Transport Layer
Part 4

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EECS 325/425
Fall 2018

"Got my 45 on …
…so I …
… can rock on"

These slides are more-or-less directly from the slide set developed by Jim Kurose and Keith Ross for their book "Computer Networking: A Top Down Approach, 5th edition".

The slides have been lightly adapted for Mark Allman's EECS 325/425 Computer Networks class at Case Western Reserve University.

Traffic By Protocol

CCZ, Sept. 10 2018

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Traffic By Protocol

	Bytes
TCP	856.2 GB ~89%
UDP	102.8 GB ~11%

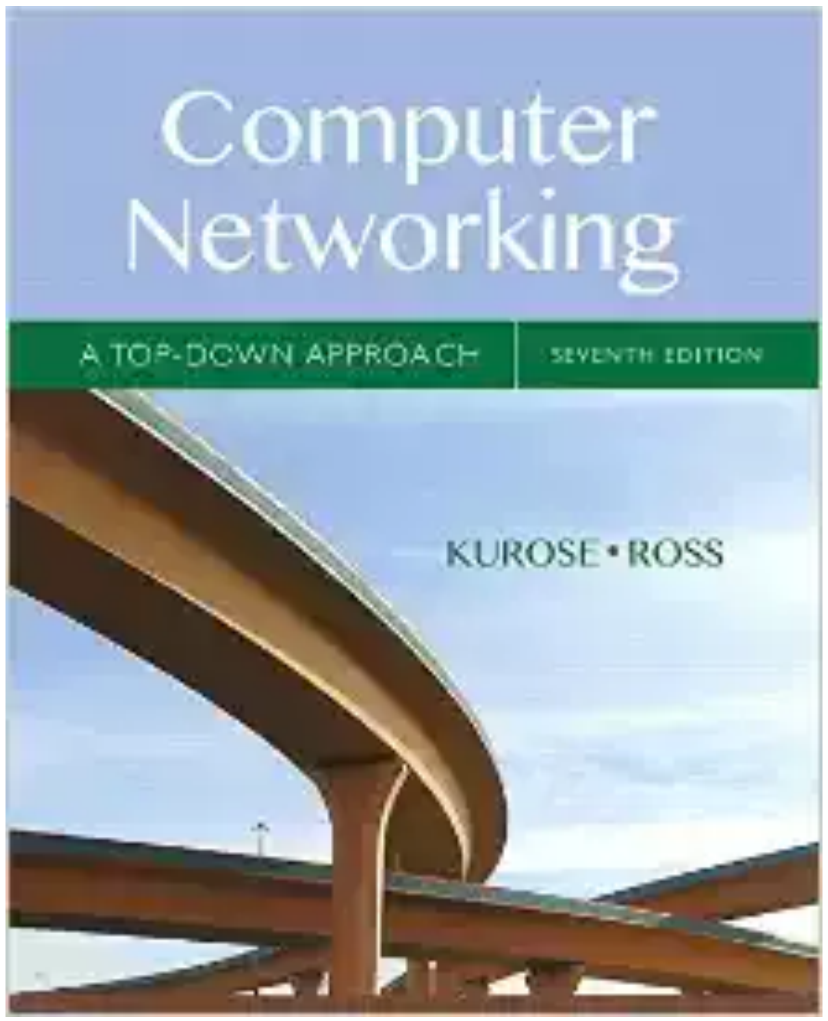
CCZ, Sept. 10 2018

Traffic By Protocol

	Bytes	Connections
TCP	856.2 GB ~89%	1.7 M ~53%
UDP	102.8 GB ~11%	1.5 M ~47%

CCZ, Sept. 10 2018

Reading Along ...



- 3.5: Connection-oriented transport: TCP

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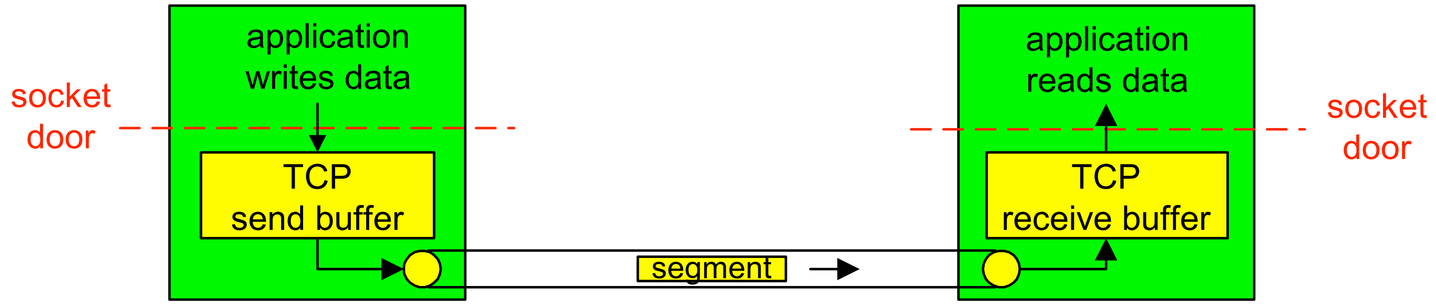

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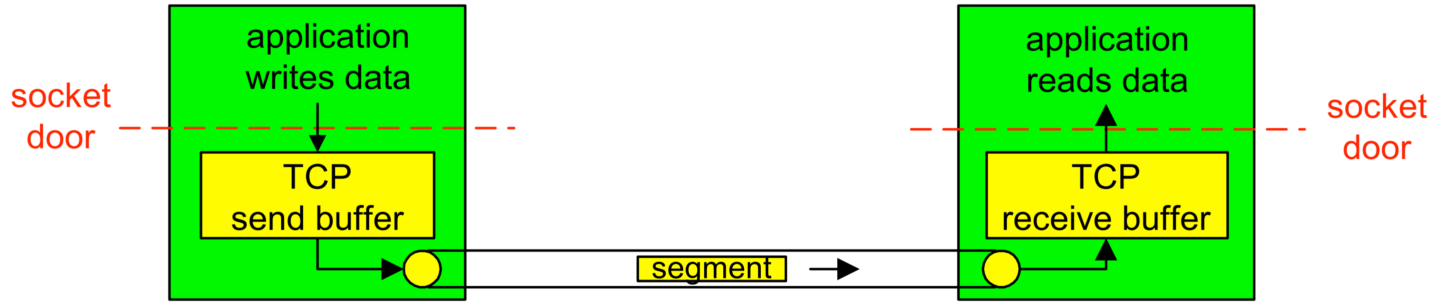

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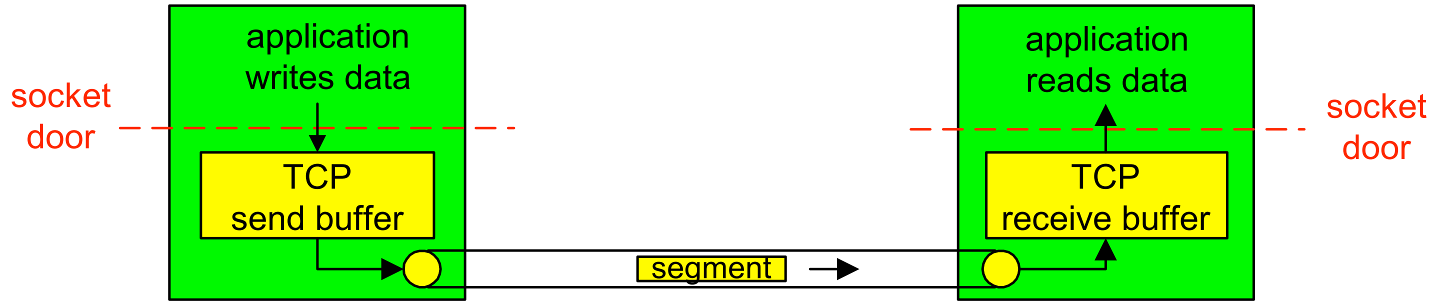

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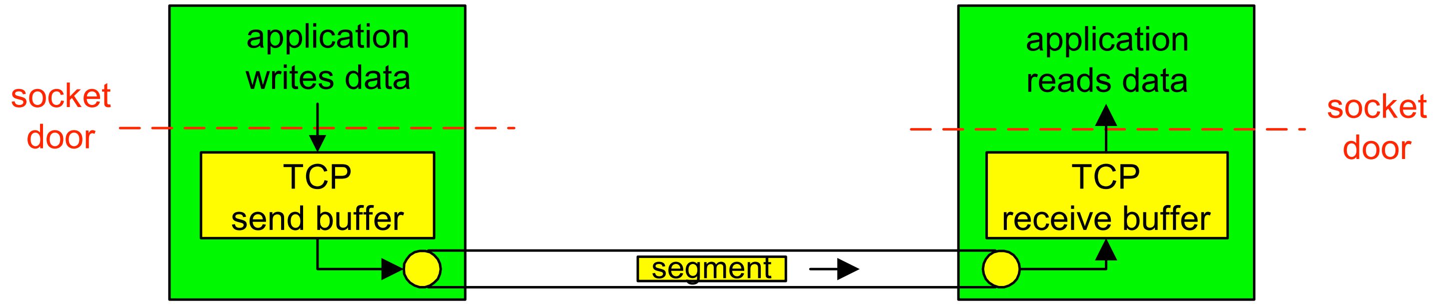

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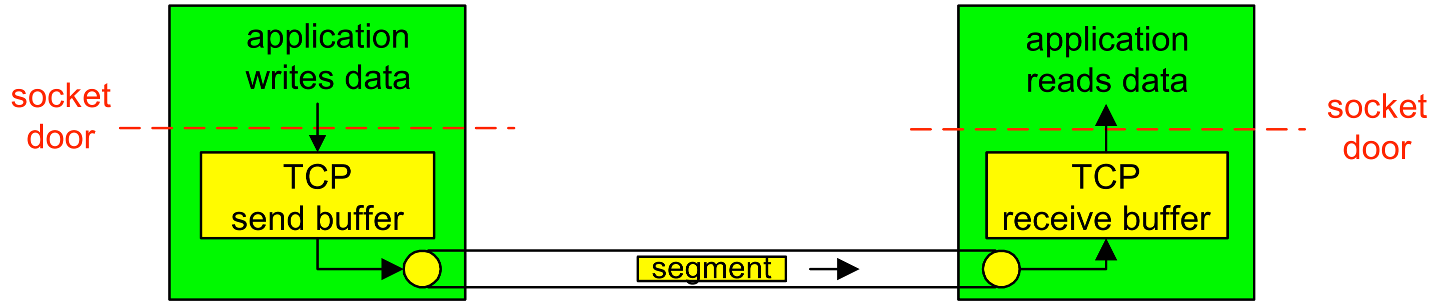

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RFCs: 793, 1122, 1323, 2018, 2883, 3042, 3390, 5681, 6298, 6675, etc

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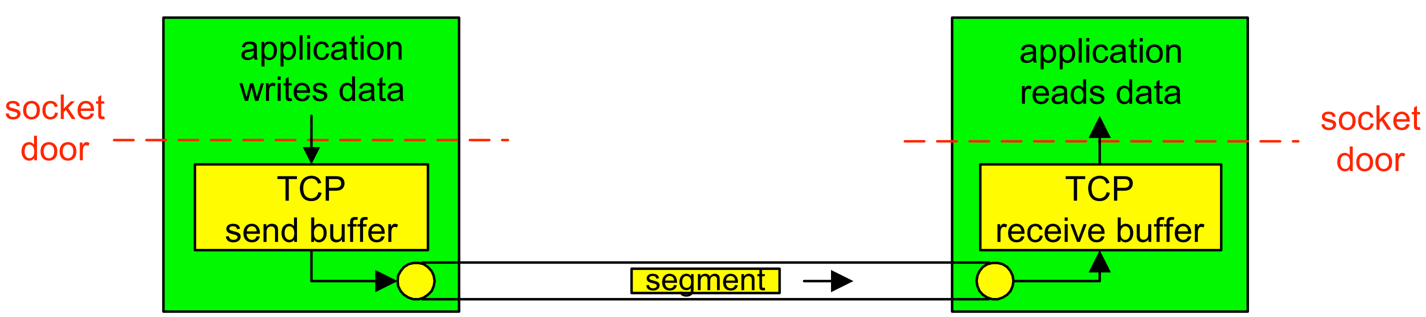

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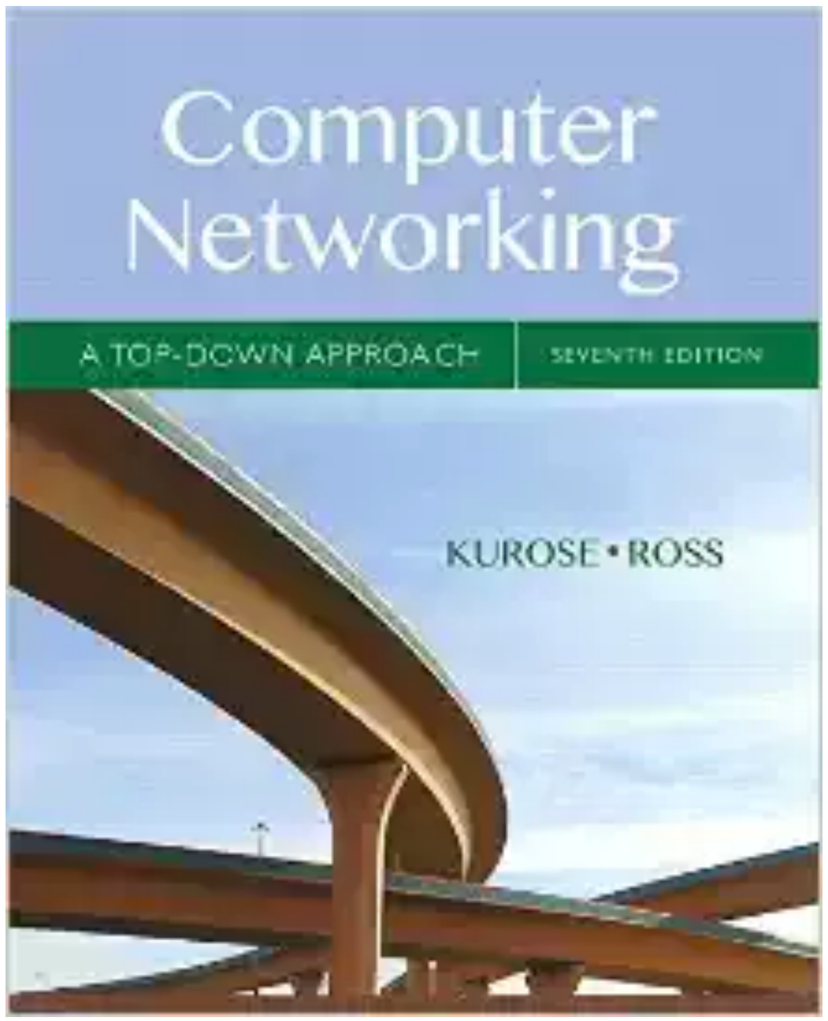
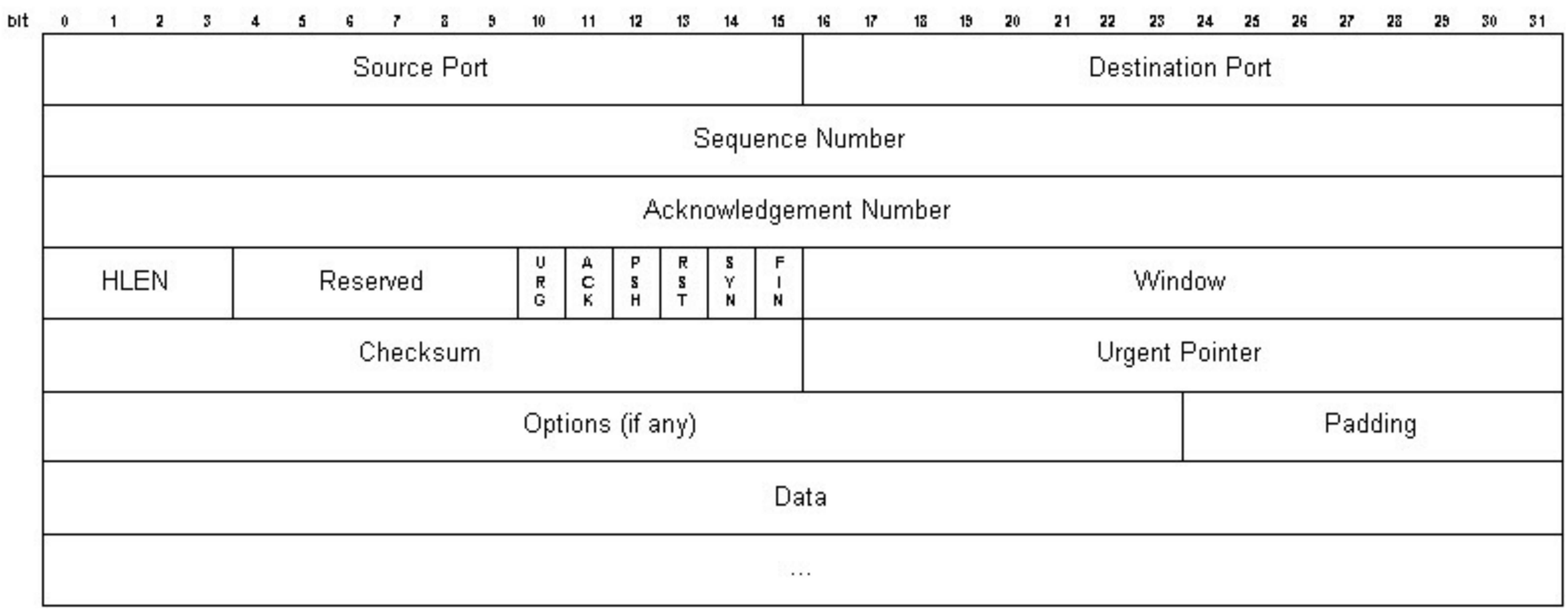


- 3.5: Connection-oriented transport: TCP
  - segment structure

TCP Segment Structure



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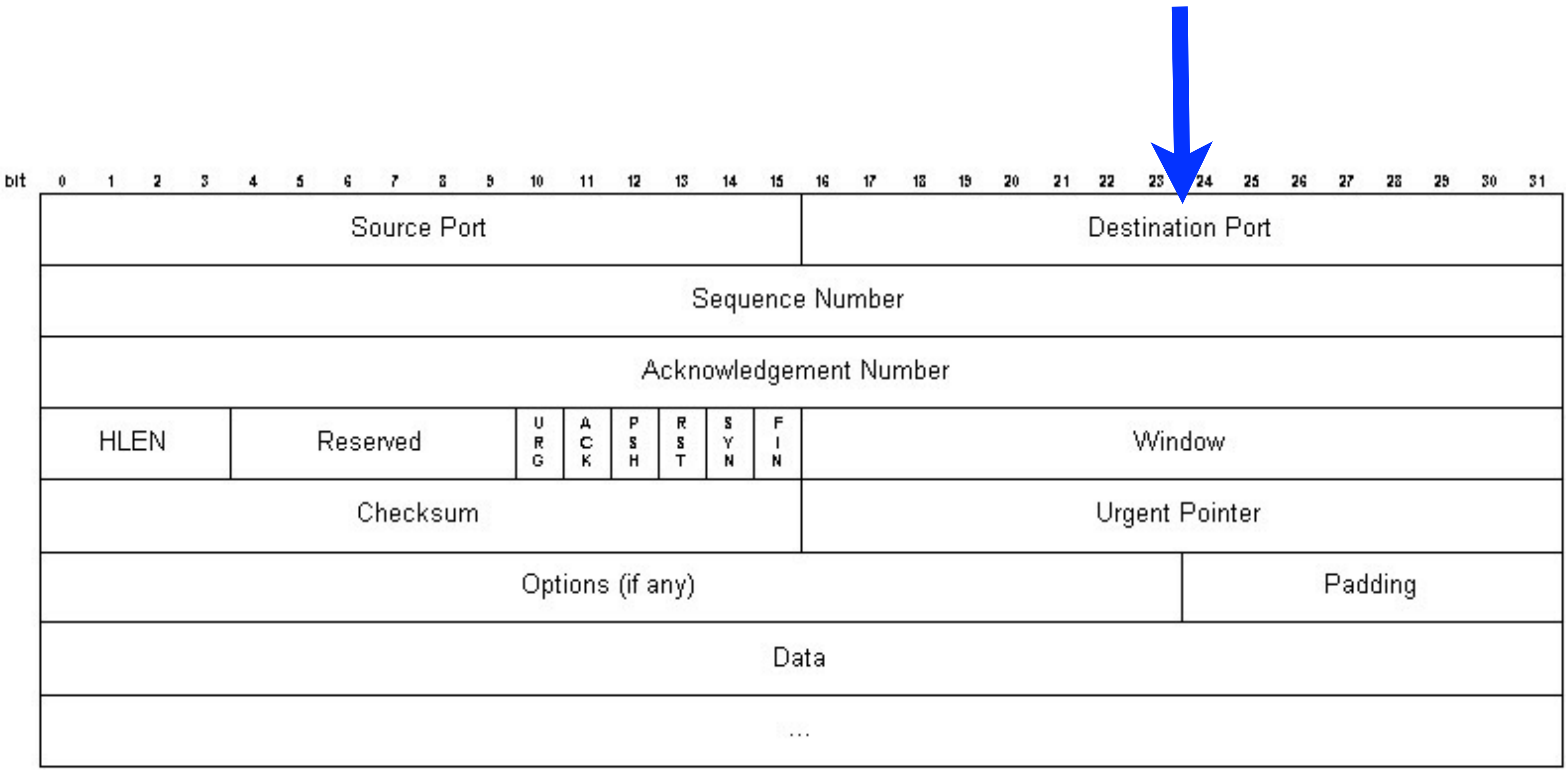

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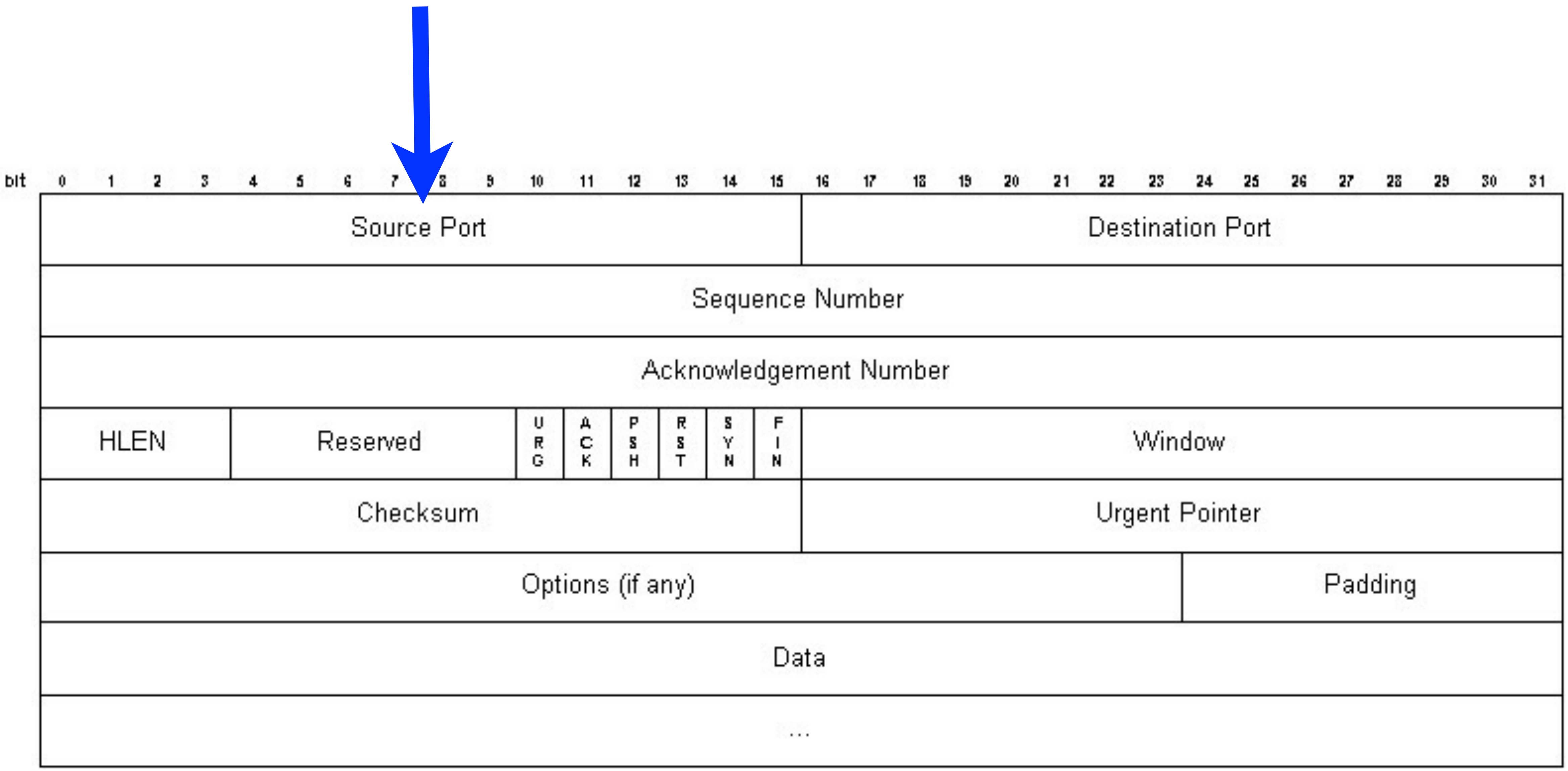

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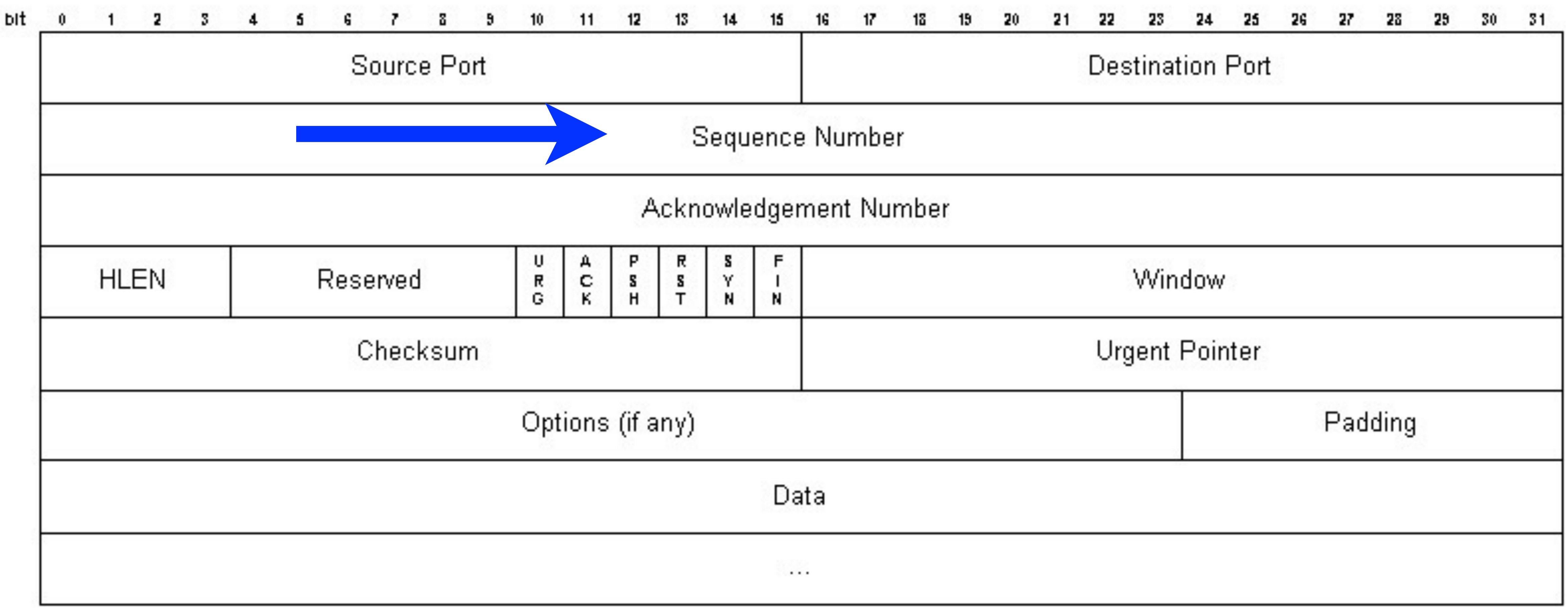

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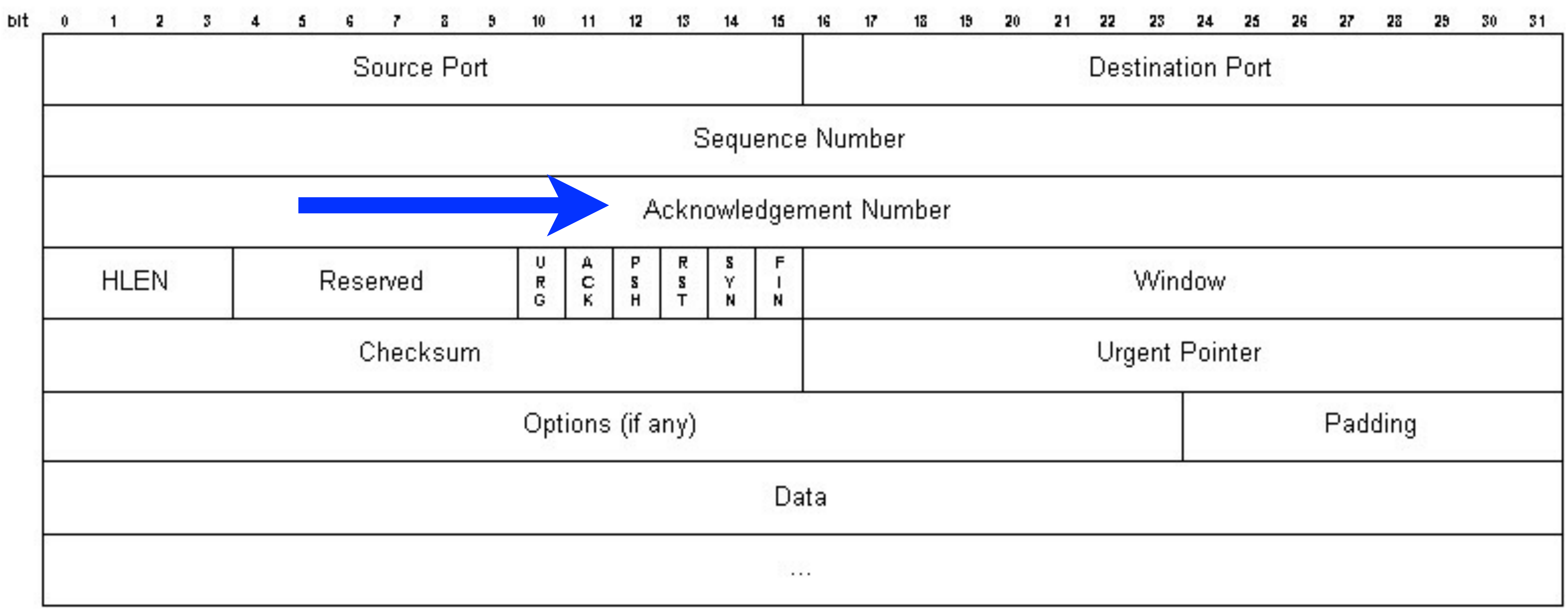

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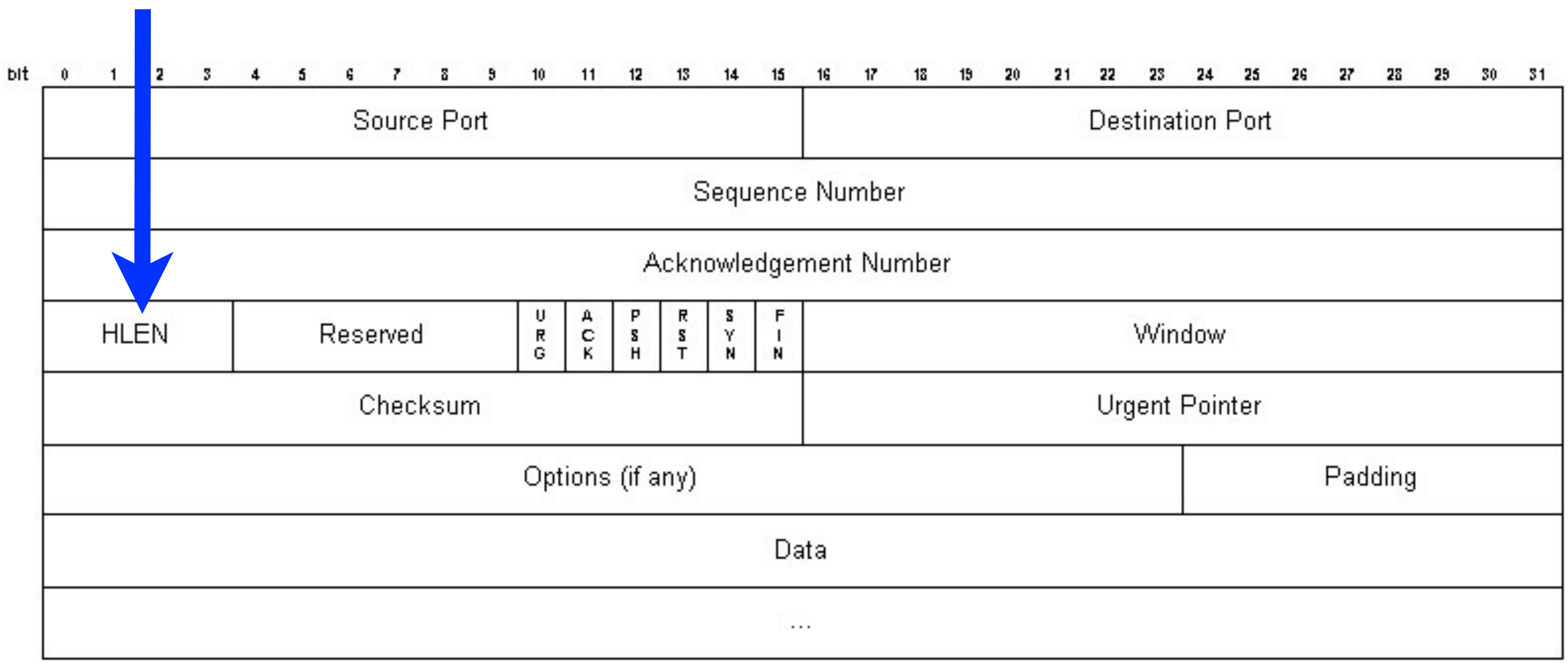

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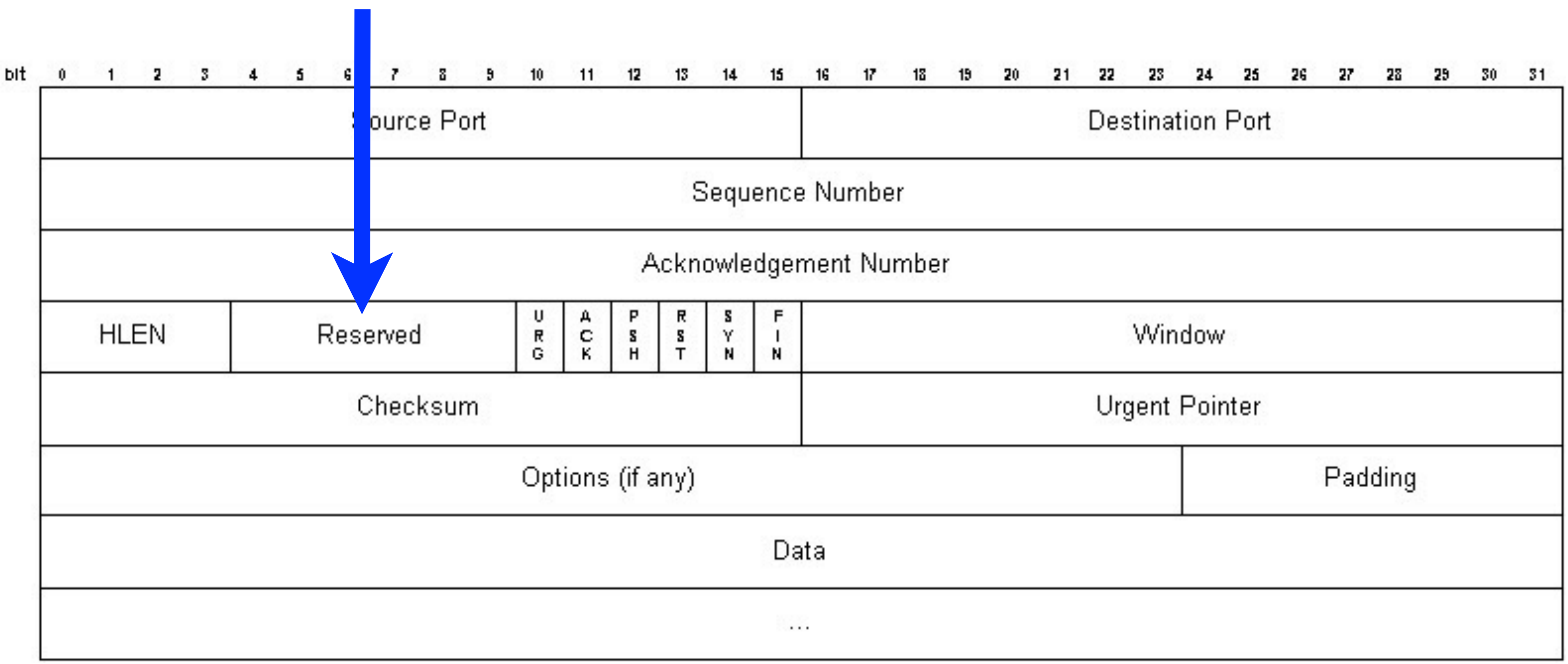

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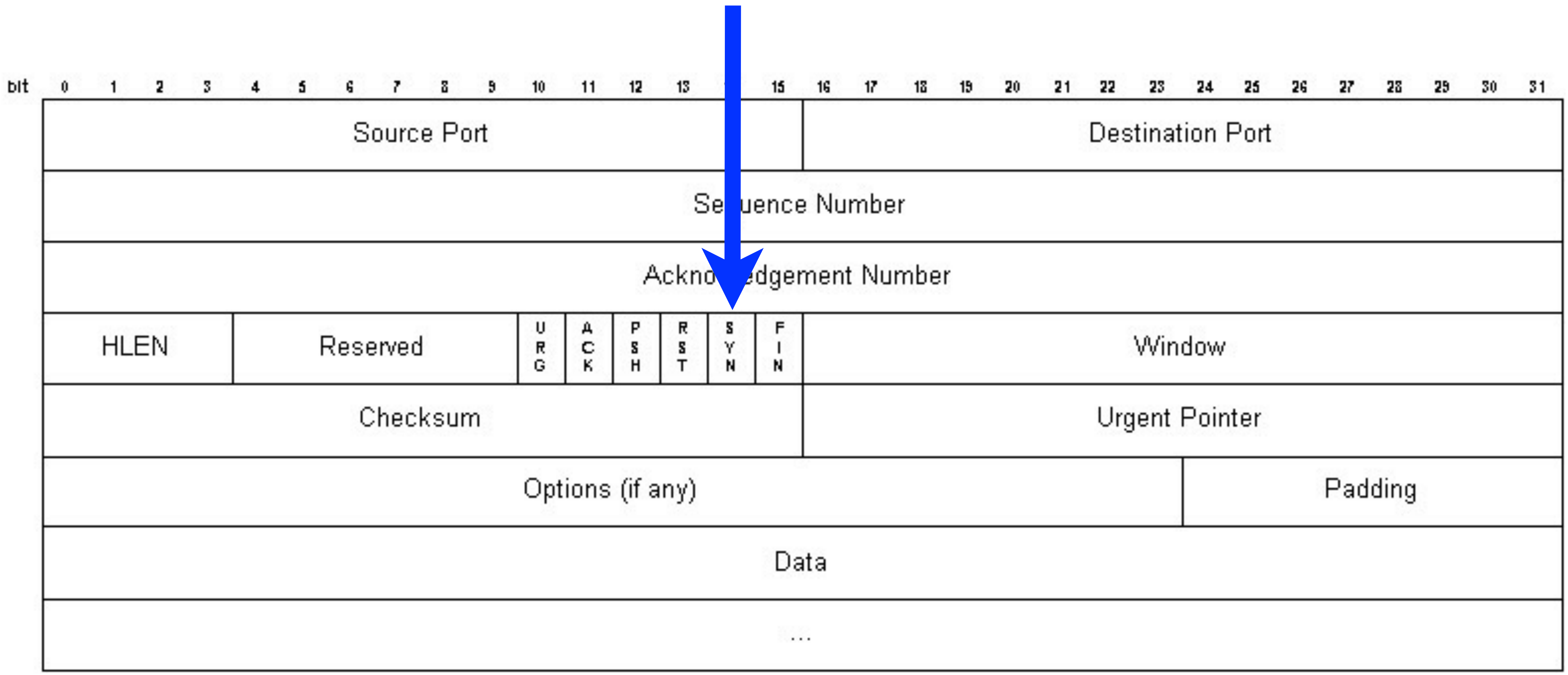

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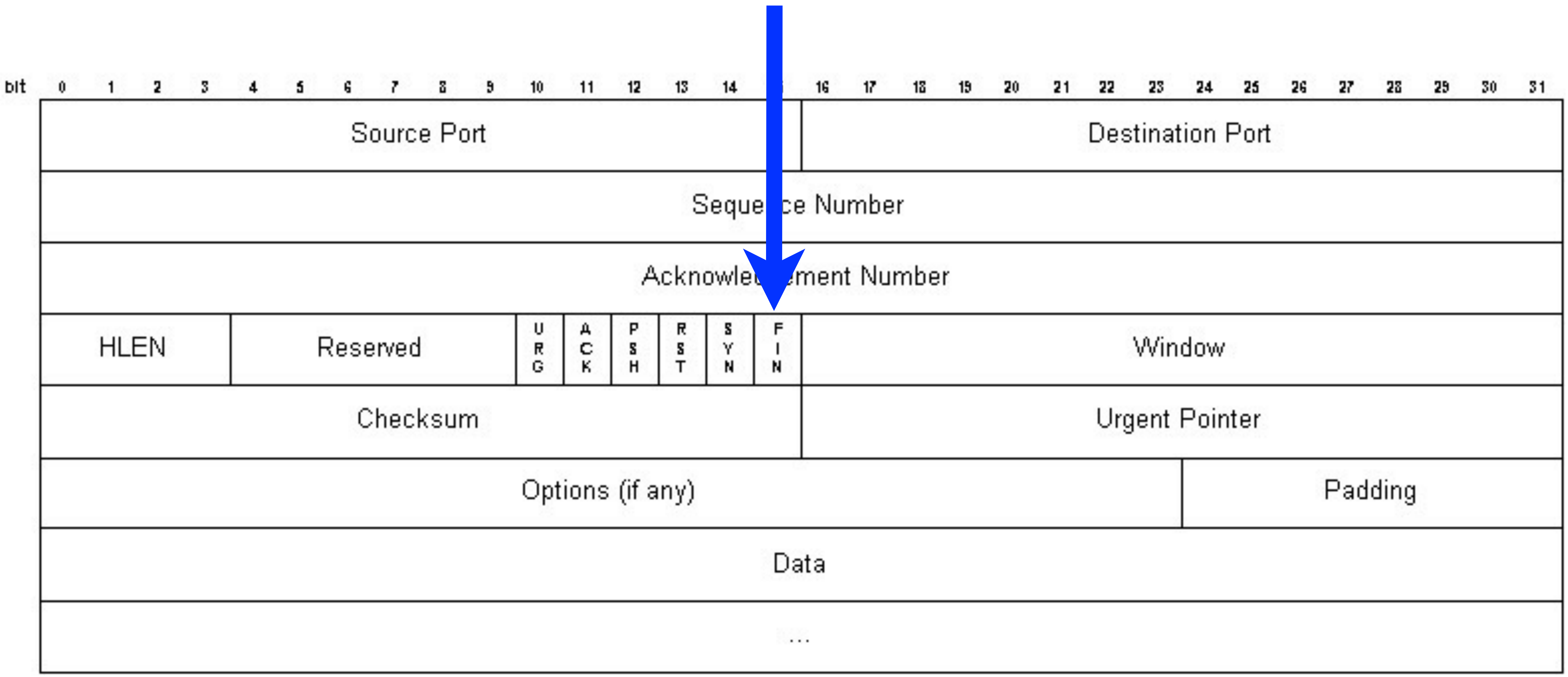

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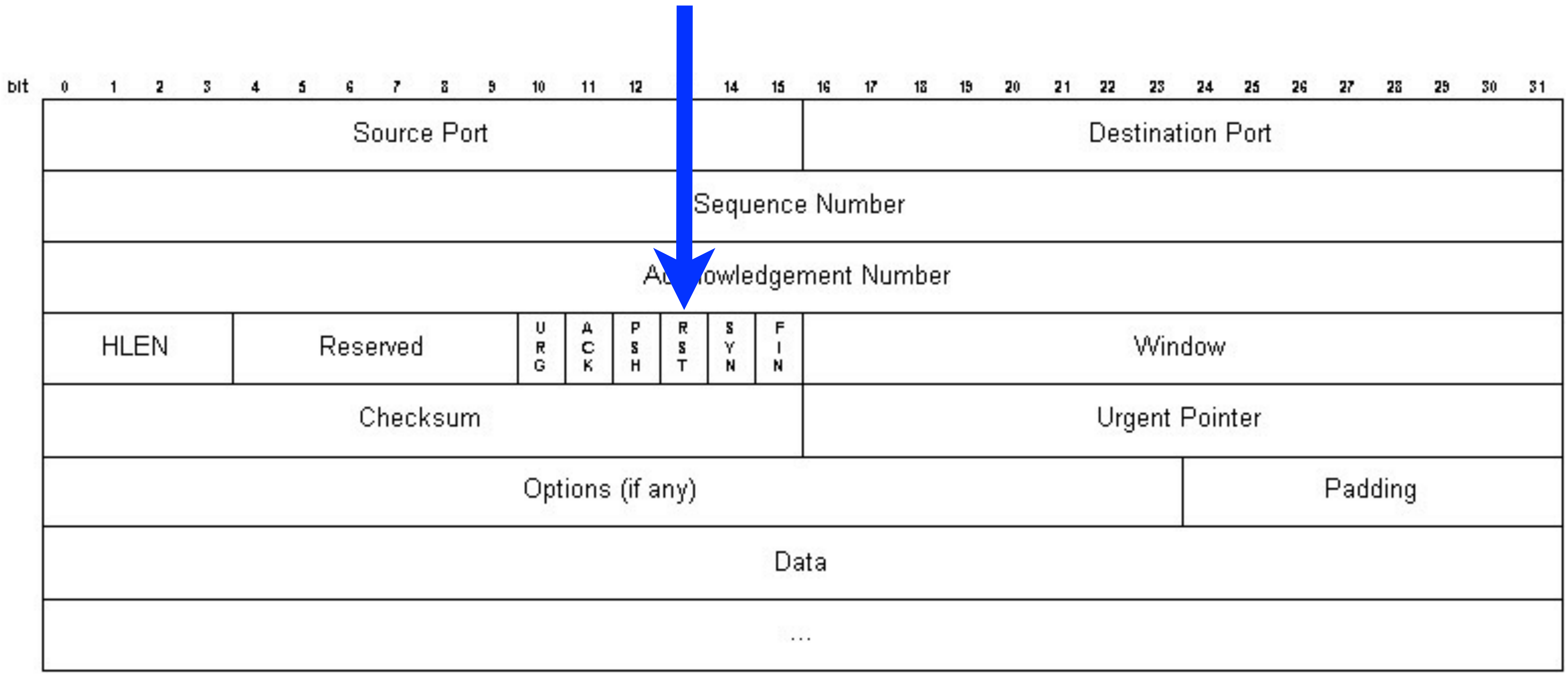

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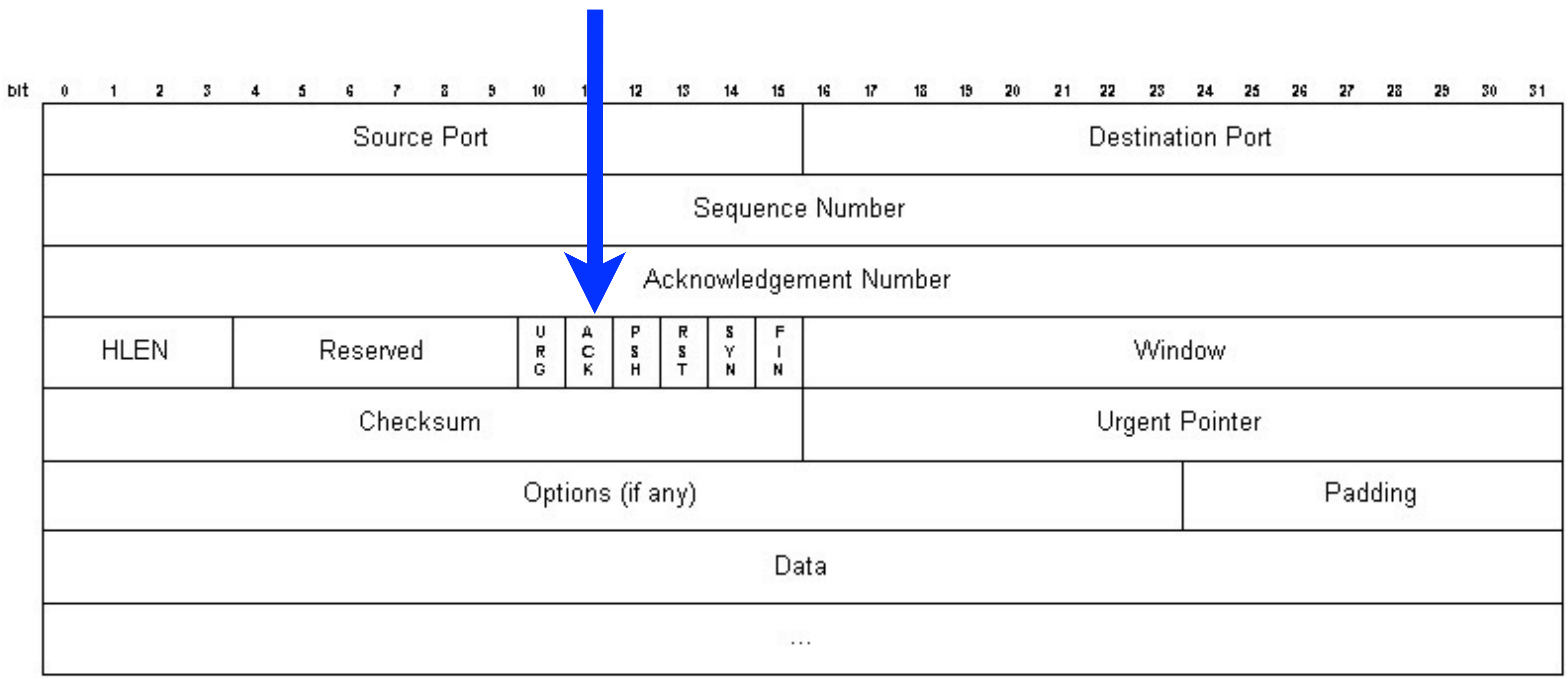

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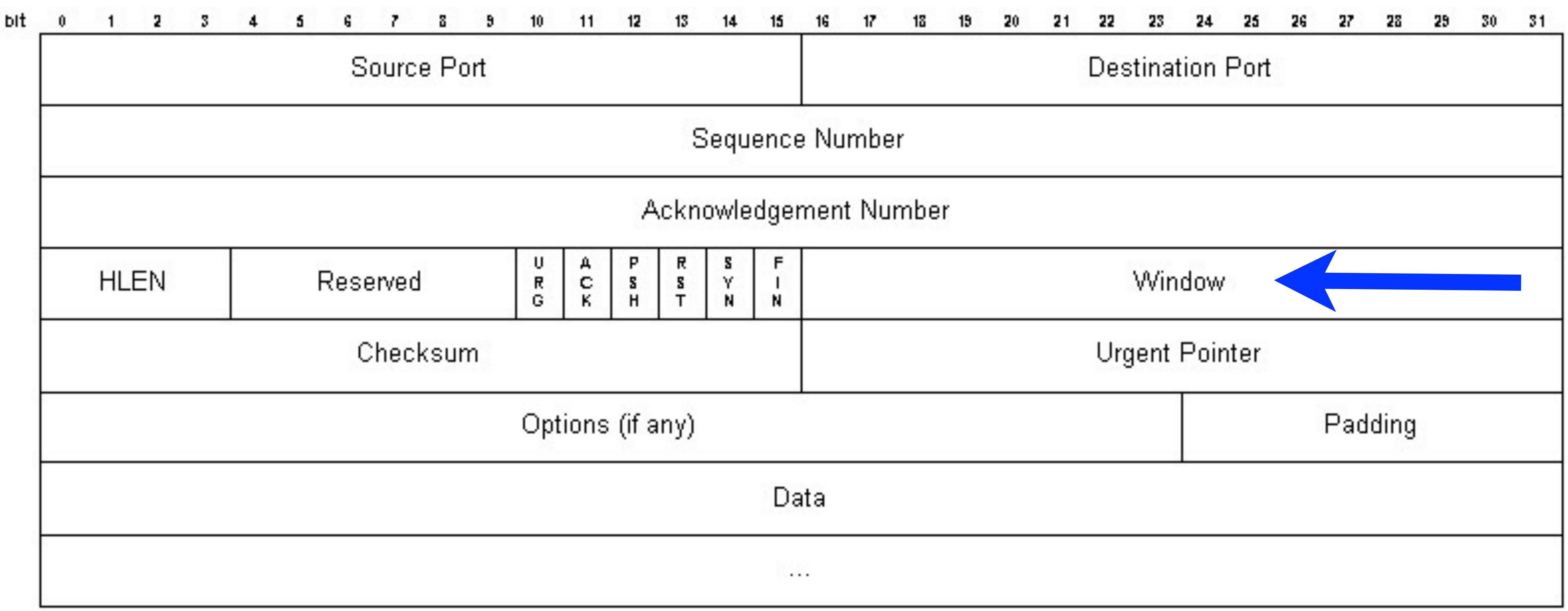

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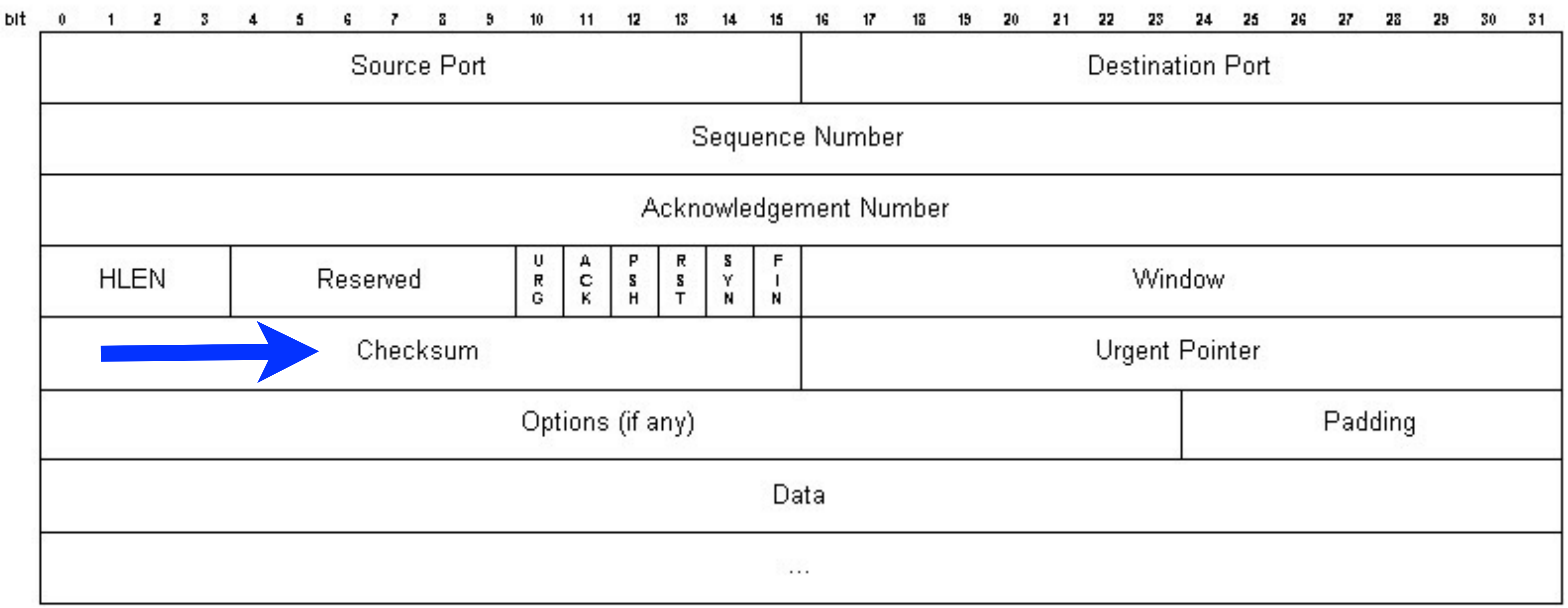

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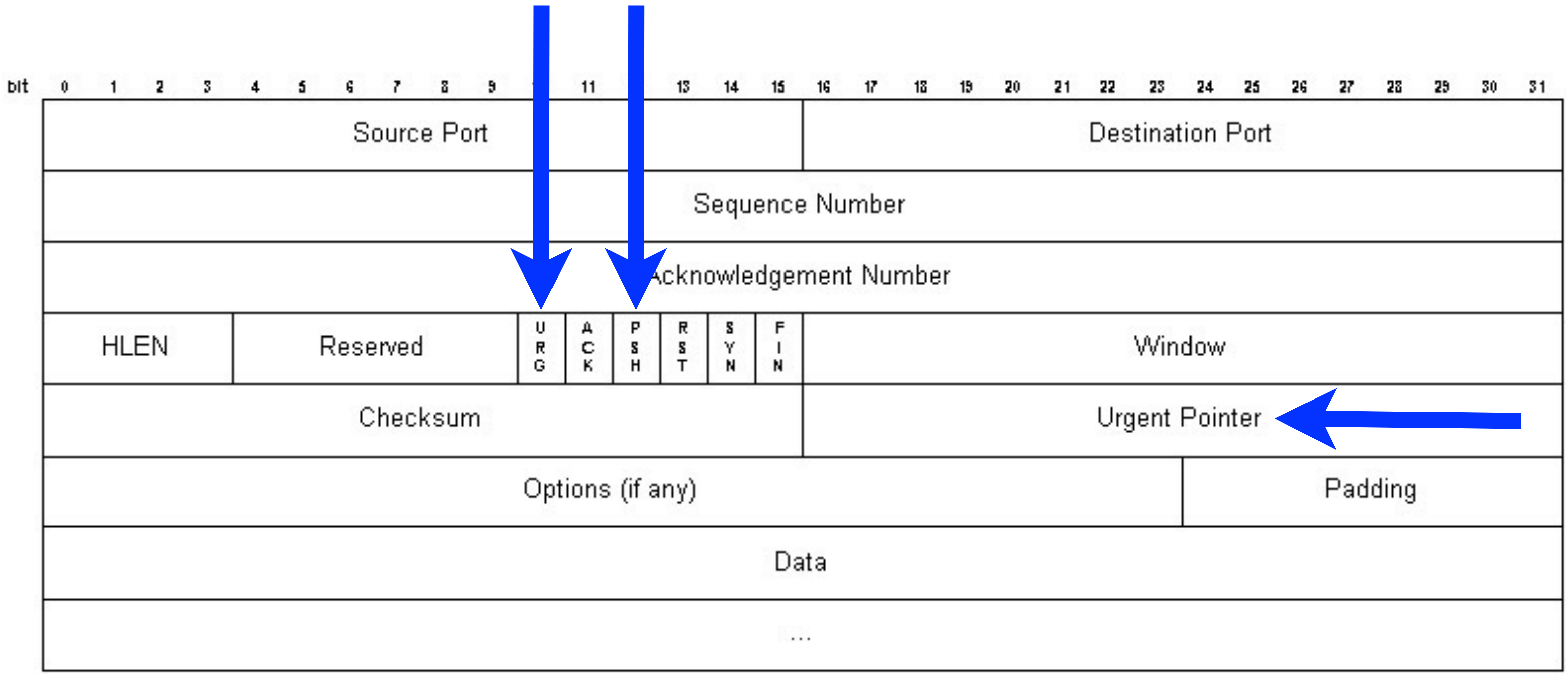

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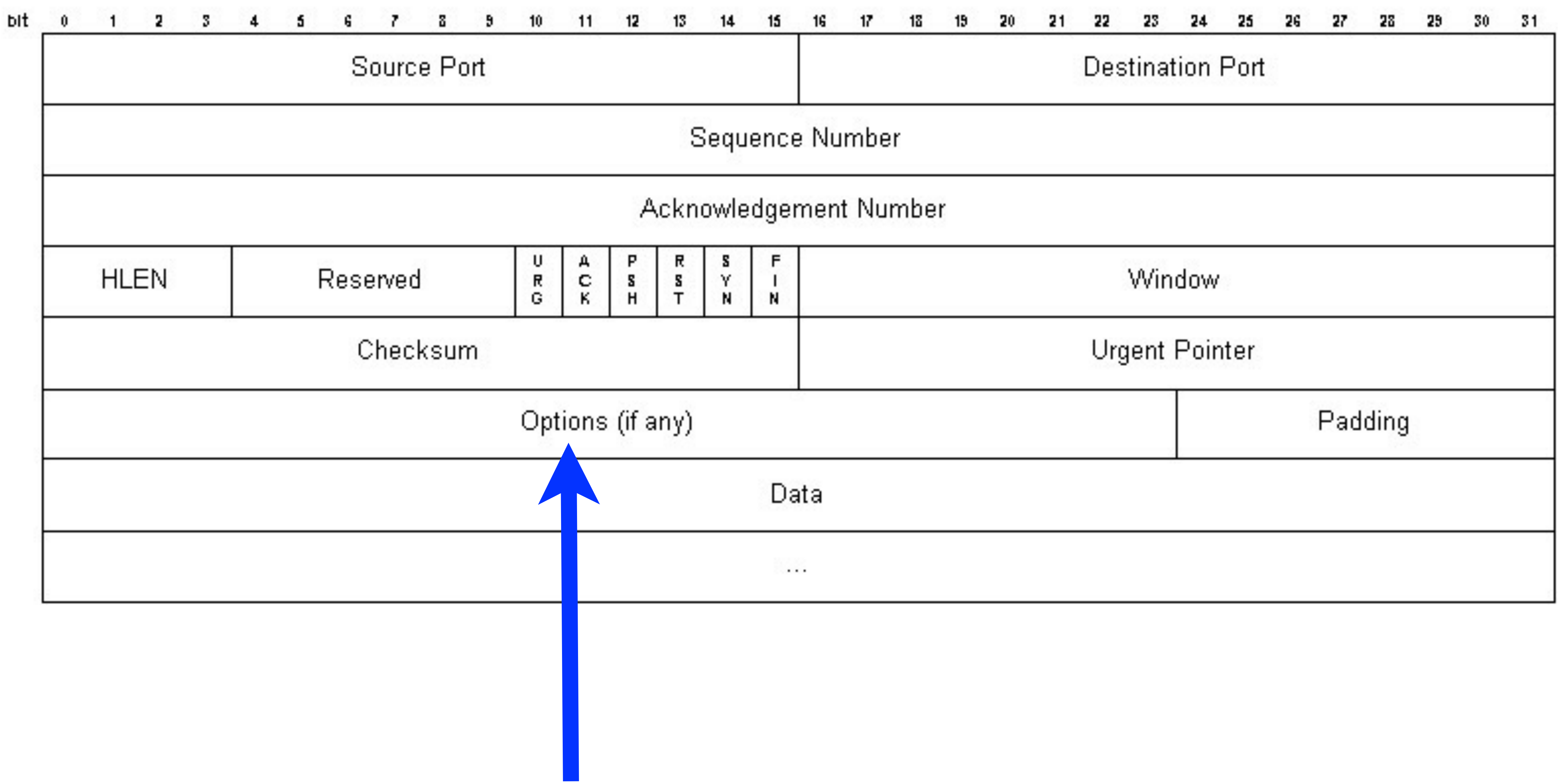

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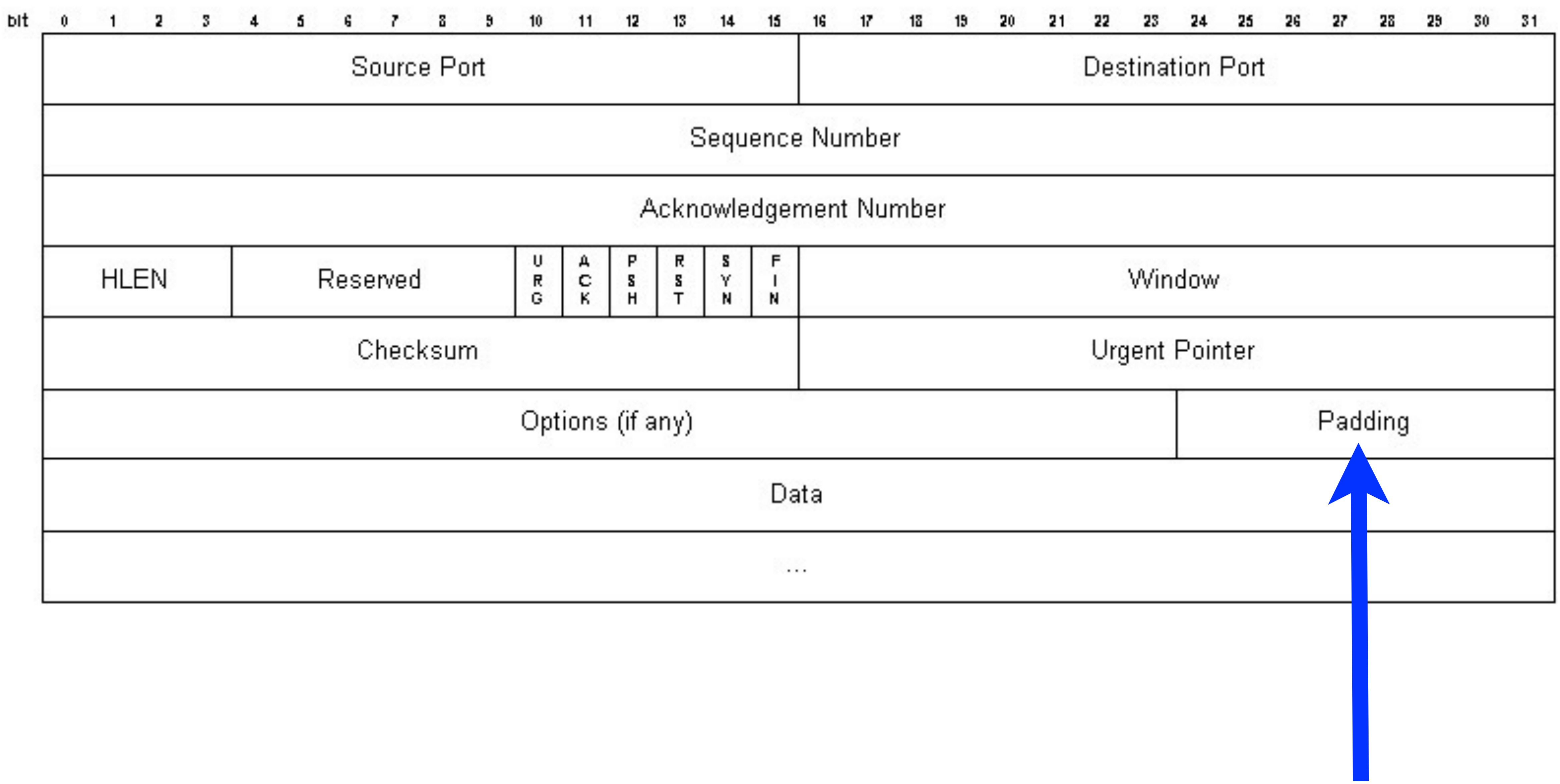

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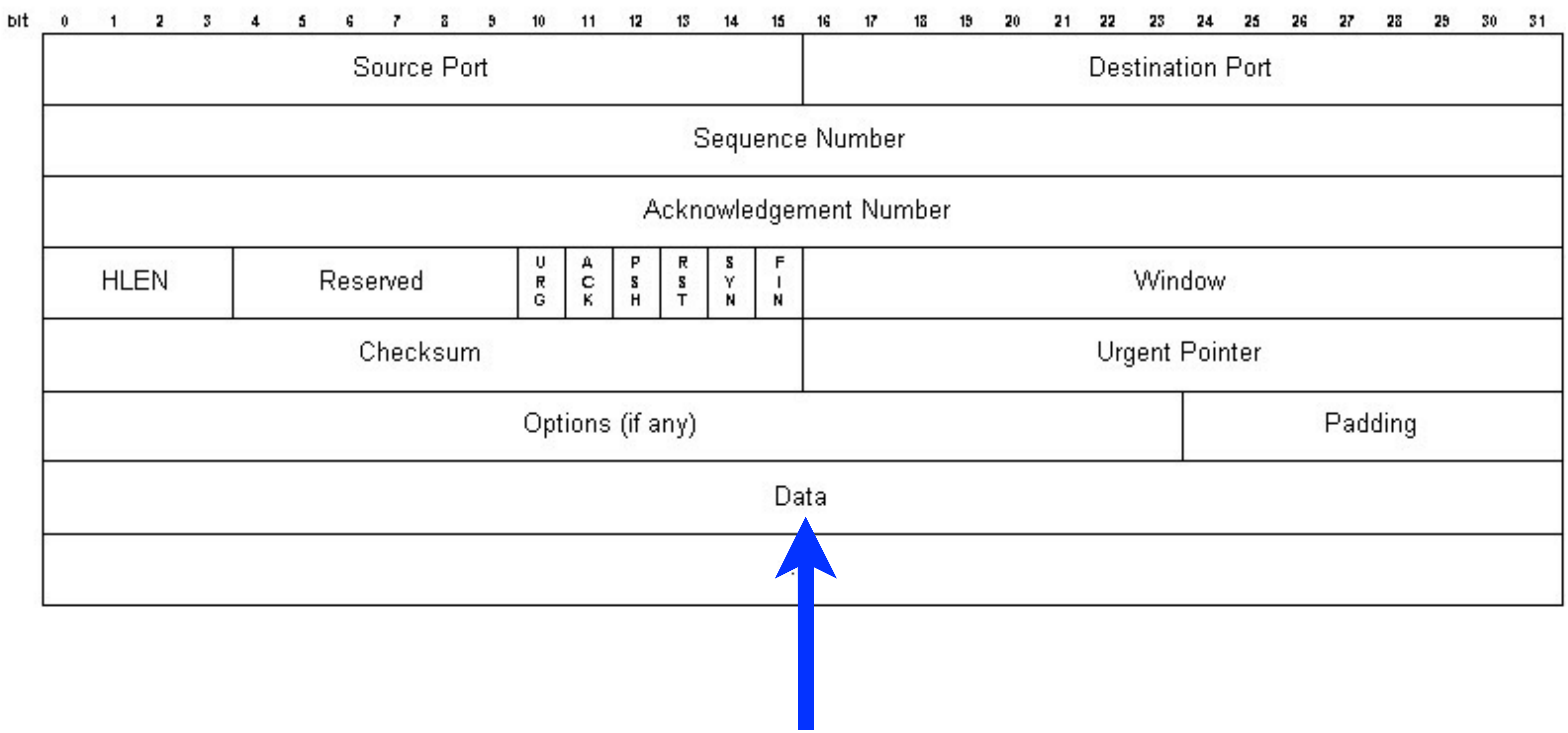

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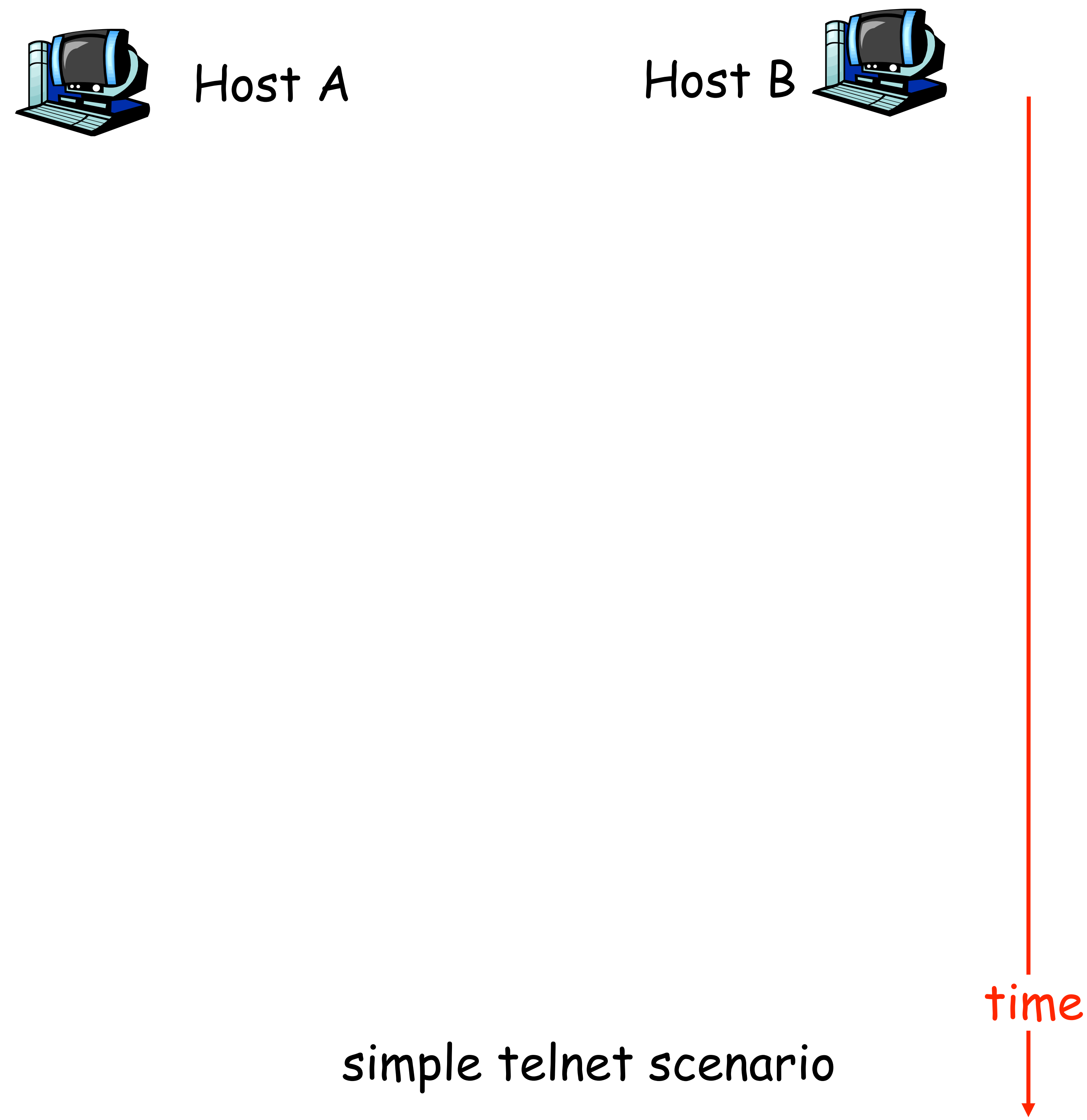

simple telnet scenario

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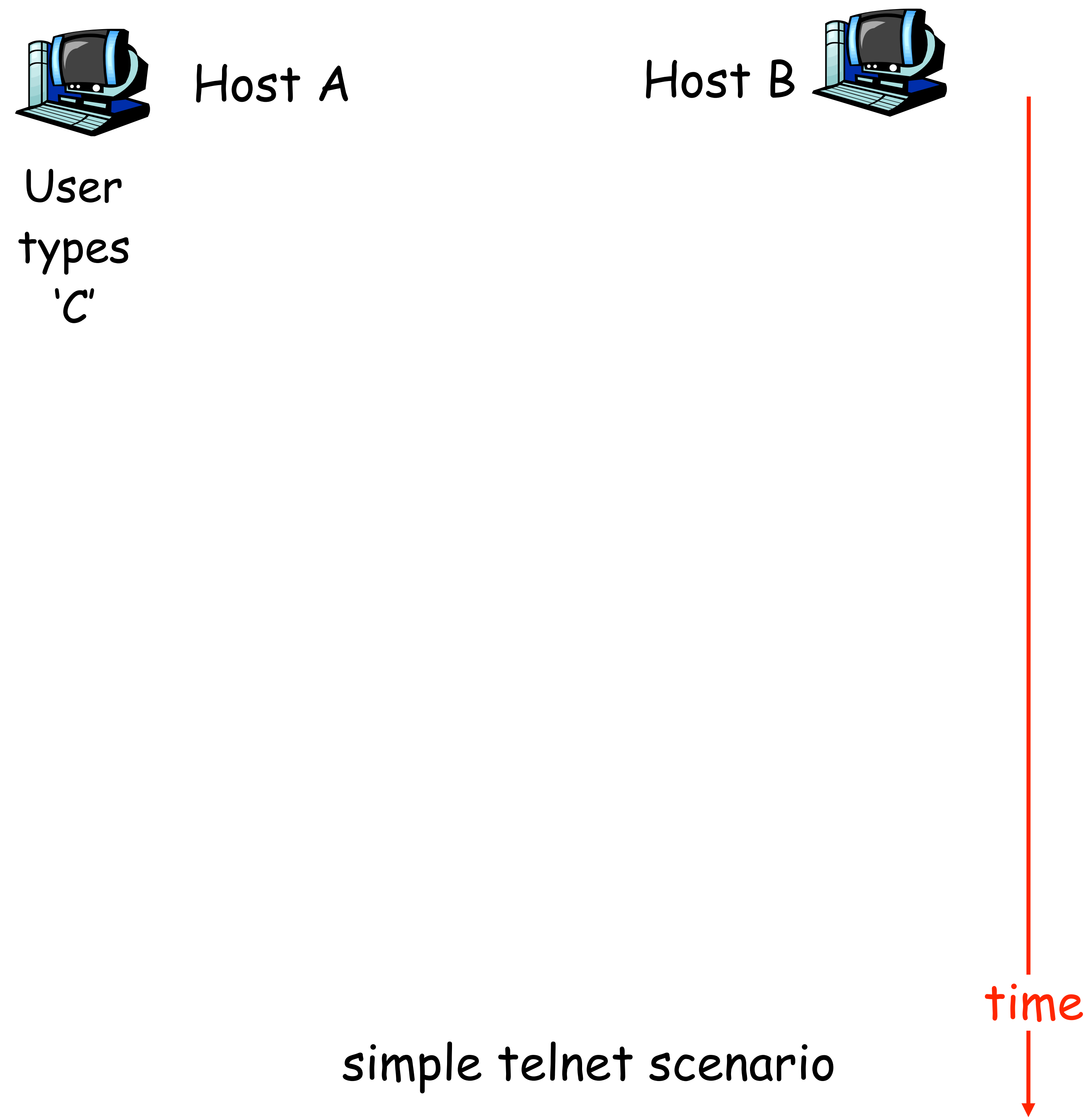

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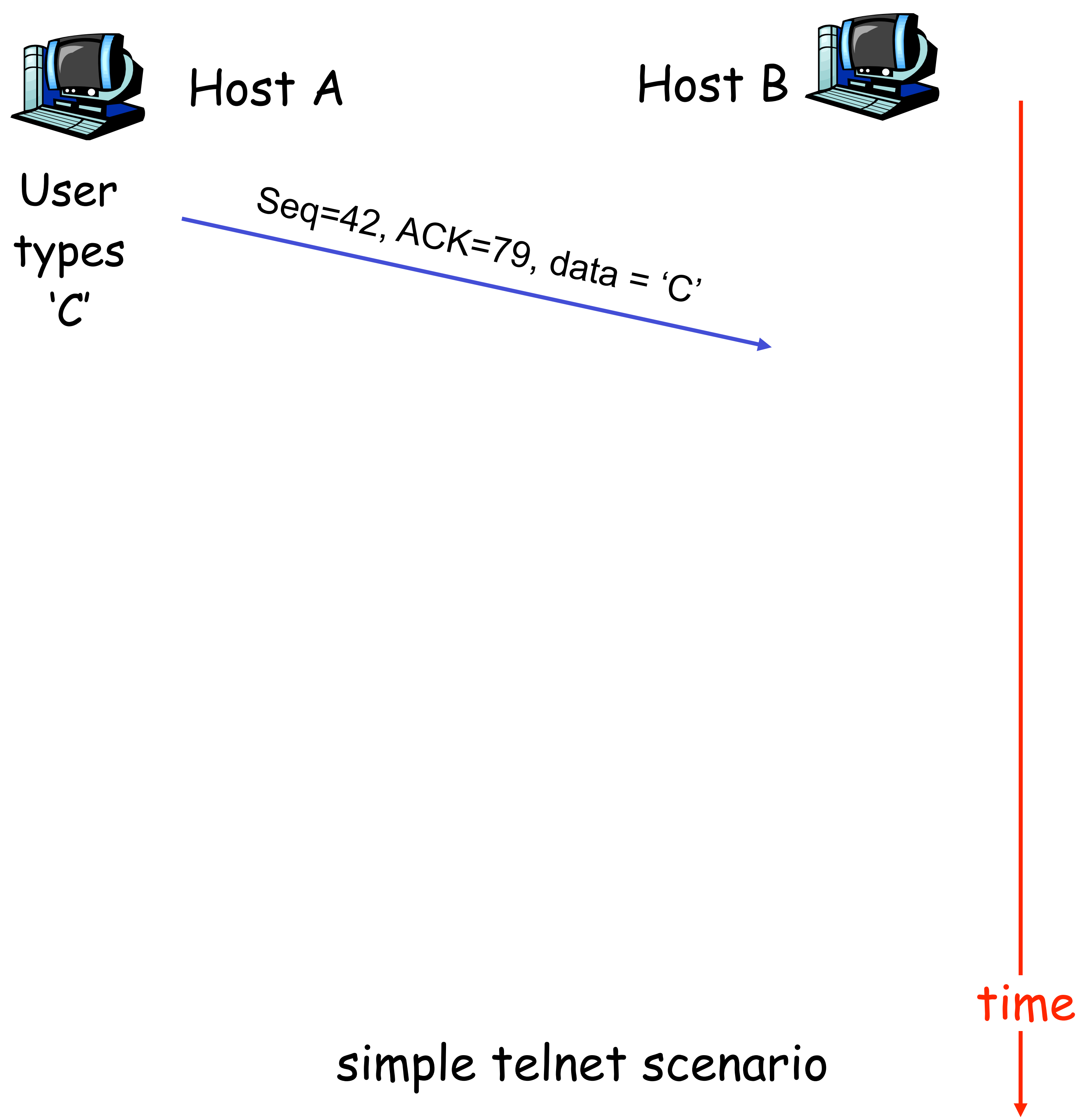

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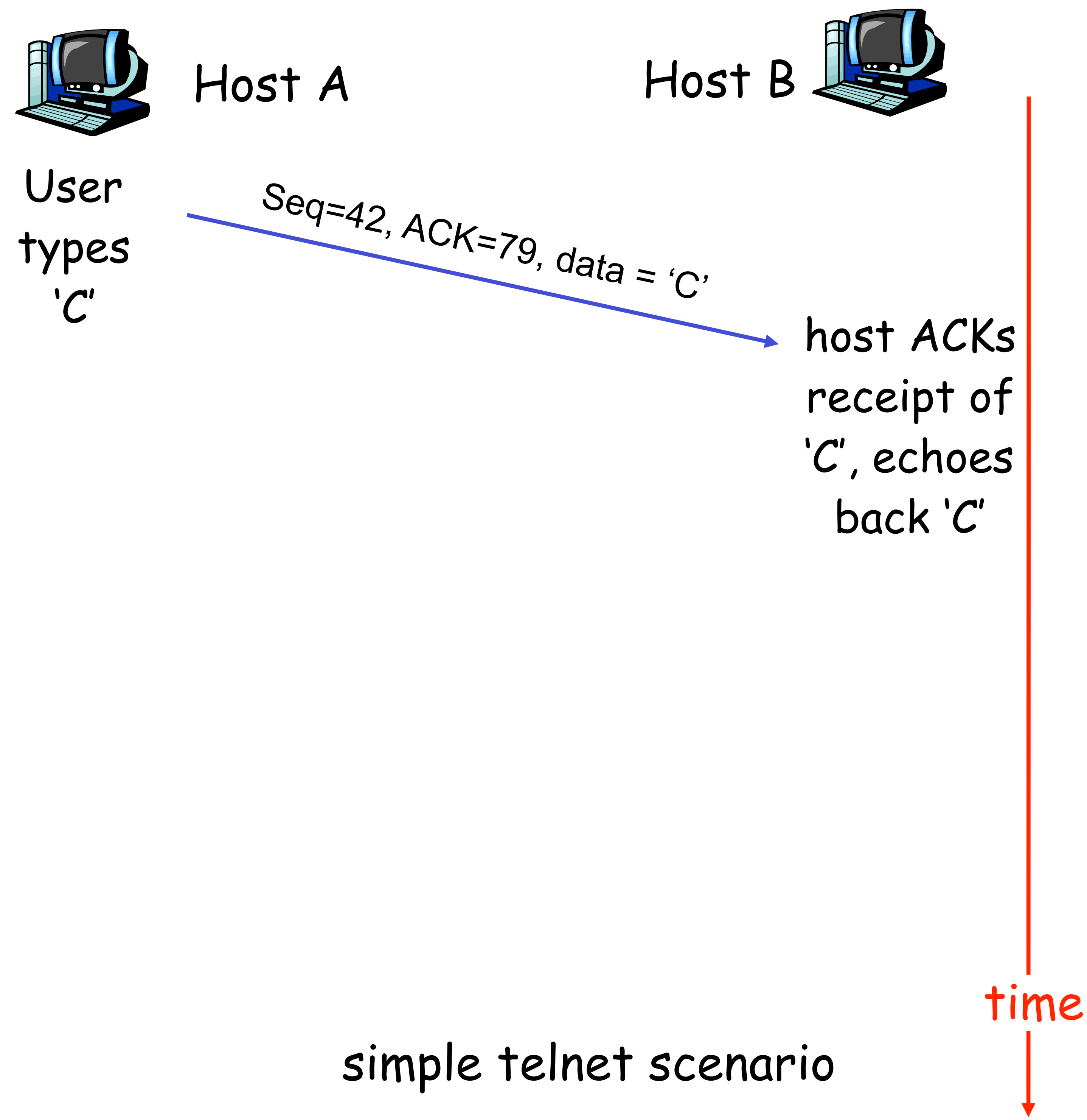

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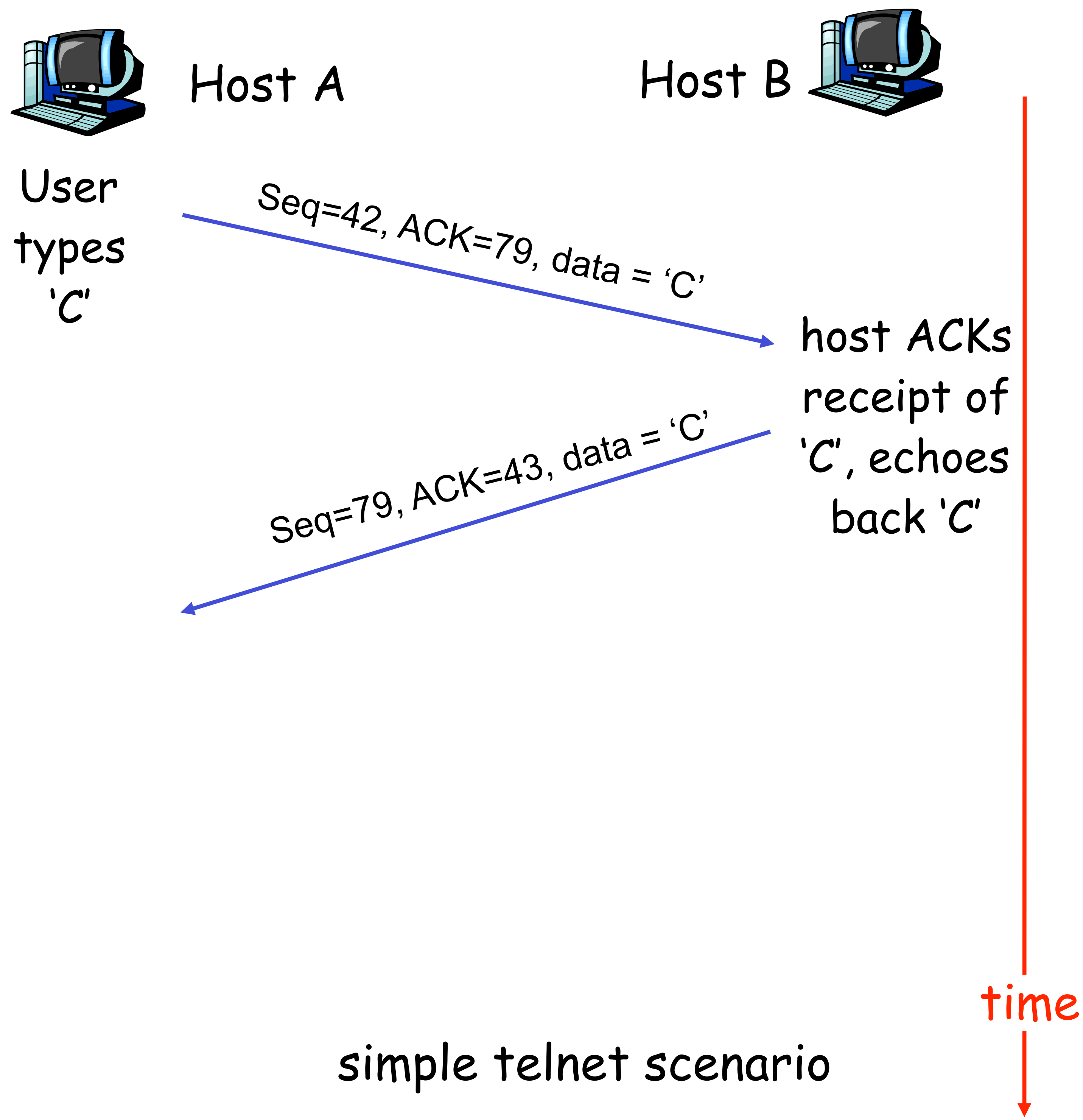

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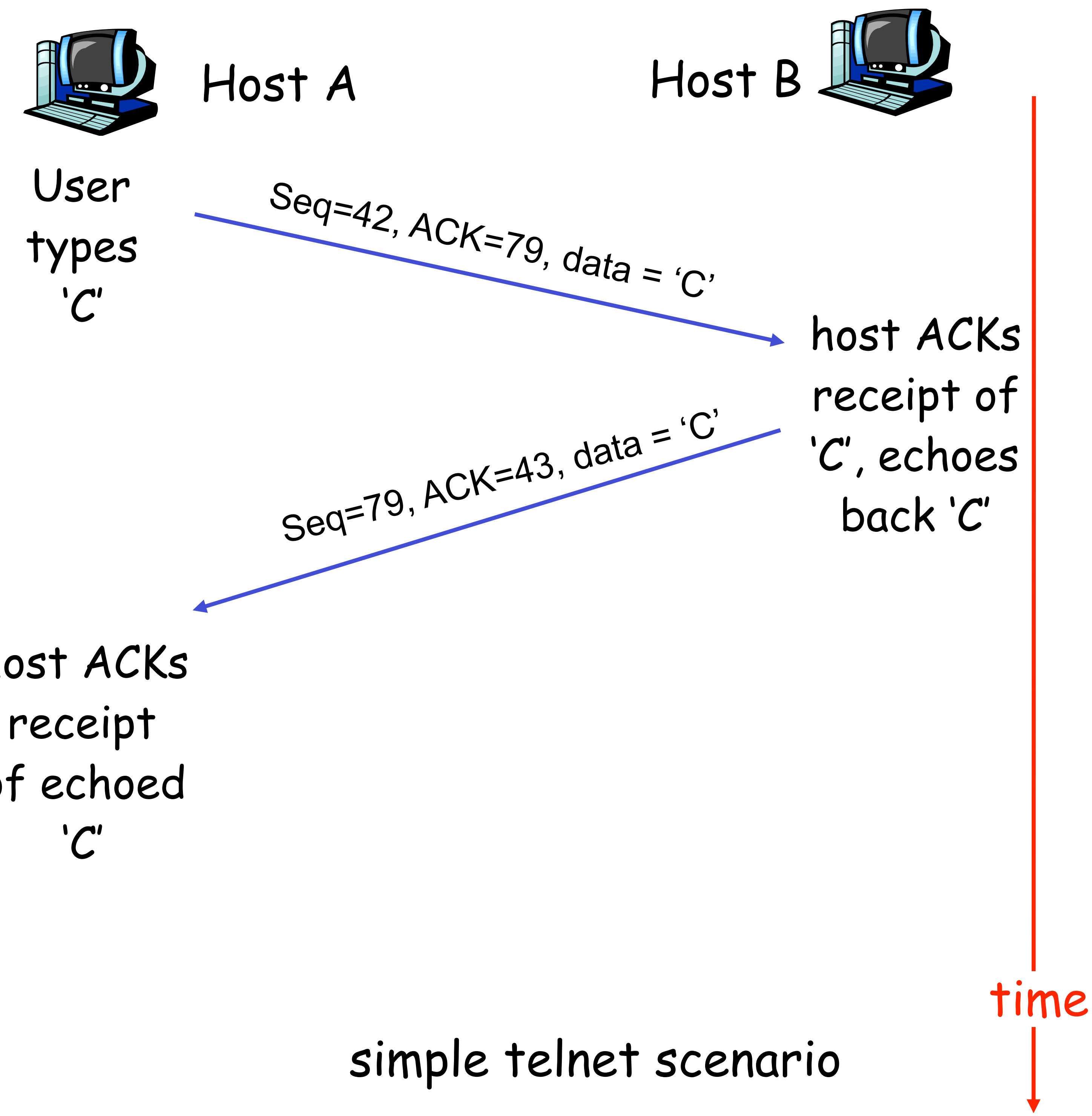

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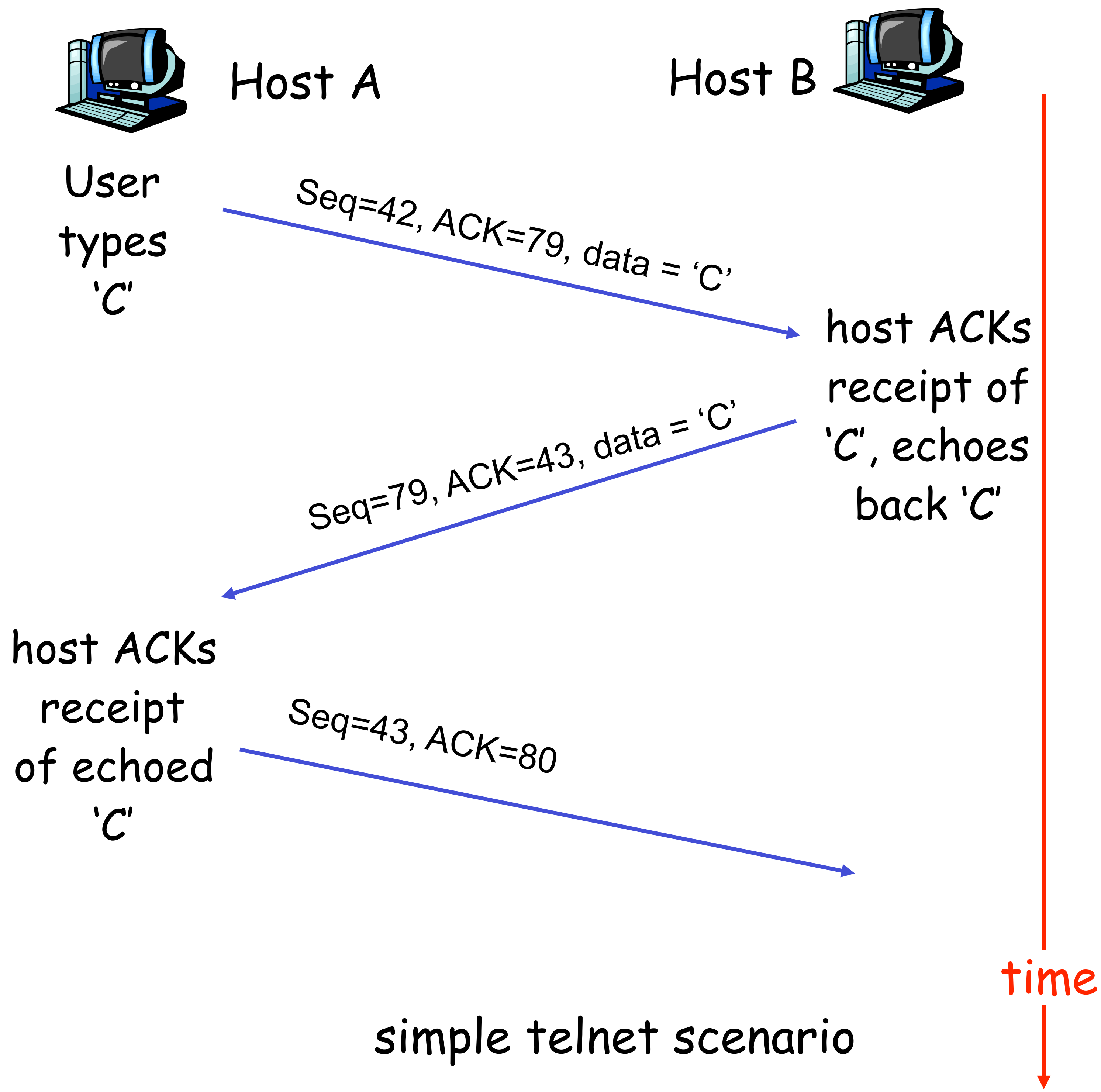

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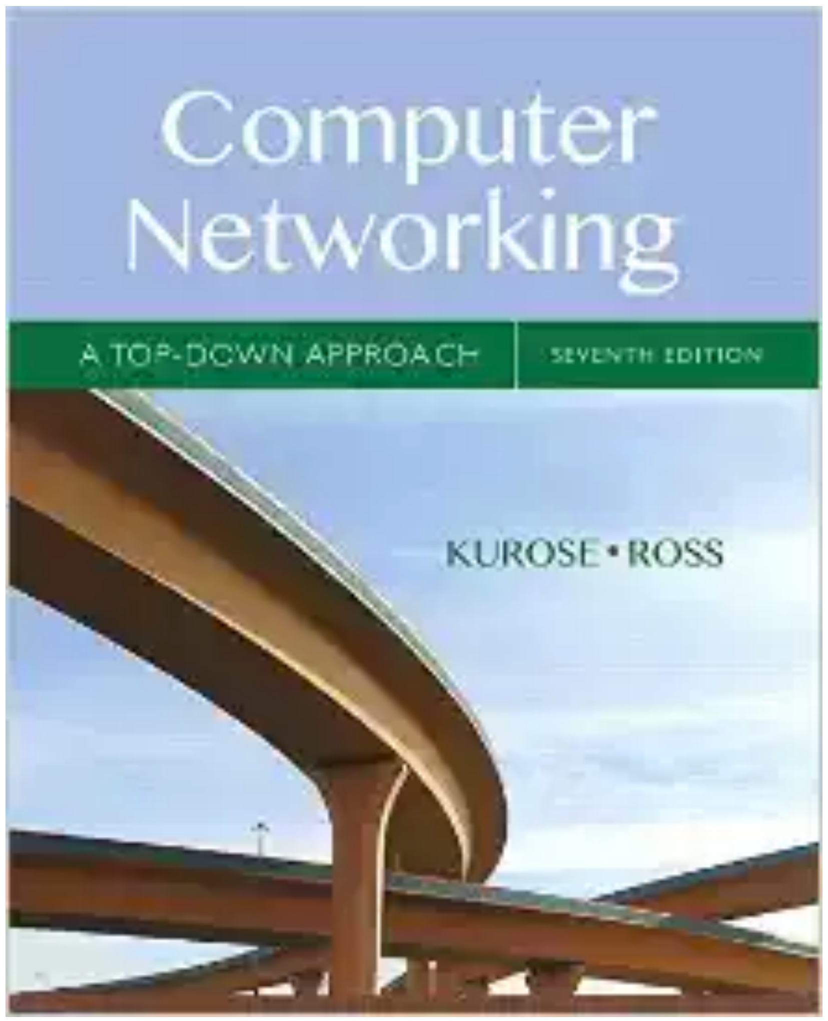

- 3.5: Connection-oriented transport: TCP
    - connection management

TCP Connection Management

Recall: TCP sender, receiver establish “connection” before exchanging data segments

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  - etc.

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Step 3: client receives SYNACK, replies with ACK segment, which may contain data

TCP Connection Management (cont.)

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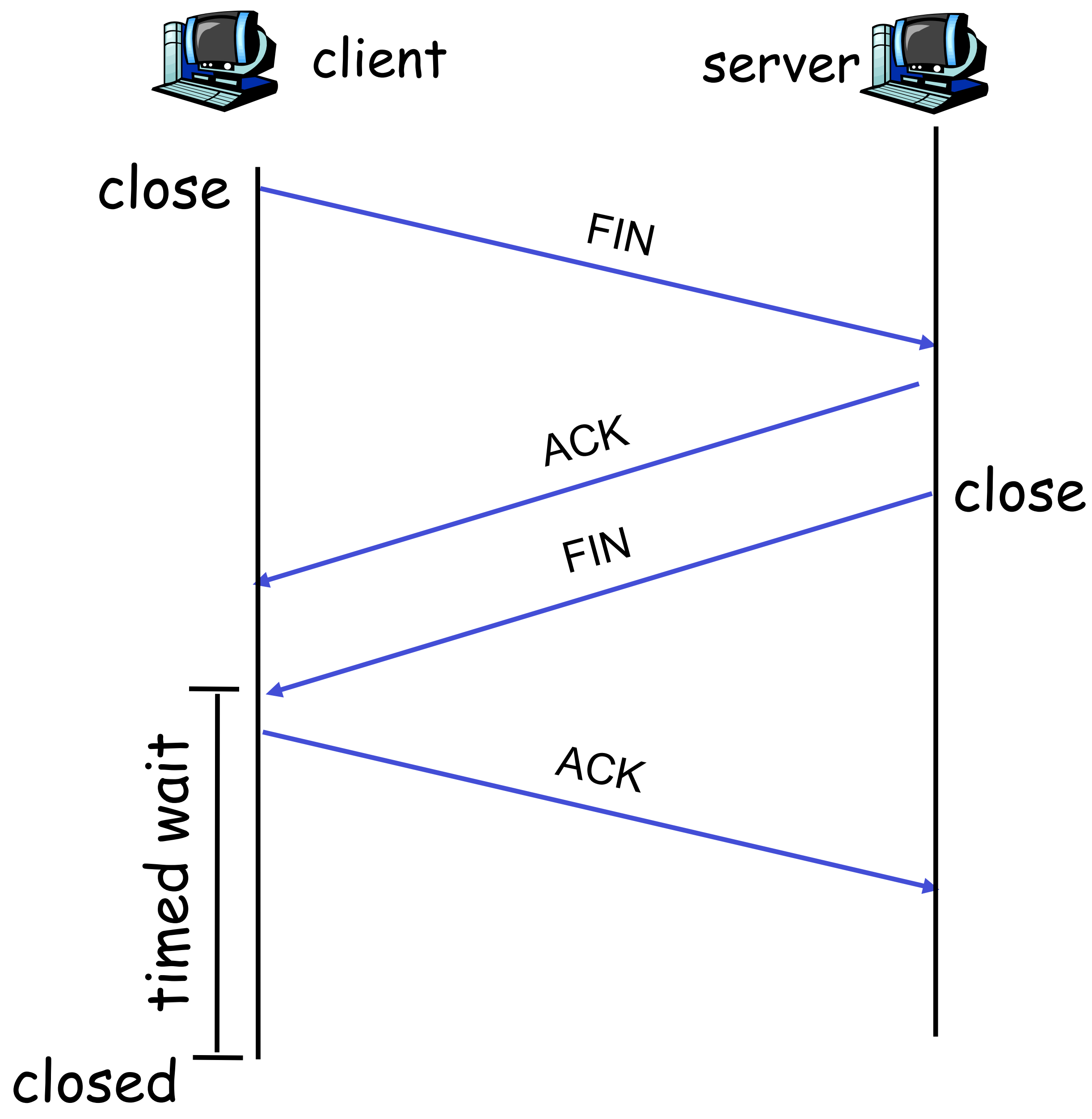

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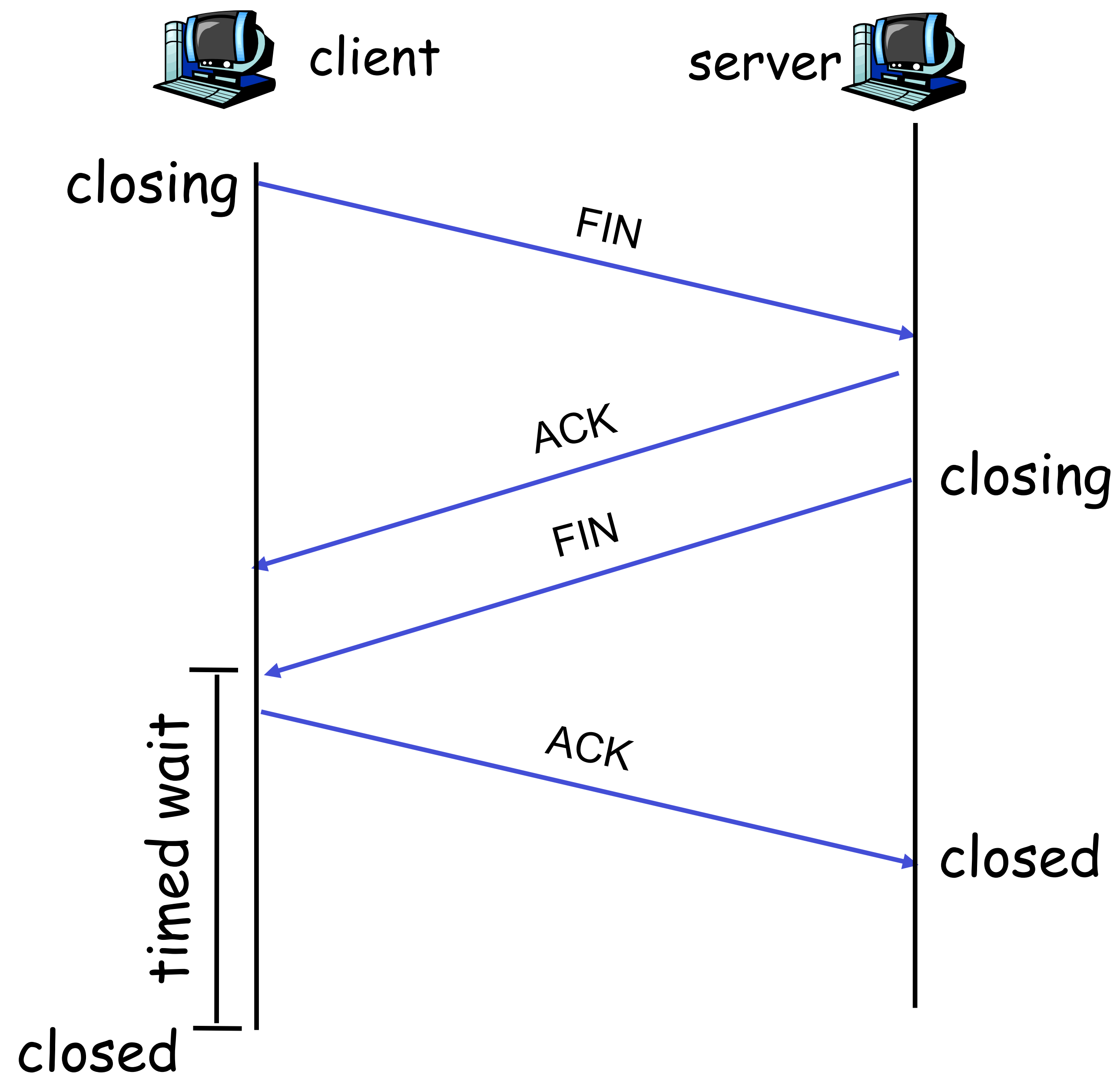

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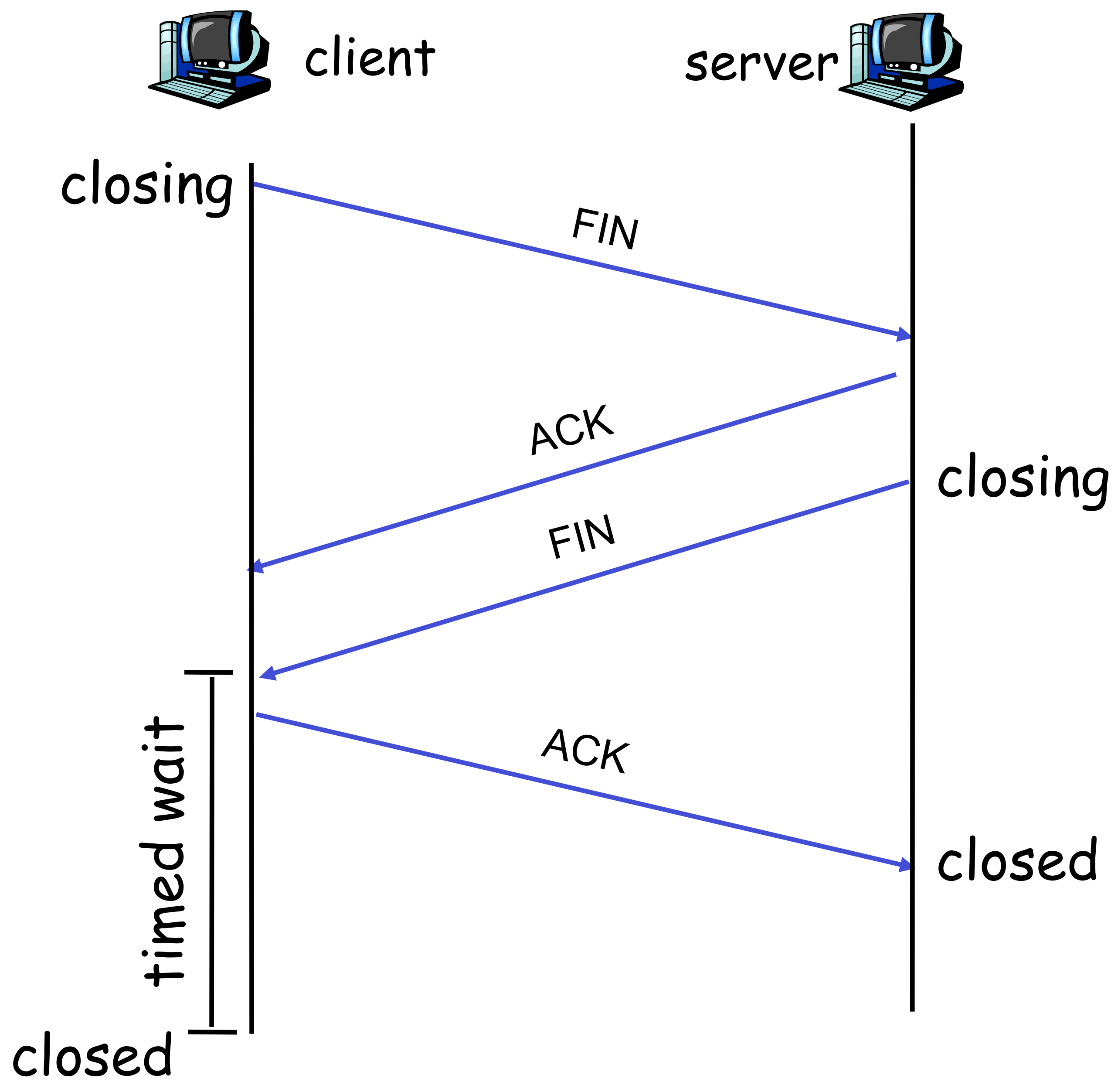

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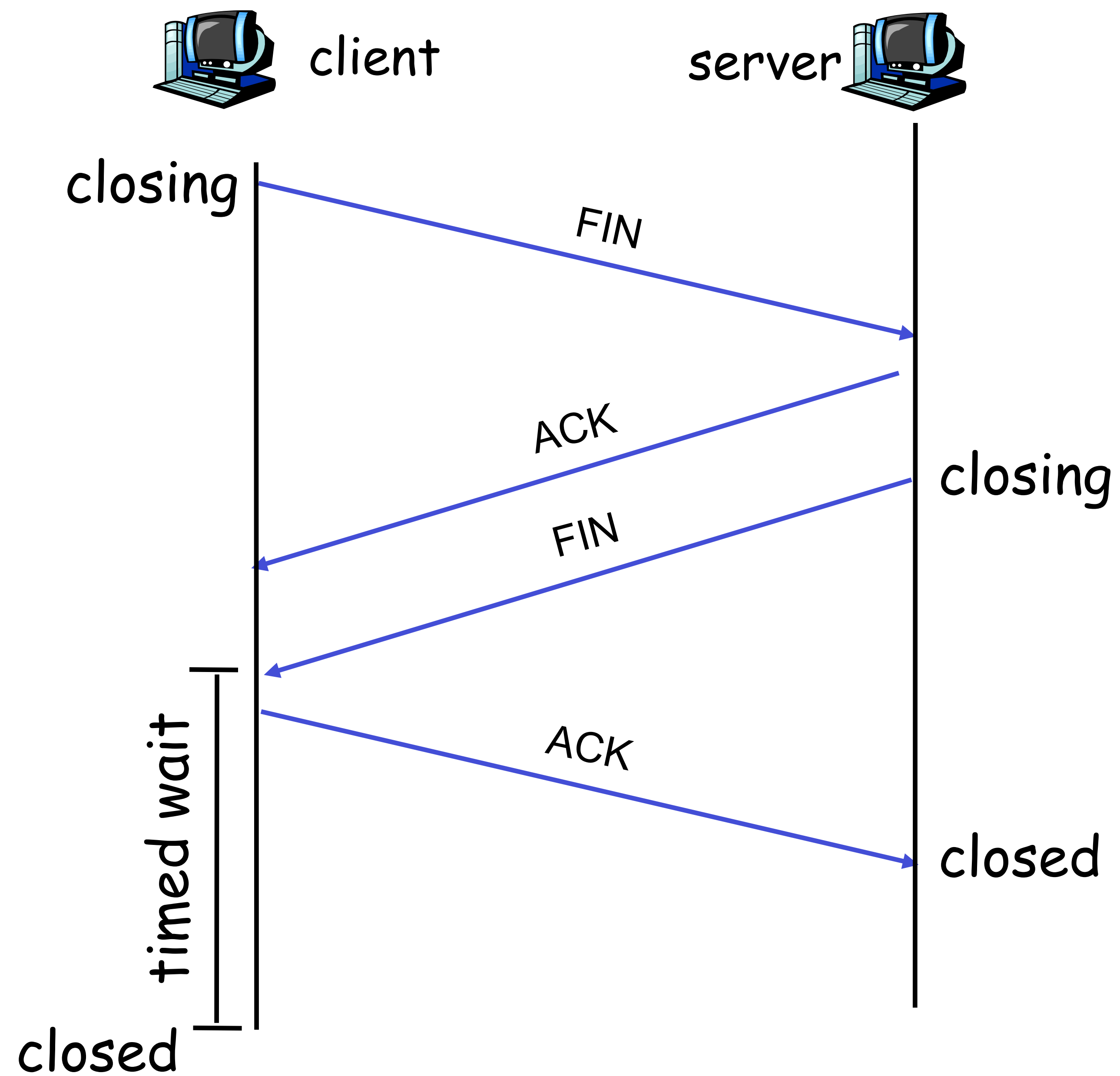
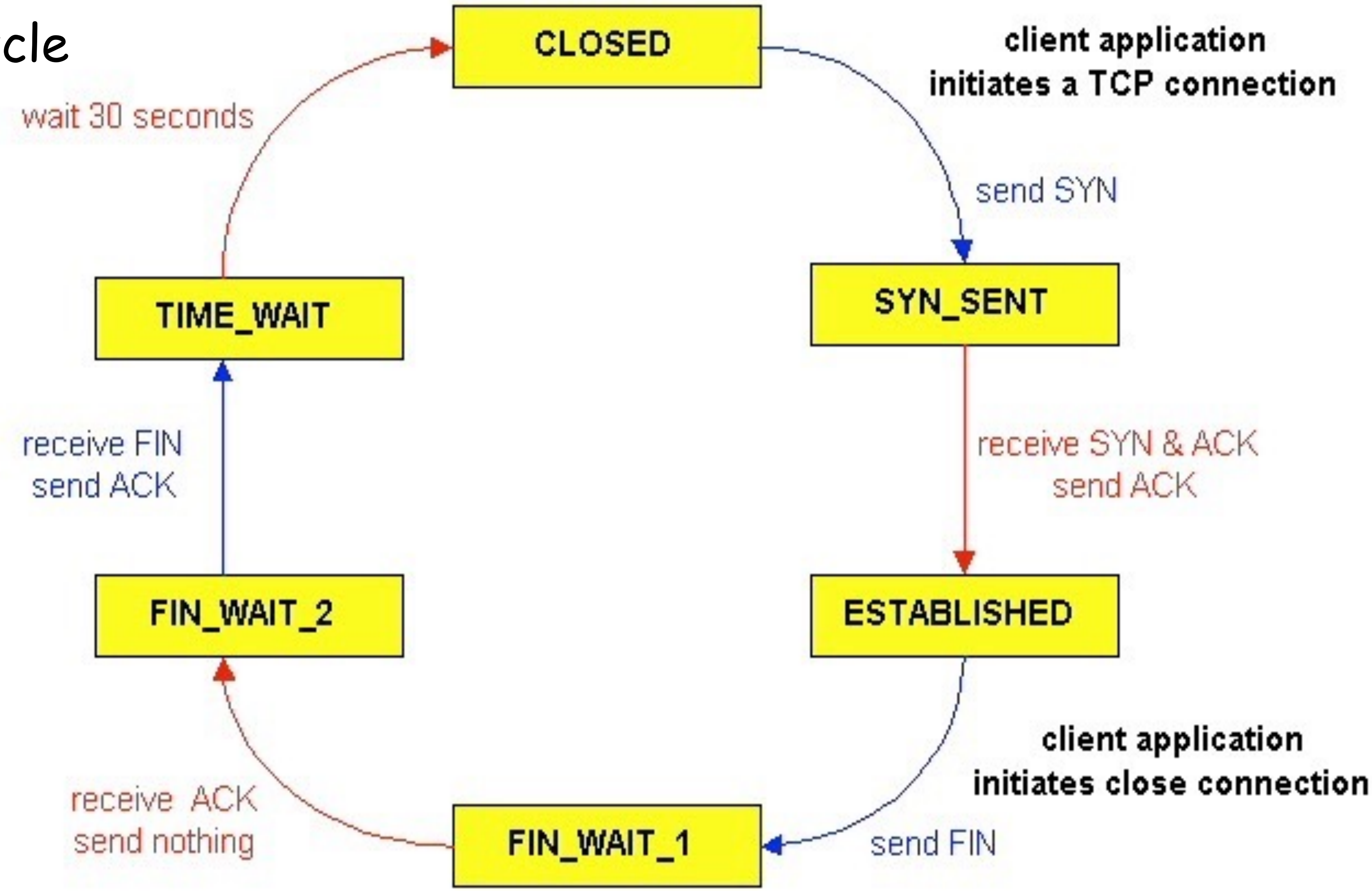
Step 4: server, receives ACK. Connection closed.



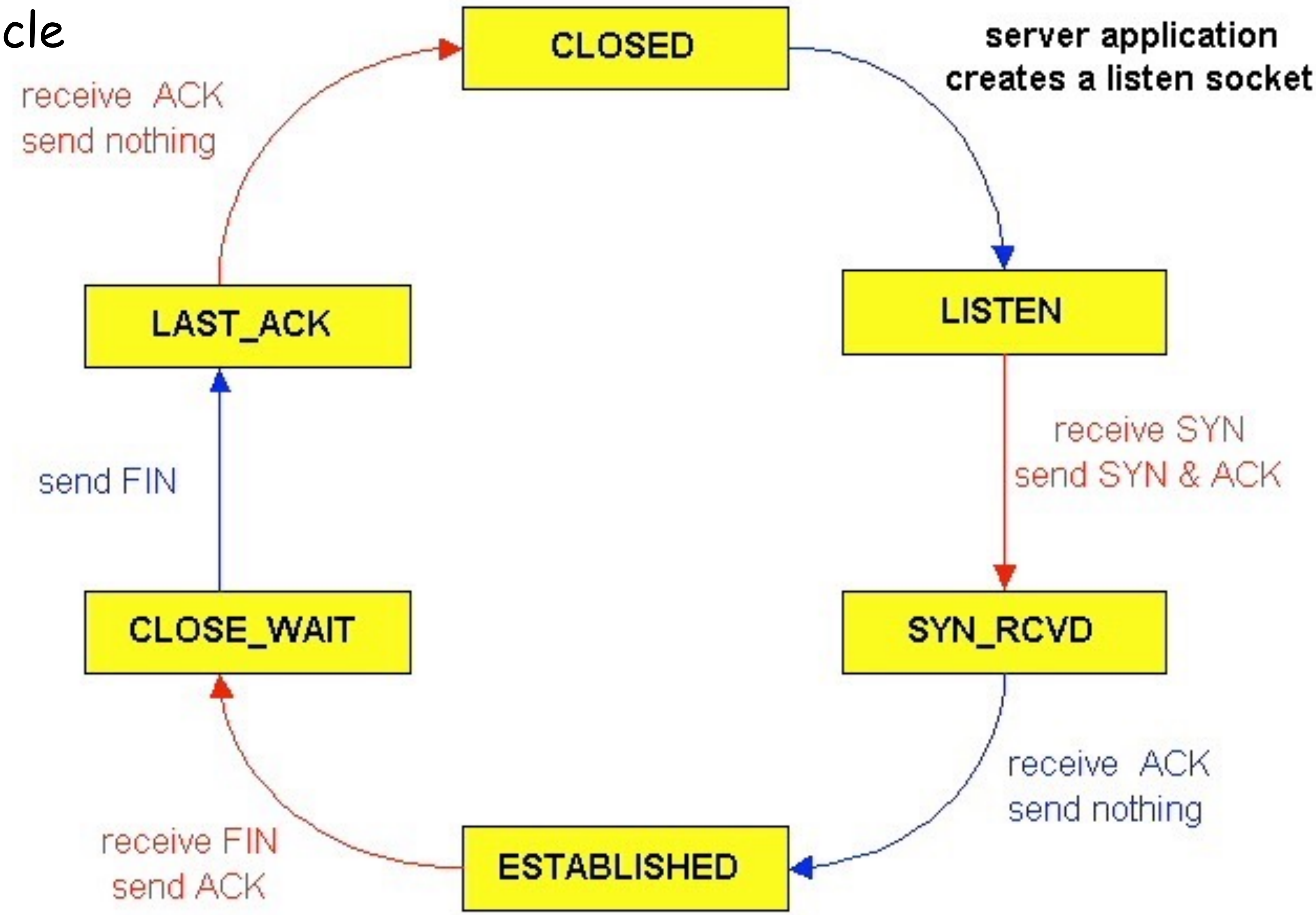
TCP Connection Management (cont)

TCP client lifecycle



TCP Connection Management (cont)

TCP server lifecycle



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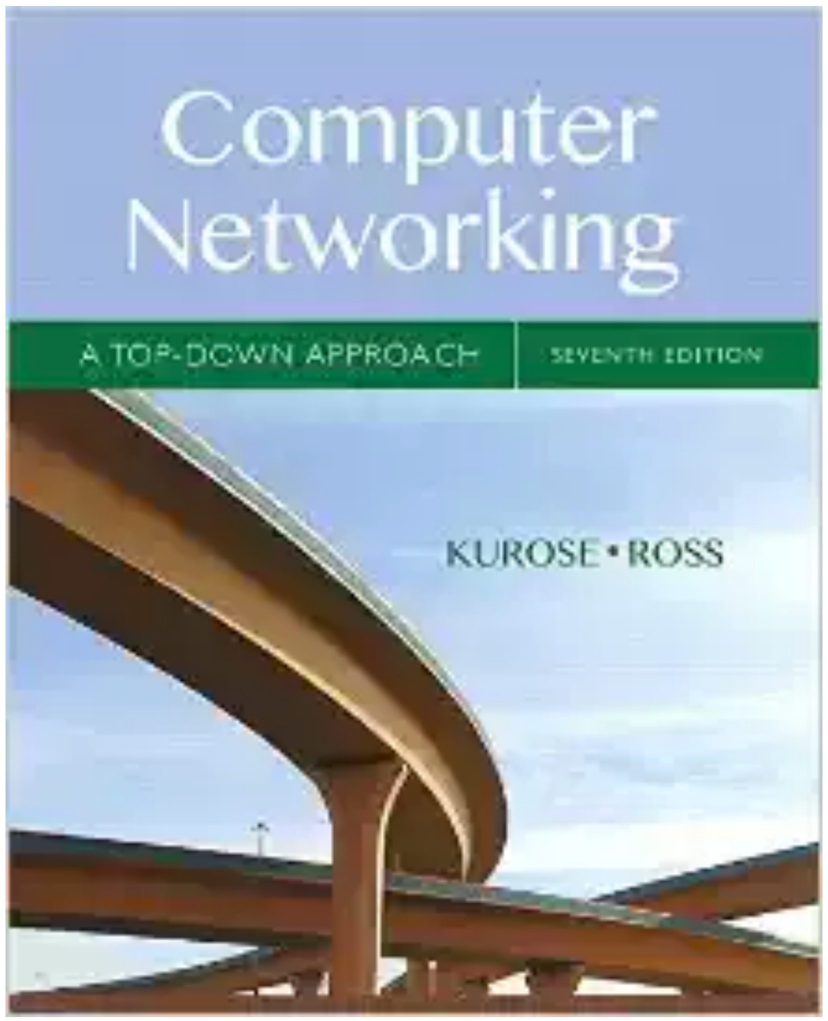

- 3.5: Connection-oriented transport: TCP
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TCP Timeouts and the RTT

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Measured RTTs

- ping measurements from eecslab-5

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  - do not time retransmissions
    - (Karn/Partridge algorithm)

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- Q: How do we estimate the RTT?
  - measure time between data transmission and ACK
  - do not time retransmissions
    - (Karn/Partridge algorithm)
- RTT will vary across measurements

TCP Timeouts and the RTT

- Q: How do we estimate the RTT?
  - measure time between data transmission and ACK
  - do not time retransmissions
    - (Karn/Partridge algorithm)
- RTT will vary across measurements
  - want something smoother
  - instead of just the current RTT, use an average of the last few measurements
  - the "smoothed RTT" (SRTT)

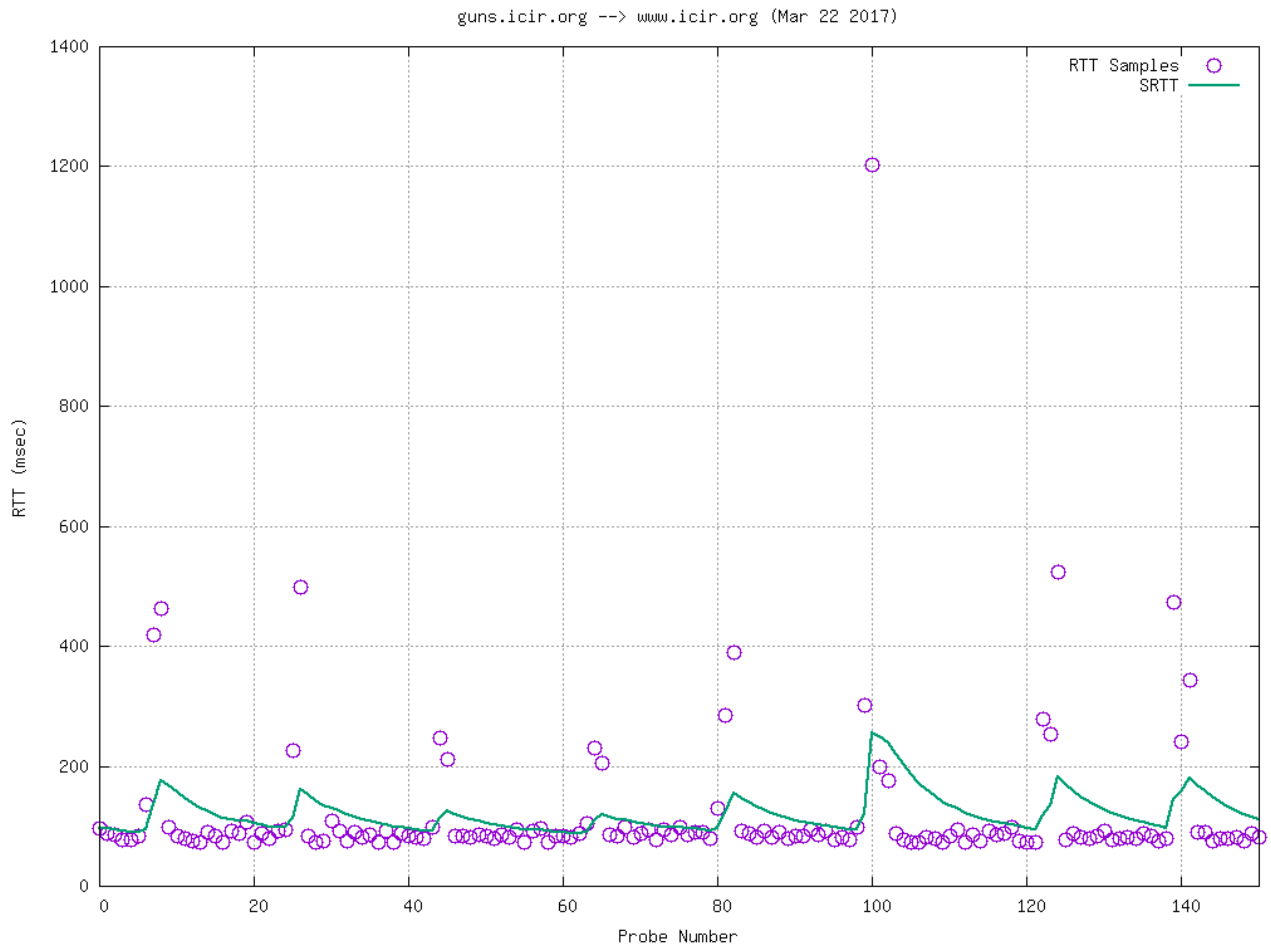
TCP RTO

- RFC 6298

$$\mathbf{SRTT = (1-\ \alpha)*SRTT + \alpha*R}$$

- Exponential weighted moving average
- influence of past sample decreases exponentially fast
- standard value: $\alpha = 0.125$

Example SRTT Computation



TCP RTO

TCP RTO

Setting the timeout

- `SRTT` plus "safety margin"
  - large variation in `SRTT` -> larger safety margin

TCP RTO

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TCP RTO

Setting the timeout

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$$\mathbf{RTTVAR = (1-\beta)*RTTVAR + \beta*|R-SRTT|}$$

(β = 0.25, per standard)

TCP RTO

Setting the timeout

- **SRTT** plus "safety margin"
  - large variation in **SRTT** -> larger safety margin

- first, estimate of how much SRTT deviates from the RTT sample:

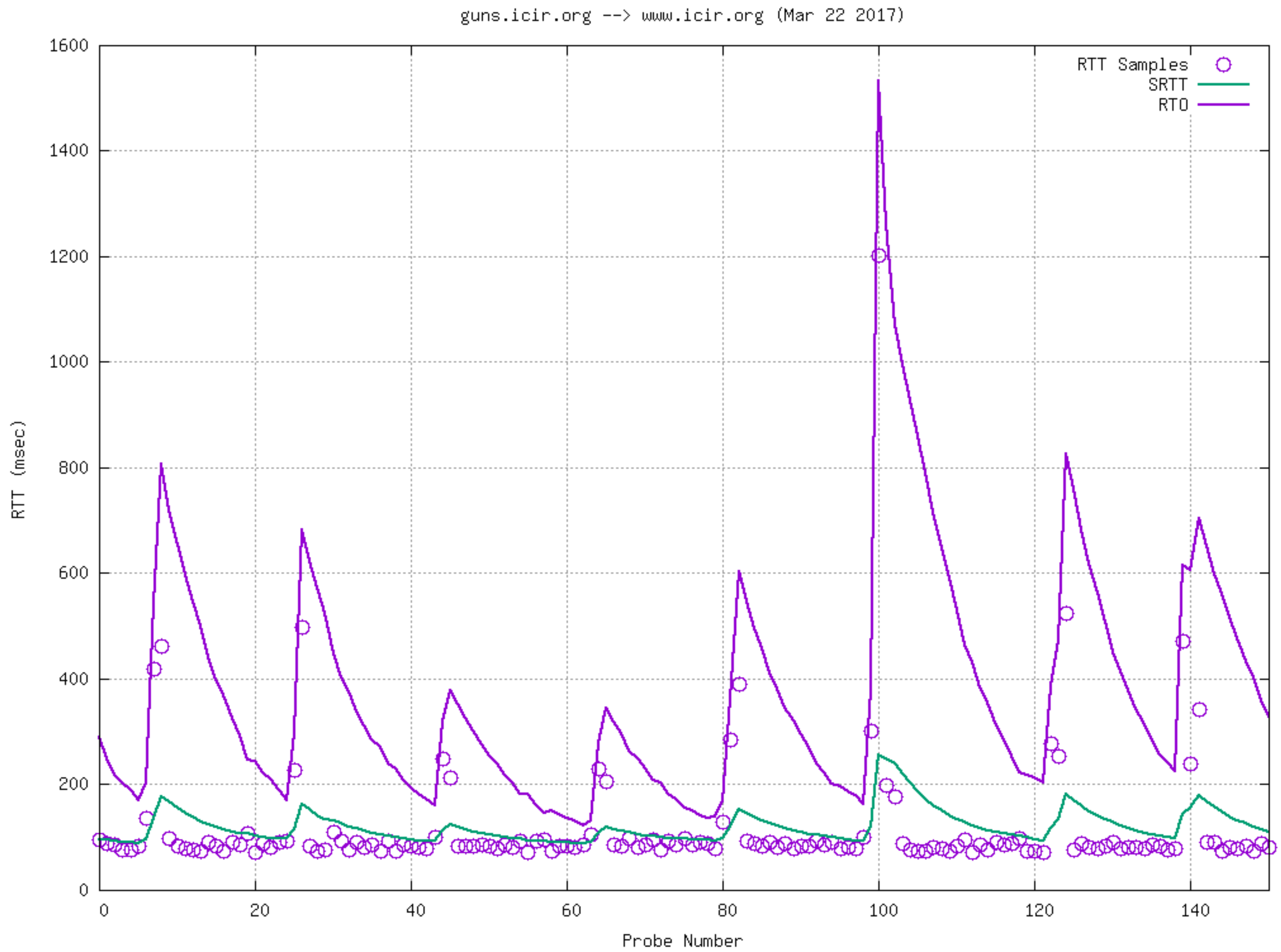
RTTVAR = (1-β)*RTTVAR + β*|R-SRTT|

(β = 0.25, per standard)

Then set timeout interval:

RTO = SRTT + 4*RTTVAR

Example RTO Computation



TCP RTO

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TCP RTO

- But, one issue remains ...
  - where do we start?!
- RFC 1122, RFC 2988 specify 3 seconds
  - why?
- RFC 1122 published in 1989. RFC 2988 published in 2000.
  - does this constant still apply?

TCP Initial RTO

TCP Initial RTO

- Matt Sargent
- Case PhD, 2015

TCP Initial RTO

- Matt Sargent
- Case PhD, 2015

- Hypothesizes that an initial RTO developed in 1989 might not be appropriate anymore

- Conducts an empirical investigation

TCP Initial RTO

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- How do we choose?

TCP Initial RTO

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  - look at some data!
  - investigated eight datasets (spanning 6 years)
  - datasets are packet traces!

TCP Initial RTO

- How do we choose?
  - look at some data!
  - investigated eight datasets (spanning 6 years)
  - datasets are packet traces!
- Lowering the InitRTO from 3 seconds to 1 second has cost:
  - .... less than 0.1% of the connections spuriously retransmit the SYN in most datasets
  - .... 1.1% of the connections in a wireless network spuriously retransmit the SYN

TCP Initial RTO

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- Connections experience performance boost when SYN is lost and requires retransmission
  - i.e., connections only wait for 1sec when previously waited 3sec

TCP Initial RTO

- Connections experience performance boost when SYN is lost and requires retransmission
  - i.e., connections only wait for 1sec when previously waited 3sec

- Connections realizing >= 10% boost:
  - 10-43% (across datasets)
- Connections realizing >= 50% boost:
  - 17-73% (across datasets)

TCP Initial RTO

- The IETF decided that Matt's evidence was compelling

- The initial RTO was lowered from 3sec to 1sec
  - specified in RFC 6298

- Details of Matt's investigation are given in appendix of RFC 6298

TCP RTO

TCP RTO

- One more thing ...
- What if we retransmit and the resent segment is dropped?

TCP RTO

- One more thing ...

- What if we retransmit and the resent segment is dropped?
  - backoff the RTO
  - RTO *= 2
  - (similar to collision backoff in Ethernet)

- Part of TCP's congestion control mechanism

Magic Numbers

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- Where do the constants in the RTO mechanism come from?
  - e.g., alpha = 0.125
  - e.g., initRTO = 1sec
  - e.g., we multiple RTTVAR by 4

Magic Numbers

- Where do the constants in the RTO mechanism come from?
  - e.g., alpha = 0.125
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  - e.g., we multiple RTTVAR by 4

- Rough consensus …
  - but, it still stinks
  - we strive for mechanisms that do not require magic constants