Transmission Control Protocol (TCP)

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November 5, 2014

Outline

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

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- Full-duplex service
  - both endpoints can both send and receive, at the same time

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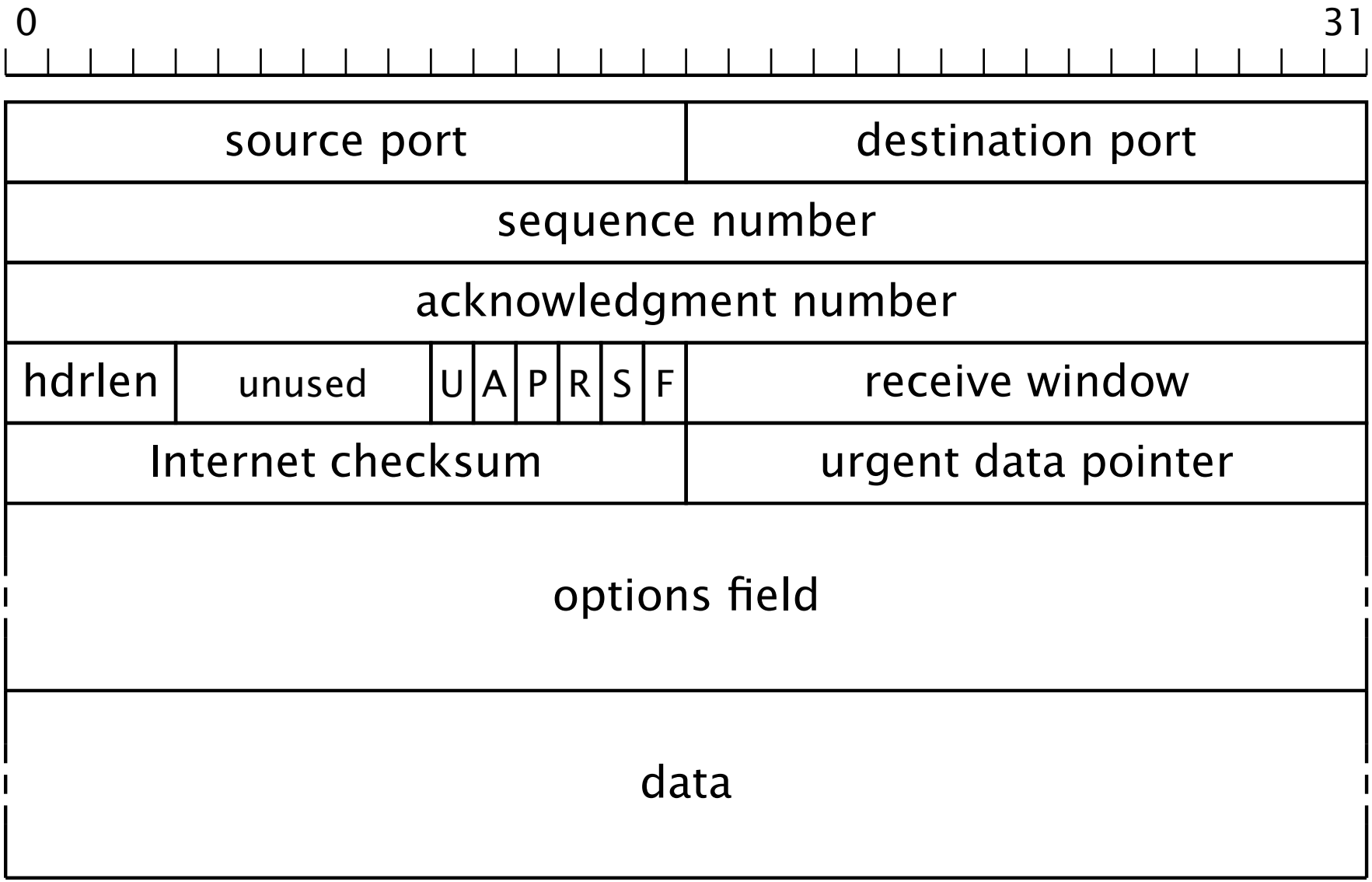
- *Maximum transmission unit (MTU):* largest link-layer frame available to the sender host
  - *path MTU:* largest link-layer frame that can be sent on all links from the sender host to the receiver host

TCP Segment Format



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

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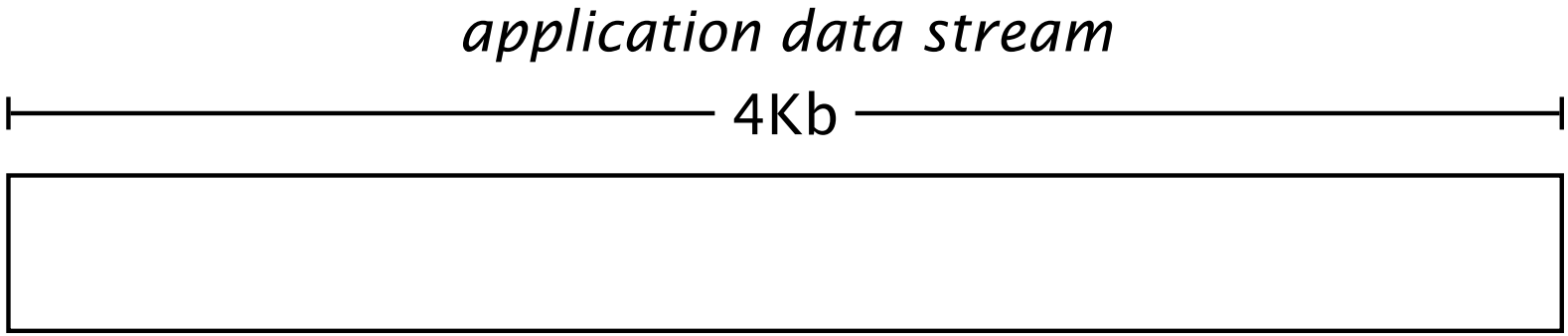

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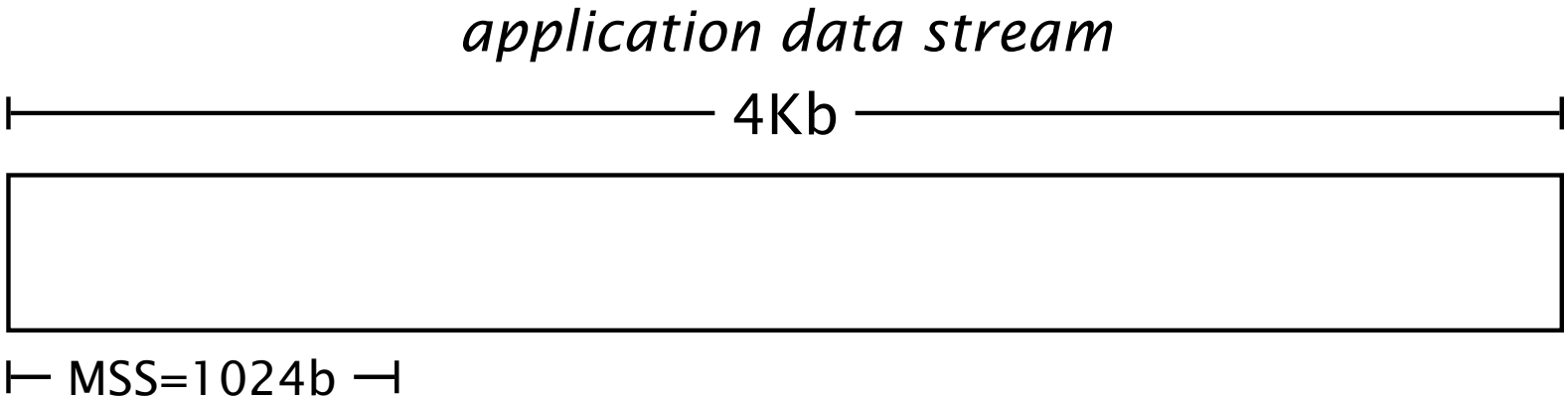

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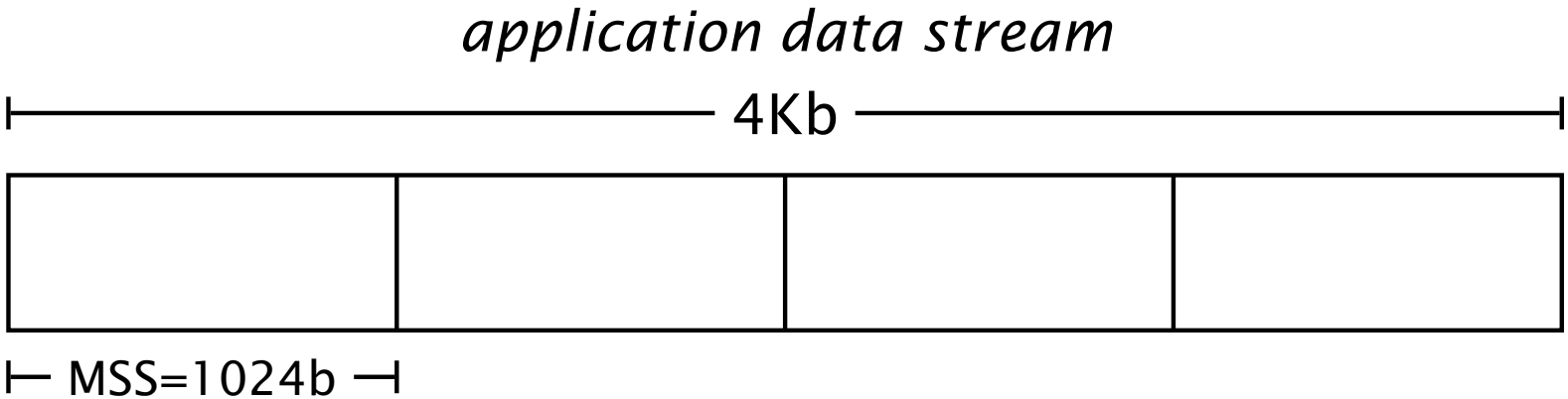

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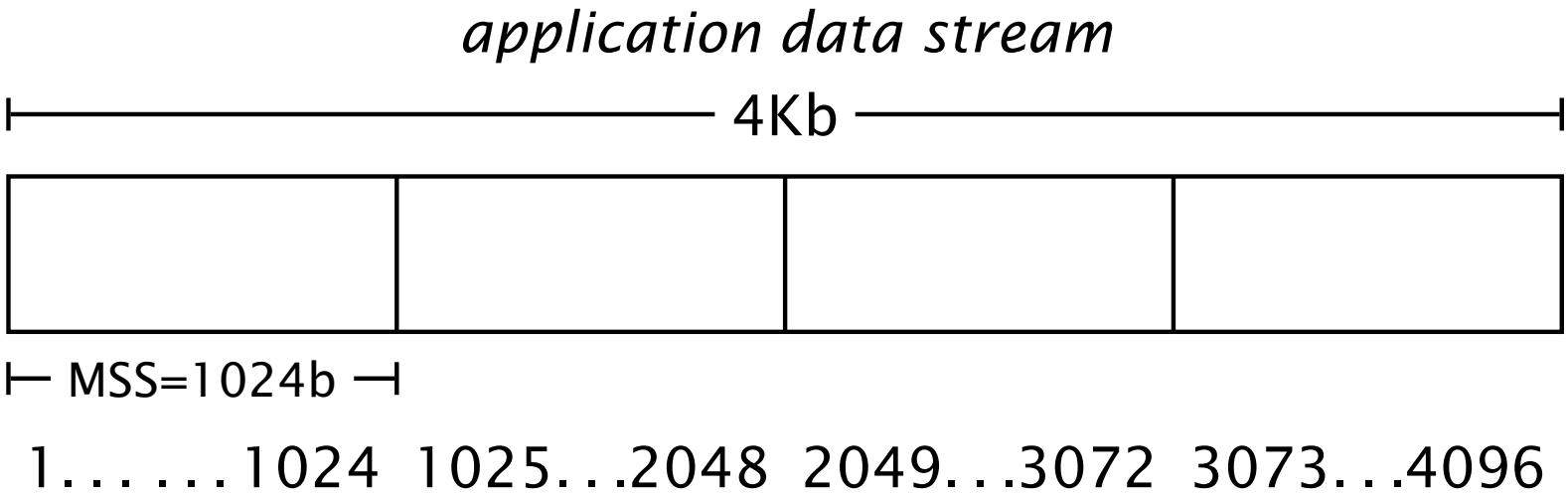

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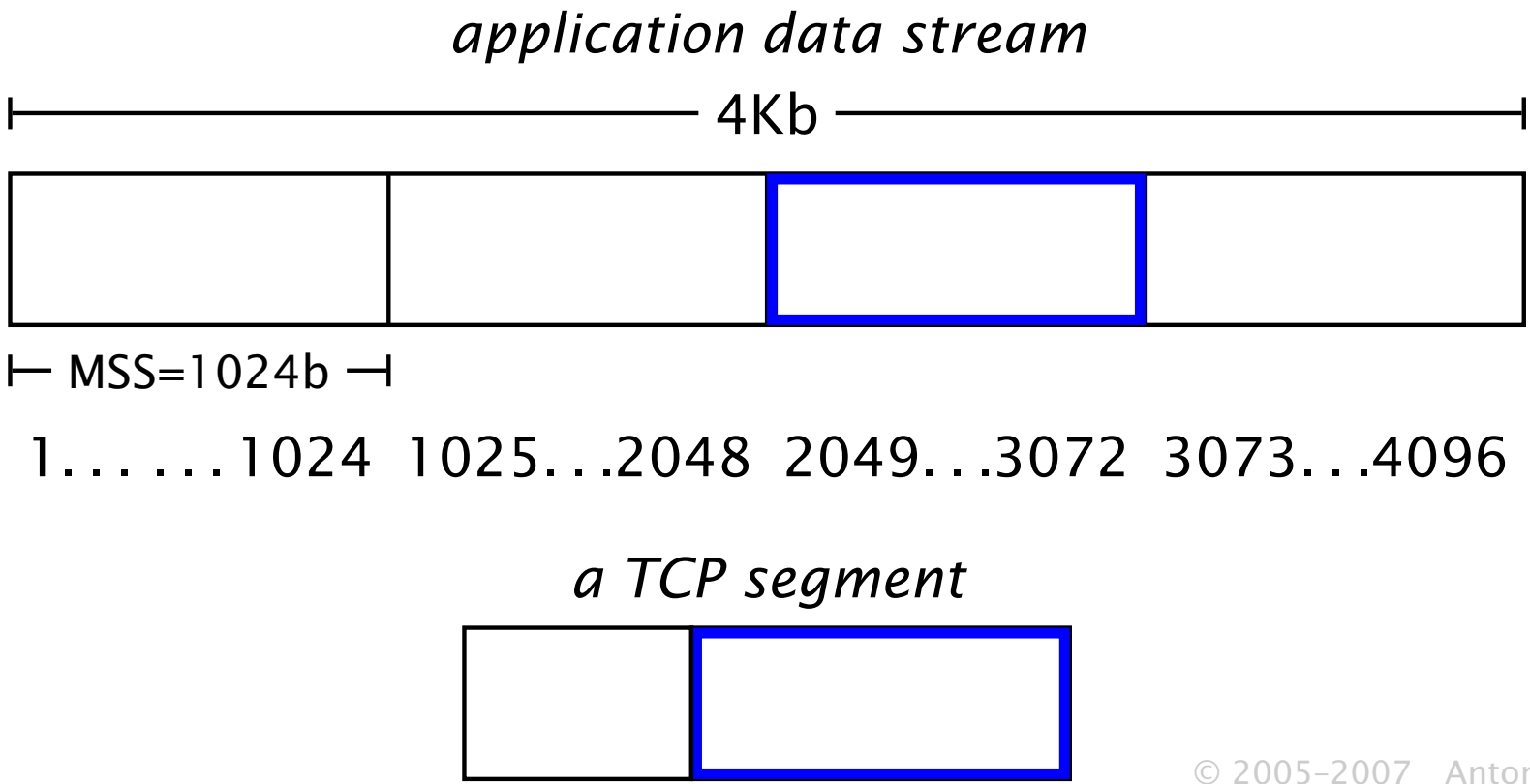

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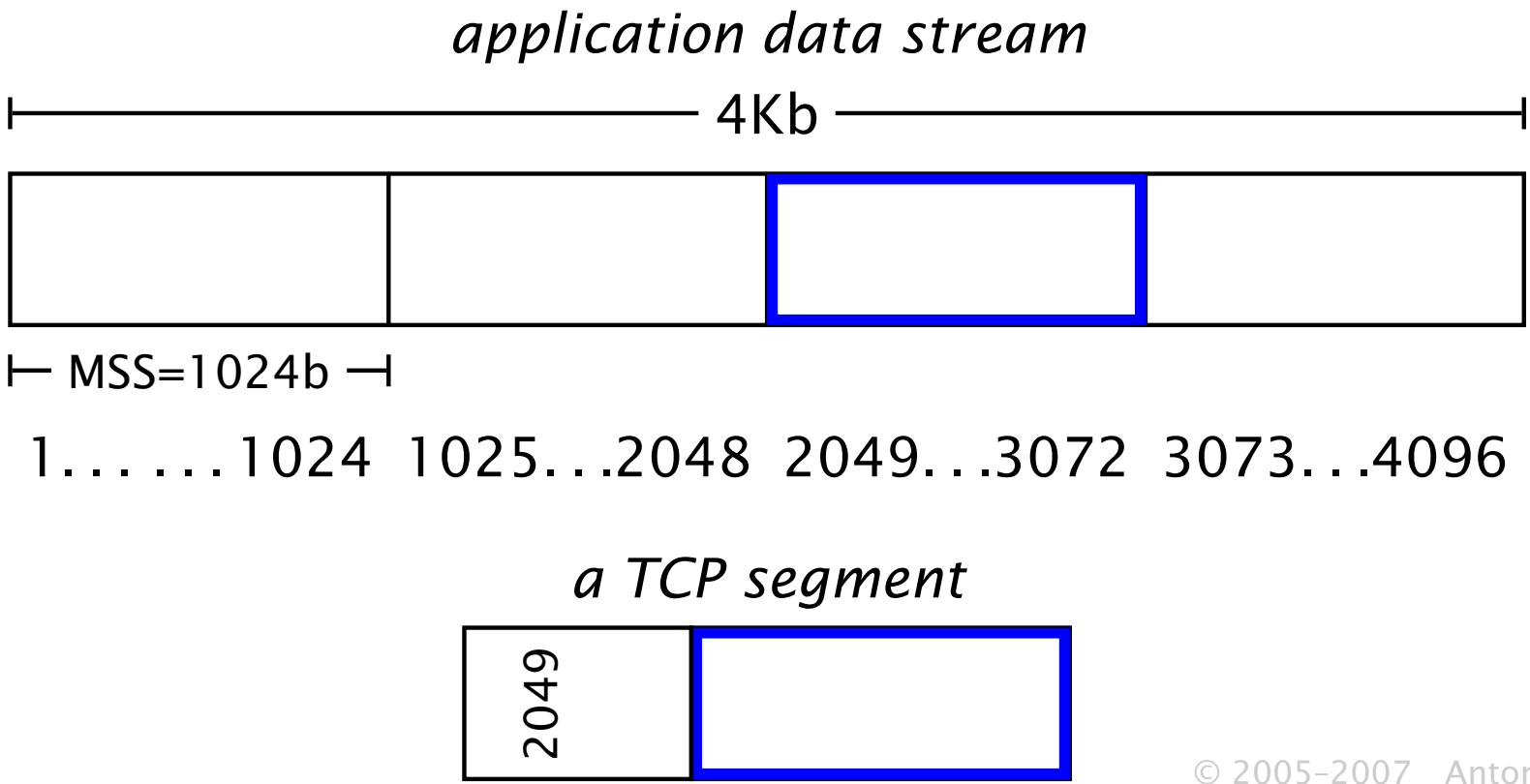

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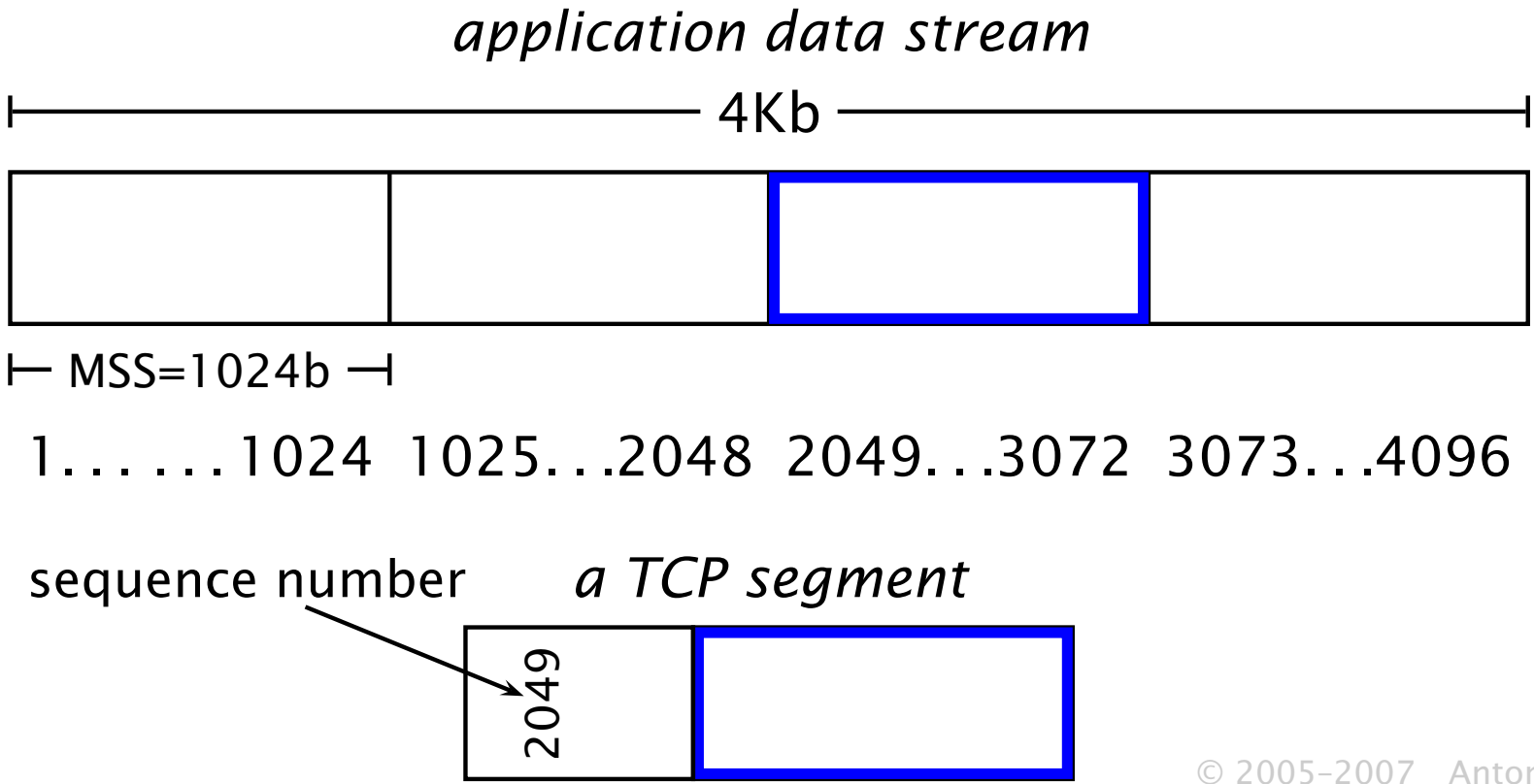

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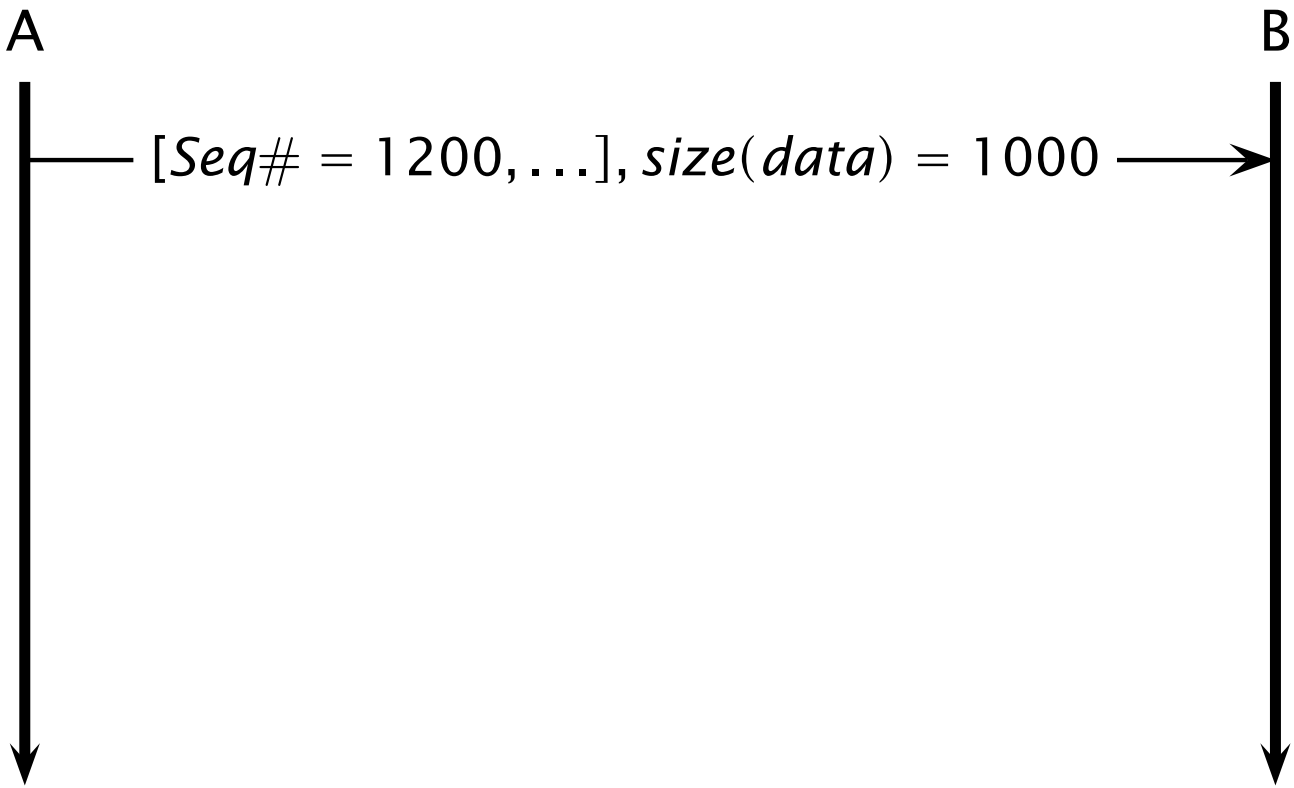

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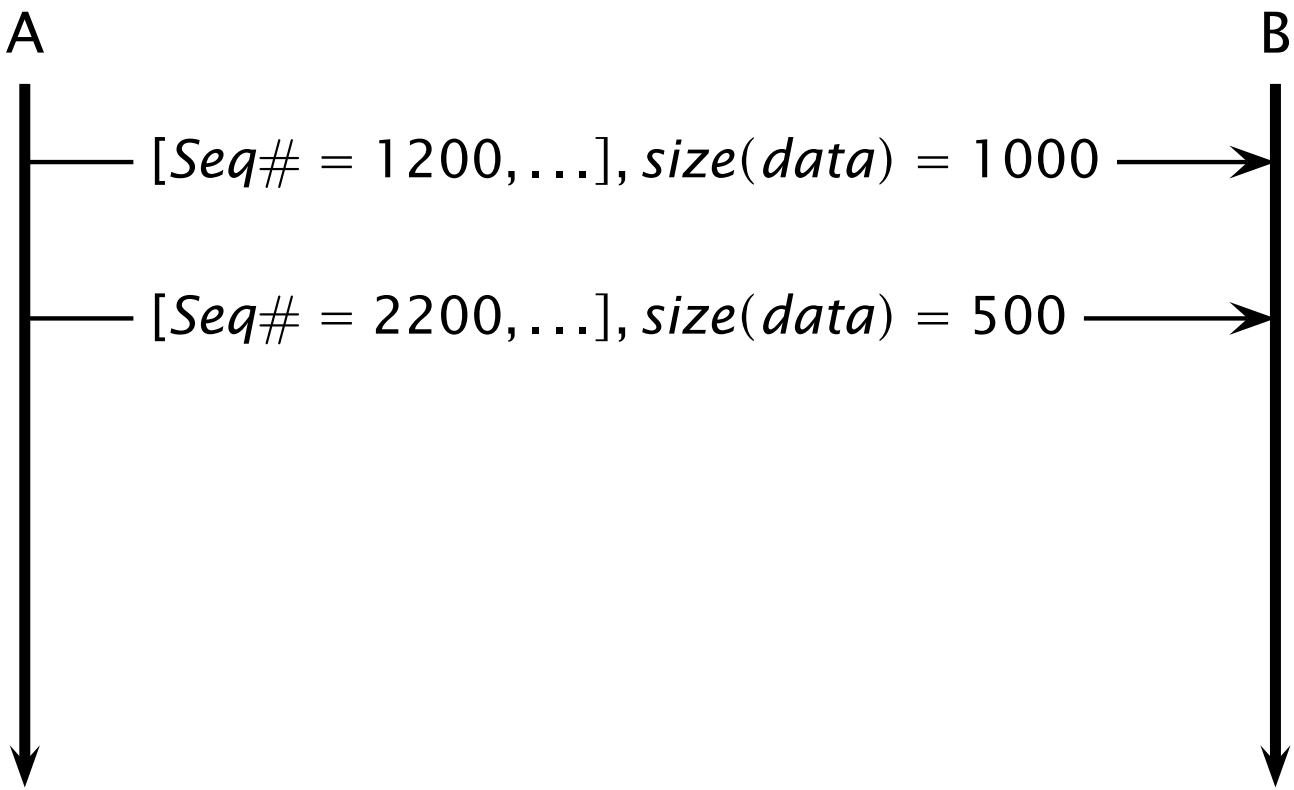

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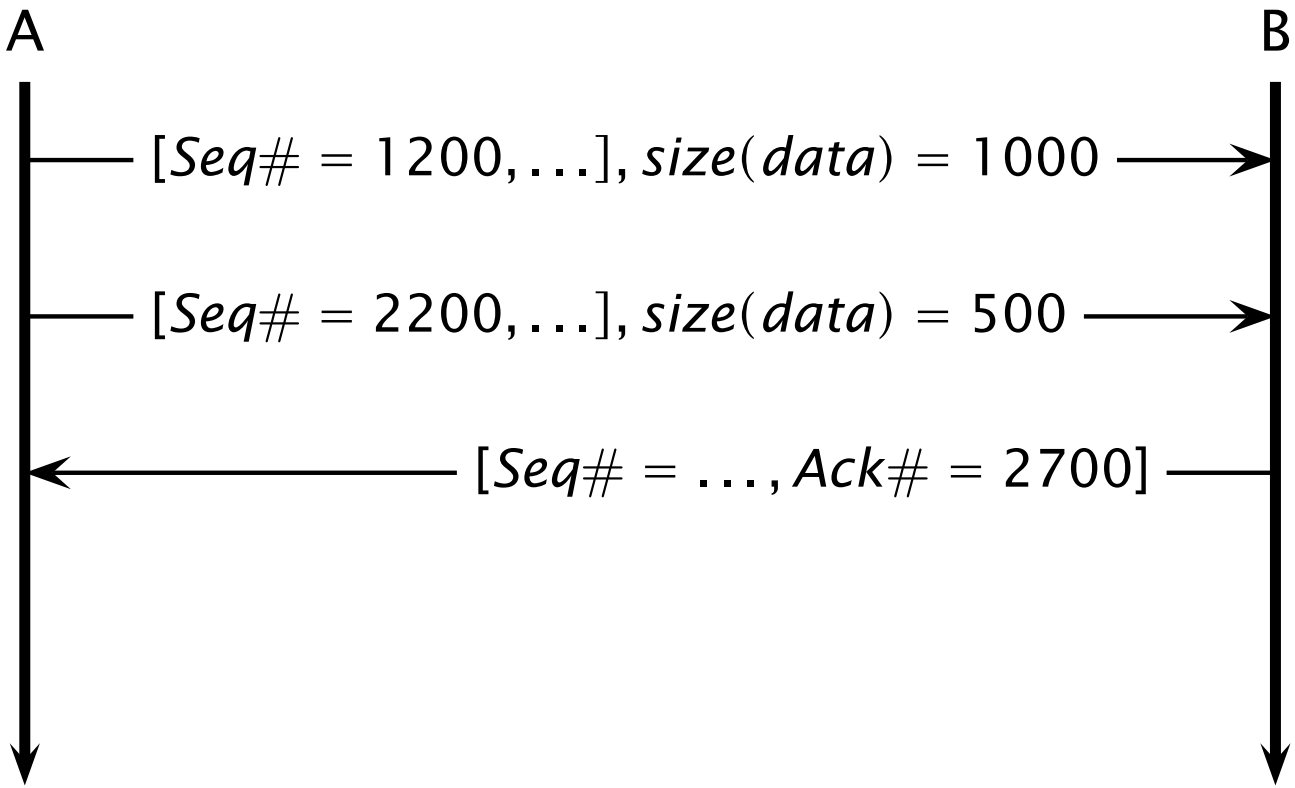

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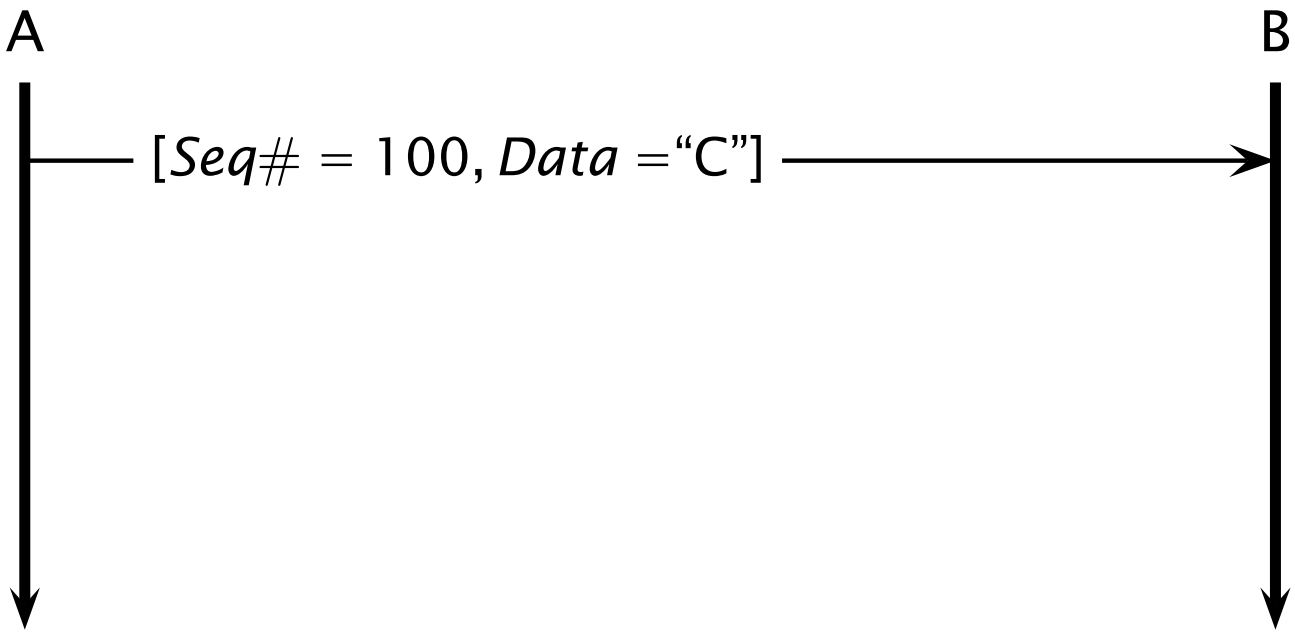

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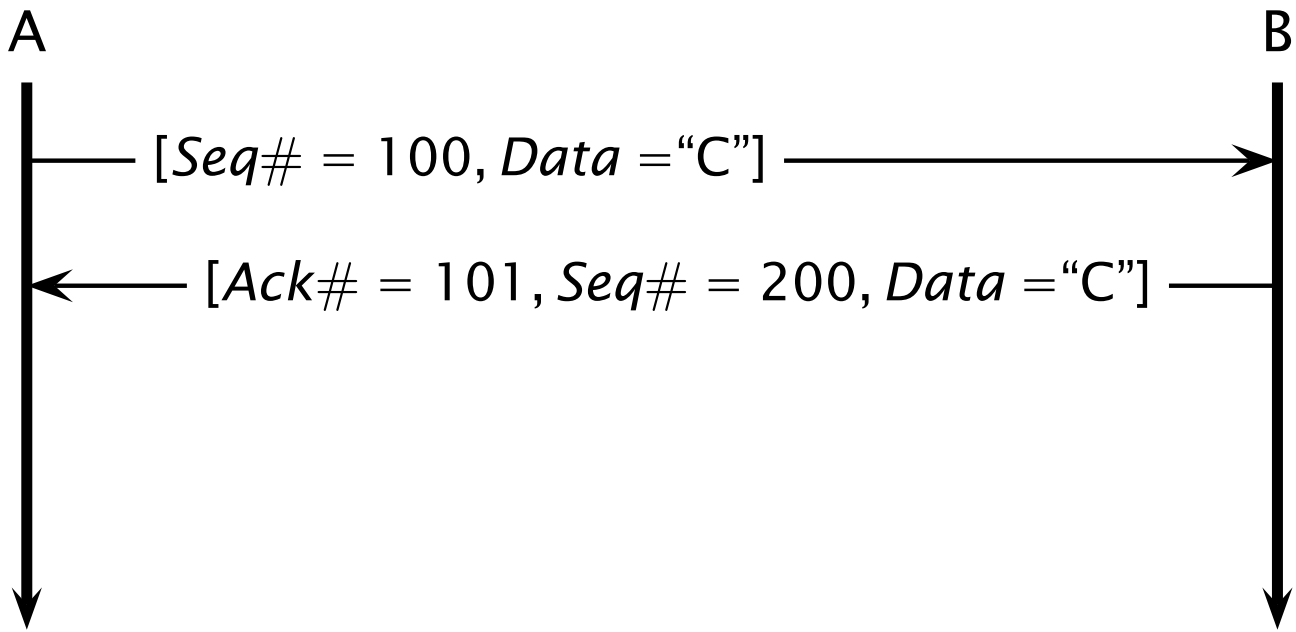

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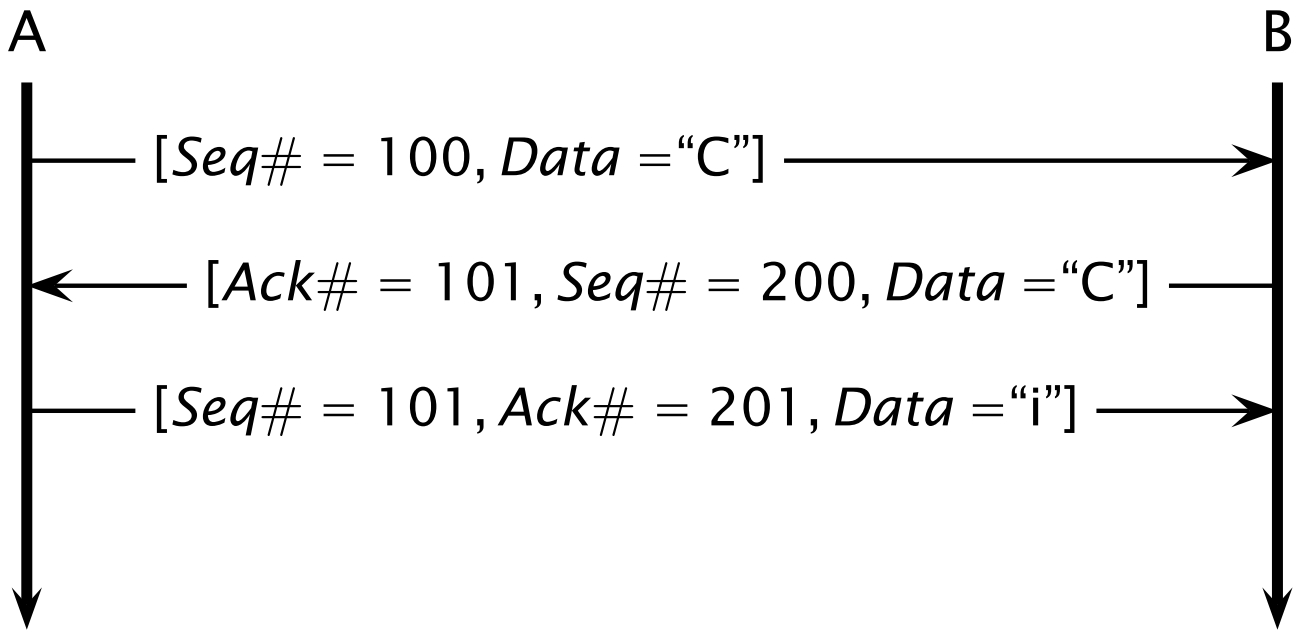

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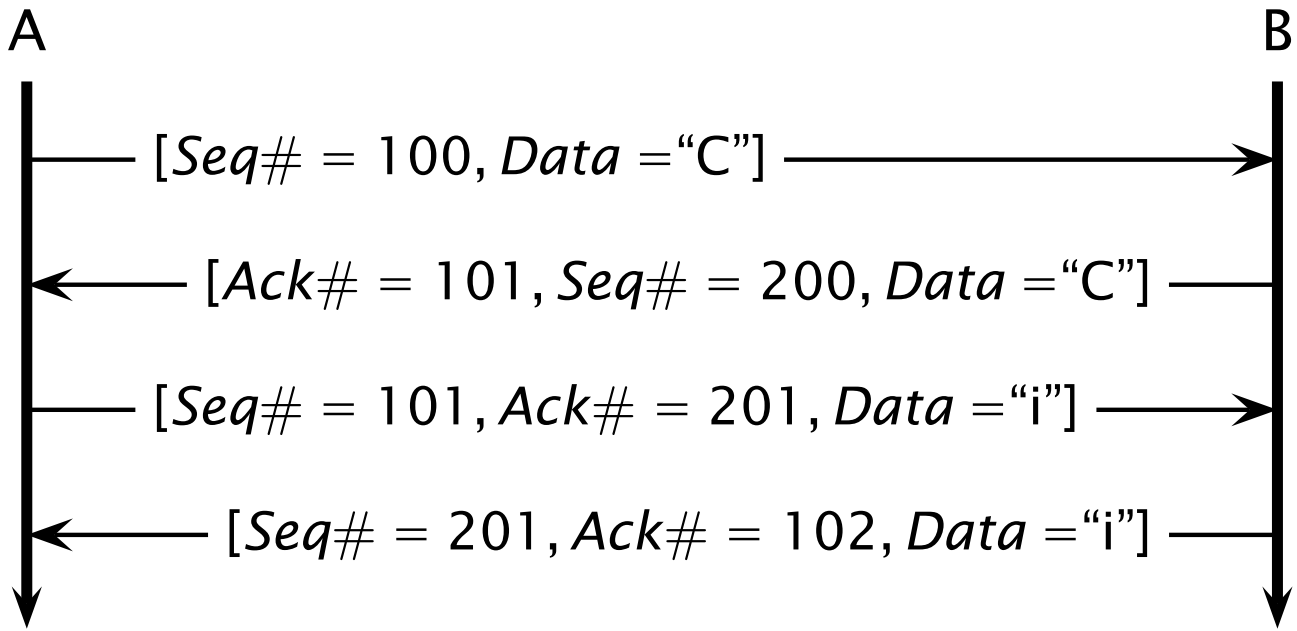

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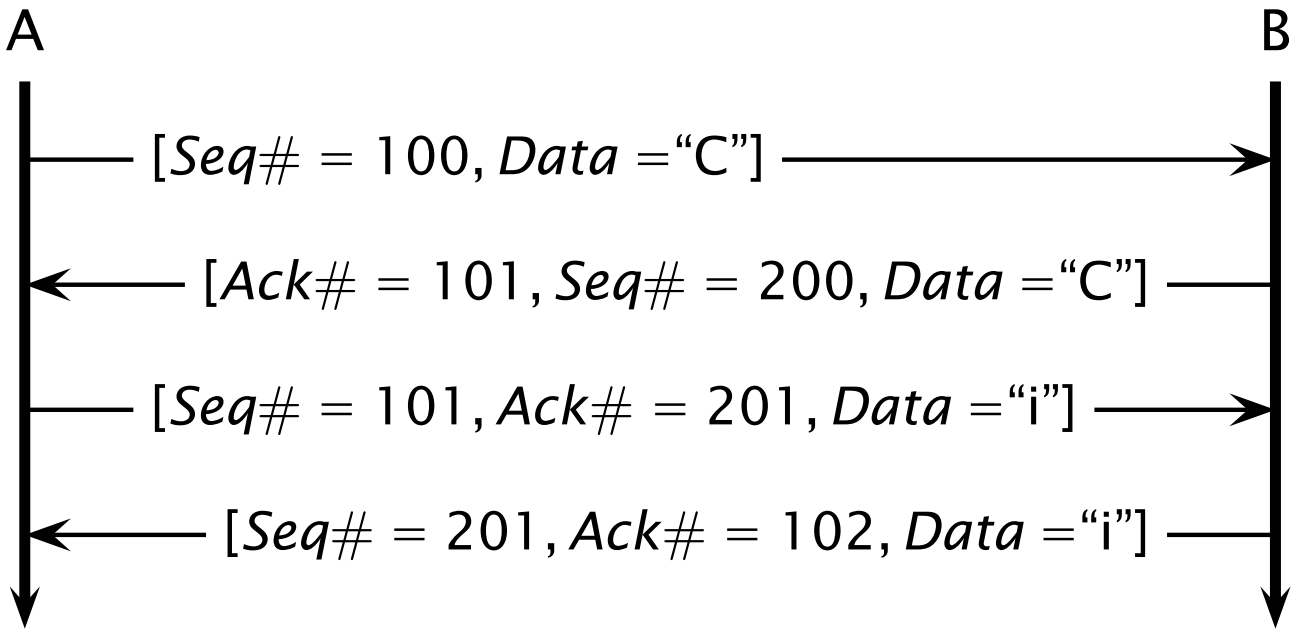

- Acknowledgments are "piggybacked" on data segments

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

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

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A simplified TCP sender

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- u_recv([ACK,*y*])

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   if (ack_counter[y] = 3)
      u_send(segment with sequence number y)
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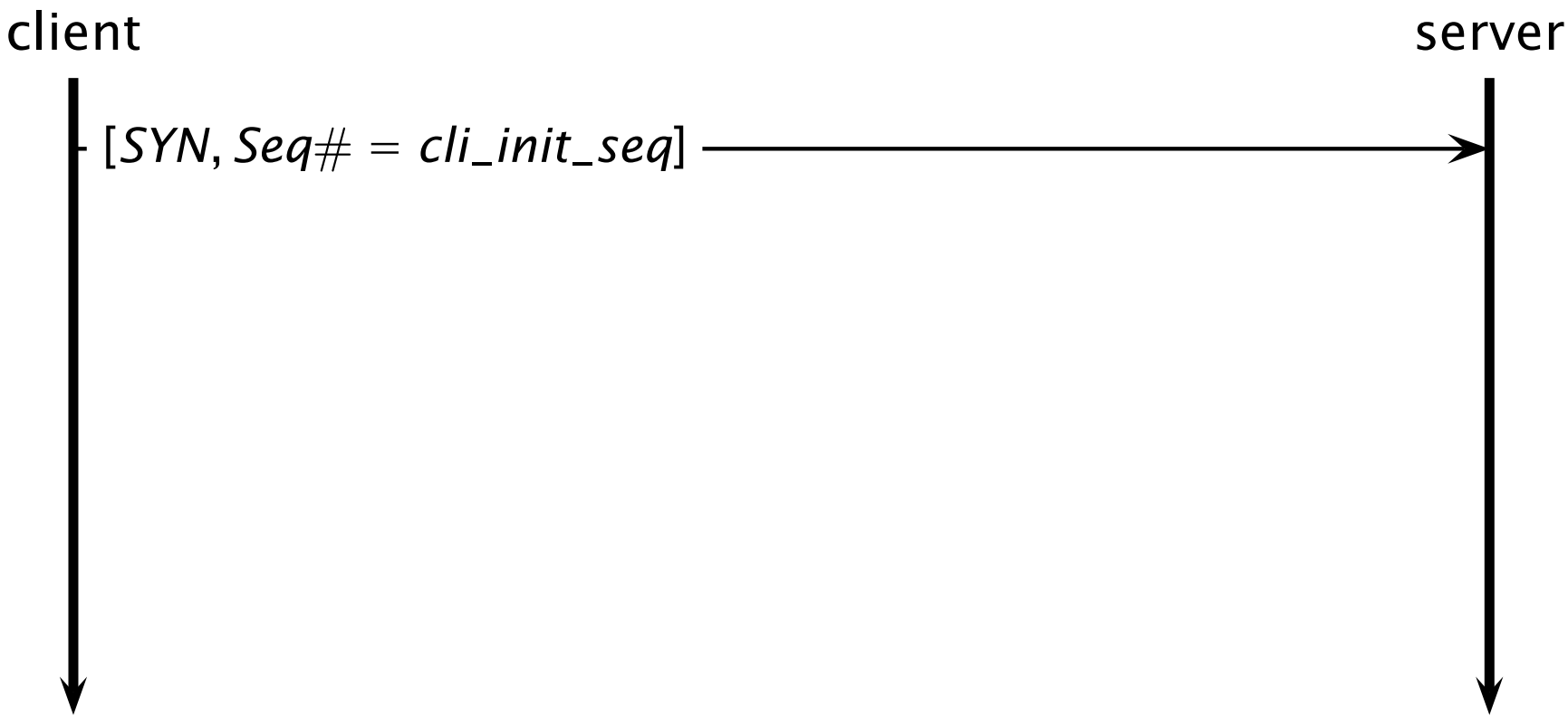

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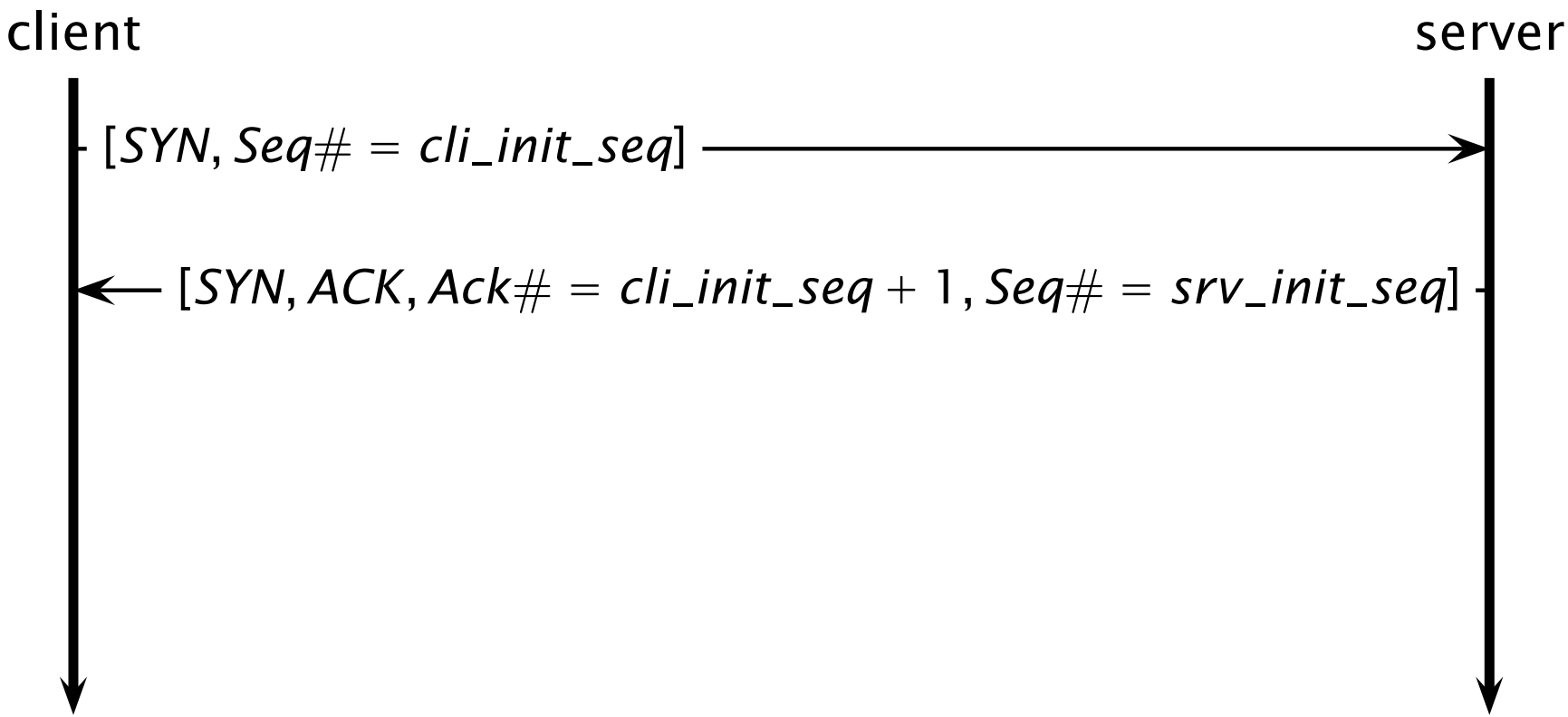

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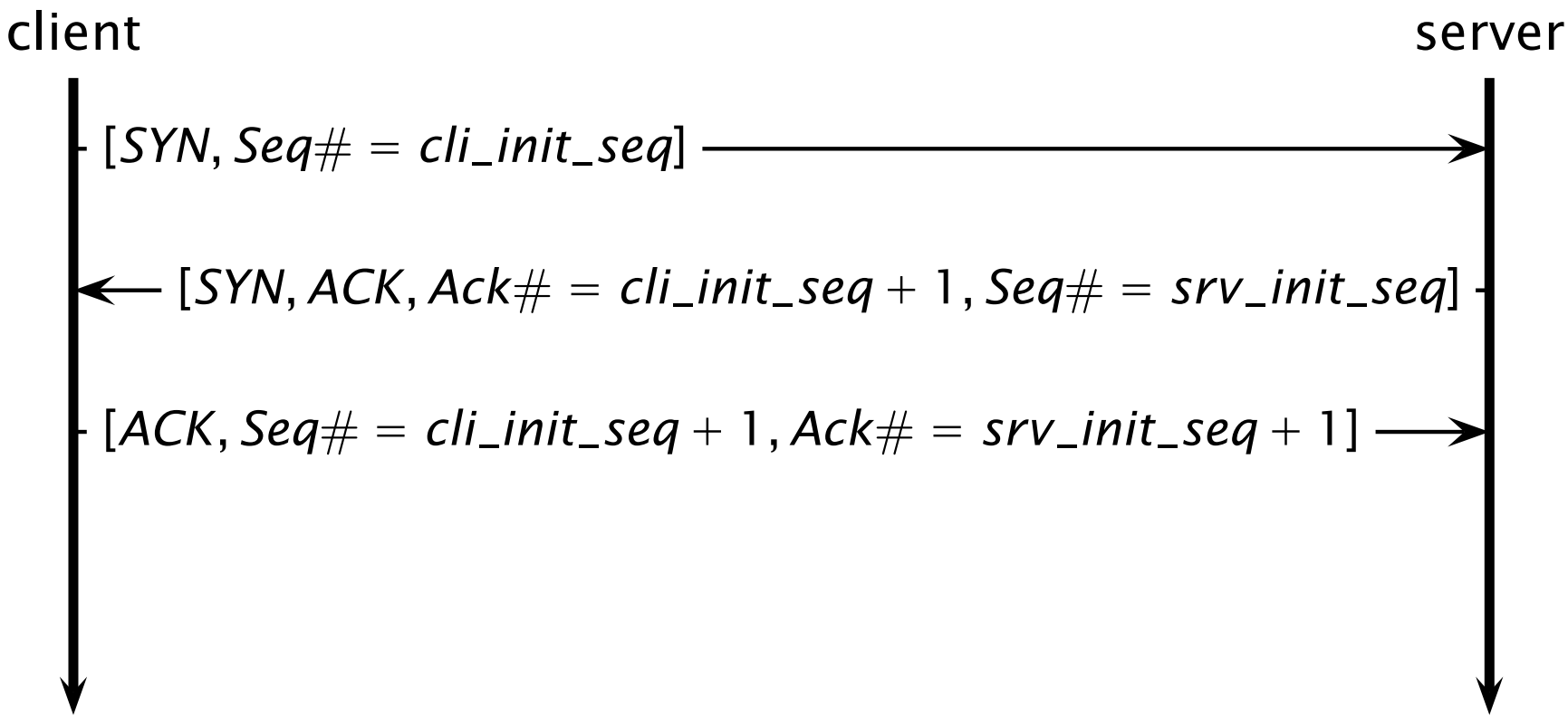

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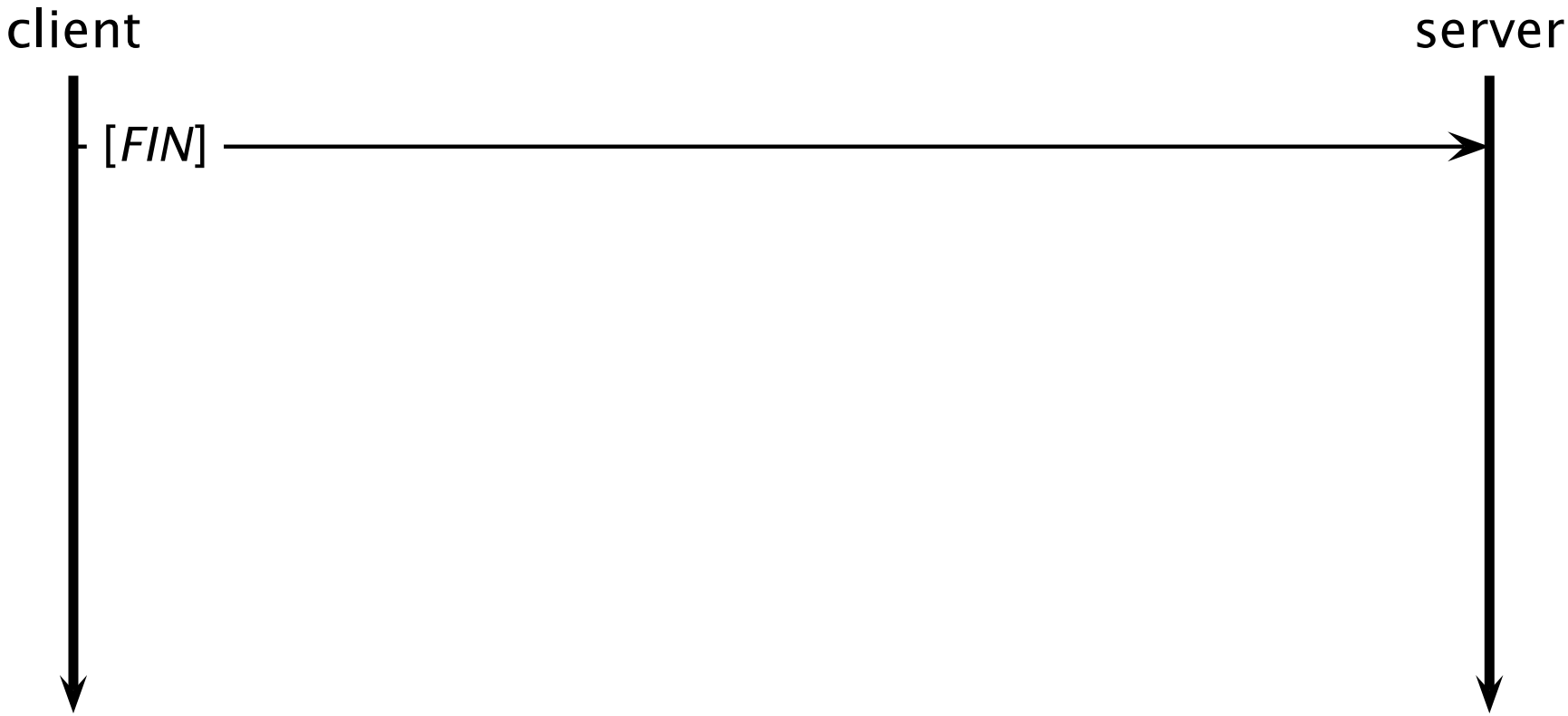

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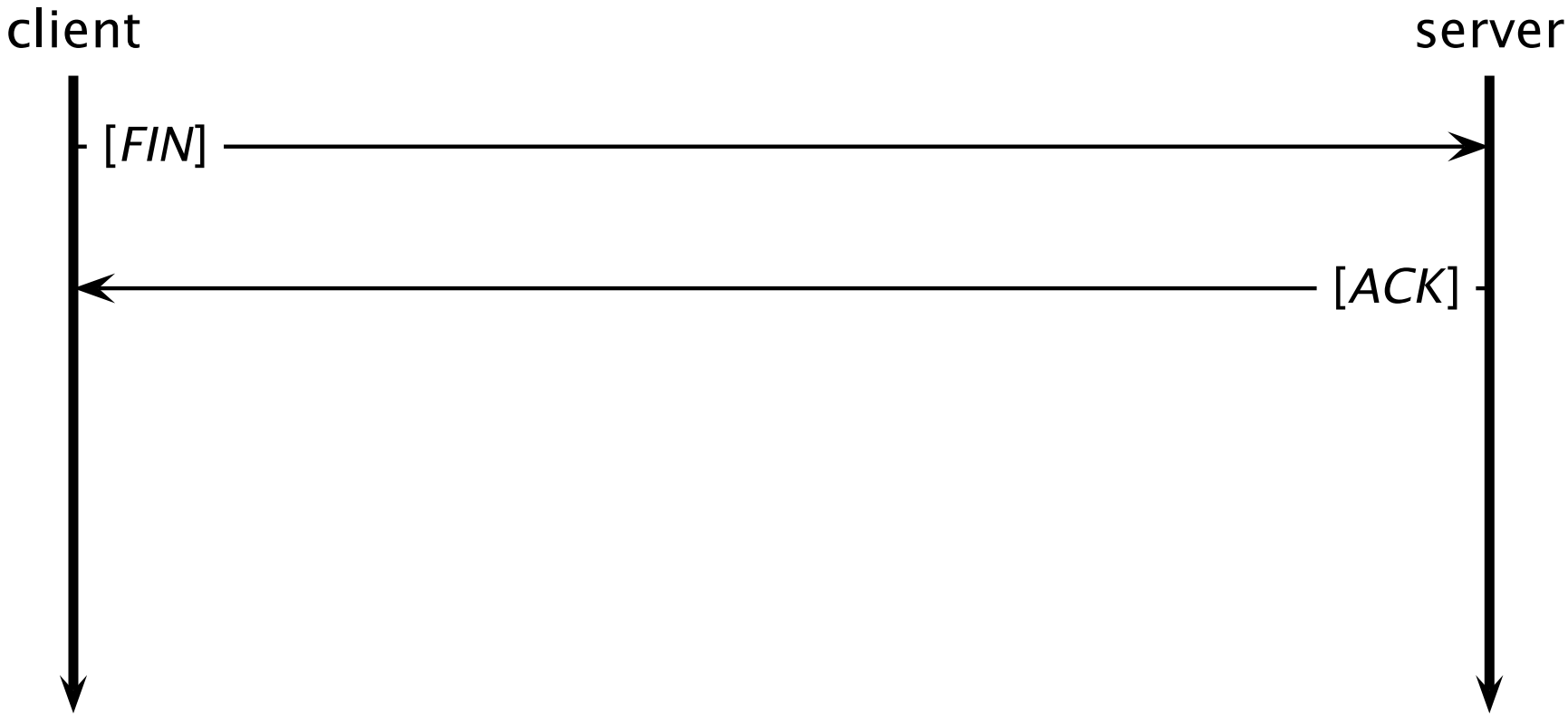

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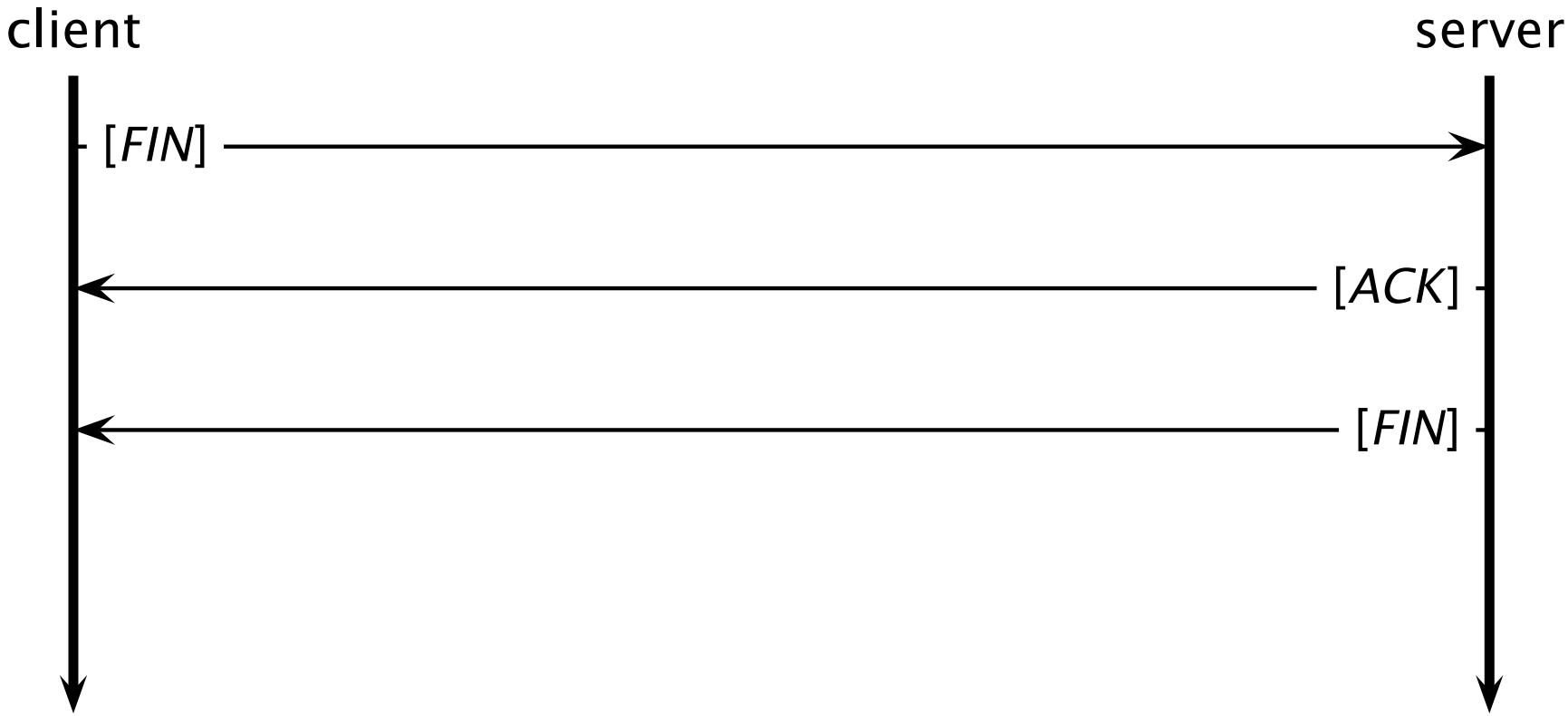
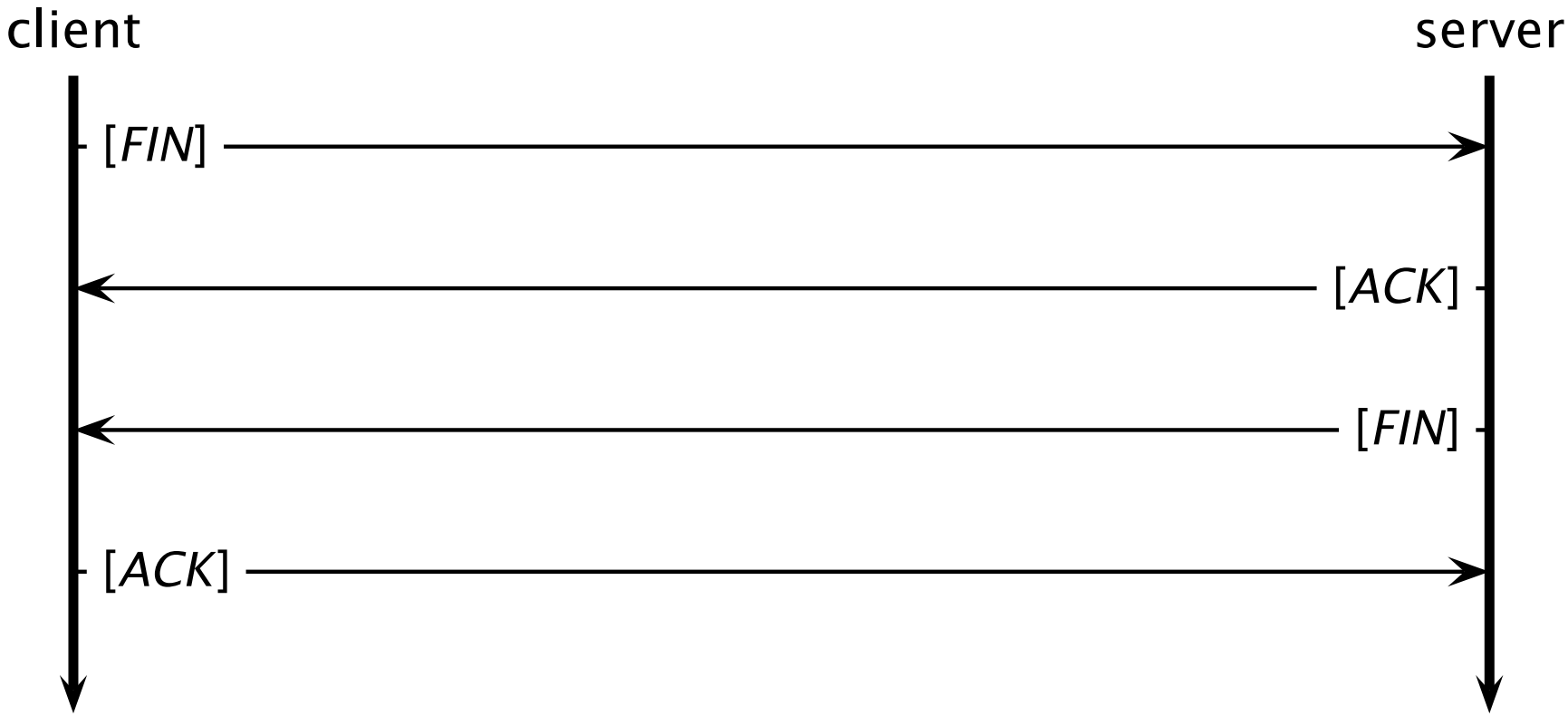
"Okay, Bye now."
"Bye."



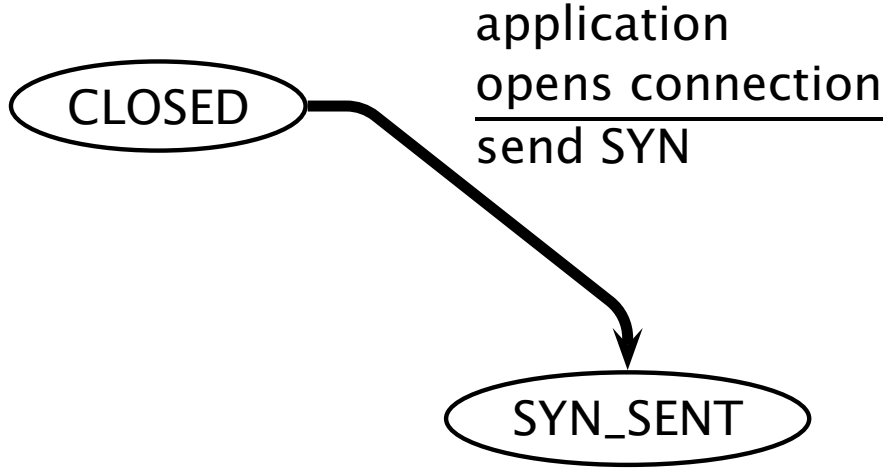
Connection Shutdown

"This is it."
"Okay, Bye now."
"Bye."

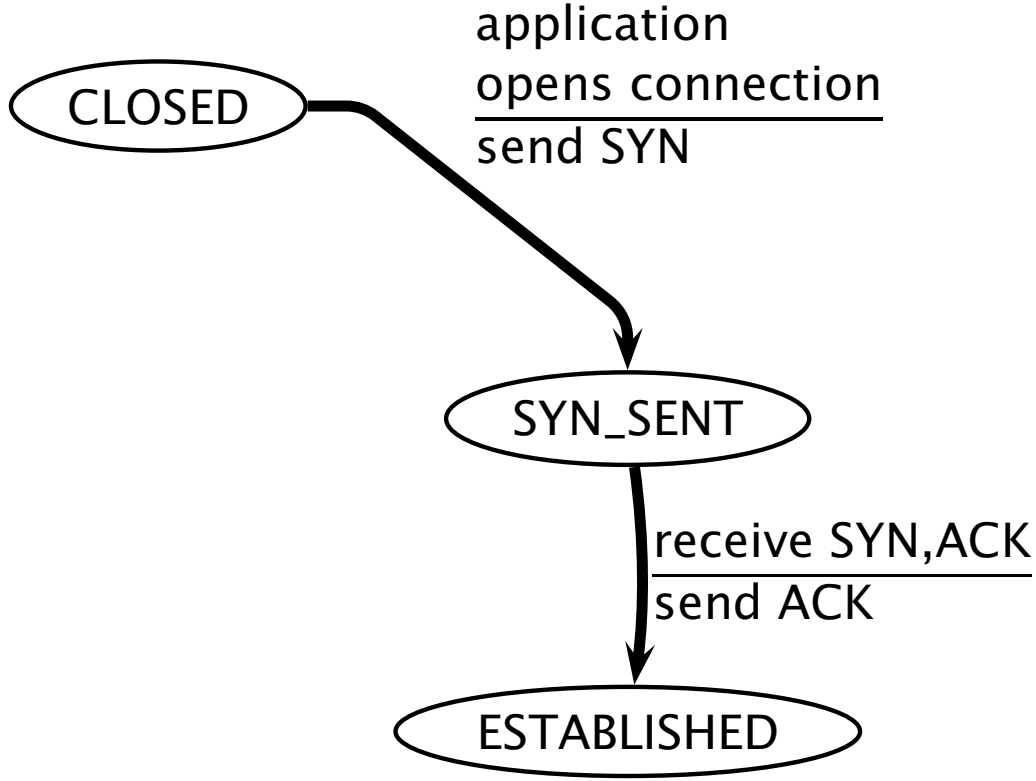


The TCP State Machine (Client)

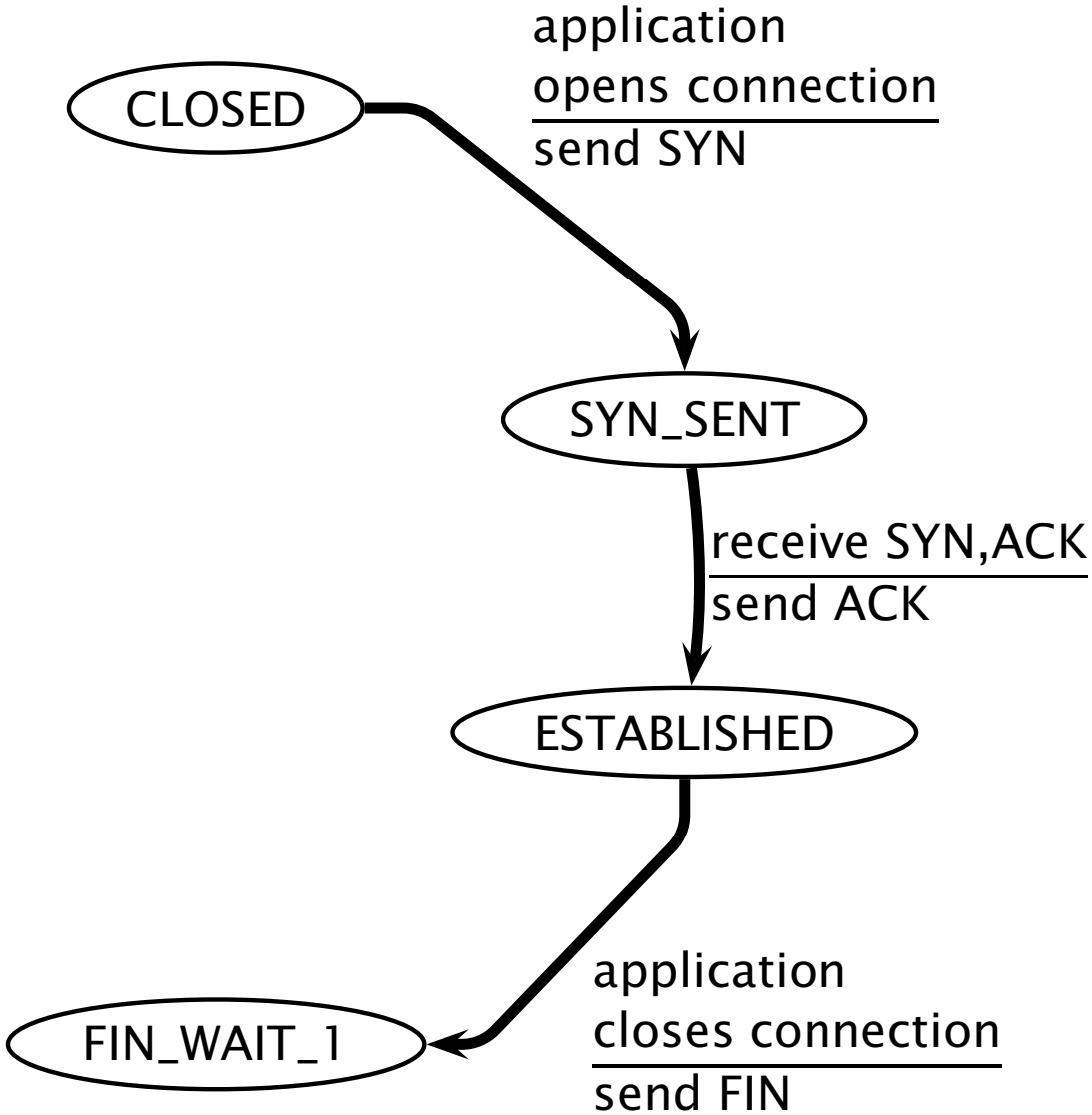
The TCP State Machine (Client)



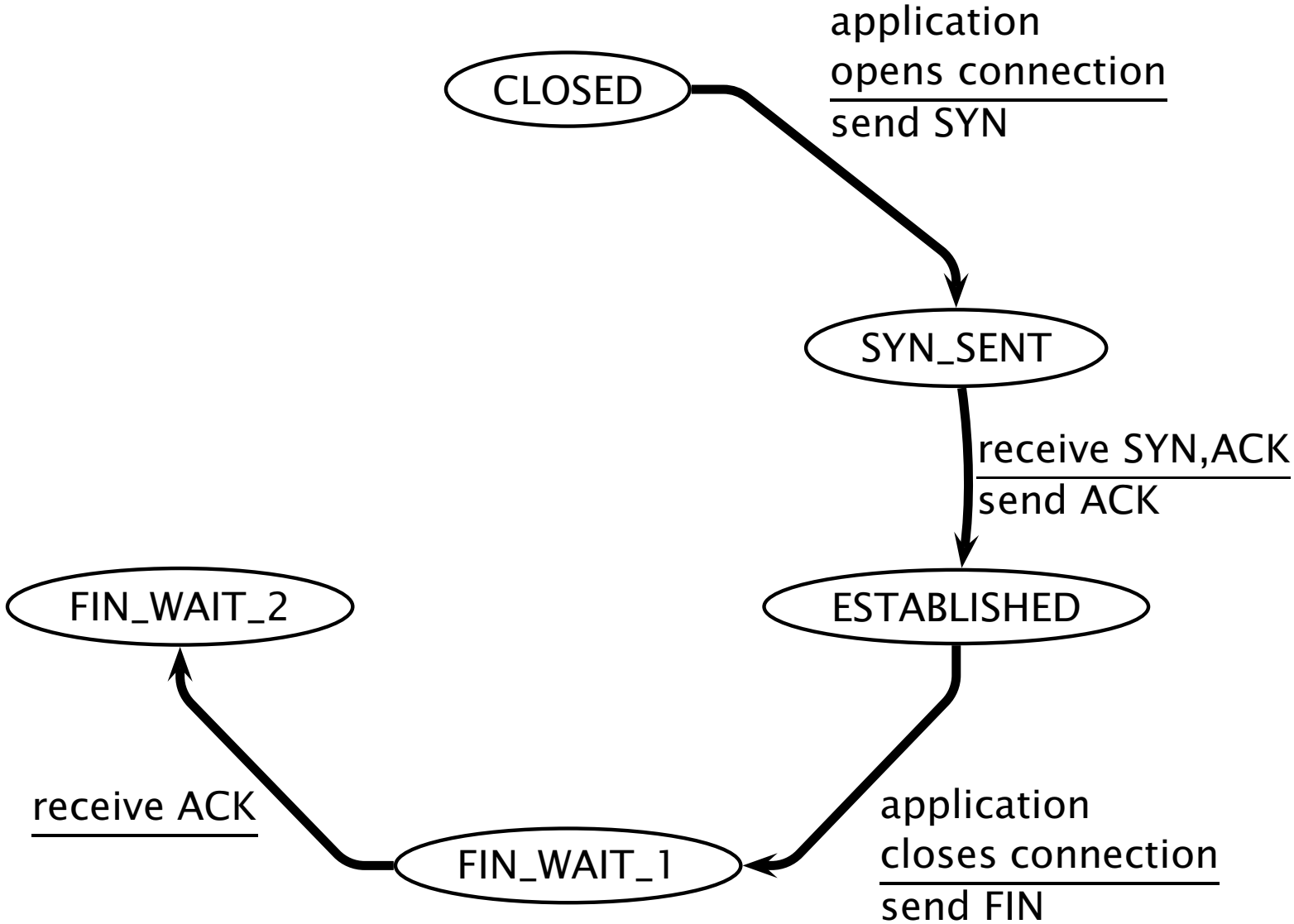
The TCP State Machine (Client)



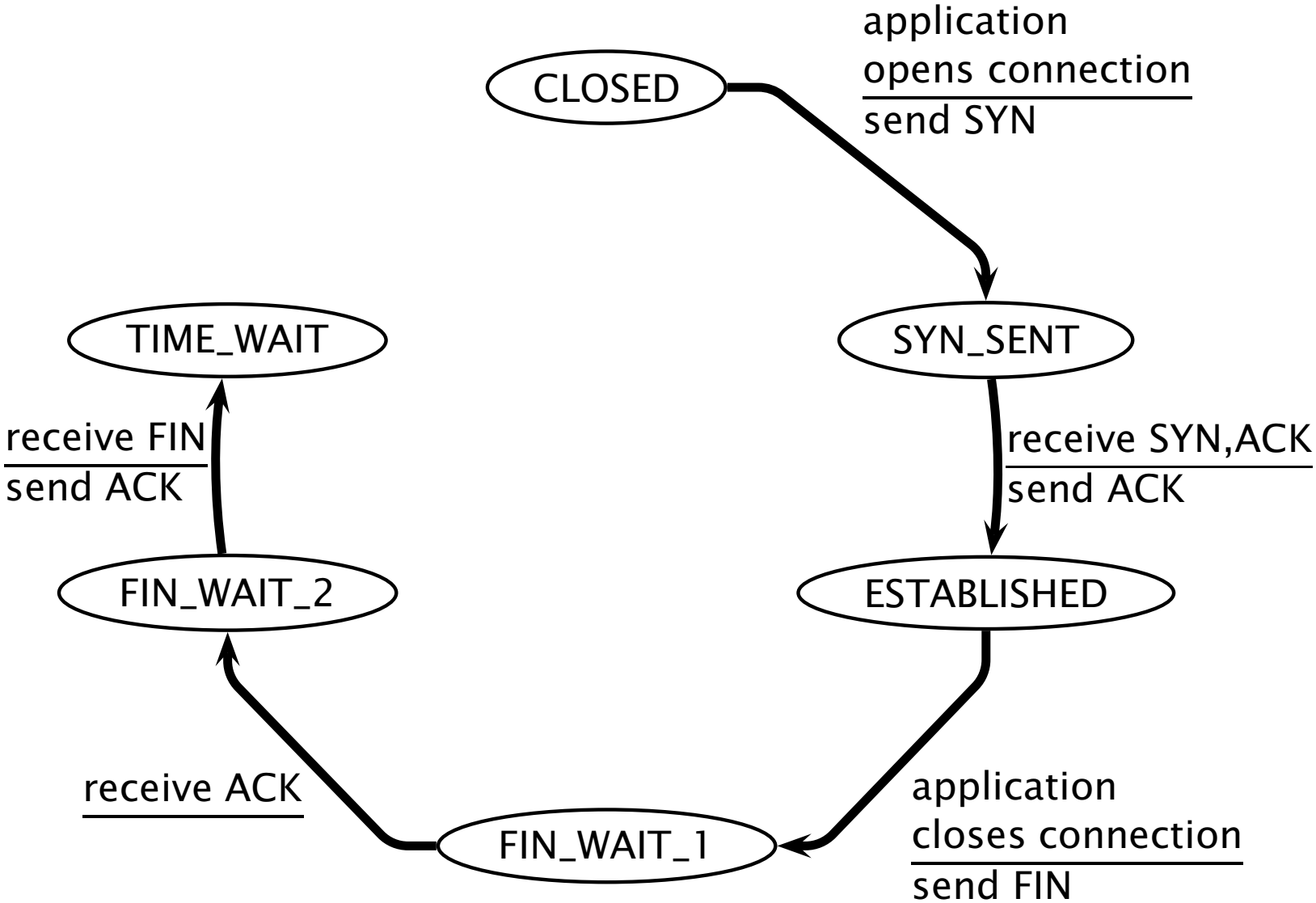
The TCP State Machine (Client)



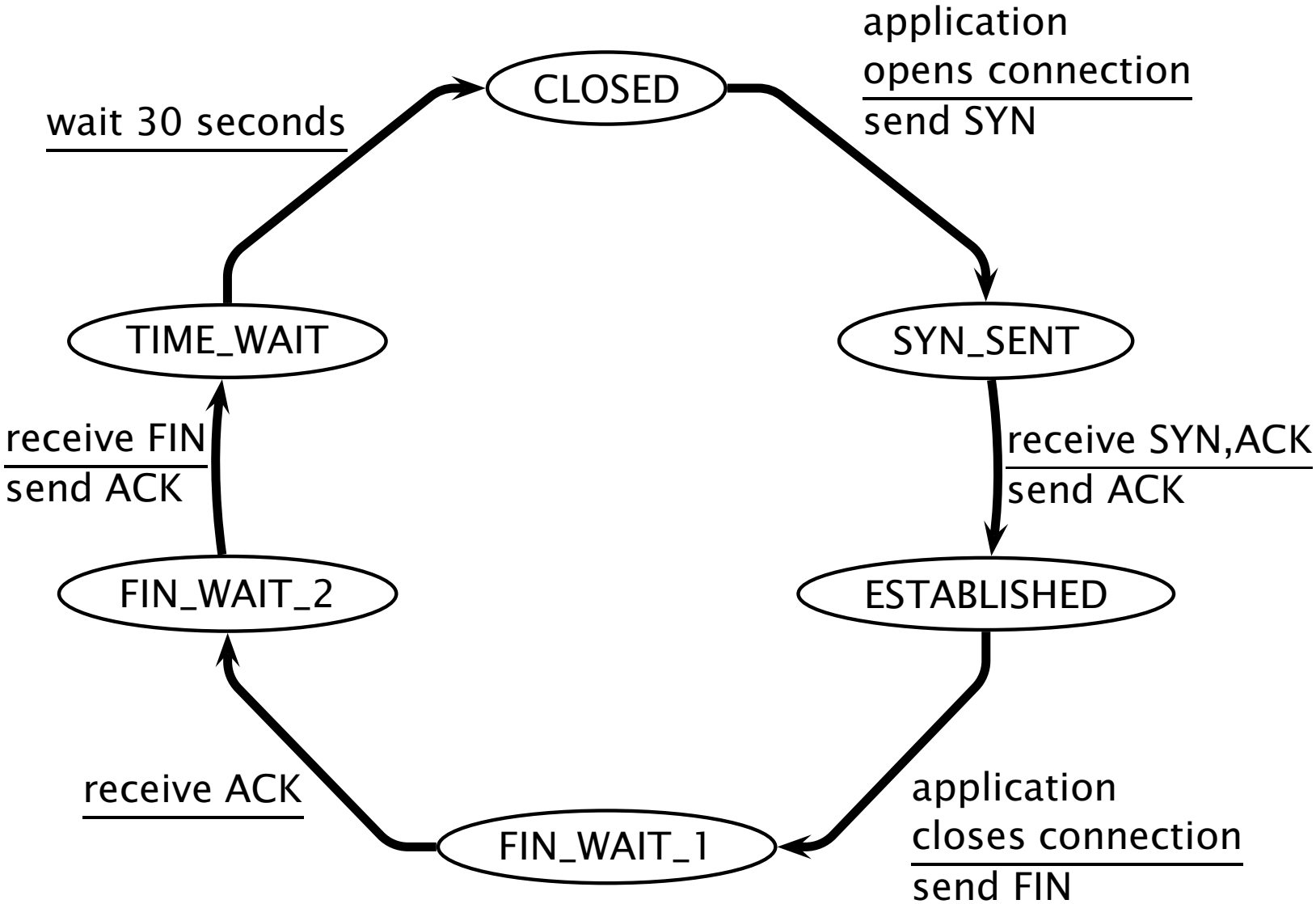
The TCP State Machine (Client)



The TCP State Machine (Client)

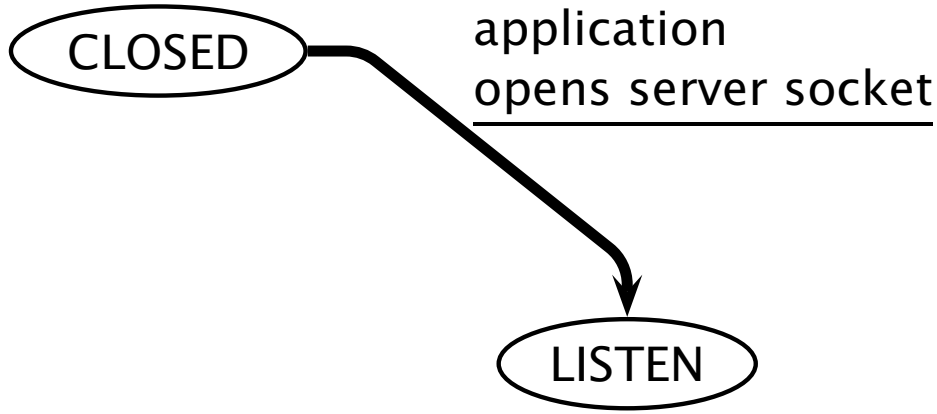


The TCP State Machine (Client)

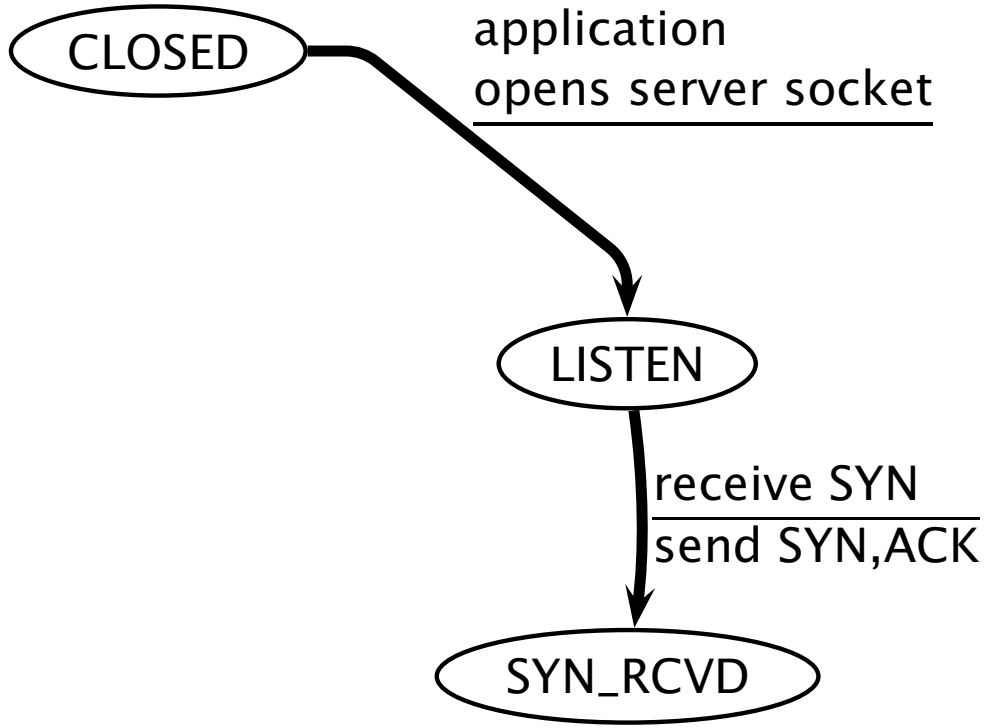


The TCP State Machine (Server)

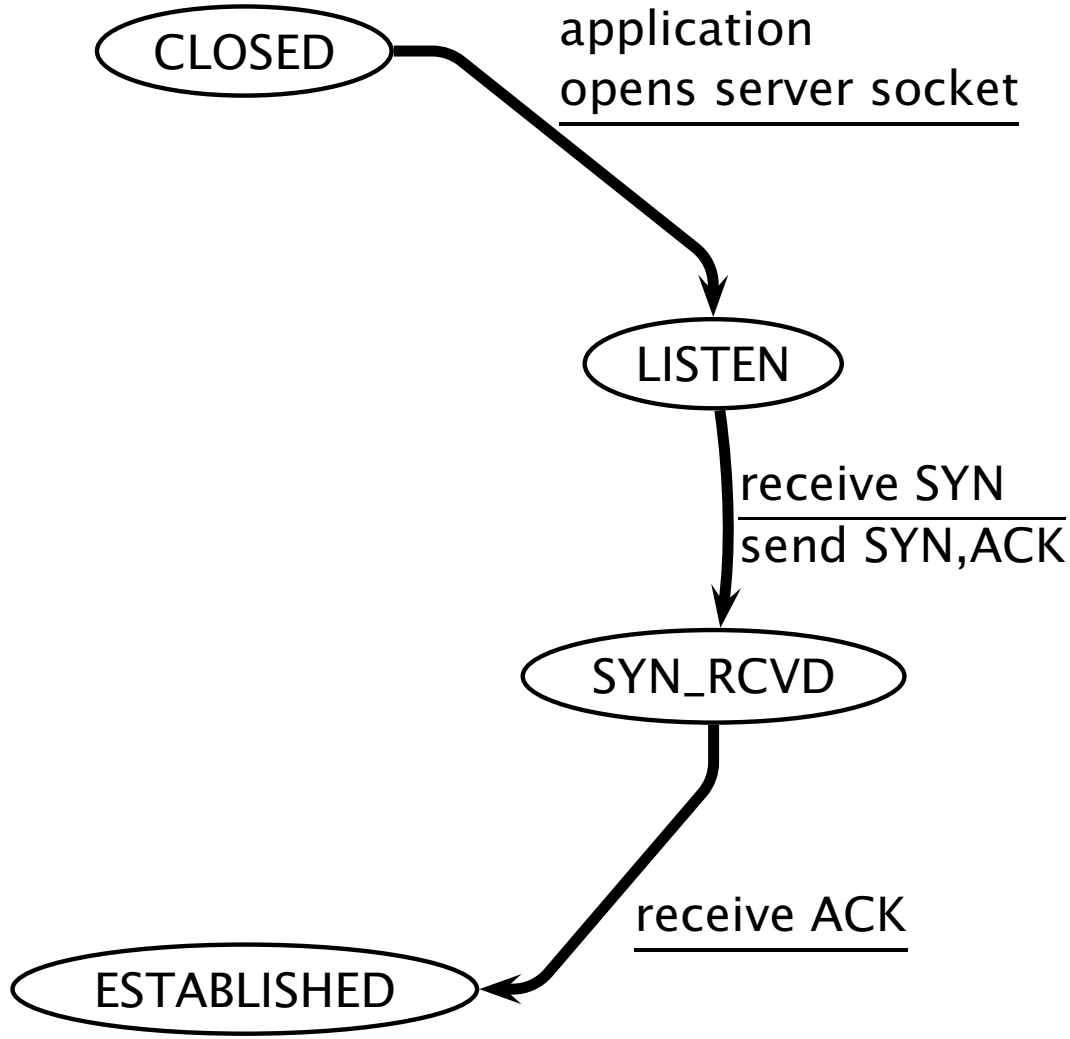
The TCP State Machine (Server)



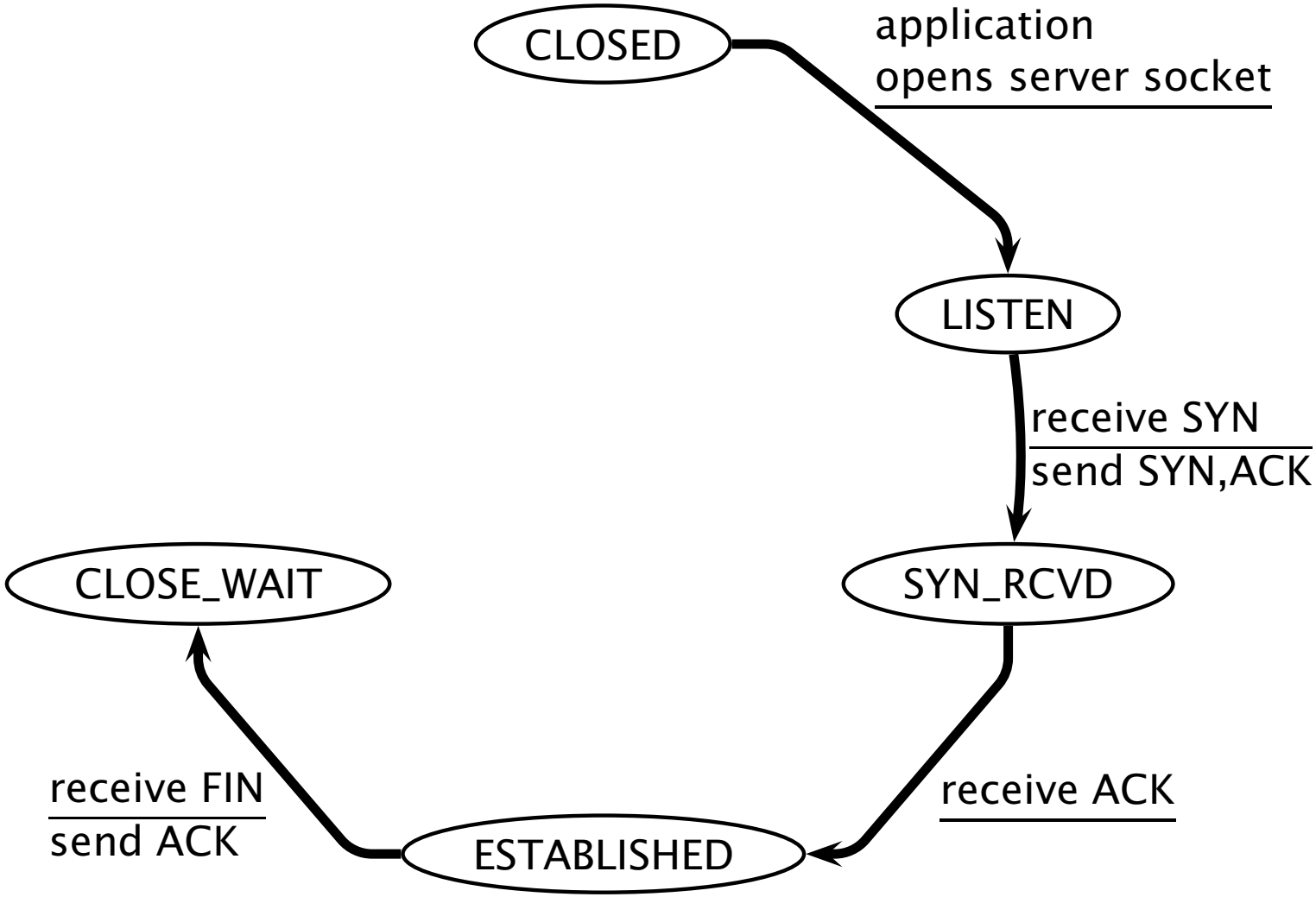
The TCP State Machine (Server)



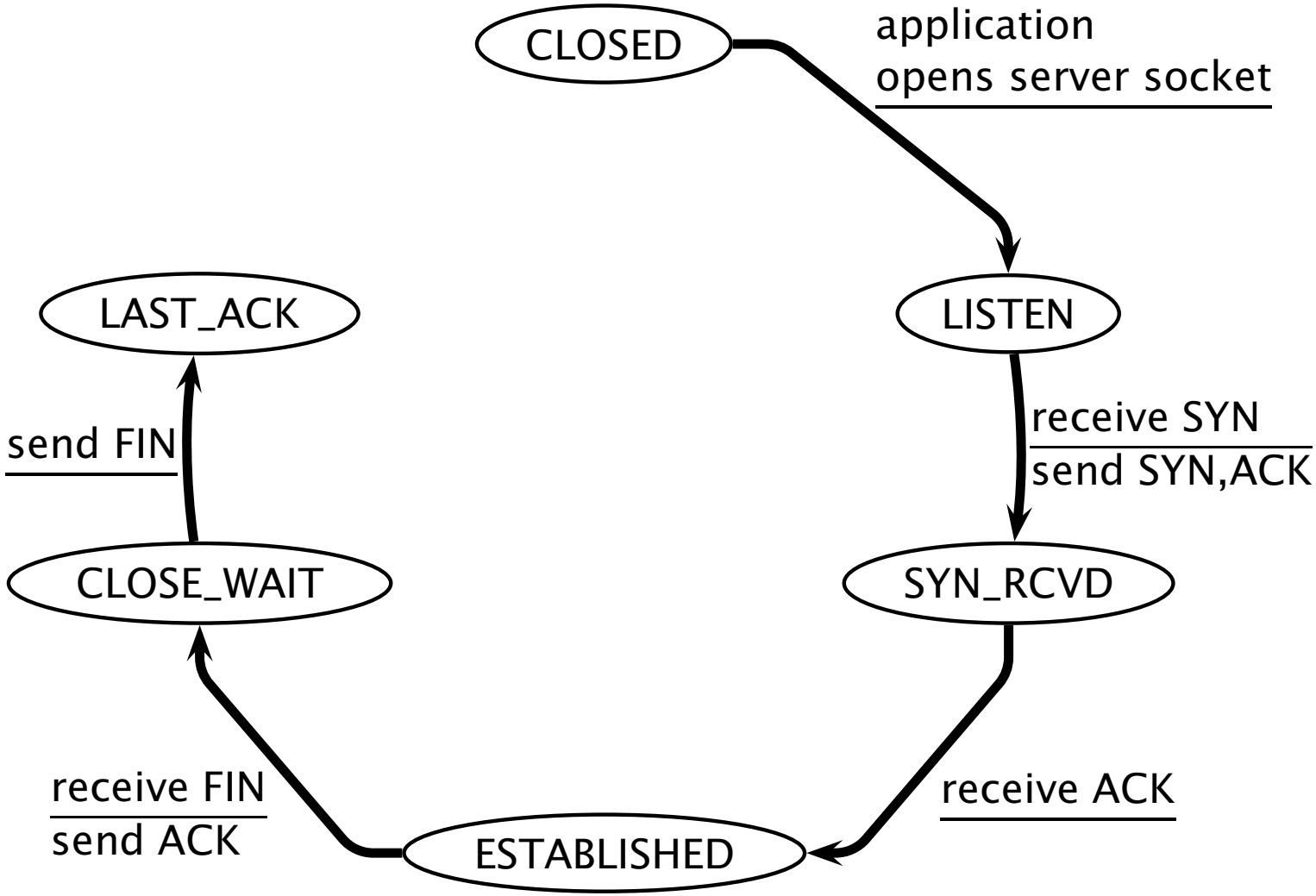
The TCP State Machine (Server)



The TCP State Machine (Server)



The TCP State Machine (Server)



The TCP State Machine (Server)