Batching with End-to-End Performance Estimation

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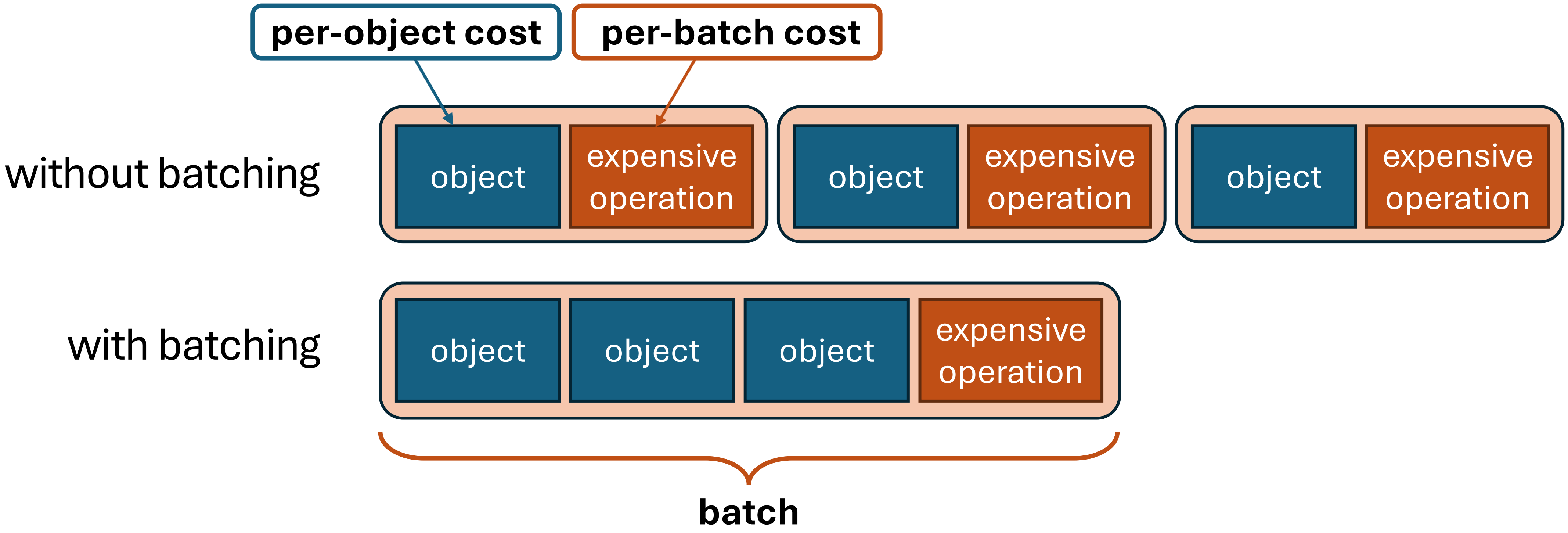
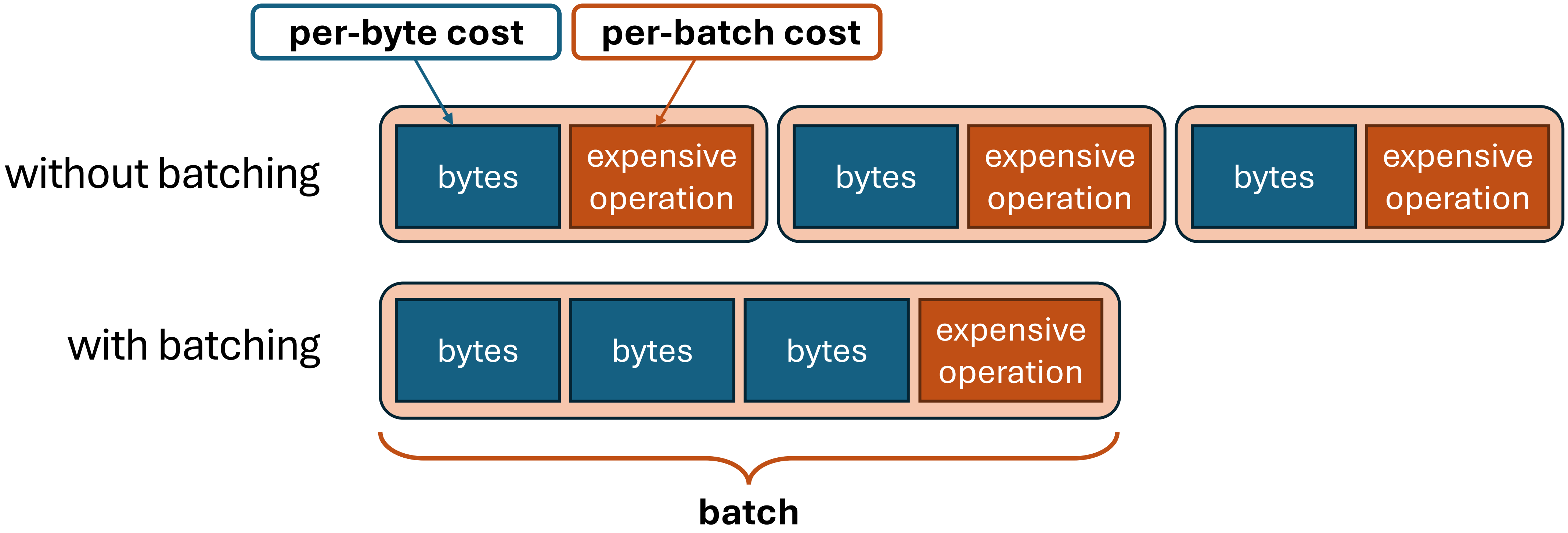
[†]Technion

Background: batching



Background: batching in networking



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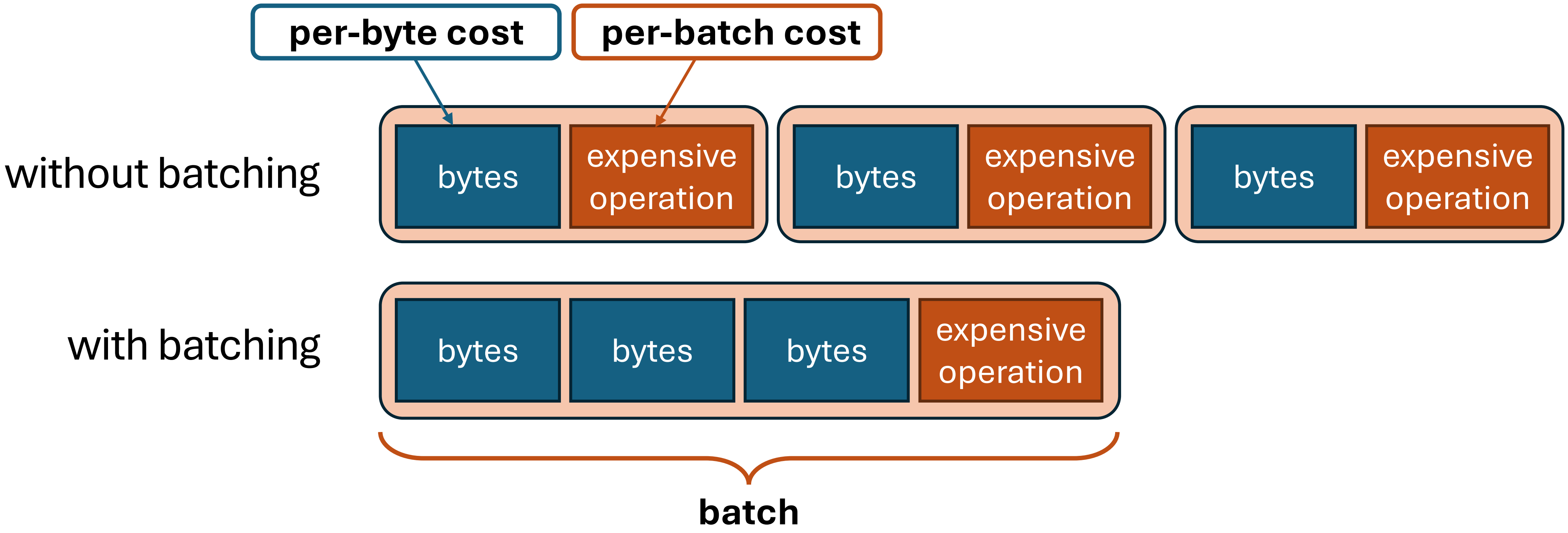

- “Batching trades-off latency for throughput”

Seemingly “ideal” batching

- Assume batching never waits for more objects
  - Batching is only done in presence of congestion
  - IX [OSDI’14] calls this “adaptive batching”

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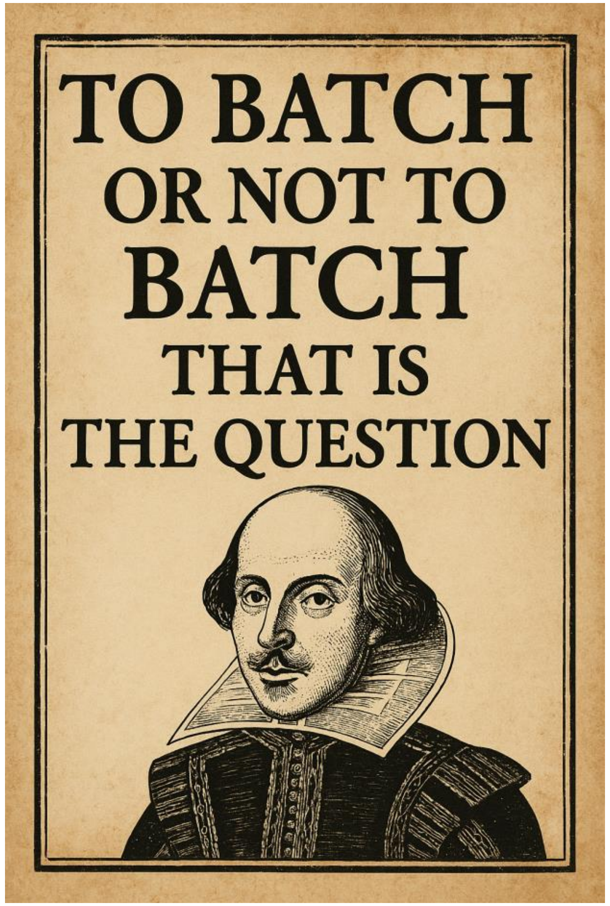
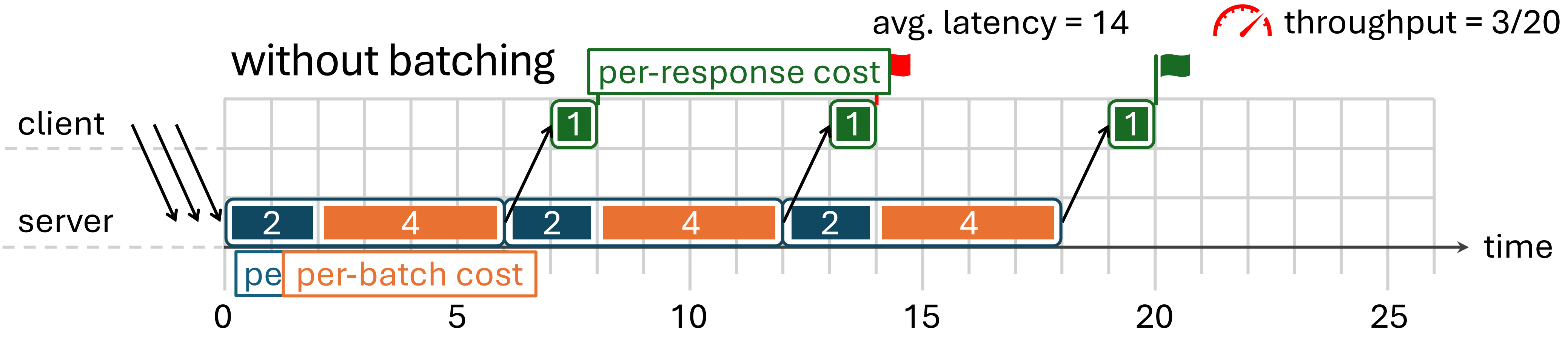
- 3 requests have arrived together to the server
  - Should the server process them as one batch?



To batch or not to batch?



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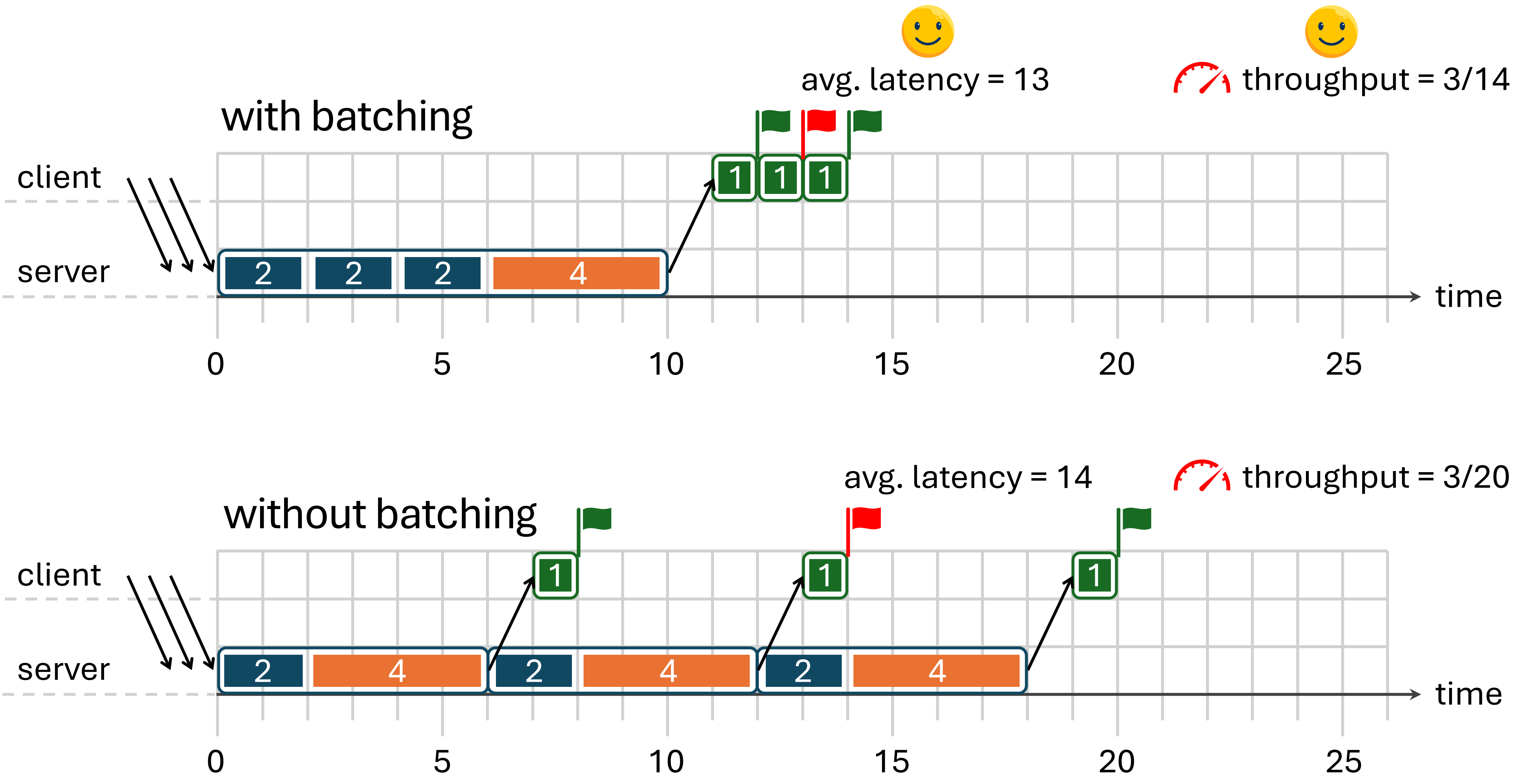

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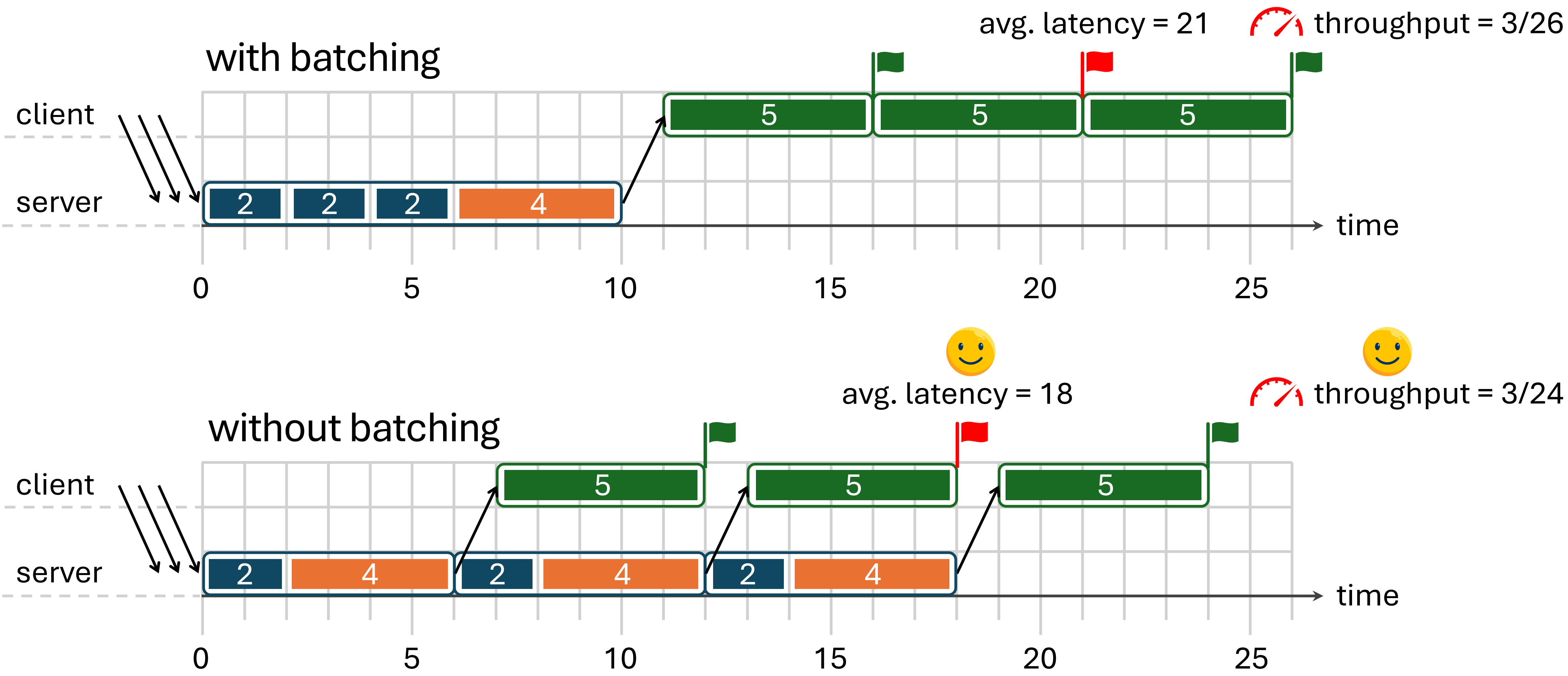

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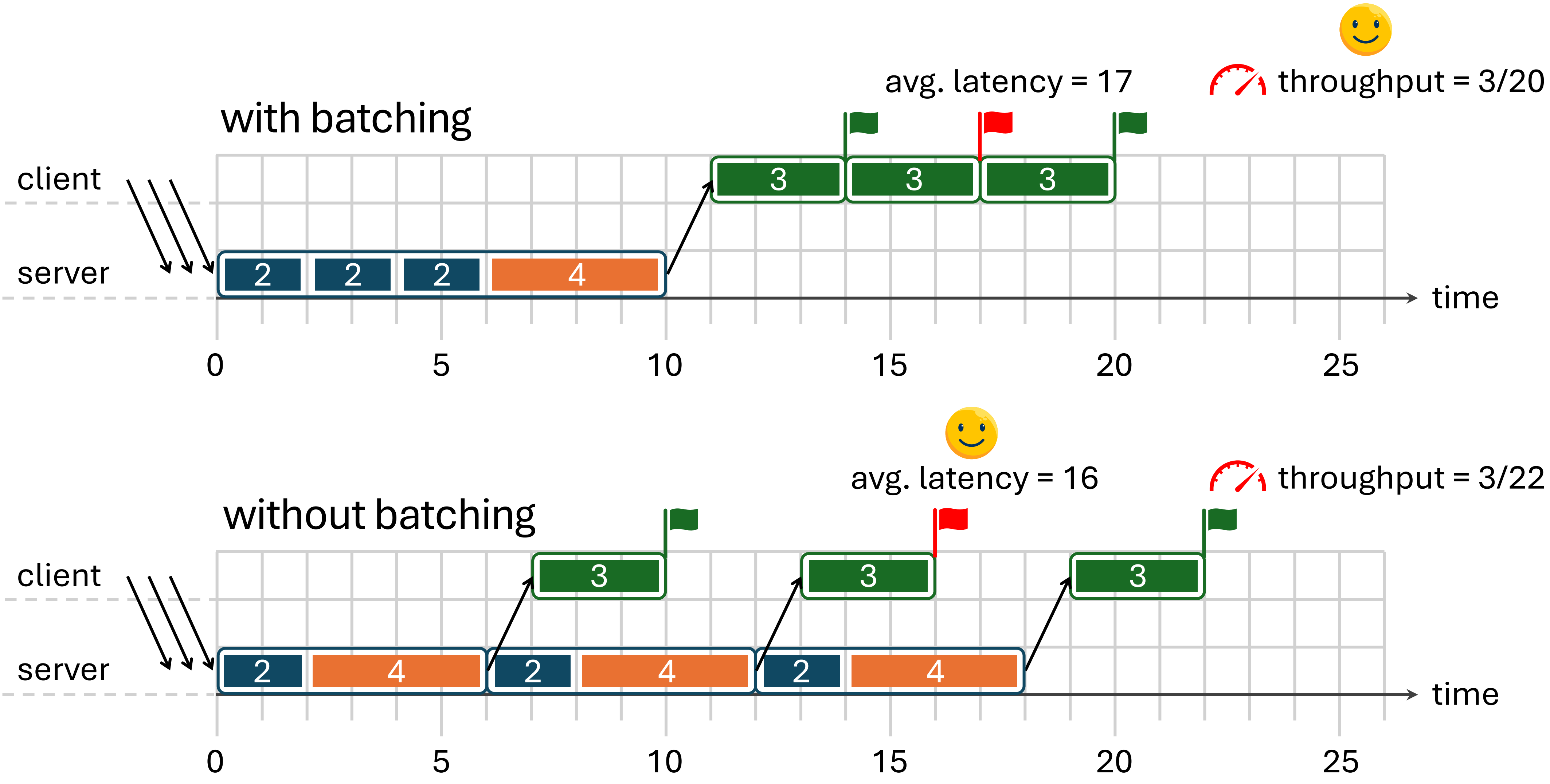
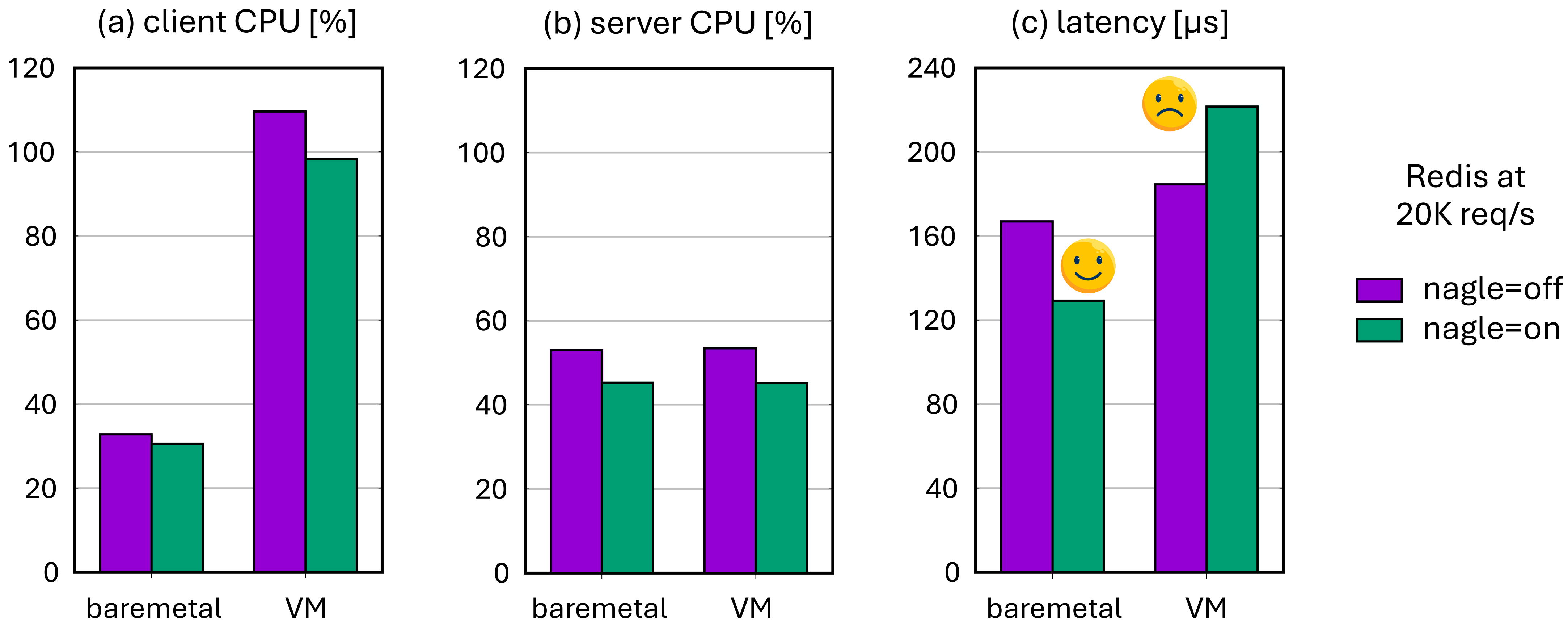


To batch or not to batch?

- Same server-side activity
- Completely different results

client-side cost	latency	throughput
1	better	better
5	worse	worse
3	worse	better

Not just in theory



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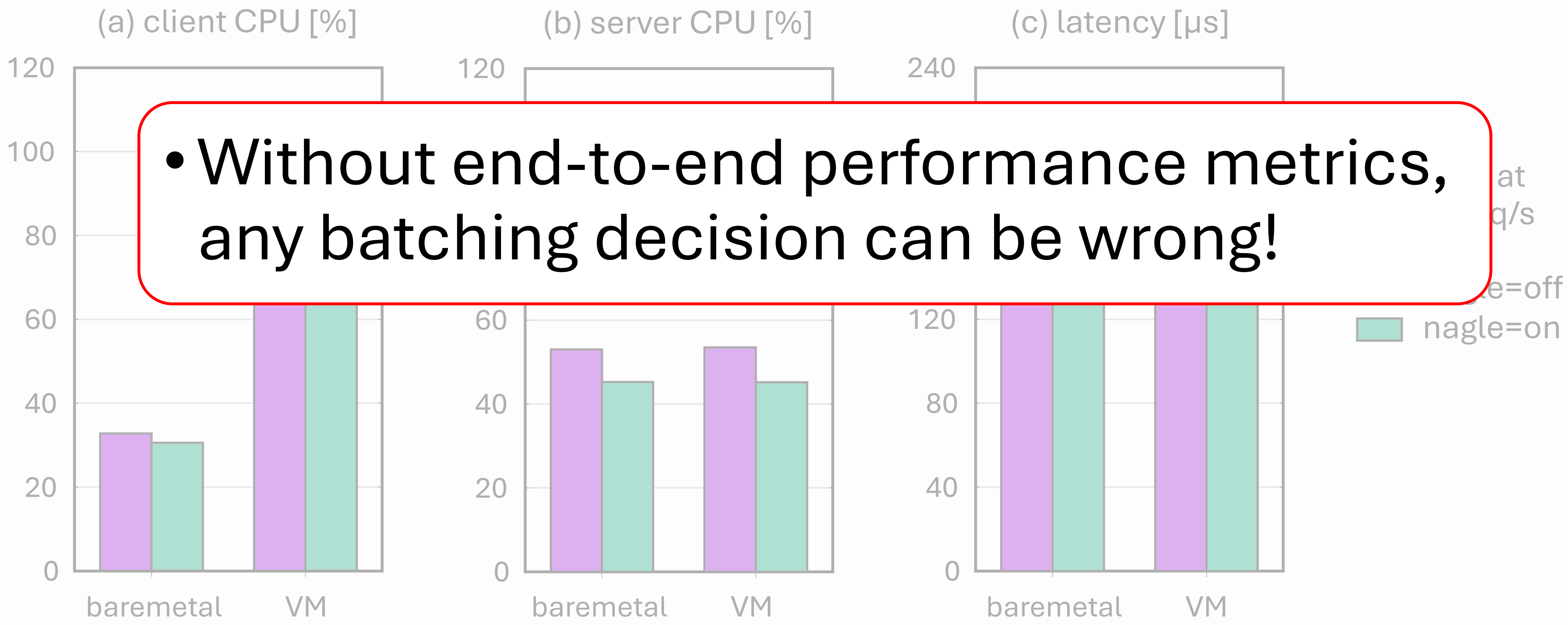

- Without end-to-end performance metrics, any batching decision can be wrong!

What does the literature say?

- State-of-the-practice (Linux)
  - Nagle
  - Auto-corking
  - TSO
  - xmit_more
  - …
- State-of-the-art
  - Netmap [ATC’12]
  - MegaPipe [OSDI’12]
  - IX [OSDI’14]
  - mTCP [NSDI’14]
  - Stackmap [ATC’16]
  - ZygOS [SOSP’17]
  - …
- None utilize end-to-end performance

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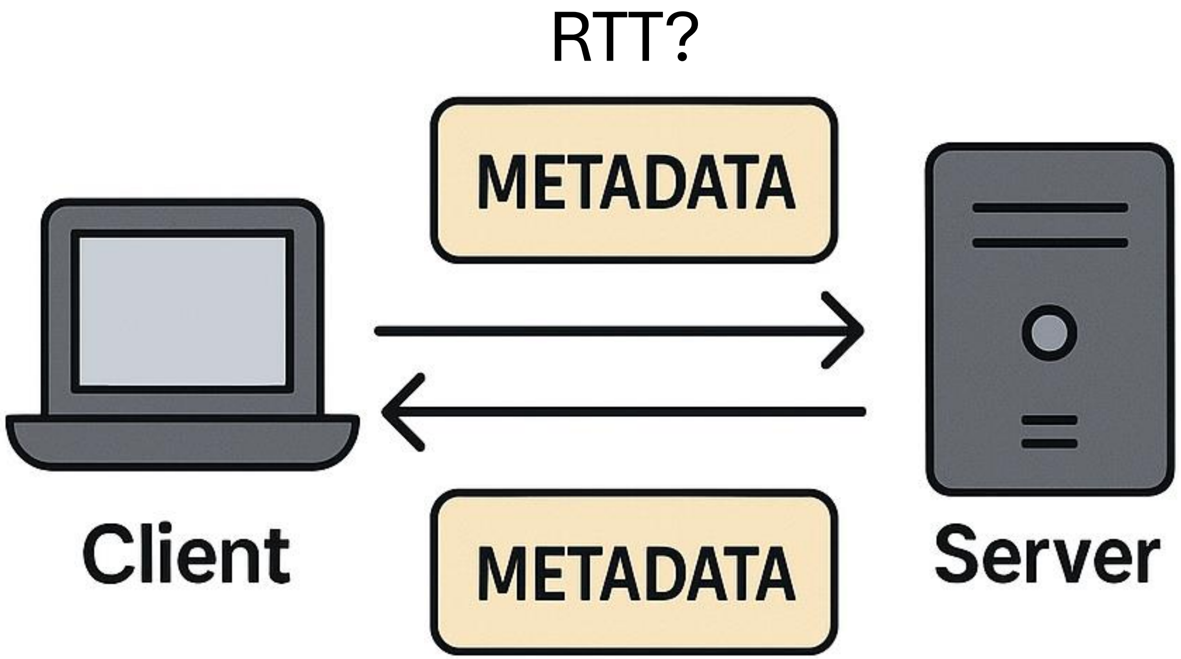
- None utilize end-to-end performance
  - Hypothesis: all may benefit

End-to-end latency is unknown



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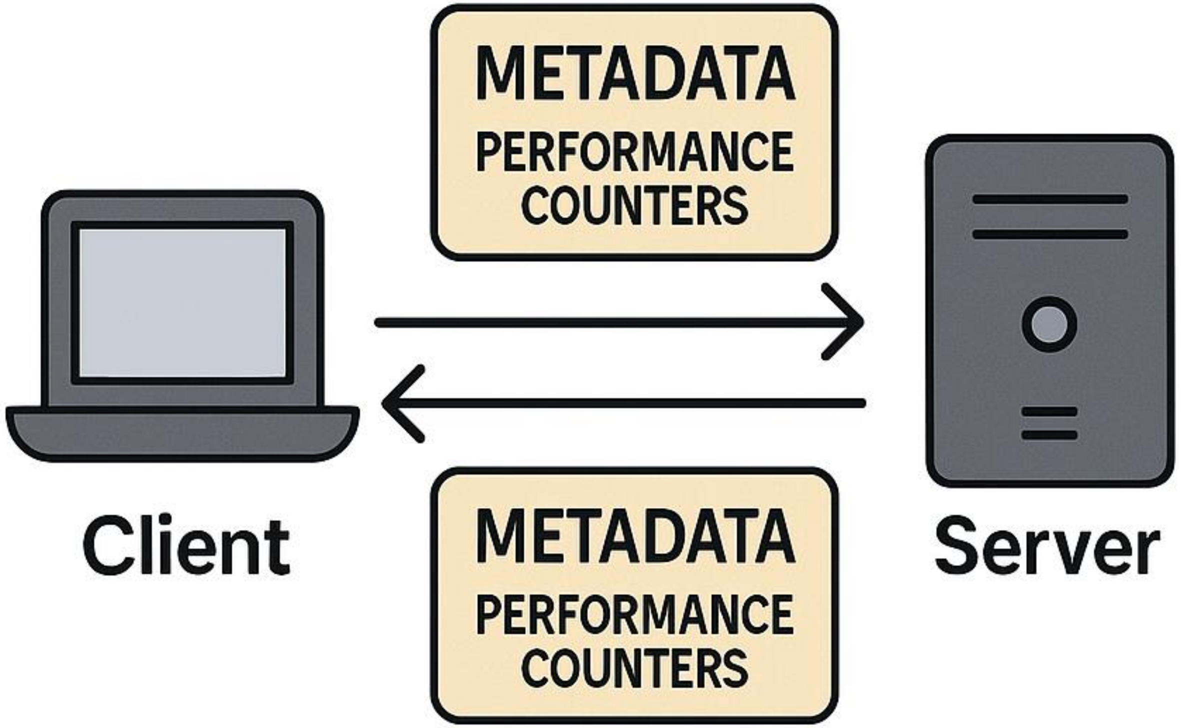
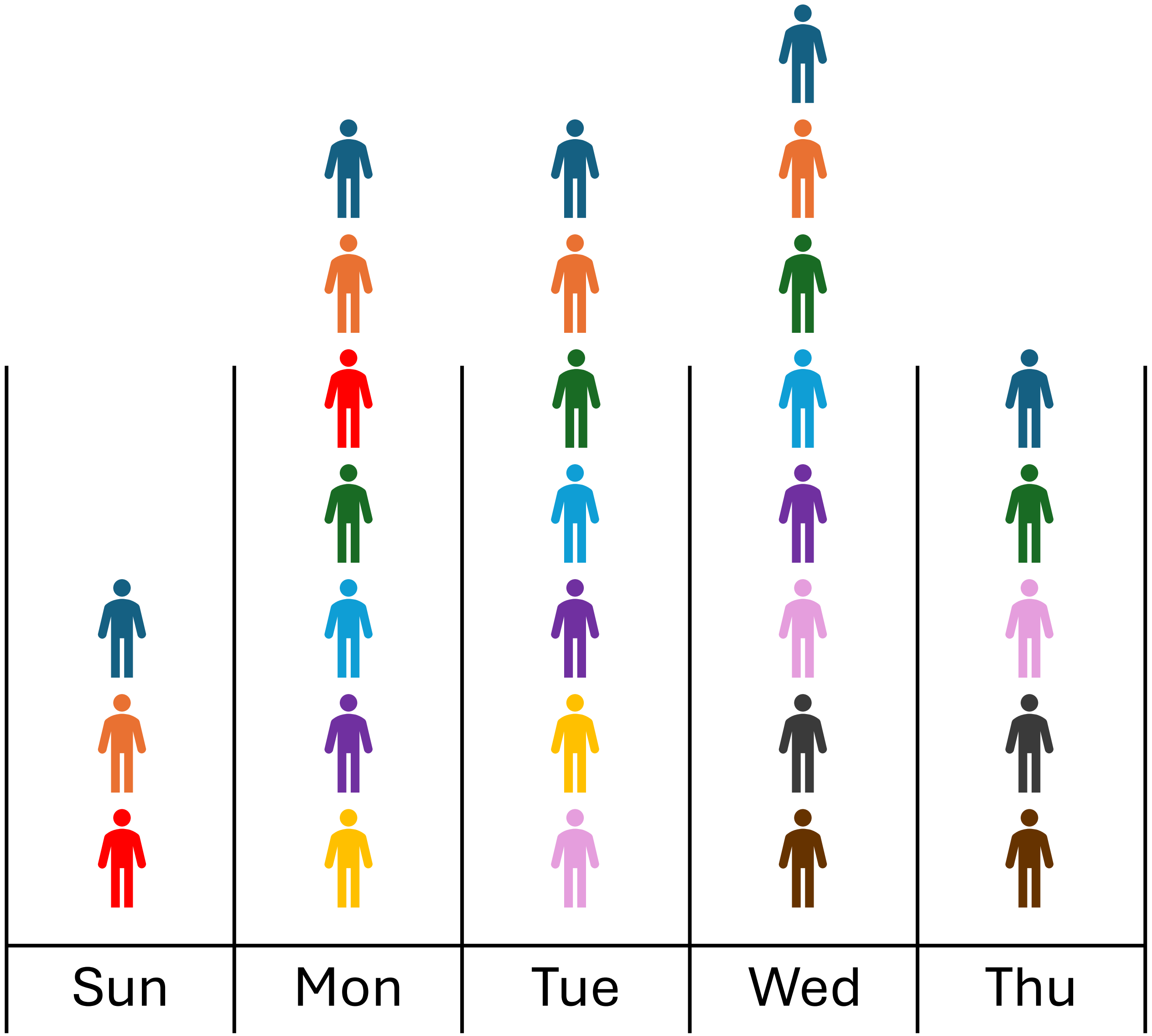


Little's law

$$Q = \lambda \times D$$

average occupancy | average rate | average delay

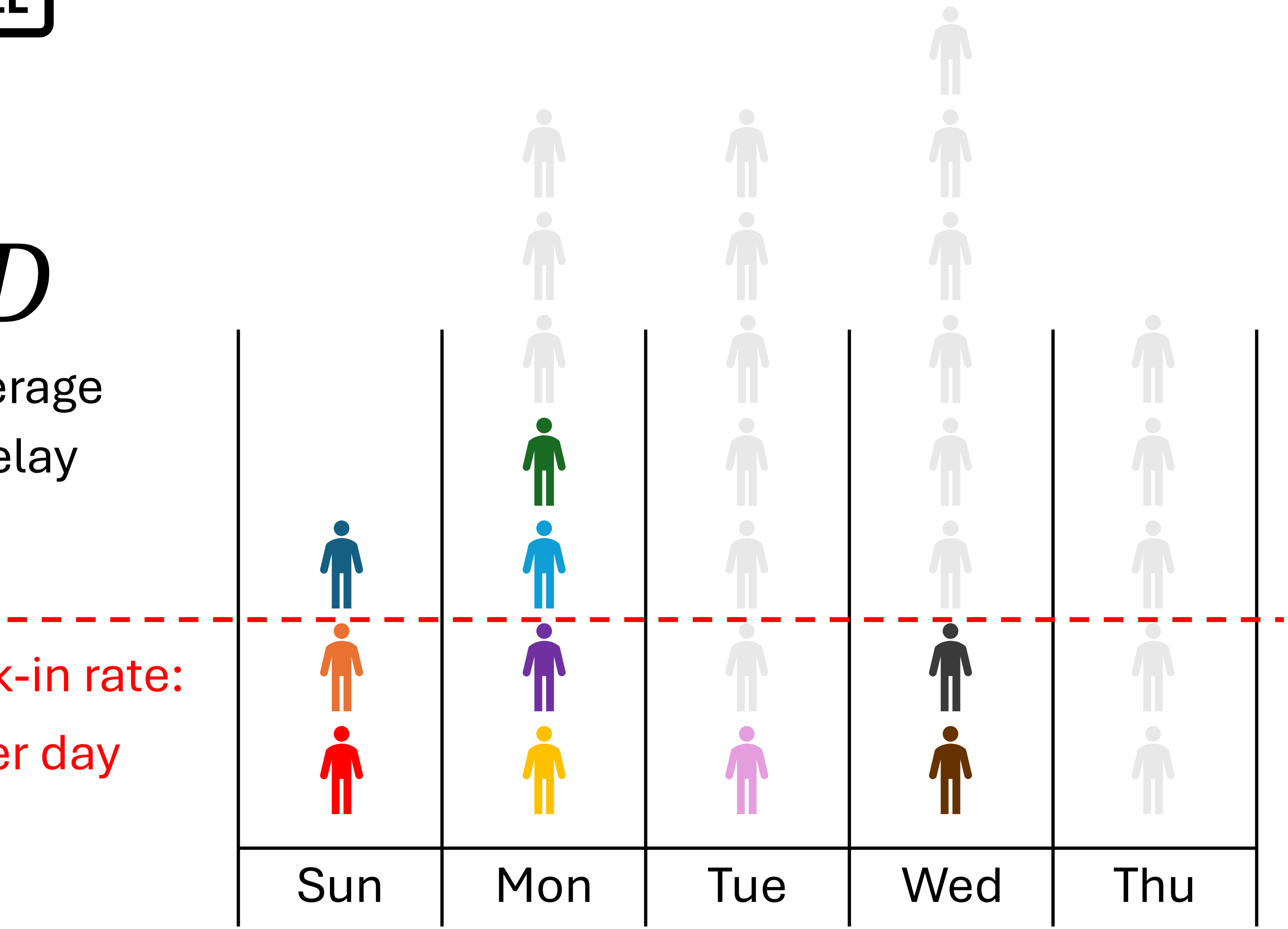


Little’s law

$$Q = \lambda \times D$$

average occupancy — average rate — average delay

average check-in rate:
2 guests per day



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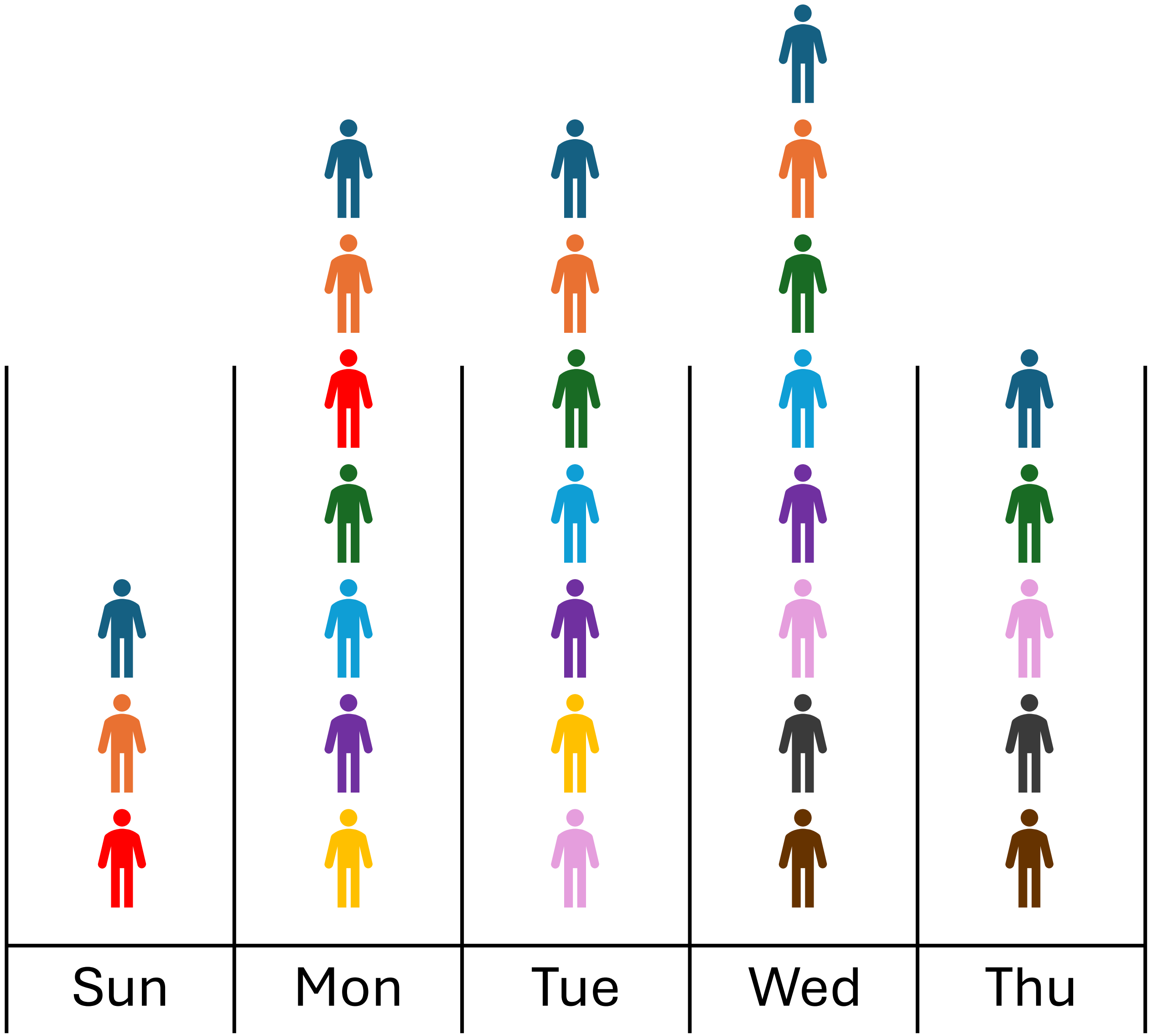

Little's law

HOTEL

$$Q = \lambda \times D$$

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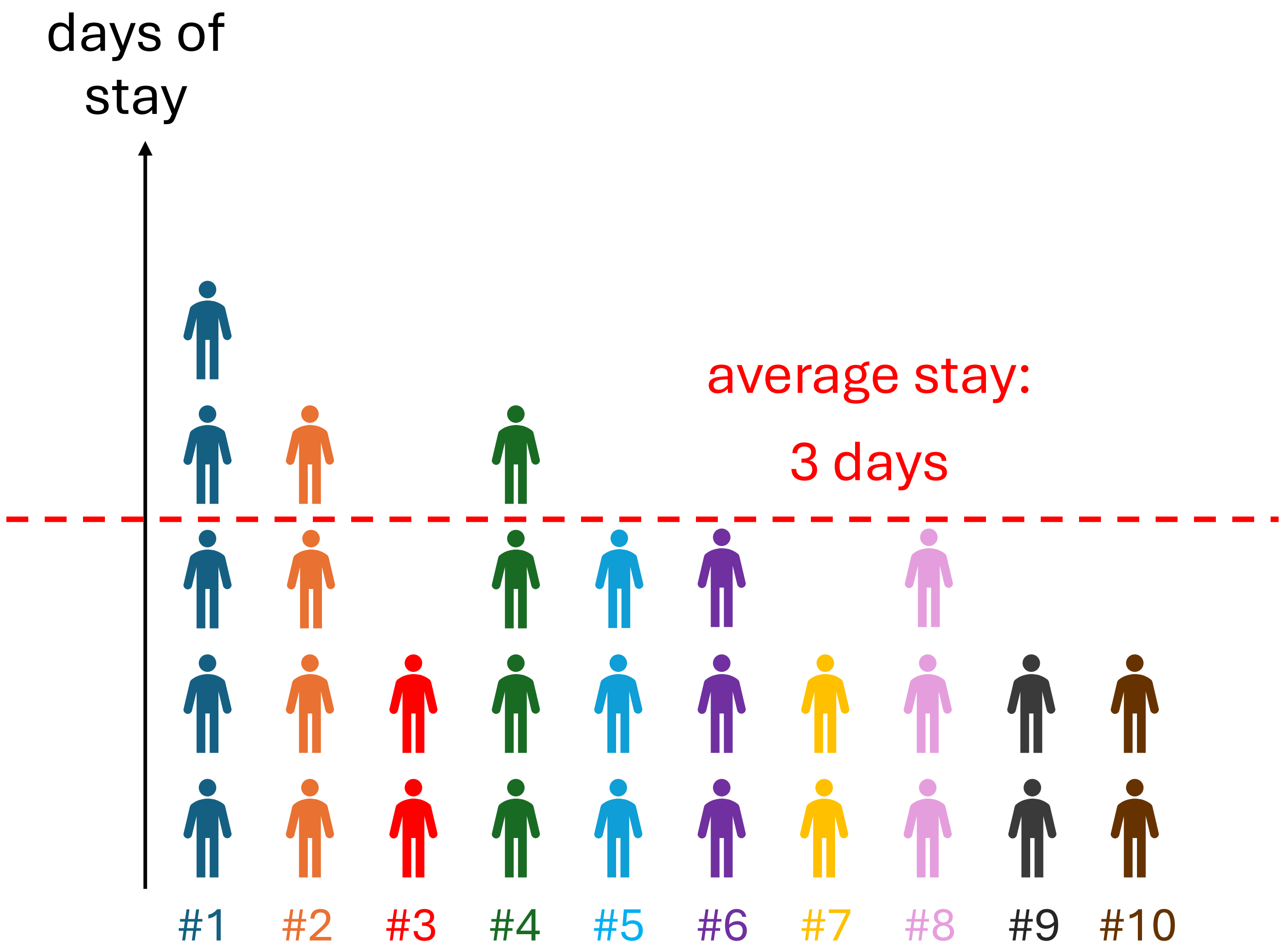

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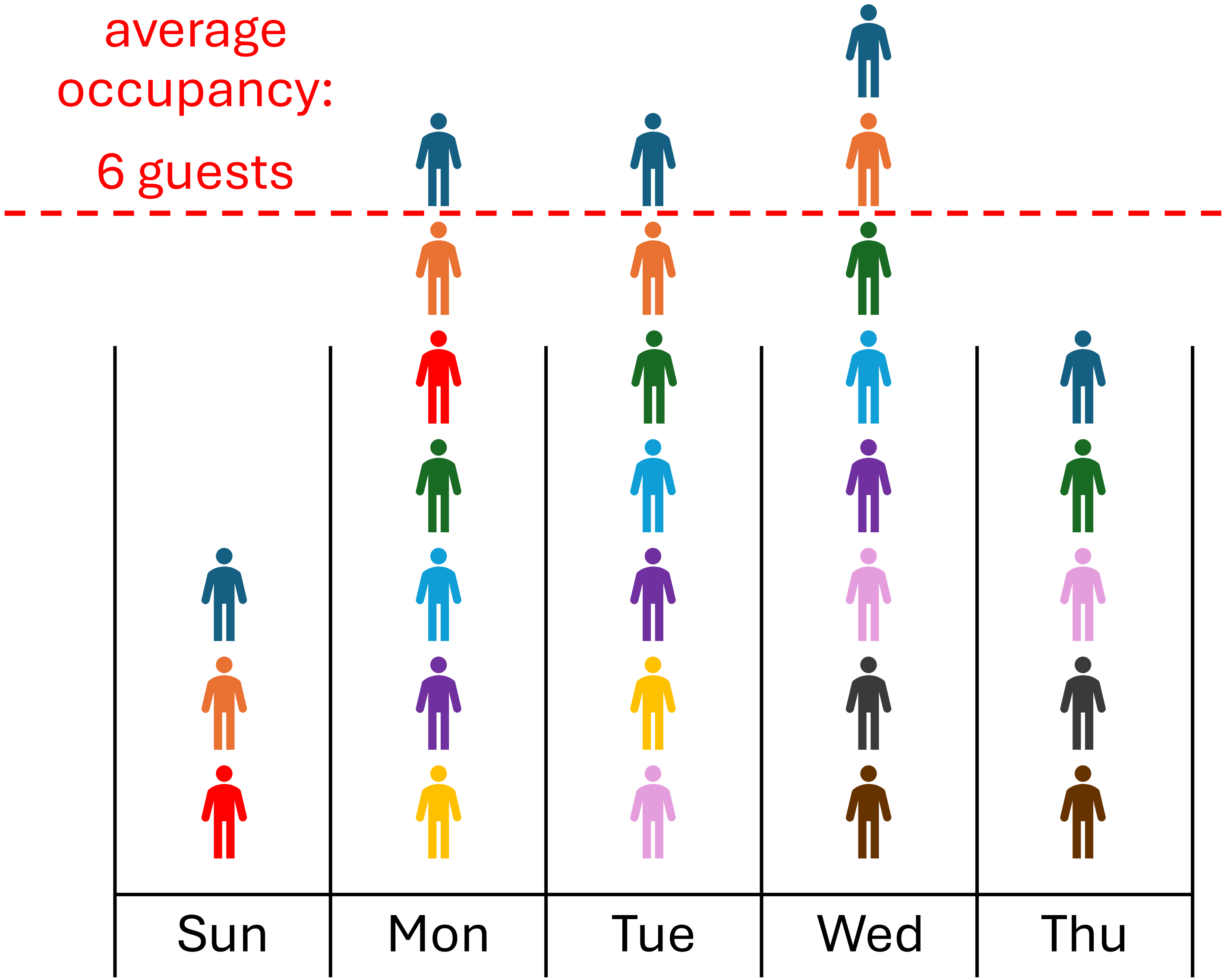


Little's law in network queues

On average:

easy easy hard

$$Q = \lambda \times D$$

queue size arrival rate queuing delay

Little’s law in network queues

On average:

easy easy

$$D = Q/\lambda$$

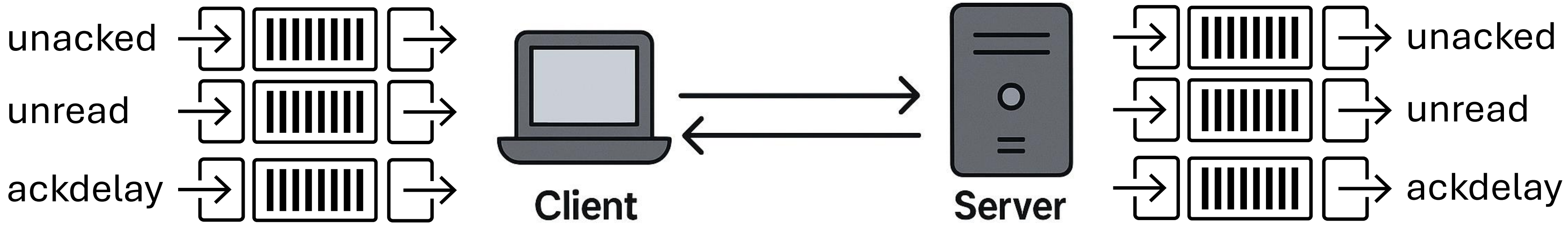
queuing delay queue size arrival rate

Combining delays into end-to-end latency

- Latency is a combination of queuing delays (*)

$$L_{unacked}^{local} + L_{unread}^{local} + L_{unread}^{remote} - L_{ackdelay}^{remote}$$

- These queues already exist in the Linux kernel
  - Just need to extract L from them



Queue performance tracking algorithm

- Simple 4-tuple structure pluggable to any queue:

$$q_s = (\text{time}, \text{size}, \text{total}, \text{integral})$$

timestamp of last state update

current #items in queue

total #items that left the queue until now

time-weighted accumulator of queue size

- Simple algorithms to maintain (`Track`) and extract metrics (`GetAvgs`)

- Passing this tuple to peers allows calculating remote performance

Bridging the semantic gap

- Previous approach needs no app assistance
  - Assumption – bytes/packets correlate to messages
  - Not always true

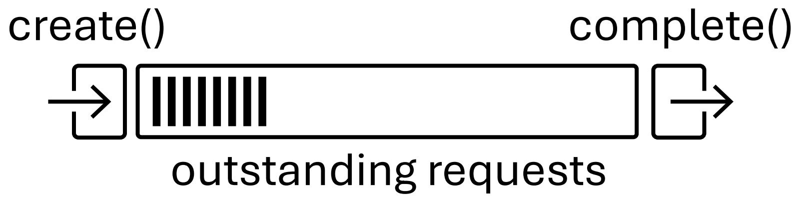
- Better correlation – count send() system calls
  - Deals with messages fragmented by network stack
  - Not always true

- Most accurate – let the app tell you. How?

Bridging the semantic gap

- Just one client-side user-space “request queue”
  - Same Little’s law-based algorithms in user-space
  - State shared via send() metadata

- Simple API with two functions
  - create(n)
  - complete(n)



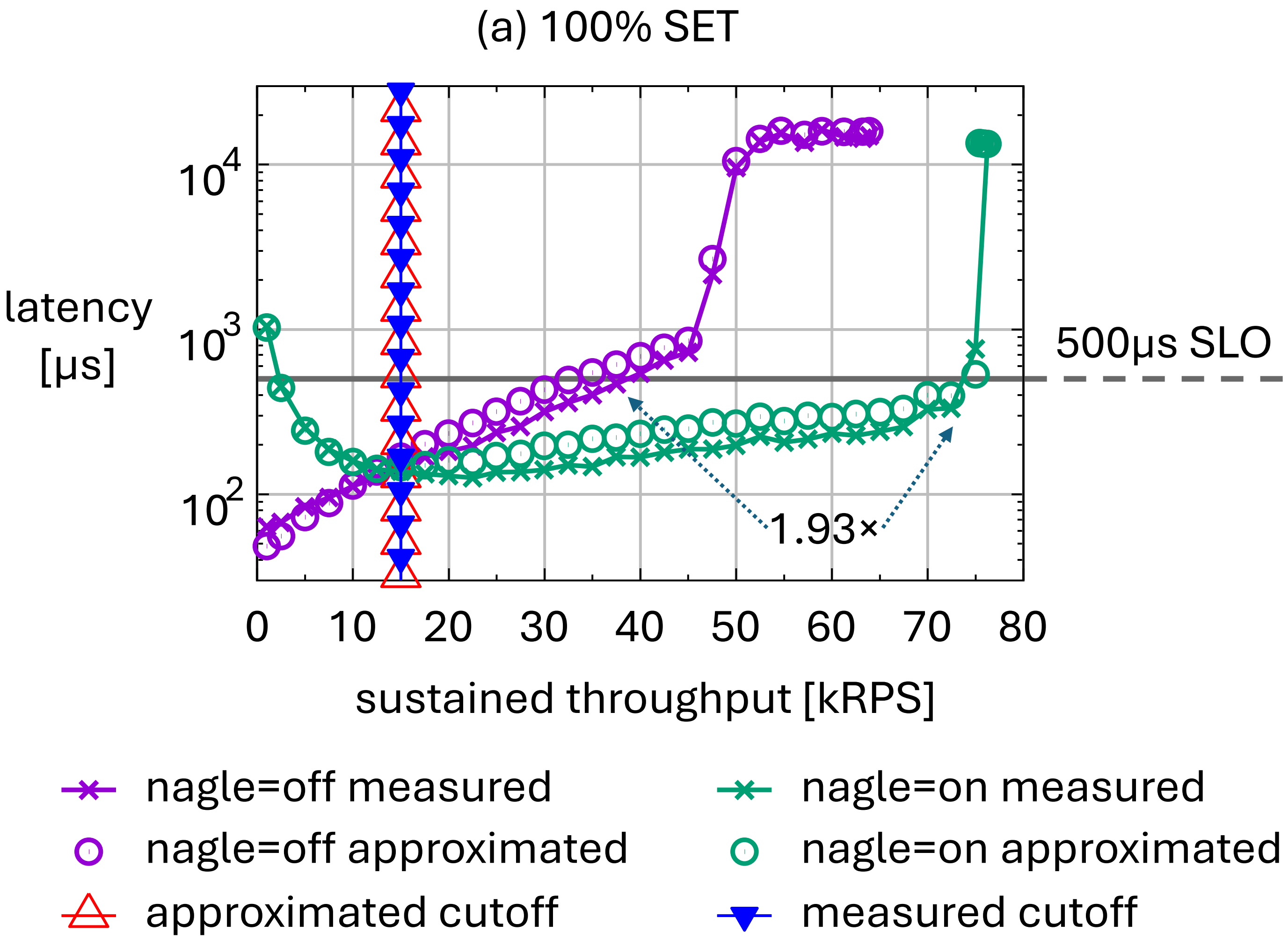
- Easy adoption into libc, gRPC, etc.

Evaluation

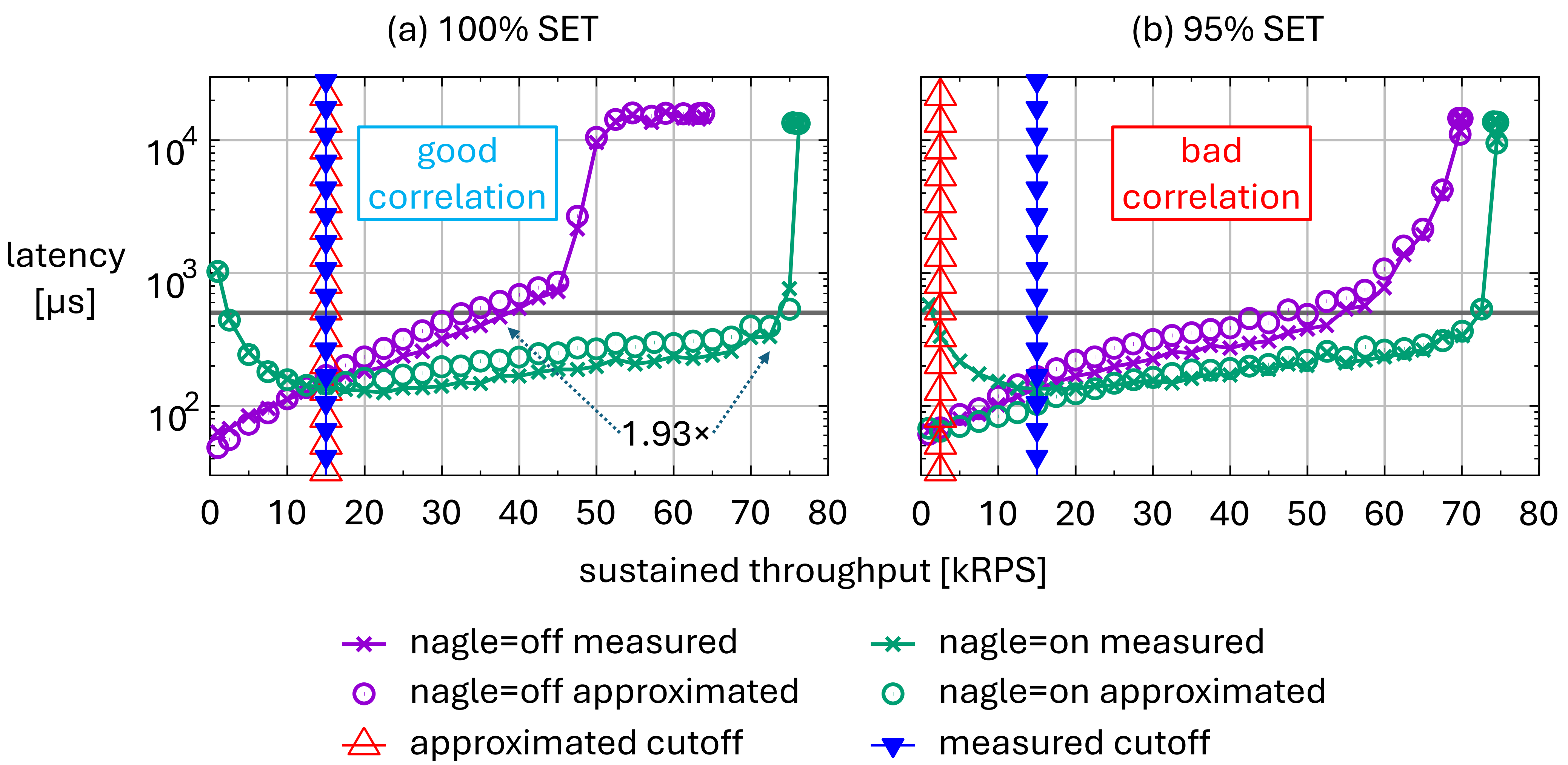
- *Offline prototype – shows potential*
  - Bytes as units
  - No exchange
  - No dynamic toggling – workload runs twice

- Nagle as batching algorithm
- Redis as server app
  - Hardcoded to disable Nagle
- Lancet as client app
  - Measures latency for varying load rates

Evaluation


(a) 100% SET
latency [μs]
10^4
10^3
10^2
500μs SLO
1.93×
0
10
20
30
40
50
60
70
80
sustained throughput [kRPS]
nagle=off measured
nagle=off approximated
approximated cutoff
nagle=on measured
nagle=on approximated
measured cutoff

Evaluation


(a) 100% SET
(b) 95% SET
latency [µs]
10^4
10^3
10^2
good correlation
bad correlation
1.93×
0 10 20 30 40 50 60 70 80
sustained throughput [kRPS]
nagle=off measured
nagle=off approximated
approximated cutoff
nagle=on measured
nagle=on approximated
measured cutoff

Future work and challenges

- Dynamic toggling
  - Granularity
  - Policy
- Metadata exchange
- Better batching heuristics

Conclusion

- The success of batching depends on end-to-end performance
- Approximating this information can improve batching