Syllabus

- Introduction to fault-tolerant distributed systems
- Models of distributed systems and related faults
- Data replication
- Distributed consensus
- **State machine replication**
- Database replication

State machine replication

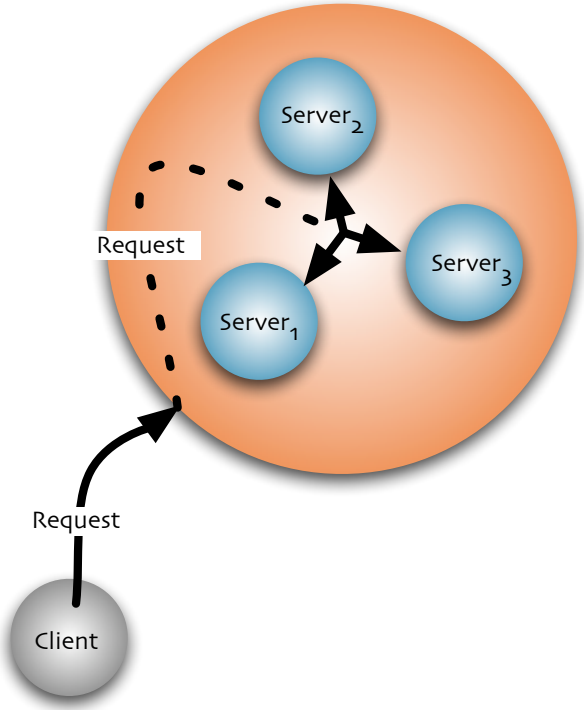
- Active replication
- Passive replication
- A functional model of replication
- Replica integration
- (Replica consistency)

State machine replication

- We now consider the **replication of any generic function:** a function differs from the previous read and write operations as they might read and write any finite set of state variables and return some value as the result of executing some arbitrary code
- Model
  - Asynchronous sequential client and server processes
  - Asynchronous reliable communication channels
  - Omissions faults
  - Consensus is solvable
- In this chapter we review the two major function replication techniques of **state machine replication**: active and passive replication

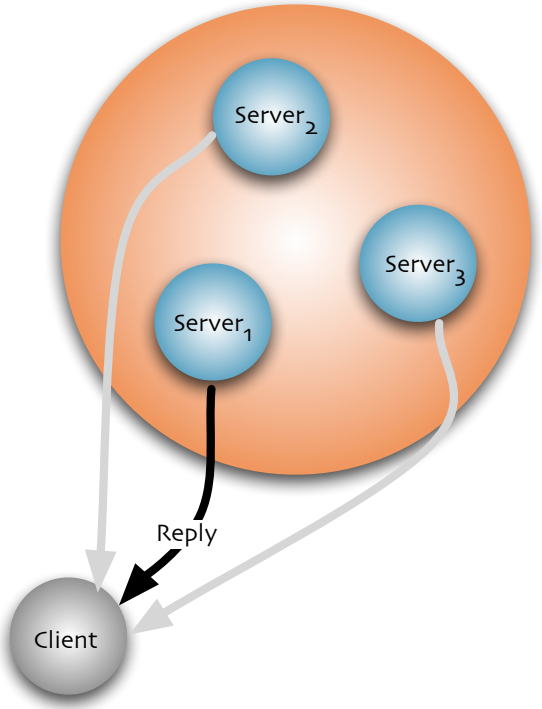
State machine replication

Active replication



1.
Request is sent to all the replicas: client uses **abcast** or uses any replica as proxy.

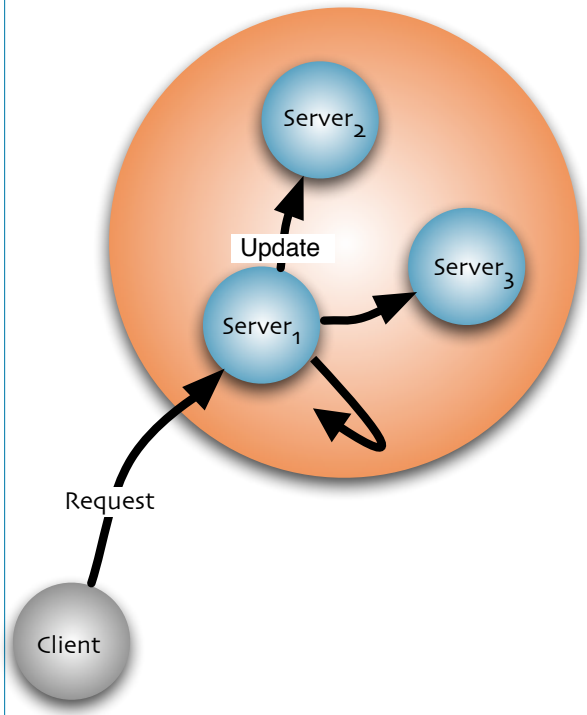
2.
Each replica processes the request, updates its own state, and replies to the client, or its proxy.



3.
Client, or proxy, waits until it receives the first response (or a majority of identical responses the Byzantine fault model)

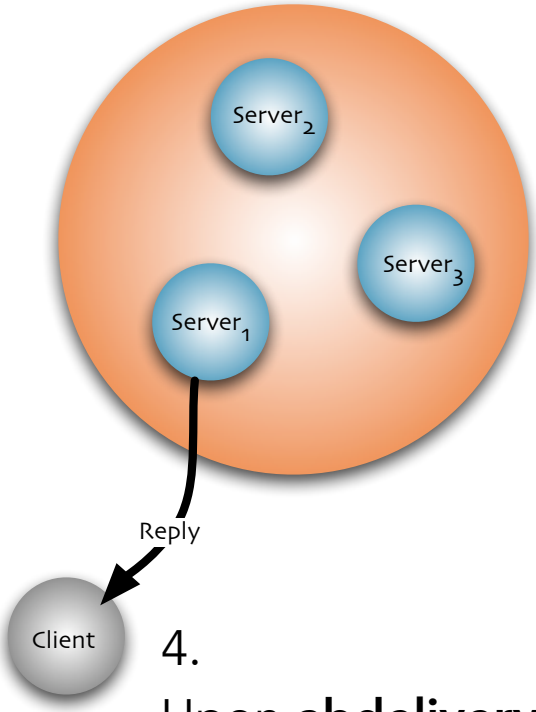
State machine replication

Passive replication or Primary-Backup replication



1.
Request is addressed to a distinguished, primary replica: directly or through any replica

2.
The primary executes the request, updates its own state, and **abcasts** a (request id, state update, reply) message to all other replicas

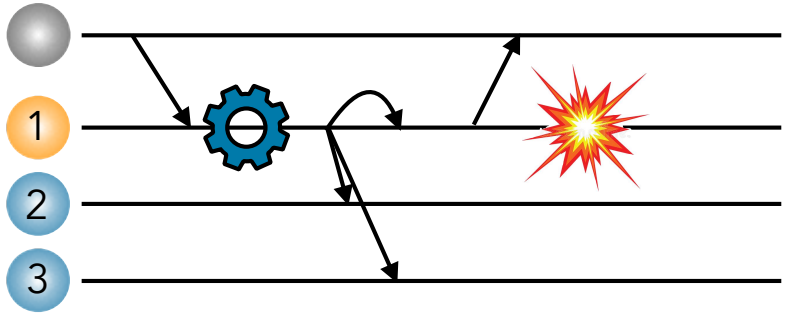


3.
Upon **abdelivery** each replica updates its state

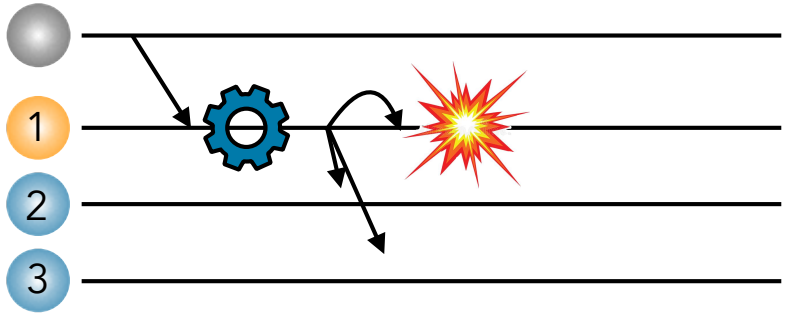
4.
Upon **abdelivery** the primary replies to the client

State machine replication

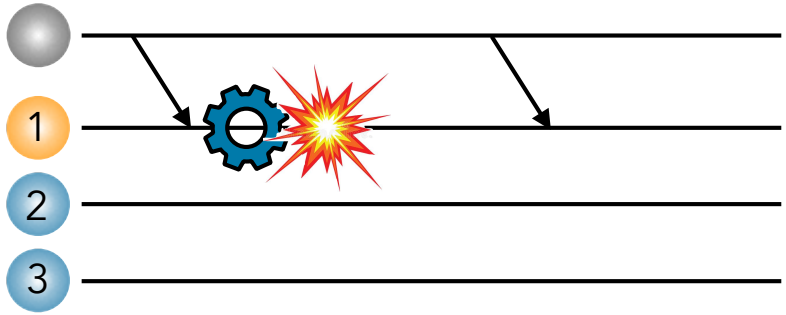
Passive replication or Primary-Backup replication



Transparent for the client



Might not be transparent for the client



Not transparent for the client

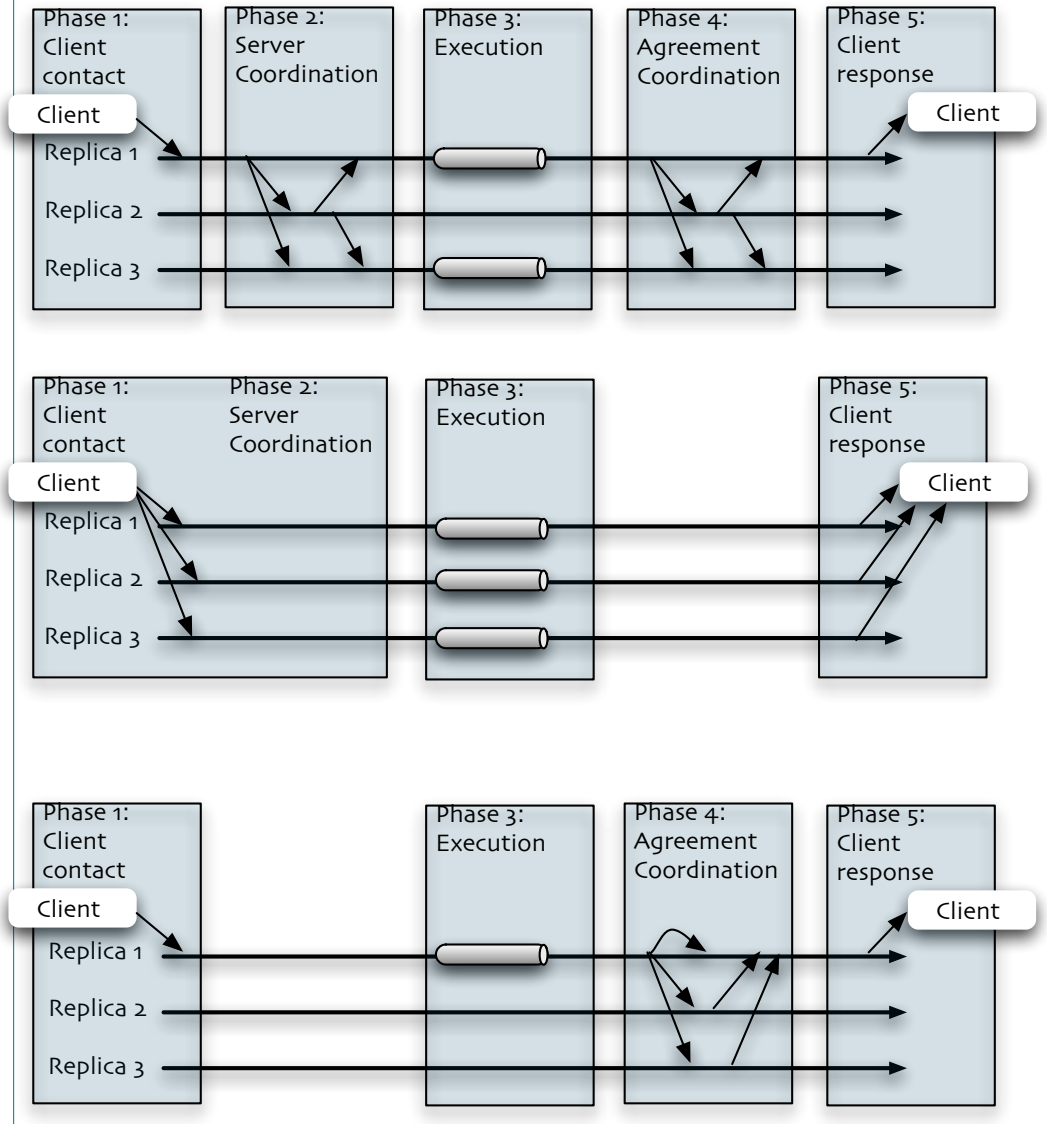
State machine replication

Active vs. Passive replication

Active	Passive
Only deterministic functions	Any function
Replication is transparent	Awarness of a primary replica
Replica failures are transparent	Primary failure can be perceived

State machine replication

A functional model of replication



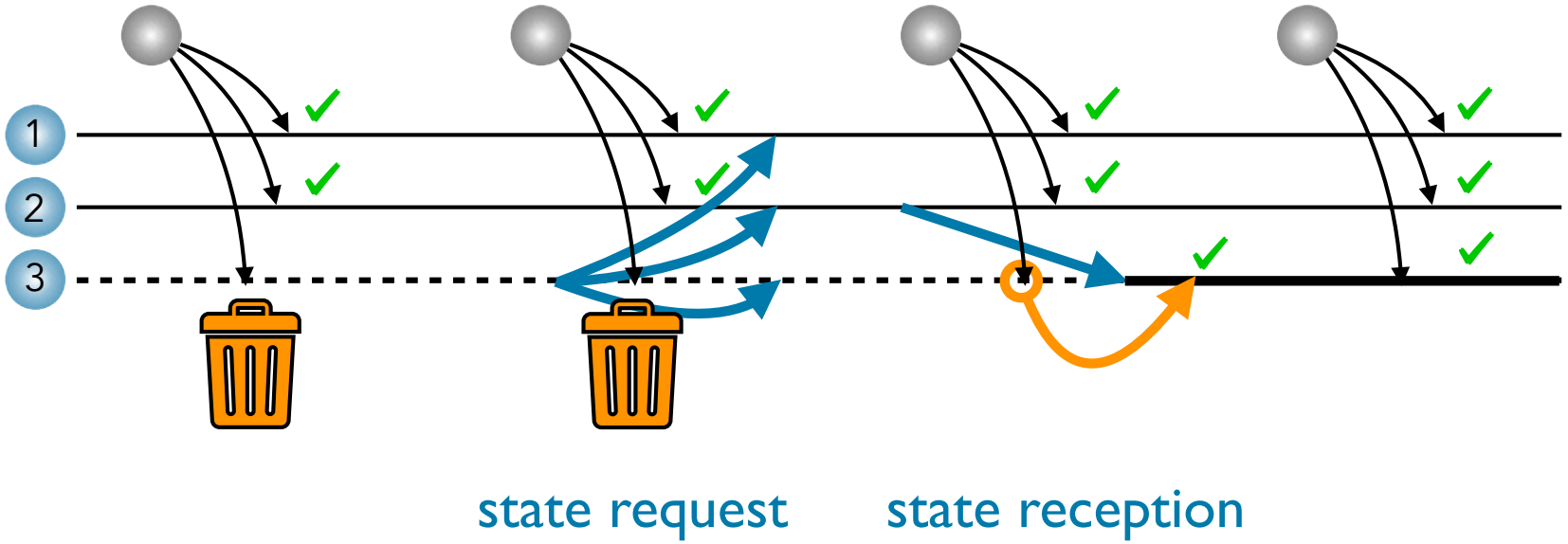
Active Replication

Passive Replication

State machine replication

Replica integration

- To restore or increase the systems resilience we need to add replicas to the system. Before being able to handle any requests the replica's state need to be consistent with the others'.
- Replica integration should be done with minimal disruption to the system's availability and performance. We aim at online integration.



State machine replication

Reading material

- M. Wiesmann, F. Pedone, A. Schiper, B. Kemme, G. Alonso
  "Understanding Replication in Databases and Distributed Systems"
  INTERNATIONAL CONFERENCE ON DISTRIBUTED COMPUTING SYSTEMS (2000)

- R. Guerraoui, A. Schiper
  "Software-Based Replication for Fault Tolerance"
  IEEE COMPUTER (1997)