# Reliable Data Transfer II

Antonio Carzaniga

Faculty of Informatics
Università della Svizzera italiana

March 25, 2020

# Outline

- Performance of the stop-and-wait protocol
- Go-Back-N
- Selective repeat

# Back to Reliable Data Tranfer

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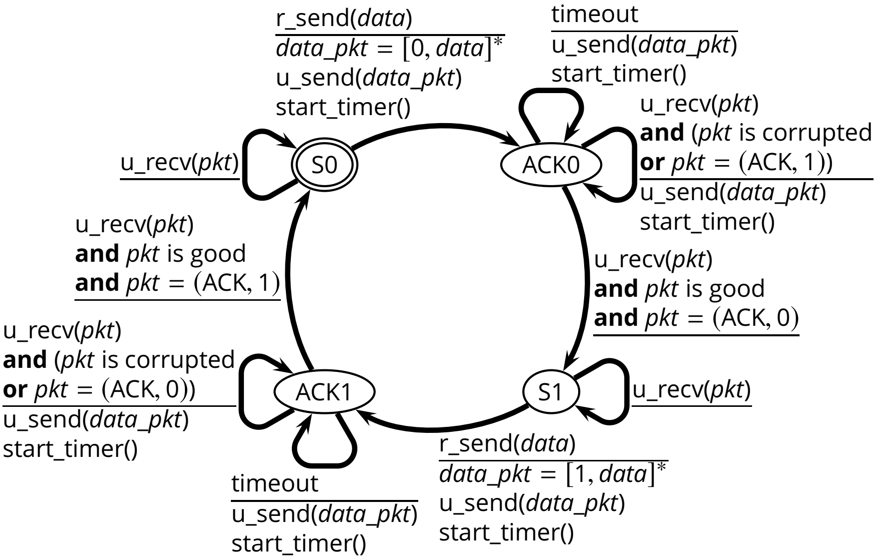

r_send(*data*)
*data_pkt* $= [0, \mathit{data}]^*$
u_send(*data_pkt*)
start_timer()

timeout
u_send(*data_pkt*)
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u_recv(*pkt*)
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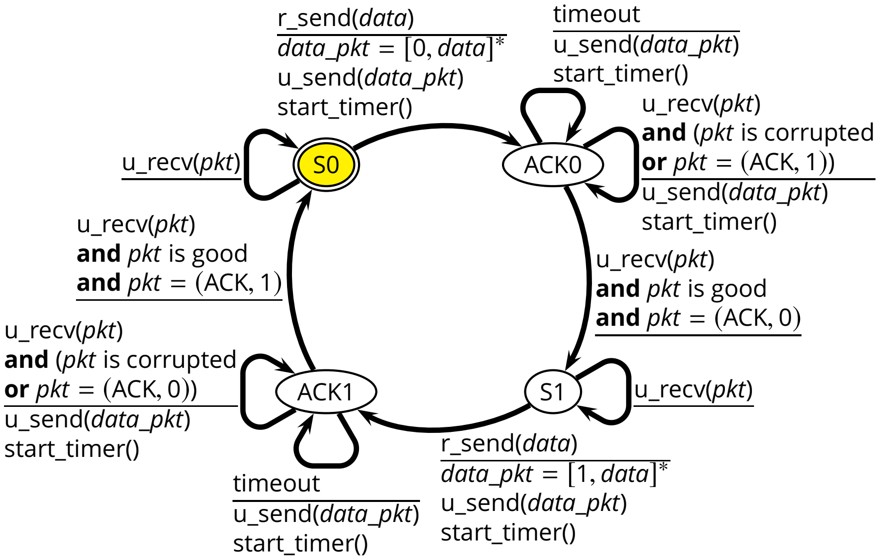

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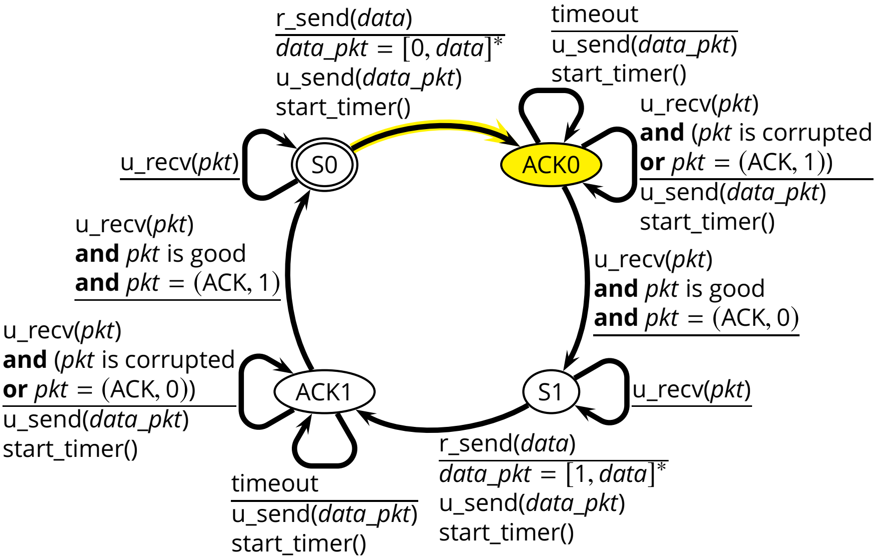

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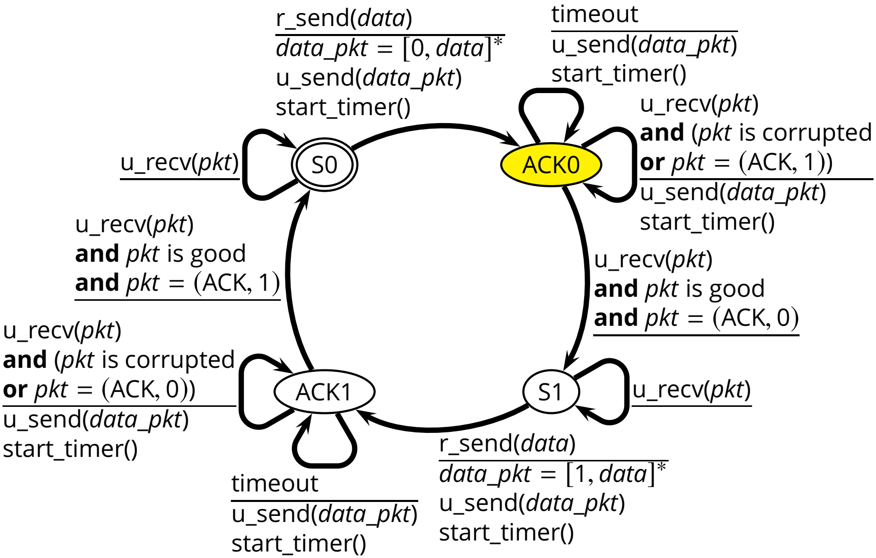

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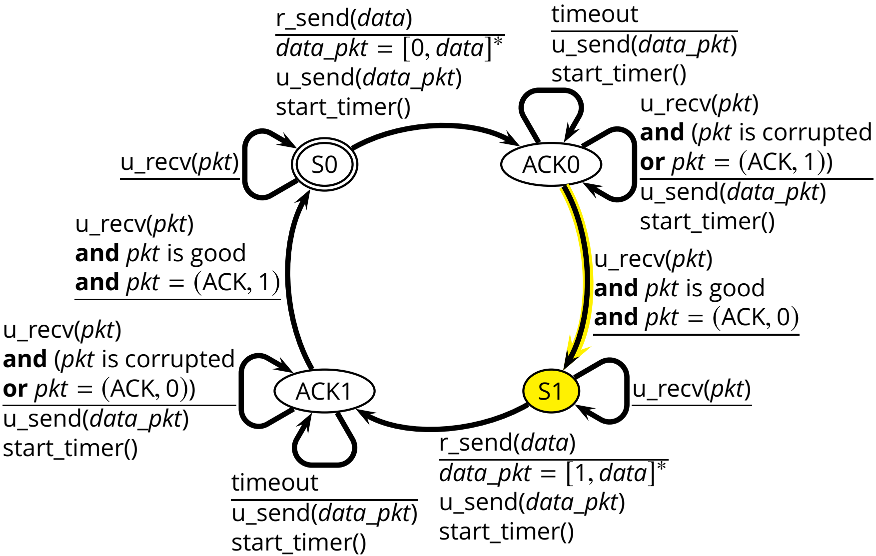

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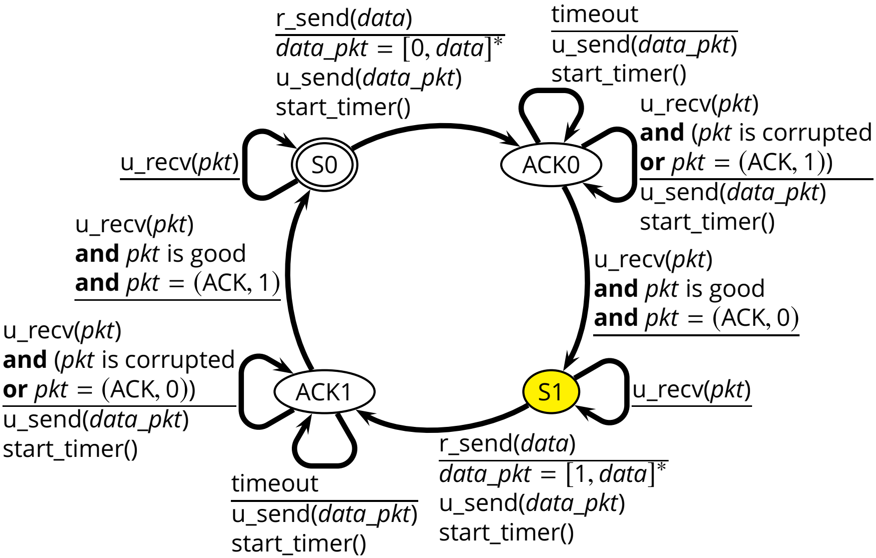

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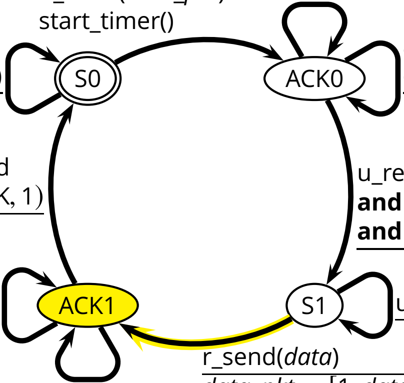

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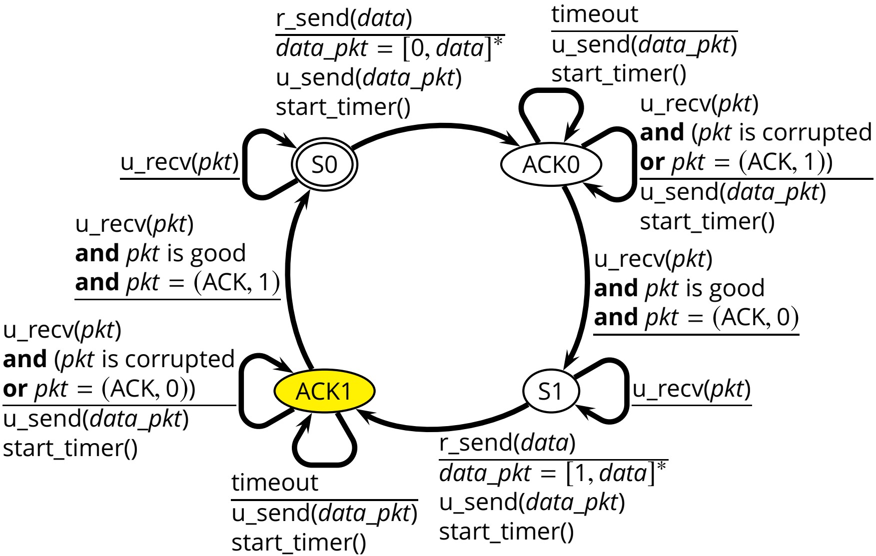

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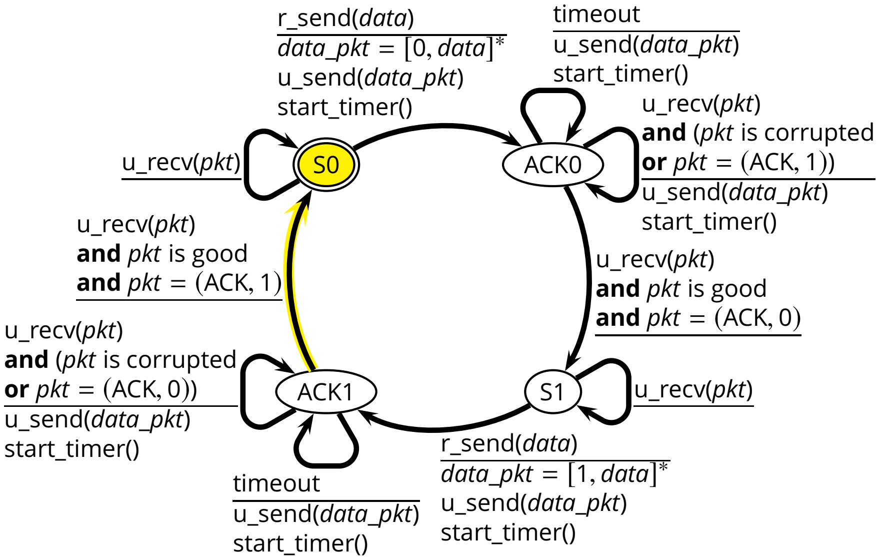

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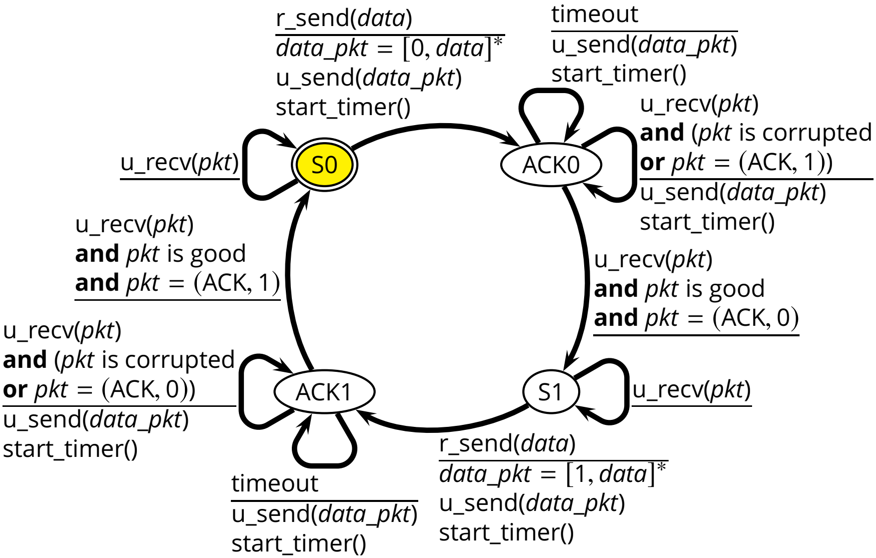

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$data\_pkt = [1, data]^*$
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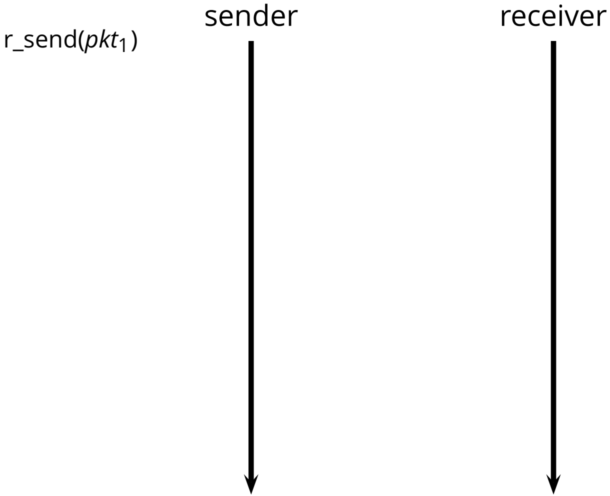
start_timer()

timeout

u_send(*data_pkt*)
start_timer()

# Network Usage

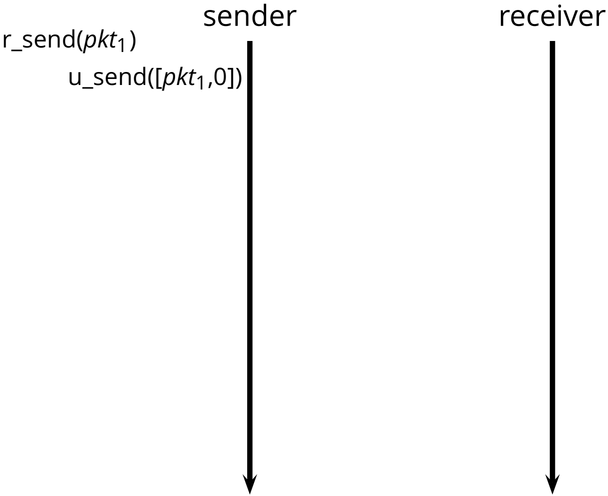


sender

receiver

r_send($pkt_1$)

# Network Usage



sender

receiver

r_send($pkt_1$)

u_send([$pkt_1$,0])

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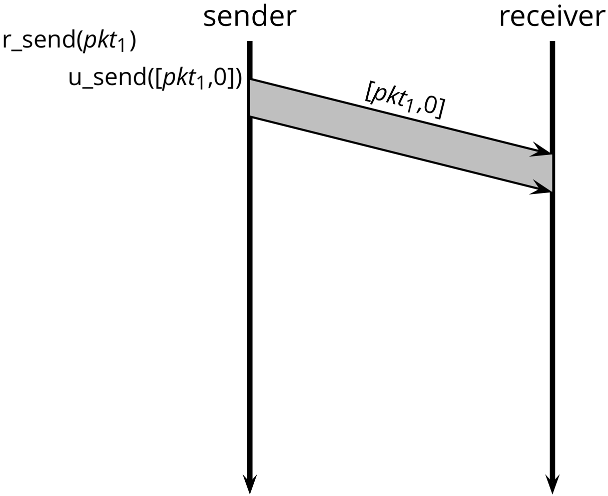

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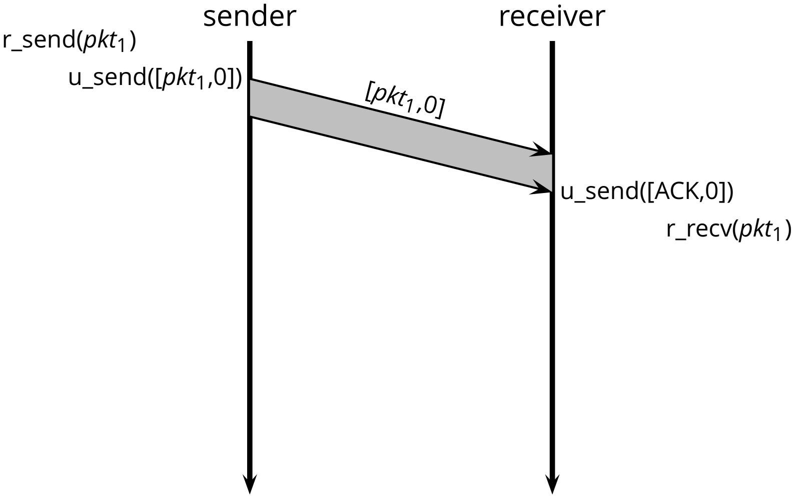

sender

receiver

r_send($pkt_1$)

u_send([$pkt_1$,0])

[$pkt_1$,0]

u_send([ACK,0])

r_recv($pkt_1$)

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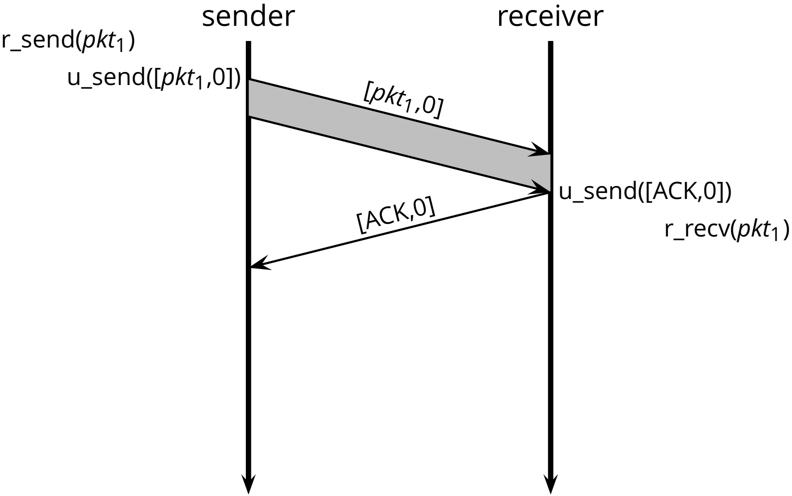

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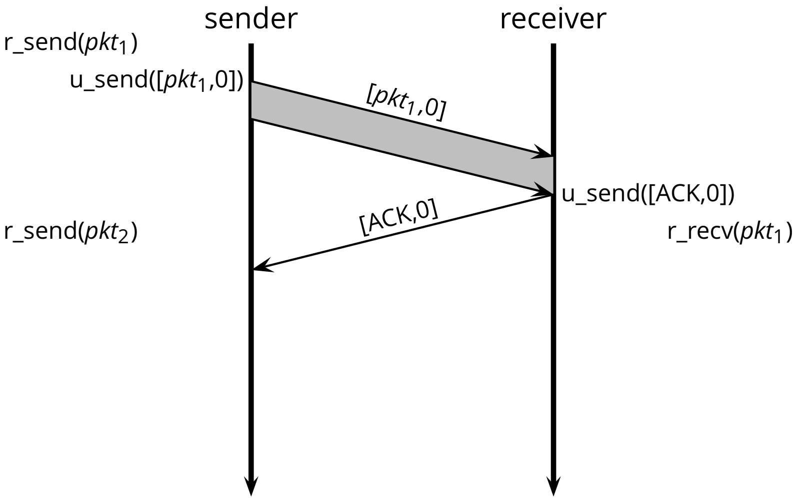

sender

receiver

r_send($pkt_1$)

u_send([$pkt_1$,0])

[$pkt_1$,0]

u_send([ACK,0])

[ACK,0]

r_send($pkt_2$)

r_recv($pkt_1$)

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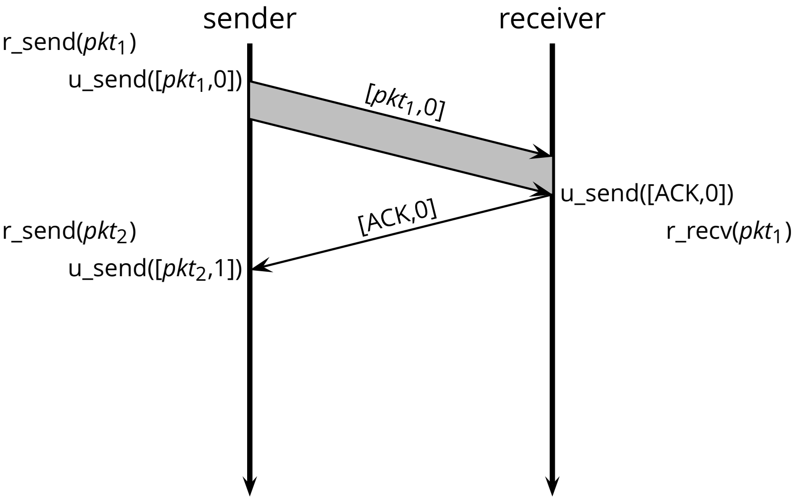

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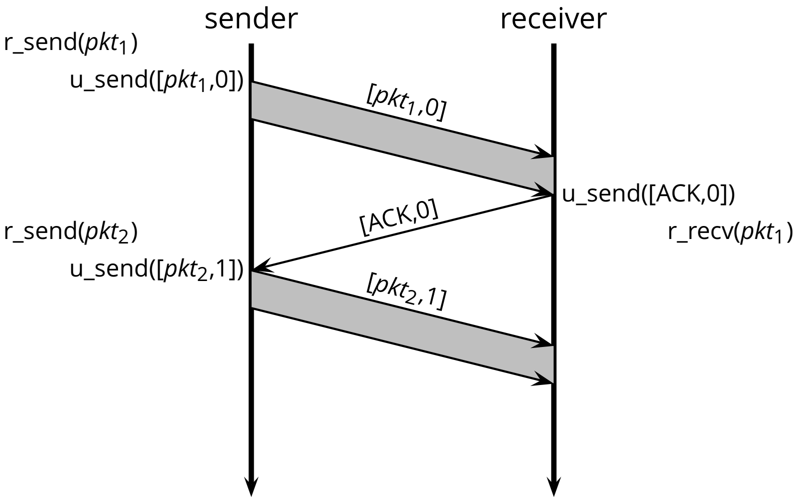

sender

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r_send($pkt_1$)

u_send([$pkt_1$,0])

[$pkt_1$,0]

u_send([ACK,0])

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r_send($pkt_2$)

r_recv($pkt_1$)

u_send([$pkt_2$,1])

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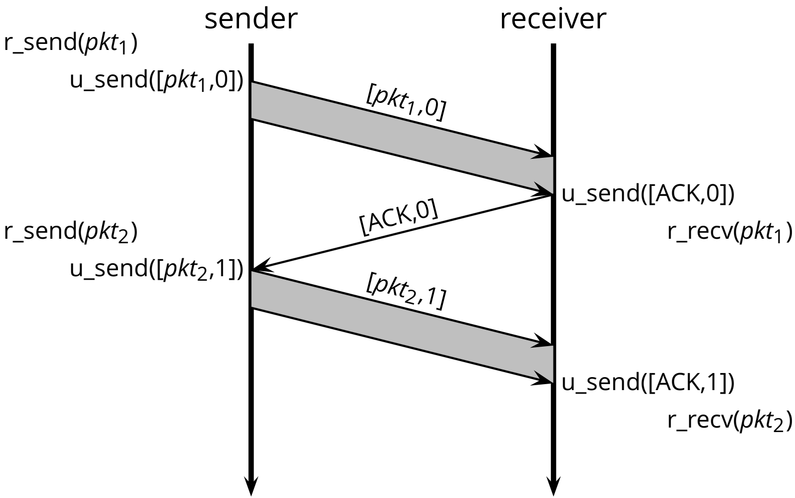

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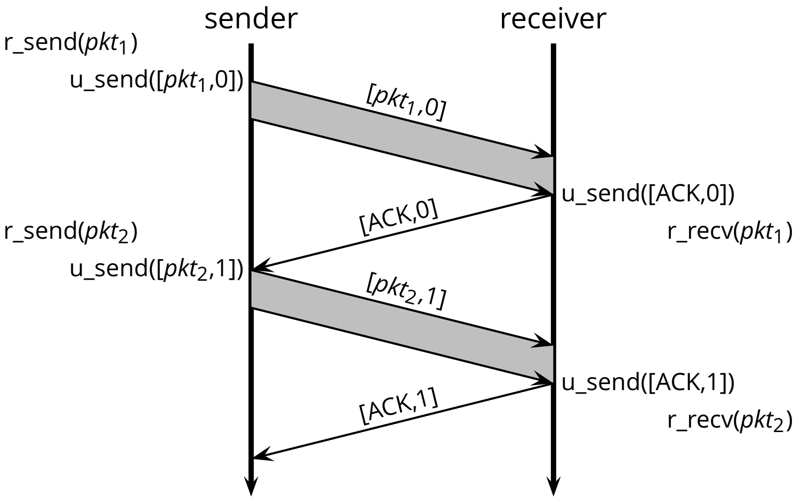

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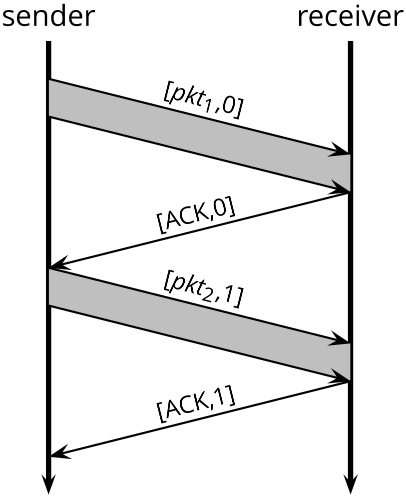

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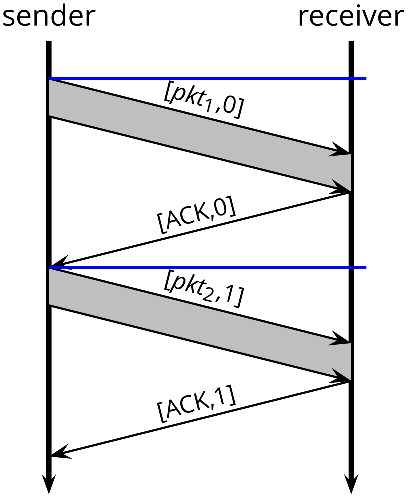

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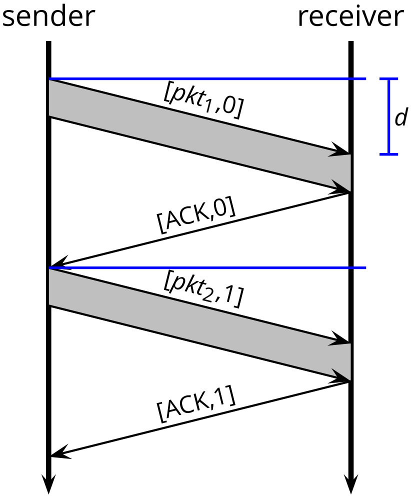

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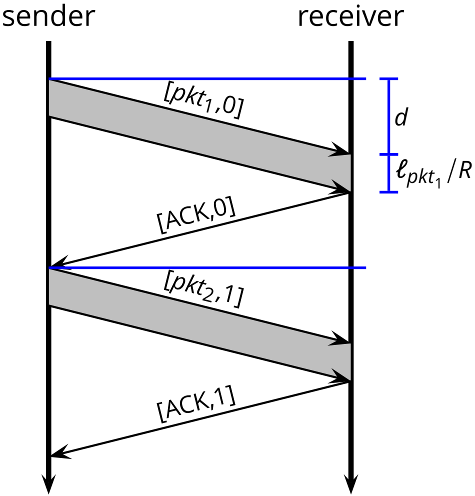

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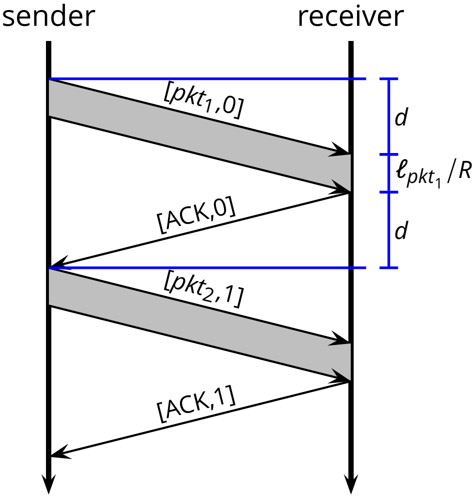
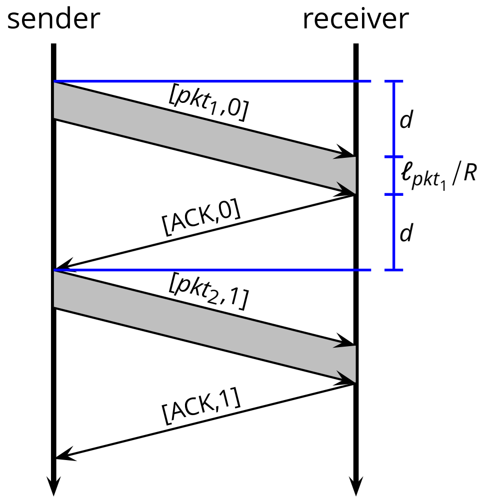


# Network Usage

*utilization factor*

$$U = \frac{\ell_{pkt}/R}{2d + \ell_{pkt}/R}$$



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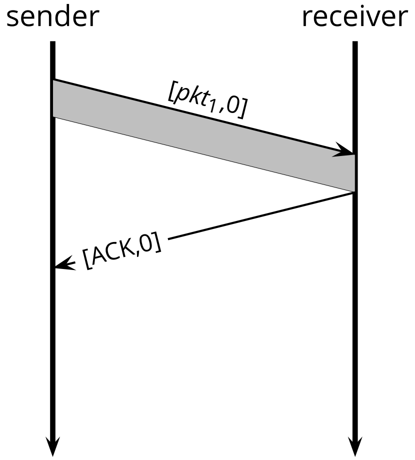

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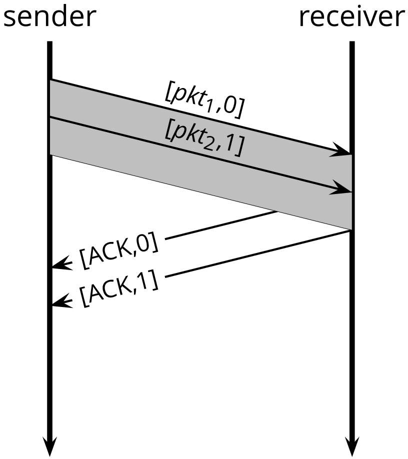

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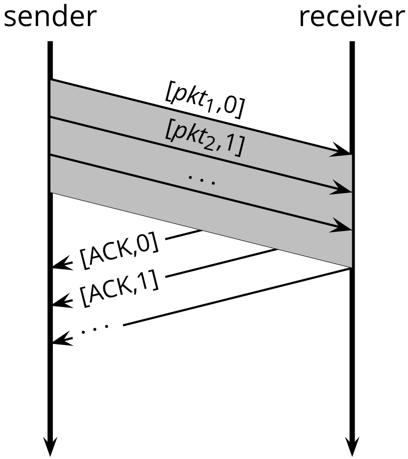

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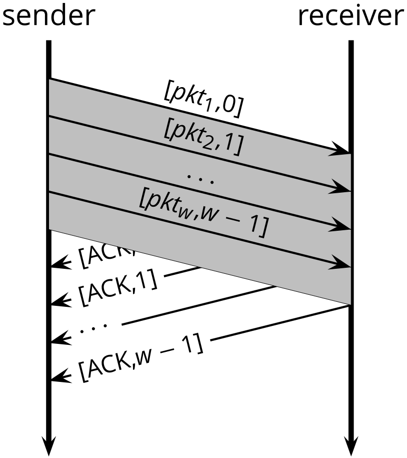

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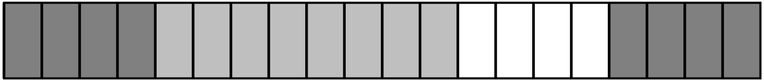

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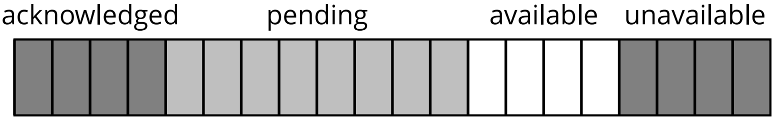

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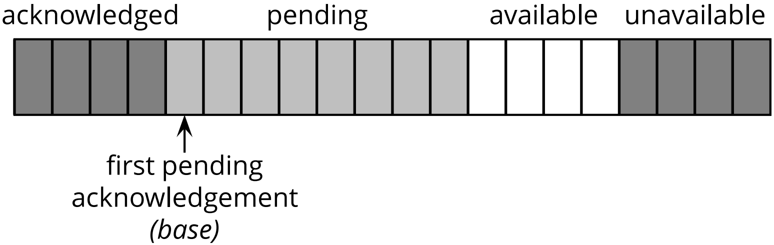

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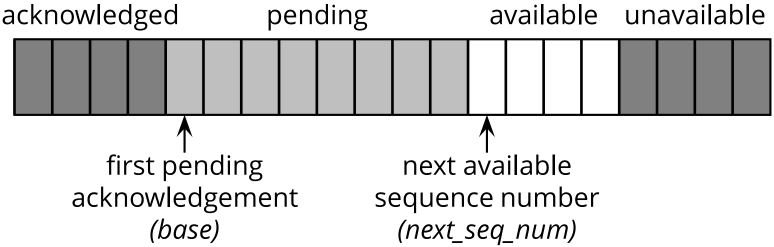

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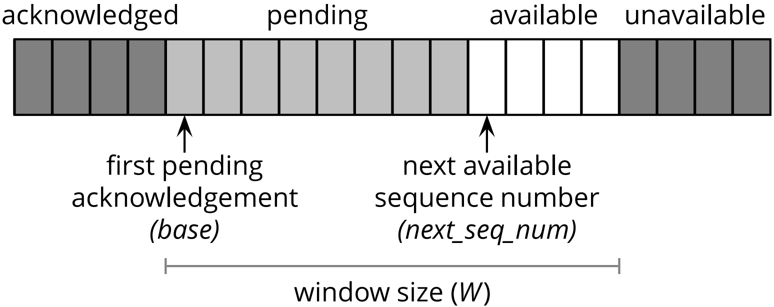


acknowledged

pending

available

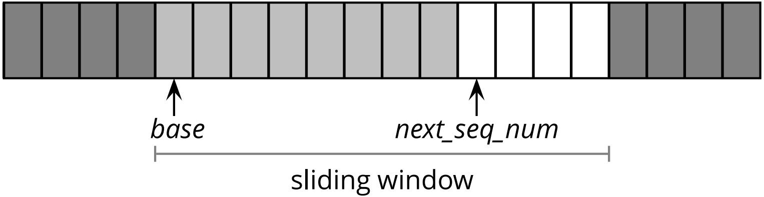
unavailable

first pending acknowledgement *(base)*

next available sequence number *(next_seq_num)*

window size (*W*)

# Sliding Window Protocol: Sender



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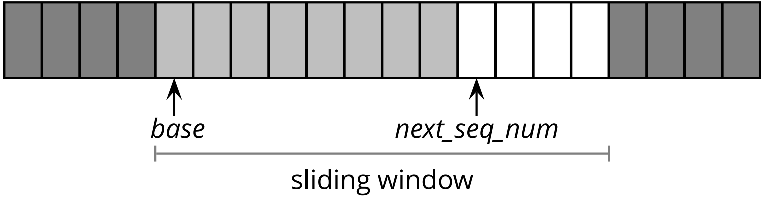
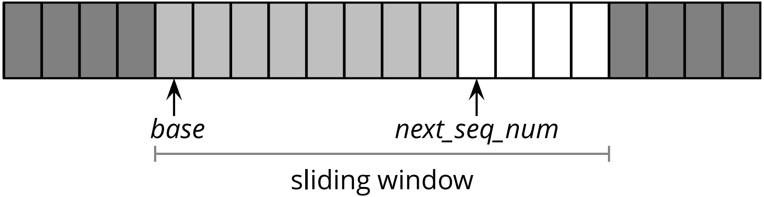


- r_send($pkt_1$)

# Sliding Window Protocol: Sender



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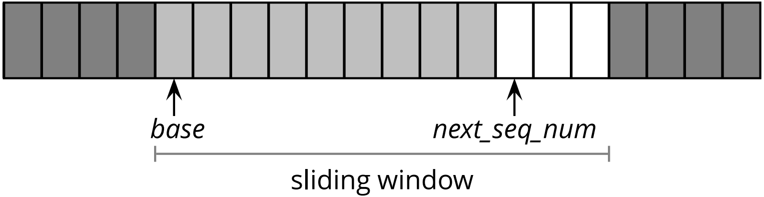

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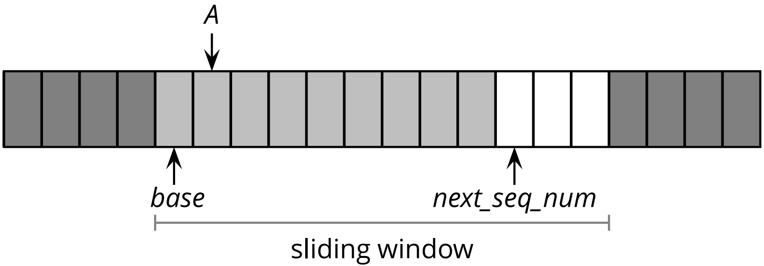

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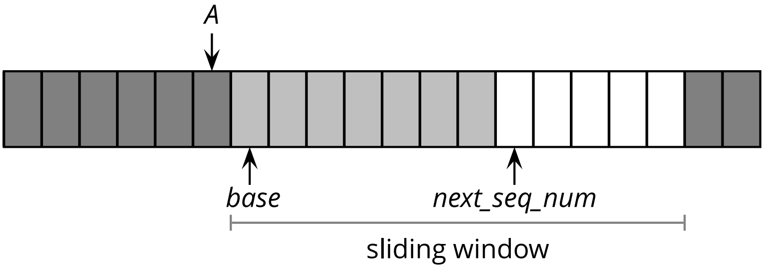

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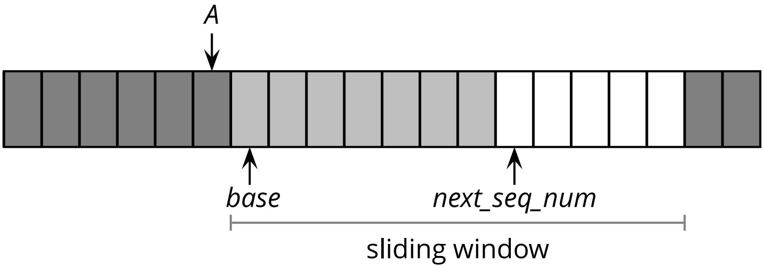

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  - notice that acknewledgements are “cumulative”

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  - *r_send():* invocation from the application layer: send more data if a sequence number is available
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  - *timeout:* “Go-Back-N.” I.e., resend all the packets that have been sent but not acknowledged

# Sliding Window Protocol: Sender

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# Sliding Window Protocol: Sender

- *init*

```
$base = 1$
$next\_seq\_num = 1$
```

- r_send(*data*)

```
if $next\_seq\_num < base + W$:
    $pkt[next\_seq\_num] = [next\_seq\_num, data]^*$
    u_send($pkt[next\_seq\_num]$)
    if $next\_seq\_num == base$:
        start_timer()
    $next\_seq\_num = next\_seq\_num + 1$
else:
    refuse_data(data)        // block the sender
```

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base = ack_num + 1        // resume the sender
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- timeout

```
start_timer()
foreach i in base ... next_seq_num − 1:
    u_send(pkt[i])
```

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- The problem may seem a bit underspecified. What is the (average) packet size?

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  - $W \times \ell_{pkt} \leq 2d \times R$
    - why $W \times \ell_{pkt} > 2d \times R$ doesn't make much sense?
  - maximum channel utilization when $W \times \ell_{pkt} = 2d \times R$
  - $2d \times R$ can be thought of as the *capacity* of a connection

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- Is there a better way to deal with retransmissions?

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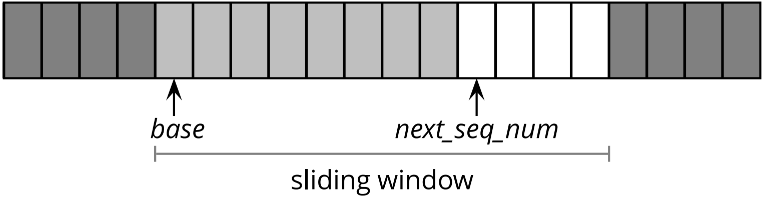
  - sender slides the window when the lowest pending sequence number is acknowledged

# Selective Repeat: Sender



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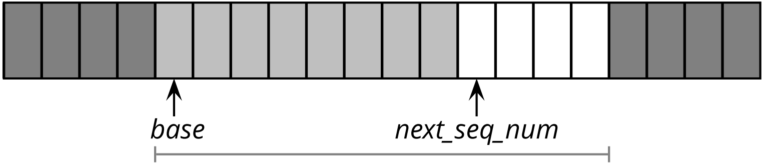

sliding window

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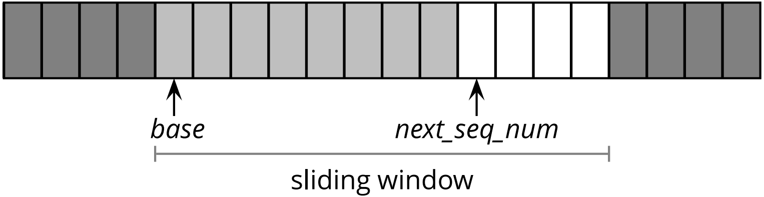

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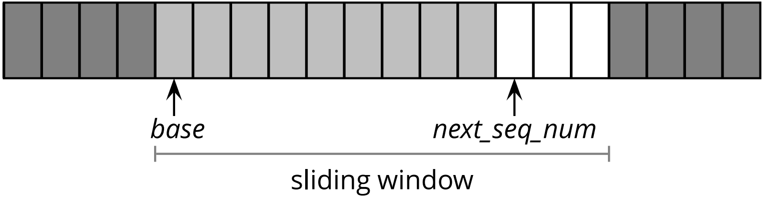

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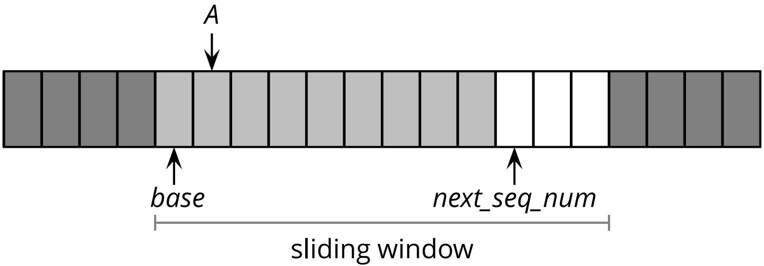

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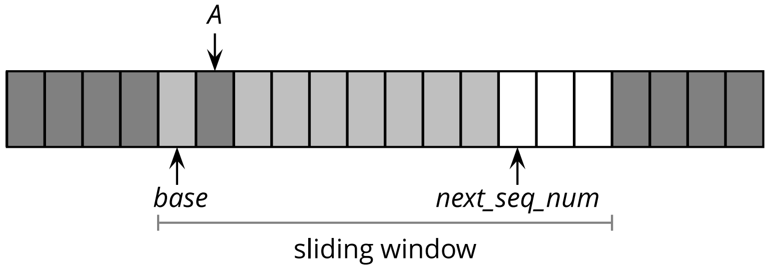

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- u_recv([ACK,*A*])
  - $acks[A] = 1$ *// remember that A was ACK'd*

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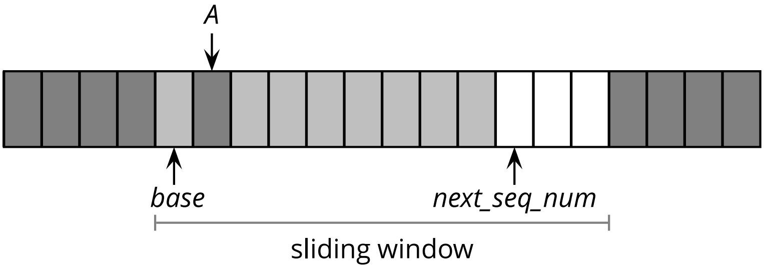

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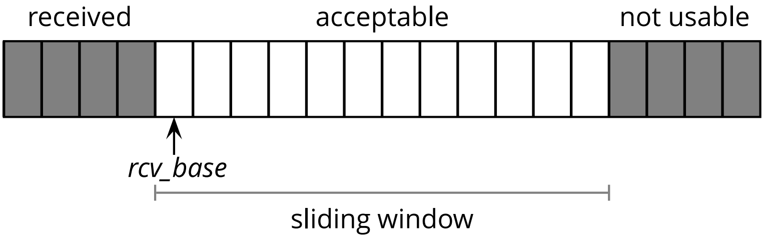

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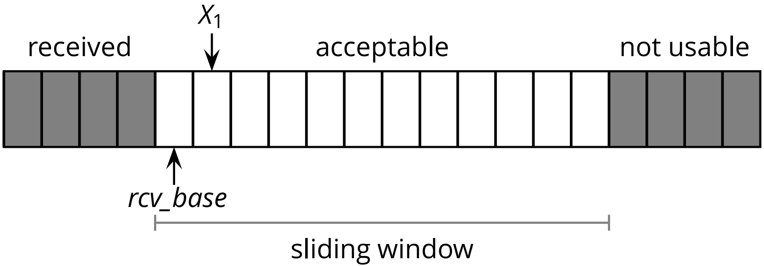

- u_recv([$pkt_1$,$X_1$]) **and** $rcv\_base \leq X_1 < rcv\_base + W$

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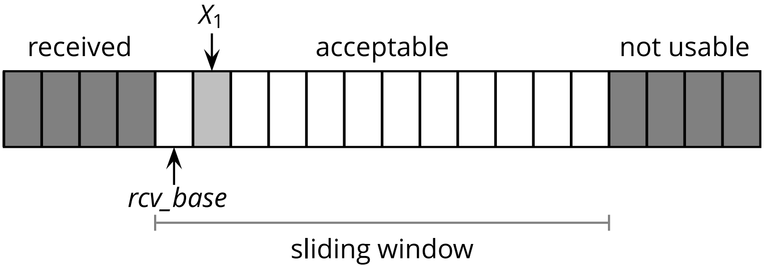

- u_recv([$pkt_1$,$X_1$]) **and** $rcv\_base \le X_1 < rcv\_base + W$
  - $buffer[X_1] = pkt_1$
  - u_send($[ACK, X_1]^*$) *// no longer a "cumulative" ACK*

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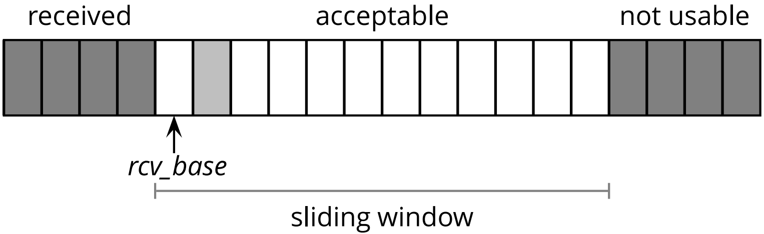

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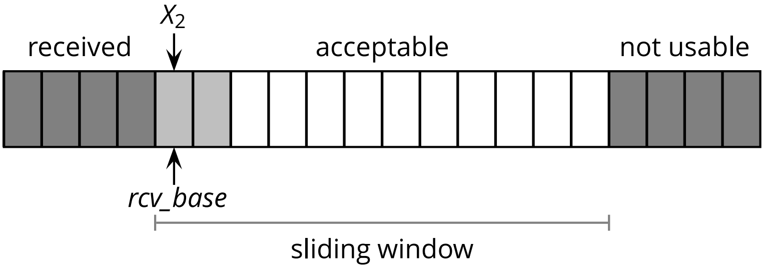

- u_recv([$pkt_2$,$X_2$]) **and** $rcv\_base \leq X_2 < rcv\_base + W$
  - $buffer[X_2] = pkt_2$
  - u_send($[ACK, X_2]^*$)

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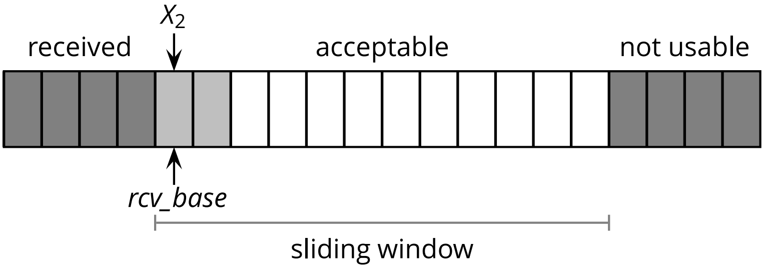

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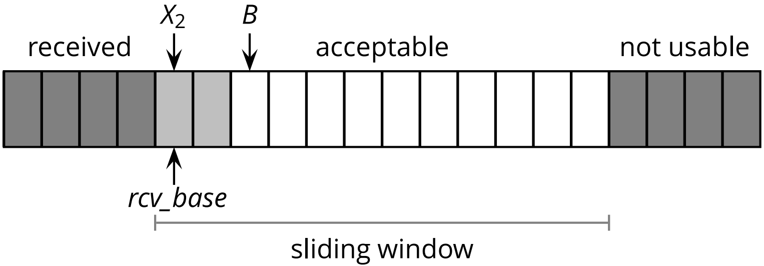

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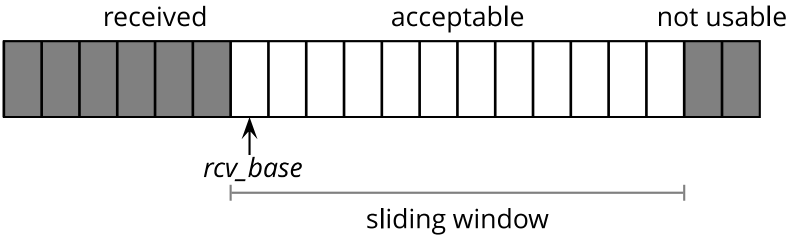

- u_recv([$pkt_2$,$X_2$]) **and** $rcv\_base \le X_2 < rcv\_base + W$
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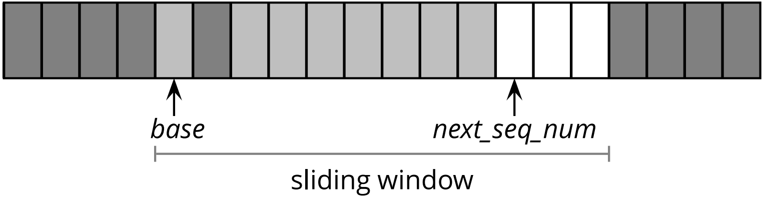

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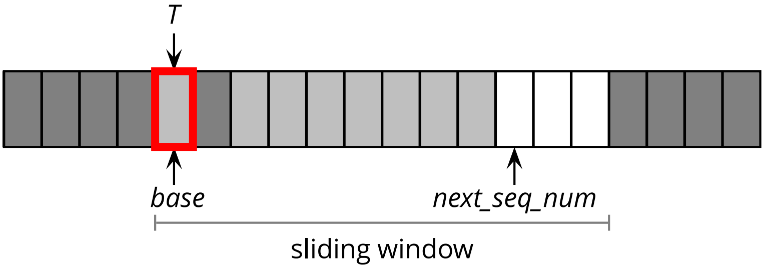

- Timeout for sequence number *T*

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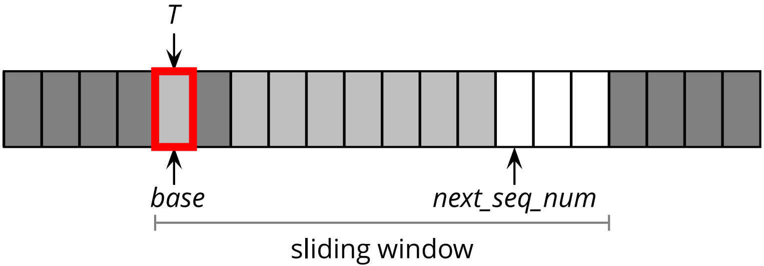
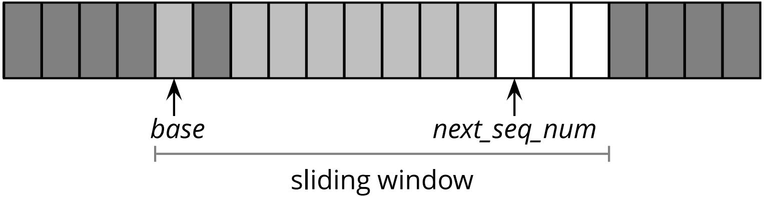
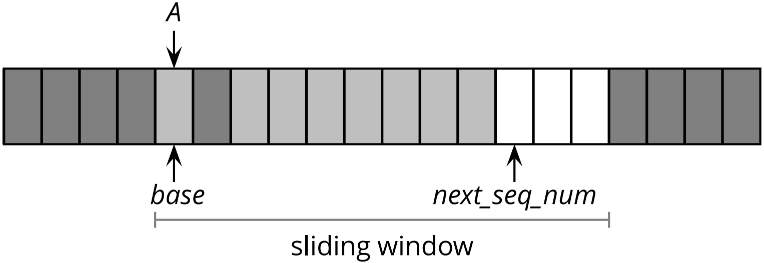


- Timeout for sequence number *T*
  - u_send([*pkt*[*T*], *T*]$^*$)

# Selective Repeat: Sender

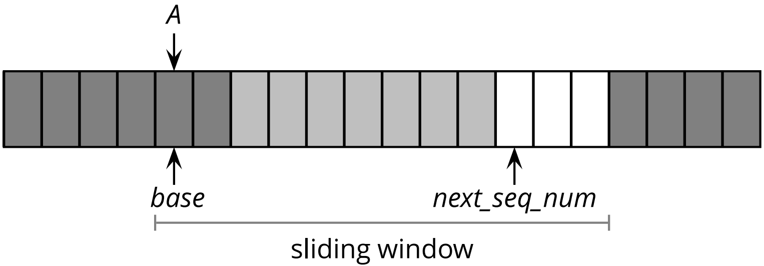


# Selective Repeat: Sender



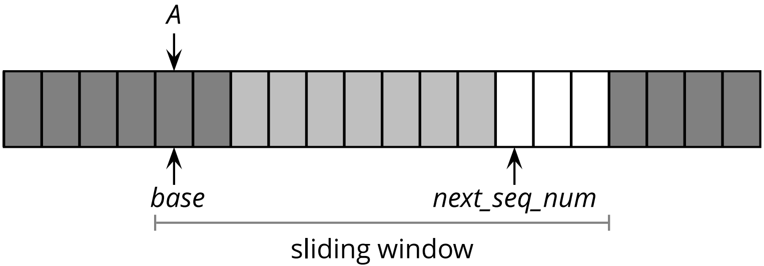
- u_recv([ACK,*A*])

# Selective Repeat: Sender



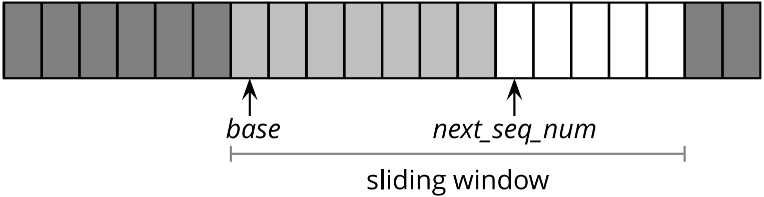
- u_recv([ACK,*A*])
  - $acks[A] = 1$

# Selective Repeat: Sender



- u_recv([ACK,*A*])
  - $acks[A] = 1$
  - **if** *A* == *base*:

# Selective Repeat: Sender



- u_recv([ACK,*A*])

```
acks[A] = 1
if A == base:
        base = first_missing_ack_num()
```