WAN Technologies

# Lesson overview.

In this lesson, we will cover:

* Public switched telephone network.
* Broadband cable.
* Fiber.
* GSM/CDMA WAN connections.
* WiMAX WAN connections.
* Satellite WAN connections.
* Metro Ethernet WAN connections.
* Leased line WAN connections and standards.
* Circuit switched vs. packet switched networks.
* Frame relay vs. Asynchronous Transfer Mode.
* Multiprotocol Label Switching.

# Public switched telephone network.

Before I begin with the public switched telephone network, let's talk about what makes a WAN a WAN, as opposed to a LAN. As a general rule, if you own and control the line that the data is using to get from one place to another, you are not using wide area network (WAN) technology.

On the other hand, if you are using a form of transmission that you don’t own (e.g., you are leasing it or paying for the use of it), then you are likely using WAN technology. One of the most common physical infrastructures used in WAN technology is the public switched telephone network (PSTN) due to its widespread availability.

## Dial-up.

An older technology, dial-up is WAN technology that utilizes the PSTN to transmit network traffic as an analog signal. Dial-up requires an analog modem to format the network traffic correctly so it can be transmitted. The maximum theoretical speed on dial-up is 56 kilobits per second; it's not very fast.

#### Highlights:

* Dial-up utilizes the PSTN to transmit network traffic as an analog signal.
* Dial-up requires an analog modem to format the network traffic.
* Its maximum theoretical speed is 56 Kbps.

## ISDN (Integrated Services Digital Network).

ISDN (Integrated Services Digital Network) is a digital point-to-point WAN technology that utilizes the PSTN. It is a completely digital service. ISDN requires the use of a terminal adapter (TA) to make the connection to the end nodes. This TA is often called a digital modem, but it's not actually a modem; it's a terminal adapter.

ISDN can use a primary rate interface (PRI). A PRI is composed of 23 64-kilobit-per-second B channels and one 64-kilobit-per-second D channel. The D channel is used for call setup and link management. A PRI can achieve 1.544-megabits-per-second speed and that is commonly referred to as a T1 leased line.

The most commonly implemented form of ISDN is though the BRI (Basic Rate Interface). It uses only two B channels and one D channel, and the BRI can achieve speeds of up to 128 kilobits per second. ISDN is not as capable as a digital subscriber line (DSL), but it can often be implemented where DSL cannot be installed.

#### Highlights:

* ISDN is digital point-to-point WAN technology using the PSTN.
* Requires the use of a TA for the connection to the end node.
* A PRI uses 23 64 Kbps B channels and one 64 Kbps D channel for call setup and link management.
* Commonly implemented as a BRI, using two B channels and one D channel.
* Not as capable as a DSL, but it can often be implemented where DSL cannot.

## xDSL.

The term for generic DSL is actually xDSL. DSL is a digital WAN technology that utilizes the PSTN. DSL requires the use of a digital modem. It uses a dedicated digital line between the endpoint and a class-5 central office (CO). In order for the most basic forms of DSL to be installed, it has to be within 18,000 feet of the CO. DSL is capable of carrying voice and data. When it does carry both, filters are required for the voice signal to come through without any interference.

#### Highlights:

* DSL is a digital WAN technology using the PSTN.
* DSL requires the use of a digital modem and uses a dedicated digital line between the endpoint and a class-5 CO.
* DSL is only possible within 18,000 feet of the CO.
* Carries voice and data (filters are put in place to get voice).

## SDSL (Symmetric DSL)

Symmetric DSL (SDSL) is synchronous in nature; that means that the upload and download speeds are the same. SDSL does not carry voice communication, so if voice service is necessary, an additional line is required. SDSL is used by businesses that do not need the performance of a T1 leased line but do require symmetrical upload and download speeds.

#### Highlights:

* SDSL is synchronous in nature (upload and download speed is the same).
* Does not carry voice communications.
* Used by businesses that don’t need the performance of a T1 leased line, but that do require symmetrical upload and download speeds.

## ADSL (Asymmetric DSL).

More common than SDSL, is Asymmetric DSL (ADSL). It is asynchronous in nature, which means that the upload speed is slower than the download speed. ADSL can carry data and voice. Common upload speeds for ADSL are 768 kilobits per second, with download speeds of up to nine megabits per second. It is the most common implementation of DSL in the small office, home office (SOHO) environment.

#### Highlights:

* ASDL is asynchronous in nature and is the most common implementation of DSL in the SOHO environment.
* It can carry data and voice.
* Common upload speeds of 768 Kbps with download speeds of up to 9 Mbps.

## VDSL (Very-high-bit-rate DSL).

VDSL (Very-high-bit-rate DSL) is asynchronous in nature as well. It is used when high quality video and Voice over IP is necessary. VDSL is commonly limited to download speeds of 52 megabits per second with upload speeds of 12 megabits per second. VDSL is only possible when you're located within a maximum of 4,000 feet of a CO. The current standards do allow for up to 100-megabits-per-second speed over the PSTN using VDSL; however, in order to achieve that speed, the connection must be within 300 meters of the CO.

#### Highlights:

* VDSL is asynchronous in nature.
* Used when high quality video and VoIP is necessary.
* It is only possible when located within 4,000 feet of a CO.
* Current standard allows for up to 100 Mbps over PSTN, if the endpoint is within 300 meters of a CO.

# Broadband cable.

Cable television companies developed broadband cable to offer an alternative Internet connection for their customers. Broadband cable uses the cable company’s infrastructure as the media to deliver cable networking.

## Coaxial cable networking.

A broadband connection is delivered from the cable company using coaxial cable to a customer’s location. Broadband cable can deliver voice, data, and television—all through the same connection.

With broadband cable, the digital signal is delivered to the headend. This is where all the cable signals are received. The signal is processed, formatted, and then transmitted to the distribution network. The distribution network is a smaller service area served by the cable company.

The distribution network architecture can be composed of fiber optic cabling, or coaxial cabling, and/or a hybrid fiber coaxial cabling (HFC). Unlike DSL, the bandwidth of the distribution network is shared by all of those who connect to it. This can lead to increased latency and congestion during busy times.

The final distribution to the premises is usually through a coaxial cable. With broadband cable, it is important to know that all cable modems and similar devices must measure up to the ISP's required Data Over Cable Service Interface Specification (DOCSIS) standard. If the equipment does not meet the standard, the expected speeds will not be achieved.

#### Highlights:

* Broadband connection to a location delivered by the cable company.
* Headend: all cable signals are received at this point; signals are processed and formatted then transmitted to the distribution network.
* Distribution network: smaller service areas served by the cable company. The distribution network architecture can be composed of fiber optic cabling, coaxial cabling, and/or hybrid fiber-coaxial cabling (HFC).
* Final distribution to a premises is usually through a coaxial cable.
* DOCSIS: the specifications for how the signal will be received.

# Fiber.

Fiber optic networking is using light to transmit data and voice. This supports greater bandwidth over further distances. Both traditional telecommunication companies and cable providers are now offering fiber optic networking to their enterprise and consumer customers.

## Fiber-optic networking.

Fiber optic networking is more expensive to install, but it is also less susceptible to line noise. The fiber synchronous data transmission standard in the United States is called the Synchronous Optical Network (SONET) standard. The international standard is called the Synchronous Digital Hierarchy (SDH). Both SONET and SDH define the base rates of transmission over fiber optic cabling, which are known as optical carrier (OC) levels.

Dense wavelength-division multiplexing is a method of multiplexing several OC levels together—up to 32 of them into a single fiber optic cable—which effectively increases the bandwidth of that single optical fiber.

An alternative to DWDM is coarse wavelength-division multiplexing (CWDM). It is similar to DWDM, but it only allows for up to eight channels on a single fiber.

When fiber optic is delivered to a premises, it is usually delivered over a passive optical network (PON). A PON is a point-to-multipoint technology that uses a single optical fiber to connect multiple locations to the Internet. A PON uses unpowered optical splitters.

#### Highlights:

* Fiber optic networking uses light to transmit data and voice, which allows for more bandwidth over greater distances.
* SONET is the U.S. and SDH is the international fiber synchronous data transmission standard.
	+ These define the base rates of transmission, which are known as OC levels.
* DWDM is a method of multiplexing several OC levels (up to 32 channels) into a single optical fiber, effectively increasing the bandwidth of a single optical fiber.
* CWDM is similar to DWDM, but only allows for up to eight channels on a single fiber.
* PON is a point-to-multipoint technology that uses a single optical fiber to connect multiple locations to the Internet, using unpowered optical splitters.

# GSM/CDMA WAN connections.

All cellular carriers use one of two methods for connecting devices to their networks. Currently, in the United States, AT&T and T-Mobile use the Global System for Mobile Communications (GSM) standard to connect devices to their networks. Both Sprint and Verizon use code division multiple access (CDMA), as their method of connecting to networks. These two standards are not compatible. The majority of the rest of the world utilizes GSM as the method for cellular network access.

## Cellular networking.

Cellular networking involves using the cellular phone system for more than just phone calls. Cellular networking has been available for some time. It originally wasn't known as cellular networking, but the first version of it is first G (or 1G) cellular, which was only capable of voice transmissions.

2G was the second iteration and consists of cellular service with simple data transmission capabilities, as in text messaging. Later, 2G EDGE offered some basic cellular networking connectivity and was a stopgap measure between 2G and third generation cellular. The beginning of cellular WAN networking came about with 3G cellular. It is giving way to 4G cellular, which is still an emerging technology. 4G currently consists of both LTE and WiMAX.

Evolved High Speed Packet Access (HSPA+) was a stopgap between 3G and 4G networking. It is still available today. The current standard for HSPA+ allows for up to a maximum data rate of 84 megabits per second. HSPA+ is not as capable as LTE (Long Term Evolution). LTE uses an all IP based core, which supports higher transfer speeds. LTE is compatible with both 3G and WiMAX. The current standard for LTE allows for up to 300 megabits per second in download speeds, and up to 75 megabits per second in upload speeds.

#### Highlights:

* 1G cellular was only capable of voice transmissions.
* 2G cellular added simple data transmission capability (text).
* 2G EDGE offered some basic cellular networking connectivity and was a stopgap between 2G and 3G.
* 3G cellular is the beginning of cellular WAN networking.
* 4G is an emerging technology; it currently consists of LTE and WiMAX.
* HSPA+ is a stopgap between 3G and 4G.
* LTE uses an all-IP based core with high data transfer rates. It is compatible with 3G and WiMAX.

# WiMAX WAN connections.

WiMAX (Worldwide Interoperability for Microwave Access) was originally developed as a last mile alternative for use when DSL or cable was not available. WiMAX can provide an alternative broadband connection to a fixed location. It uses microwave transmissions as an over-the-air method to transmit voice and data. WiMAX requires line of sight between relay stations, but WiMAX can be used to cover significant geographical distances.

Many municipalities are exploring the use of WiMAX as a means of providing reasonably priced broadband to their citizens without having to wire every household. WiMAX is often considered to be a type of 4G technology because it is compatible with LTE networks; however, it is not compatible with 3G networks.

#### Highlights:

* WiMAX was originally developed as a last mile alternative for use when DSL or cable was not available.
* It uses microwave transmissions as an over-the-air method to transmit voice and data.
* WiMAX can be used to cover significant geographic distances, but requires a line of sight between relay stations.
* It is often considered to be a type of 4G technology because it is compatible with LTE networks.

# Satellite WAN connections.

Satellite WAN connections are a form of microwave satellite networking. Satellite WAN connections use microwave transmissions as an over-the-air method of transmitting voice and data, just like WiMAX. They can be an effective means of extending networks into places that are hard to reach. Satellite WAN connections use microwave radio relay as the method of transmitting data through the atmosphere. Just like WiMAX connections, they require line-of-sight relay stations. However, they can cover greater distances than WiMAX, because they utilize a satellite network.

The distances that satellite transmissions cover can lead to latency issues. Keep in mind that signals must go from a terrestrial location up to the satellite, probably over to another satellite, and then down to another terrestrial station. These significant distances will introduce some lag into the communication.

Communication satellites, also known as comsats, form part of the microwave relay network. Comsats can use a variety of orbits, including the Molniya, geostationary, low polar, and polar orbits. The low polar and polar orbits are used to boost microwave signals before sending the signal back to Earth.

#### Highlights:

* Satellite WAN connections use microwave transmissions as an over-the-air method to transmit voice and data.
* Can be an effective means of extending networks into places that are hard to reach.
* The distances covered by the satellite network may lead to latency problems.
* A communication satellite (comsat) forms part of the microwave relay network.
* Comsats may use a variety of orbits, including Molniya, geostationary, low-polar, and polar.

# Metro Ethernet WAN connections.

A metro Ethernet connection is when the service provider connects to the customer’s site through an RJ45 connector. Customers view the WAN connection as an Ethernet connection, while, in reality, the type of connection will be dependent on the level of service that has been purchased.

The service provider may actually use a variety of WAN technologies behind the scenes, but the customer will only view it as being Ethernet. Metro Ethernet is commonly deployed as a WAN technology by municipalities at the metropolitan area network (MAN) level.

#### Highlights:

* A metro Ethernet connection is when the service provider connects to the customer's site through an RJ45 connector.
* Metro Ethernet is commonly deployed as a WAN technology by municipalities at the MAN level.

# Leased line WAN connections.

A leased line is a dedicated circuit or connection between two endpoints used for communication. When we are talking about IT, a leased line is usually a digital point-to-point connection. A leased line can utilize either a plain old telephone service (POTS) line on the PSTN, or it can be a fiber optic circuit provided by a telecommunications company. Leased lines tend to be more expensive for the customer. Because the circuit cannot be utilized by any other entity, the entire cost is borne by the customer.

Most often, the speed of a leased line is limited by what the customer is willing to pay. There are multiplexing technologies available that can be used to increase the amount of channels that are provided on the connection.

#### Highlights:

* A leased line is a dedicated circuit (connection) between two end points used for communication, using a digital point-to-point connection.
* A leased line can utilize a POTS line or it can be a fiber optic circuit provided by a telecommunications company.
* Leased lines tend to be more expensive for the customer, as the circuit cannot be utilized by any other entity so the whole cost is borne by the customer.
* Multiplexing technology can be used to increase the amount of channels that are provided on the connection.

## Leased line connections and standards.

There are different types of leased line connections and standards. What is available depends upon the geographic location.

### T-carrier lines.

In the United States, Japan, and South Korea, T-carrier lines are used. Each T line is composed of 24 digital signal channels. These are often called digital signal zero (DS0) channels. Each channel is capable of carrying 64 kilobits per second. Collectively, the 24 DS0s make up what is called a DS1 channel.

A T1 line is composed of 24 DS0 channels. The 24 DS0 channels are also known as a DS1. A T1 line is capable of achieving speeds of up to 1.544 megabits per second. If that is not fast enough, a T3 line (which is composed of 28 T1 lines) can be leased. A T3 line, also known as a DS3, can achieve speeds of up to 44.736 megabits per second.

#### Highlights:

* Each T line circuit level is composed of 24 digital signal channels called DS0 channels, with each channel capable of carrying 64 Kbps.
	+ The 24 DS0s make what is called a Digital Signal 1 (DS1) channel.
* A T1 is composed of 24 DS0 channels (also known as a DS1); it provides 1.544 Mbps speed.
* A T3 is composed of 28 T1 lines (also known as a DS3); it provides 44.736 Mbps speed.

### E-carrier lines.

E-carrier lines are used in Europe. Each E line is composed of 30 digital signal channels. These are also called DS0 channels. The 30 DS0 channels create what is called a DS1 channel.

An E1 line is composed of 30 DS0 channels and can achieve speeds of up to 2.048 megabits per second. If faster speeds are necessary, an E3 line, which is composed of 16 E1 lines, provides speeds of up to 34.368 megabits per second. While a T1 is slower than an E1, a T3 is faster than an E3.

#### Highlights:

* Each E line circuit level is composed of 30 digital signal channels, called DS0 channels; 30 DS0s make up a DS1 channel.
* An E1 is composed of 30 DS0 channels and provides 2.048 Mbps speed.
* An E3 is composed of 16 E1 lines and provides 34.368 Mbps speed.

### Optical carrier (OC) lines.

When are talking about fiber optic speeds, we often discuss Optical Carrier (OC) lines. The OC data transmission rates per channel are established by both the SONET and SDH networking standards. SONET is the United States’ standard and SDH is the international standard. Interestingly enough, the OC data transmission rates are the same across the two standards.

It is possible to multiplex multiple channels into the same fiber using different methods. The first method is dense wavelength-division multiplexing (DWDM). It allows for up to 32 separate channels on a single fiber cable. The alternative is coarse wavelength-division multiplexing (CWDM), which allows for up to eight separate channels on a single fiber optic cable.

There are numerous OC line options. An OC1 is capable of 51.84 megabits per second in speed. An OC3 provides speeds of up to 155.52 megabits per second. OC12s are becoming more common; they provide speeds up to 622.08 megabits per second.

If gigabit type speed is required, leasing an OC48 may be an option. An OC48 provides up to 2.488 gigabits per second in bandwidth. Currently, the OC192, which provides speeds up to 9.953 gigabits per second, is the fastest line available. An OC192 essentially provides 10 gigabits per second worth of bandwidth.

#### Highlights:

* The OC data transmission rates per channel are established by both the SONET (United States) and SDH (international) networking standards. These rates are the same across the two standards.
* Using dense wavelength-division multiplexing (DWDM) allows for up to 32 separate channels on a single fiber cable.
* Using coarse wavelength-division multiplexing (CWDM) allows for up to eight separate channels on a single fiber cable.
* The two most common OC lines are OC1 (which provides 51.84 Mbps speed) and the OC3 (which provides 155.52 Mbps speed).

## Leased line communication protocol.

The Point-to-Point Protocol (PPP) is a common data link layer (OSI Layer 2) protocol that is used with leased line networks. PPP simultaneously transmits multiple Layer 3 protocols (e.g., IP and IPX) through the use of control protocols (which are specific to the Layer 3 protocol being transmitted).

PPP includes a feature called Multilink PPP, which allows for multiple physical interfaces to be bonded together and act as a single logical interface—effectively increasing the available bandwidth.

#### Highlights:

* PPP is a common data link layer, or Layer 2, protocol that is used with leased line networks.
* PPP can simultaneously transmit multiple Layer 3 protocols.

# Circuit switched vs. packet switched networks.

WAN connections are either circuit switched or packet switched. What is implemented will depend upon the needs of the network and on budget considerations.

## Circuit switched networks.

Circuit switched networks have a dedicated circuit between two endpoints that is used for communication. While set up, the circuit can only be used for communication between those ends. Circuit switched networks are most common in networks with leased line communication channels. They are best used when there needs to be a fair amount of continuous data traffic between the endpoints. With circuit-switched networks, there is only one path for the data to take. Due to the dedicated circuit required, circuit-switched networks tend to be the more expensive connection type.

#### Highlights:

* Circuit switched networks have a dedicated circuit (connection) between two endpoints used for communication.
* Circuit switched networks are most common in networks with leased line communication.
* Best use is when there needs to be a fair amount of continuous data traffic between two points, as there is only one communication path.

## Packet switched networks.

In packet switched networks, data is broken up into smaller chunks and moved through the network, only to be reassembled at the other end. The data is routed using the destination address and the data may make take different paths through the network through which it is traveling. As a general rule, packet switched networks are less expensive to maintain, because the user doesn't have to maintain a dedicated circuit 24/7. Instead, users only pay for what they use.

#### Highlights:

* In packet switched networks, data is broken up into smaller chunks and moved through the network, only to be reassembled at the other end.
* Data traffic is routed using the destination address and the data may take different paths through the network.
* As a general rule, packet switched networks are less expensive to maintain.

# Frame relay vs. Asynchronous Transfer Mode.

Packet switched networks allow for greater flexibility in how the data is transmitted. Frame relay and Asynchronous Transfer Mode (ATM) are two common options. The option chosen will depend on the needs of the network and/or the required efficiency.

## Frame relay.

Frame relay is a WAN technology in which variable length packets are switched across a network. Frame relay is less expensive than leased lines. And frame relay can be made to look like a leased line through virtual circuits (VCs). A frame relay network will track a VC using a data link connection identifier (DLCI) to identify the ends of the VC.

There are two terms associated with frame relay that should be noted. The first is access rate, which is the maximum speed of the frame relay interface. The other term is the committed information rate (CIR), which is the guaranteed bandwidth that a customer receives. This is the minimum speed of a frame relay network. The access rate may actually be higher, but the customer is always guaranteed the committed information rate.

#### Highlights:

* Frame relay is a WAN technology in which variable length packets are switched across a network.
* Can be made to look like a leased line through the use of a VC.
	+ Frame relay tracks a VC using a DLCI.
* The access rate is the maximum speed of the frame relay interface.
* The CIR is the guaranteed bandwidth (may go faster but never slower).

## Asynchronous Transfer Mode (ATM).

Asynchronous Transfer Mode (ATM) is a WAN technology in which fixed length cells are switched across a network. These cells are always 53 bytes long. ATM can handle real time voice and video because it is very fast. Unfortunately, the strict 53-byte requirement results in poor bandwidth utilization. Common speeds on an ATM network are 51.84 megabits per second and 155.52 megabits per second.

#### Highlights:

* ATM is a WAN technology in which fixed length cells (53 bytes long) are switched across a network.
* Can handle real time voice and video.
* Very fast technology with poor bandwidth utilization.
* Common ATM speeds are 51.84 Mbps and 155.52 Mbps.

# Multiprotocol Label Switching (MPLS).

Multiprotocol Label Switching (MPLS) is a topology that is growing in popularity. The reason for its growing popularity is that it is scalable and it is protocol independent. MPLS can be used to replace both frame relay switching and ATM switching. It can be used to packet switch both frame relay and ATM network traffic. This allows MPLS to be used with both frame relay and ATM technologies.

MPLS is often used to improve Quality of Service (QoS) and flow of network traffic. It uses a label edge router (LER) to add MPLS labels to incoming packets if they don't have them. The label edge router then passes those packets on to a label switching router (LSR). The LSR forwards those packets, based on their MPLS labels, to their final destination.

#### Highlights:

* MPLS is a topology that is growing in popularity because it is scalable and is protocol independent.
* It can also be used to packet switch both frame relay and ATM network traffic. This allows MPLS to be used in conjunction with both frame relay and ATM technologies.
* MPLS is used to improve the QoS and flow of network traffic.
* The LER adds MPLS labels to incoming packets, and the LSR forwards packets based on their MPLS labels.

# What was covered.

## Public switched telephone network.

One of the best indications of a WAN is if the infrastructure is not owned by a single entity. The PSTN is one of the most widely used WAN infrastructures. The PSTN can be used to carry analog traffic through a dial-up connection or digital traffic through ISDN or xDSL connections.

## Broadband cable.

Cable companies can provide broadband cable connections to customers. These are capable of carrying voice, data, and television—all through the same cable. The signal is formatted at the headend and delivered to the distribution network to be sent on to the end users. The end users all share the bandwidth of the distribution network.

## Fiber.

Fiber is a fast, high bandwidth WAN technology that uses light to transmit voice and data down a fiber optic cable. It is capable of achieving multiple gigabit transmission levels. SONET (in the U.S.) and SDH establish the base rates of the OC levels. DWDM and CWDM are the methods used to multiplex multiple OC levels into a single fiber optic cable.

## GSM/CDMA WAN connections.

GSM and CDMA are the two main methods of connecting cellular devices to cellular networks and they are not compatible. True WAN cellular connections were not available until HSPA+, which is a stopgap measure between 3G and 4G networking. The emerging standard for cellular networking is 4G, which currently consists of LTE and WiMAX.

## WiMAX WAN connections.

WiMAX was originally designed as a last mile solution for areas in which DSL and cable were not available. It utilizes microwave signals between line-of-sight relay stations to deliver broadband traffic to a fixed location. It is compatible with LTE, so it is considered a 4G technology. It can span significant geographic distances.

## Satellite WAN connections.

Satellite uses microwave radio transmissions as a method of transmitting data over the air. It uses microwave radio relays and satellites to span large distances that are still line of site. These vast distances often lead to latency in the transmissions.

## Metro Ethernet WAN connections.

In a metro Ethernet environment, the service provider supplies the customer with what appears to be an Ethernet connection to the network. While the customer views the connection as being Ethernet, the service provider may use a variety of different WAN technologies, depending on the level of service required.

## Leased line WAN connections and standards.

A leased line is a dedicated connection between two end nodes that the customer leases from a telecommunications company. Usually, it will either utilize POTS or a fiber optic connection. A T-carrier line is composed of 24 DS0 channels, each capable of handling 64 Kbps. The 24 DS0 channels make up a single DS1 line, which is also known as a T1. A T3 line is composed of 28 T1 lines. The most common T-carrier lines are T1 (1.544 Mbps) and T3 (44.736 Mbps). An E-carrier line is composed of 30 DS0 channels and is capable of handling 64 Kbps. The 30 DS0 channels make up a single DS1 line, which is also known as an E1. An E3 line is composed of 16 E1 lines. The most common E-carrier lines are the E1 (2.048 Mbps) and the E3 (34.368 Mbps). OC levels are established by SONET and SDH and may use CWDM or DWDM to increase capacity on a cable. The two most common OC lines are the OC1 (51.84 Mbps) and OC3 (155.52 Mbps).

## Circuit switched vs. packet switched networks.

A circuit switched network involves a dedicated point-to-point connection between two nodes. They are commonly used with leased line networks. In a packet switched network, data is broken down into smaller packets and routed through the network using the destination address. The data may take differing paths to reach the final destination.

## Frame relay vs. Asynchronous Transfer Mode.

Frame relay is a packet switching technology in which network packets can be different sizes. Frame relay may be set up to mimic a circuit switched network. ATM technology uses a fixed cell size (53 bytes) to quickly move network traffic. While ATM is a fast technology, it doesn’t use the available bandwidth efficiently due to the fixed size of all of the cells.

## Multiprotocol Label Switching.

MPLS is a WAN packet switching technology that has gained in popularity because of its scalability and protocol independence. It can be used to replace both frame relay and ATM, or it can be used in conjunction with either or both of those technologies. It uses LERs to insert MPLS labels into packets and LSRs to route the packets to their destinations.