

Ethernet IEEE 802.3

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Ethernet

- Most successful local area networking technology of last 20 years.
- Developed in the mid-1970s by researchers at the Xerox Palo Alto Research Centers (PARC).
- Uses CSMA/CD technology
 - Carrier Sense Multiple Access with Collision Detection.
 - A set of nodes send and receive frames over a shared link.
 - Carrier sense means that all nodes can distinguish between an idle and a busy link.
 - Collision detection means that a node listens as it transmits and can therefore detect when a frame it is transmitting has collided with a frame transmitted by another node.

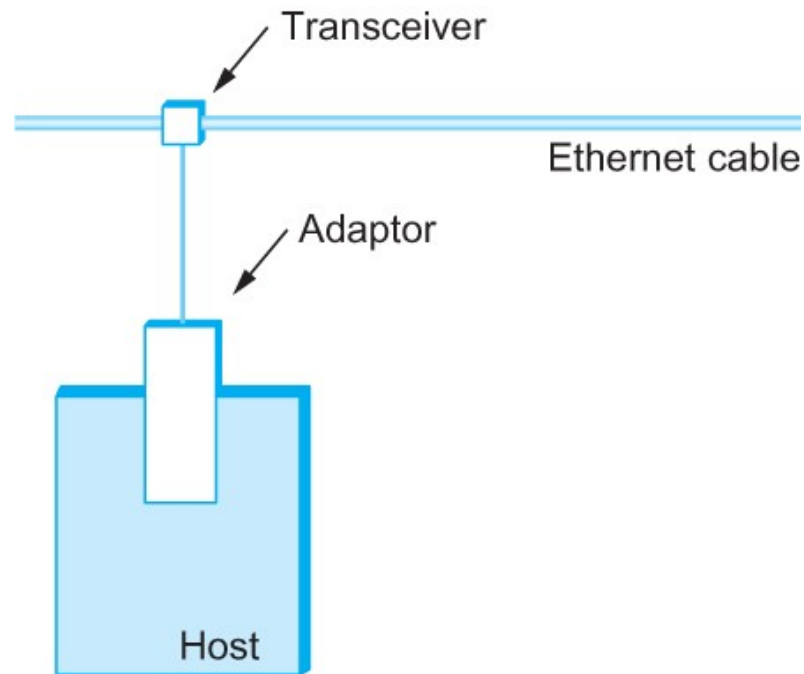
Ethernet

- Uses ALOHA (packet radio network) as the root protocol
 - Developed at the University of Hawaii to support communication across the Hawaiian Islands.
 - For ALOHA the medium was atmosphere, for Ethernet the medium is a coax cable.
- DEC and Intel joined Xerox to define a 10-Mbps Ethernet standard in 1978.
- This standard formed the basis for IEEE standard 802.3
- More recently 802.3 has been extended to include a 100-Mbps version called Fast Ethernet and a 1000-Mbps version called Gigabit Ethernet.

Ethernet

- An Ethernet segment is implemented on a coaxial cable of up to 500 m.
 - This cable is similar to the type used for cable TV except that it typically has an impedance of 50 ohms instead of cable TV's 75 ohms.
- Hosts connect to an Ethernet segment by tapping into it.
- A transceiver (a small device directly attached to the tap) detects when the line is idle and drives signal when the host is transmitting.
- The transceiver also receives incoming signal.
- The transceiver is connected to an Ethernet adaptor which is plugged into the host.
- The protocol is implemented on the adaptor.

Ethernet

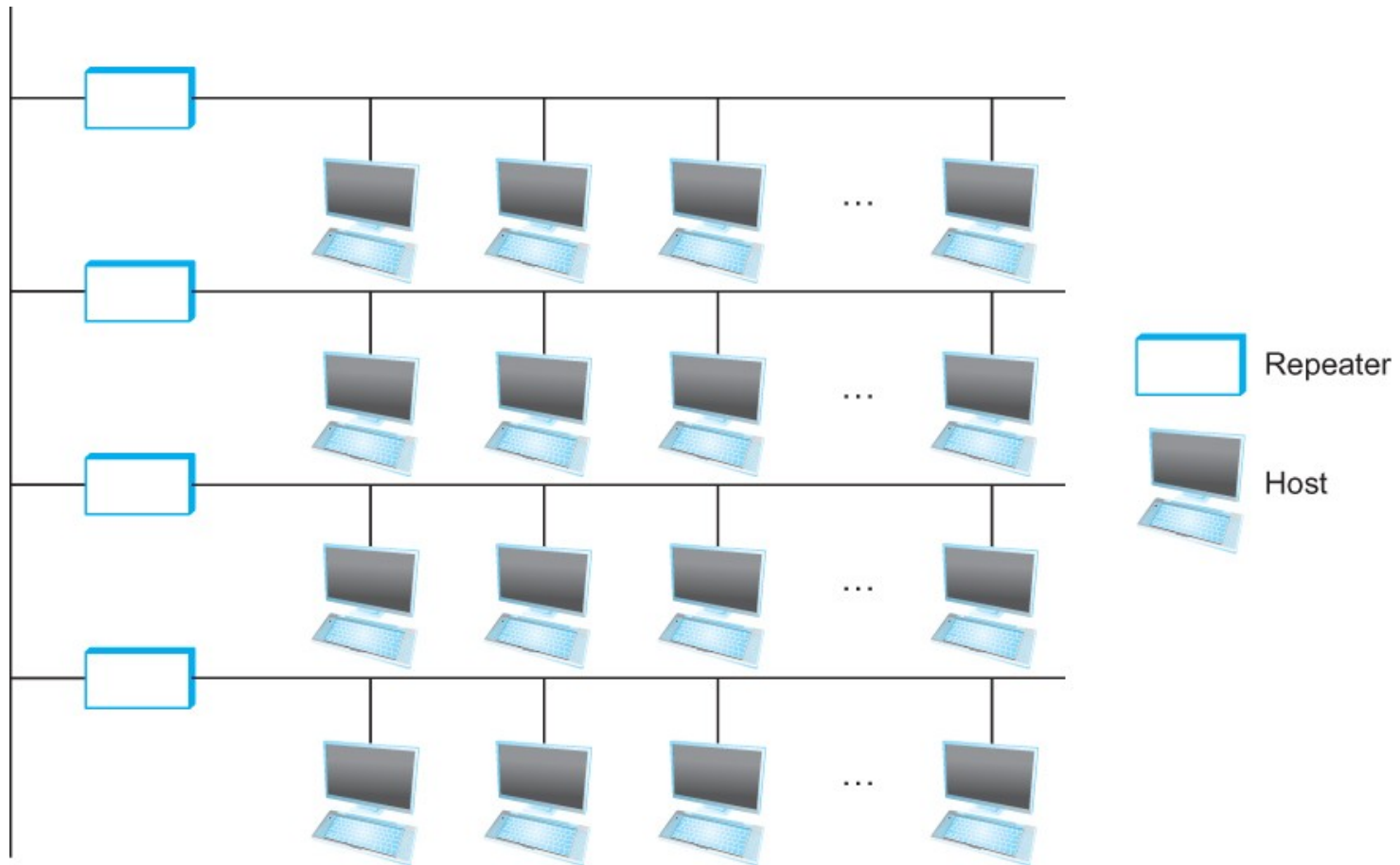


Ethernet transceiver and adaptor

Ethernet

- Multiple Ethernet segments can be joined together by *repeaters*.
- A *repeater* is a device that forwards digital signals.
- No more than four repeaters may be positioned between any pair of hosts.
 - An Ethernet has a total reach of only 2500 m.

Ethernet



Ethernet repeater

Ethernet

- Any signal placed on the Ethernet by a host is broadcast over the entire network
 - Signal is propagated in both directions.
 - Repeaters forward the signal on all outgoing segments.
 - Terminators attached to the end of each segment absorb the signal.
- Ethernet uses Manchester encoding scheme.

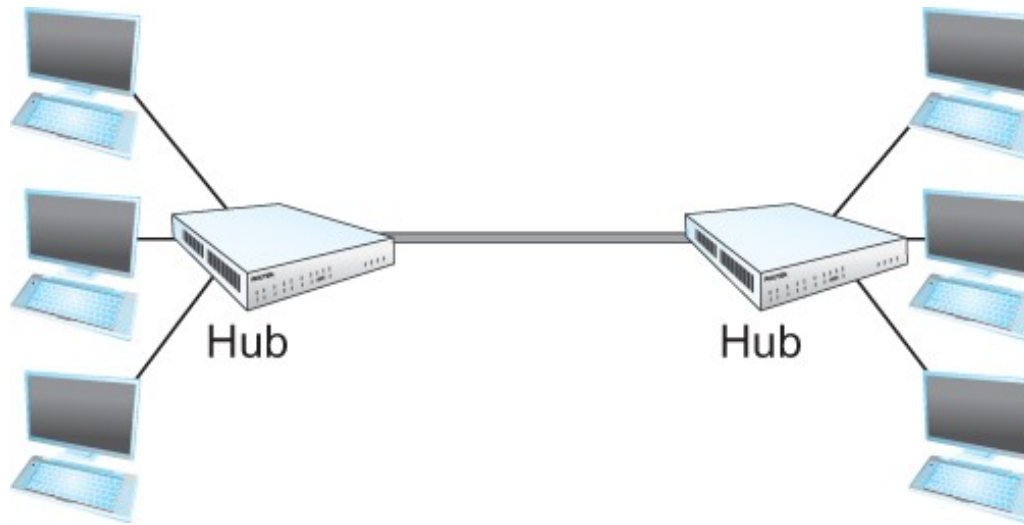
Ethernet

- New Technologies in Ethernet
 - Instead of using coax cable, an Ethernet can be constructed from a thinner cable known as 10Base2 (the original was 10Base5)
 - 10 means the network operates at 10 Mbps
 - Base means the cable is used in a baseband system
 - 2 means that a given segment can be no longer than 200 m

Ethernet

- New Technologies in Ethernet
 - Another cable technology is 10BaseT
 - T stands for twisted pair
 - Limited to 100 m in length
 - With 10BaseT, the common configuration is to have several point to point segments coming out of a multiway repeater, called *Hub*

Ethernet

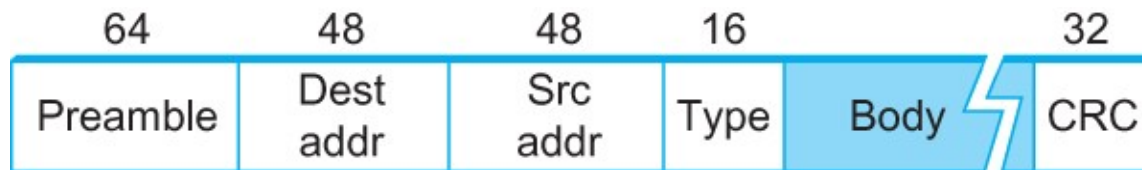


Ethernet Hub

Access Protocol for Ethernet

- The algorithm is commonly called Ethernet's Media Access Control (MAC).
 - It is implemented in Hardware on the network adaptor.
- Frame format
 - Preamble (64bit): allows the receiver to synchronize with the signal (sequence of alternating 0s and 1s).
 - Host and Destination Address (48bit each).
 - Packet type (16bit): acts as demux key to identify the higher level protocol.
 - Data (up to 1500 bytes)
 - Minimally a frame must contain at least 46 bytes of data.
 - Frame must be long enough to detect collision.
 - CRC (32bit)

Ethernet Frame



Ethernet Frame Format

Ethernet Addresses

- Each host on an Ethernet (in fact, every Ethernet host in the world) has a unique Ethernet Address.
- The address belongs to the adaptor, not the host.
 - It is usually burnt into ROM.
- Ethernet addresses are typically printed in a human readable format
 - As a sequence of six numbers separated by colons.
 - Each number corresponds to 1 byte of the 6 byte address and is given by a pair of hexadecimal digits, one for each of the 4-bit nibbles in the byte
 - Leading 0s are dropped.
 - For example, 8:0:2b:e4:b1:2 is
 - 00001000 00000000 00101011 11100100 10110001

Ethernet Addresses

- To ensure that every adaptor gets a unique address, each manufacturer of Ethernet devices is allocated a different prefix that must be prepended to the address on every adaptor they build
 - AMD has been assigned the 24bit prefix 8:0:20

Ethernet Addresses

- Each frame transmitted on an Ethernet is received by every adaptor connected to that Ethernet.
- Each adaptor recognizes those frames addressed to its address and passes only those frames on to the host.
- In addition, to *unicast* address, an Ethernet address consisting of all 1s is treated as a *broadcast* address.
 - All adaptors pass frames addressed to the *broadcast* address up to the host.
- Similarly, an address that has the first bit set to 1 but is not the *broadcast* address is called a *multicast* address.
 - A given host can program its adaptor to accept some set of *multicast* addresses.

Ethernet Addresses

- To summarize, an Ethernet adaptor receives all frames and accepts
 - Frames addressed to its own address
 - Frames addressed to the broadcast address
 - Frames addressed to a multicast address if it has been instructed

Ethernet Transmitter Algorithm

- When the adaptor has a frame to send and the line is idle, it transmits the frame immediately.
 - The upper bound of 1500 bytes in the message means that the adaptor can occupy the line for a fixed length of time.
- When the adaptor has a frame to send and the line is busy, it waits for the line to go idle and then transmits immediately.
- The Ethernet is said to be 1-persistent protocol because an adaptor with a frame to send transmits with probability 1 whenever a busy line goes idle.

Ethernet Transmitter Algorithm

- Since there is no centralized control it is possible for two (or more) adaptors to begin transmitting at the same time,
 - Either because both found the line to be idle,
 - Or, both had been waiting for a busy line to become idle.
- When this happens, the two (or more) frames are said to be *collide* on the network.

Ethernet Transmitter Algorithm

- Since Ethernet supports collision detection, each sender is able to determine that a collision is in progress.
- At the moment an adaptor detects that its frame is colliding with another, it first makes sure to transmit a 32-bit jamming sequence and then stops transmission.
 - Thus, a transmitter will minimally send 96 bits in the case of collision
 - 64-bit preamble + 32-bit jamming sequence

Ethernet Transmitter Algorithm

- One way that an adaptor will send only 96 bit (called a *runt frame*) is if the two hosts are close to each other.
- Had they been farther apart,
 - They would have had to transmit longer, and thus send more bits, before detecting the collision.

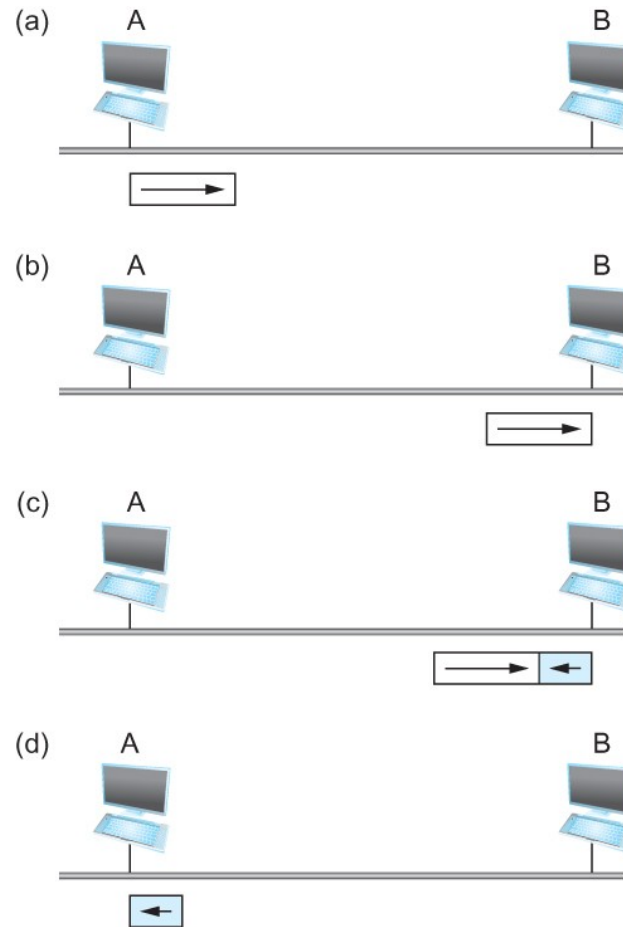
Ethernet Transmitter Algorithm

- The worst case scenario happens when the two hosts are at opposite ends of the Ethernet.
- To know for sure that the frame its just sent did not collide with another frame, the transmitter may need to send as many as 512 bits.
 - Every Ethernet frame must be at least 512 bits (64 bytes) long.
 - 14 bytes of header + 46 bytes of data + 4 bytes of CRC

Ethernet Transmitter Algorithm

- A begins transmitting a frame at time t
- d denotes the one link latency
- The first bit of A's frame arrives at B at time $t + d$
- Suppose an instant before host A's frame arrives, host B begins to transmit its own frame
- B's frame will immediately collide with A's frame and this collision will be detected by host B
- Host B will send the 32-bit jamming sequence
- Host A will not know that the collision occurred until B's frame reaches it, which will happen at $t + 2 * d$
- Host A must continue to transmit until this time in order to detect the collision
 - Host A must transmit for $2 * d$ to be sure that it detects all possible collisions

Ethernet Transmitter Algorithm



Worst-case scenario: (a) A sends a frame at time t ; (b) A's frame arrives at B at time $t + d$; (c) B begins transmitting at time $t + d$ and collides with A's frame; (d) B's runt (32-bit) frame arrives at A at time $t + 2d$.

Ethernet Transmitter Algorithm

- Consider that a maximally configured Ethernet is 2500 m long, and there may be up to four repeaters between any two hosts, the round trip delay has been determined to be $51.2 \mu\text{s}$
 - Which on 10 Mbps Ethernet corresponds to 512 bits
- The other way to look at this situation,
 - We need to limit the Ethernet's maximum latency to a fairly small value ($51.2 \mu\text{s}$) for the access algorithm to work
 - Hence the maximum length for the Ethernet is on the order of 2500 m.

Ethernet Transmitter Algorithm

- Once an adaptor has detected a collision, and stopped its transmission, it waits a certain amount of time and tries again.
- Each time the adaptor tries to transmit but fails, it doubles the amount of time it waits before trying again.
- This strategy of doubling the delay interval between each retransmission attempt is known as *Exponential Backoff*.

Ethernet Transmitter Algorithm

- The adaptor first delays either 0 or 51.2 μs , selected at random.
- If this effort fails, it then waits 0, 51.2, 102.4, 153.6 μs (selected randomly) before trying again;
 - This is $k * 51.2$ for $k = 0, 1, 2, 3$
- After the third collision, it waits $k * 51.2$ for $k = 0 \dots 2^3 - 1$ (again selected at random).
- In general, the algorithm randomly selects a k between 0 and $2^n - 1$ and waits for $k * 51.2 \mu\text{s}$, where n is the number of collisions experienced so far.

Experience with Ethernet

- Ethernets work best under lightly loaded conditions.
 - Under heavy loads, too much of the network's capacity is wasted by collisions.
- Most Ethernets are used in a conservative way.
 - Have fewer than 200 hosts connected to them which is far fewer than the maximum of 1024.
- Most Ethernets are far shorter than 2500m with a round-trip delay of closer to 5 μ s than 51.2 μ s.
- Ethernets are easy to administer and maintain.
 - There are no switches that can fail and no routing and configuration tables that have to be kept up-to-date.
 - It is easy to add a new host to the network.
 - It is inexpensive.
 - Cable is cheap, and only other cost is the network adaptor on each

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THANK YOU