



ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

# Scalability

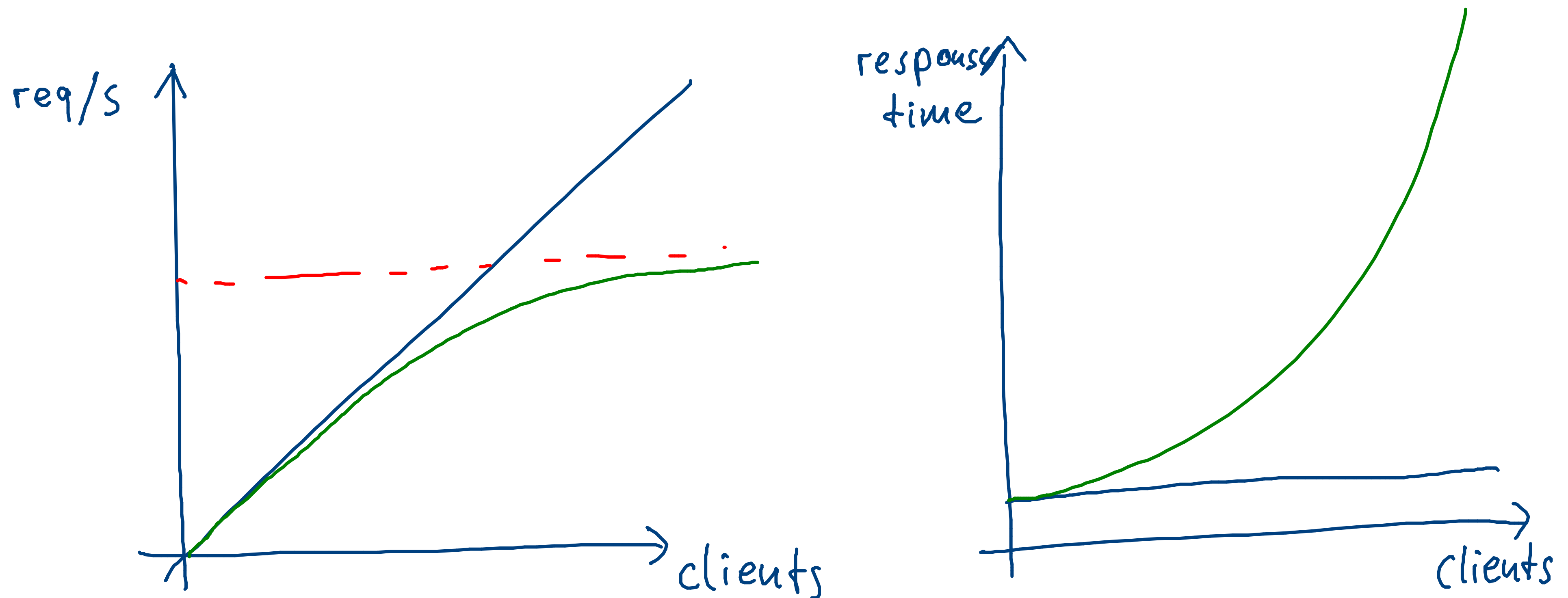
Principles of Reactive Programming

Roland Kuhn

# Scalability

Low performance means the system is slow for a single client.

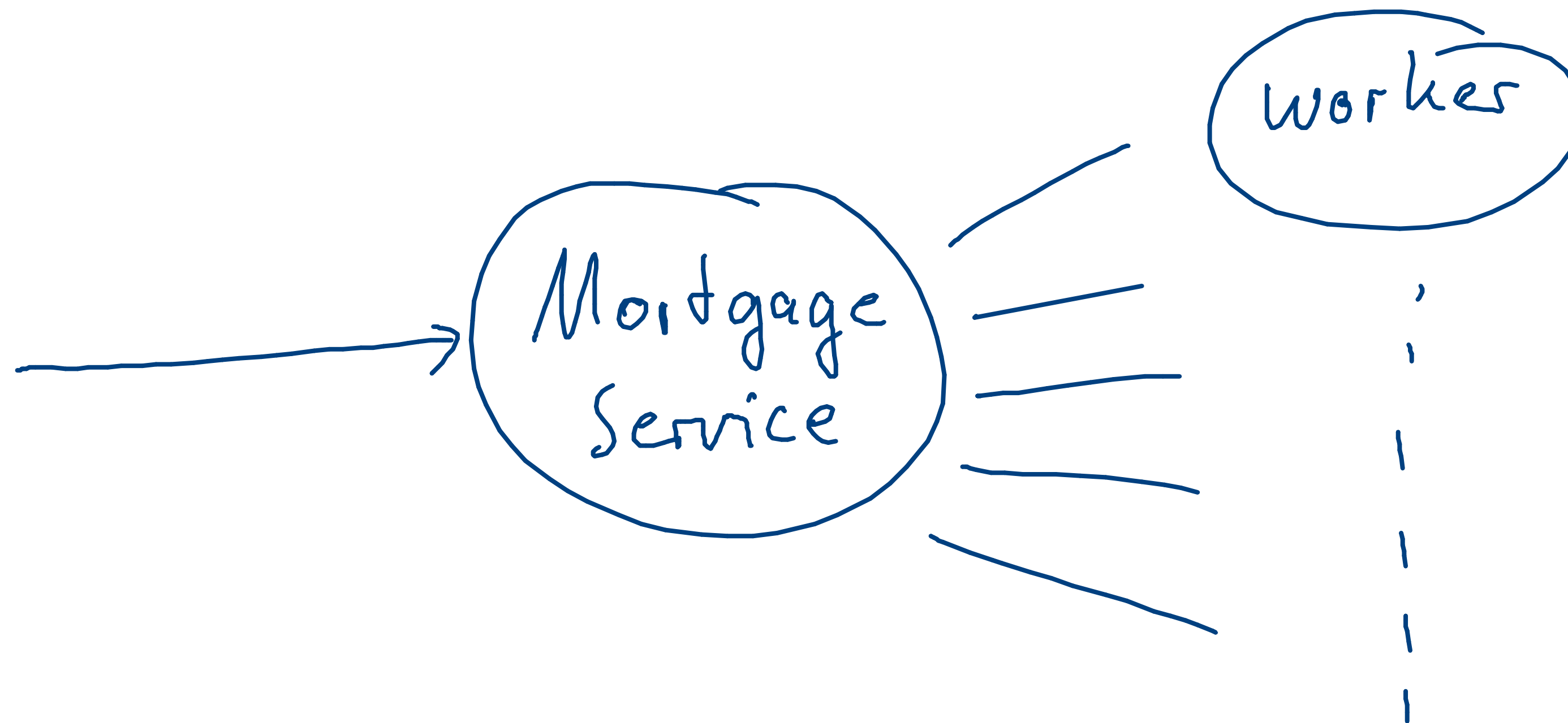
Low scalability means the system is fast when used by a single client but slow when used by many clients.



# Replication of Actors

One actor can process one message at a time.

Stateless replicas can run concurrently.



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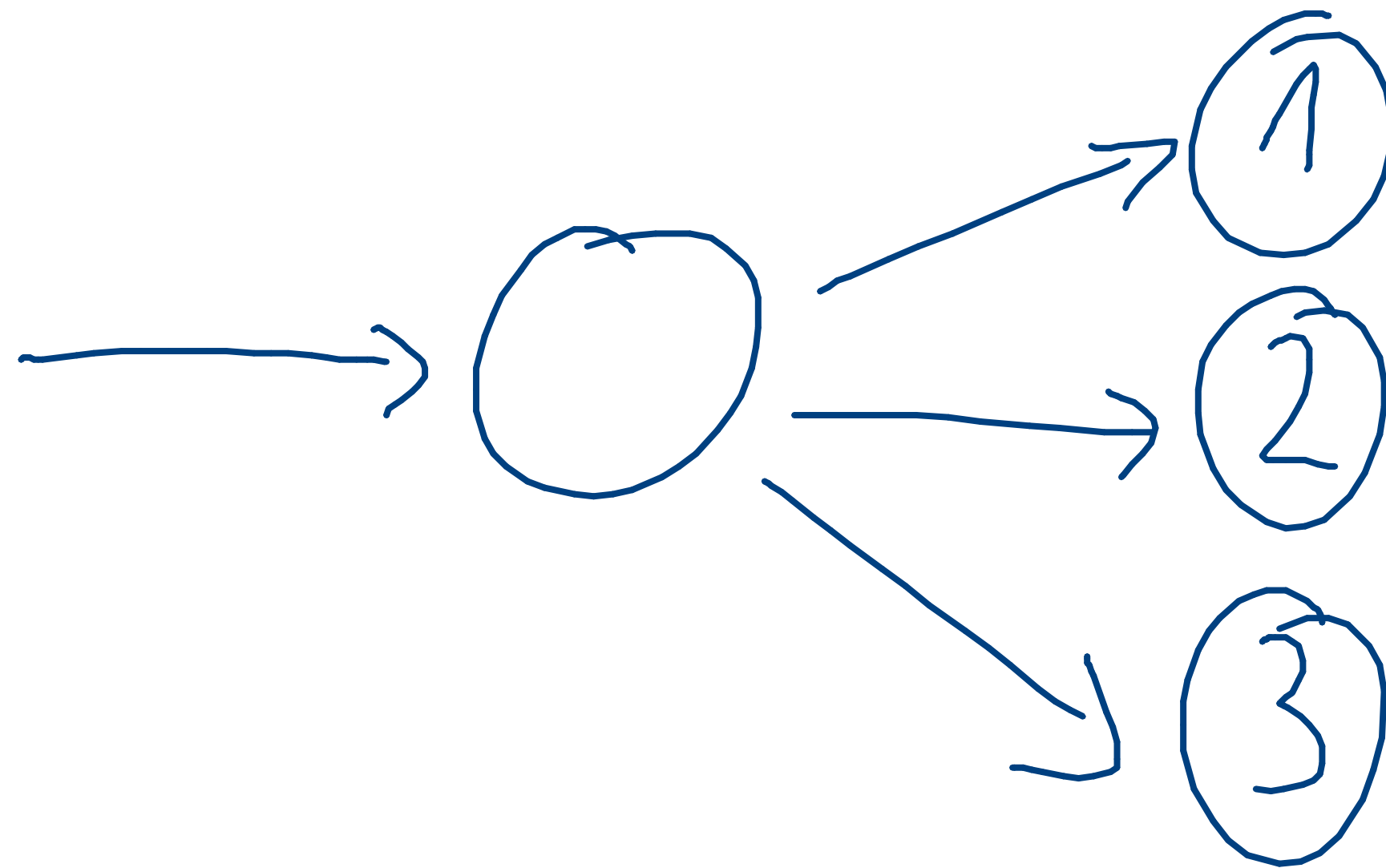
Routing messages to worker pools:

- ▶ stateful (round robin, smallest queue, adaptive, ...)
- ▶ stateless (random, consistent hashing, ...)



# Round-Robin Routing

- ▶ equal distribution of messages to routees
- ▶ hiccups or unequal message processing times introduce imbalance
- ▶ imbalances lead to larger spread in latency spectrum

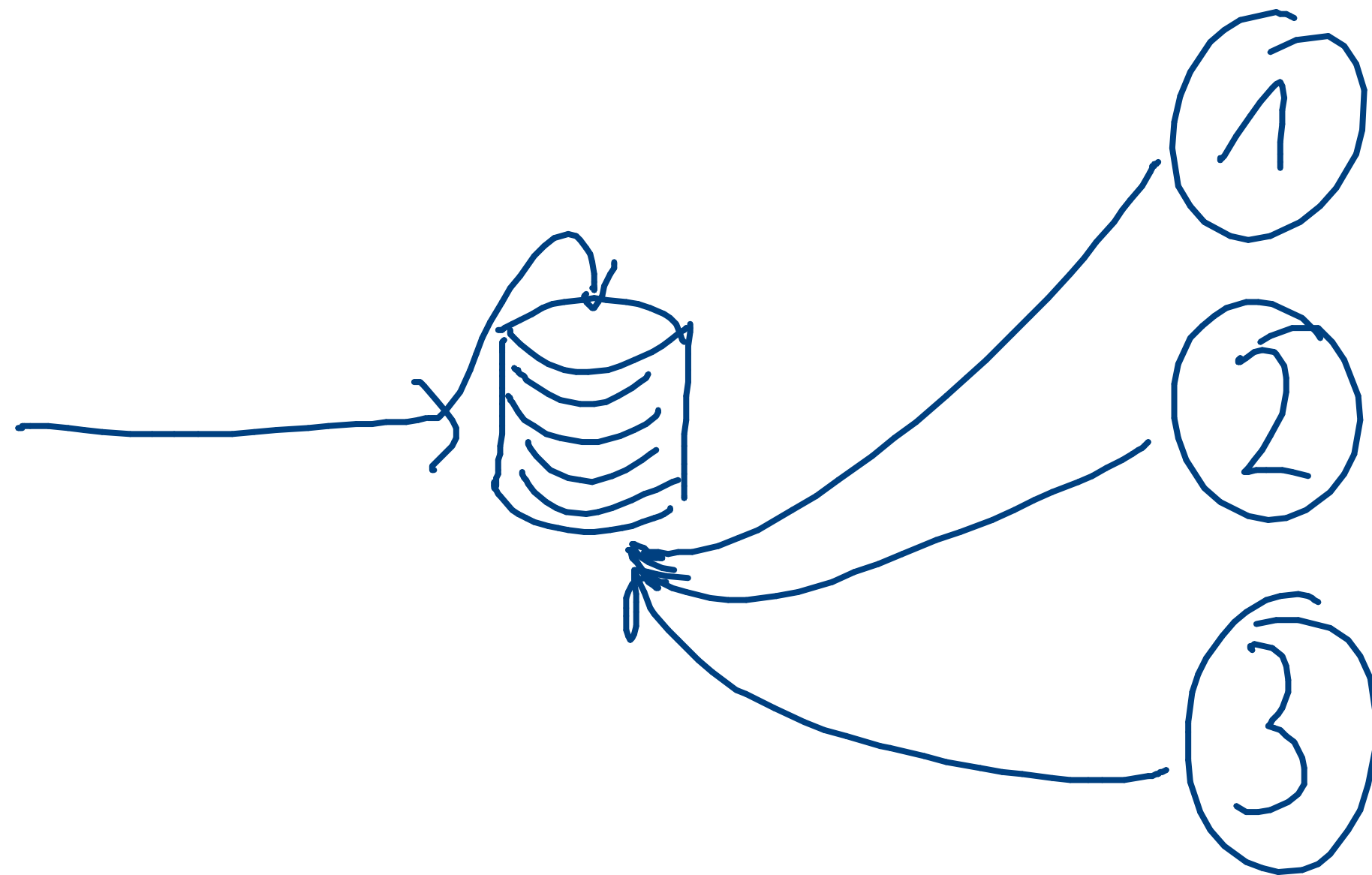


# Smallest Mailbox Routing

- ▶ requires routees to be local to inspect message queue
- ▶ evens out imbalances, less persistent latency spread
- ▶ high routing cost, only worth it for high processing cost

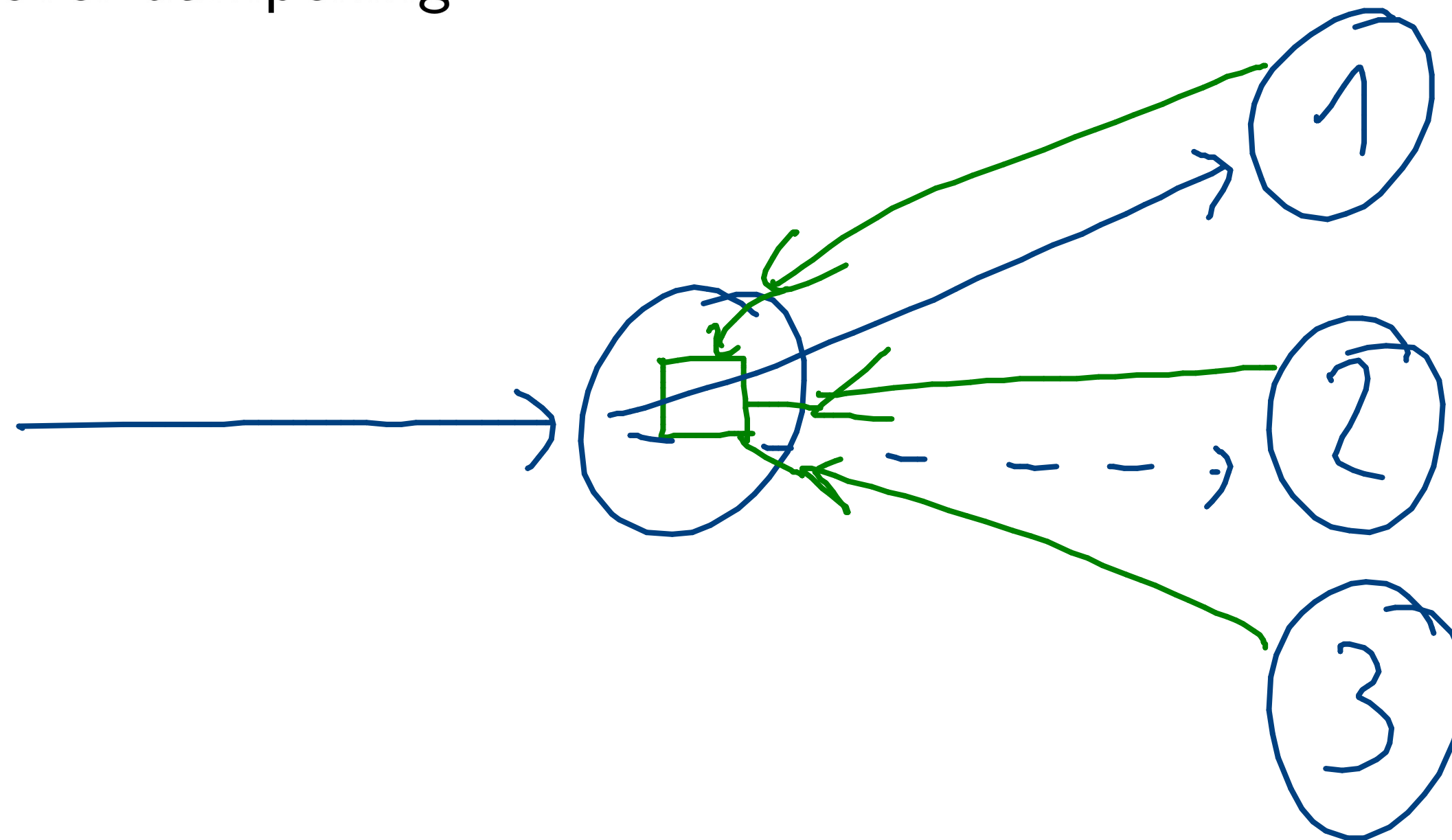
# Shared Work Queue

- ▶ requires routees to be local
- ▶ most homogenous latency
- ▶ effectively a pull model



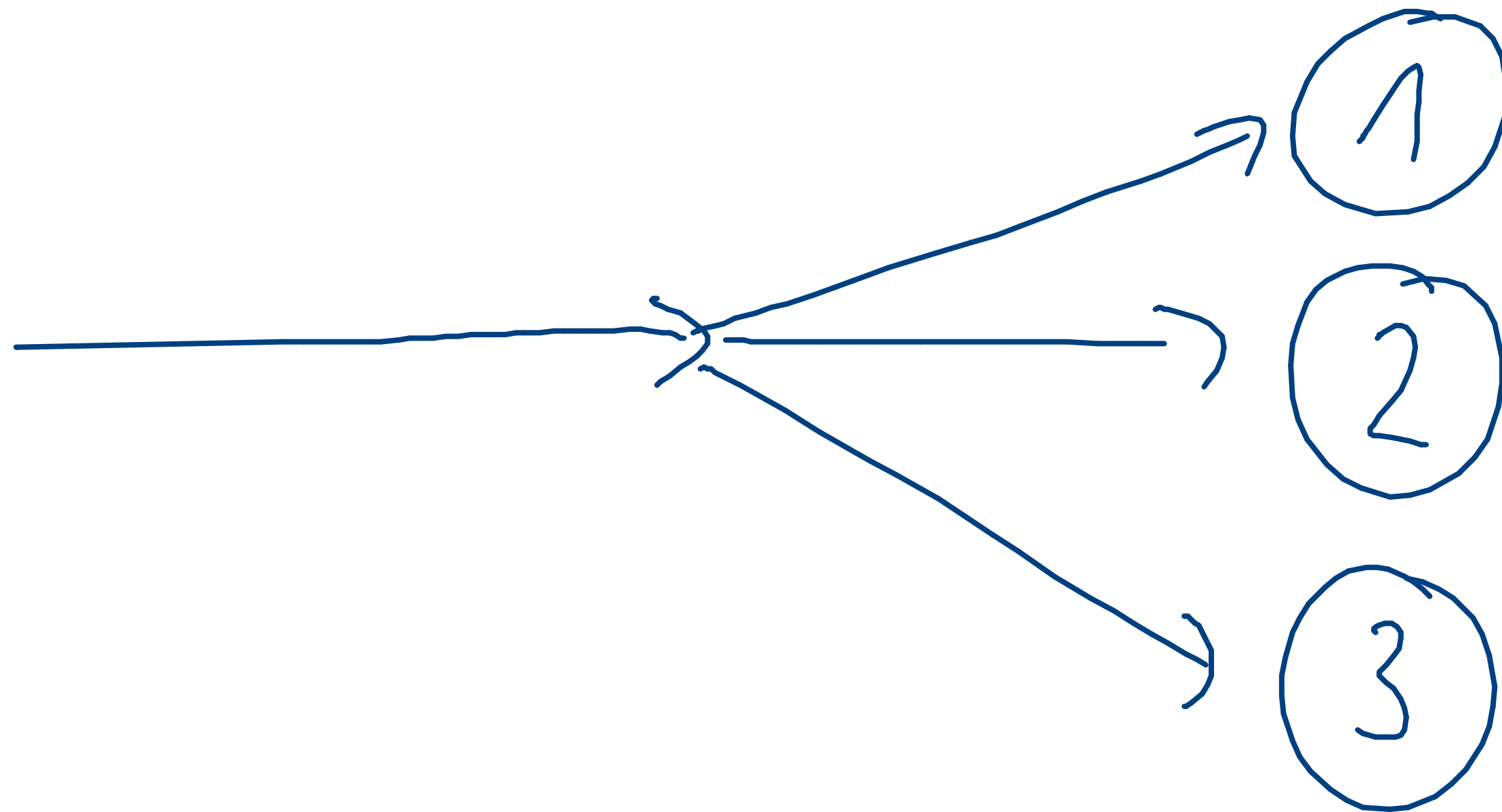
# Adaptive Routing

- ▶ requires feedback about processing times, latencies, queue sizes
- ▶ feedback can be sampled coarsely
- ▶ steering the routing weights subject to feedback control theory
  - ▶ oscillations
  - ▶ over-dampening



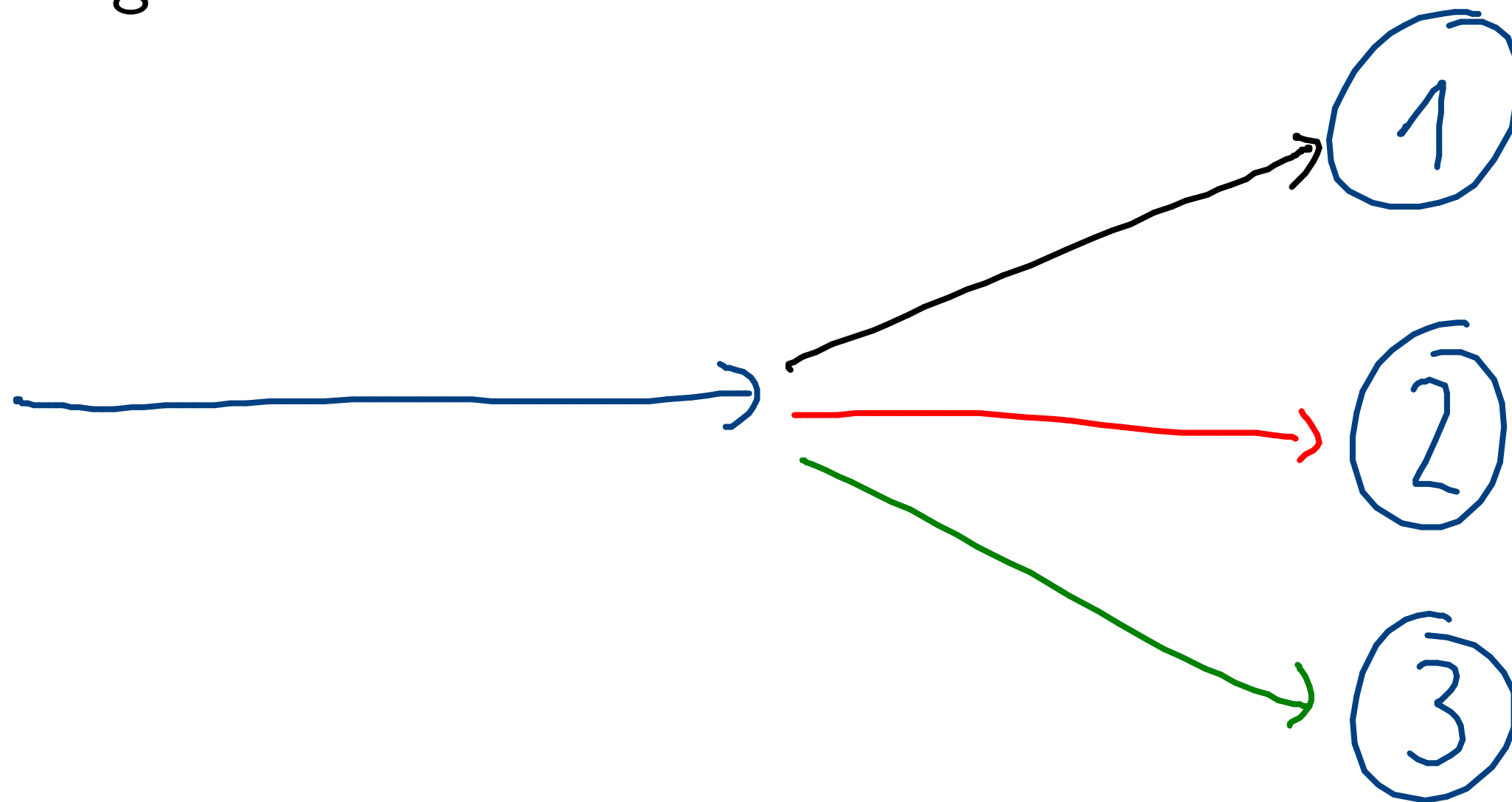
# Random Routing

- ▶ asymptotically equal distribution of messages to routees
- ▶ no shared state necessary: low routing overhead
- ▶ works with several distributed routers to the same routees
- ▶ can stochastically lead to imbalances



# Consistent Hashing

- ▶ splitting incoming message stream according to some criterion
- ▶ bundle substreams and send them to the same routees consistently
- ▶ can exhibit systematic imbalances based on hashing function
- ▶ different latencies for parts of the input spectrum
- ▶ no shared state necessary between different routers to the same targets



# Replication of Stateful Actors

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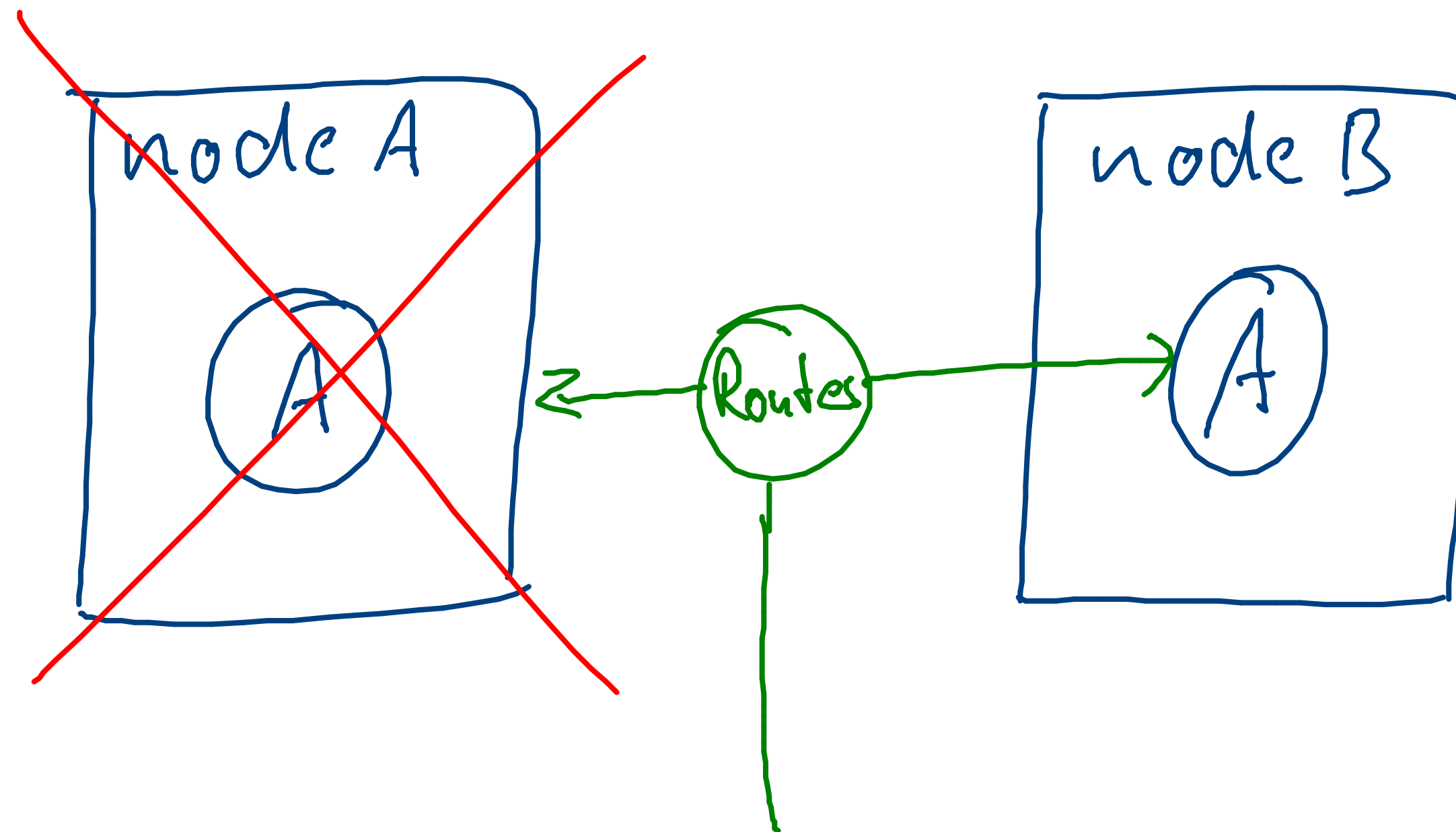
Multiple writers to the same state require appropriate data structures and are eventually consistent.





# Replication of Stateful Actors

- ▶ based on persisted state
- ▶ only one instance active at all times
- ▶ consistent routing to the active instance
- ▶ possibly buffering messages during recovery
- ▶ migration means recovery at a different location



# Summary

Asynchronous message passing enables vertical scalability.

Location transparency enables horizontal scalability.