

Transmission Control Protocol (TCP)

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- Introduction to TCP
- Sequence numbers and acknowledgment numbers
- Timeouts and RTT estimation
- Reliable data transfer in TCP
- Connection management

Transmission Control Protocol

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 - ▶ defined in RFC 793, RFC 1122, RFC 1323, RFC 2018, and RFC 2581

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 - ▶ not a circuit-switched connection, nor a virtual circuit
- Full-duplex service
 - ▶ both endpoints can both send and receive, at the same time

Preliminary Definitions

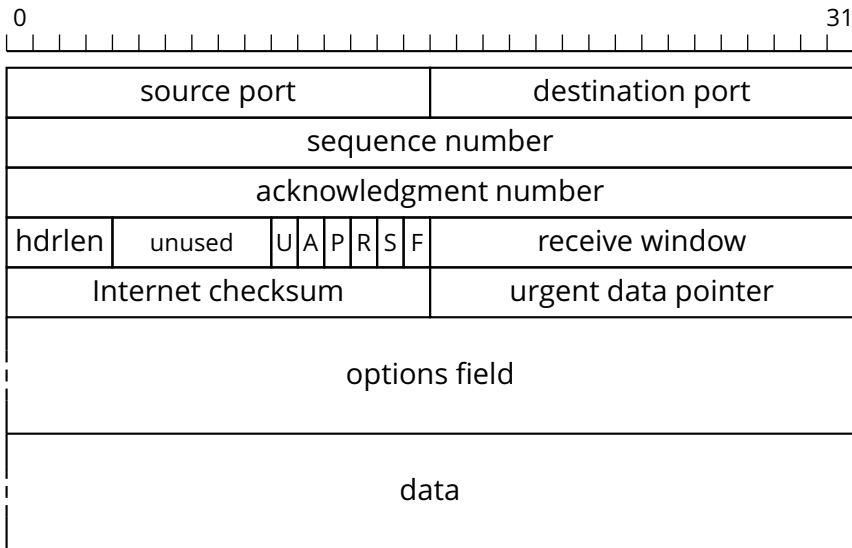
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- **Maximum transmission unit (MTU):** largest link-layer frame available to the sender host
 - ▶ *path MTU*: largest link-layer frame that can be sent on all links from the sender host to the receiver host

TCP Segment Format



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- *Optional and variable-length options field:* may be used to negotiate protocol parameters

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- *Checksum*: (16-bit) used to detect transmission errors

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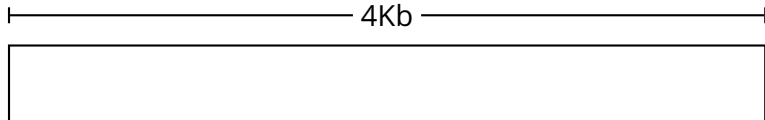
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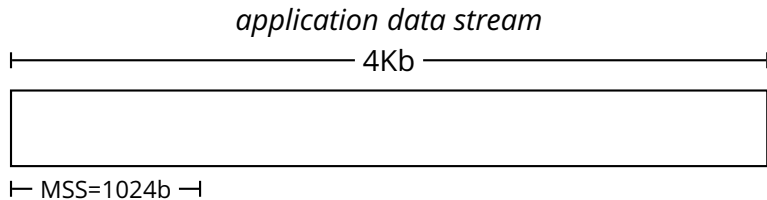
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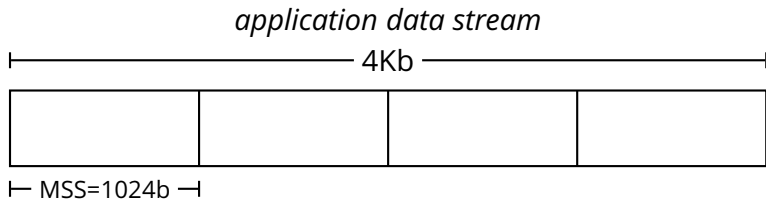
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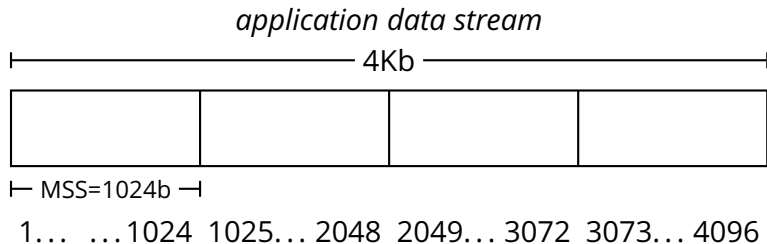
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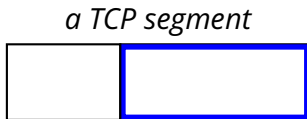
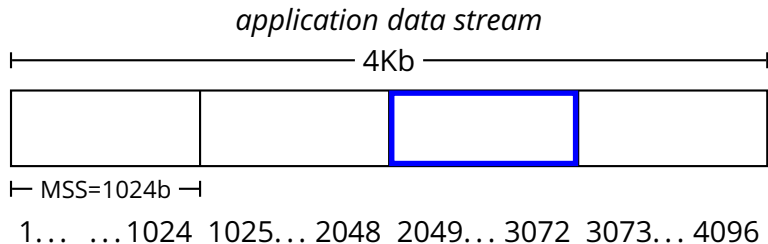


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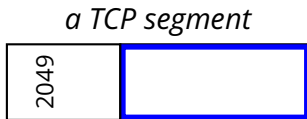
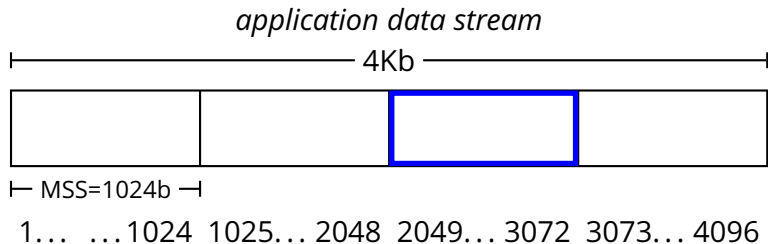


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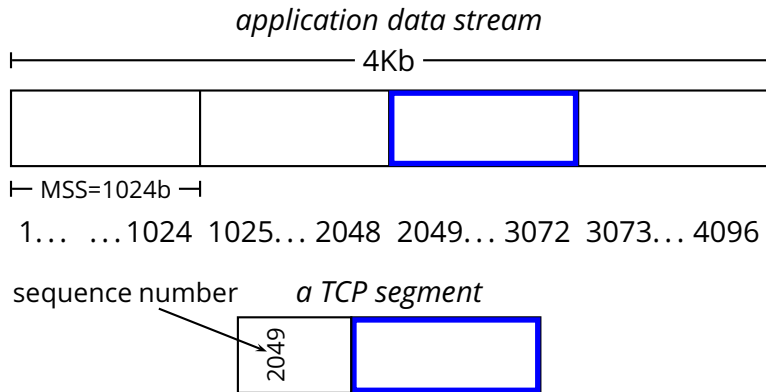
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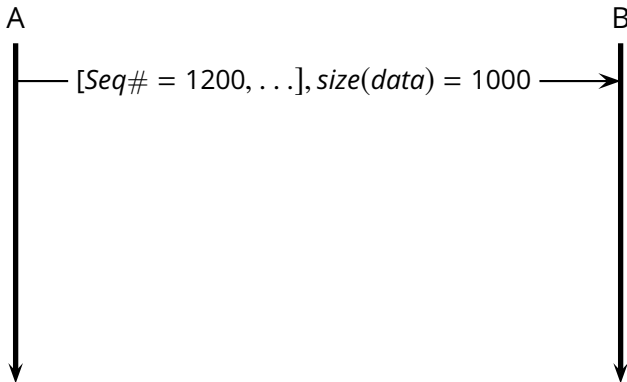


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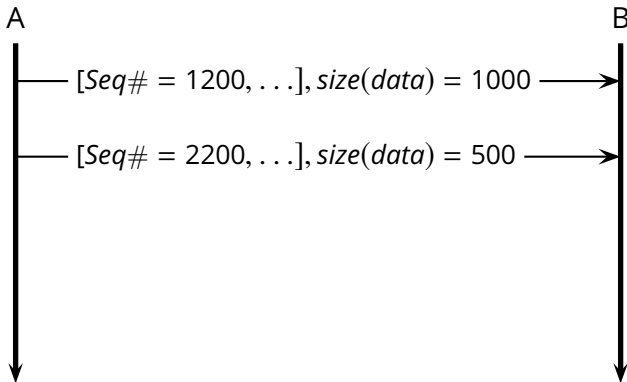
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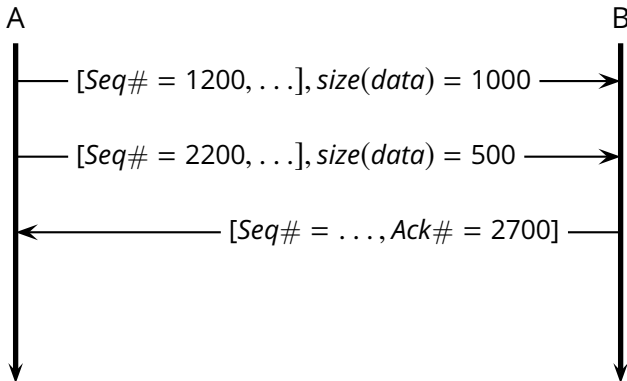
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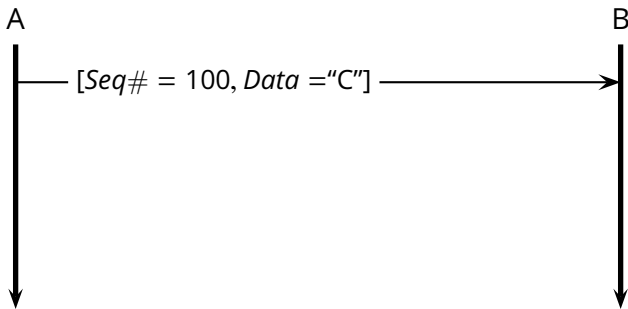
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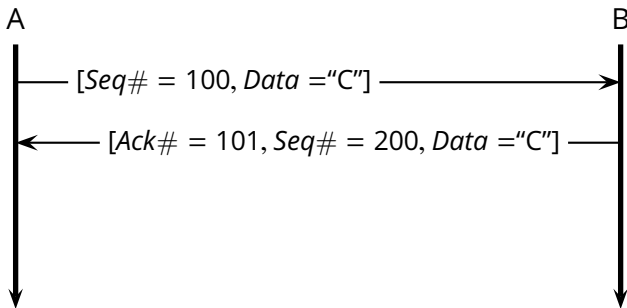
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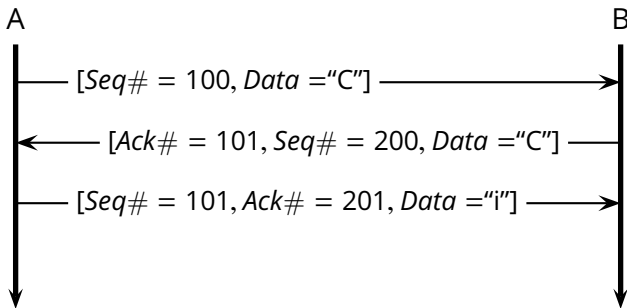
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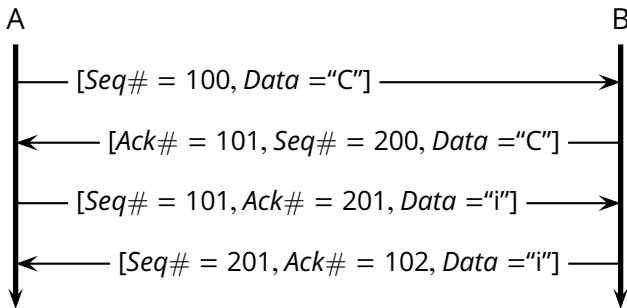
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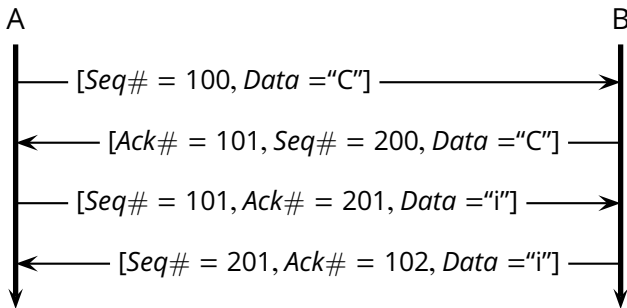
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- TCP controls its timeout by continuously *estimating the current RTT*

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- TCP sets its timeouts using the estimated RTT (\overline{RTT}) and the variability estimate \overline{DevRTT} :

$$T = \overline{RTT} + 4\overline{DevRTT}$$

A simplified TCP sender

■ `r_send(data)`

if (timer not running)

`start_timer()`

`u_send([data, next_seq_num])`

$next_seq_num \leftarrow next_seq_num + length(data)$

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■ $u_rcv([ACK, y])$

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else ...

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 - ▶ *Immediate ACK*: immediately send ACK if the packet start at the lower end of the gap

Reaction to ACKs (Sender)

- `u_rcv([ACK,y])`

if ($y > base$)

$base \leftarrow y$

if (there are pending segments)

`start_timer()`

- $u_recv([ACK,y])$

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$base \leftarrow y$

if (there are pending segments)

$start_timer()$

else

$ack_counter[y] \leftarrow ack_counter[y] + 1$

if ($ack_counter[y] = 3$)

$u_send(\text{segment with sequence number } y)$

Three-way handshake

Connection Setup

Three-way handshake

client

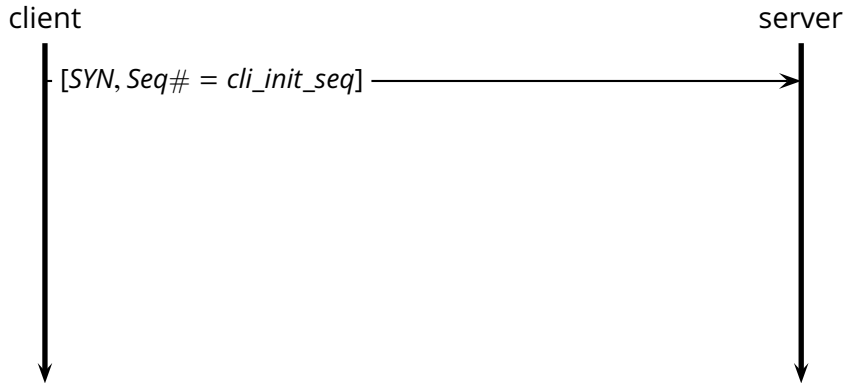


server



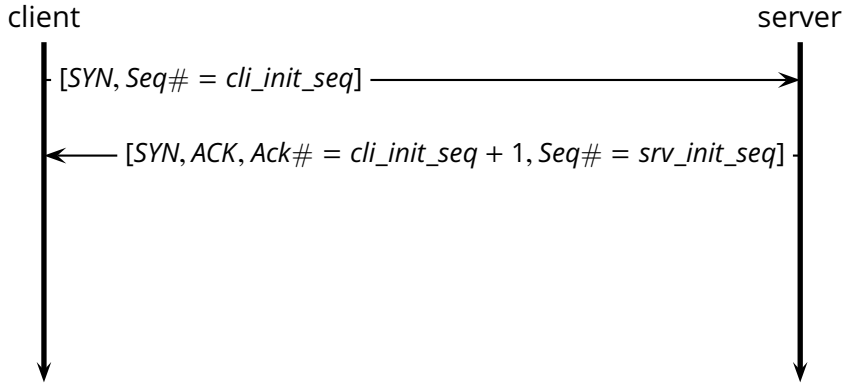
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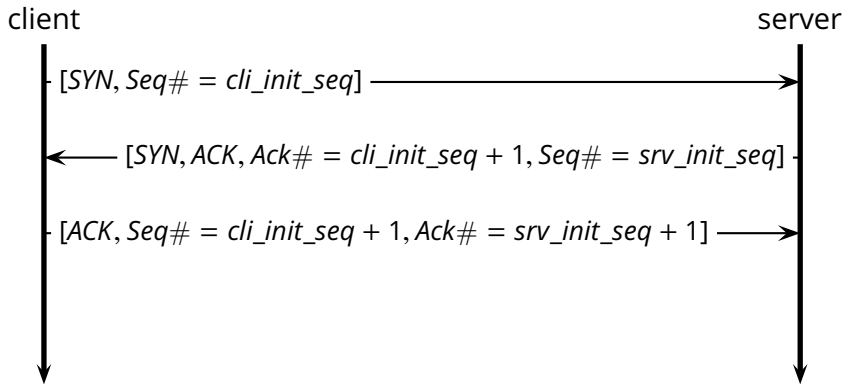


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"Okay, Bye now."

"Bye."

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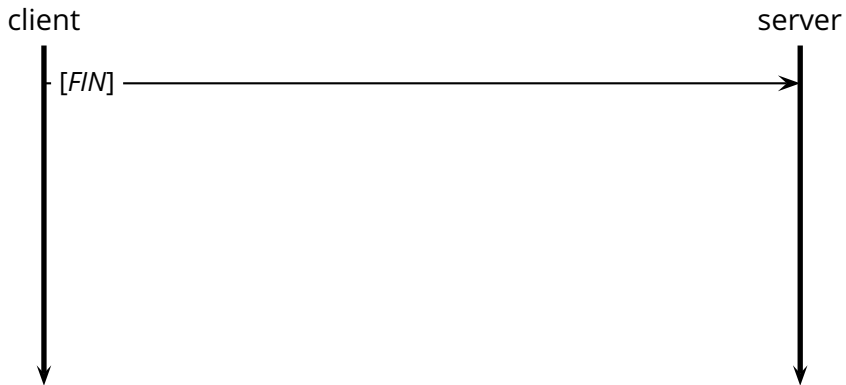


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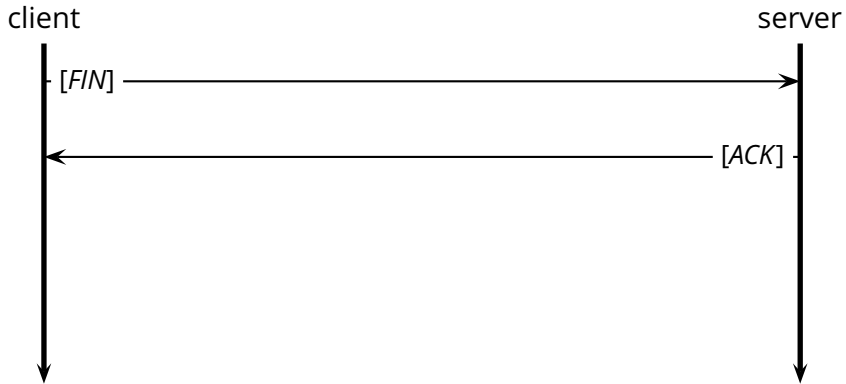


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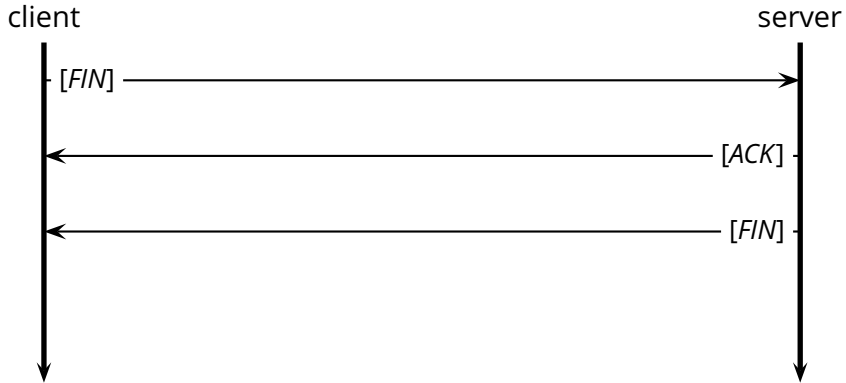


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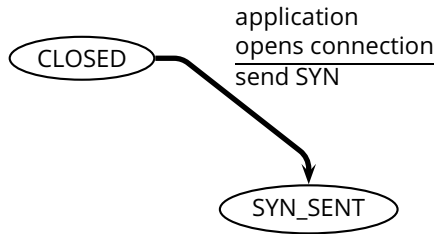
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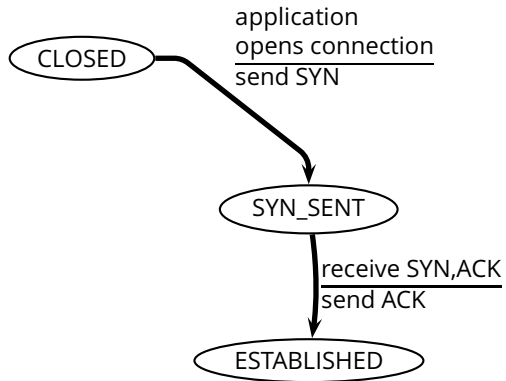
The TCP State Machine (Client)

CLOSED

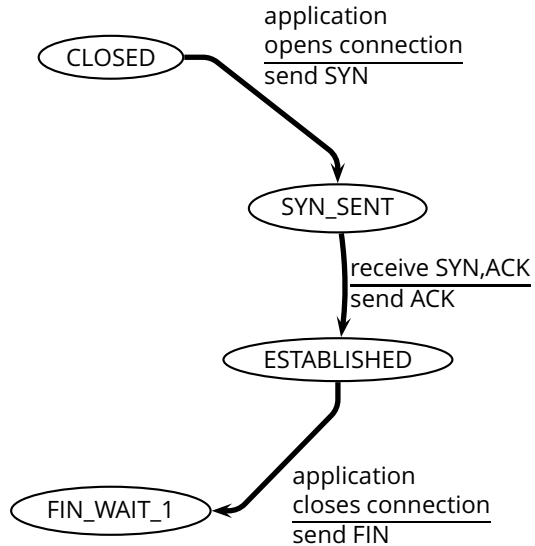
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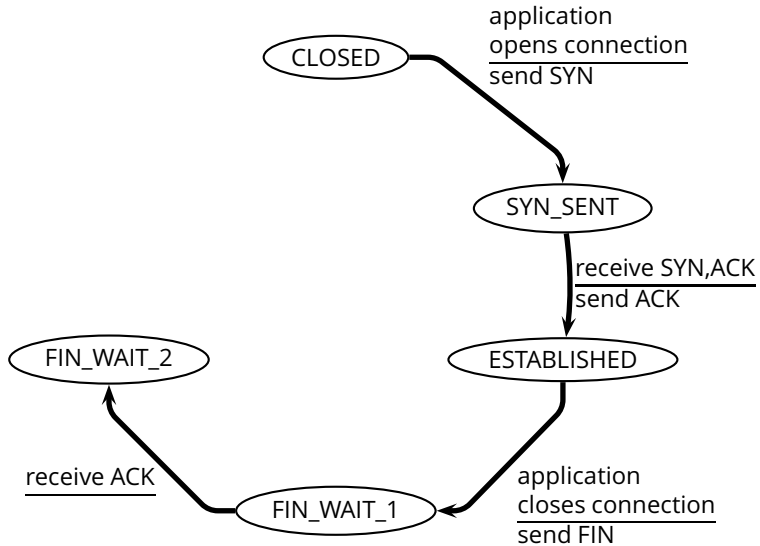
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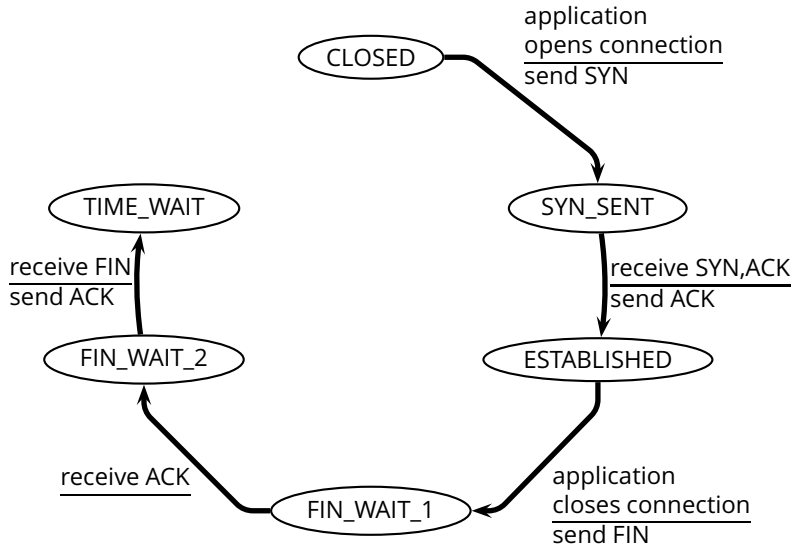
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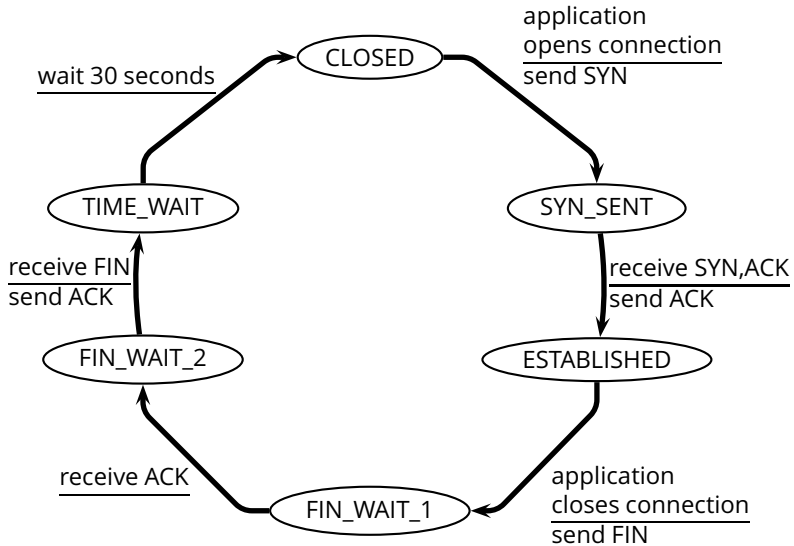
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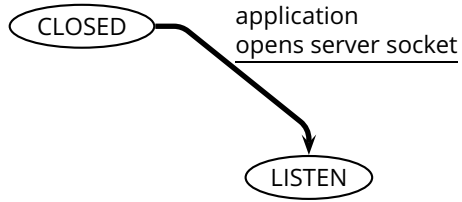
The TCP State Machine (Client)



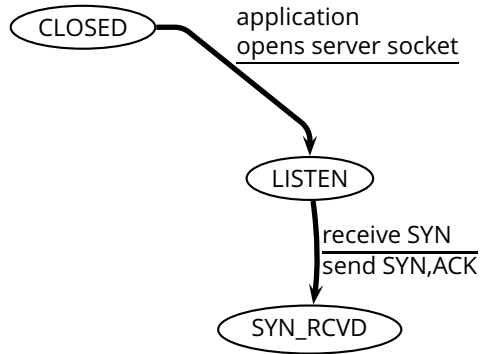
The TCP State Machine (Server)

CLOSED

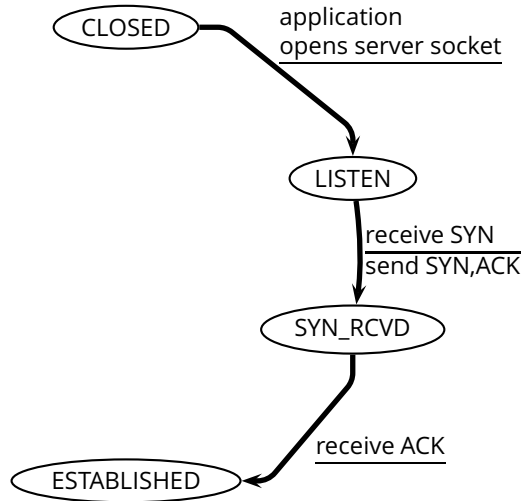
The TCP State Machine (Server)



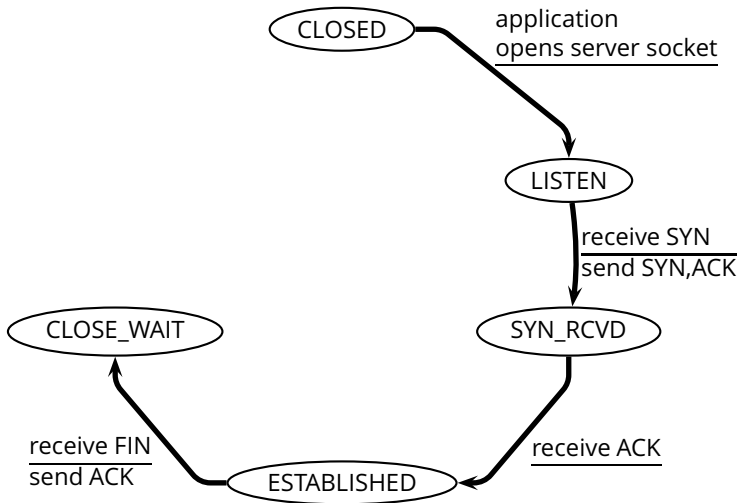
The TCP State Machine (Server)



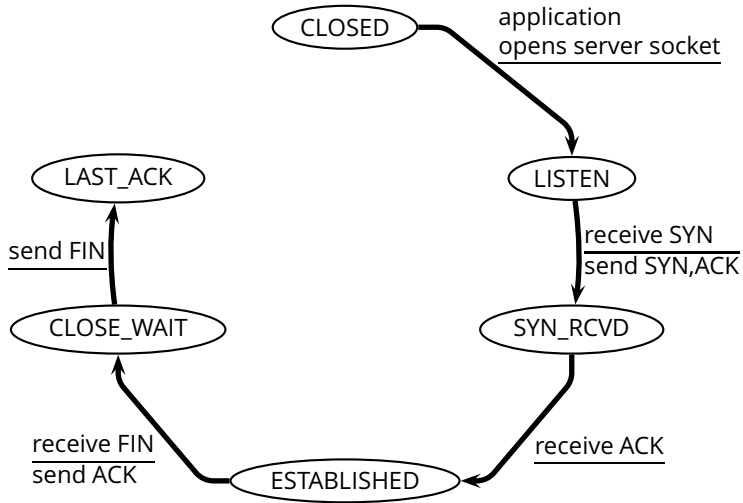
The TCP State Machine (Server)



The TCP State Machine (Server)



The TCP State Machine (Server)



The TCP State Machine (Server)

