Unit 2: Wide Area Networks

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6G7Z1004: ADVANCED COMPUTER NETWORKS AND OPERATING SYSTEMS

After reading this unit and completing the exercises, you will be able to:

1. Identify a variety of uses for WANs
2. Explain different WAN topologies, including their advantages and disadvantages
3. Compare the characteristics of WAN technologies, including their switching type, throughput, media, security, and reliability
4. Describe several WAN transmission and connection methods, including PSTN, ISDN, T-carriers, DSL, broadband cable, ATM, and SONET

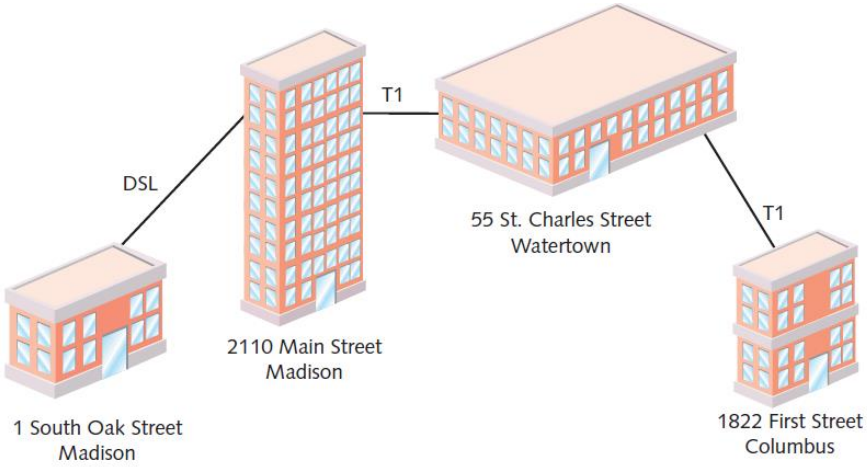
WAN Essentials

- A WAN is a network that traverses some distance and usually connects LANs, whether across the city or across the nation
- WANs arise from the simple need to connect one location to another
- Depending on the traffic load, budget, geographical breadth, and commercially available technology, organisations implement a different transmission method
- LANs and WANs often differ at Layers 1 and 2 of the OSI model in access methods, topologies, media and the extent to which the organization that uses the network is responsible for the network

WAN Topologies

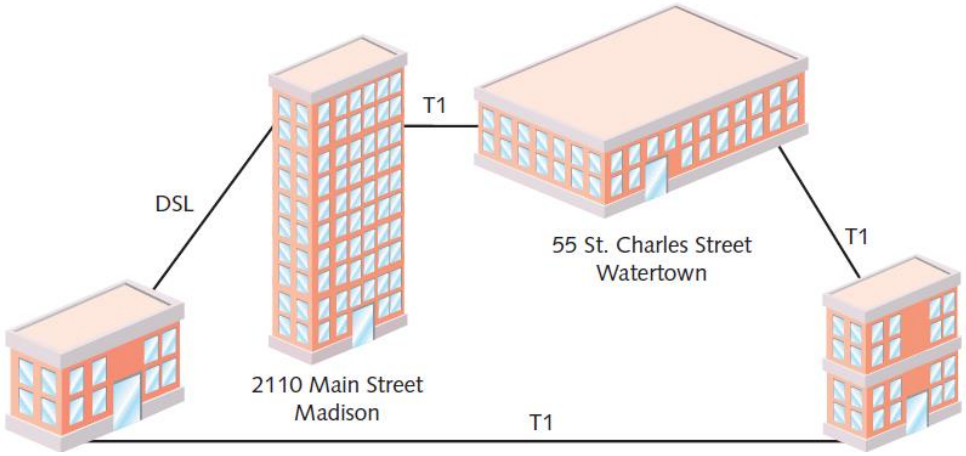
WAN topologies resemble LAN topologies, but their details differ because of the distance they must cover, the larger number of users they serve, and the heavy traffic they often handle

WAN Topologies:
Bus



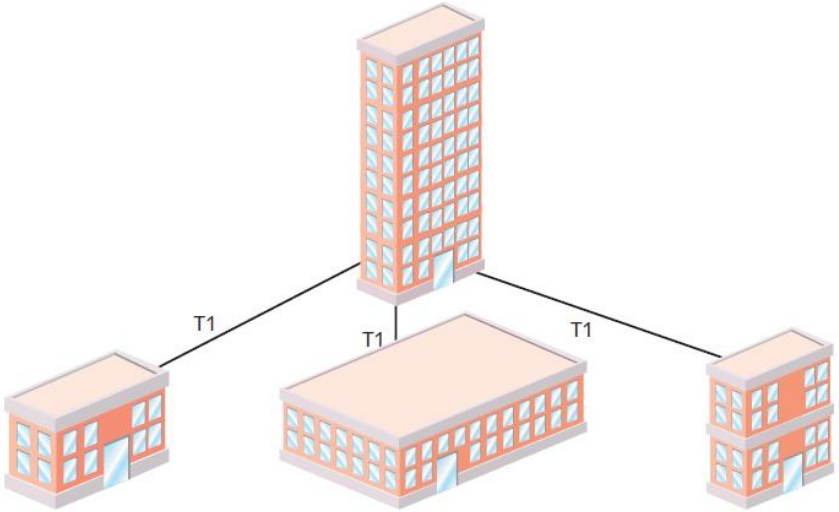
- Suitable for organizations with only a few sites and the capability to use dedicated circuits
- Because all sites between the sending and receiving location must participate in carrying traffic, this model does not scale well
- Adding more sites can cause performance to suffer
- A single failure on a bus topology WAN can take down communications between all sites.

WAN Topologies:
Ring



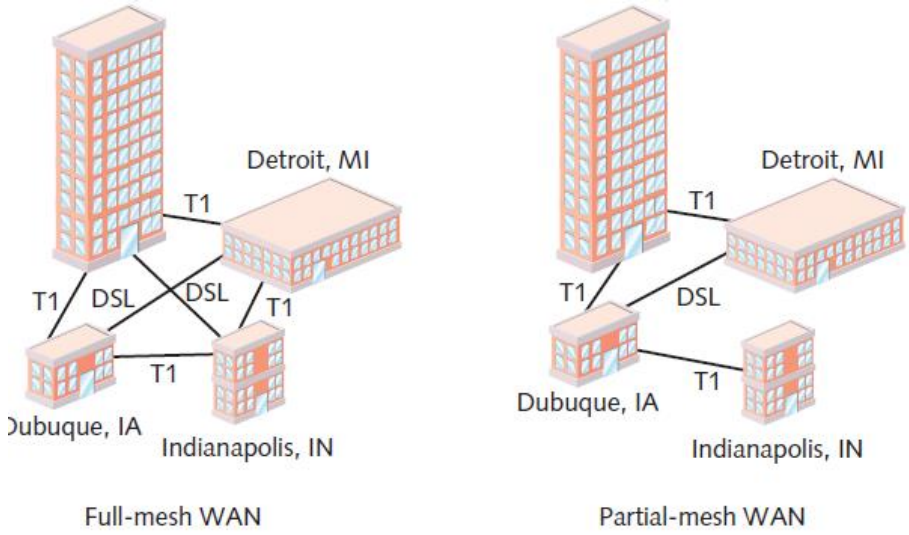
- Each site is connected to two other sites so that the entire WAN forms a ring pattern
- Expanding ring-configured WANs can be difficult and expensive

WAN Topologies:
Star



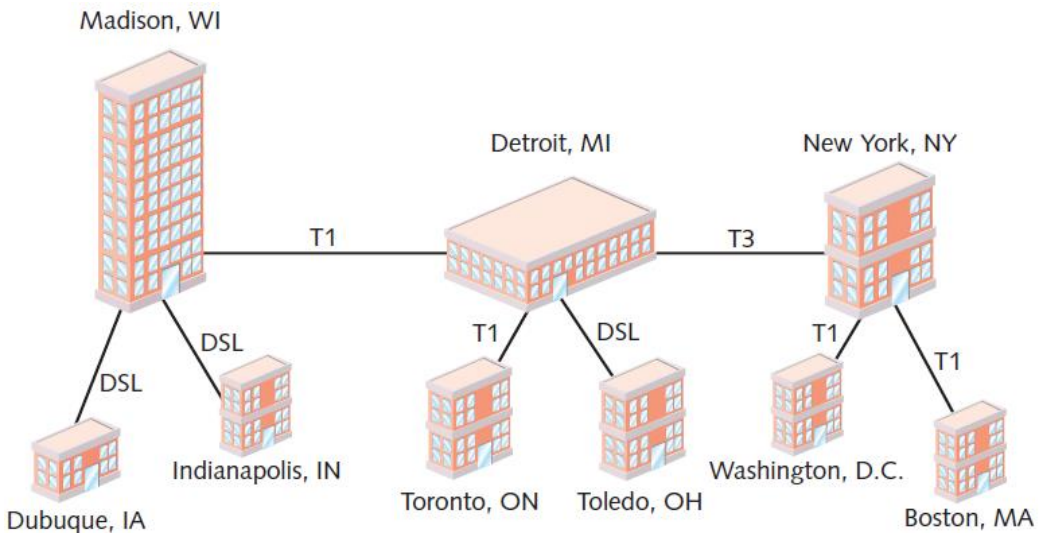
- A single site acts as the central connection point for several other points
- Provides shorter data paths between any two sites
- Extending a star WAN is relatively simple and less costly
- Failure at the central connection point can bring down the entire WAN

WAN Topologies:
Mesh



- A mesh topology WAN incorporates many directly interconnected sites
- The most fault-tolerant type of WAN
- One drawback to a mesh WAN is the cost

WAN Topologies:
Tiered



- WAN sites connected in star or ring formations are interconnected at different levels, with the interconnection points being organized into layers to form hierarchical groupings
- Flexibility makes the tiered approach practical. A network architect can determine the best placement of top-level routers based on traffic patterns or critical data paths
- Tiered systems allow for easy expansion and inclusion of redundant links to support growth

WAN Technologies

WAN technologies differ in terms of speed, reliability, cost, distance covered, and security

Some are defined by specifications at the Data Link layer, whereas others are defined by specifications at the Physical layer of the OSI model

PSTN

Public Switched Telephone Network (PSTN) may also be called POTS (Plain Old Telephone Service)

Refers to the network of lines and carrier equipment that provides telephone service to most homes and businesses

PSTN - History

In the 1990s, most home users logged on to the Internet via a dial-up connection

- A user connects her computer, via a modem, to a distant network and stays connected for a finite period of time
- *Modem* is always necessary

PSTN - Switching

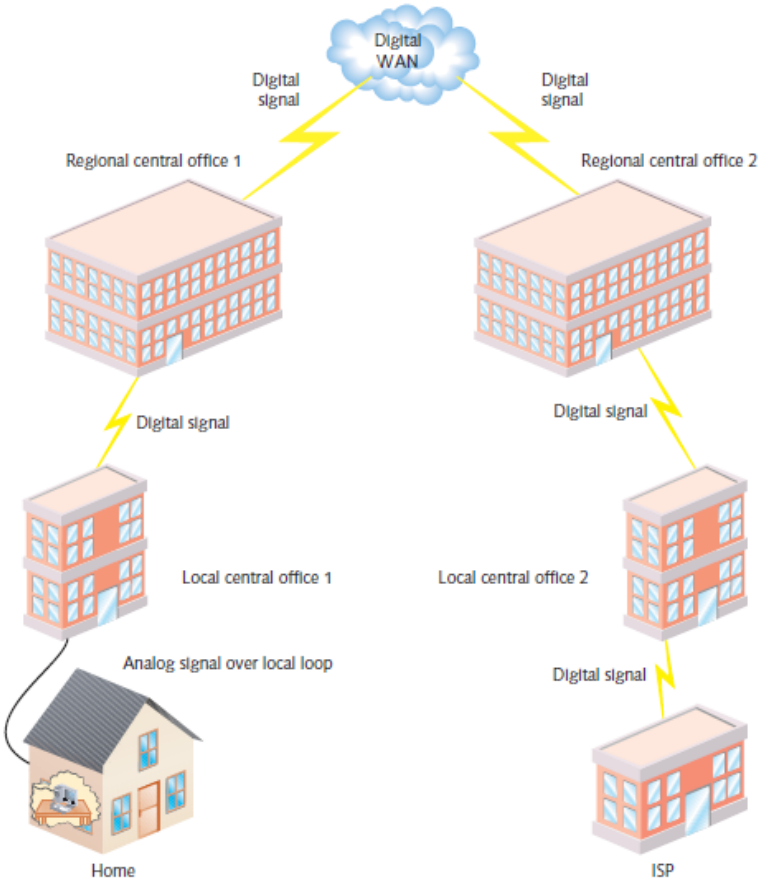
Handled by operators who manually connected calls upon request

Computer controlled

Dial-up connection

1. Initiate a call through your computer's dial-up software
2. Modem establish a connection
3. Signal reaches the Central Office (CO)
   - The CO is the place where the telephone company terminates and switches lines
4. At the CO, the signal is converted back to digital pulses
5. The signal is switched from your incoming connection (directly or indirectly) to the ISP

A long distance dial-up connection



The last mile

Local loop: The portion of the PSTN that connects any premise to the nearest CO

Most likely use copper wire and carry analog signals

Example: FTTH (fiber to the home) or FTTP (fiber to the primises)

PON (passive optical network)

- A network in which a carrier uses fiber-optic cabling to connect multiple endpoints
- **Passive**: in PON no connectivity devices intervene between the carrier and its customers
- The PON consists of fiber-optic distribution cable leading to the vicinity of its many subscribers
- Fiber-optic local loop may be part of a PON

OLT (optical line terminal)

In the point-to-multiple structure of a PON, OLT is the single point at the carrier's central office

OLT is a device with multiple optical ports or PON interfaces

ONU (optical network unit)

At the subscribers side, the connection terminates at an ONU (optical network unit)

The OLT contains a splitter that subdivides the capacity of each port into up to 32 logical channels

PONs Transmission Technologies

It can handle one of several transmission technologies

The carrier controls which standard and the throughput

X.25

Standardized by ITU in the mid-1970s

Analog, packet-switched technology designed for log-distance data transmission

Maximum throughput of 2.048 Mbps

It was developed as a more reliable alternative to the voice telephone system for connecting mainframe computers and remote terminals.

X.25 (Cont'd)

- The X.25 standard specifies protocols at Layers 1 - 3 of the OSI model
- It provides excellent flow control and ensures data reliability over long distances
- X.25 comparatively slow and unsuitable for time-sensitive applications, such as audio or video
- X.25 benefits from being a long-established, well-known, and low-cost technology
- X.25 was never widely adopted in the USA, but was accepted by other countries and was for a long time the dominant packet-switching technology used on WANs around the world

Frame Relay

ITU and ANSI standardized frame relay in 1984

Operates at the Data Link layer of the OSI model and can support multiple different Network and Transport layer protocols

The name is derived from the fact that data is separated into frames, which are then relayed from one node to another without any verification or processing

Frame Relay (Cont'd)

Does not guarantee reliable delivery of data

Simply checks for errors. It leaves the error correction up to higher-layer protocols

Supports higher throughput than X.25. It offers throughputs between 64 Kbps and 45 Mbps

Both X.25 and frame relay rely on virtual circuits

X.25 and Frame Relay Configuration

X.25 and frame relay may be configured as:

1. SVCs (switched virtual circuits)
   - are connections that are established when parties need to transmit then terminated after the transmission is complete

2. PVCs (permanent virtual circuits).
   - are connections that are established before data needs to be transmitted and maintained after the transmission is complete
   - the connection is established only between the two points (the sender and receiver)

Frame Relay Advantages

The advantage to leasing a frame relay circuit over leasing a dedicated service :

- is that you pay for only the amount of bandwidth required
- is less expensive than some other WAN technologies, depending on your location and its network availability
- is a long-established worldwide standard

Frame Relay Drawbacks

Throughput remains at the mercy of variable traffic patterns

Because of a lack of compatibility with other WAN technologies at the time, frame relay did not become popular in north America until the late 1980s

Frame relay circuits are not as private (and potentially not as secure) as dedicated circuits

ISDN

- ISDN (Integrated Services Digital Network) is an international standard, originally established by the ITU in 1984

- Specifies protocols at the Physical, Data Link, and Transport layers of the OSI model
  - handle signalling, framing, connection setup and termination, routing, flow control, and error detection and correction

ISDN Connections

can be either dial-up or dedicated

- Dial-up ISDN relies exclusively on digital transmission
- It can simultaneously carry as many as two voice calls and one data connection on a single line

ISDN Channels

B channel is the “bearer” channel

- employing circuit-switching techniques to carry voice, video, audio, and other types of data
- a single B channel has a maximum throughput of 64 Kbps

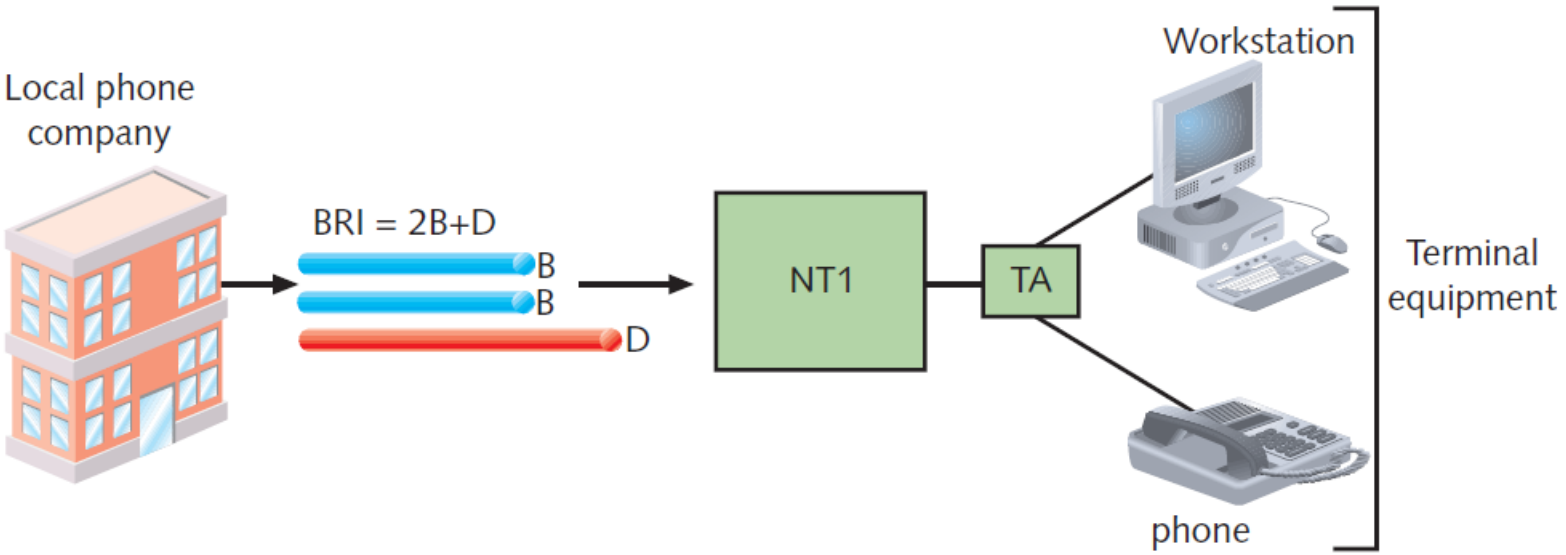
D channel is the “delta” channel

- employing packet-switching techniques to carry information about the call, such as session initiation and termination signals, caller identity, call forwarding, and conference calling signals
- a single D channel has a maximum throughput of 16 or 64 Kbps
- each ISDN connection uses only one D channel.

Types of ISDN Connections

BRI (Basic Rate Interface)

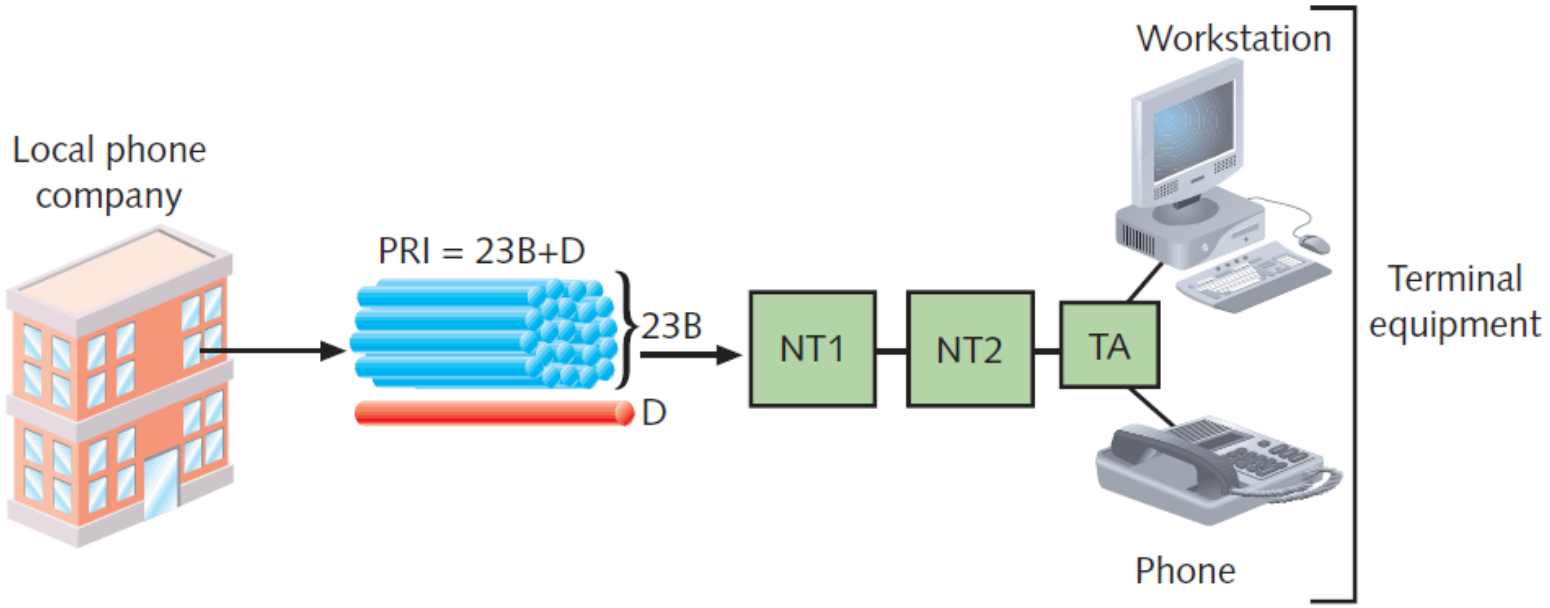
- 2B+D



Types of ISDN Connections

PRI (Primary Rate Interface)

- 23B+D



T-Carriers - Overview

- T-carrier standards specify a method of signalling, which means they belong Layer 1 of the OSI model
- A T-carrier uses TDM (time division multiplexing) over two wire pairs (one for transmitting and one for receiving) to divide a single channel into multiple channels
- T1 circuit carry 24 channels, each capable of 64-Kbps throughput; maximum capacity $= \ 24 \ \times \ 64 \ Kbps \ = 1.544 \ Mbps$
- Each channel may carry data, voice, or video signals

The Speed of T-carriers

The speed of a T-carrier depends on its signal level

The signal level refers to the T-carrier's Physical layer electrical signaling characteristics as defined by ANSI standards

DS0 (digital signal, level 0) is the equivalent of one data or voice channel

Carrier Specifications

Signal level	Carrier	Number of T1s	Number of channels	Throughput (Mbps)
DS0	—	1/24	1	.064
DS1	T1	1	24	1.544
DS1C	T1C	2	48	3.152
DS2	T2	4	96	6.312
DS3	T3	28	672	44.736
DS4	T4	168	4032	274.176
DS5	T5	240	5760	400.352

E-Carrier

# DS-0 Signals	bps	MUX'ed Equivalent	E Carrier Designation
1	64 Kbps	1 DS-0	--
32	2.048 Mbps	32 DS-0	E1
128	8.448 Mbps	4 E-1's	E2
512	34.368 Mbps	16 E-1's	E3
2048	139.264 Mbps	4 E-3's	E4
8192	565.148 Mbps	4 E-4's	E5

DSL (digital subscriber line)

It can span only limited distances without the help of repeaters

It can support multiple data and voice channels over a single line

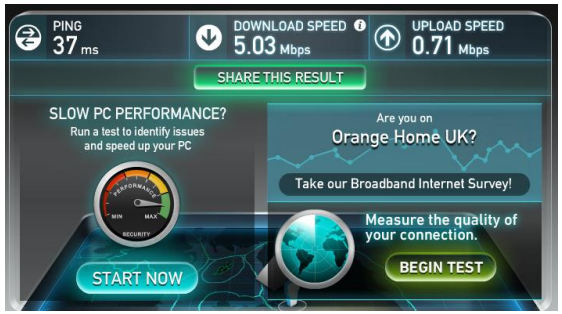
It uses advanced data modulation techniques (at Layer 1) to achieve extraordinary throughput over regular telephone lines

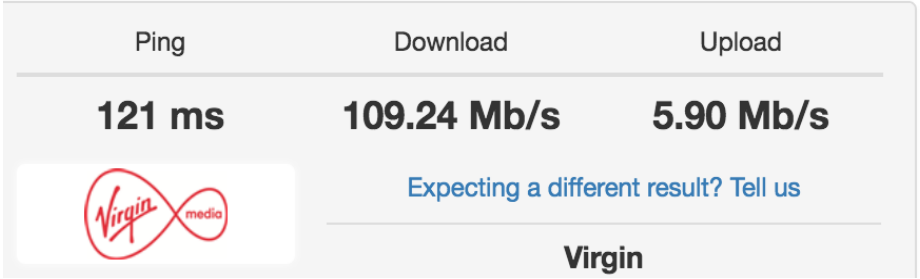
DSL Types

DSL type	Maximum upstream throughput (Mbps)	Maximum downstream throughput (Mbps)	Distance limitation (feet)
ADSL ("full rate")	0.640	6.144	18,000
G.Lite (a type of ADSL)	0.512	1.544	25,000
HDSL or HDSL-2	1.544 or 2.048	1.544 or 2.048	18,000 or 12,000
SDSL	1.544	1.544	12,000
SHDSL	2.36 or 4.7	2.36 or 4.7	26,000 or 18,000
VDSL	1.6, 3.2, or 6.4	12.9, 25.9, or 51.8	1000–4500

Broadband Cable

- is a dedicated service that relies on the cable wiring used for TV signals
- can theoretically provide as much as 36-Mbps downstream and 10-Mbps upstream throughput





Broadband Cable (Cont'd)

- Broadband cable connections require that the customer use a special cable modem to transmit and receive signals over coaxial cable wiring

- In addition, cable companies must have replaced their coaxial cable plant with hybrid fiber-coax cable to support bidirectional, digital communications

ATM (Asynchronous Transfer Mode)

A Data Link layer standard that relies on fixed packets, called cells, consisting of 48 bytes of data plus a 5-byte header

It’s a connection-oriented technology based on virtual circuits

ATM guarantee QoS levels for designated transmissions

Gigabit Ethernet

Cheaper technology to replace ATM

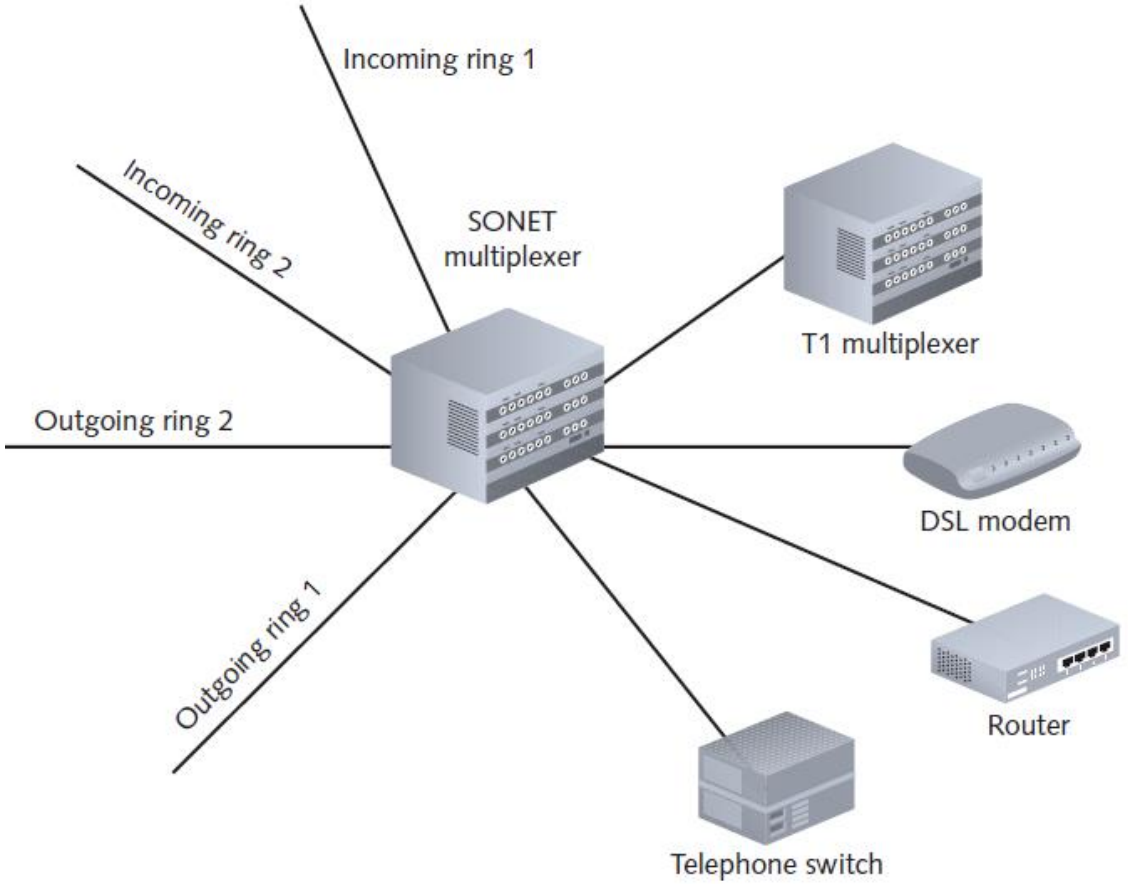
Gigabit Ethernet is a more natural upgrade for the multitude of Fast Ethernet users

It overcomes the QoS issue by simply providing a larger pipe for the greater volume of traffic using the network

SONET (Synchronous Optical Network)

- A high-bandwidth WAN signaling technique
- Specifies framing and multiplexing techniques
- Its key strengths are:
    1. it can integrate many other WAN technologies
    2. it offers fast data transfer rates
    3. it allows for simple link additions and removals
    4. it provides a high degree of fault tolerance
    5. it provides interoperability

SONET Connectivity



WAN Technologies Compared

WAN technology	Typical media	Maximum throughput
Dial-up over PSTN	UTP or STP	56 Kbps theoretical; actual limit is 53 Kbps
X.25	UTP/STP (DS1 or DS3)	64 Kbps or 2.048 Mbps
Frame relay	UTP/STP (DS1 or DS3)	45 Mbps
BRI (ISDN)	UTP/STP (PSTN)	128 Kbps
PRI (ISDN)	UTP/STP (PSTN)	1.544 Mbps
T1	UTP/STP (PSTN), microwave, or fiber-optic cable	1.544 Mbps
Fractional T1	UTP/STP (PSTN), microwave, or fiber-optic cable	*n* times 64 Kbps (where *n* = number of channels leased)
T3	Microwave link or fiber-optic cable	45 Mbps
xDSL	UTP/STP (PSTN)	Theoretically, 1.544 Mbps–52 Mbps (depending on the type), but typical residential DSL throughputs are limited to 1.5 Mbps
Broadband cable	Hybrid fiber-coaxial cable	Theoretically, 56 Mbps downstream, 10 Mbps upstream, but actual throughputs are approximately 1.5–3 Mbps upstream and 256–768 Kbps downstream
ATM	Fiber-optic cable, UTP/STP (PSTN)	25 Mbps to 622 Mbps (depending on the customer's preferred bit rate)
SONET	Fiber-optic cable	51, 155, 622, 1244, 2488, 4976, 9952, or 39813 Mbps (depending on the OC level)