

Possible Link Layer Services

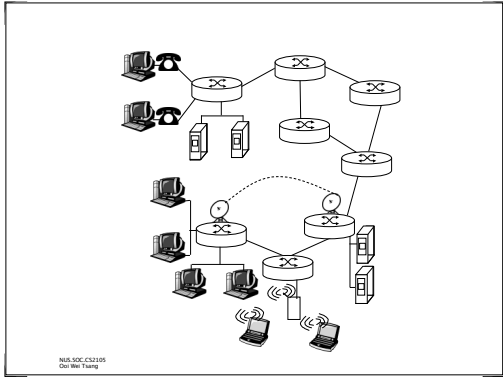
Framing

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Possible Link Layer Services

Shared Point-to-Point

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Possible Link Layer Services

Flow Control

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Possible Link Layer Services

Reliable Unreliable

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Possible Link Layer Services

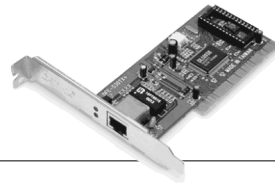
Error Detection & Recovery

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Link Layer Services

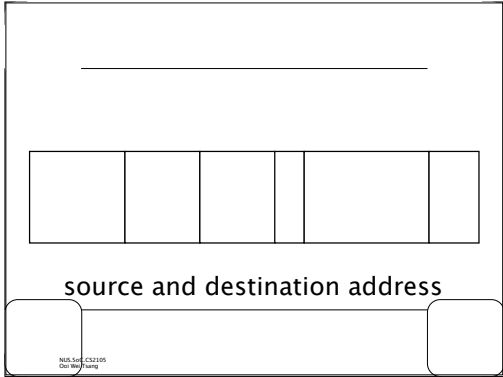
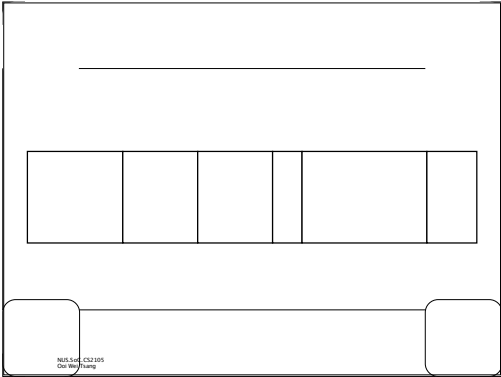
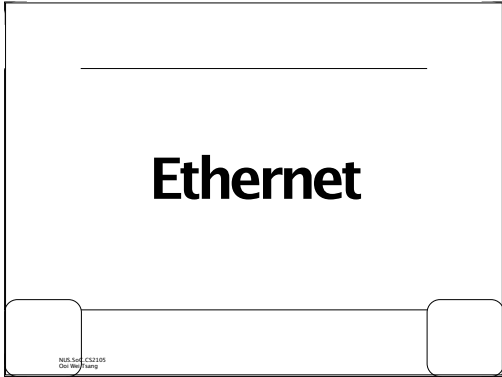
- The link layer is responsible for frame-level node-to-node communication. Datagram from network layer is encapsulated into a link-layer frame for transmission over the physical medium.
- Link layer may provide the following services: (i) access to physical medium -- either shared access or dedicated access via point-to-point link; (ii) reliable or unreliable services, depending on the bit error rate of the medium; (iii) flow control; (iv) error detection; (v) error correction (where receiver not only knows there is error but knows which bit is in error).

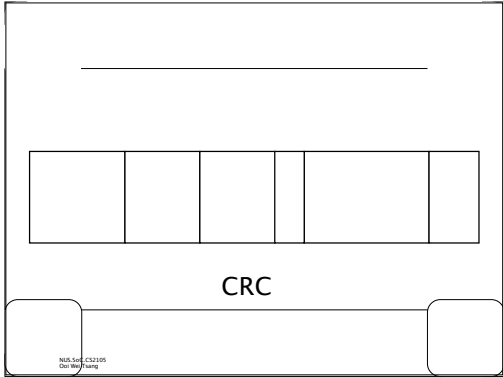
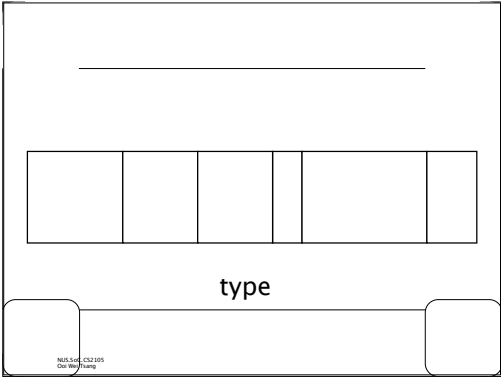
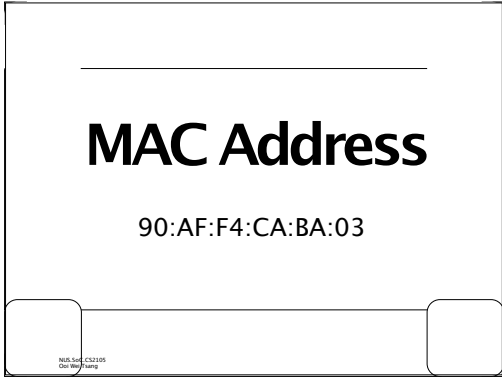
Link Layer Adapter

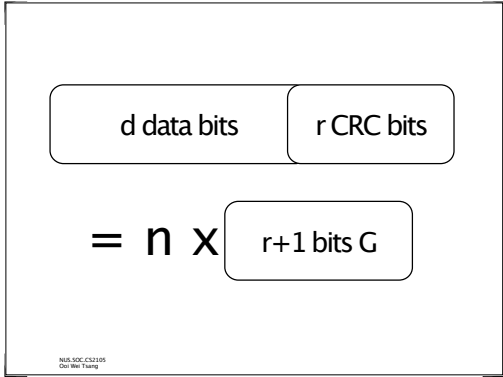
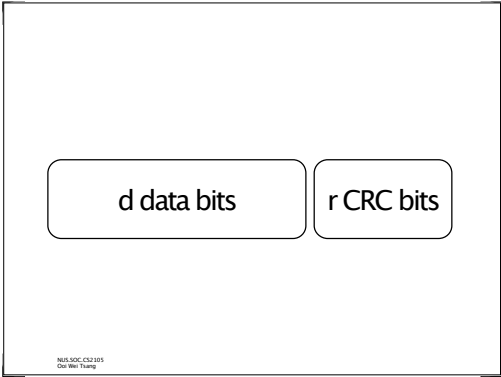
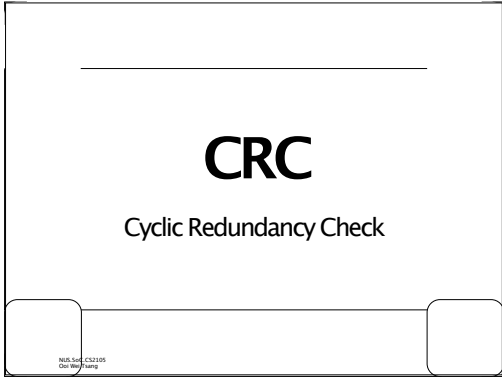


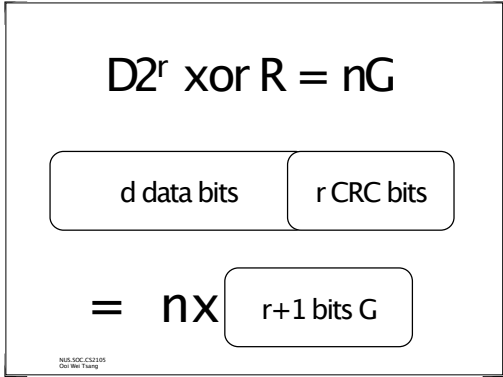
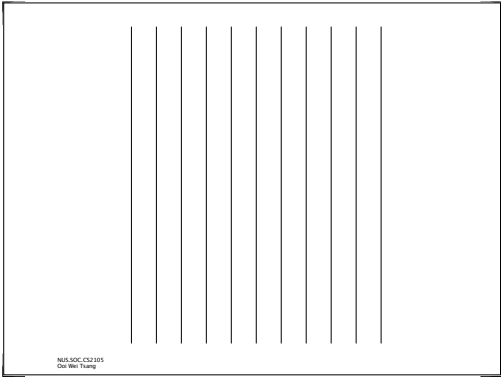
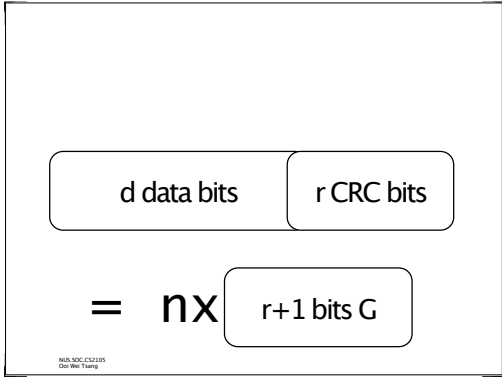
Link Layer Adapters

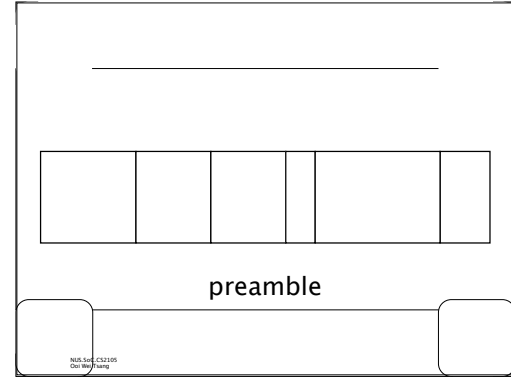
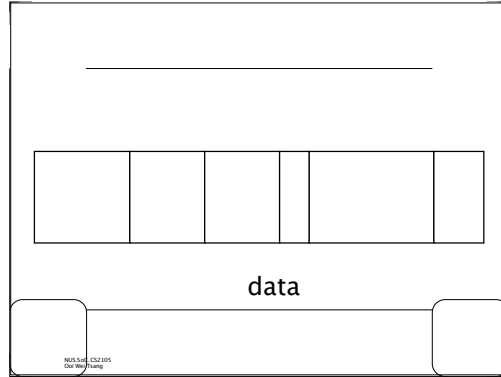
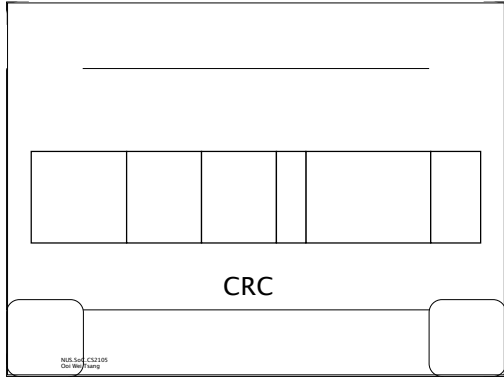
- Most of link layer is implemented in hardware in the form of an adapter. The adapter is a semi-autonomous unit which can decide to discard frames in error without notifying the OS.
- Due to its implementation in hardware, we can afford to use more sophisticated/powerful error detection and correction technique in the link layer.











Ethernet

- Ethernet is the current dominant wired link layer protocol. The Ethernet carries up to 1500 bytes of data, with 22 bytes header and 4 bytes trailer. The header consists of (a) source and destination MAC (medium access control) **addresses** (6 bytes each), (b) a protocol **type** field (2 byte), indicating which upper layer protocol should handle the data, (c) an 8-byte **preamble** to “synchronize the adapter” and (d) a 4-byte cyclic redundancy code (**CRC**) for error correction.
- The data size of an Ethernet frame must be at least 46 bytes.

CRC

- CRC is a error detection technique. To use CRC, both sender and receiver agree on an $r+1$ bit pattern, called **generator**, or G . Leftmost bit of G must be 1.
- Given a d -bit data to be sent, the sender find a r -bit CRC code such that appending the code to the data (giving $d+r$ bit string) is divisible by G . The resulting $d+r$ bits are sent.
- The receiver, upon receiving the $d+r$ bits, divide by G to see if the remainder is zero. If not, then error has occurred.

Different Link Layer Services

Shared Point-to-Point

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Multiple Access Protocols

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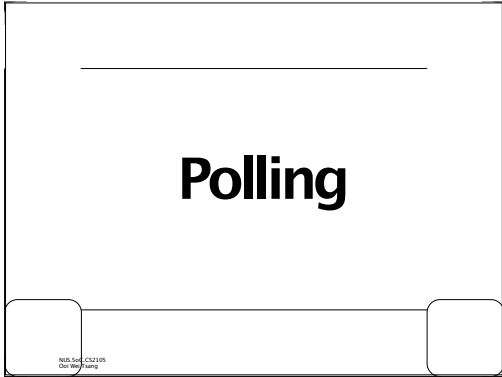
1. Channel Partitioning

TDM, FDM

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2. Taking Turns

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Medium Access Protocol

- When more than one nodes share a medium, we need a protocol to coordinate the access to the medium.
- The **channel partitioning** approach divides the channel into slots and dedicate each slot to a node. **TDM** and **FDM** are two examples of such method.
- The second approach is to **take turns**. In **polling**, one node is designated as master, and, in a round robin manner, poll other nodes to send data. In **token passing**, a special frame called token is passed around. After a node that receives the token, it can transmit for sometime, before giving up the token to another node.

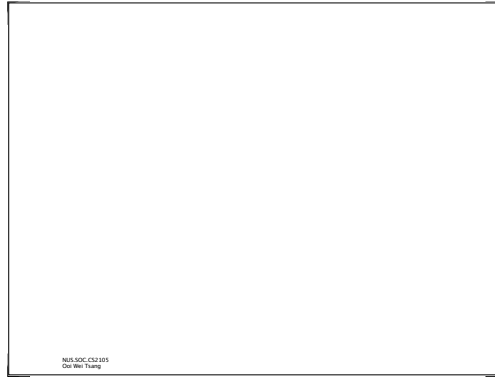
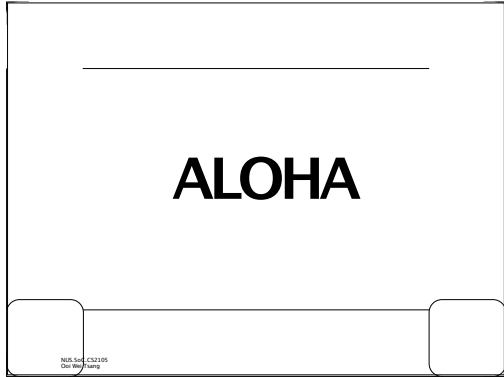
3. Random Access

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Slotted ALOHA

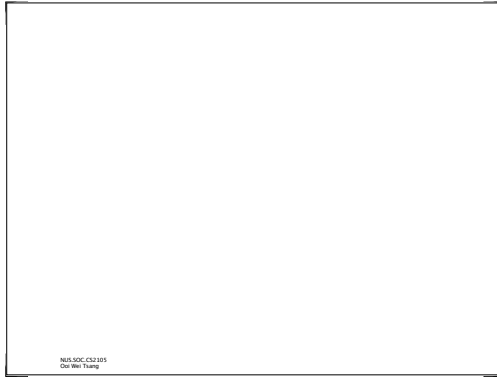
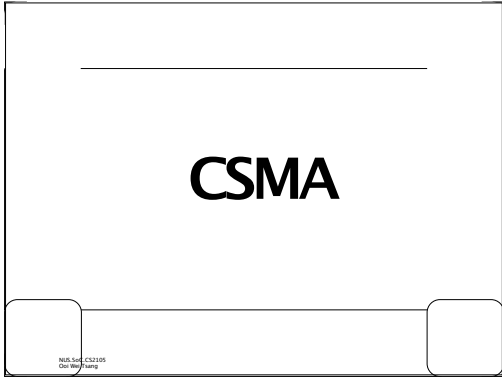
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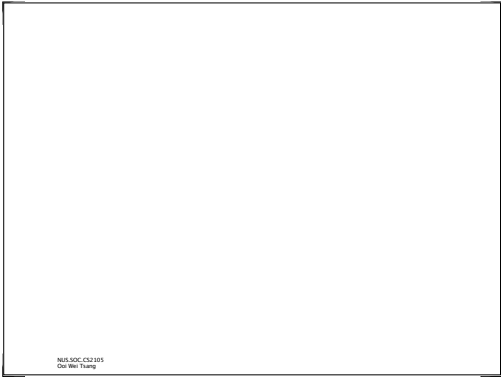
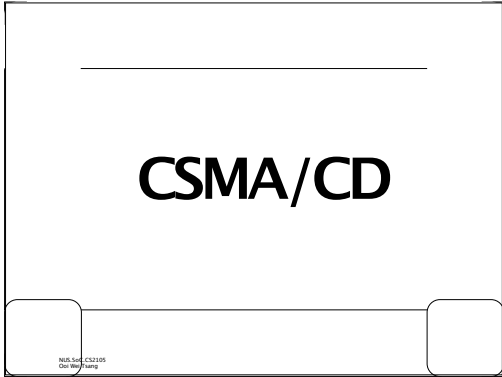
Medium Access Protocol

- The third approach is random access. A node try to transmit, and if collide with another node, it will wait a random time before retransmitting the frame.
- In Slotted ALOHA, time is divided into slots of one *frame time* (time to transmit a frame). A node wait until beginning of slot to transmit. If collide, retransmit in subsequent slot with probability p . Repeat until success.
- ALOHA is similar to slotted ALOHA, except that there is no slot -- nodes transmit as soon as they have data to send.



Medium Access Protocol

- Two simple modifications can improve the efficiency of ALOHA/slotted ALOHA. First, listen before transmit. If another node is sending at the moment, don't send now. Wait random amount of time and listen again. Second, if another node started sending in the middle of transmission, abort sending. These two modifications are called **carrier sensing** and **collision detection**.
- CSMA perform carrier sensing but not collision detection.
- CSMA/CD has both. Ethernet uses CSMA/CD.



CSMA/CD Protocol

- Sense the channel for 96 bit time. If the channel is currently idle, transmit now. If channel is busy, wait until the channel is idle, plus 96 bit time, then transmit.
- While transmitting, if collision is detected, stop transmitting data, transmit a 48 bit jam signal.
- Let the current round be the n-th collision in a row for this frame. Pick K randomly from $\{0, 1, \dots, 2^{n-1}\}$ ($m = \min(n, 10)$) and wait for $512 * K$ bit time, and repeat again (sense the channel for 96 bit time)
- Note: one bit time = time to transmit one bit
