CS 640: Computer Networks

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Lecture 6 -
Error/Flow Control
&
Intro to Switching
and Medium Access Control

Error Coding

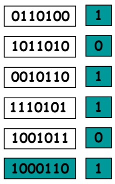
- Transmission process may introduce errors into a message.
  - Single bit errors versus burst errors
- Detection: e.g. CRC
  - Requires a check that some messages are invalid
  - Hence requires extra bits
  - "redundant check bits"
- Correction
  - Forward error correction: many related code words map to the same data word
  - Detect errors and retry transmission

Parity

- Even parity
  - Append parity bit to 7 bits of data to make an even number of 1's
  - Odd parity accordingly defined. 1010100 | 1 ; 1001011 | 0
- 1 in 8 bits of overhead?
  - When is this a problem?
- Can detect a single error 1010101 | 1
- But nothing beyond that 1000010 | 0

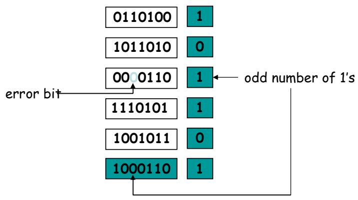
2-D Parity

- Make each byte even parity
- Finally, a parity byte for all bytes of the packet
- Example: five 7-bit character packet, even parity



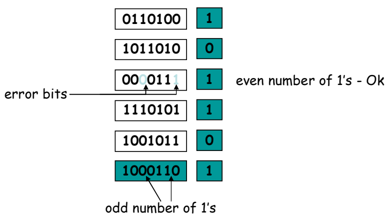
Effectiveness of 2-D Parity

- 1-bit errors can be detected, corrected
- Example with even parity per byte:



Effectiveness of 2-D Parity

- 2-bit errors can also be detected
- Example:



- What about 3-bit errors? >3-bit errors?

Cyclic Redundancy Codes (CRC)

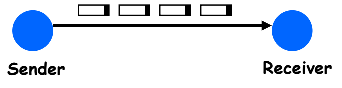
- Commonly used codes that have good error detection properties
  - Can catch many error combinations with a small number or redundant bits
- Based on division of polynomials
  - Errors can be viewed as adding terms to the polynomial
  - Should be unlikely that the division will still work
- Can be implemented very efficiently in hardware
- Examples:
  - CRC-32: Ethernet
  - CRC-8, CRC-10, CRC-32: ATM

Link Flow Control and Error Control

- Dealing with receiver overflow: flow control.
- Dealing with packet loss and corruption: error control.
- Actually these issues are relevant at many layers.
  - Link layer: sender and receiver attached to the same "wire"
  - End-to-end: transmission control protocol (TCP) - sender and receiver are the end points of a connection
- How can we implement flow control?
  - "You may send" (windows, stop-and-wait, etc.)
  - "Please shut up" (source quench, 802.3x pause frames, etc.)

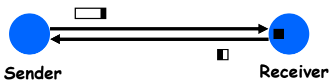
Flow Control: A Naïve Protocol

- Sender simply sends to the receiver whenever it has packets.
- Potential problem: sender can outrun the receiver.
  - Receiver too slow, small buffer overflow, ..
- Not always a problem: receiver might be fast enough.



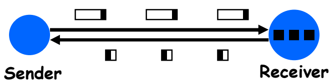
Adding Flow Control

- Stop and wait flow control: sender waits to send the next packet until the previous packet has been acknowledged by the receiver.
  - Receiver can pace the sender
- Drawbacks: adds overheads, slowdown for long links.



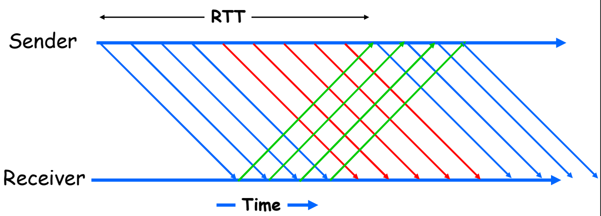
Window Flow Control

- Stop and wait flow control results in poor throughput for long-delay paths: packet size/ roundtrip-time.
- Solution: receiver provides sender with a window that it can fill with packets.
  - The window is backed up by buffer space on receiver
  - Receiver acknowledges the a packet every time a packet is consumed and a buffer is freed



Window Limitations

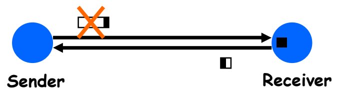
Window Size = 4pkts



$$\text{Throughput} = \frac{\text{Window Size}}{\text{Roundtrip Time}}$$

Error Control: Stop and Wait Case

- Packets can get lost, corrupted, or duplicated.
- Duplicate packet: use sequence numbers.
- Lost packet: time outs and acknowledgements.
  - Positive versus negative acknowledgements
  - Sender side versus receiver side timeouts
- Window based flow control: more aggressive use of sequence numbers (see transport lectures).



What is Used in Practice?

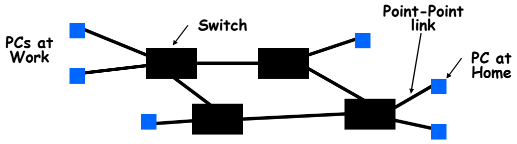
- No flow or error control.
  - E.g. regular Ethernet, just uses CRC for error detection
- Flow control only.
  - E.g. Gigabit Ethernet
- Flow and error control.
  - E.g. X.25 (older connection-based service at 64 Kbs that guarantees reliable in order delivery of data)

Switching and Media Access Control

- How do we transfer packets between two hosts connected to the a switched network?
- Switches connected by point-to-point links -- store-and-forward.
  - Multiplexing and forwarding
  - Used in WAN, LAN, and for home connections
  - Conceptually similar to "routing"
    - But at the datalink layer instead of the network layer
- Multiple access networks -- contention based.
  - Multiple hosts are sharing the same transmission medium
  - Used in LANs and wireless
  - Need to control access to the medium

A Switch-based Network

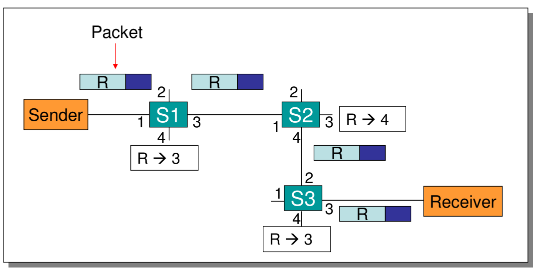
- Switches are connected by "point-to-point" links.
- Packets are forwarded hop-by-hop by the switches towards the destination.
  - Many forms of forwarding
- Many datalink technologies use switching.
  - Virtual circuits: Frame-relay, ATM, X.25, ..
  - Packets: Ethernet, MPLS, …



Three techniques for switching

- Global addresses - connection-less
  - Routers keep next hop for destination
  - Packets carry destination address
- Virtual circuits – connection oriented
  - Connection routed through network to set up state
  - Packets forwarded using connection state
- Source routing
  - Packet carries path

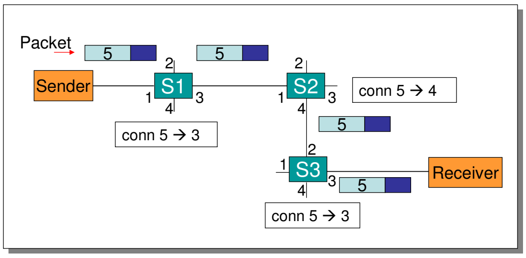
Global Address Example



Global Addresses

- Advantages
  - Stateless – simple error recovery
- Disadvantages
  - Every switch knows about every destination
    - Potentially large tables
  - All packets to destination take same route
  - Need special approach to fill table

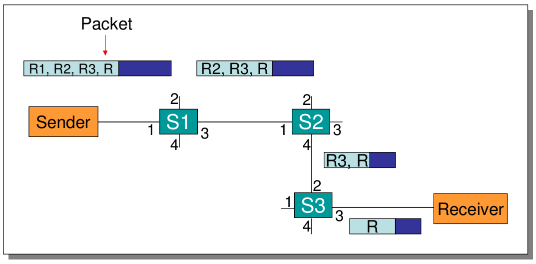
Simplified Virtual Circuits Example



Virtual Circuits

- Advantages
  - Efficient lookup (simple table lookup)
  - Can reserve bandwidth at connection setup
  - Easier for hardware implementations
- Disadvantages
  - Still need to route connection setup request
  - More complex failure recovery – must recreate connection state
- Typical use → fast router implementations
  - ATM – combined with fix sized cells
  - MPLS – tag switching for IP networks

Source Routing Example



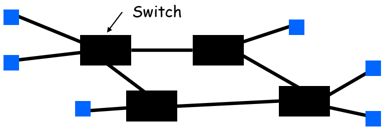
Source Routing

- Advantages
  - Switches can be very simple and fast
- Disadvantages
  - Variable (unbounded) header size
  - Sources must know or discover topology (e.g., failures)
- Typical uses
  - Ad-hoc networks (DSR)
  - Machine room networks (Myrinet)

Comparison

	Source Routing	Global Addresses	Virtual Circuits
Header Size	Worst	OK – Large address	Best
Router Table Size	None	Number of hosts	Number of circuits
Forward Overhead	Best	Table lookup	Pretty Good
Setup Overhead	None	None	Connection Setup
Error Recovery	Tell all hosts	Tell all switches	Tell all switches and Tear down circuit and re-route

Most Popular: Address Lookup-based Approach



Address	Next Hop	Info
B31123812508	3	13
38913C3C2137	3	-
A21023C90590	0	-
128.2.15.3	1	(2,34)

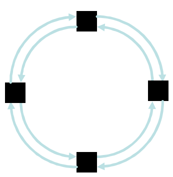
- Address from header.
  - Absolute address (e.g. Ethernet)
  - (IP address for routers)
  - (VC identifier, e.g. ATM))
- Next hop: output port for packet.
- Info: priority
- We will see how this table is filled (learning bridges)

Multiple Access Protocols

- Prevent two or more nodes from transmitting at the same time over a broadcast channel.
  - If they do, we have a collision, and receivers will not be able to interpret the signal
- Several classes of multiple access protocols.
  - Partitioning the channel, e.g. frequency-division or time division multiplexing
    - With fixed partitioning of bandwidth – not flexible
  - Taking turns, e.g. token-based, reservation-based protocols, polling based
  - Contention based protocols, e.g. Aloha, Ethernet
    - Next lecture

Fiber Distributed Data Interface (FDDI)

- One token holder may send, with a time limit.
  - known upper bound on delay.
- Optical version of 802.5 token ring, but multiple packets may travel in train: token released at end of frame.
- 100 Mbps, 100km.
- Optional dual ring for fault tolerance.
- CDDI: FDDI over unshielded twisted pair, shorter range



Other "Taking Turn" Protocols

- Central entity polls stations, inviting them to transmit.
  - Simple design – no conflicts
  - Not very efficient – overhead of polling operation
- Stations reserve a slot for transmission.
  - For example, break up the transmission time in contention-based and reservation based slots
    - Contention based slots can be used for short messages or to reserve time
    - Communication in reservation based slots only allowed after a reservation is made
  - Issues: fairness, efficiency