Fast Ethernet

- Also called the IEEE 802.3 u standard approved in June 1995.
- Supports data transmission speed of 100 Mbps.
- Backward compatible with existing Ethernet LANs.

Fast Ethernet cabling schemes

Name	Cable	Max. Segment	Advantages
100 Base-T4	Twisted pair	100 m	Uses category 3 UTP Encoding scheme used : 8B/6T
100 Base-TX	Twisted pair	100 m	Supports full duplex at 100 Mbps Uses CAT 5 UTP Encoding scheme used : 4B/5B
100 Base-FX	Fiber optics	2000 m	Supports full duplex at 100 Mbps Long runs

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Fast Ethernet Cabling Schemes

100 Base-T4

- Uses **category 3 UTP**
- Uses a **signaling speed of 25 MHz**
- Requires **four twisted pairs** per cable.
- Of the 4 twisted pairs, one is always to the hub, one is always from the hub, and the other two are switchable to the current transmission direction.
- Ternary signals are sent, so that during a single clock period, the wire can contain a 0, a 1, or a 2.
- With 3 twisted pairs going in the forward direction and ternary signaling, any one of 27 possible symbols can be transmitted. Therefore, 4 bits can be sent with some redundancy.
- **Transmitting 4 bits in each of the 25 million clock cycles per second gives the necessary data transmission speed of 100 Mbps.**
- This **encoding scheme** is known as **8B/6T** (8 bits map to 6 trits).

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Fast Ethernet Cabling Schemes

100 Base-TX

- Uses **category 5 UTP**
- Uses a **clock rate of 125 MHz**
- **Two twisted pairs** per station are used. One to the hub and one from the hub.
- Straight binary encoding is not used.
- **Encoding scheme used is : 4B/5B**
- Every group of 5 clock periods, each containing one of two signal values, yields 32 combinations (16 out of 32 combinations are used to transmit 4 bits. Some of the remaining 16 are used for control purposes such as marking frame boundaries.).
- Supports full duplex transmission. Stations transmit at 100 Mbps and receive at 100 Mbps at the same time.

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Fast Ethernet Cabling Schemes

100 Base-FX

- Uses **two strands of multimode fiber, one for each direction.**
- Supports **full duplex transmission** with **100 Mbps in each direction.**
- **The distance between a station and a hub can be up to 2 Km.**

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Gigabit Ethernet

- Ratified by IEEE in 1998 under the name IEEE 802.3 z
- **Supports data transmission speed of 1 Gbps.**
- Backward compatible with all existing Ethernet standards.
- **Supports two different modes of operation : full-duplex mode and half-duplex mode.** The full-duplex mode allows traffic in both directions at the same time.
- All **configurations of gigabit Ethernet** are **point-to-point** rather than multidrop. In the simplest gigabit Ethernet configuration, two computers are directly connected to each other.

Gigabit Ethernet

- The more **common configuration of gigabit Ethernet** is having a switch or a hub connected to multiple computers and possibly additional switches or hubs. Each individual Ethernet cable has exactly two devices on it.
- In the **full duplex mode**, commonly, **a central switch is connected to computers (or other switches) on the periphery.** In this configuration, **all lines are buffered**, so each computer and switch is free to send frames whenever it wants to. The sender does not have to sense the channel to see if anybody else is using it because contention is not possible. Hence, the CSMA/CD protocol is not used. The line between a computer and a switch is full duplex.
- The **half-duplex mode** of operation is used when the computers are connected to a **hub** rather than a switch. **A hub does not buffer incoming frames. Instead, it electrically connects all the lines internally**, simulating the multidrop cable used in classic Ethernet. In this mode, collisions are possible, so the standard CSMA/CD protocol is required.

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Gigabit Ethernet Cabling Schemes

Name	Cable	Max. Segment	Advantages/Features
1000 Base-SX	Fiber optics	550 m	Multimode fiber (50, 62.5 microns) Uses 8B/10B encoding scheme
1000 Base-LX	Fiber optics	5000 m	Single (10 µ) or multimode (50, 62.5 µ) Uses 8B/10B encoding scheme 1.3 µ lasers operating over 10 µ fiber Best choice for campus backbones Expected to be popular
1000 Base-CX	2 Pairs of STP	25 m	Uses Shielded twisted pair Competing with high-performance fiber from above and cheap UTP from below
1000 Base-T	4 Pairs of UTP	100 m	Standard category 5 UTP Supports clock speed of 125 MHz 4 twisted pairs x 2 bits per twisted pair [illegible]r clock cycle

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Gigabit Ethernet Cabling Schemes

- Gigabit Ethernet supports both **copper** and **fiber** cabling.
- **Lasers** are used as **light source**. Two wavelengths are permitted : **0.85 microns** (short) and **1.3 microns** (long).
- Three fiber **diameters** are permitted : 10, 50 and 62.5 microns.

  10μ is for single mode and the other two for multimode. Not all six combinations are allowed. The max distance depends on the combination used.

Gigabit Ethernet Cabling Schemes

1000 Base-SX

- Uses multimode fiber (50, 62.5 microns)
- Uses an **encoding scheme** called **8B/10B**
- Each 8-bit byte is is encoded on the fiber as 10 bits.
- Since there are 1024 possible output codewords for each input byte, some guidelines are used to slelect codewords.
- 1. No codeword may have more than 4 identical bits in a row.
- 2. No codeword may have more than six 0s or six 1s.
- These choices are made to keep enough transitions in the stream to make sure the receiver stays in sync with the sender and also keep the number of 0s and 1s on the fiber as close to equal as possible. This keeps DC component as low as possible to allow it to pass through transformers unmodified.

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Gigabit Ethernet Cabling Schemes

1000 Base-CX

- Uses Shielded twisted pair
- Supports maximum length of a cable segment : 25m
- Competing with high-performance fiber from above and cheap UTP from below
- Unlikely to be used much.

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Gigabit Ethernet Cabling Schemes

1000 Base-T

- Supports maximum length of a cable segment : 100 m
- Standard category 5 UTP
- 4 pairs of UTP used
- Supports clock speed of 125 MHz
  4 twisted pairs x 2 bits per twisted pair
- = 8 data bits per clock cycle

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Communication Satellites

- A **modern artificial satellite** is typically equipped with **multiple antennas** and **multiple transponders**.
- A sattellite can be thought of as a **big microwave repeater** in the sky.
- It contains **several transponders**, each of which
- ✓ **listens** to some portion of the spectrum,
- ✓ **amplifies** the incoming signal, and then
- ✓ **rebroadcasts** it at another frequency to avoid inteference with the incoming signal.
- Can be quite large, weighing up to 4000 kg and consuming several kilowatts of electric power produced by the solar panels.
- The effects of solar, lunar, and planerary gravity tend to move satellites away from their assigned orbit slots and orientations, an effect countered by on-board rocket motors. This **fine-tuning activity** is called **station keeping.**

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Communication Satellites

The downward beams - can be **broad**, covering a substantial fraction of the earth's surface, or **narrow**, covering an area only hundreads of kilometers in diameter. This mode of operation is known as a bent pipe.

Satellite's period :

- Kepler's law : the orbital period of a satellite varies as the radius of the orbit to the 3/2 power.
- The higher the satellite, the longer the period.
- Low-orbit satellites pass out of view fairly quickly, so many of them are needed to provide continuous coverage.
- Near the surface of the earth, the period is about 90 minutes.
- At an altitude of about 35,800 km, the period is 24 hours.
- At an altitude of 3,84,000 km, the period is about 1 month.

Presence of Van Allen belts :

- Layers of highly charged particles trapped by the earth's magnetic field.

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Communication Satellites

Geostationary Satellites :

- A satellite at **an altitude of 35,800 km** in a circular equatorial orbit would appear to remain motionless in the sky, so it would not need to be tracked.
- With current technology, it is unwise to have geostationary satellites placed much closer than 2 degrees in the 360-degree equatorial plane, to avoid inteference. With a spacing of 2 degrees, there can only be 360/2 = 180 satellites.
- Each transponder can use multiple frequencies and polarizations to increase the available bandwidth.
- To prevent total chaos in the sky, orbit slot allocation is done by ITU.
- Applications / Requirements : commercial telecommunication,
- television broadcasters,
- governments,
- military

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Communication Satellites

Geostationary Satellites :

Issues :

- Orbit slots
- Frequencies
- **The principal satellite bands**

Band	Downlink	Uplink	Bandwidth	Problems
L	1.5 GHz	1.6 GHz	15 MHz	Low bandwidth; crowded
S	1.9 GHZ	2.2 GHz	70 MHz	Low bandwidth; crowded
C	4.0 GHz	6.0 GHz	500 MHz	Terrestrial interference
Ku	11 GHz	14 GHz	500 MHz	Rain
Ka	20 GHz	30 GHz	3500 MHz	Rain; Equipment cost

Low-Earth Orbit Satellites (LEO)

Low-Earth Orbit Satellites (LEO)

- Due to their rapid motion, large number of LEO satellites are needed for a complete system.
- LEO satellites are close to earth.
- They zip into and out of view very quickly.
- Ground stations do not need much power.
- Round-trip delay is only a few milliseconds.

Examples :

- **Iridium**
- **Globalstar**
- **Teledesic**

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Low-Earth Orbit Satellites (LEO)

Iridium

- Iridium project : **a chain of low-orbit satellites**
  - proposal filed by Motorola (1990) and launched in 1997
- Original proposal : 77 low-orbit satellites
- Revised version : 66 low-orbit satellites
- Basic idea : As soon as one satellite goes out of view, another would replace it.
- Positioned at an altitude of 750 km in circular polar orbits.
- **Providing worldwide telecommunication service** using hand-held devices tat communicate directly with the Iridium satellites.
- It **provides voice, data, paging, fax, and navigation service everywhere on land, sea and, air.**

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Satellites versus Fiber

- A single **fiber** has, in principle, **more potential bandwidth** than all the satellites ever launched.
- **Mobile communication** : Many people nowadays want to communicate while jogging, driving, sailing, and flying. Terrestrial fiber optic links are of no use to them, but satellite links potentially are.
- Situations in which **broadcasting** is essential :

  A message sent by a satellite can be received by thousands of ground stations at once. e.g., an organization transmitting a stream of stock, bond, or commodity prices to thousands of dealers, might find a satellite system to be much cheaper than simulating broadcasting on the ground.

Satellites versus Fiber

- **Communication in places with** hostile terrain or **a poorly developed terrestrial infrastructure** :

  e.g. Indonesia has itsown satellite for domestic telephone traffic. (13,677 islands)

- Requirement of **covering areas where obtaining the right of way for laying fiber is difficult or unduly expensive**.

- When **rapid deployment** is critical, satellites are preferred.

  e.g. military communication system.

Public Switched Telephone Network (PSTN)

- Original goal : **transmitting human voice in a more-or-less recognizable form.**
- Its **suitability for use in computer-computer communication** is **often marginal** at best, but the situation is rapidly changing with the **introduction of fiber optics** and **digital technology**.

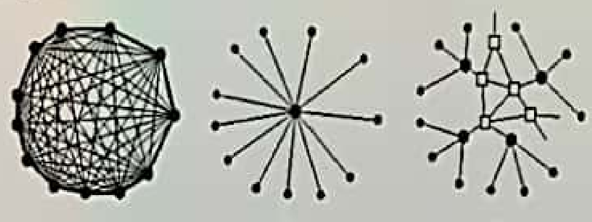
- Alexander Graham Bell patented the telephone in 1876.

Structure of a Telephone System

- The telephone was patented by Graham Bell in 1876. Initially, the telephones were sold in pairs and it was up to customer to string a single wire between them. The electrons returned thr

Bell formed also the Bell Telephone Company which opened its first switching office in New Haven, Connecticut, in 1878. To make a call, the customer would crank the phone to ring in company office where the operator manually connected the caller to the callee using a jumper cable. (Fig. 2-14(b)).

Later, the switching offices had to be connected to make long-distance calls possible. Therefore second-level switching offices became necessary (Fig. 2-14(c)) and successively the hiera levels. This scheme remained essentially intact for over 100 years.



(a) (b) (c)

Fig. 2-14. (a) Fully interconnected network. (b) Centralized network. (c) Two level hierarchy.

At present, the telephone system can be, with some simplifications, described as follows: Each telephone has two copper wires coming out of it that go directly to the telephone company's (in the US there are about 19000 end offices). The two wire connection of the telephone and end office is called local loop.

If a subscriber attached to a given end office calls another subscriber attached to the same end office, the switching mechanism within the office sets up a direct electrical connection betw loops that remains intact for the duration of the call.

If a called telephone is attached to another end office, the path will have to be established somewhere higher up in the hierarchy. There are toll offices, primary, sectional, and regional offi network by which the end offices are connected. They communicate with each other via high bandwidth interoffice trunks formed today by coaxial cables, microwaves and especially fibe

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PSTN

- Prior to 1984, the **telephone system** was **organized as a highly-redundant , multilevel hierarchy.**
- Each telephone has two copper wires coming out of it that go directly to the telephone company's nearest end office (also called a local central office). Two-wire connections between each subscriber's telephone and the end office are known in the trade as the **local loop**.

- If a subscriber attached to a given end office calls another subscriber attached to the same end office, the switching mechanism within the office sets up a direct electrical connection between the two local loops. This connection remains intact for the duration of the call.

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Comparison of Datagram Subnets and Virtual-Circuit Subnets

Issue	Datagram subnet	Virtual-circuit subnet
Circuit setup	Not needed	Required
Addressing	Each packet contains the full source and destination address	Each packet contains a short VC number
State information	Routers do not hold state information about connections	Each VC requires router table space per connection
Routing	Each packet is routed independently	Route chosen when VC is set up; all packets follow it
Effect of router failures	None, except for packets lost during the crash	All VCs that passed through the failed router are terminated
Quality of Service	Difficult	Easy if enough resources can be allocated in advance for each VC
Congestion control	Difficult	Easy if enough resources can be allocated in advance for each VC

Routing Algorithms

- Routing algorithms : generally grouped into two major classes : non-adaptive and adaptive.
- **Non-adaptive routing algorithms** do not base their routing decisions on measurements or estimates of the current traffic and topology. Instead, the choice of the **route** to use to get from I to J (for all I and J) is **computed in advance, off-line, and downloaded to the routers when the network is booted**. This procedure is sometimes called **static routing**.

- **Adaptive routing algorithms**, in contrast, change their routing decisions to reflect changes in the topology, and usually the traffic as well. Adaptive algorithms differ in where they get their information (e.g., locally, from adjacent routers, or from all routers), when they change the routes (e.g., every T sec, when the load changes or when the topology changes), and what metric is used for optimization (e.g., distance, number of hops, or estimated transit time).

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Routing Algorithms

- Shortest Path Routing
- Flooding
- Distance Vector Routing
- Link State Routing
- Hierarchical Routing
- Broadcast Routing
- Multicast Routing
- Routing for Mobile Hosts
- Routing in Ad Hoc Networks

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Shortest Path Routing

- Build a **graph** of the **subnet**.
- **Each node** of the graph represents a **router** and
  each arc represents a **communication line** (often called a **link**).
- Different **<u>metrics</u>** used **to measure path length** :
  - physical distance
  - number of hops
  - mean queueing and transmission delay

  etc.
- The **labels on the arcs** could be computed as a function of **the distance, bandwidth, average traffic, communication cost, mean queue length, measured delay, and other factors**.

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Shortest Path Routing

- Several algorithms for computing shortest path between two nodes of a graph are known.
- One well-known algorithm is from **Dijkstra (1959)**.
- Each node is labeled (in parentheses) with its distance from the source node along the best known path.
- Initially, no paths are known, so all nodes are labeled with infinity.
- As the algorithm proceeds and paths are found, the labels may change, reflecting better paths.
- A label may be either tentative or permanent.
- Initially, all labels are tentative.
- When it is discovered that a label represents the shortest possible path from the source to that node, it is made permanent and never changed thereafter.

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Shortest Path Routing

- We now start at B and examine all nodes adjacent to B.
- If the sum of the label on B and the distance from B to the node being considered is less than the label on that node, we have a shorter path, so the node is relabeled.

After all the nodes adjacent to the working node have been inspected, and the tentative labels changed if possible, the entire graph is searched for the tentatively-labeled node with the smallest value. This node is made permanent and becomes the working node for the next round.

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Flooding

- Static routing algorithm
- Every incoming packet is sent out on every outgoing line except the one it arrived on.
- Flooding generates vast numbers of duplicate packets.
- Some measures must be taken to damp the process.

e.g. Have a hop counter contained in the header of each packet, which is decremented at each hop. The packet may be discarded when the counter reaches zero.

Ideally, the hop counter should be initialized to the length of the path from source to destination.

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Selective Flooding

- In selective flooding algorithm,

  the routers do not send every incoming packet out on every line, but only on those lines that are going approximately in the right direction.

There is usually little point in sending a westbound packet on an eastbound line.

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Uses of Flooding

- In **military applications**, where large number of routers may be blown to bits at any instant, the tremendous robustness of flooding is highly desirable.
- **Distributed database applications** – to update all the databases concurrently.
- **Wireless networks** – All messages transmitted by a station can be received by all other stations within its radio range, which is in fact flooding.
- **As a metric against which other routing algorithms can be compared**

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Distance Vector Routing

- Dynamic routing algorithm
- Also known as distributed Bellman-Ford routing algorithm and the Ford-Fulkerson algorithm. It was the original ARPANET routing algorithm and was also used in the Internet under the name RIP.
- Each router maintains a table (i.e., a vector) giving the best known distance to each destination and which line t use to get there.
- These tables are updated by exchanging information with the neighbours.

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Distance Vector Routing

- Each router maintains a **routing table** indexed by, and containing one entry for, each router in the subnet.
- Each entry contains two parts : the preferred outgoing line to use for that destination and an estimate of the time or distance to that destination.
- The metric used might be

    number of hops,

    time delay in milliseconds,

    total number of packets queued along the path,

  etc.
- The router is assumed to know the "distance" to each of its neighbours.

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The Count-to-Infinity Problem

- The distance vector routing algorithm has a serious drawback.
- It reacts rapidly to good news, but leisurely to bad news
- Example
- Consider a five-node linear subnet as shown in the figure.
- Assume that the delay metric is the number of hops.
- Suppose A is down initially and all other routers know this.

  In other words, they have all recorded the delay to A as infinity.
- When A comes up, the other routers learn about it via the vector exchanges.
- At the time of first exchange, B learns that its left neighbor has zero delay to A. B now makes an entry in its routing table that A is one hop away to the left.
- All other routers still think that A is down.
- On the next exchange, C learns that B has a path of length 1 to A, so it updates its routing table to indicate a path of length 2. But D and E do not hear the good news until later.
- Clearly, the good news is spreading at the rate of one hop per exchange.

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