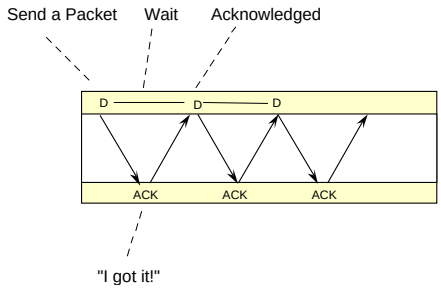
Reliable Services

- **Definition of Reliability**
- **Stop & wait ARQ**
  - Timers
  - NACK
- **Continuous ARQ**
  - Connection Management
  - Buffers
  - Cumulative ACK
  - Go-Back ARQ
  - Selective Repeat ARQ

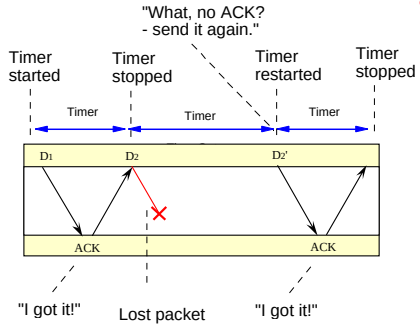
Implies....

All information is received	(no loss, no residual errors)
No information is duplicated	(no extra copies)
Sequencing	(original order is preserved)

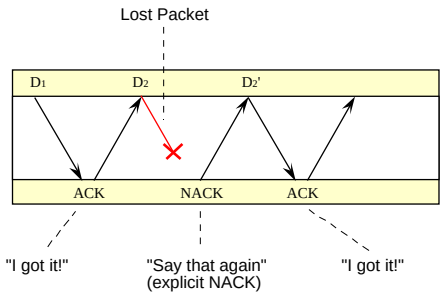
Stop and Wait / Idle ARQ



Recovery by Timer Using Stop and Wait

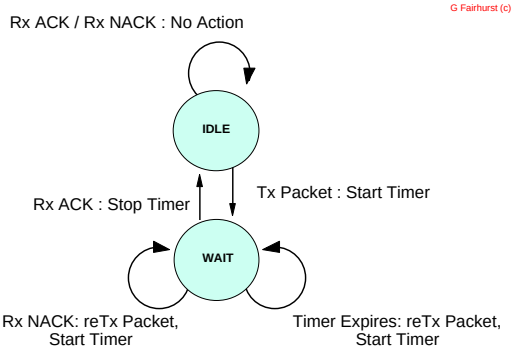


Recovery by ACK/NACK Using Stop and Wait



May be much faster than waiting for a timer

State Diagram for Stop and Wait



Stop & Wait

Advantages:

Very simple to implement

Disadvantages:

Response to every transmitted frame

Half duplex operation

Timers are needed to recover from loss of frames

Continuous ARQ

Stop & Wait (Idle)

Wasteful with long delays

Continuous ARQ

Uses a modulo sequence number

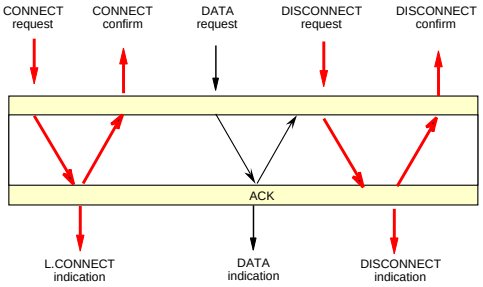
Numbers each packet to protect from duplication

Numbers ACKs/NACKs

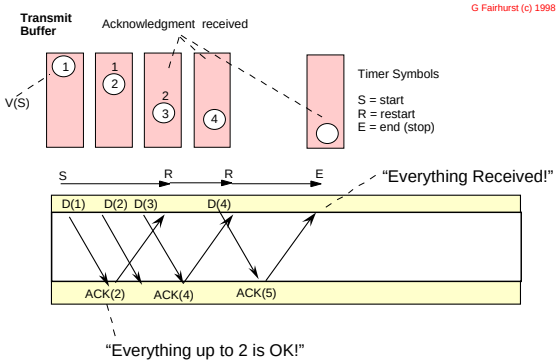
Requires buffers to store unacknowledged packets

Requires connection management

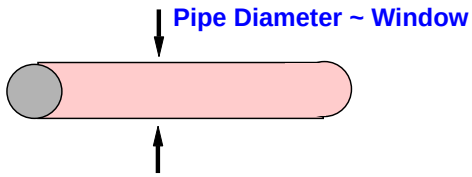
Connection Management



Culmultaive ACKs



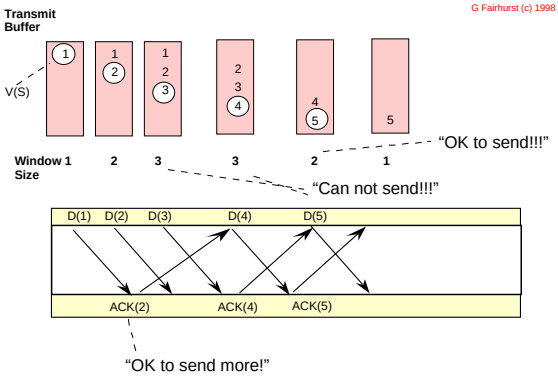
Transmit Window



Window size defines the maximum number of unacknowledged packets which may be in transit

It is a measure of the "diameter" of the communications "pipe" since it controls the maximum throughput

Transmit Window (Example with Window = 3)



Transmit Timer

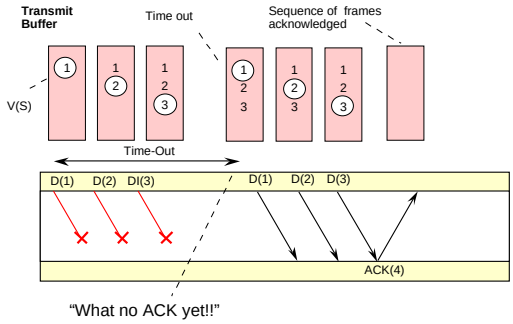
The transmit timer monitors the receipt of acknowledgements

Starts: When a Data Packet sent, and not already running

Restarts: When a new acknowledgment is received

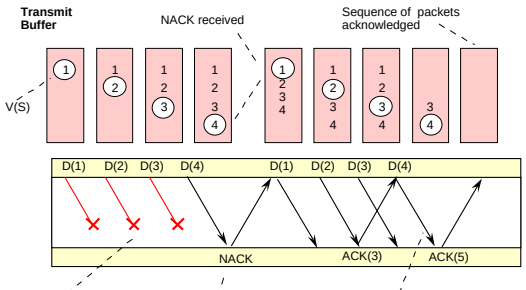
Stops: When all packets have been acknowledged

Time-Out Recovery



"What no ACK yet!!"

Go Back-N Recovery

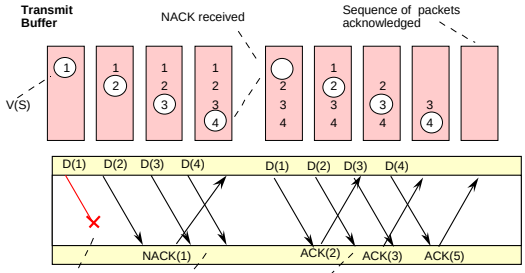


3 Packets corrupted

Out-of-sequence Packet detected

"D(4) has to be sent again too!"

Go Back-N Recovery

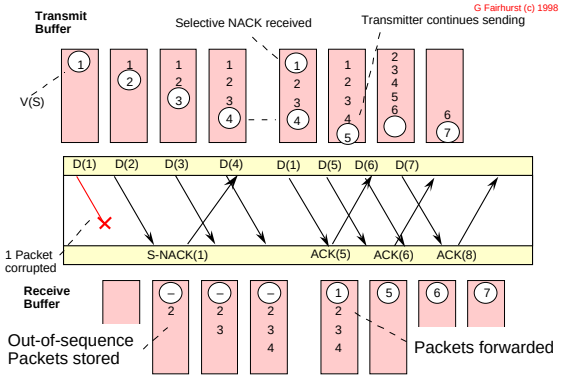


1 Packet corrupted

Receiver discards out of sequence packets (unless it can buffer them)

Re-transmitted Packets forwarded

Selective Repeat Recovery

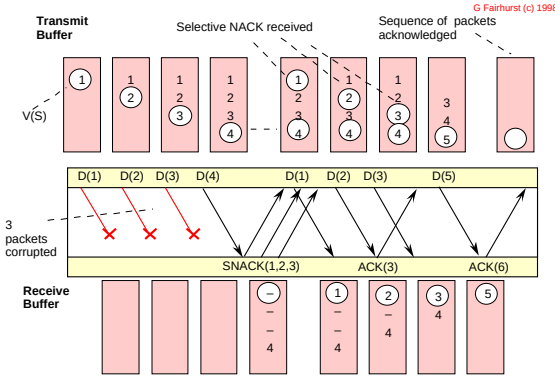


1 Packet corrupted

Out-of-sequence Packets stored

Packets forwarded

Selective Repeat Recovery



3 packets corrupted

Reliability

Connection-Less	**Connection-Oriented**
Best Effort	Reliable
CRC Required	CRC Required
Little setup required	Management Exchange
No Confirmed Delivery	Acknowledgments
No Retransmission	ARQ

ARQ Comparison

	S&W or Idle	Go-Back-N	Selective-Repeat
Protocol Design	Very simple	More Complex	Most Complex
Packet Types	I, ACK, NACK	I, ACK NACK (numbered)	I, ACK SNACK (numbered)
Buffer Requirements	One at Tx	Tx Window	Tx & Rx Window
Reliability?	Poss duplication	Reliable	Reliable
Timer?	Timer Needed	Timer Needed	Timer Needed
Efficiency	Low efficiency	Better efficiency with long delay x bandwidth	Best efficiency with long delay x bandwidth