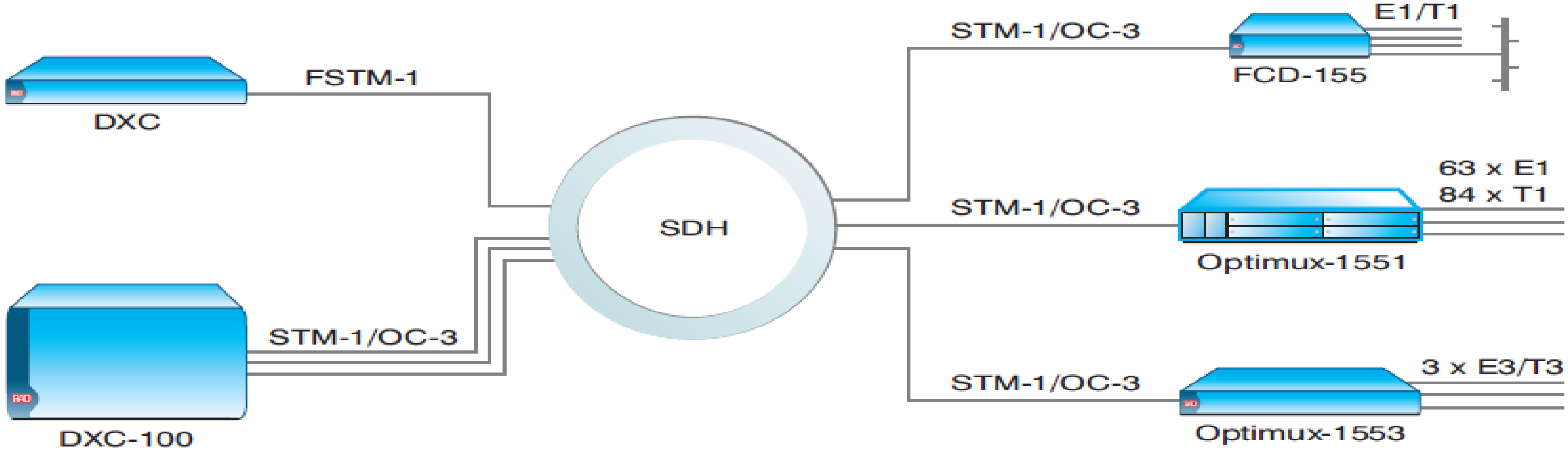
Table 1. Non-Synchronous, PDH Hierarchy

Signal	Digital Bit Rate	Channels
E0	64 kbit/s	One 64 kbit/s
E1	2.048 Mbit/s	32 E0
E2	8.448 Mbit/s	128 E0
E3	34.368 Mbit/s	16 E1
E4	139.264 Mbit/s	64 E1

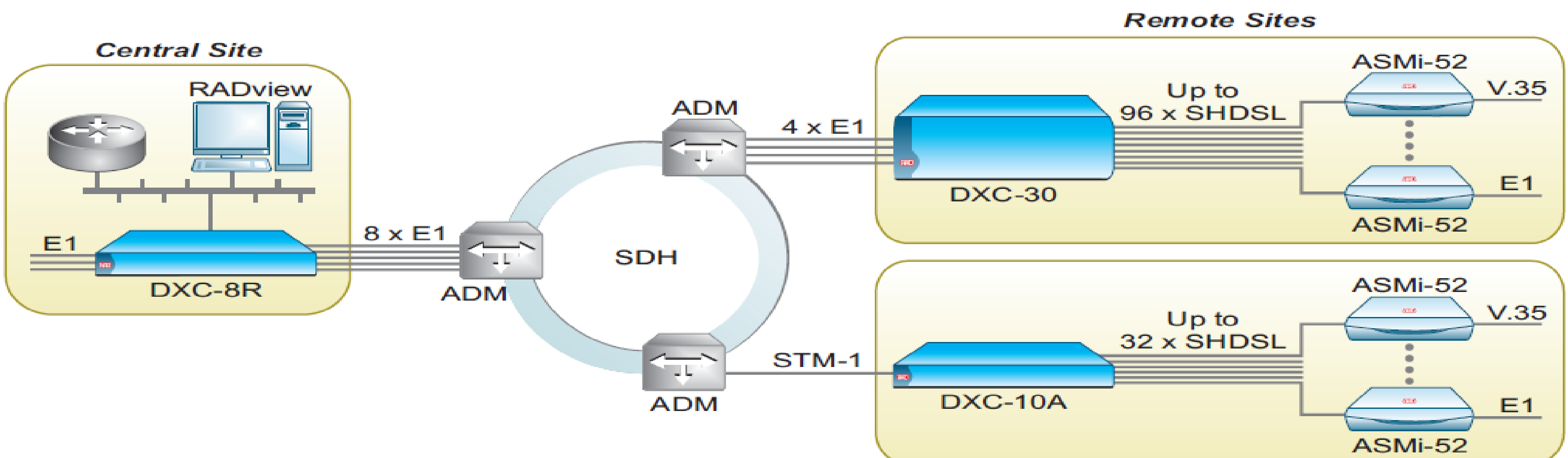
Table 2. SDH Hierarchy

Bit Rate	Abbreviated	SDH	SDH Capacity
51.84 Mbit/s	51 Mbit/s	STM-0	21 E1
155.52 Mbit/s	155 Mbit/s	STM-1	63 E1 or 1 E4
622.08 Mbit/s	622 Mbit/s	STM-4	252 E1 or 4 E4
2488.32 Mbit/s	2.4 Gbit/s	STM-16	1008 E1 or 16 E4
9953.28 Mbit/s	10 Gbit/s	STM-64	4032 E1 or 64 E4
39813.12 Mbit/s	40 Gbit/s	STM-256	16128 E1 or 256 E4

STM = Synchronous Transport Module

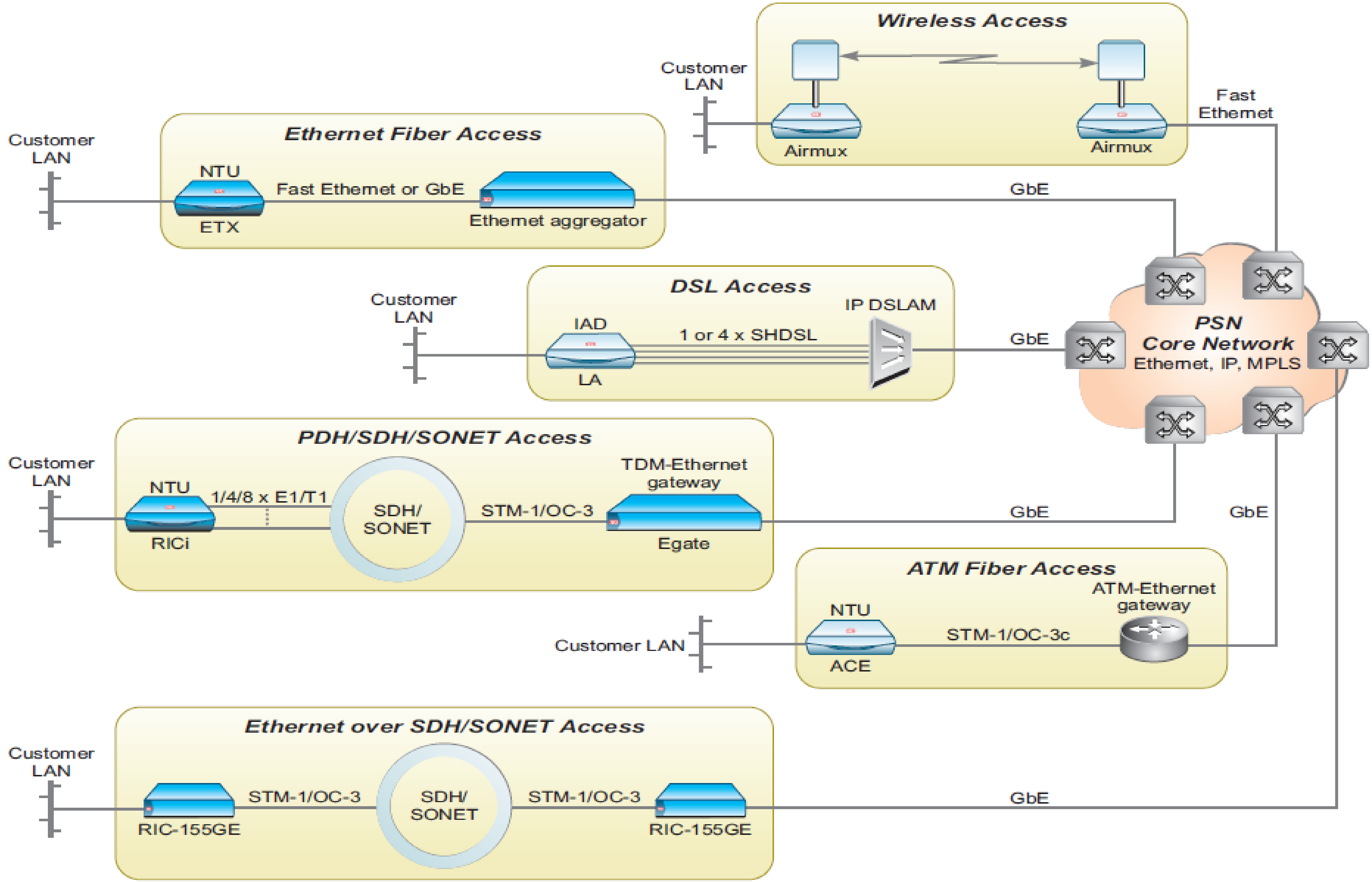


High rate access from SDH

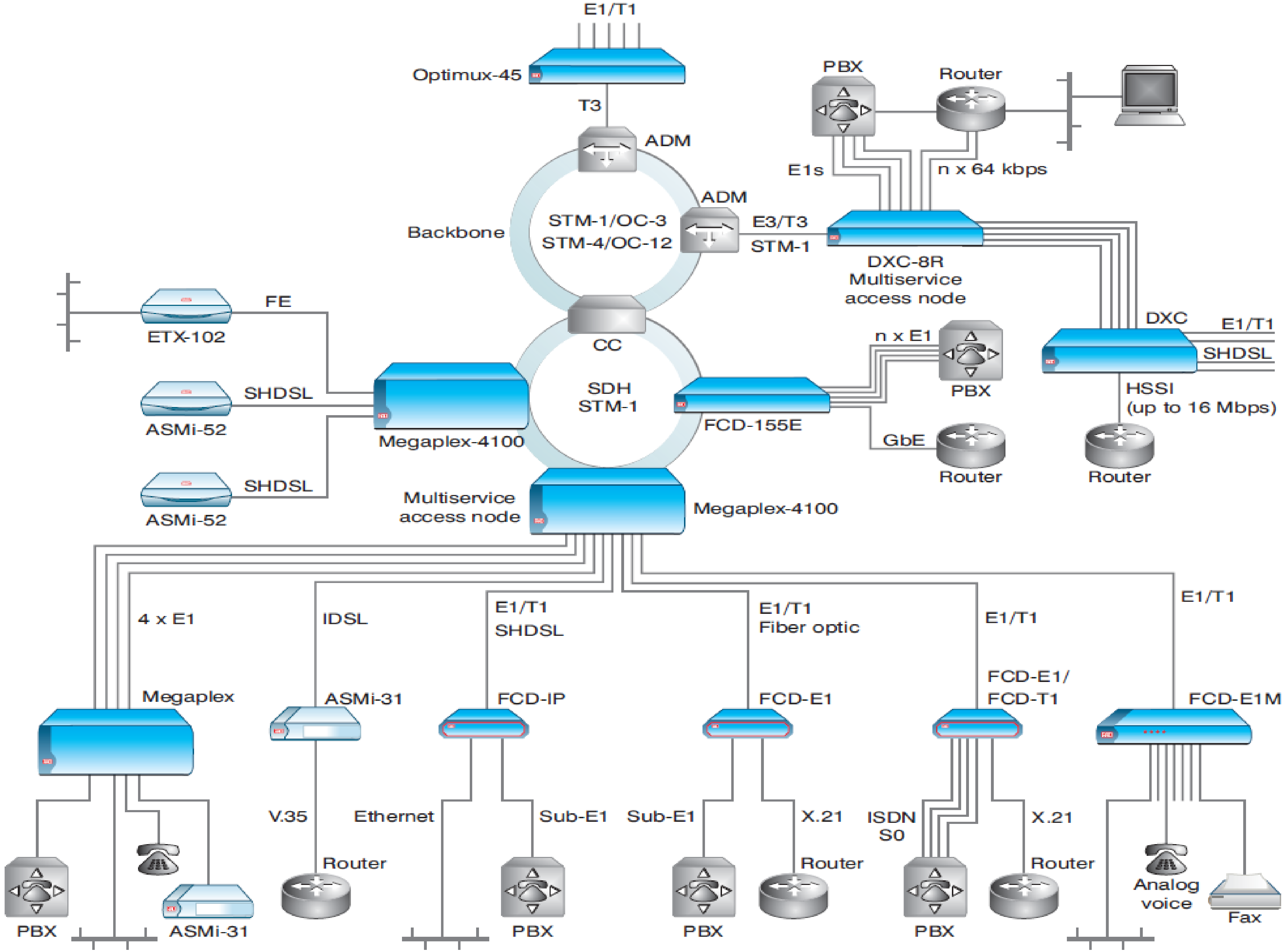


Extending services over copper

- Data rates up to 2.3 Mbps over 2-wire and 4.6 Mbps over 4-wire
- Extended range up to 10 km (6.2 miles)



Ethernet service over packet-switched network using different Local Loop technologies



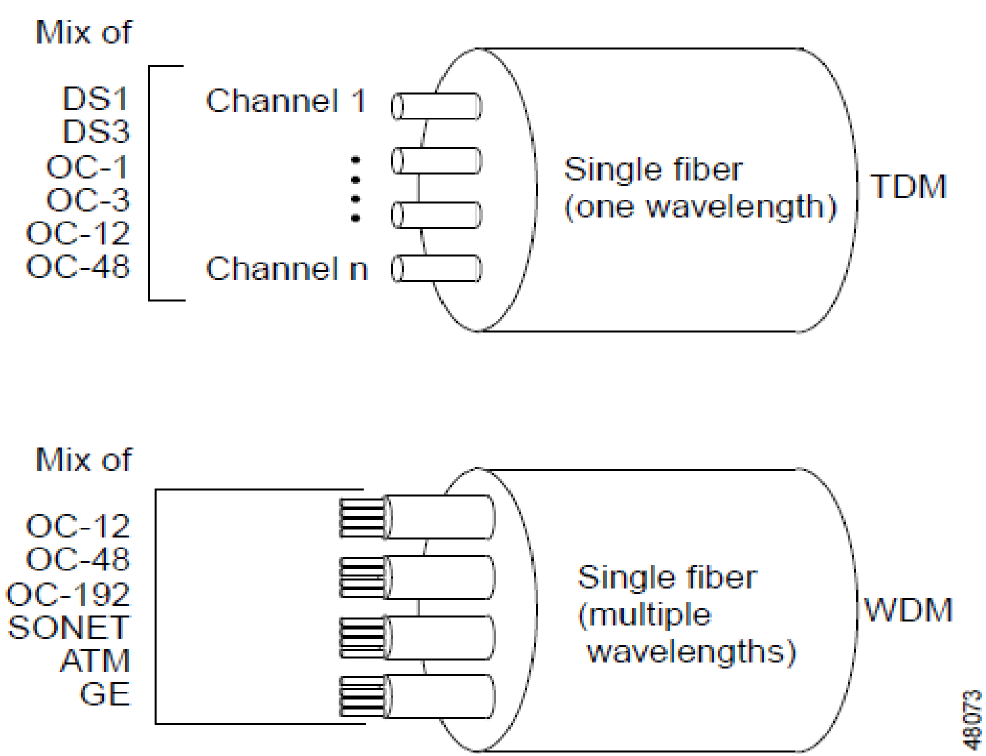
Multiservice SDH access

Why DWDM?

Note The term *wavelength* is used instead of the term frequency to avoid confusion with other uses of frequency. Wavelength is often used interchangeably with *lambda* and *channel*.

From both technical and economic perspectives, the ability to provide potentially unlimited transmission capacity is the most obvious advantage of DWDM technology. The current investment in fiber plant can not only be preserved, but optimized by a factor of at least 32. As demands change, more capacity can be added, either by simple equipment upgrades or by increasing the number of lambdas on the fiber, without expensive upgrades. Capacity can be obtained for the cost of the equipment, and existing fiber plant investment is retained.

Figure 1-8 TDM and WDM Interfaces



Wavelength Division Multiplexing

WDM increases the carrying capacity of the physical medium (fiber) using a completely different method from TDM. WDM assigns incoming optical signals to specific frequencies of light (wavelengths, or lambdas) within a certain frequency band. This multiplexing closely resembles the way radio stations broadcast on different wavelengths without interfering with each other (see Figure 1-7). Because each channel is transmitted at a different frequency, we can select from them using a tuner. Another way to think about WDM is that each channel is a different color of light; several channels then make up a "rainbow."

Figure 1-7 Increasing Capacity with WDM

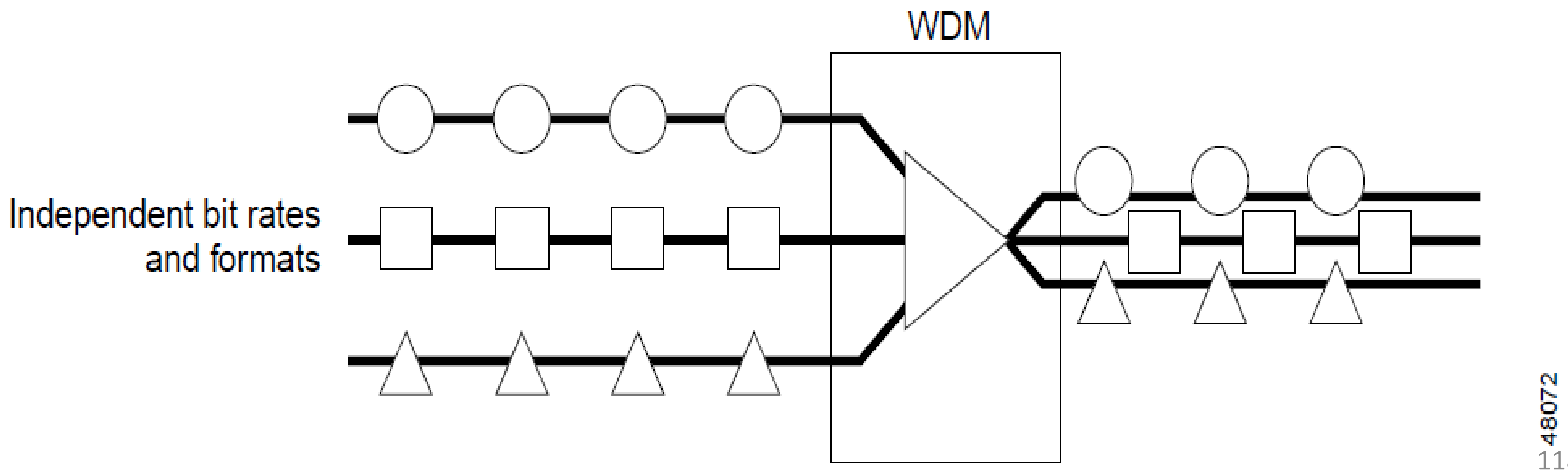
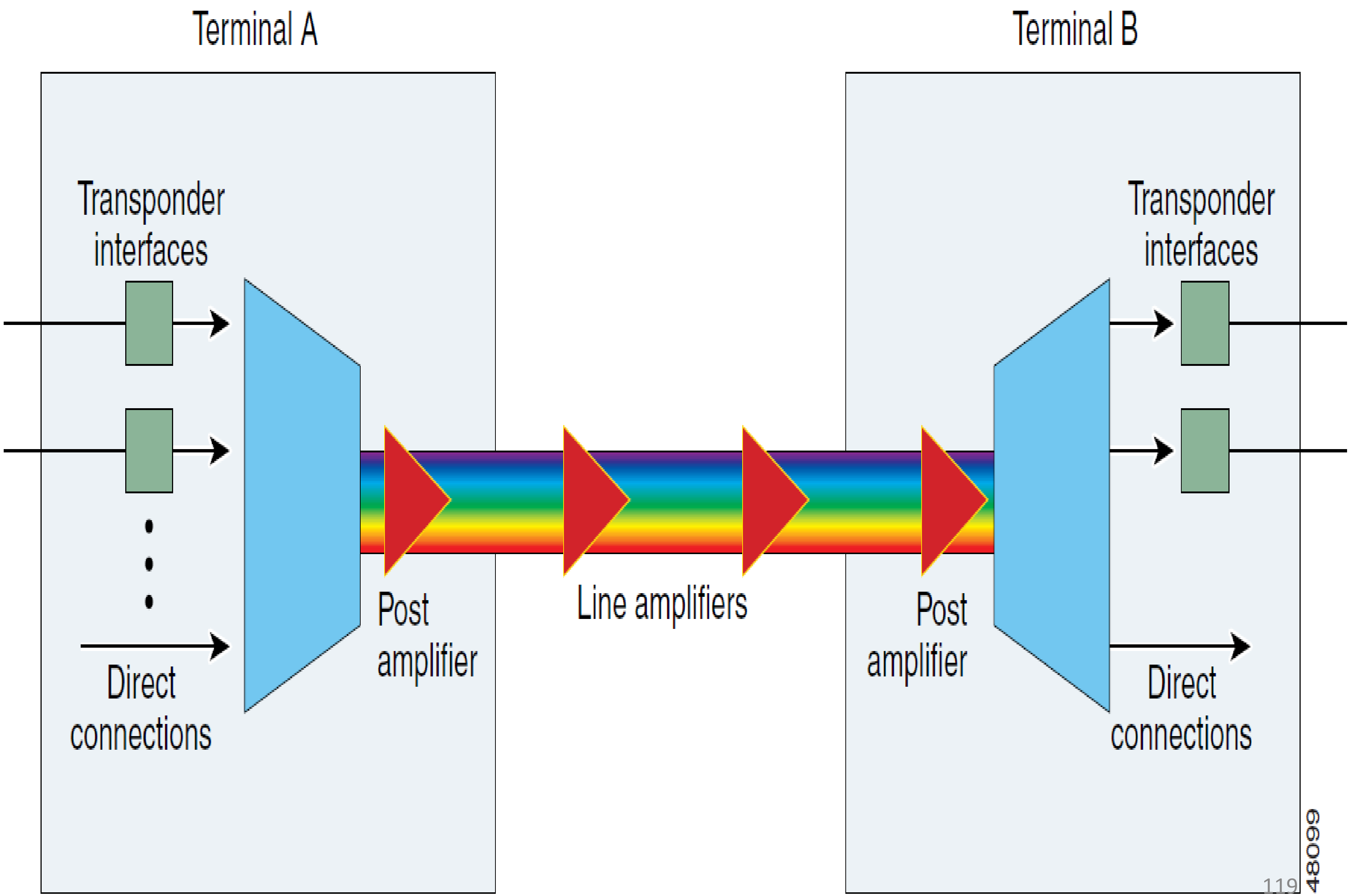


Figure 2-26 Anatomy of a DWDM System

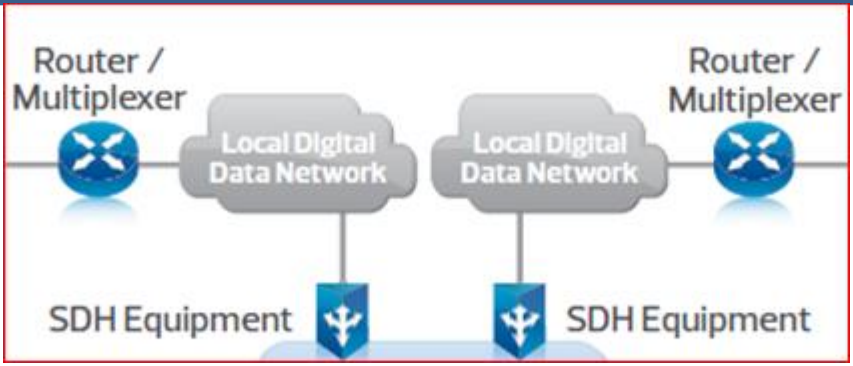


The following steps describe the system shown in Figure 2-26:

1. The transponder accepts input in the form of standard single-mode or multimode laser. The input can come from different physical media and different protocols and traffic types.
2. The wavelength of each input signal is mapped to a DWDM wavelength.
3. DWDM wavelengths from the transponder are multiplexed into a single optical signal and launched into the fiber. The system might also include the ability to accept direct optical signals to the multiplexer; such signals could come, for example, from a satellite node.
4. A post-amplifier boosts the strength of the optical signal as it leaves the system (optional).
5. Optical amplifiers are used along the fiber span as needed (optional).
6. A pre-amplifier boosts the signal before it enters the end system (optional).

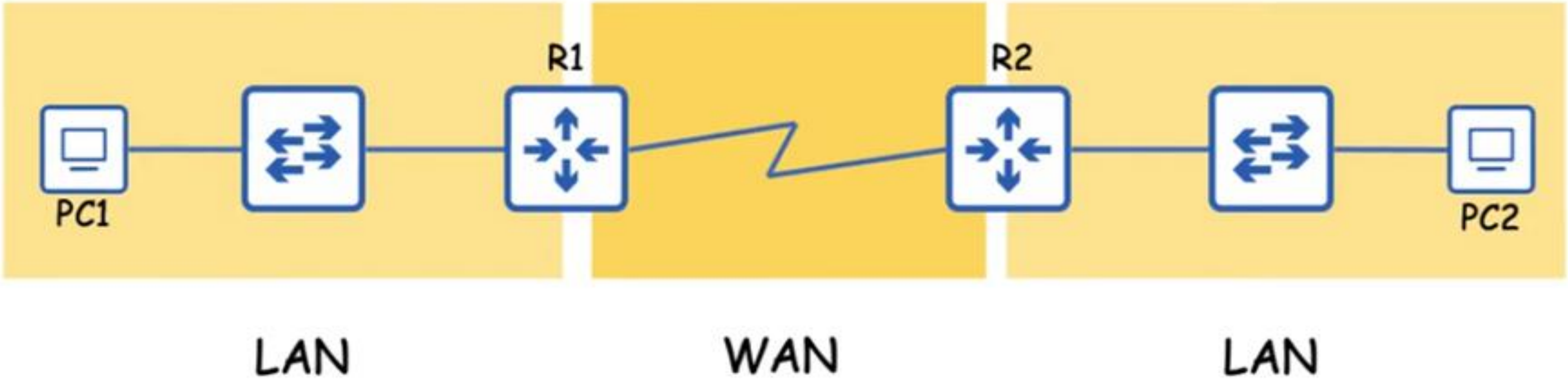
7. The incoming signal is demultiplexed into individual DWDM lambdas (or wavelengths).
8. The individual DWDM lambdas are mapped to the required output type (for example, OC-48 single-mode fiber) and sent out through the transponder.

International Private Leased Circuit (IPLC)



What is WAN?

- WAN = Wide Area Network
- WAN is a large network of information that is not tied to a single location.
- WANs facilitate communication, the sharing of information, etc between devices from around the world through a WAN provider.
- WAN technologies define the physical(layer-1) standards and data-link(layer-2) protocols used to establish connectivity between the end-points.



Note:

- The crooked line is used to represent a leased line
- WAN connections are usually slower than the LAN sides

Different Names of Leased Line

- Leased Circuit – Circuit refers to the electrical circuit between the endpoints
- Serial Link/Line – Serial here refers to the data flowing serially and that the routers uses a serial interface
- Point-to-point Links/Line – This refers to the fact that the link/line stretches between two end points only
- T1 – This specific type of leased line transmits data at 1.544 Megabits per second (Mbps)
- WAN Link/Line – General terms, with no reference to any specific technology
- Private Line – Refers to the fact that the data is being transmitted is private and cannot be copied by the intermediary.

HDLC (High-Level Data Link Control)

- Leased Circuit provides layer-1 service.
- HDLC and PPP(Point-to-point protocol) provide the data-link layer protocol to the leased circuit
- Like Ethernet which uses Destination Address so that correct device gets data and FCS to check if any error has occurred, HDLC provides similar functions.
- HDLC is point-to-point unlike Ethernet which works on a broadcast domain and can be point-to-multipoint, the frames of HDLC when transmitted by a side can go to only the other end of the link.

HDLC FRAME

	Flag	Address	Control	Type	Data	FCS
Bytes	1	1	1	2	variable	2

Wide Area Networks (WANs):

HDLC Data-Link Frame Format Fields:

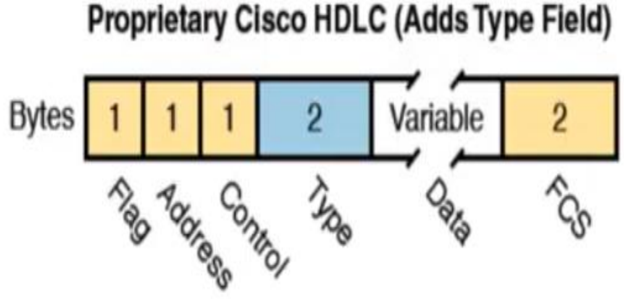


Figure 3-4 *HDLC Framing*

HDLC Field	Ethernet Equivalent	Description
Flag	Preamble, SFD	Lists a recognizable bit pattern so that the receiving nodes realize that a new frame is arriving.
Address	Destination Address	Identifies the destination device.
Control	N/A	Mostly used for purposes no longer in use today for links between routers.
Type	Type	Identifies the type of Layer 3 packet encapsulated inside the frame.
FCS	FCS	Identifies a field used by the error detection process.

Wide Area Networks (WANs):

Ethernet WANs:

- For the first several decades of the existence of Ethernet, Ethernet was only appropriate for LANs.
- The restrictions on cable lengths and devices might allow a LAN that stretched a kilometer or two, to support a campus LAN, but that was the limit.
- As time passed, the IEEE improved Ethernet standards in ways that made Ethernet a reasonable WAN technology.
- For example, the 1000BASE-LX standard uses single-mode fiber cabling, with support for a 5-km cable length; the 1000BASE-ZX standard supports an even longer 70-km cable length.
- As time went by, and as the IEEE improved cabling distances for fiber Ethernet links, Ethernet became a reasonable WAN technology.

Wide Area Networks (WANs):

Ethernet WANs:

- Today, many WAN service providers (SP) offer WAN services that take advantage of Ethernet.
- SPs offer a wide variety of these Ethernet WAN services, with many different names.
- But all of them use a similar model, with Ethernet used between the customer site and the SP's network, as shown in Figure 3-7:

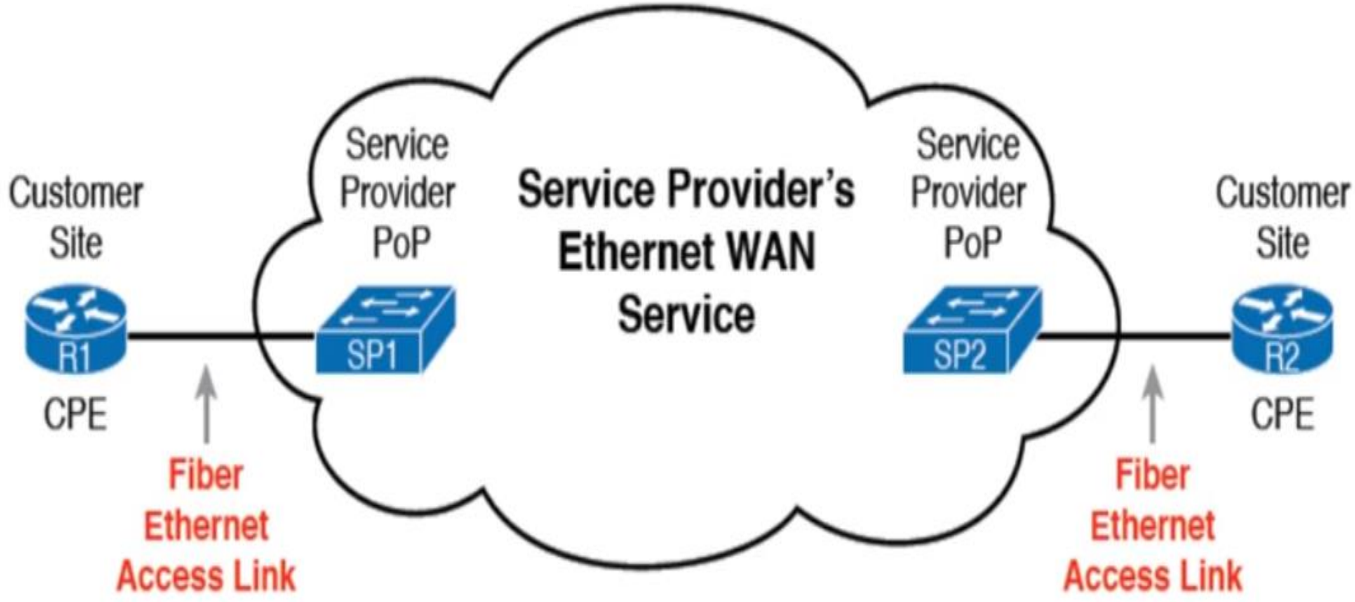


Figure 3-7 *Fiber Ethernet Link to Connect a CPE Router to a Service Provider's WAN*

Wide Area Networks (WANs):

Ethernet WANs:

- The customer connects to an Ethernet link using a router interface.
- The (fiber) Ethernet link leaves the customer building and connects to some nearby SP location called a point of presence (PoP).
- Instead of a telco switch as shown in Figure 3-3, the SP uses an Ethernet switch.
- Inside the SP's network, the SP uses any technology that it wants to create the specific Ethernet WAN services.

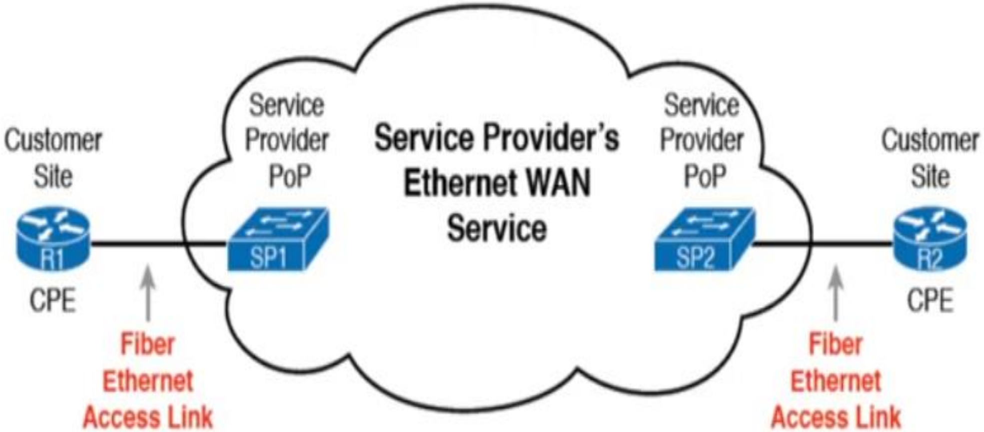


Figure 3-7 *Fiber Ethernet Link to Connect a CPE Router to a Service Provider's WAN*

Wide Area Networks (WANs):

Ethernet WANs:

- If you can imagine two routers, with a single Ethernet link between the two routers, you understand what EoMPLS service does, as shown in Figure 3-8:

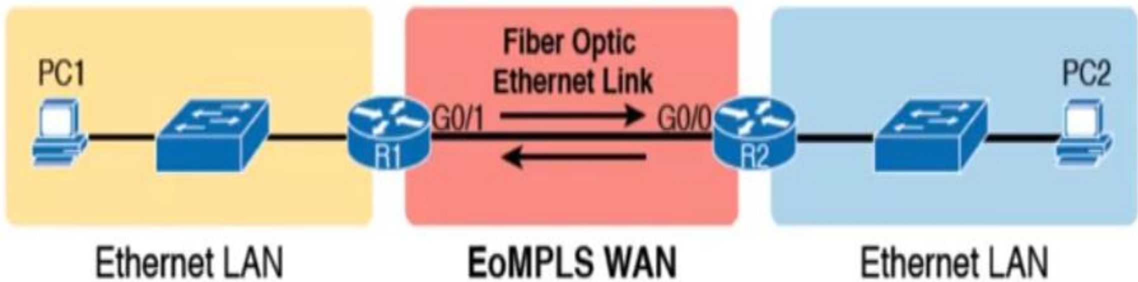


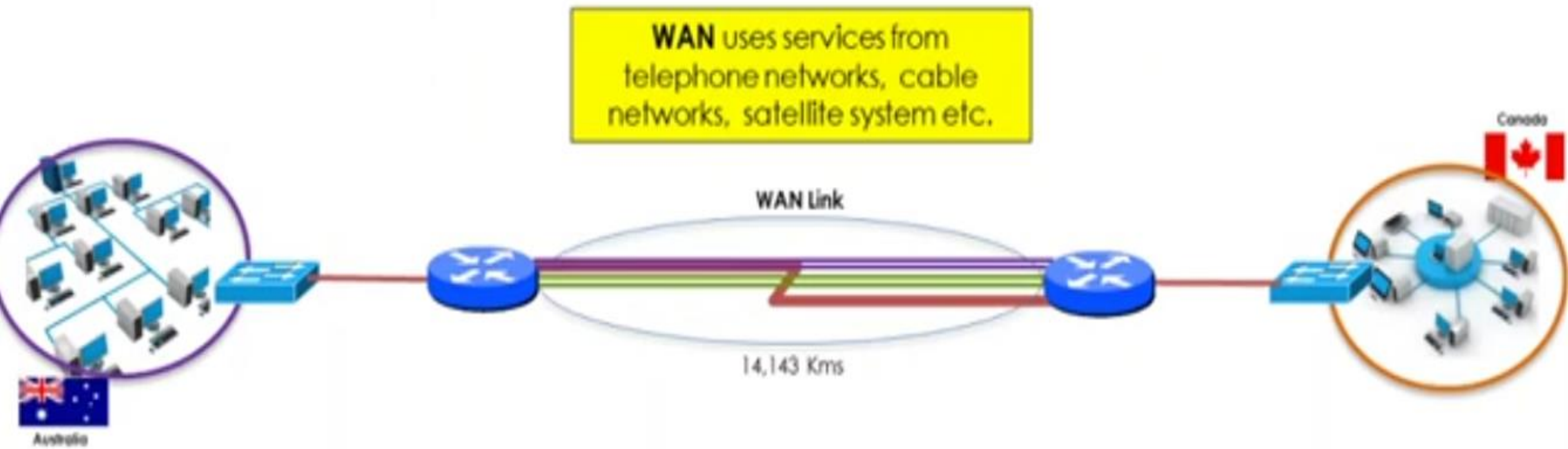
Figure 3-8 *EoMPLS Acting Like a Simple Ethernet Link Between Two Routers*

- In this case, the two routers, R1 and R2, connect with an EoMPLS service instead of a serial link.
- The routers use Ethernet interfaces, and they can send data in both directions at the same time.
- Physically, each router connects to some SP PoP, as shown earlier in Figure 3-7, but logically, the two routers can send Ethernet frames to each other over the link.

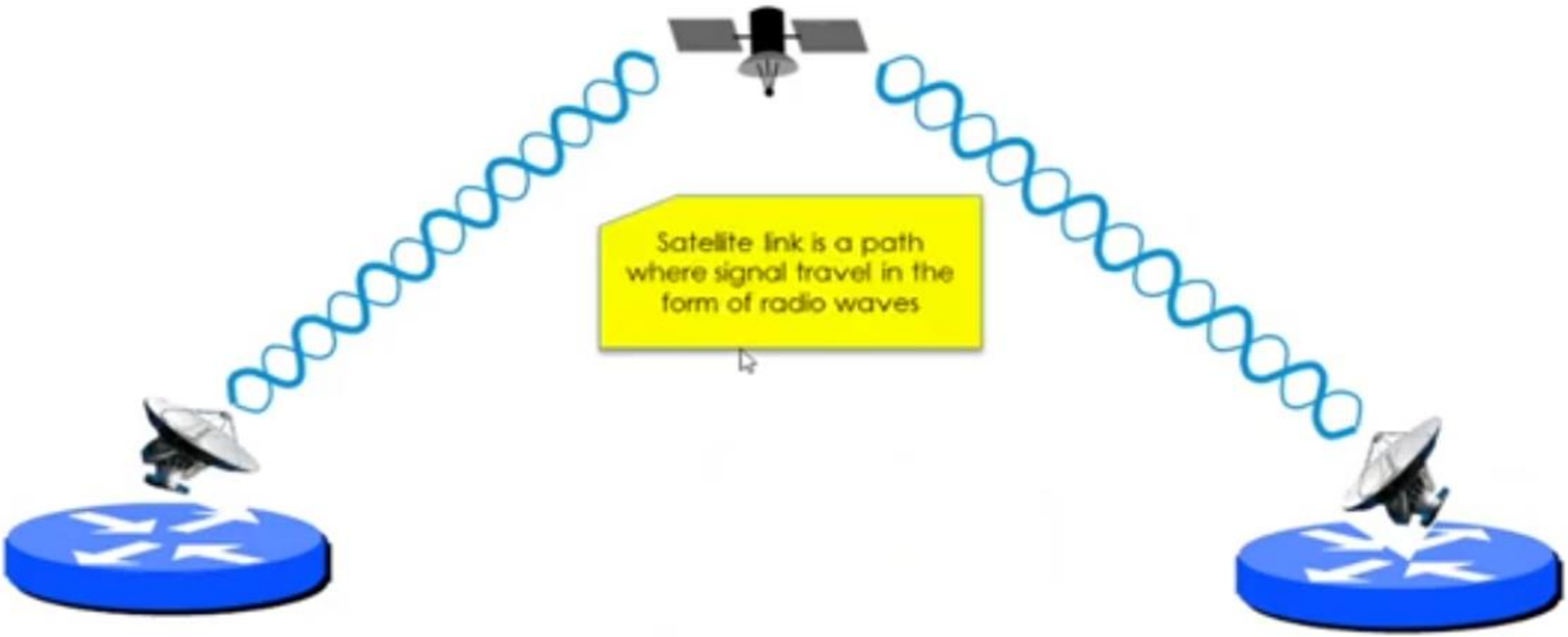
Leased-line Wide Area Network (WAN)

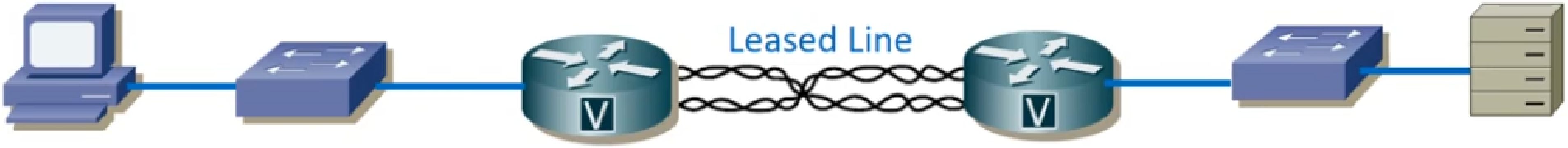
A **WAN** spans a large geographical area, often a <u>country</u> or <u>continent</u>

A **WAN** is a computer network created with an area having a radius of more than 100Km (roughly)

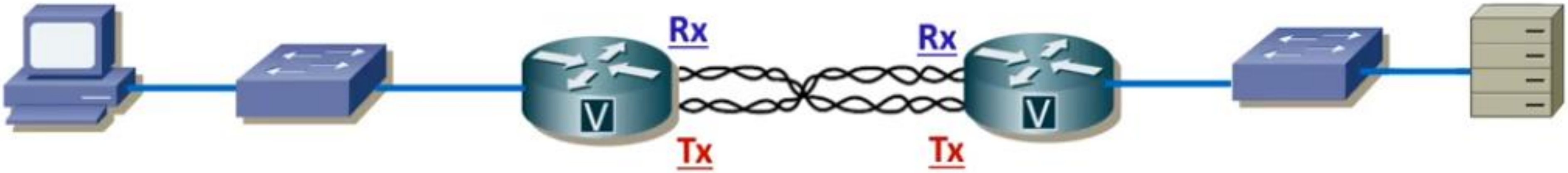


The leased line link between sites may be a satellite link





Names	Explanation
Leased line	The company using the leased line does not own the line but paying a monthly fee to use it
Leased circuit	It refers to the electrical circuit between two endpoints
Serial link	Router uses serial interface for this type of connection and the bits flow serially
Point to Point	This connection allows to connect only two endpoints together
T1	It transmits data at a specific speed 1.544 Mbps
WAN	It is usually used to connect devices in a WAN of an Enterprise
Private	Data sent over the line cannot be copied by other customers



INSIDE

- Uses two pairs of wires
- One pair for sending and the other pair for receiving data

CHARACTERISTICS

- Full duplex: Sending and receiving bits in both directions at a specific speed
- Distance: Up to 1000 miles
- It is a point-to-point link which means the bits can only flow serially from one end to the other end of the link. Therefore, physical address of the link is not important.

DATA LINK PROTOCOLS FOR LEASED LINES

- PPP: Point to Point protocol
- HDLC: High Level Data Link Control protocol

Cisco HDLC Frame

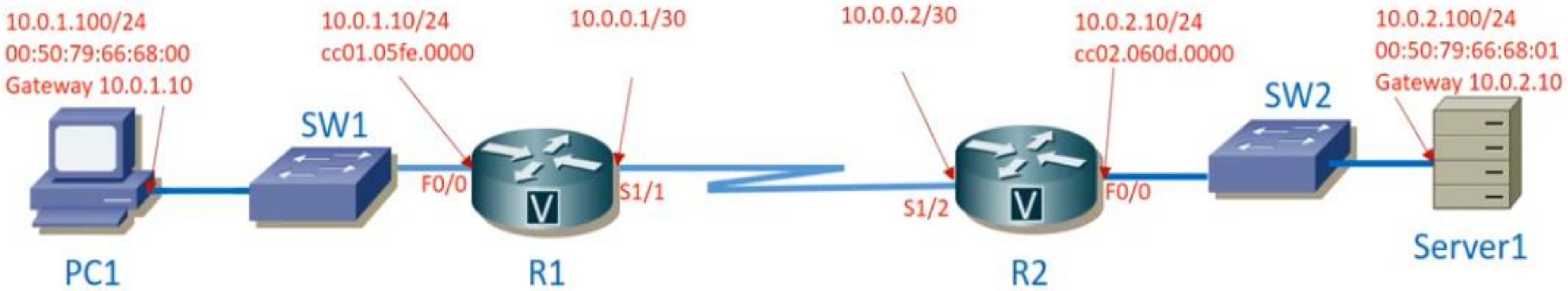
- **Flag**: It is an 8-bit sequence with the pattern of 01111110 that marks the beginning and the end of the frame.
- **Address**: The link physical address of the destination device.
- **Control**: Has flow and error control information between the two routers.
- **Type/Protocol**: Only exists in Cisco HDLC frame. It is used to identify the type of the packet in the Data field.
- **Data**: Carries layer 3 packet
- **FCS**: Identifies if the frame has any errors


```
Frame 20: 98 bytes on wire (784 bits), 98 bytes captured (784 bits) on interface -, id 0
Ethernet II, Src: Private_66:68:00 (00:50:79:66:68:00), Dst: cc:01:05:fe:00:00 (cc:01:05:fe:00:00)
Internet Protocol Version 4, Src: 10.0.1.100, Dst: 10.0.2.100
Internet Control Message Protocol
```

Upon receiving the Ethernet frame, router R1 performs the following actions:

1. First, it de-encapsulates the IP packet from the Ethernet frame
2. Next, it reads the IP packet and searches in its routing table to find the route containing the destination IP
3. Assume it found the route with the instruction to forward the packet out via interface S1/1 to the next hope with IP 10.0.0.2
4. After that, it encapsulates the IP packet into a new HDLC frame then forward to R2

```
Frame 27: 88 bytes on wire (704 bits), 88 bytes captured (704 bits) on interface -, id 0
Cisco HDLC
   Address: Unicast (0x0f)
   Control: 0x00
   Protocol: IP (0x0800)
Internet Protocol Version 4, Src: 10.0.1.100, Dst: 10.0.2.100
Internet Control Message Protocol
```



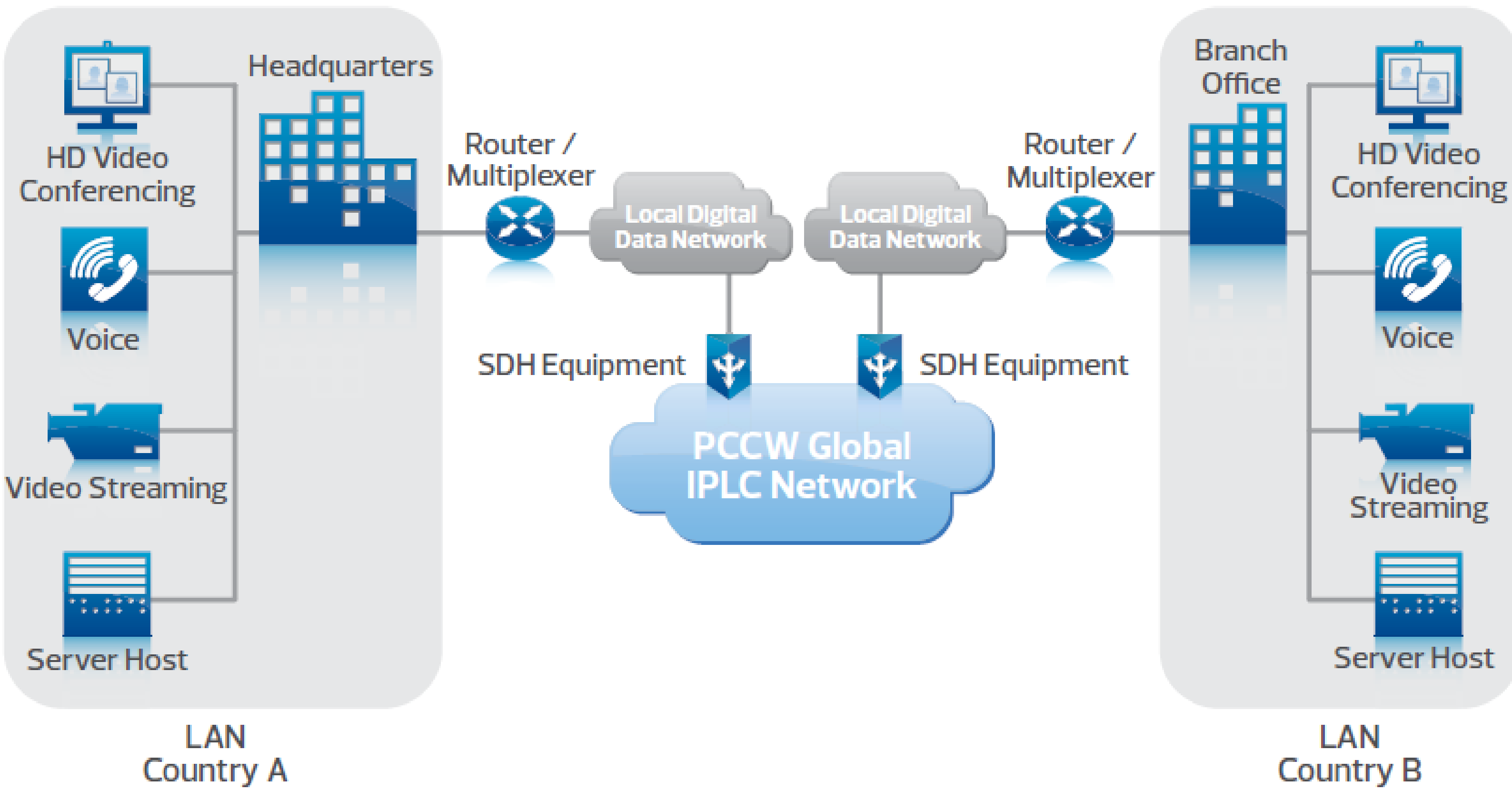
Like router R1, router R2 performs the following actions to process the HDLC frame:

1. First, it de-encapsulates the IP packet from the HDLC frame
2. It repeats the same process as the router R1 and finds the destination attaches to its F0/0 interface.
3. After that, it encapsulates the IP packet into a new Ethernet frame then forwards the frame to Server1 for consuming the data which ends the routing process.

```
Frame 23: 98 bytes on wire (784 bits), 98 bytes captured (784 bits) on interface -, id 0
Ethernet II, Src: cc:02:06:0d:00:00 (cc:02:06:0d:00:00), Dst: Private_66:68:01 (00:50:79:66:68:01)
Internet Protocol Version 4, Src: 10.0.1.100, Dst: 10.0.2.100
Internet Control Message Protocol
```

- A leased line provides a Layer 1 service to connect only two endpoints at the distance up to 1000 miles.
- It uses two pair of wires to transfer data in Full duplex mode which means one pair for sending data and the other pair for receiving data.
- It guarantees to deliver bits at a specific speed between the two devices.
- Data sent over a leased line is private because it cannot be copied by other customers.
- The two data link protocols used for leased line are:
    - PPP: Point to Point protocol
    - HDLC: High Level Data Link Control protocol
- Cisco added the Type/Protocol field into the standard HDLC frame to identify what has been encapsulated within that frame.
- Only the data link layer addresses get changed during the transmission across multiple types of physical links.

Network diagram



Key benefits to your business

- Cross-border connections for every network topology and bandwidth need
- Exclusive dedicated end-to-end links to prevent hacker attacks
- Protocol transparency with minimal transmission delay, supporting the most demanding client-server applications
- Wide selection of bandwidth and interface options for seamless integration

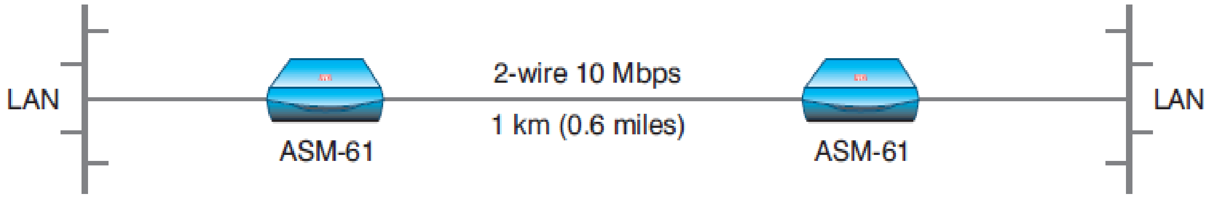
A leased line is a service contract between a provider and a customer, whereby the provider agrees to deliver a symmetric telecommunications line connecting two or more locations.

Typically, leased lines are used by businesses to connect geographically distant offices. Unlike dial-up connections, a leased line is always active. The fee for the connection is a fixed monthly rate. The primary factors affecting the monthly fee are distance between end points and the speed of the circuit. Because the connection does not carry anybody else's communications, the carrier can assure a given level of quality.

An Internet leased line is a premium internet connectivity product, delivered over fiber normally, which is dedicated and provides uncontended, symmetrical speeds, full-duplex. It is also known as an ethernet leased line.

ASM-61

2-Wire Symmetrical VDSL Modem



- Data rate of 10 Mbps
- Range of up to 1 km (0.6 miles) over 24 AWG cable
- User interface is a built-in 10/100BaseT Ethernet bridge
- Plug-and-play operation

A complete solution for high speed services over existing copper lines, the ASM-61 provides full duplex, symmetrical 10 Mbps Ethernet traffic over 2-wire 24 AWG (0.5 mm) copper cable, for distances of up to 1 km (0.6 miles).

The ASM-61 extends the range of internal LANs using VDSL technology, based on ETSI QAM line coding requirements for the physical medium.

The ASM-61 compensates for line impairments and mixed cabling by using advanced equalization, adaptive filtering and echo cancellation technology.

An internal clock is available. In this mode, the internal clock generator provides the clock for the digital interface and the line.

The ASM-61 is powered by AC voltage. It is available as a standalone unit that can be mounted in a standard 19" rack using special hardware.

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Wire gauge	Wire size
24 AWG	0.5 mm
26 AWG	0.4 mm

ASM-60

4-Wire Symmetrical VDSL Modem

Using symmetrical VDSL technology, ASM-60 operates at rates up to 10 Mbps over 4-wire lines. The ASM-60 extends the range of digital equipment up to 2 km (1.2 miles) over 24 AWG (0.5 mm) 4-wire copper cable. This eliminates the need for optical cable in the Last Mile (Local Loop) or in the campus network environment.

The ASM-60 compensates for line impairments and mixed cabling by using advanced equalization, adaptive filtering, echo cancellation technology, and QAM line coding.

Setup, control and monitoring of status and diagnostic information can be performed using an ASCII terminal connected to the async control port.

The ASM-60 is available as a standalone unit, which can be mounted in a standard 19" rack using special hardware. Two ASM-60 units can be mounted side-by-side.

- **Data rates of 4, 6 and 10 Mbps**
- **Range up to 2 km (1.2 miles) over 24 AWG cable**
- **Reliable performance over poor quality or noisy lines**
- **Digital interfaces: built-in IP router, Ethernet bridge**
- **Setup and monitoring via ASCII terminal**

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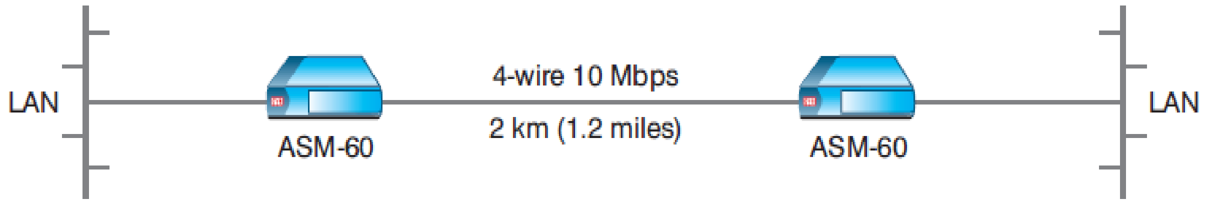
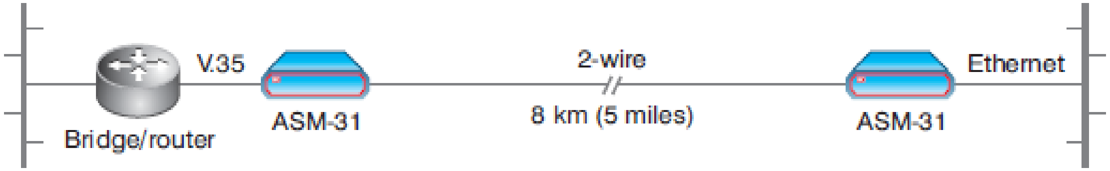


ASM-31

2-Wire Multirate Short Range Modem



- **Selectable data rates:**
  - **1.2 kbps up to 128 kbps (sync)**
  - **Up to 38.4 kbps (async)**
- **2-wire full duplex**
- **Adaptive echo canceller**
- **Range up to 8 km (5 miles) over 24 AWG lines**
- **2B1Q line code**
- **DTE interfaces: V.24/RS-232, V.35, V.36, RS-530, X.21, Ethernet (bridge) or G.703 codirectional (64 kbps)**
- **Optional built-in router**

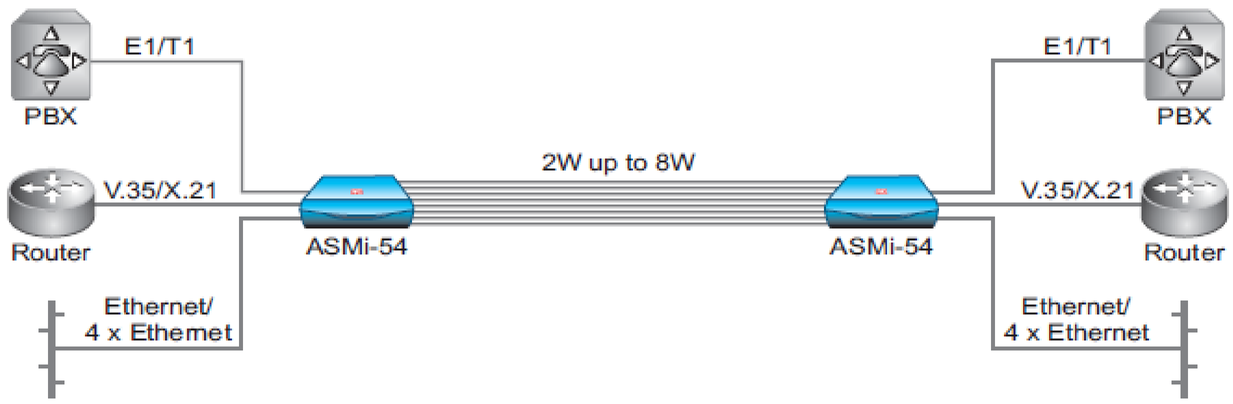
The ASM-31 multirate sync/async short range modem operates full duplex over a 2-wire twisted pair. The ASM-31 can operate at selectable data rates from 1.2 kbps to 128 kbps.

Full-duplex operation is achieved using the adaptive echo cancellation technique. This method entails setting one modem as a master and the other as a slave (switch-selectable). 2B1Q line coding provides an operating range of up to 8 km (5 miles) for all data rates, with an internal rate converter that converts all DTE data rates to a line data rate of 128 kbps.

Local and remote loopbacks can be activated from either side of the line, to test both modems and the line. Loopbacks are controlled by a manual switch or from the DTE interface. The modem includes a BER tester for complete end-to-end integrity testing. An error LED indicates each bit error detected. The ASM-31 has line protection circuits against lightning and power surges.

Interface options include V.24/RS-232, V.35, V.36, X.21, RS-530, built-in Ethernet bridge, router, and G.703 codirectional 64 kbps. The analog line connectors are RJ-45 and terminal block.

The ASM-31 is available as a standalone unit or as a card for the 19" ASM-MN-214 rack that holds up to 14 cards (see page 152).



High rate services over SHDSL

ASMi-54

G.SHDSL.bis Modem

- Complies with enhanced SHDSL ITU-T G.991.2 and ETSI 101524 standards for SHDSL
- Uses TC-PAM 16 or TC-PAM 32 to support higher rate for G.991.2 Annexes F & G
- Data rates up to 20 Mbps over 8-wire (4 pairs) and 5.7 Mbps over 2-wire (1 pair)
- Reliable performance over poor quality or noisy lines
- Available with four 10/100BaseT user ports with integral switch
- VLAN prioritization and Ethernet QoS support
- Managed via SNMP, Telnet and ASCII terminal

FOM-E3, FOM-T3

E3, T3 Fiber Optic Modems

The high speed FOM-E3 and FOM-T3 fiber optic modems extend transmission range of electrical E3 or T3 signals over fiber optic cables up to 110 km (68 miles).

Two models are available:

- FOM-E3 for E3 rates (34.368 Mbps)
- FOM-T3 for T3 rates (44.736 Mbps)

The FOM-E3 and FOM-T3 support a wide range of fiber optic interfaces, including long haul laser for extended ranges and WDM laser for transmission over a single fiber.

Transparent to E3/T3 framing, the FOM-E3 and FOM-T3 modems operate opposite RAD's DXC cross connect, Optimux-34 multiplexer (FOM-E3) and Optimux-45 multiplexer (FOM-T3). Similarly, they can operate opposite an ACE ATM access device, enabling E3/T3 ATM traffic to be transported over long distances on fiber and connect to an ATM or SDH network device with an electrical E3/T3 port.

FOM-E3 and FOM-T3 operation complies with ITU G.703, G.921 and G.956 standards. In addition, the modems support activation of local and remote loopbacks in compliance with the ITU V.54 standard.

The FOM-E3 and FOM-T3 modems include a dry contact alarm port for relay of alarm conditions to external alert equipment.

- **Extends the range of E3 or T3 signals over fiber optic cable up to 110 km (68 miles)**
- **Wave Division Multiplexing (WDM) module for operation over a single fiber strand**
- **Wide range of optical modules including long haul lasers for extended range**
- **Operates opposite Optimux, ACE and DXC**
- **Built-in diagnostics comply with V.54 standard**
- **Dry contact alarm port for external alert devices**

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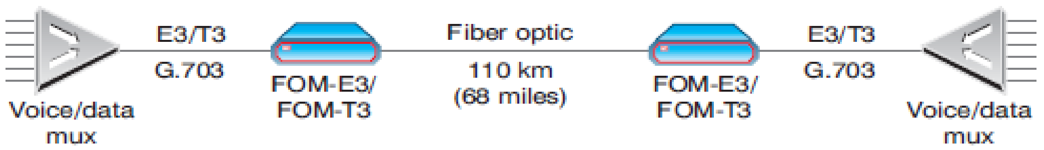

FOM-E1/T1

E1/T1 Fiber Optic Modem

The FOM-E1/T1 fiber optic modem converts an E1/T1 electrical signal into an optical signal. After the conversion, the signal is transmitted over fiber optic cable, extending the E1/T1 service range up to 144 km (89.4 miles).

The FOM-E1/T1 is transparent to E1/T1 framing (G.704), which enables it to transmit both framed or unframed E1/T1 signals.

Using the FOM-E1/T1 opposite the DXC cross connect system, Megaplex access multiplexer or FCD access unit reduces the cost of the fiber optic link when accessing the SDH/SONET network.

The FOM-E1/T1 supports various optical interfaces:

- 850 nm for multimode fiber
- 1310 nm for single mode or multimode fiber
- 1550 nm laser diode for extended range over single mode fiber
- WDM for single fiber extension

FOM-E1/T1 operation complies with ITU G.703, G.921 and G.956 standards. The modem supports activation of local and remote loopbacks in compliance with the ITU V.54 standard.

Front panel LEDs indicate system faults in the electrical and fiber optic circuits.

- **Extends the range of E1/T1 services over fiber optic cables up to 144 km (89.4 miles)**
- **Transparent to E1/T1 framing**
- **Operates opposite RAD's DXC cross connect system, Megaplex access multiplexers and FCD access units**
- **Conforms to all relevant ITU series standards, including V.54 diagnostics support**

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