CIS 551 / TCOM 401

Computer and Network Security

Spring 2007

Lecture 7

Announcements

- Reminder:
  - Project 1 is due on Thursday.

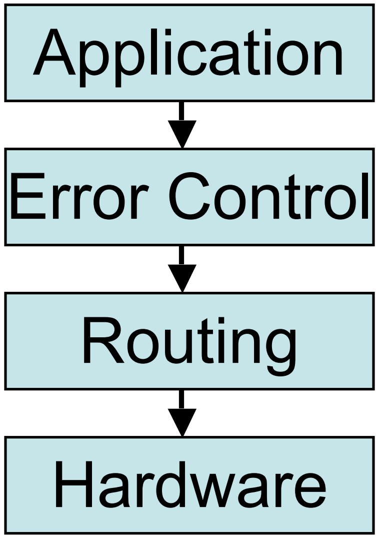
Network Architecture

- General blueprints that guide the design and implementation of networks
- Goal: to deal with the complex requirements of a network
- Use *abstraction* to separate concerns
  - Identify the useful service
  - Specify the interface
  - Hide the implementation

Layering

- A result of abstraction in network design
  - A stack of services (layers)
  - Hardware service at the bottom layer
  - Higher level services are implemented by using services at lower levels

- Advantages
  - Decompose problems
  - Modular changes

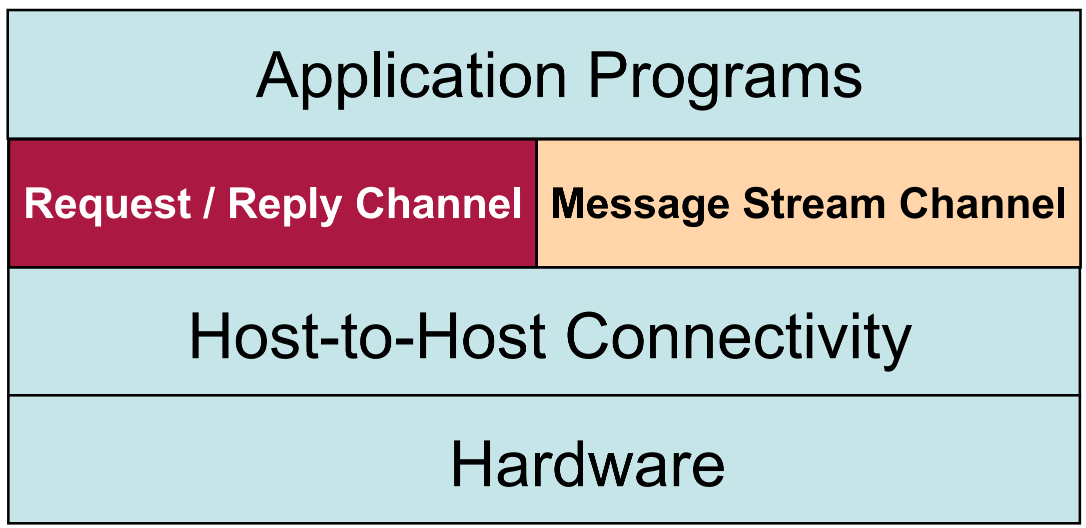


Protocols

- A *protocol* is a specification of an interface between modules (often on different machines)

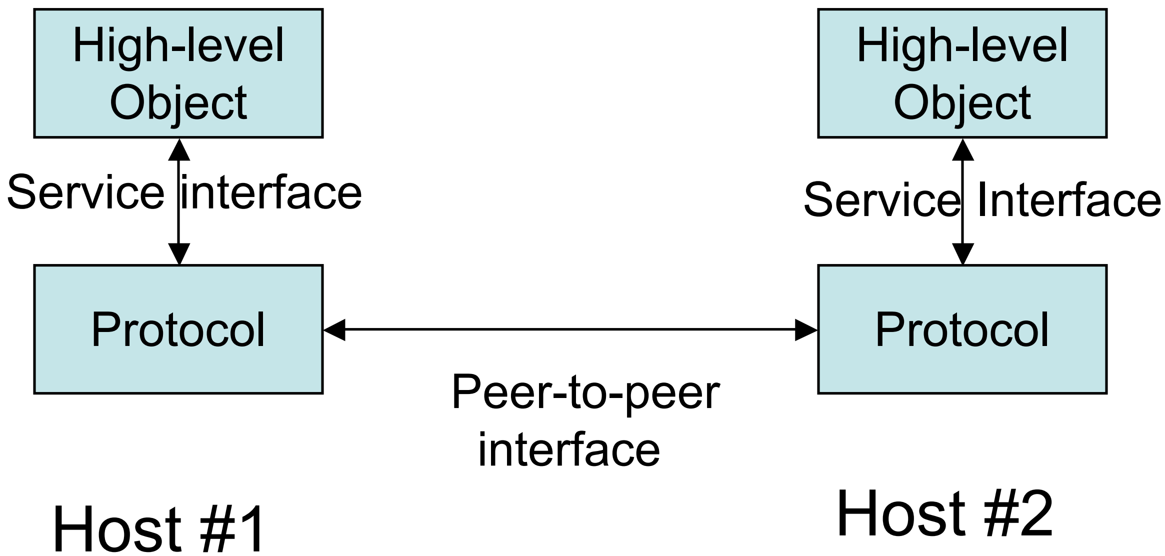
- Sometimes "protocol" is used to mean the implementation of the specification.

Example Protocol Stack

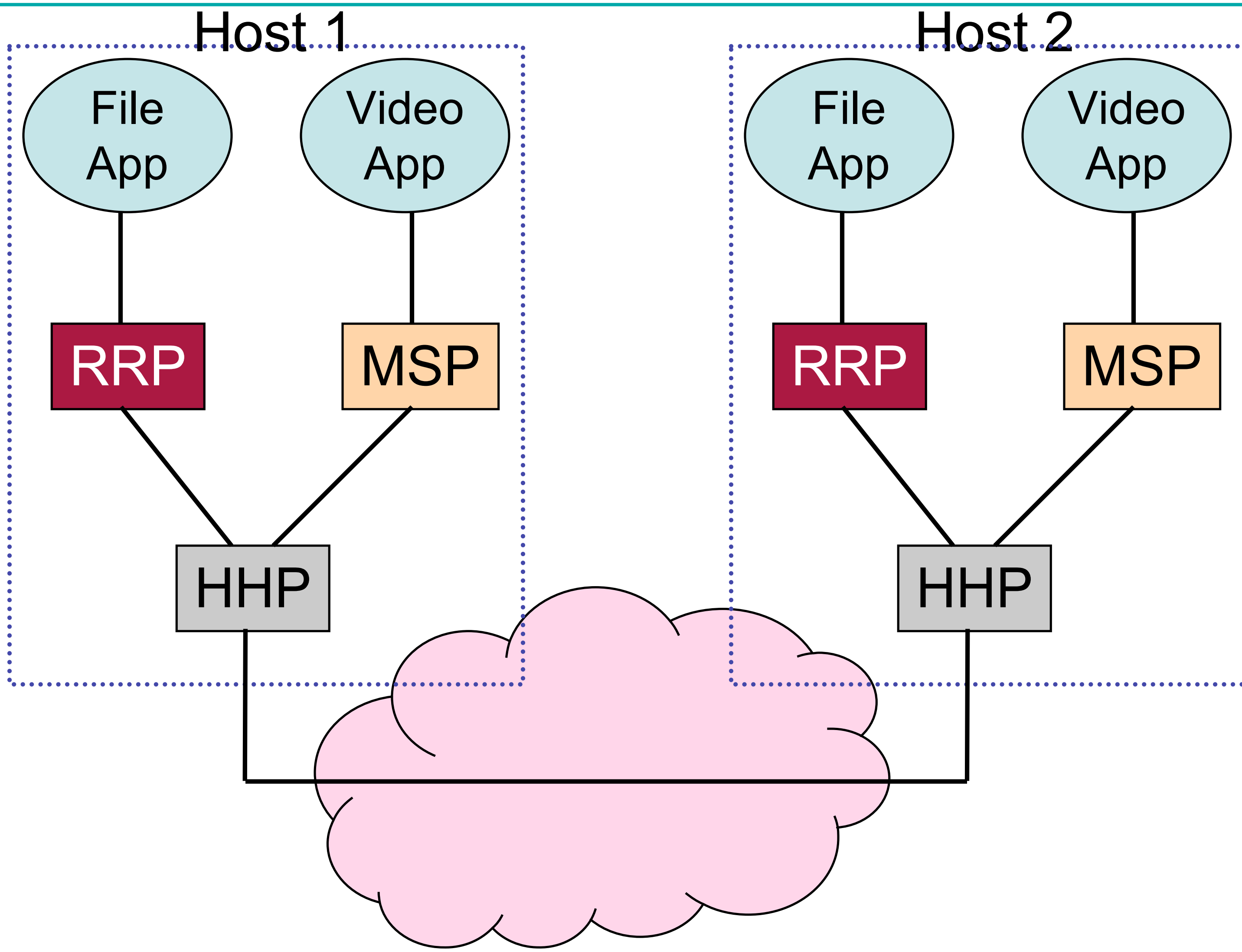


Protocol Interfaces

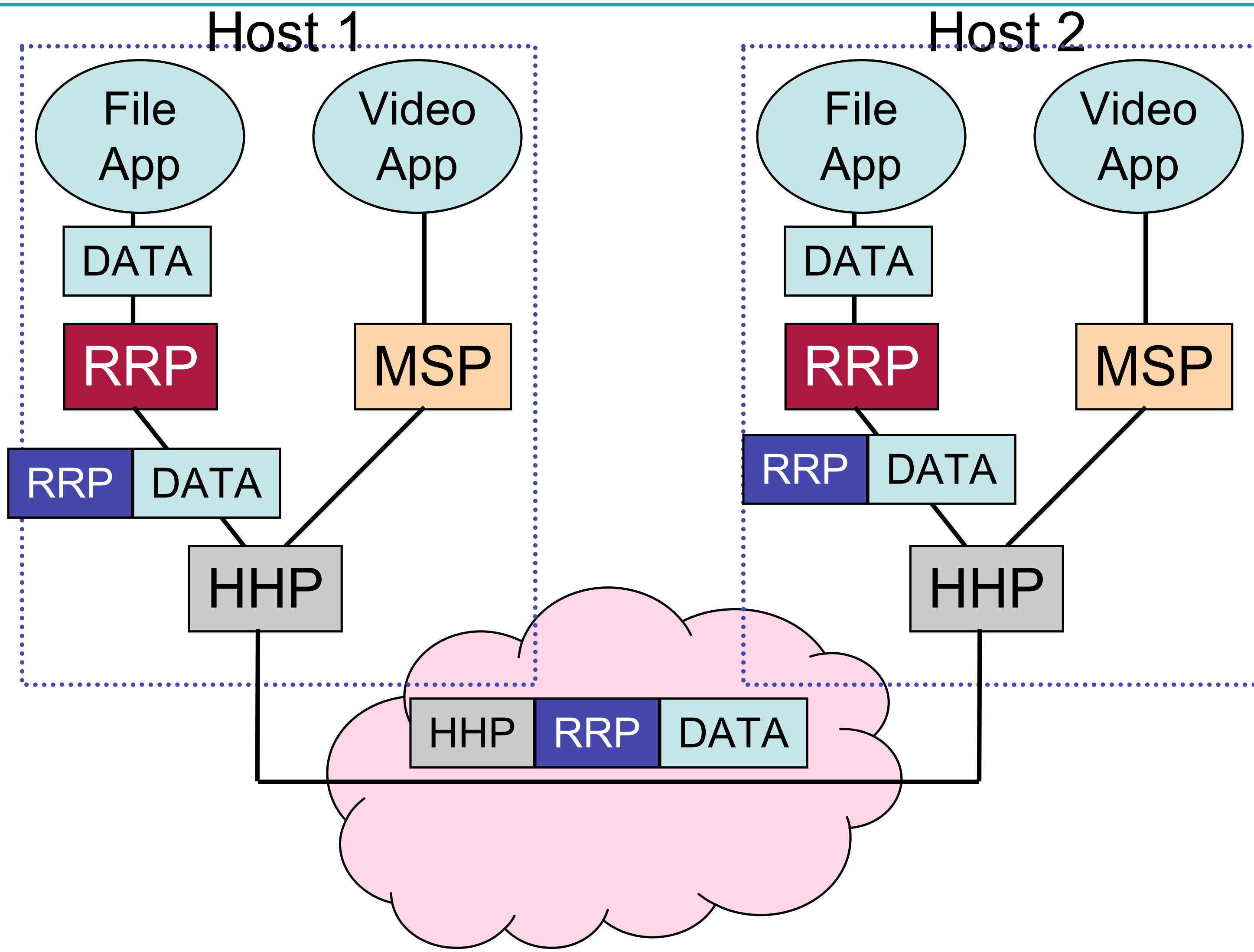
- Service Interfaces
  - Communicate up and down the stack
- Peer Interfaces
  - Communicate to counterpart on another host



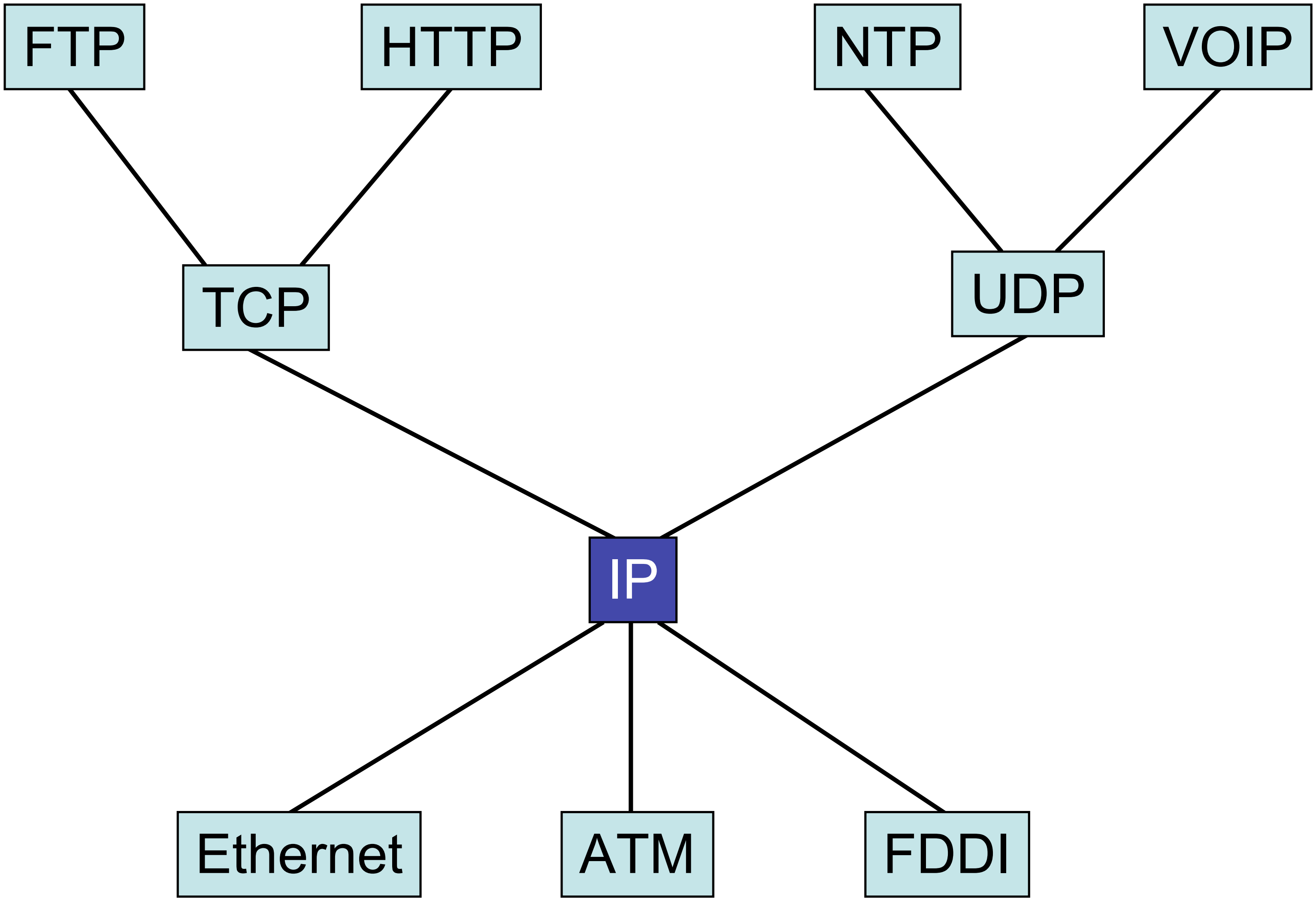
Example Protocol Graph



Encapsulation



Internet Protocol Graph



Open Systems Interconnection (OSI)

End Host	Reference model – not actual implementation.
Application	Transmits *messages* (e.g. FTP or HTTP)
Presentation	Data format issues (e.g. big- vs. little-endian)
Session	Manages multiple streams of data
Transport	Process to process protocols
Network	Routes *packets* among nodes in network
Data Link	Packages bit streams into *frames*
Physical	Transmits raw bits over link

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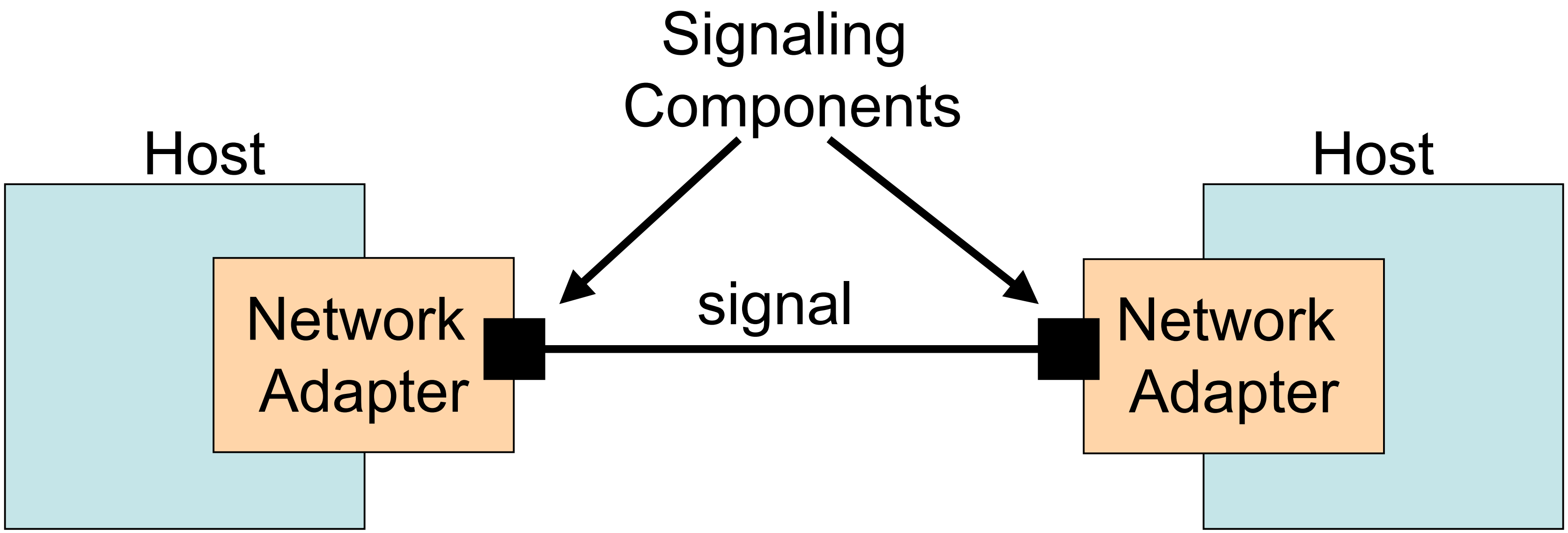
Signaling Components



Network adapters encode streams of bits into signals.

Simplification: Assume two discrete signals—high and low.

Practice: Two different voltages on copper link or different brightness of light on fiber link.
(leads to some interesting encoding issues)

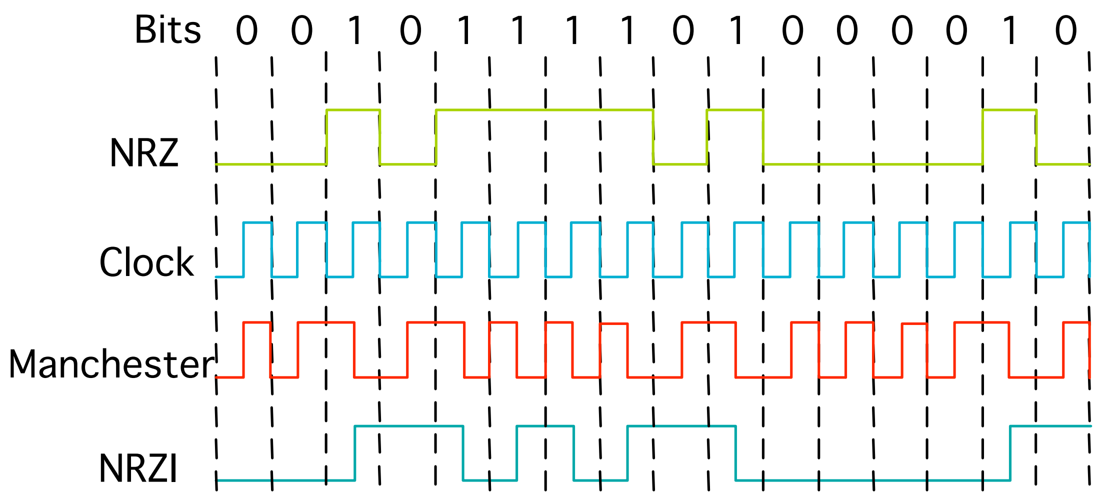
Not in this course

$$\nabla \bullet \vec{E} = \varepsilon_0 \rho$$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\nabla \bullet \vec{B} = 0$$

$$\nabla \times \vec{B} = \mu_0 \vec{J} + \mu_0 \varepsilon_0 \frac{\partial \vec{E}}{\partial t}$$



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Framing

- Need a way to send blocks of data.
  - How does the network adapter detect when the sequence begins and ends?
  - Are there transmission errors in the data?
- *Frames* are link layer unit of data transmission
  - Byte oriented vs. Bit oriented
  - Point-to-point (e.g. PPP) vs. Multiple access (Ethernet)

A Multi-access, Bit-oriented Protocol

- Frames contain sequences of bits
  - Could be ASCII
  - Could be pixels from an image
- Frames read by many nodes
  - Address distinguishes intended recipient

- HDLC (High-level Data Link Control)
  - Begin and ending = 01111110
  - Uses *bit stuffing:* suffix five 1's with a 0

8	16		16	8
Begin	Header	Body	CRC	Ending

HDLC frame format

Problem: Error Detection & Correction

- Bit errors may be introduced into frames
  - Electrical interference
  - Thermal noise
- Could flip one bit or a few bits independently
- Could zero-out or flip a sequence of bits (*burst error*)

- How do you detect an error?

- What do you do once you find one?

Error Detection

- General principal: Introduce redundancy
- Trivial example: send two copies
  - High overheads: 2n bits to send n
  - Won’t detect errors that corrupt same bits in both copies
- How can we do better?
  - Minimize overhead
  - Detect many errors
  - General subject: error detecting codes

Simple Error Detection Schemes

- Parity
  - 7 bits of data
  - 8^{th} bit is sum of first seven bits mod 2
  - Overhead: 8n bits to send 7n
  - Detects: any odd number of bit errors
- Internet Checksum algorithm
  - Add up the words of the message, transmit sum
  - 16 bit ones-complement addition
  - Overhead: 16 bits to send n
  - Does not detect all two bit errors

Cyclic Redundancy Check

- Reading: Wikipedia entry on CRC
- Used in link-level protocols
  - CRC-32 used by Ethernet, 802.5, PKzip, …
  - CRC-CCITT used by HDLC
  - CRC-8, CRC-10, CRC-32 used by ATM
- Better than parity or checksum
  - (e.g. 32 bits to send 12000)
- Simple to implement

Cyclic Redundancy Check (CRC)

- Consider (n+1)-bit message as a n-degree polynomial
  - Polynomial arithmetic modulo 2
  - Bit values of message are coefficients
  - Message = 10011010
  - Polynomial

    $M(z) = (1 \cdot z^7) + (0 \cdot z^6) + (0 \cdot z^5) + (1 \cdot z^4) + (1 \cdot z^3) +$

    $(0 \cdot z^2) + (1 \cdot z^1) + (0 \cdot z^0)$

    $= z^7 + z^4 + z^3 + z^1$

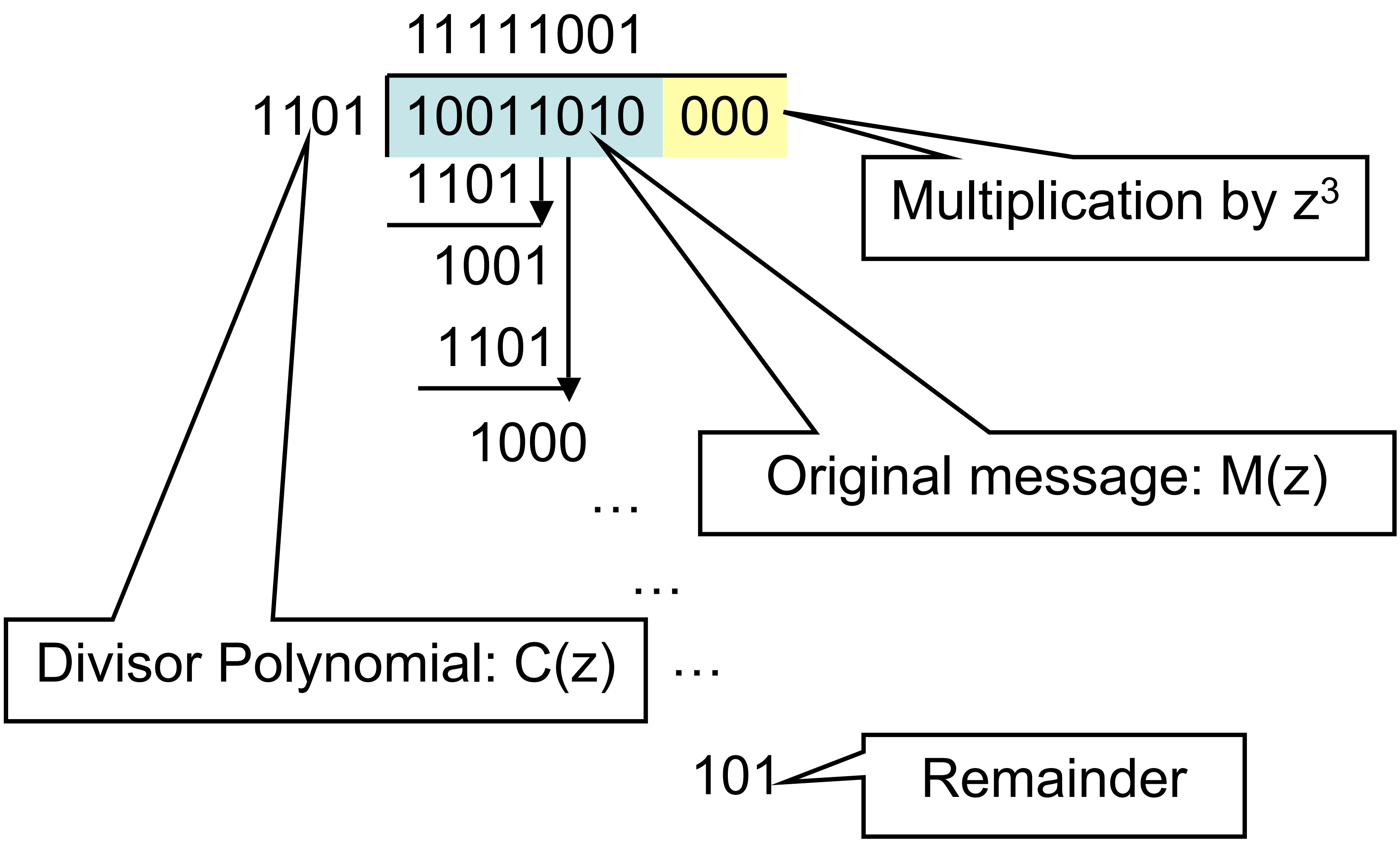
Cyclic Redundancy Check

- Sender and receiver agree on a *divisor polynomial* C(z) of degree k
  - Example k = 3
  - $C(z) = z^3 + z^2 + 1$
  - Coefficients are 1101
- Error correction bits are remainder of

$$(M(z) \cdot z^k) \text{ divided by } C(z)$$

- This yields a n+k bit transmission polynomial P(z) that is *exactly* divisible by C(z)

Example CRC Calculation



Example CRC Calculation

$Z^3 \cdot$ Original Message M(z) =		10011010 000
Remainder =	+	101
Transmitted message P(z) =		10011010 101

- Recipient checks that C(z) evenly divides the received message.

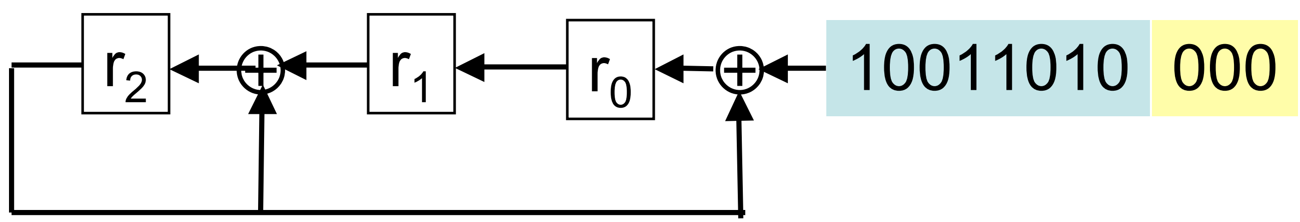
CRC Error Detection

- Must choose a good divisor $C(z)$
  - There are many standard choices:
    CRC-8, CRC-10, CRC-12, CRC-16, CRC-32
  - CRC-32: 0x04C11DB7
- All 1-bit errors as long as z^k and z^0 coefficients are 1
- All 2-bit errors as long as $C(z)$ has three terms
- Any odd number of errors if $(z+1)$ divides $C(z)$
- Any burst errors of length $\leq k$

CRC Implementations

- Easy to implement in hardware
  - Base 2 subtraction is XOR
  - Simple k-bit shift register with XOR gates inserted before 1's in C(z) polynomial
  - Message is shifted in, registers fill with remainder

- Example C(z) = 1101



Error Correction Codes

- Redundant information can be used to *correct* some errors
- Typically requires more redundancy

- Tradeoffs:
  - Error detection requires retransmission
  - Error correction sends more bits all the time
- Forward Error Correction is useful:
  - When errors are likely (e.g. wireless network)
  - When latency is too high for retransmission (e.g. satellite link)

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IEEE 802 network standards

The IEEE 802 committee produces standards & specifications for Local Area Networks (LAN):

- **802.3 CSMA/CD Networks (Ethernet)**
- 802.4 Token Bus Networks
- 802.5 Token Ring Networks
- 802.6 Metropolitan Area Networks
- **802.11 Wireless LAN (Wifi) [Thursday]**

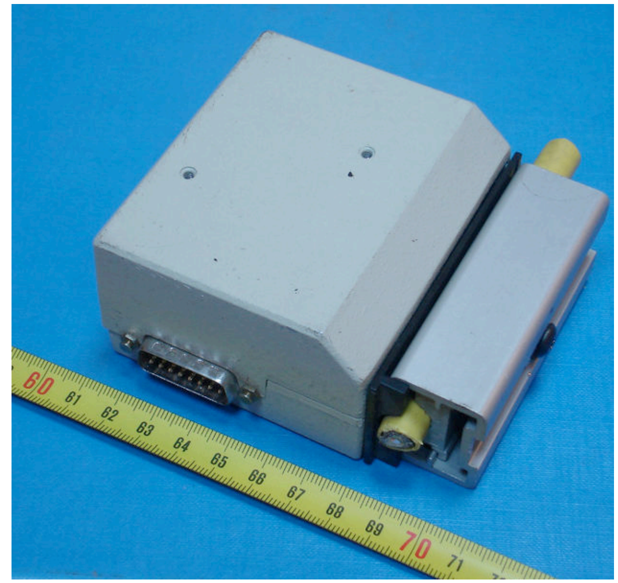
Ethernet (802.3)

- A standard for local area networks (LAN)

- Developed in mid-70's at Xerox PARC
  - Descendent of Aloha, a U. of Hawaii radio packet network
  - DEC, Intel, and Xerox standard: 1978 for 10Mbps
  - IEEE 802.3 standard grew out of that

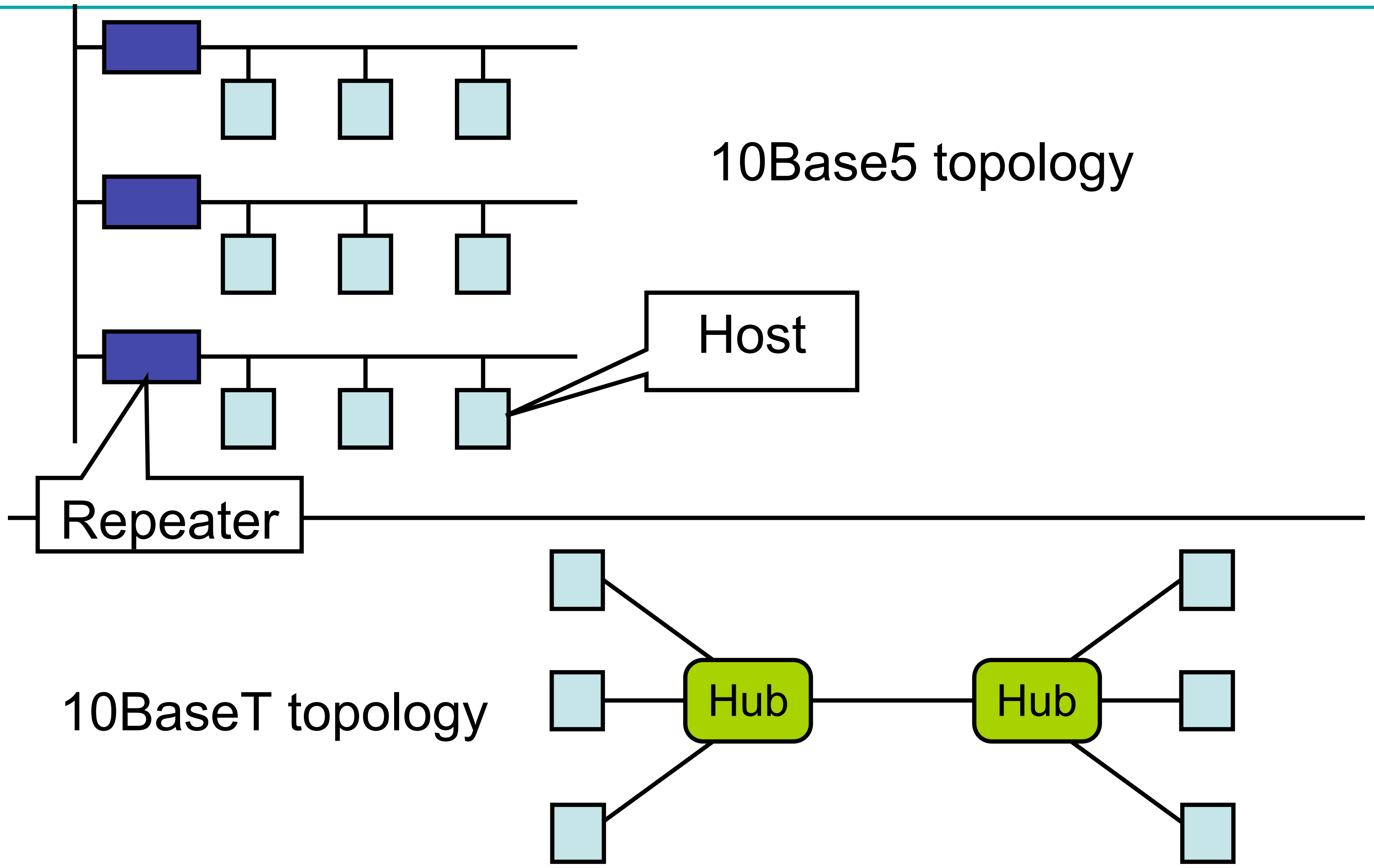
- Physical implementations:
  - 10Base5, 10BaseT, 100BaseT, 1000BaseT…
  - Speed: 10Mbps,100Mbps, 1000Mbps, …

Ethernet Physical links



- Originally used "Thick-net" 10Base5
  - 10 = 10Mbps
  - 5 = maximum of 500 meters segments
  - Up to 4 repeaters between two hosts
    =2500m max
- More common: 10BaseT
  - 10 = 10Mbps
  - T = Twisted pair (typically Category 5), Maximum of 100 meter segments
  - Connected via *hubs* (still 2500m max)
- Today's standards: 100BaseT, 1000BaseT

Ethernet topologies



How the ethernet works

- The Ethernet link is *shared*
  - A signal transmitted by one host reaches *all* hosts
- Method of operation: **CSMA/CD**
  - Carrier Sense, Multiple Access, with Collision Detection
- Hosts competing for the same link are said to be in the same ***collision domain***
  - Good news: easy to exchange data
  - Bad news: have to regulate link access
- Procotol: *Media Access Control* ***(MAC)***

Ethernet Addresses

- Every adapter manufactured has a unique address
  - 6 bytes (48 bits) usually written in Hex.
  - Examples: 00-40-50-B1-39-69 and 8:0:2b:e4:b1:2
  - Each manufacturer is assigned 24bit prefix
  - Manufacturer ensures unique suffixes

Ethernet Frame Format

64	48	48	16		32
Preamble	Dest	Src	Type	Body	CRC

- Preamble – repeating pattern of 0’s & 1’s
  - Used by receiver to synchronize on signal
- Dest and Src – Ethernet Addresses
- Type – demultiplexing key
  - Identifies higher-level protocol
- Body – payload
  - Minimum 46 Bytes
  - Maximum 1500 Bytes

Addresses in an ethernet frame

- All bits = 1 indicates a *broadcast* address
  - Sent to all adapters
- First bit = 0 indicates *unicast* address
  - Sent to only one receiver
- First bit = 1 indicates *multicast* address
  - Sent to a group of receivers

An Ethernet Adapter Receives:

- Frames addressed to the broadcast address
- Frames addressed to its own address
- Frames sent to a multicast address
  - If it has been programmed to listen to that address
- All frames
  - If the adapter has been put into *promiscuous mode*

Ethernet Transmitter Algorithm

- If the link is idle transmit the frame immediately
  - Upper bound on frame size means adapter can't hog the link
- If the link is busy
  - Wait for the line to go idle
  - Wait for 9.6μs after end of last frame (sentinel)
  - Transmit the frame

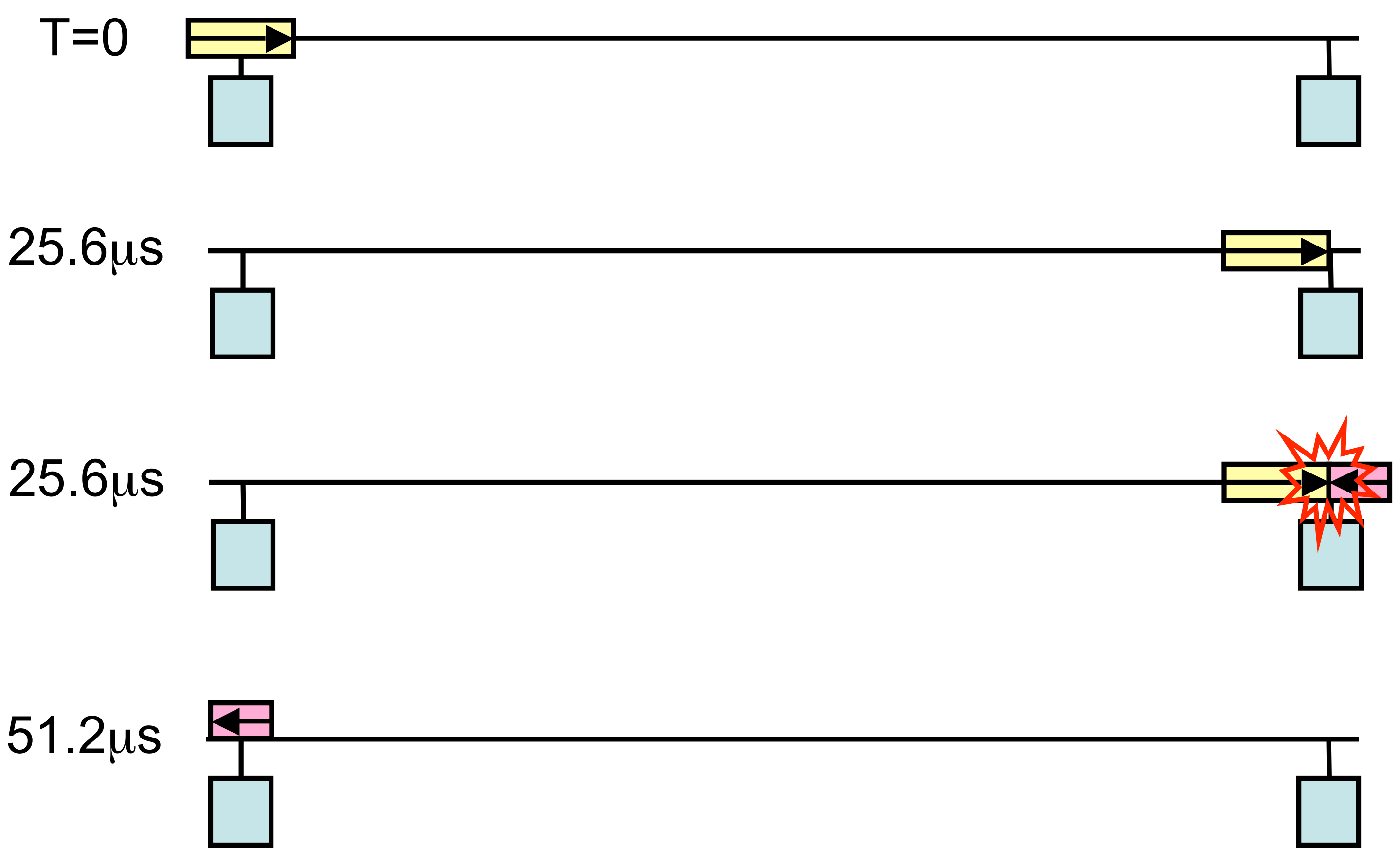
- Two (or more) frames may *collide*
  - Simultaneously sent frames interfere

Collision Detection

- When an adapter detects a collision
  - Immediately sends 32 bit *jamming signal*
  - Stops transmitting

- A 10MBps adapter may need to send 512 bits in order to detect a collision
  - Why?
  - 2500m + 4 repeaters gives RTT of 51.2μs
  - 51.2μs at 10Mbps = 512 bits
  - Fortunately, minimum frame (excluding preamble) is 512 bits = 64 bytes
    - 46 bytes data + 14 bytes header + 4 bytes CRC

Ethernet Collision (Worst Case)



Exponential Backoff

- After it detects 1st collision
  - Adapter waits either 0 or 51.2μs before retrying
  - Selected randomly
- After 2nd failed transmission attempt
  - Adapter randomly waits 0, 51.2, 102.4, or 153.6μs
- After nth failed transmission attempt
  - Pick k in 0 … 2^n-1
  - Wait k x 51.2μs
  - Give up after 16 retries (but cap n at 10)

Ethernet Security Issues

- Promiscuous mode
  - *Packet sniffer* detects all Ethernet frames
- Less of a problem in *switched* Ethernet
  - Why?