Digital Communications over Packet-Switched Networks

(ECE 446 – Lecture #3)

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Outline

- Last time: Basic Network Elements and Mechanisms.
  - Links, Switches, Service Characteristics, Multiplexing, Switching.
- Today: More Network Mechanisms and Layered Architectures.
  - Error Control, Retransmissions, Flow/Congestion Control, Layers.

Error Control Mechanisms

Link-level Error Detection:

- A simple detection method: add a parity bit (as in RS-232 serial lines).
- Want to transmit 7 bits: 0110100.
- Add bit so that # of 1s is even: 01101001.
- If a single error occurs (e.g., 01001001), receiver can detect.
- If an even number of errors occurs, those go *undetected*.

Error Control Mechanisms

Link-level Error Correction:

- A simple correction method: add multiple parity bits.

0	1	0	1	1	0	0	1
1	0	1	0	0	1	1	0
0	0	1	0	1	1	0	1
1	0	0	1	0	0	1	1
1	1	0	0	1	1	0	0
0	0	1	0	0	1	0	0
1	1	1	0	1	0	1	1
0	1	0	0	0	0	1	

- An error can be corrected:

0	1	0	1	1	0	0	1
1	0	1	0	0	1	1	0
0	0	1	0	1	1	0	1
1	0	0	1	1	0	1	1
1	1	0	0	1	1	0	0
0	0	1	0	0	1	0	0
1	1	1	0	1	0	1	1
0	1	0	0	0	0	1	

- By carefully adding parity bits, more errors can be detected and/or corrected.

Error Control Mechanisms

Computer networks use both forms:

- Add parity bits to a packet for error detection:
  - If no error detected, send acknowledgement for packet.
  - If error detected, discard and *retransmission needed*.

  Useful on noisy links with a feedback channel.

- Add parity bits to a packet for error correction:
  - Add enough parity bits to correct for largest possible # of errors.

  Useful on noisy links without feedback, or with long propagation times.

- Add parity *packets*.
  - Put parity bits in separate packets.
  - If packet is lost, can recover missing from packets received.

  Useful to deal with loss of packets due to discarding or congestion.

Error Control Mechanisms

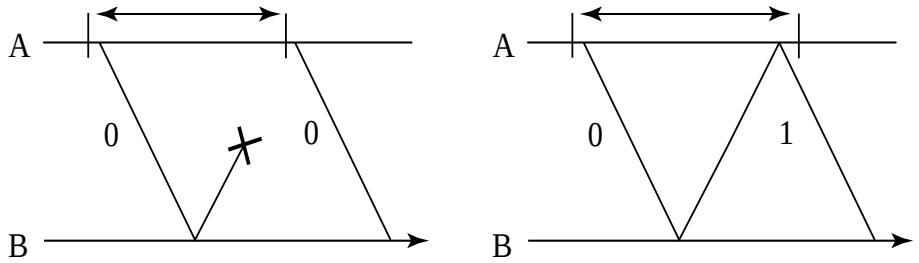
Retransmissions: the Alternating Bit Protocol.

- Sender numbers packets with alternating 0s and 1s.
- Receiver acknowledges each correctly received packet with its bit.
- Sender waits to get ack to send next packet.
- If error in packet transmission, no ack sent.
- If no ack received, or ack received in error, resend after timeout.

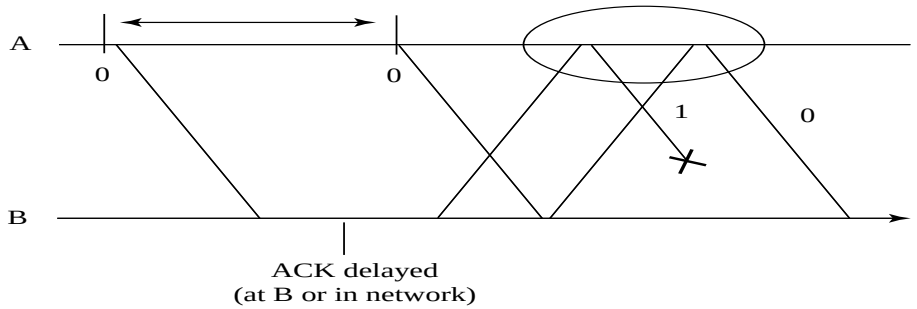
Error Control Mechanisms

What can go wrong in ABP without numbering packets:

- If ack lost, cannot distinguish packet from retransmission.



- If ack delayed, deadlock can result.



Error Control Mechanisms

Retransmissions: the Go-Back-N Protocol.

- ABP can be inefficient if propagation times are long (sender waits idle while packet is in flight).
- Choose a window size N, large enough so that "the pipe is full."
- Sender numbers packets sequentially modulo N $(0, 1, ..., N-1, 0, ...)$.
- Receiver acks correctly received packets with last one released:

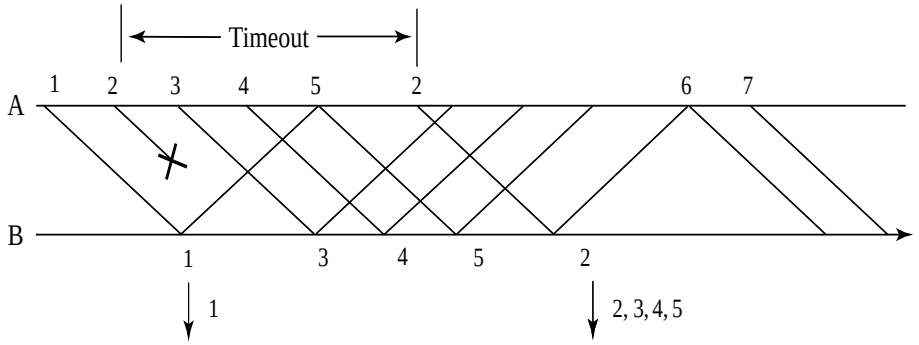
  e.g.: Receive: $1, 2, 4, 5$; Acks sent: $1, 2, 2, 2$.

More efficient because, when errors are rare, roughly N-fold throughput increase.

Error Control Mechanisms

Retransmissions: the Selective Repeat Protocol.

- Go-Back-N can be inefficient if cost of sending a packet is high.
- Instead of resending the whole window after ack, only send next packet.



- Saves on number of retransmissions.

Flow/Congestion Control

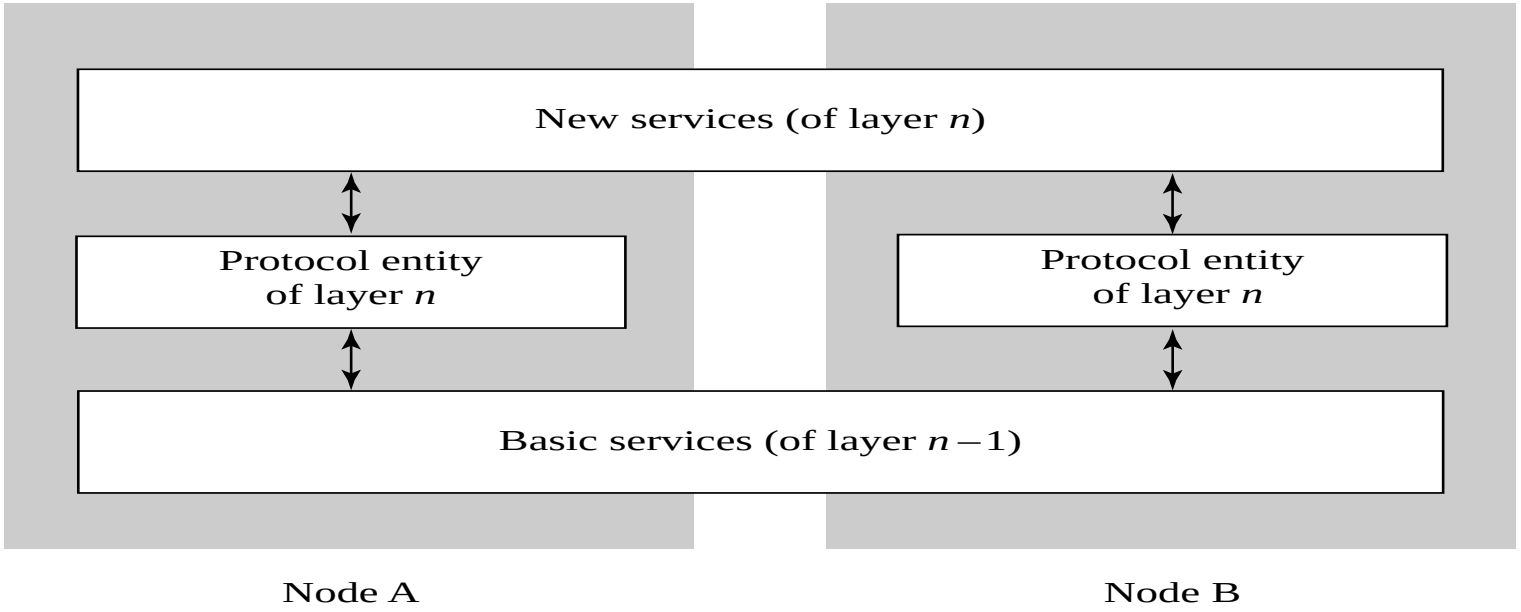
Sometimes might need to dynamically throttle sources:

- If receiver's memory is filling up.
- If routers/switches multiplexing many streams become congested.

Can do by dynamically adapting window size. Will spend *a lot* of time studying this later.

Layered Architecture

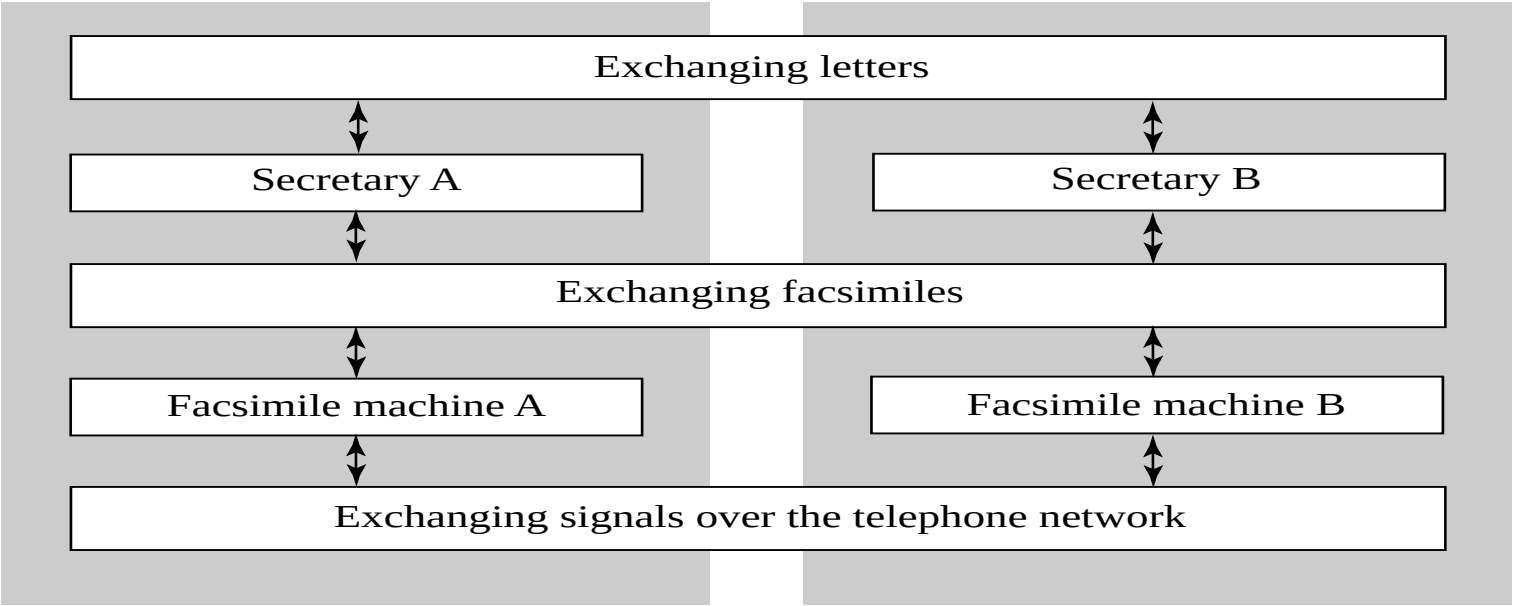
The idea of creating complex services out of simpler ones:



Example: reliable packet delivery, built on top of error detection/correction codes and retransmission protocols.

Layered Architecture

A non-technical example: two managers exchanging letters.



Will spend *a lot* of time studying layered protocols later.

Next

- Complete reading chapter 2, start browsing chapter 3.
- Homework #2 and *graded* homework #1 due on Tue 2/08.
- Homework #3 will be available over the weekend.
- Guidelines and solutions to homework #1 available on the web.

Credits: the five figures used in these slides are from our textbook.