

18-345 – Fall 08

Lecture 12

**Medium Access Control Protocols and
Local Area Networks**

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reading: Chapter 6

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Datalink Lectures

- Datalink functions
- Framing
- Datalink architectures
- Switching and packet forwarding
- Flow and error control
- Virtual circuits
- Taking turn protocols
- Contention-based access
- LANs, ethernet, and bridging
- Connectivity to the home
- Wireless

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Flow Control

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Flow Control

- Receiver has limited buffering to store arriving frames
- Several situations cause buffer overflow
 - Mismatch between sending rate & rate at which user can retrieve data
 - Surges in frame arrivals
- *Flow control* prevents buffer overflow by regulating rate at which source is allowed to send information

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X ON / X OFF

Threshold must activate OFF signal while buffer still has space remaining for $2T_{prop}$ R bits

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Window Flow Control

- Sliding Window ARQ method with W_s equal to buffer available
 - Transmitter can never send more than W_s frames
- ACKs that slide window forward can be viewed as permits to transmit more
- Can also pace ACKs as shown above
 - Return permits (ACKs) at end of cycle regulates transmission rate
- Problems using sliding window for both error & flow control
 - Choice of window size
 - Interplay between transmission rate & retransmissions
 - TCP separates error & flow control

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Circuit Versus Packet Switching

Circuit Switching

- Fast switches can be built relatively inexpensively
- Inefficient for bursty data
- Predictable performance (e.g. hard QoS)
- Requires circuit establishment before communication

Packet Switching

- Switch design is more complex and expensive
- Allows statistical multiplexing
- Difficult to provide QoS guarantees
- Data can be sent without signaling delay and overhead

Can we get the benefits of both?

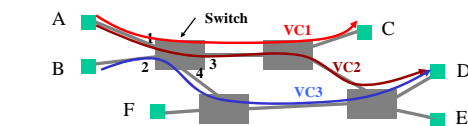
Virtual Circuits

Section 7.3

Virtual Circuits

- Establish circuit before communication
- Frames carry address that identifies virtual circuit that "frame" belongs to
- Switches forward packets based on virtual circuit identifier
- Allows statistical multiplexing of links

Virtual Circuit Forwarding



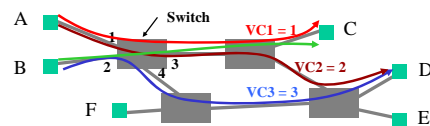
Address	Next Hop
VC1	3
VC2	3
VC3	4
VC4	?
VC5	?

- Address used for look up is a virtual circuit identifier (VC id)
- Forwarding table entries are filled in during signaling
- VC id is typically shorter than destination address

Virtual Circuit Properties

- Supports statistical multiplexing
- Address look up easier than in packet switched networks
- Can force data to follow specific path
- Need to establish circuits before communication can start
- You pay header and signaling overhead
- Switches have a lot of state: complicates failure recovery but simplifies QoS

How to Pick a VC Id?



- When B establishes green virtual circuit, how does it know what VC ids are available?
- Even worse: every VC id may already be used on a link along the path to the destination
- Solution: VC id swapping

VC id Swapping

Address	Next Hop	Next id
VC1 = 1	3	2
VC2 = 2	3	3
VC3 = 1	4	1
VC4 = 2	3	1

- Look up is based on VC id in header + incoming port number
- Forwarding table specifies outgoing port and new VC id
- VC id conflicts can be resolved locally during signaling

Does this look familiar?

ATM

Section 9.1, 9.2, 9.3

ATM History

- Telephone companies supported voice telephony: 4 kHz analog, 64 kbs digital
- They provided lines for data networking
 - ISDN: 64 kbps and faster channels
 - T1 (1.544 Mbps)
 - T3 (44.736 Mbps)
- Wanted to become the primary service provider for data networking services
 - file transfer: bursty, many Mbps peak
 - database access: bursty, low latency
 - Multimedia: synchronized
 - Video: 6 MHz analog, 1.2-200 Mbps digital

ATM Features

- Virtual circuit technology using hierarchical virtual circuits (VP, VC)
- Fixed size cells (53 bytes)
- Support for multiple traffic classes by adaptation layer
 - E.g. voice channels, data traffic
- Elaborate signaling stack
 - Backwards compatible with telephone standards
- Standards defined by ATM Forum.
 - Organization of manufacturers, providers, users

The ATM Cell (UNI)

ATM Standard Protocol Layers

	Upper Layer Protocols		
Convergence sublayer	CS	AAL	ATM adaptation layer
Segmentation and reassembly	SAR		
	ATM		
Physical medium dependent	PMD		
Transmission convergence	TC	PHY	

ATM Adaptation Layers

1	2	3	4	5
synchronous		asynchronous		
constant		variable bit rate		
connection-oriented		connectionless		

- AAL 1: audio, uncompressed video
- AAL 2: compressed video
- AAL 3: long term connections
- AAL 4/5: data traffic

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AAL5 Adaptation Layer

includes EOF flag

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Virtual Path Trunking

- Virtual path is a bundle of VCs
 - All follow the same path through the network
 - No remapping of VC id in virtual paths – fast setup
- Allows aggregated resource management and fault recovery.

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Q.SAAL: Signaling ATM Adaptation Layer

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Datalink Classification

```

    graph TD
      DL1[Datalink] --> S[Switch-based]
      DL1 --> MA[Multiple Access]
      S --> PS[Packet Switching]
      S --> VC[Virtual Circuits]
      MA --> SA[Scheduled Access]
      MA --> RA[Random Access]
      MA --> W[Wireless]
      PS --- PS_L[DL1, DL2, DL5]
      VC --- VC_L[DL3]
      SA --- SA_L[DL3]
      RA --- RA_L[DL4, DL5]
      W --- W_L[DL6]
      PS --- PS_T[Bridged LANs]
      VC --- VC_T[ATM, framerelay]
      SA --- SA_T[Token ring, FDDI, 802.11]
      RA --- RA_T[Ethernet, 802.11, Aloha]
      W --- W_T[Wifi 802.11]
  
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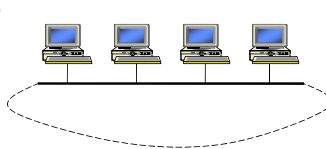
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Media Access Control Scheduling

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Scheduling for Medium Access Control

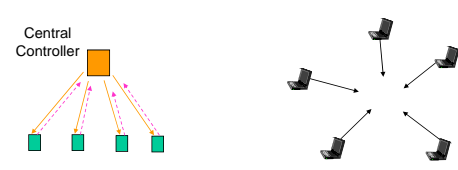
- Schedule frame transmissions to avoid collision in shared medium
 - More efficient channel utilization
 - Less variability in delays
 - Can provide fairness to stations
 - Increased computational or procedural complexity
- Main approaches
 - Reservation
 - Polling
 - Token Ring



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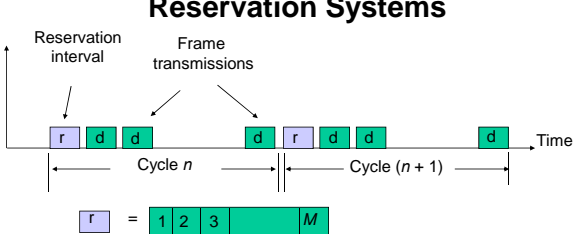
Reservations Systems

- Centralized systems:** A central controller accepts requests from stations and issues grants to transmit
- Distributed systems:** Stations implement a decentralized algorithm to determine transmission order



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Reservation Systems



- Transmissions organized into cycles
- Cycle: reservation interval + frame transmissions
- Reservation interval has a minislot for **each** station to request reservations for frame transmissions

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Reservation System Options

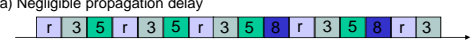
- Single or Multiple Frames
 - Single frame reservation:** Only one frame transmission can be reserved within a reservation cycle
 - Multiple frame reservation:** More than one frame transmission can be reserved within a frame
- Channelized or Random Access Reservations
 - Channelized (typically TDMA) reservation:** Reservation messages from different stations are multiplexed without any risk of collision
 - Random access reservation:** Each station transmits its reservation message randomly until the message goes through. i.e., Aloha used during reservation period

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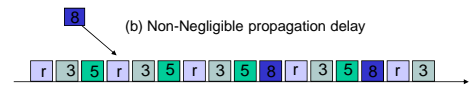
Example

- Initially stations 3 & 5 have reservations to transmit frames
- Station 8 becomes active and makes reservation
- Cycle now also includes frame transmissions from station 8

(a) Negligible propagation delay



(b) Non-Negligible propagation delay



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Efficiency of Reservation Systems

- Assume minislot duration = vX (X is frame interval)
- TDM single frame reservation scheme
 - If propagation delay is negligible, a single frame transmission requires $(1+v)X$ seconds
 - Link is fully loaded when all stations transmit, maximum efficiency is:

$$\rho_{\max} = \frac{MX}{MXv + MX} = \frac{1}{1+v}$$

- TDM k frame reservation scheme
 - If k frame transmissions can be reserved with a reservation message and if there are M stations, as many as Mk frames can be transmitted in $XM(k+v)$ seconds
 - Maximum efficiency is:

$$\rho_{\max} = \frac{MkX}{MXv + MkX} = \frac{1}{1 + \frac{v}{k}}$$

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Random Access Reservation Systems

- *Large number of light-traffic stations*
 - Dedicating a minislot to each station is inefficient
- **Slotted ALOHA reservation scheme**
 - Stations use slotted Aloha on reservation minislots
 - On average, each reservation takes at least e minislot attempts
 - Effective time required for the reservation is evX

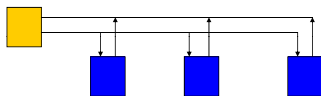
$$\rho_{\max} = \frac{X}{X(1+ev)} = \frac{1}{1 + 2.71v}$$

Example: GPRS

- **General Packet Radio Service**
 - Packet data service in GSM cellular radio
 - GPRS devices, e.g. cellphones or laptops, send packet data over radio and then to Internet
 - Slotted Aloha MAC used for reservations
 - Single & multi-slot reservations supported

Polling

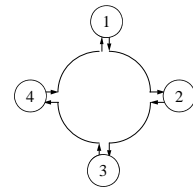
- **Hub Polling**



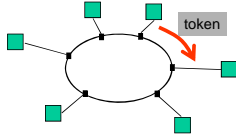
Controller polls each station

Token Ring

- Token ring is identical to **hub polling** except that the token-passing scheme has no central controller.
 - Fully distributed solution
- Only station with token can transmit
- All messages move around the ring and are actively repeated by each station.
- A station reading its own address as a destination copies the frame to its buffer, while passing it on, bit by bit.
- Source station removes packet from the ring

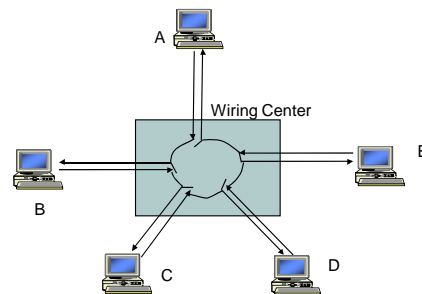
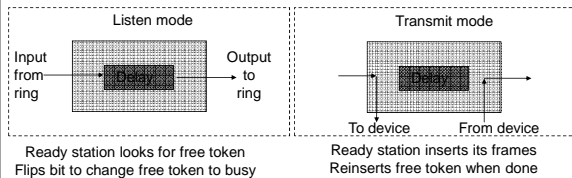


Token Ring



Free Token = Poll

Frame Delimiter is Token
Free = 01111110
Busy = 01111111



4 Mbps token ring LAN

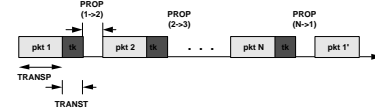
Improved reliability using relays in wiring center to bypass failed stations

Token Passing Methods

- Two token passing methods: Release After Transmission (RAT) and Release After Reception (RAR)
 - RAT: Transmitting station issues a token as a part of the frame transmitted, in essence passing permission to transmit on to the next station as soon as the last bit of the frame has cleared the transmitting station.
 - RAR: issue a token only when the transmitting station receives its message back again. Thus, the station waits until the entire message has traveled around the ring before it passes on the token. It can thus check for errors.

Efficiency of Token Ring with RAT

- Assume that all stations have packets to transmit.
- Find the total time to transmit packets from all stations once.



- Total time = $TRANSP + TRANST + PROP(1 \rightarrow 2) + TRANSP + TRANST + PROP(2 \rightarrow 3) + \dots + TRANSP + TRANST + PROP(N \rightarrow 1) = N \times (TRANSP + TRANST) + PROP$
- Then,

$$\eta_{RAT} = \frac{N \times TRANSP}{TOTAL} = \frac{N \times TRANSP}{N \times (TRANSP + TRANST) + PROP}$$

$$\approx \frac{1}{1 + \frac{PROP}{N \times TRANSP}} \text{ if } TRANST \ll TRANSP$$

Example

- Find the efficiency of the token ring with RAT method if there are 20 workstations transmitting 1000 bit messages in 10 Mbps coaxial cable ring of 2300 meters long. Ignore the token transmission time and message processing time (TRANST) at the workstations.

Token Holding Time

- Further improvement in RAT method?
- Increasing the token holding time?
 - If each station is allowed to hold the token for the **maximum** token holding time (THT), then the efficiency equation becomes

$$\eta_{RAT}(THT) = \frac{N \times TRANSP}{TOTAL} = \frac{N \times THT}{N \times (THT + TRANST) + PROP}$$

$$\approx \frac{1}{1 + \frac{PROP}{N \times THT}} \text{ if } TRANST \ll THT$$

- Example with 23,000 meter long token ring.

Maximum Media Access Time (MMAT)

- Maximum Media Access Time (MMAT) is defined as the maximum time that a node has to **wait** before it can transmit.
- An important design parameter for real-time networks.
- What is MMAT for the token ring with RAT(THT)?
 - The worst case scenario
 - A packet arrives at the node 1 just after that node has started to transmit another packet and the node cannot transmit the new packet without exceeding THT.
 - All other N-1 nodes transmit for the maximum acceptable duration (i.e. THT).
 - Then, $MMAT_{RAT} = PROP + N \times TRANST + TRANSP + (N-1)THT$

Comparison of MAC approaches

- Reservation
 - On-demand transmission of bursty or steady streams
 - Accommodates large number of low-traffic users with slotted Aloha reservations
 - Can incorporate **QoS**
 - Handles **large delay-bandwidth product** via delayed grants
- Polling and token ring
 - Generalization of time-division multiplexing
 - Provides **fairness** through regular access opportunities
 - Can provide **bounds on access delay**
 - Performance deteriorates with large delay-bandwidth product**