CS 348: Computer Networks

- Sliding Window; 6th Aug 2012

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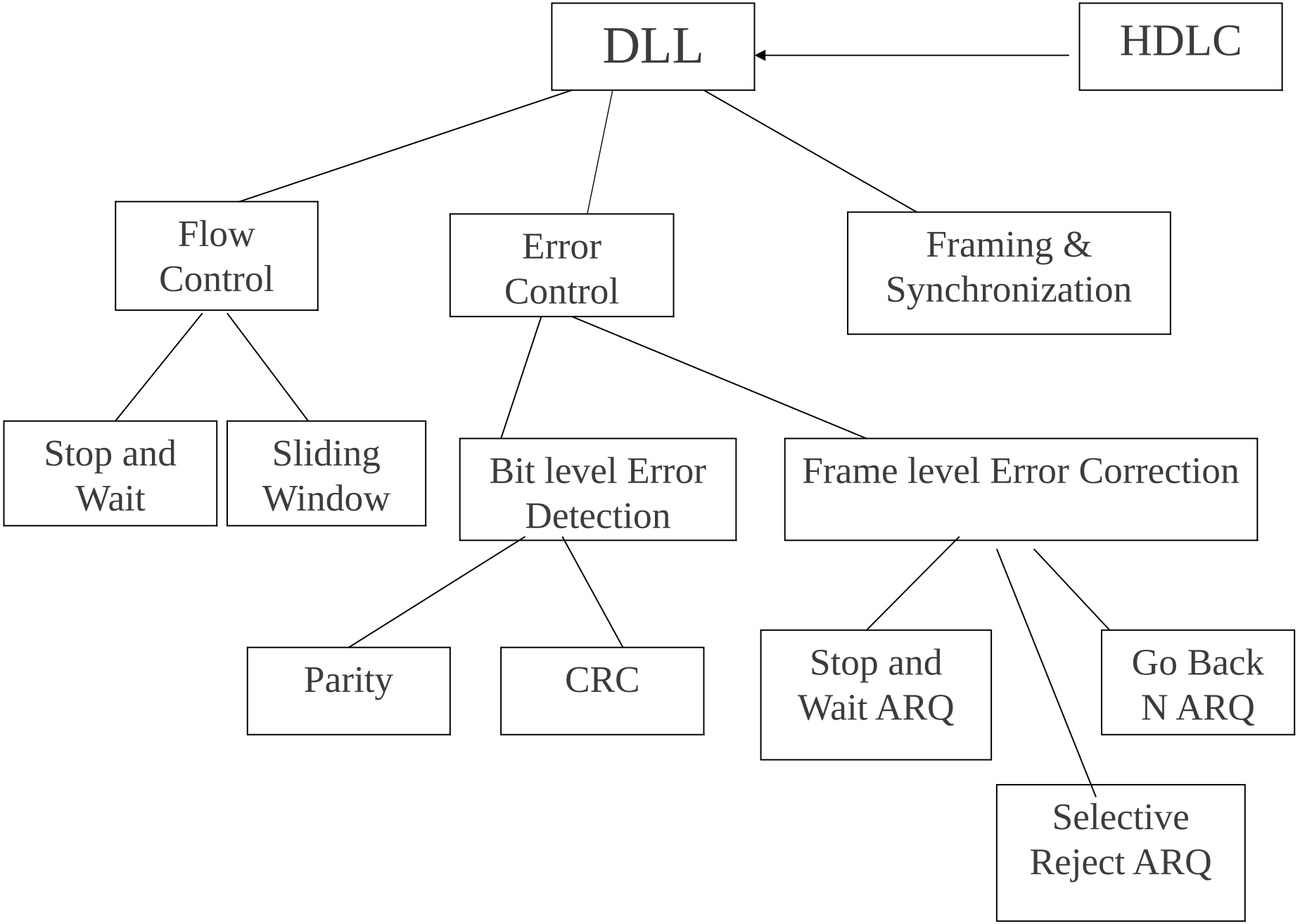
Performance Metrics

- Throughput
  - Amount of data transmitted per unit time.
  - May be different at different layers!
- Link Utilization (Efficiency)
  - Throughput / Bandwidth (Capacity of link)
- Mean Delay
  - Average amount of time a sender has to wait before it can successfully transmit a packet.

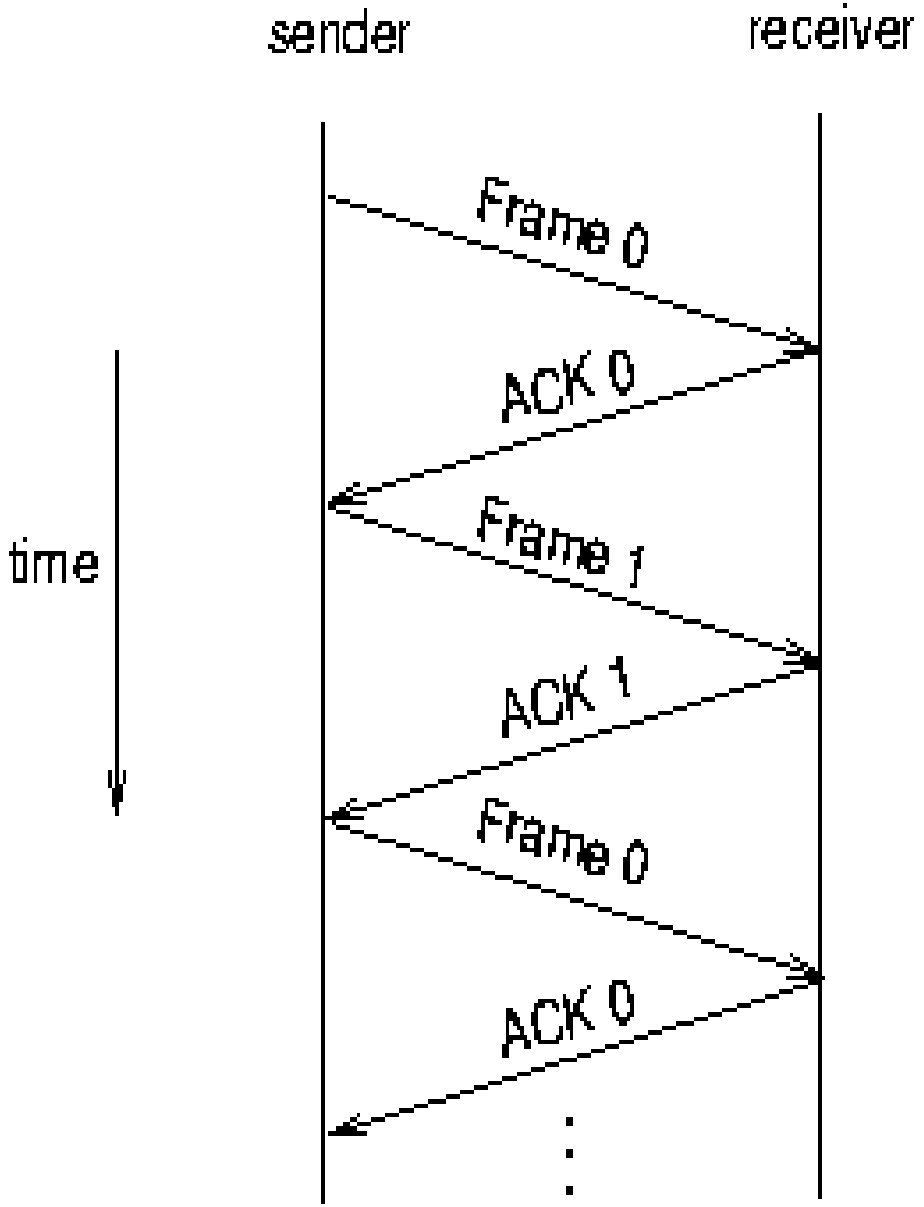
Goodput (Normalized Througput)

- Goodput: Fraction of link capacity devoted to carrying non-retransmitted packets
  - Number of 'useful' data/bits per unit time.
  - Excludes time lost due to protocol overheads, collisions, re-transmission, etc
- Example
  - 1Mbps link can ideally carry 1000 packets/sec of size 125 bytes.
  - If a scheme reduces throughput to 250 packets/sec then goodput of scheme is 0.25.


DLL
HDLC
Flow Control
Error Control
Framing & Synchronization
Stop and Wait
Sliding Window
Bit level Error Detection
Frame level Error Correction
Parity
CRC
Stop and Wait ARQ
Go Back N ARQ
Selective Reject ARQ

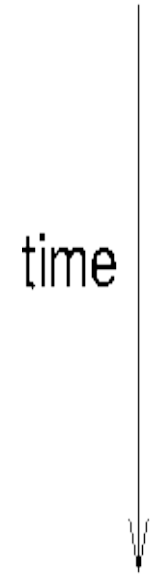
Retransmission Schemes
Stop and Wait ARQ

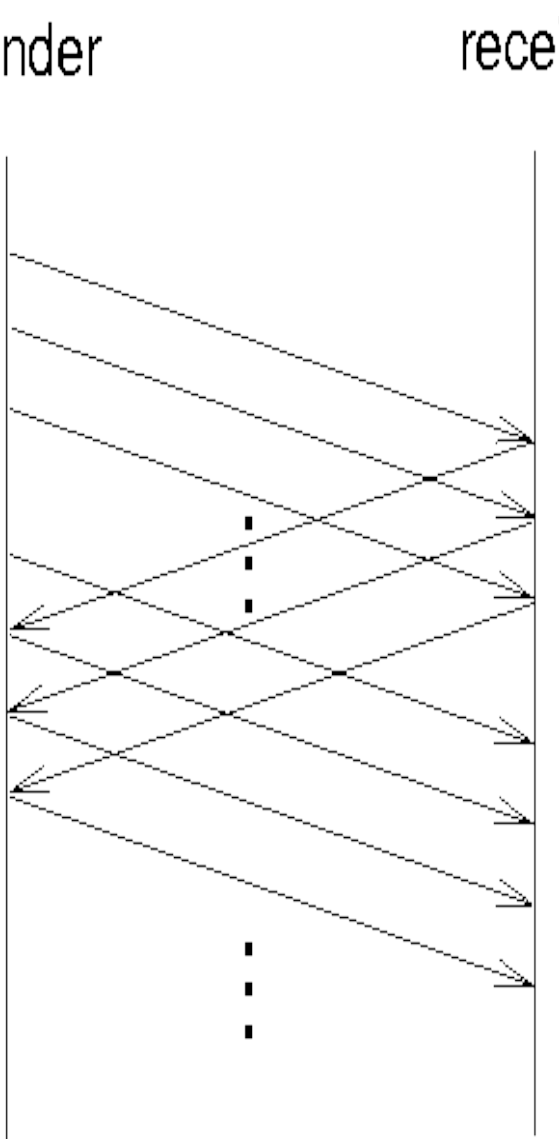
- Sender waits for ACK after transmitting each frame.
- Receiver sends ACK if received frame is error free.
- Sender retransmits frame if ACK not received before timer expires.



Flow control

- Sliding window
- Allows sender to transmit multiple frames before receiving an ACK.
- Upper limit on number of outstanding (un-ACKed) frames.





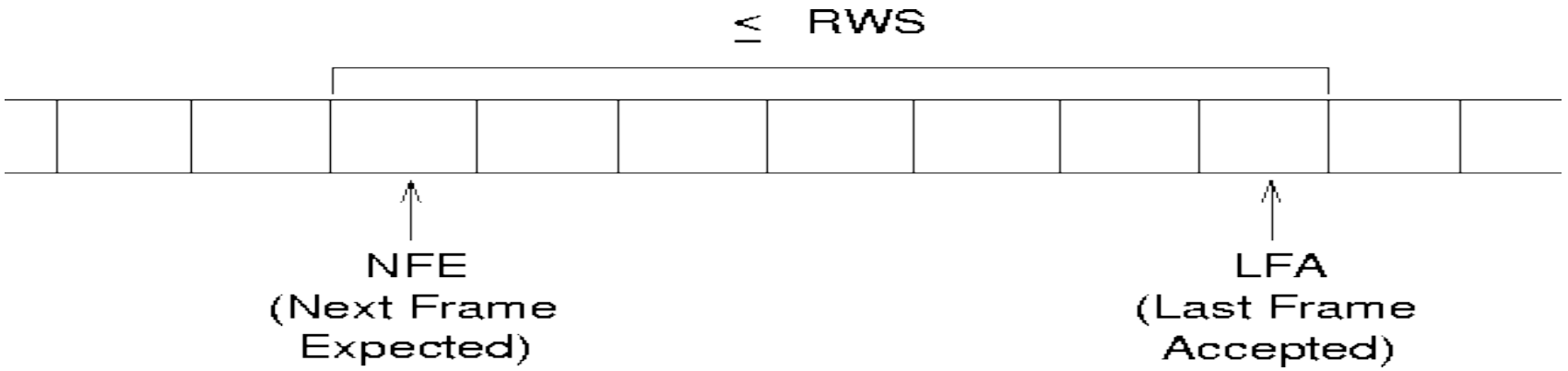
Sliding window ARQ

- Sender buffers all transmitted frames until they are ACKed.
- Receiver sends ACK (with SeqNum of next frame expected).

Sliding window sender

- Maintain three state variables:
  - send window size (SWS)
  - last acknowledgment received (LAR)
  - last frame sent (LFS)
- Maintain invariant: LFS - LAR < SWS
  - When ACK arrives, advance LAR, thereby opening window

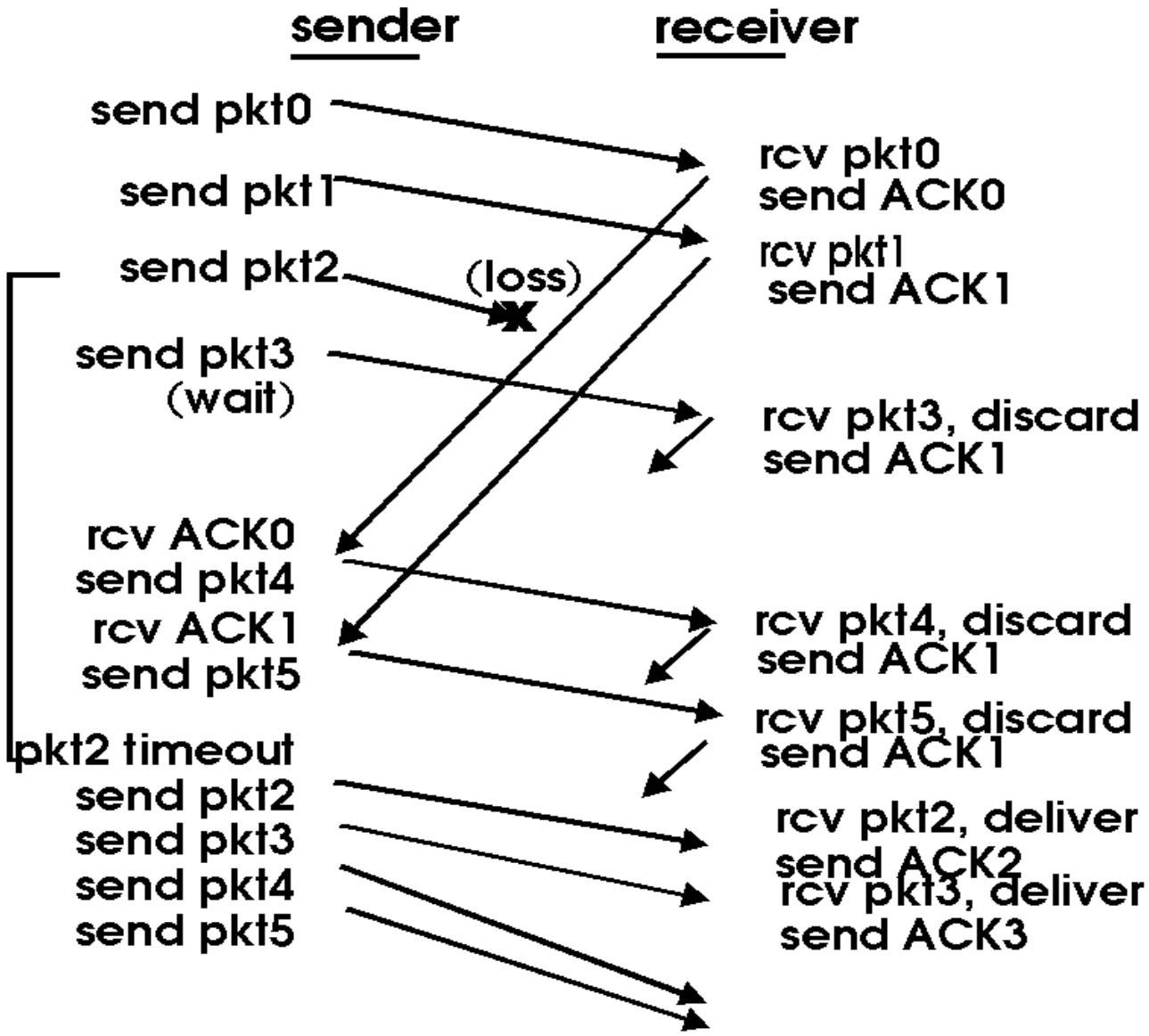
Sliding window receiver



- Maintain three state variables:
  - receive window size (RWS)
  - last frame accepted (LFA)
  - next frame expected (NFE)
- Maintain invariant: LFA - NFE < RWS
  - if received SeqNum is between NFE and LFA, send ACK else discard

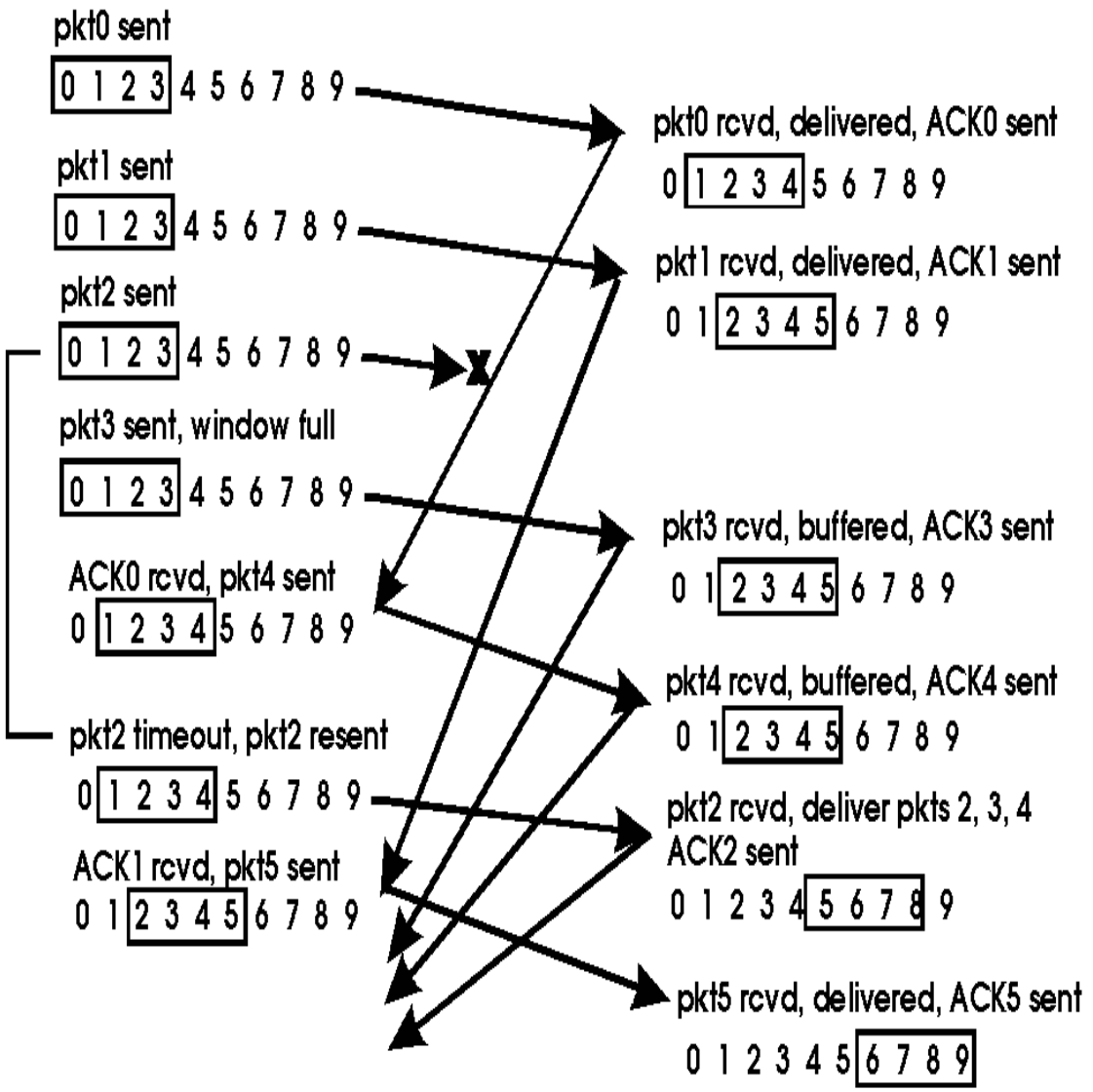
Go-back-N ARQ

- Receiver discards out-of-seq pkt received and ACKs LFA.
- Simple in buffering & processing



Selective Repeat ARQ

- Receiver ACKs correctly received out-of-sequence pkts
- Sender retransmits packet upon ACK timeout or NACK (selective reject)



Sliding window features

- ACKs may be cumulative.
  - ACK-6 implies all frames upto 5 received correctly.
- SeqNum field is wrap around.
  - Window size must be smaller than MaxSeqNum.

Piggybacking ACKs

- if a station has data and ACKs,
  - it can send both together in one frame.
- if a station has ACK but no data,
  - it can send a separate ACK frame.
- if station has data but no new ACK,
  - it must repeat the last ACK.
  - ACK number field in every frame must have some value.

Design Issues - ACKs

- Providing ACKs in link layer is an optimization, not a requirement.
- Transport layer can very well provide reliable service.

- Question: In what cases should ACKs be implemented in link layer?