

## CSE/EE 461 – Lecture 13

### Sliding Windows and ARQ

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### Last Time

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- We finished up the Network layer
  - Internetworks (IP)
  - Routing (DV/RIP, LS/OSPF)
  - Scalable addressing/routing (BGP, CIDR)
- It was all about routing: how to provide end-to-end delivery of packets.

Application
Presentation
Session
Transport
<b>Network</b>
Data Link
Physical

## This Time

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- We begin on the Transport layer
- Focus
  - How do we send information reliably?
- Topics
  - The Transport layer
  - Acknowledgements and retransmissions (ARQ)
  - Sliding windows

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## The Transport Layer

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- Builds on the services of the Network layer
- Communication between processes running on hosts
  - Naming/Addressing
- Stronger guarantees of message delivery
  - Reliability

## Example – Common Properties

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### TCP

- Guaranteed delivery
- In-order delivery
- Single delivery
- Arbitrarily long messages
- Synchronization
- Flow control
- Multiple processes

### IP

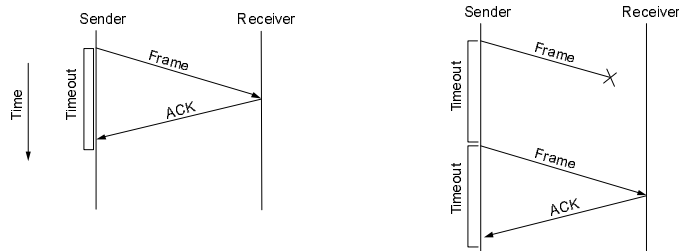
- Lost packets
- Reordered packets
- Duplicate packets
- Limited size packets

## Internet Transport Protocols

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- UDP
  - Datagram abstraction between processes
  - With error detection
- TCP
  - Bytestream abstraction between processes
  - With reliability
  - Plus congestion control (later!)

## Automatic Repeat Request (ARQ)

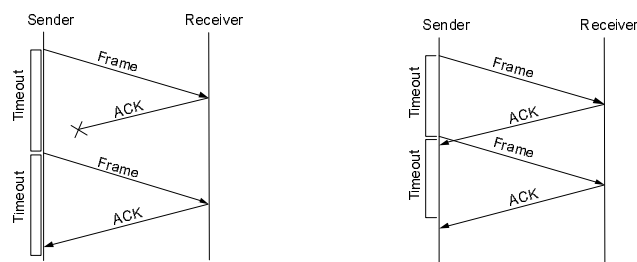


- Packets can be corrupted or lost. How do we add reliability?
- Acknowledgments (ACKs) and retransmissions after a timeout
- ARQ is generic name for protocols based on this strategy

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## The Need for Sequence Numbers



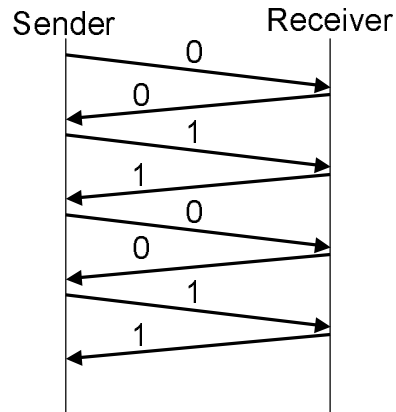
- In the case of ACK loss (or poor choice of timeout) the receiver can't distinguish this message from the next
  - Need to understand how many packets can be outstanding and number the packets; here, a single bit will do

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## Stop-and-Wait

- Only one outstanding packet at a time
- Also called alternating bit protocol



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## Limitation of Stop-and-Wait

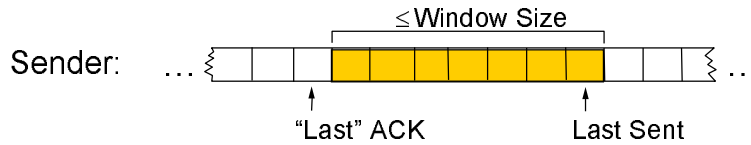


- Lousy performance if wire time  $\ll$  prop. delay
  - How bad? You do the math
- Want to utilize all available bandwidth
  - Need to keep more data “in flight”
  - How much? Remember the bandwidth-delay product?
- Leads to Sliding Window Protocol

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## Sliding Window – Sender

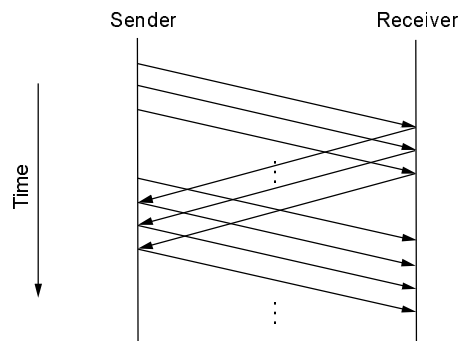


- Window bounds outstanding data
  - Implies need for buffering at sender
- “Last” ACK applies to in-order data
- Sender maintains timers too
  - Go-Back-N: one timer, send all unacknowledged on timeout
  - Selective Repeat: timer per packet, resend as needed

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## Sliding Window – Timeline

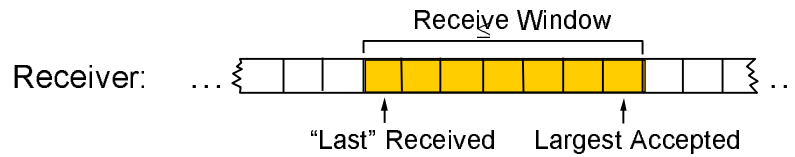


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## Sliding Window – Receiver

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- Receiver buffers too:
  - data may arrive out-of-order
  - or faster than can be consumed (flow control)
- Receiver ACK choices:
  - Individual, Cumulative (TCP), Selective (newer TCP), Negative

## Sliding Window Functions

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- Sliding window is a mechanism
- It supports multiple functions:
  - Reliable delivery
  - In-order delivery
  - Flow control

## Key Concepts

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- Transport layer allows processes to communicate with stronger guarantees, e.g., reliability
- Basic reliability is provided by ARQ mechanisms
  - Stop-and-Wait through Sliding Window plus retransmissions

## This Lecture

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# Key Concepts

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