Computer Network

Getting Connected

Internet Checksum Algorithm

- Not used at the link level
- Add up all the words that are transmitted and then transmit the result of that sum
  - The result is called the checksum
- The receiver performs the same calculation on the received data and compares the result with the received checksum
- If any transmitted data, including the checksum itself, is corrupted, then the results will not match, so the receiver knows that an error occurred

Reliable Transmission

- CRC is used to detect errors.
- Some error codes are strong enough to correct errors.
- The overhead is typically too high.
- Corrupt frames must be discarded.
- A link-level protocol that wants to deliver frames reliably must recover from these discarded frames.
- This is accomplished using a combination of two fundamental mechanisms **using ARQ (Automatic Repeat Request)**
  - **Acknowledgements and Timeouts**

Reliable Transmission

- An *acknowledgement* (ACK for short) is a small control frame that a protocol sends back to its peer saying that it has received the earlier frame.
  - A control frame is a frame with header only (no data/ payload).
- The receipt of an *acknowledgement* indicates to the sender of the original frame that its frame was successfully delivered.

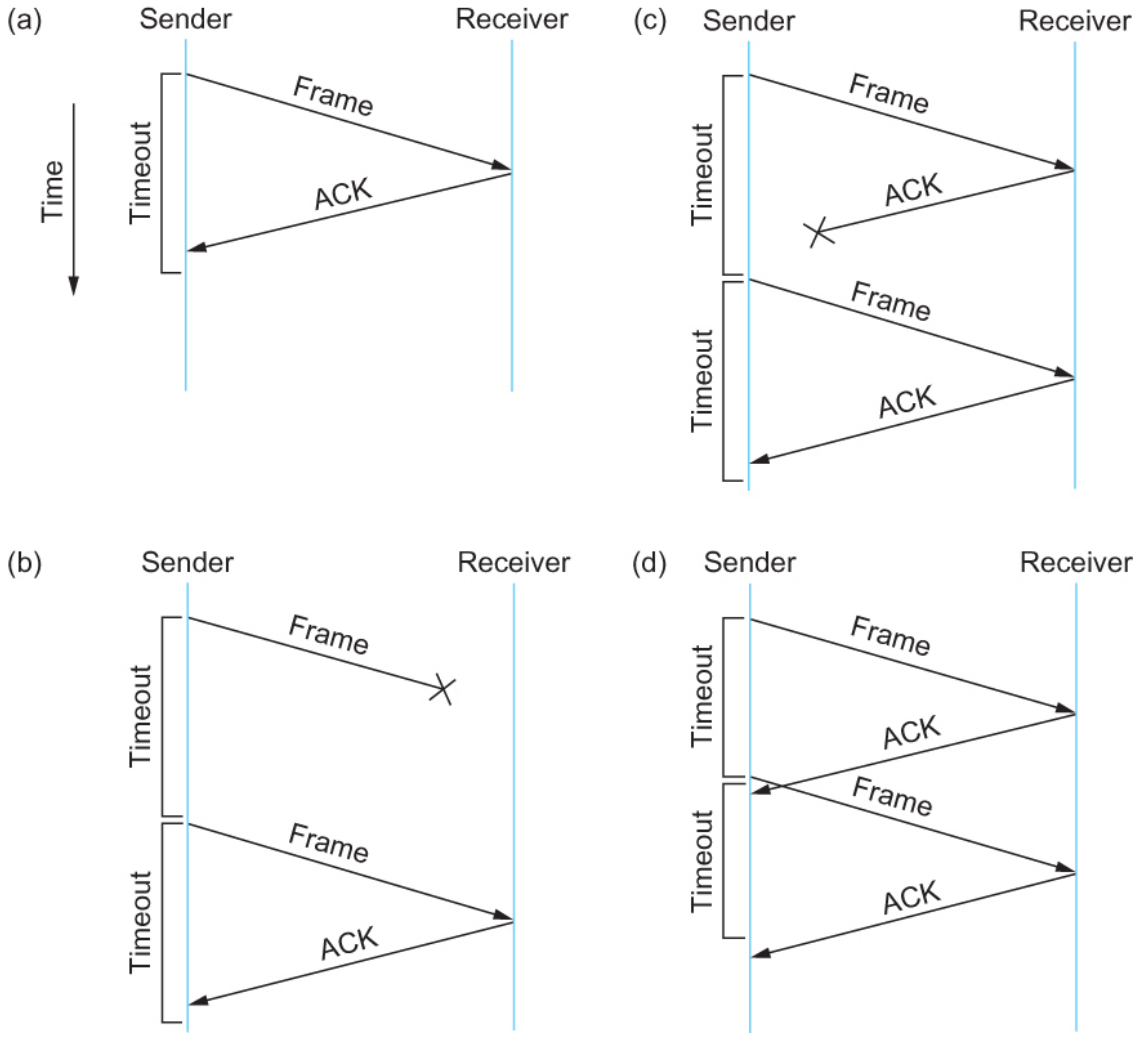
Reliable Transmission

- If the sender does not receive an *acknowledgment* after a reasonable amount of time, then it retransmits the original frame.
- The action of waiting a reasonable amount of time is called a *timeout*.
- The general strategy of using *acknowledgements* and *timeouts* to implement reliable delivery is sometimes called Automatic Repeat reQuest (ARQ).

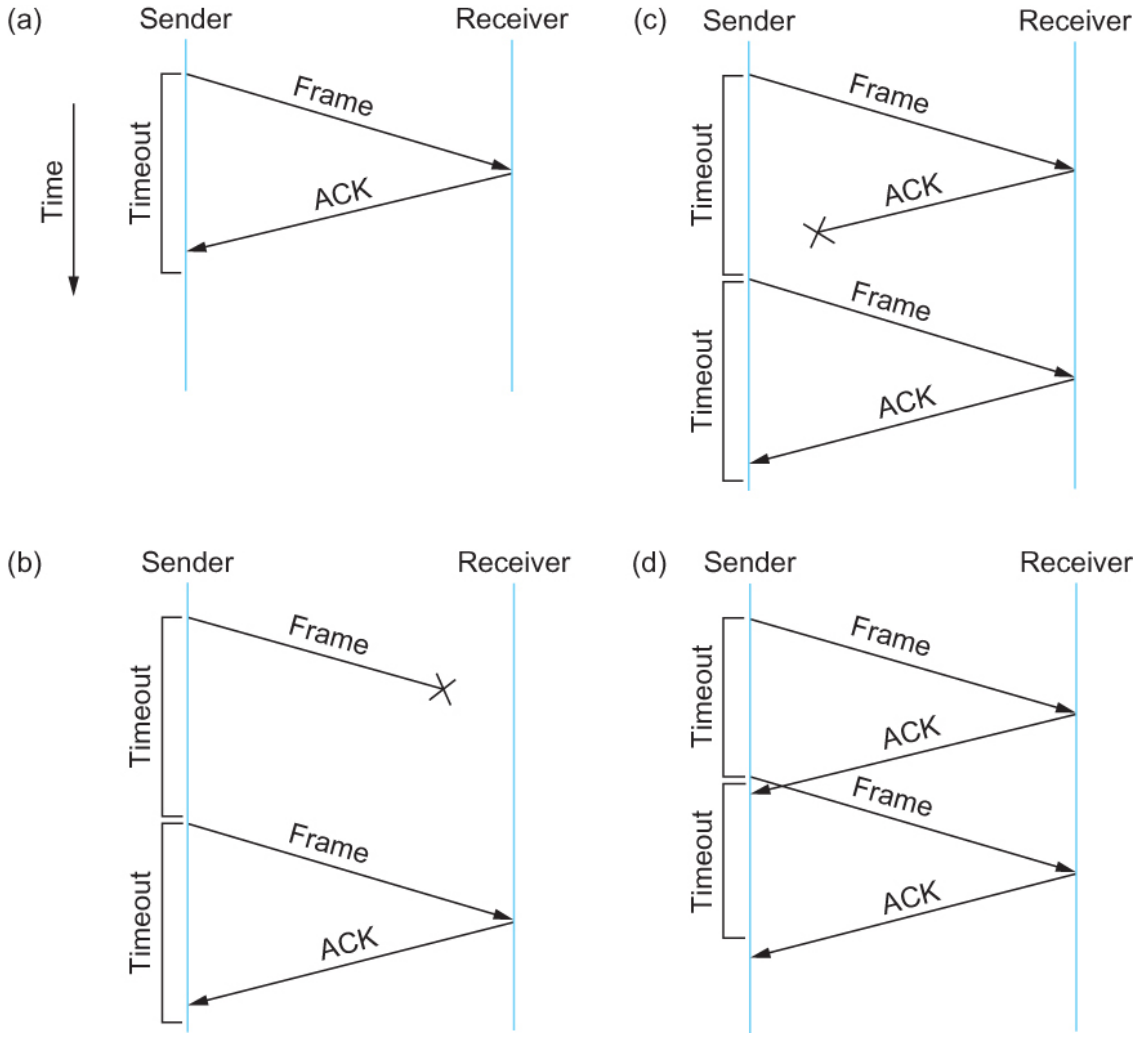
Stop and Wait Protocol

- Idea of stop-and-wait protocol is straightforward
  - After transmitting one frame, the sender waits for an acknowledgement before transmitting the next frame.
  - If the acknowledgement does not arrive after a certain period of time, the sender times out and retransmits the original frame

Stop and Wait Protocol



Stop and Wait Protocol

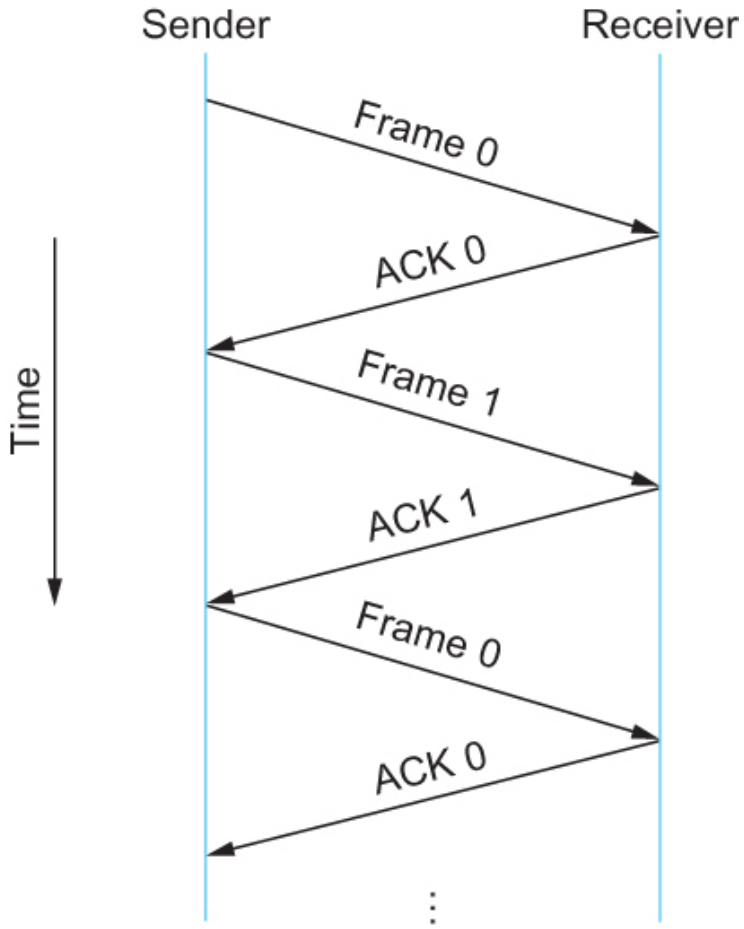


Stop and Wait Protocol

- If the acknowledgment is lost or delayed in arriving
  - The sender times out and retransmits the original frame, but the receiver will think that it is the next frame since it has correctly received and acknowledged the first frame
  - As a result, duplicate copies of frames will be delivered

- How to solve this
  - Use 1 bit sequence number (0 or 1)
  - When the sender retransmits frame 0, the receiver can determine that it is seeing a second copy of frame 0 rather than the first copy of frame 1 and therefore can ignore it
    - The receiver still acknowledges it, in case the first acknowledgement was lost

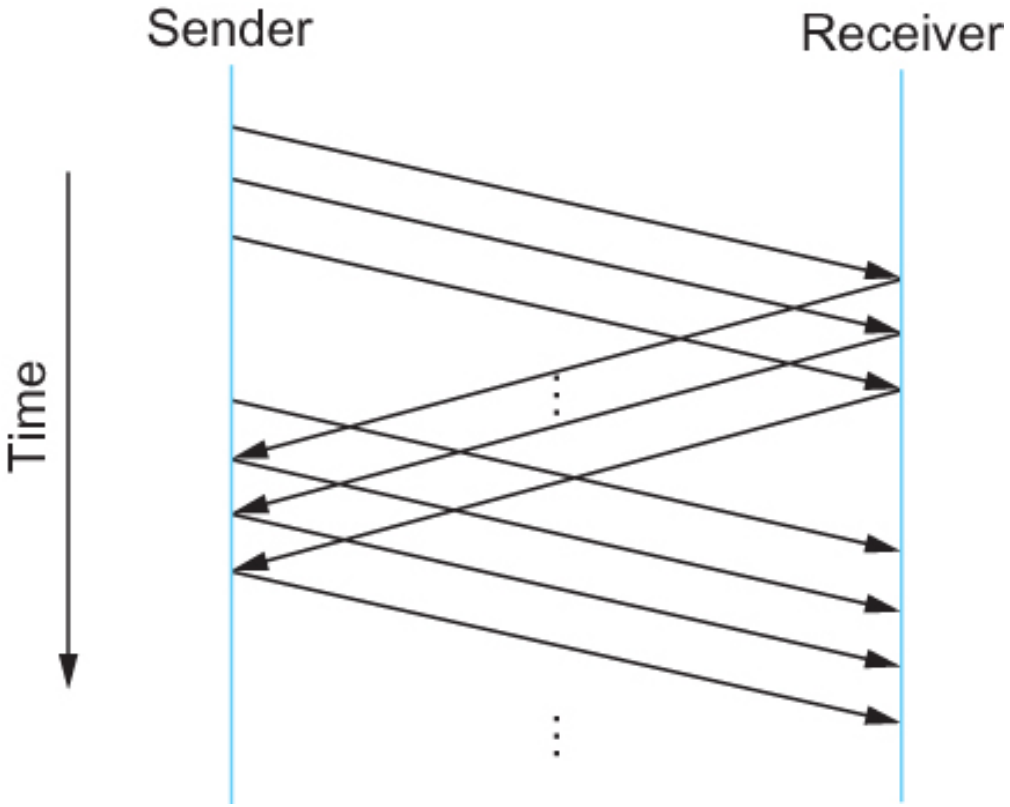
Stop and Wait Protocol



Stop and Wait Protocol

- The sender has only one outstanding frame on the link at any time
  - This may be far below the link's capacity
- Consider a 1.5 Mbps link with a 45 ms RTT
  - The link capacity can be calculated as delay × bandwidth product = 67.5 Kb or approximately 8 KB
  - (8KB)/(~1250Bytes/frame) = 6 frames
    - 6 times more frames can be supported by the link
  - To use the link fully, then sender should transmit up to six frames before having to wait for an acknowledgement

Sliding Window Protocol



Timeline for Sliding Window Protocol

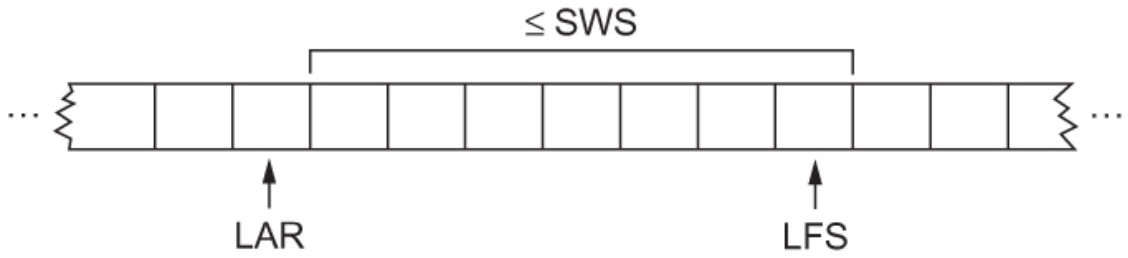
Sliding Window Protocol

- So a binary sequence number used earlier will no longer be sufficient
  - Sequence numbers needed will depend on how wide the window is
  - With 8 bits can support $2^8 = 256$ unique sequence numbers
- Sender assigns a sequence number denoted as SeqNum to each frame.
  - Assume it can grow infinitely large
  - Or the 8-bit counter that will return to zero after 255 is reached
- As a result of sending and acknowledging more than one frame at a time some book keeping will be required at both ends
- Sender maintains three variables
  1. Sending Window Size (SWS)
  2. Last Acknowledgement Received (LAR)
  3. Last Frame Sent (LFS)

Sliding Window Protocol

- Sender also maintains the following invariant

  LFS – LAR ≤ SWS



Sliding Window on Sender

if LAR is 18, LFS is 25 then SWS has to be less or equal to 7

Sliding Window Protocol

- When an acknowledgement arrives
  - the sender moves LAR to right, thereby allowing the sender to transmit another frame
- Also the sender associates a timer with each frame it transmits
  - It retransmits the frame if the timer expires before the ACK is received
- Note that the sender has to be willing to buffer up to SWS frames
  - WHY?

LFS – LAR <= 7

Say, 200 – 193 <=7 but not a good idea to go to the max because what if ack never received for any of the unacked frames ➔ retransmit w/o going over sws

Sliding Window Protocol

- When a frame with sequence number SeqNum arrives, what does the **receiver** do?
- Two scenarios:
  1. No buffer on the receiver side (only maintains the sequence number of the Last Acknowledge Sent)
     - If the next received frame has sequence number of LAS + 1 then it will accept it
  2. A buffer is used at the receiver (out of order frames can be received)

Sliding Window Protocol

- In the second scenario some book keeping is required at the receiving end
- Receiver maintains three variables
  - Receiving Window Size (RWS)
  - Largest Acceptable Frame (LAF)
  - Last Frame Received (LFR)
- If SeqNum ≤ LFR (duplicate) or SeqNum > LAF (can not fit)
  - Discard it (the frame is outside the receiver window)
- If LFR < SeqNum ≤ LAF
  - Accept the frame

Sliding Window on Receiver

Ethernet

- Protocols used to place the data on the media (Data Link layer)
  - Point to point methods
    - HDLC
    - PPP
  - Shared media methods
    - Ethernet (bus)
    - Star
    - Token Ring

Ethernet

Ethernet is the most widely-installed local area network (LAN) technology. Specified in a standard, IEEE 802.3, **Ethernet** was originally developed by Xerox from an earlier specification called Alohanet (for the Palo Alto Research Center Aloha network) and then developed further by Xerox, DEC, and Intel.

What is Ethernet? - Definition from WhatIs.com
searchnetworking.techtarget.com/definition/**Ethernet**

Ethernet

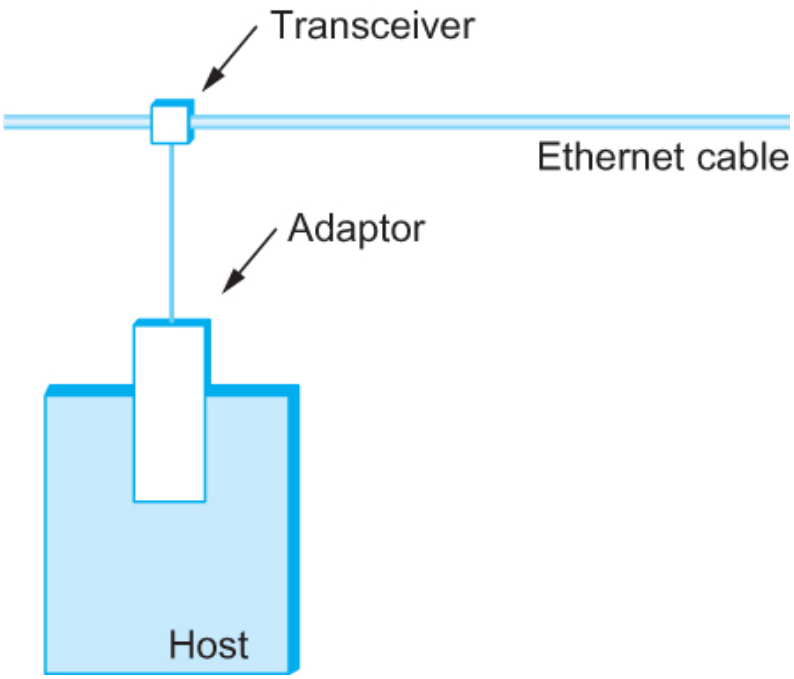
** important

- 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.
  - Multiple access means that 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

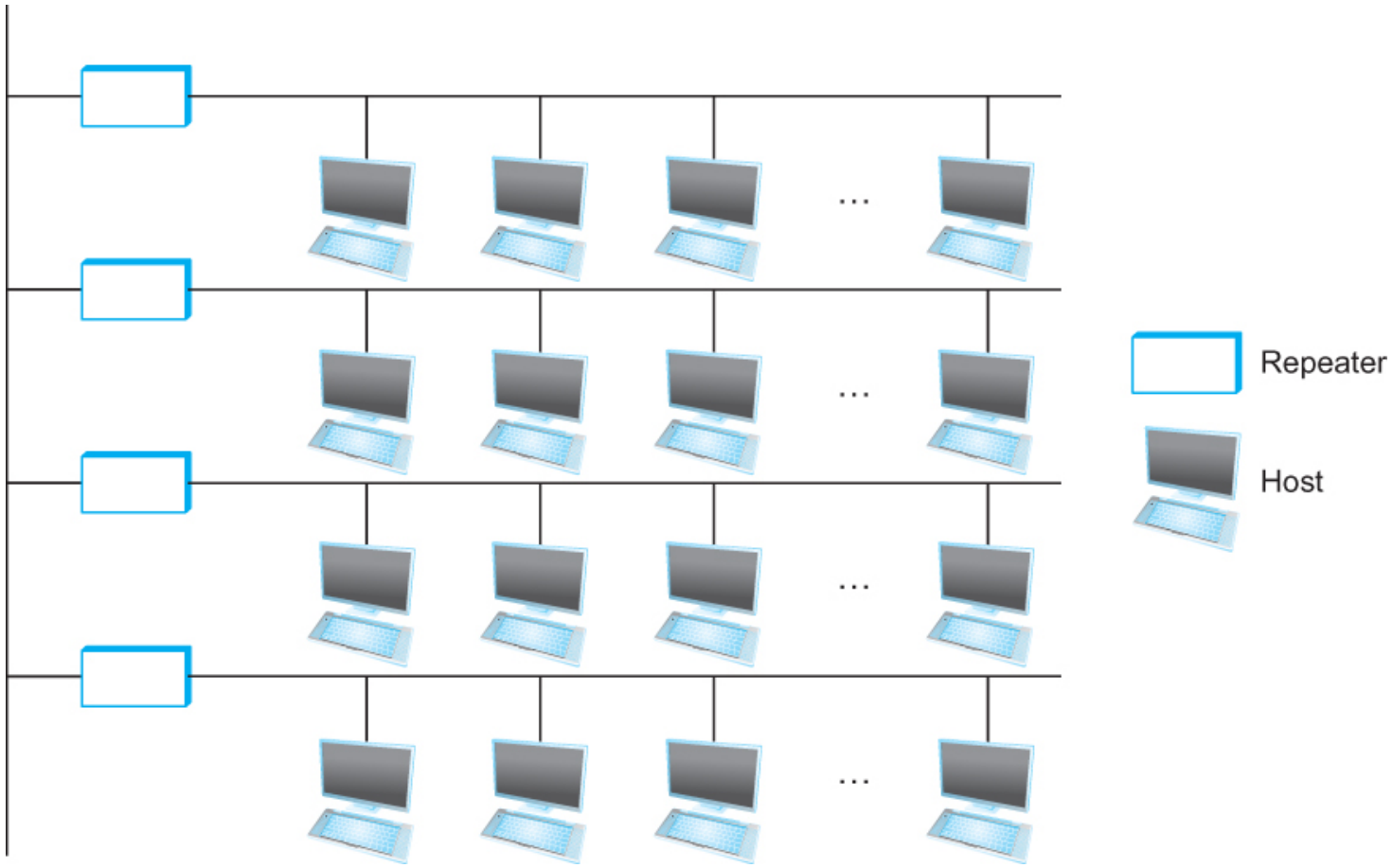
- Uses ALOHA (packet radio network) as the root protocol
  - Developed at the University of Hawaii to support communication across the Hawaiian Islands.
  - For ALOHA the medium was atmosphere, for Ethernet the medium is a coax cable.
- Digital Equipment Corporation (DEC) and Intel joined Xerox to define 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



Ethernet transceiver and adaptor

Ethernet



Ethernet repeater

Ethernet

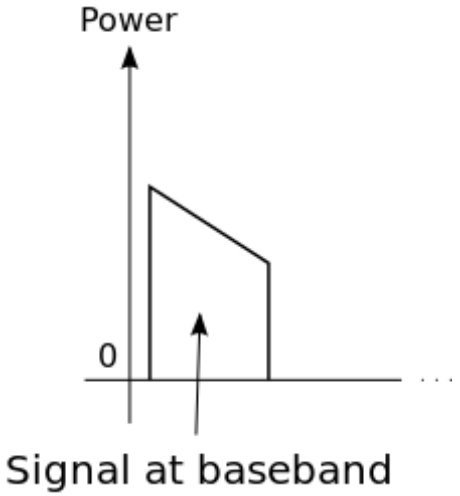
- Any signal placed on the Ethernet by a host is broadcast over the entire network
  - Signal is propagated in both directions.
  - Repeaters forward the signal on all outgoing segments.
  - Terminators attached to the end of each segment absorb the signal.

- Ethernet uses Manchester encoding scheme.

NZR XOR with Clock

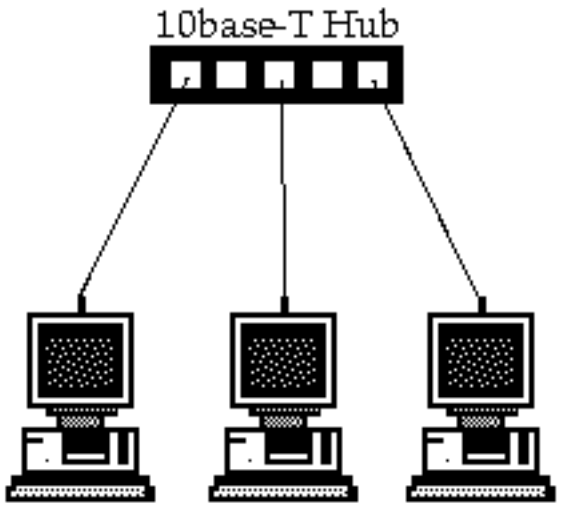
Ethernet

- 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
    - 2 means that a given segment can be no longer than 200 m
    - Base means the cable is used in a baseband system
      - Baseband digital transmission

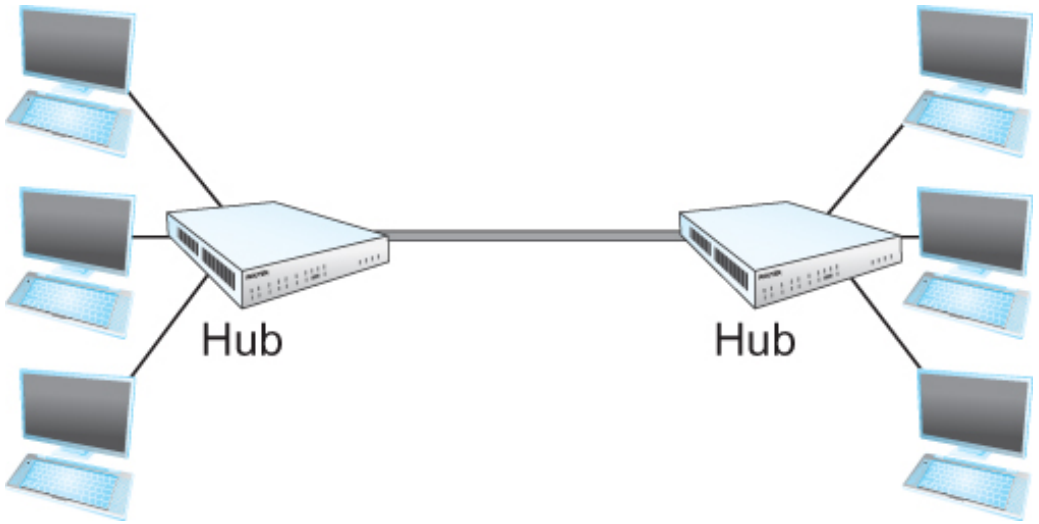


Ethernet

- New Technologies in Ethernet
  - Another cable technology is 10BaseT
    - T stands for twisted pair (same as the ones used in telephone systems)
    - Limited to 100 m in length
  - With 10BaseT, the common configuration is to have several point to point seg coming out of a multiway repeater called *Hub (10Mbps)*
  - *100Base-TX (100Mbps)*
  - *1000Base-T (1Gbps)*



Ethernet



Using Hubs in 10BaseT technology for Ethernet

Access Protocol for Ethernet

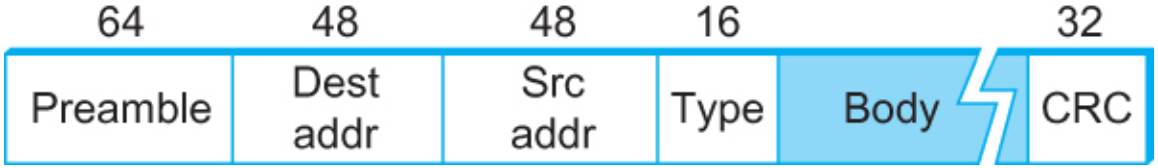
48 bits address half is used for ID number of the adapter manufacturer.that are regulated by an Internet standards & 2nd half 24 more bits represents serial # assigned to the adaptor by manufac:

- The algorithm is commonly called Ethernet's Media Access Control (MAC).
  - It is implemented in Hardware on the network adaptor.
- Frame format
  - Preamble
  - Host and Destination Address
  - Packet type
  - Data
  - CRC

algorithm that controls access to a shared Ethernet link.

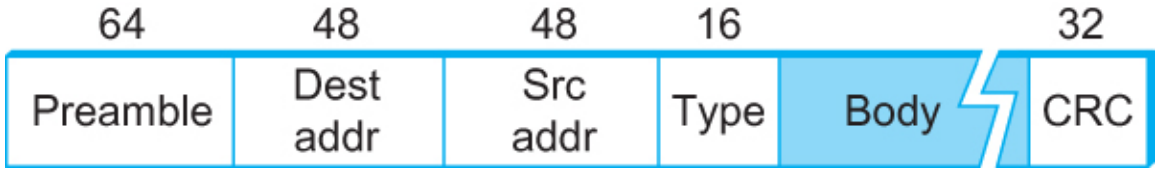
missing slide : first paragraph.

- Access Protocol algorithm is called MAC address (Ethernet's Media Access Control - physical address)
…to deliver frames using network adapter which has MAC address
- belong to network adaptor not the host
- host have more than one network adaptor



Ethernet Frame

MAC addr example, 00:A0:C9:14:C8:29
The prefix 00A0C9 indicates the manufacturer is Intel Corporation



Ethernet Frame Format

Ethernet Addresses

- 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 00000010
    - 8 : 0 : 2 b : e 4 : b 1 : 2

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.
  - For example, 88:0:2b:e4:b1:2 is
    - 10001000 00000000 00101011 11100100 10110001 00000010

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 addressed 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.
- 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. **probability is 100% sending as soon as it sees idle without waiting**
- 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.

**** we have collision when both node trying to send that time**

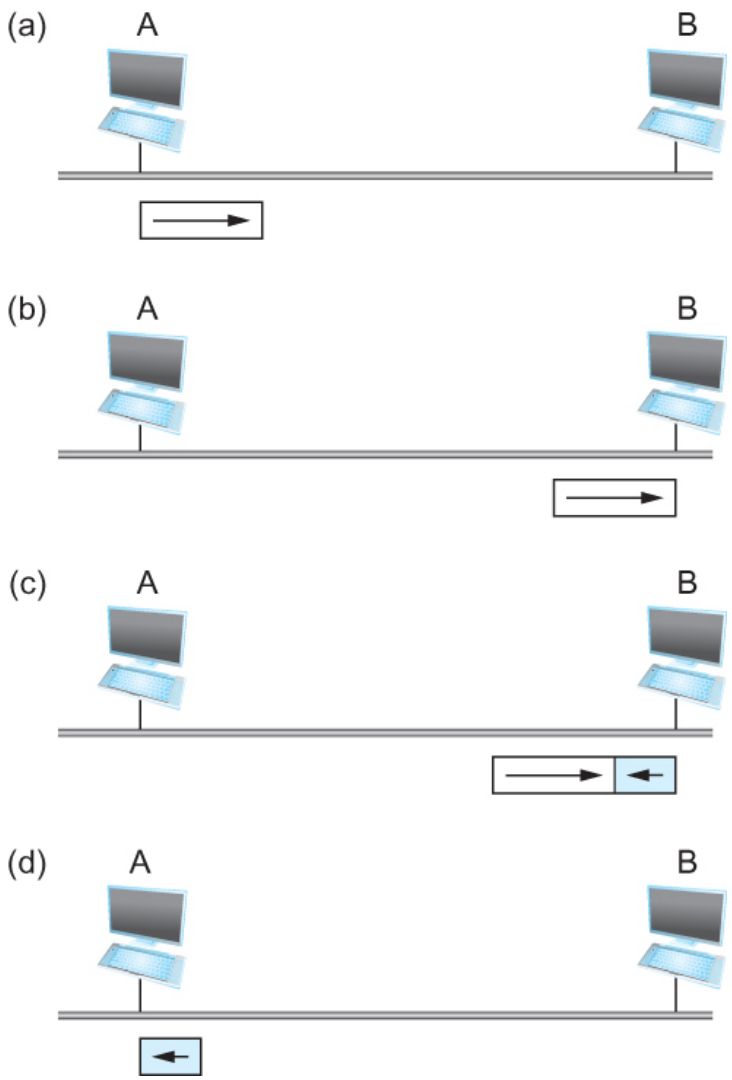
Ethernet Transmitter Algorithm

- 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



T = t

T = t + d

T = t + d

T = t + 2d

Experience with Ethernet

- Ethernets work best under lightly loaded conditions.
- Most Ethernets are used in a conservative way.
- Most Ethernets are far shorter than 2500m with a round-trip delay of closer to 5 μs than 51.2 μs.
- Ethernets are easy to administer and maintain.

Summary

- We introduced the many and varied type of links that are used to connect users to existing networks, and to construct larger networks.
- We looked at the five key issues that must be addressed so that two or more nodes connected by some medium can exchange messages with each other
  - Encoding
  - Framing
  - Error Detecting
  - Reliability
  - Multiple Access Links
    - Ethernet

all happened in Data Link Layer except encoding (in physical layer)