VE489 Mid Review -- Data Link Layer

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{:TOC}

Mid Schedule

Time: next class

Location: this classroom

Cheatsheet: A4, double-sided

- Qinye's office hour migrated to Wednesday @ ylm center
- Send me an email beforehand if you have a rather complicated question.

Background

Link Layer

- Logic Link Control (LLC) Layer
  - Error Control
    - FEC
    - ARQ
  - Flow Control (vs. Congestion Control)
- Medium Access Control (MAC) Layer
  - Framing, checksum
  - Link Control

Highlights

- Framing
    - Bit oriented framing & bit-stuffing
- ARQ
    - Stop and Wait
    - Go Back N
    - Selective Repeat

Framing

Why framing?

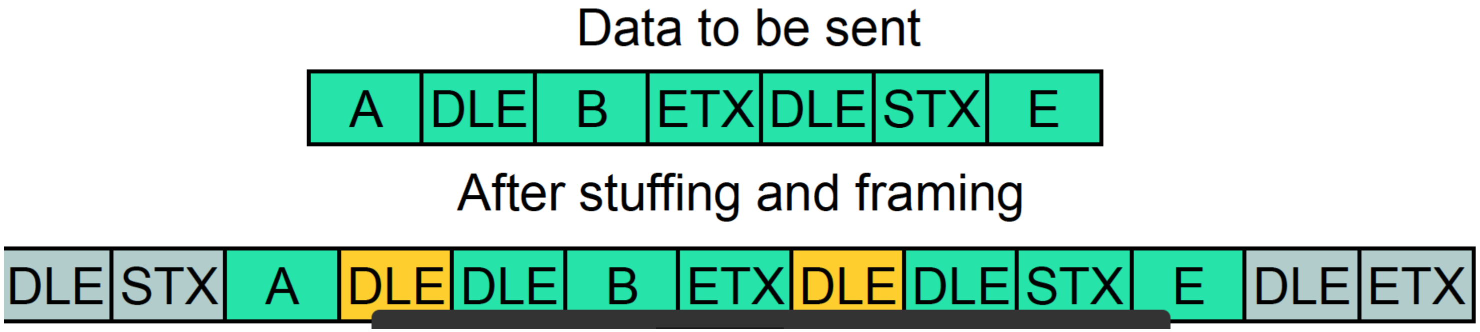
Sender needs to set boundaries in between continuous bits so that these bits can be sent out **frame by frame**;
Receiver relies on the boundaries to **detect start and end of a new frame**.

How framing?

- **Character-oriented framing** (Flog bytes with byte stuffing)
- **Bit-oriented framing** (Flag bits with **bit stuffing**)

Character-oriented framing

- **Binary Synchronous Communication**
  - Start flag: STX
  - End flag: ETX
  - Escape: DLE
  - DLE STX to indicate start; DLE ETX to indicate end
  - DLE in the original message stuffed with DLE



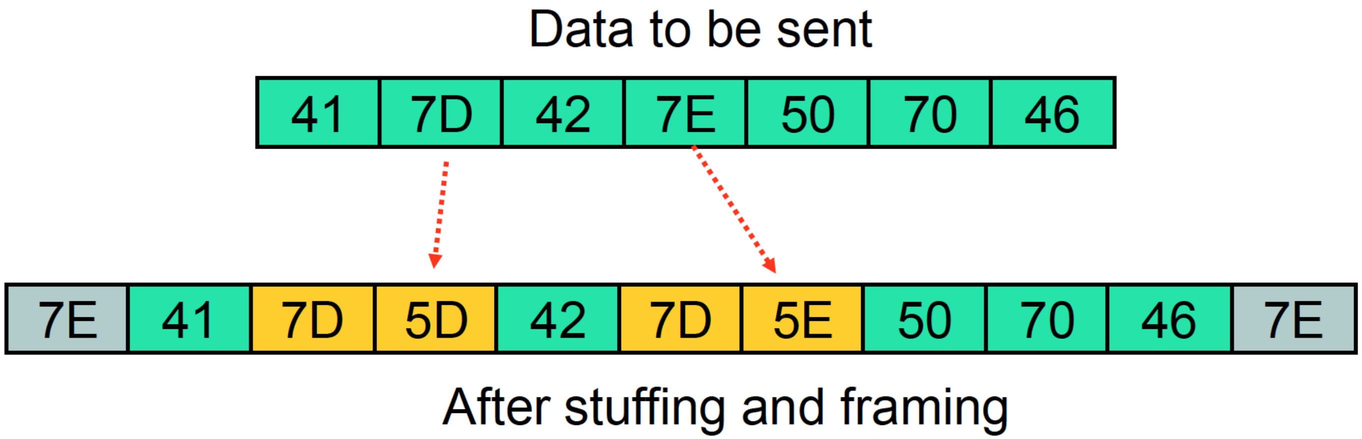
Data to be sent

A	DLE	B	ETX	DLE	STX	E

After stuffing and framing

DLE	STX	A	DLE	DLE	B	ETX	DLE	DLE	STX	E	DLE	ETX

- **Point-to-Point Protocol** (**PPP**)
  - Flag: 0x7E (01111110)
  - Escape: 0x7D (01111101)
  - Indicate start and end with Flag
  - For Flag and Excape in the original data, add Escape and XOR with 0x20 (00100000)



Data to be sent

41	7D	42	7E	50	70	46

7E	41	7D	5D	42	7D	5E	50	70	46	7E

After stuffing and framing

Bit-oriented framing

Stuffing

- Indicate start and end of frames with 0111110 (0x7E)
- Stuff a 0 after 11111 in the original data

e.g. Original message

01101111 11101011 10110100 00101111 11011011 10111111
11010111 11111110

Stuffed message:

01111110 01101111 101101011 10110100 00101111 101011011
101111101 11010111 1101111100 **01111110**

Destuffing

1. Find 5 consecutive 1s
2. If the following bit is 0, it is a stuffed bit. Destuff it.
3. If the following bits are 10, it is an flag.
4. If the following bits are 11, there must be an error.

e.g. Received message

01111110 011111 0 0011111 1 01010011 **01111110**

original message:

011111 0011111 101010011

ARQ (Automatic Repeat Request)

Why ARQ?

To ensure a sequence of information packets are delivered in-order, error-free and without loss or duplication despite tranmission errors and loess.

In a word: **To ensure in-order, error-free delivery**

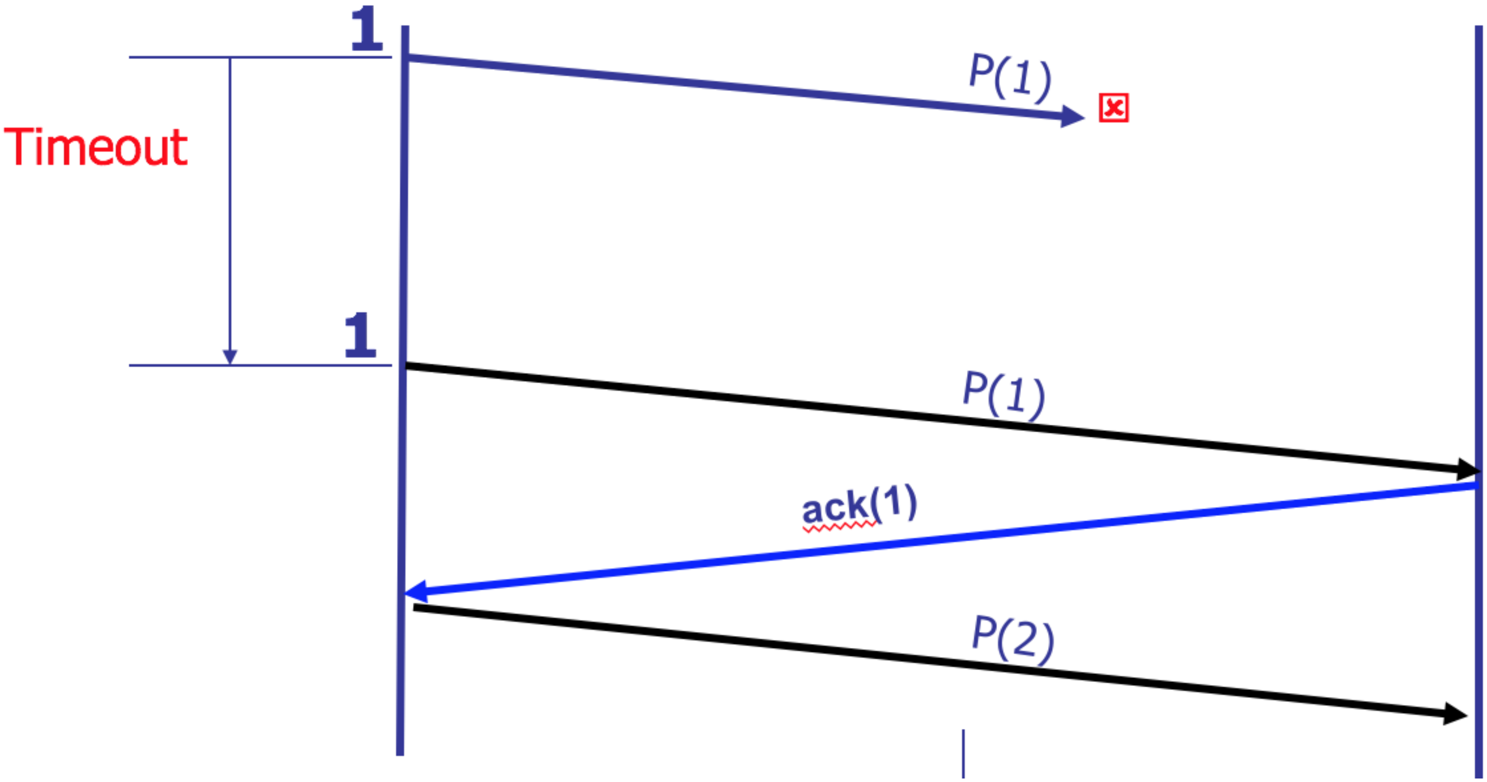
How ARQ?

- Stop and Wait
- Go-Back N
- Selective Repeat

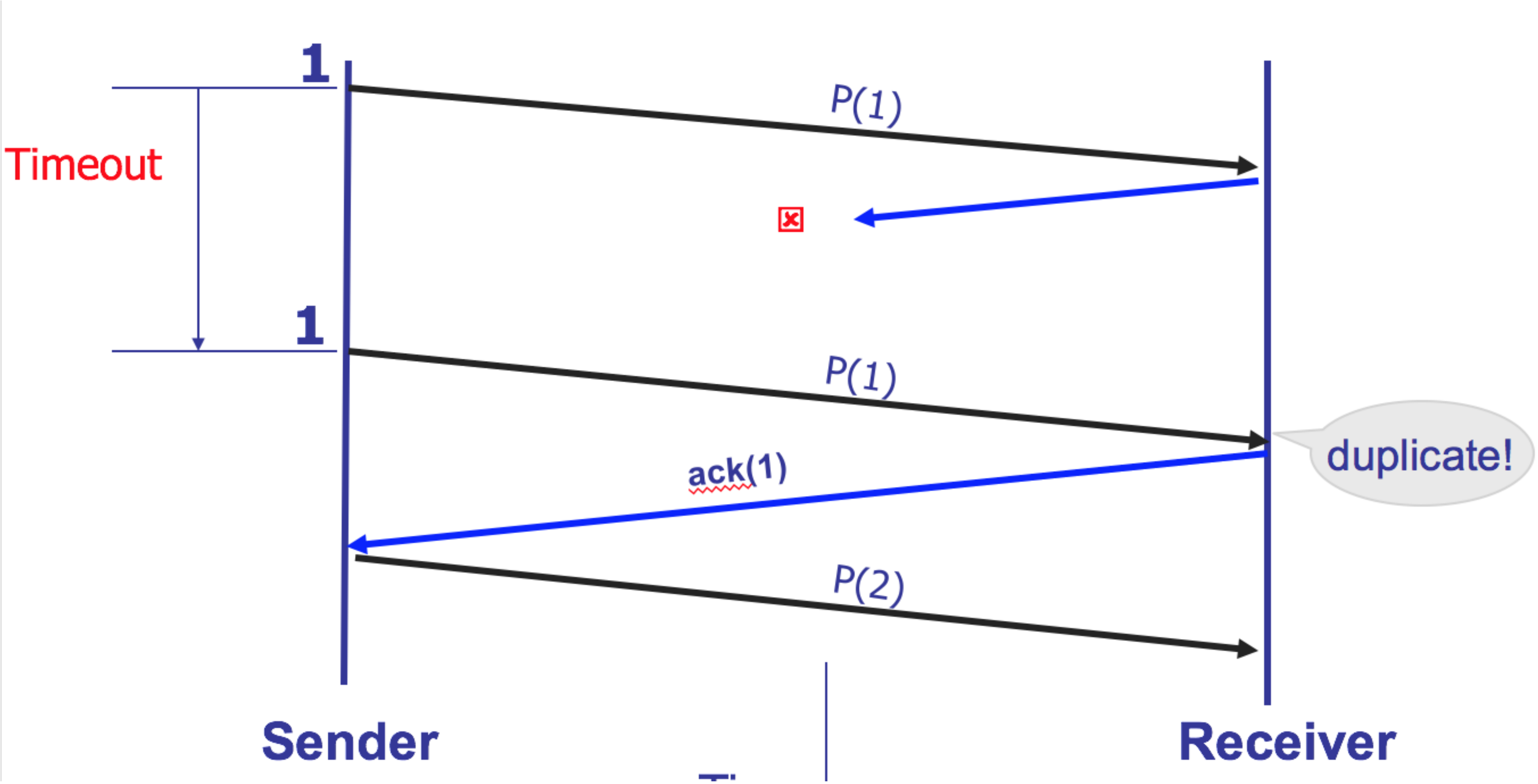
Stop-and Wait ARQ

- Transmit and wait for ACK
- Does not work well for high BDP

Why timeout?



Why sequence number?



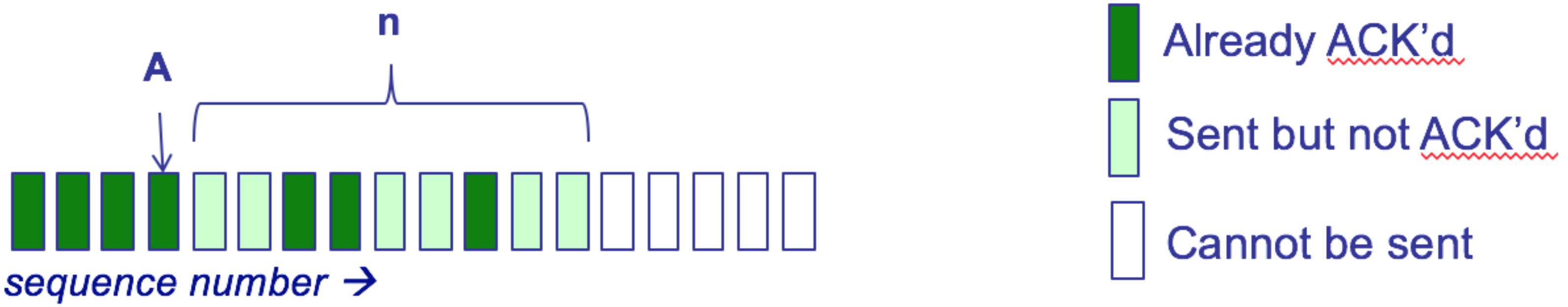
Why sliding window?

- For congestion control and/or flow control

Basic ideas of sliding window:

- Window = set of adjacent sequence numbers
- Sender can send packets in sending window
- Receiver can accept packets in receiving window
- Window of slides on successful reception/ACK

- Let A be the last ack'd packet of sender without gap; then window of sender = {A+1, A+2, …, A+n}

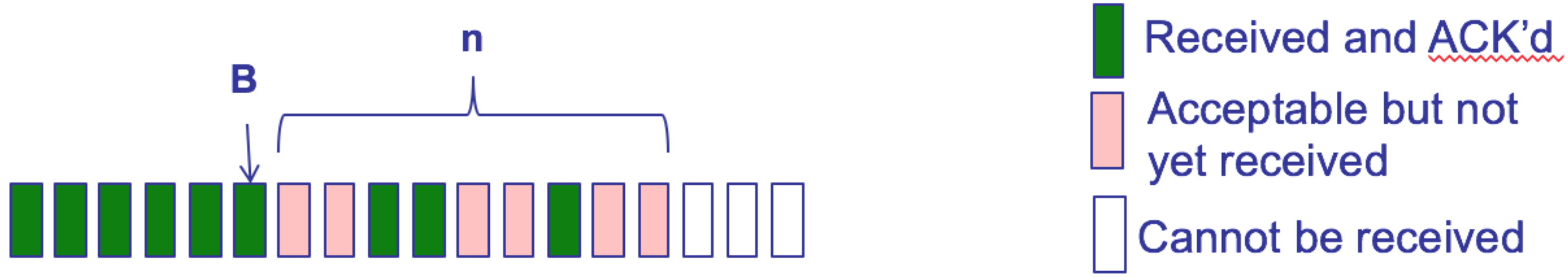


🟩 Already ACK'd

▯ Sent but not ACK'd

□ Cannot be sent

- Let B be the last received packet without gap by receiver, then window of receiver = {B+1,…, B+n}



🟩 Received and ACK'd

🟥 Acceptable but not yet received

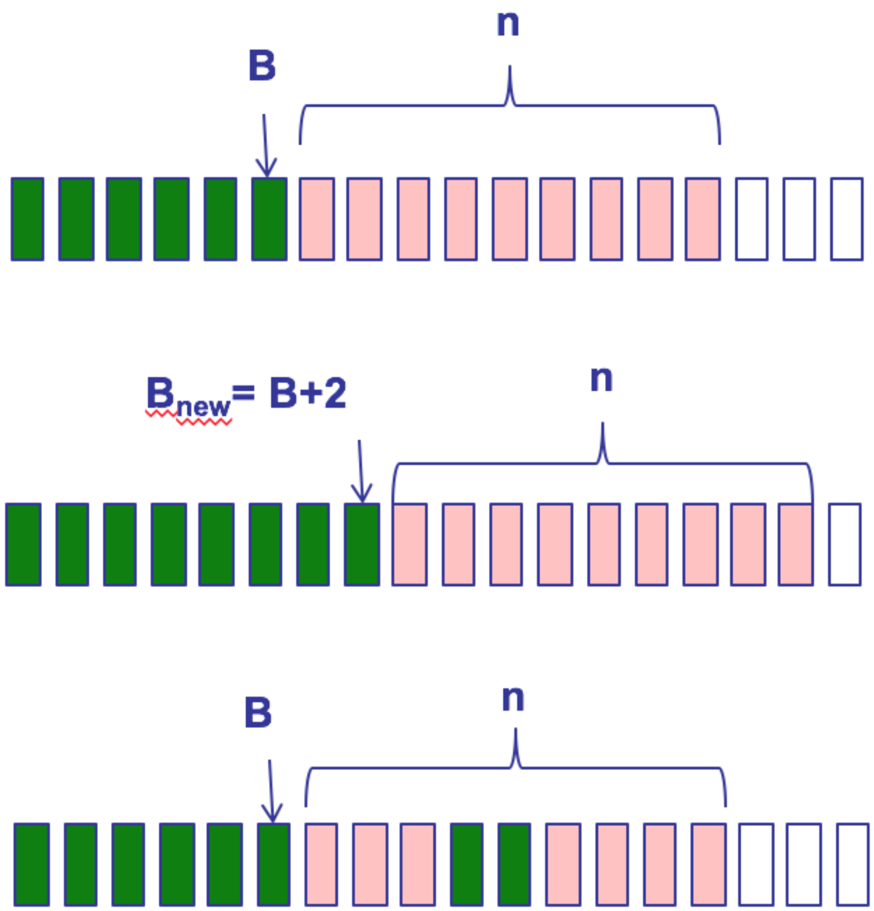
□ Cannot be received

Cumulative ACK vs. Selective ACK

- Cumulative ACK
  - carries next expected seqno
  - better when error rate is low
- Selecitve ACK
  - acknowledges received message's seqno individually
  - better when error rate is high

Cumulative ACK vs. Selective ACK

- With a focus on the receiving window



So for both cumulative ACK and selective ACK

- Sending window begins with the first unACKed data
- Receiving window begins with the first unreceived data

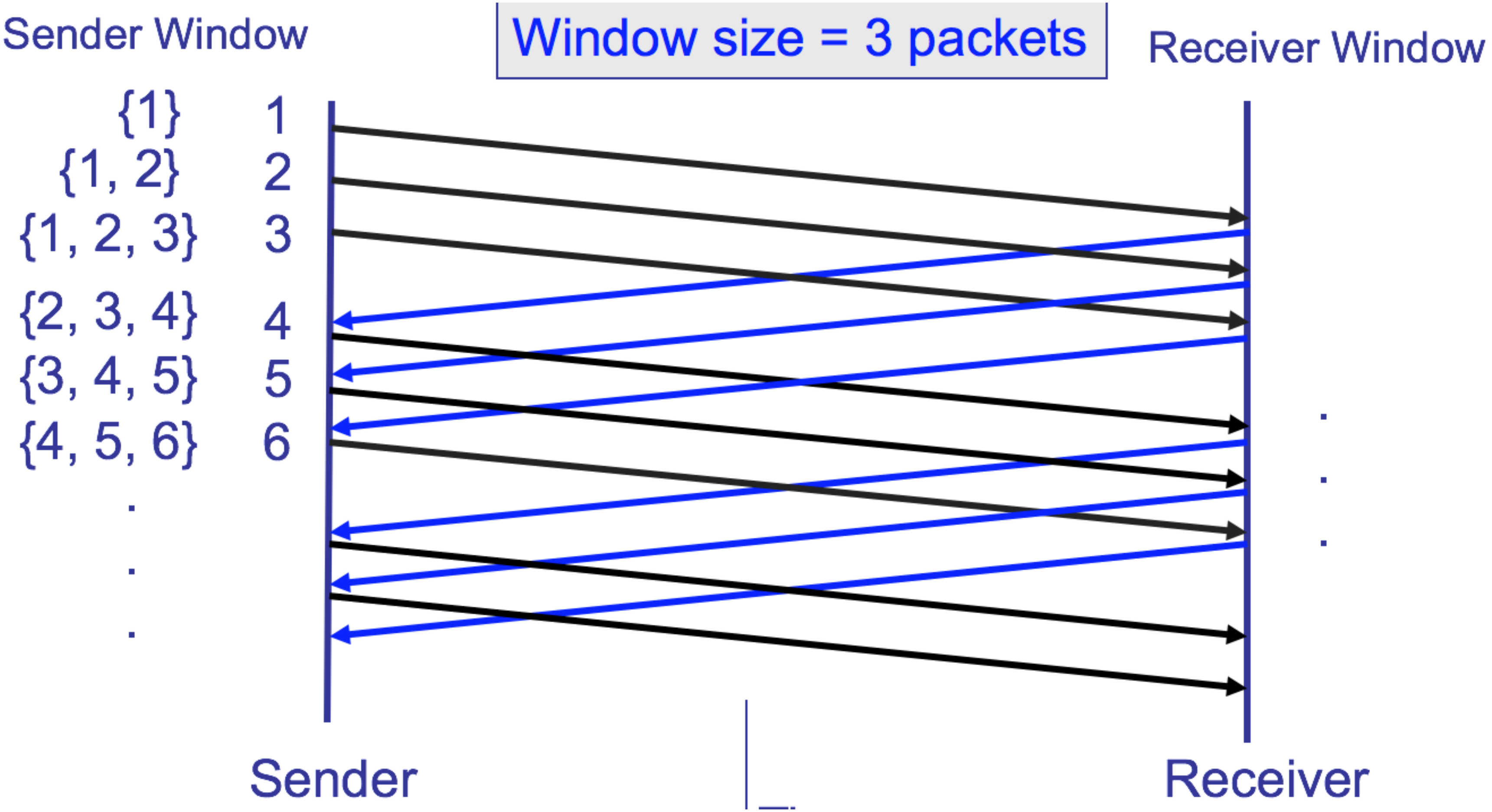
Go-Back N vs. Selective Repeat

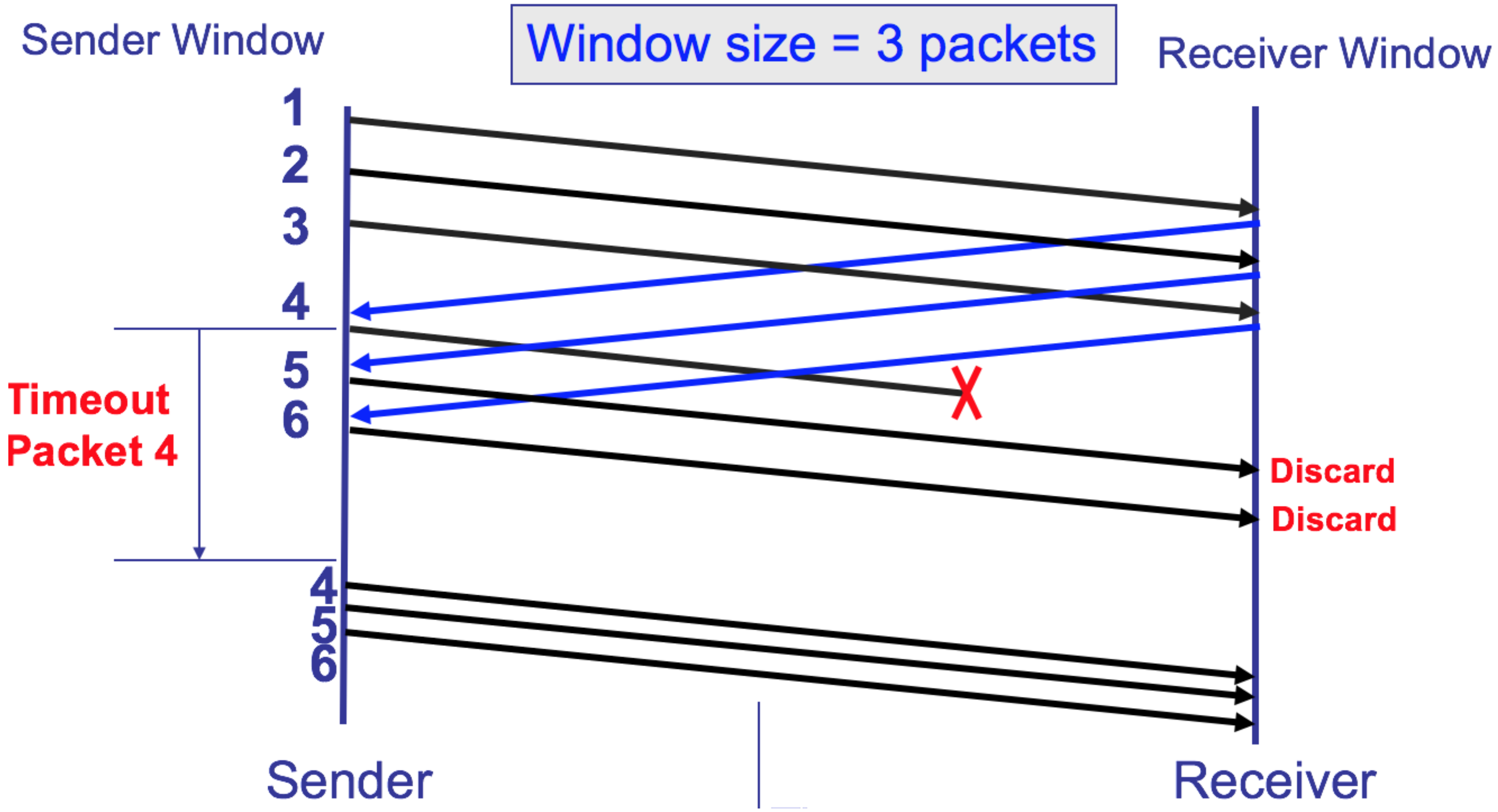
- Go-back N: receiver uses cumulative ACK
- Selective Repeat: receiver uses selective ACK

Go-Back N ARQ

- Receiver uses cumulative ack and discards out-of sequence packets
- Retransmit **from** the next expected packet

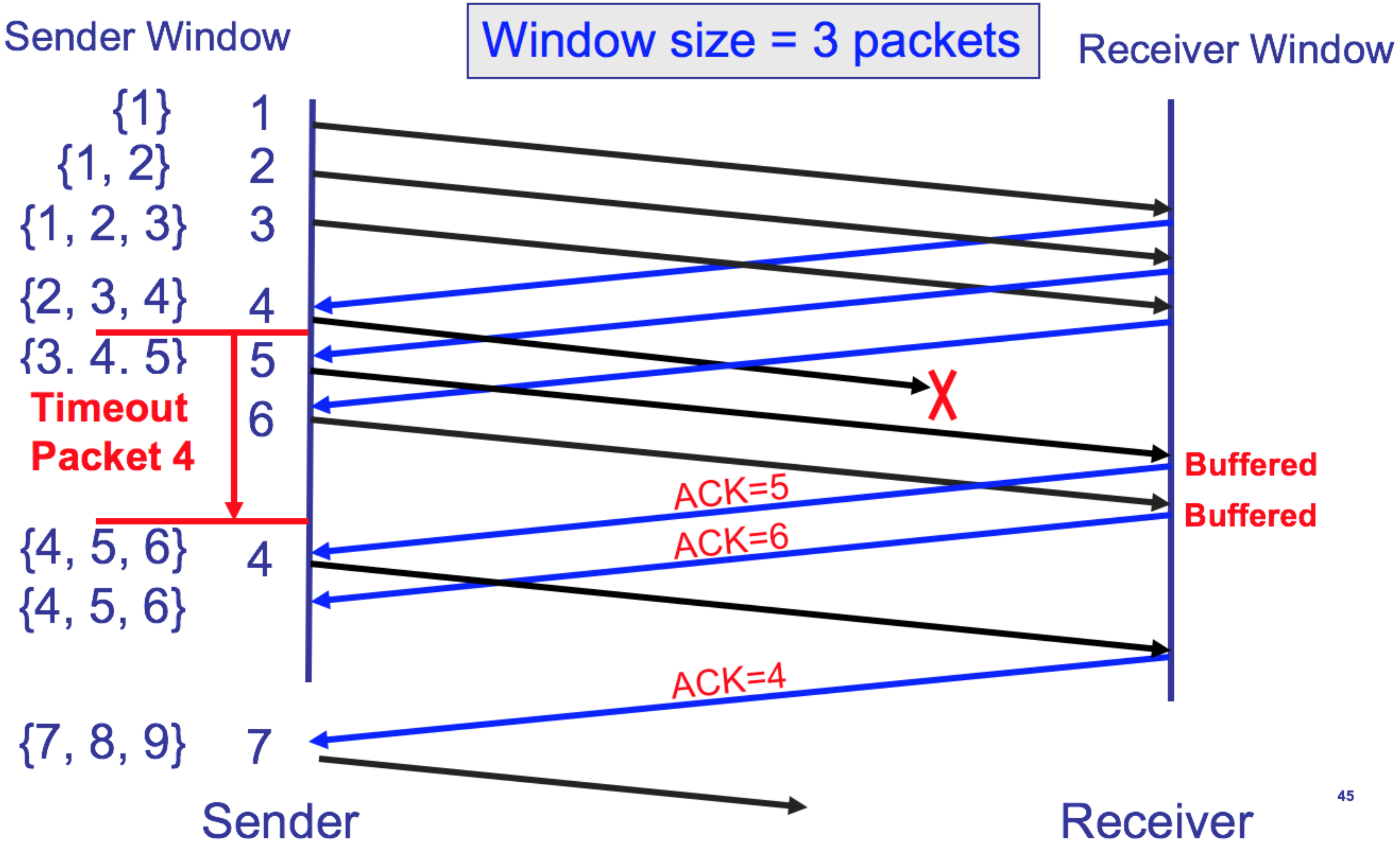
Window size = 3 packets




Sender Window
Window size = 3 packets
Receiver Window
1
2
3
4
5
6
Timeout
Packet 4
X
Discard
Discard
4
5
6
Sender
Receiver

Selective Repeat ARQ

- Receiver uses selective ack and buffers out-of-sequence packets
- Retransmit only unACK'd packets



Window size = 3 packets

Sender Window

Receiver Window

{1} 1

{1, 2} 2

{1, 2, 3} 3

{2, 3, 4} 4

{3. 4. 5} 5

Timeout Packet 4

6

{4, 5, 6} 4

{4, 5, 6}

{7, 8, 9} 7

X

Buffered

Buffered

ACK=5

ACK=6

ACK=4

Sender

Receiver

Components of ARQ

- Timeout
- ACK & NACK
- Sequence Number
- Sending Window
- Receiving Window

Their relationships

- Assuming sequence number represented with m bits
- For GBN, Ws <= 2^m
- For SR, Ws + Wr <= 2^m