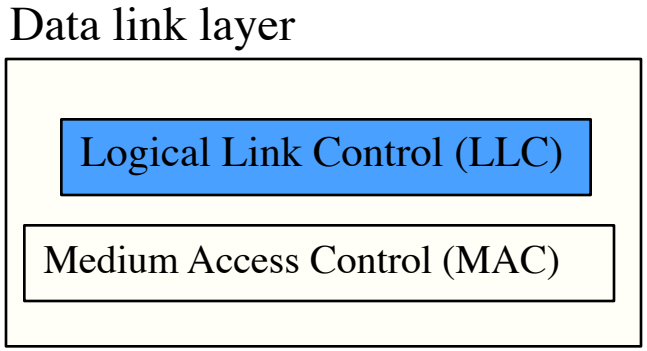
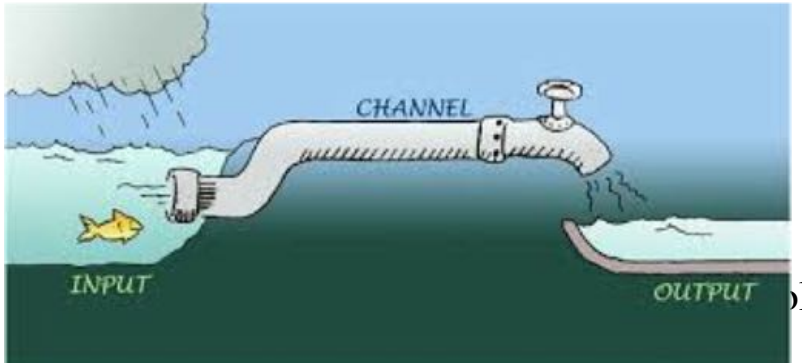
Lecture 11 Overview

- Last Lecture
  - Medium Access Control
- This Lecture
  - Flow and error control
  - Source: Sections 11.1-11.2, 23.2
- Next Lecture
  - Local Area Networks 1
  - Source: Sections 13



Why Flow and Error Control?

- What if the transmitted message is very long?
- What if the sender and receiver work at different speeds?
- How should the receiver react to damaged frames or lost frames?
- What happens if a receiver does not know it is to receive a message?
- How can a sender figure out its frame(s) got lost?



Flow Control and Error Control

- Flow control
  - Defines the way multiple frames are sent and tracked.
  - When to send frames and when to stop sending frames
- Error control
  - Defines how to check frames for errors and what to do if errors occur.
  - Ensure all frames arrive at their destination without errors.
- The protocols for flow control and error control belong to data link layer in OSI model.

Basic Flow Control (cont.)

- Frame-based Protocols
  - At data link layer, data are transmitted in frames
  - A frame is a group of bytes organized according to a specified format such as Ethernet frame
  - Frames can be carefully formatted for flow and error control

Source	Destination	Number	ACK	Type	. . . Data . . .	CRC

Typical Frame Format

Frame Format

Source	Destination	Number	ACK	Type	. . . Data . . .	CRC

Typical Frame Format

- `Source` - address of the sending station
- `Destination` - address of the receiving station
- `Number` - Each frame is numbered starting with 0.
- `ACK` - An integer value designating the frame being acknowledged. It can be sent with data, called piggyback.
- `Type` - data, ACK, NAK
- `Data` - the information being transmitted
- `CRC` - error checking bits

Frame Oriented Control

- Unrestricted Protocol
  - Assumes the receiver has unlimited capacity
  - Does not consider any problems in transmission

Frame Oriented Control (cont.)

- Stop and Wait Protocol
  - Sender sends a data frame and then waits for an ACK frame from the receiver before sending the next data frame.
  - Receiver sends an acknowledgment for each frame it gets.
  - Problem: low channel utilisation
- Error control based on Stop and Wait
  - The ACK frame tells the sender that the data frame has arrived at the destination uncorrupted.
  - The sender sets a timer for the frame sent to the receiver. If no ACK frame is received by the time that the timer expires, it will resend the frame.

Demo: https://sites.google.com/a/rcoe.co.in/prof-shiburaj-pappu/iceanim/stopandwaitarq.swf?attredirects=1

Measures of Protocol Efficiency

- How much buffer space is required?
  - Stop and Wait: one frame buffer
  - Unrestricted: as many buffers as needed
- Channel utilization
  - The percentage of time the channel is transferring data frames (e.g. Unrestricted: 95%, Stop and wait: 75%)
- Effective data rate:
  - the actual number of data bits send per unit of time (e.g. Unrestricted: 7.6 Mbps, Stop and wait: 5.7 Mbps)

Sliding Window Protocol

- Compromise between Unrestricted and Stop-and-Wait
- A window is defined as a subset of consecutive frames.
- If the window contains *i* frames numbered starting with *w*, we have the following statements
  - Every frame numbered less than *w* has been sent and acknowledged.
  - No frame numbered greater than or equal to $w + i$ is sent.
  - Every frame in the window has been sent, but may not be acknowledged. Those not acknowledged are called **outstanding frames**.
  - If frame *j* is acknowledged, the window moves down to $j+1$. (Now more frames can be sent.)

Demo: http://www.ccs-labs.org/teaching/rn/animations/gbn_sr/
http://blog.itianqi.me/Projects/goBackN/

Sliding Window Protocol (cont.)

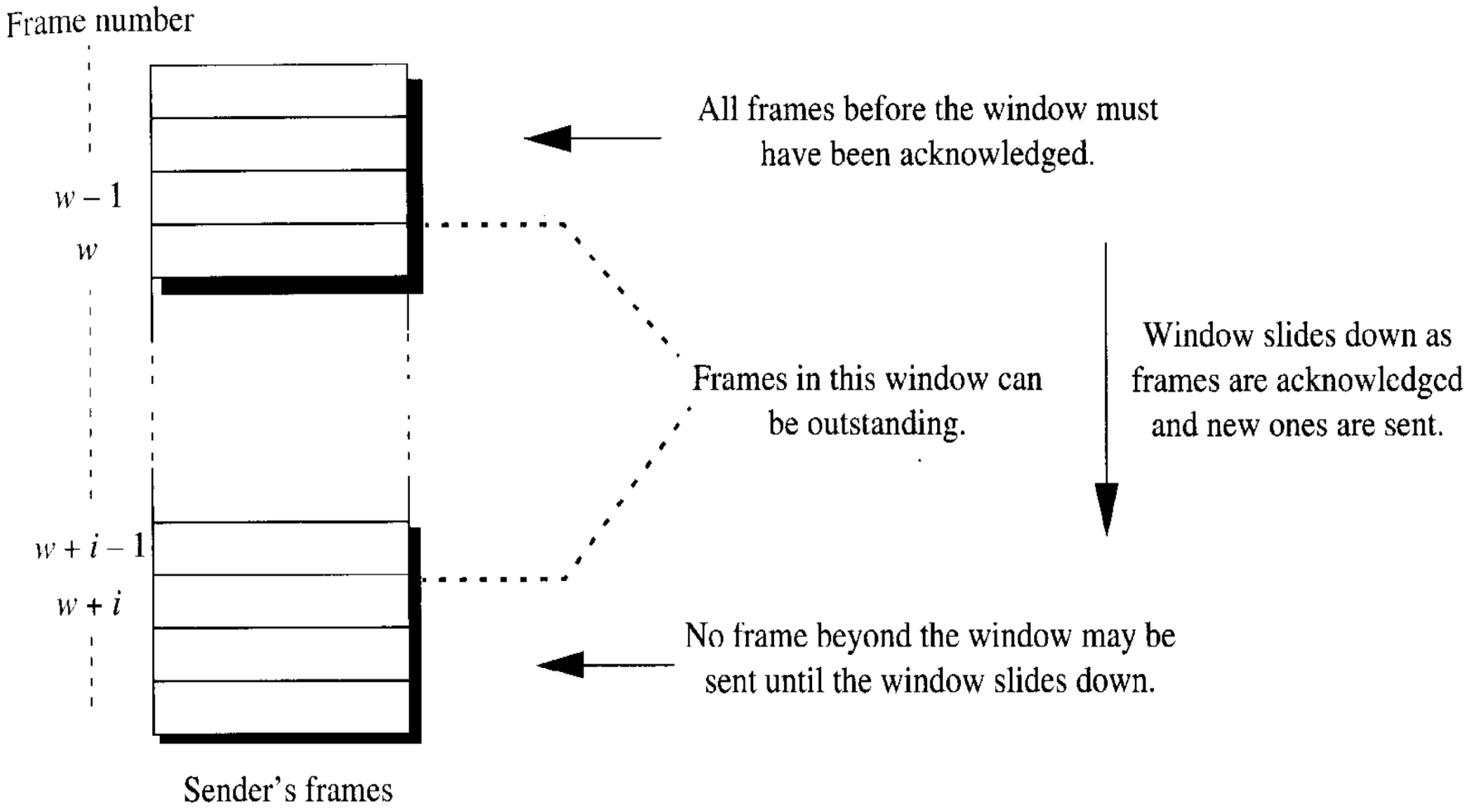


Figure 5.7 A Sliding Window Protocol

Sliding Window Protocol (cont.)

- Analysis of Sliding Window Protocol
  - It allows multiple frames to be sent before receiving acknowledgments.
  - The maximum window size defines the maximum number of frames that may be outstanding.
  - If the maximum window size is 1, it becomes the *stop and wait protocol*.
  - If the window size is unrestricted, it becomes the *unrestricted protocol*.
  - Adjusting the window size can help control the traffic on a network and change the buffering requirements.
- The protocol works well for flow control

Implementations

- Two main implementations of the sliding window protocol
  - Go-back-N protocol
  - Selective repeat protocol
- Assumptions for implementation
  - Need not maintain the distinction between sender and receiver.
  - Two stations, A and B, are sending data frames to each other.
  - A station must be able to act as both a sender and a receiver.
  - The frame numbers are from 0 to $2^k - 1$, where k is the number of bits in the frame number field. This field determines the maximum window size in the sliding window protocol.

Go-Back-N Protocol

video demo and http://www.ccs-labs.org/teaching/rn/animations/gbn_sr/

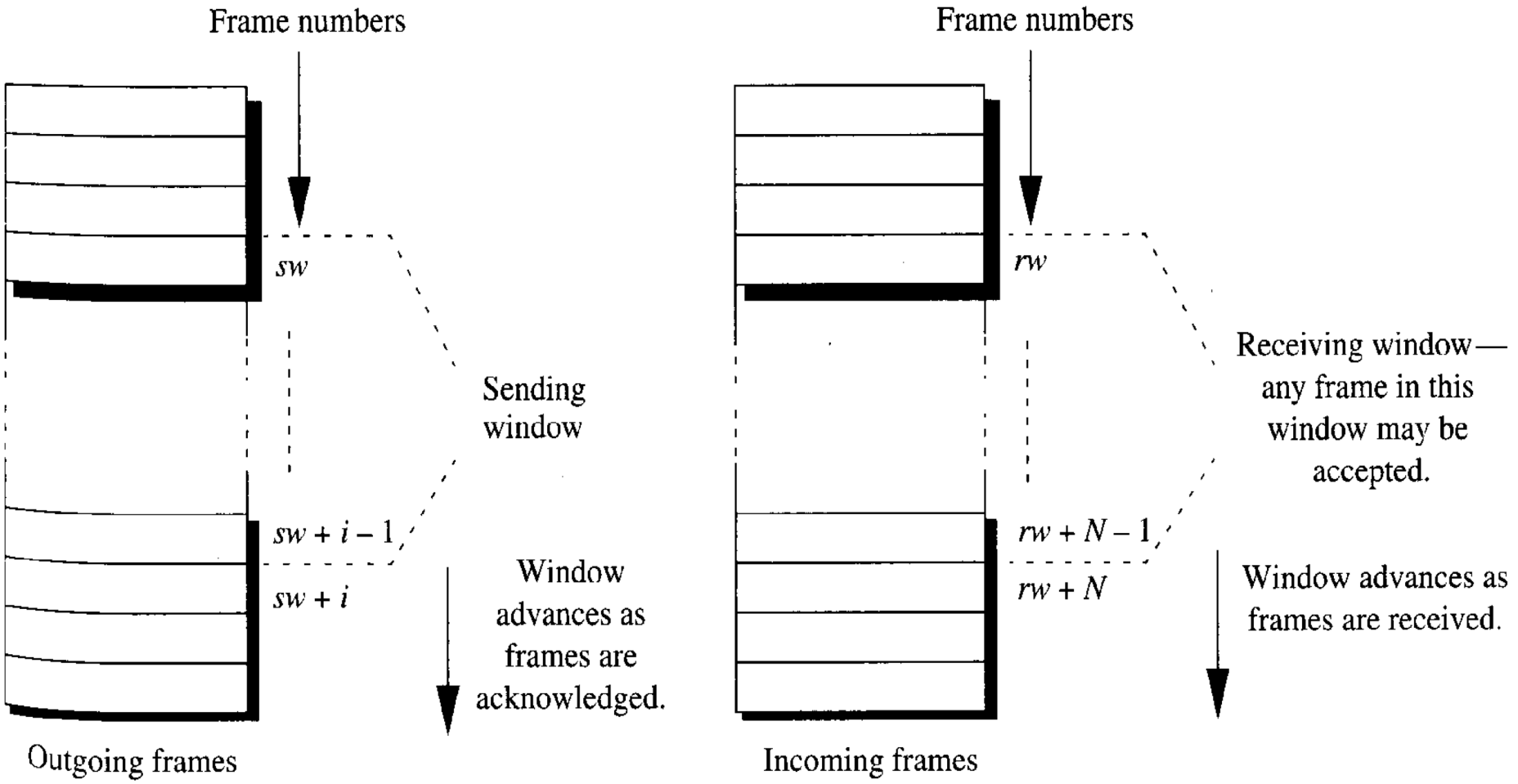
- Frames must be received in the same order as sent.
- The sender buffers the frames in the window in case it has to resend them.
- When the receiver gets a frame:
  - If the frame is out of order, the receiver ignores the frame and sends a NAK for the frame it expected.
  - If the frame is the expected one and intact, the receiver sends an ACK for the frame, which means it has received the frame and all its previous frames.
  - The receiver uses the piggyback approach for acknowledgments whenever possible.
  - If the frame is a duplicate, the receiver drops it.

Go-Back-N Protocol (cont.)

- When the sender gets an ACK/NAK:
  - If an ACK for frame *j* is received, the sender assumes all the frames before *j* were received properly and moves the window to *j+1*. (Now more frames can be sent.)
  - If a NAK is received, the sender resends all frames in the window.
- Two timers are used:
  - Frame timer - If the sender does not receive an ACK within a period of time, the timer expires and the sender resends all outstanding frames in the window.
  - ACK timer - If there is no data to send in the receiver, a separate acknowledgment frame is sent if the timer expires.

Selective Repeat Protocol

Figure 5.13 Sending and Receiving Windows for Selective Repeat Protocol



Selective Repeat Protocol (cont.)

- Allow the receiver to receive frames out of order and sort them before delivery to the patron
- Receiver uses a window to buffer out-of-order frames
- Similarities to Go-back-N:
  - Frame formats are similar and numbered with a k-bit field
  - Sender has a window defining the maximum number of outstanding frames
  - Piggybacked ACKs are used whenever possible
  - NAKs are sent for the expected frame if a damaged or an out-of-order frame is received
  - Frame and ACK timers are used (each frame has a timer)

Selective Repeat Protocol (cont.)

- Each station has a sending and receiving window.
- Receiver
  - Frames arriving out of order are received and buffered as long as they are in the receiving window. It is not given to the patron until all its predecessors arrive.
  - When an out-of-order frame arrives, the protocol sends a NAK for the frame it was expecting.
  - An ACK is sent for a frame only if the frame and all its previous frames have been received correctly.
- Sender
  - If the sender gets a NAK, it resends just the frame involved.
  - If a frame timer expires, only the timed-out frame is resent.

Sliding Window Size

- Go-Back-N Protocol:
  - Sending window size must be less than 2^k
  - Receiving window size is always 1
- Selective Repeat Protocol:
  - Sending and receiving windows must be at most one-half of 2^k
  - Usually they are the same size (2^{k-1})

Comparison

- The four flow control protocols discussed can be viewed as variations of a sliding window protocol.

Table 5.1 Comparison of Flow Control Protocols

	Stop and Wait Protocol	Unrestricted Protocol	Go-back-*N* Protocol	Selective Repeat Protocol
Sending window size	One frame	Unlimited number of frames	Less than 2^K	Less than 2^{k-1}
Receiving window size	One frame	Unlimited number of frames	One frame	Less than 2^{k-1}

Summary

- Concepts
  - Flow and error control
  - Frame format
  - Channel utilisation
- Simple flow control protocols
  - Signalling
  - Unrestricted
  - Stop and wait
- Sliding window protocols
  - Go-back-N
  - Selective repeat