ZooKeeper: Wait-free coordination for Internet-scale systems

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Presented by Justin Beemer

What is Coordination?

- Configuration Management
- Leader Election
- Group Membership
- Locks & Synchronization Primitives

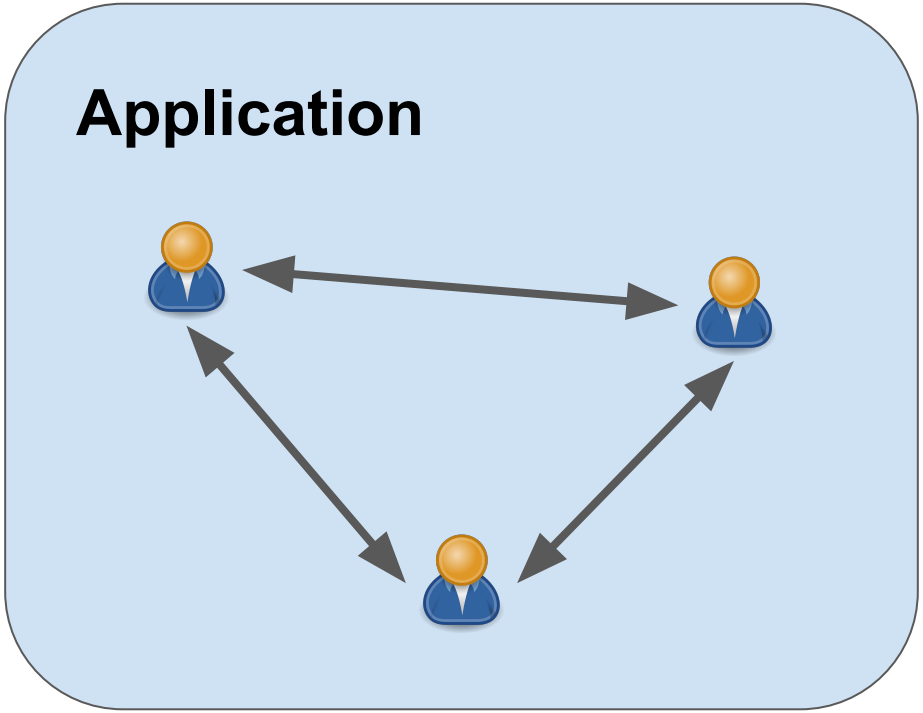
Approach #1: Implement Coordination in the Application

Pros

- Can design and optimize for specific application needs

Cons

- Not reusable
- Really hard to implement correctly



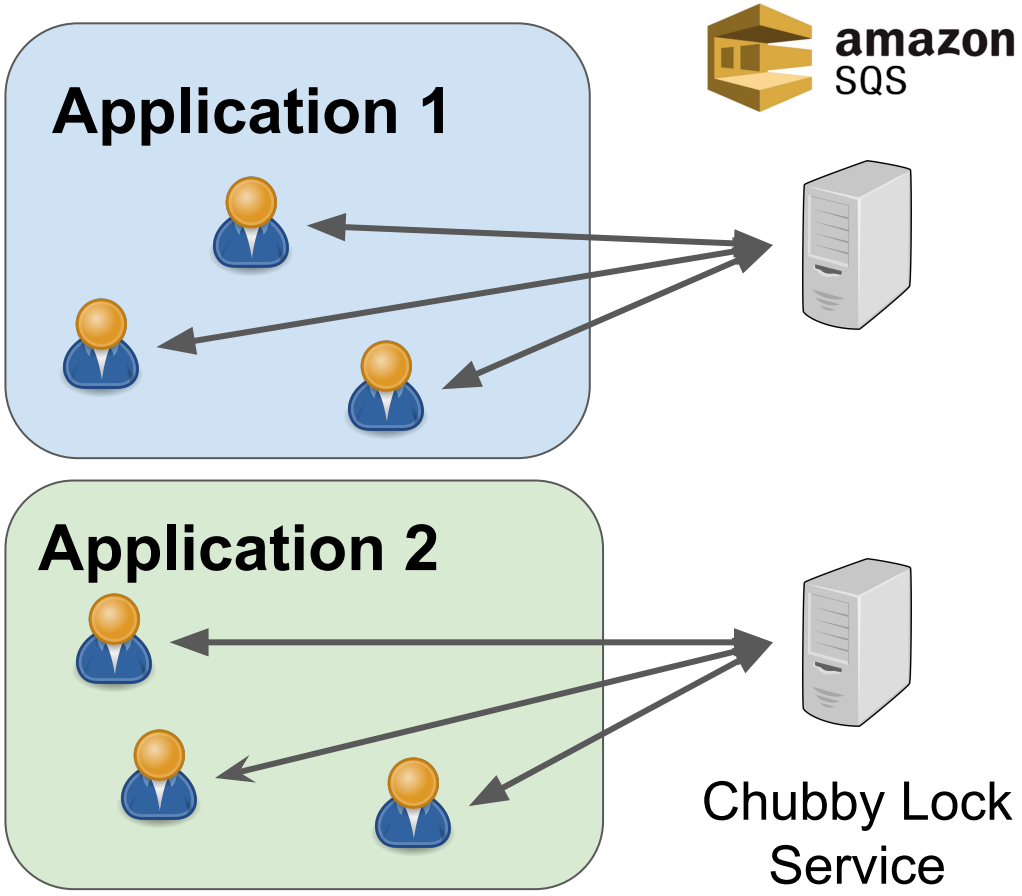
Approach #2: Implement Coordination Services

Pros

- Easier for the client to implement
- Services usable by many applications

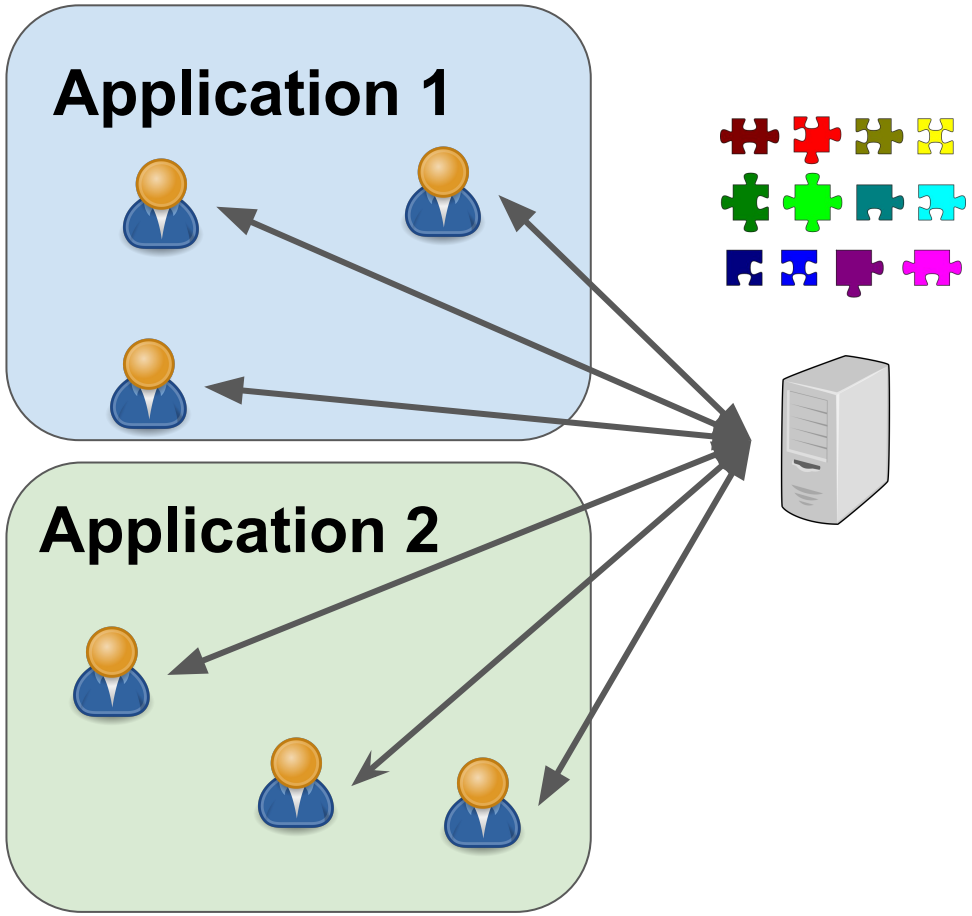
Cons

- May require multiple services
- Flexibility



Best of Both Worlds: Give Clients the Tools

- Single service
- Suitable for many different applications
- Simple for clients to implement
- Can tailor coordination to specific use-cases



What Kind of Tools Are Useful?

- Simple but Powerful
- High Performance
- Fault Tolerant
- Consistent

ZooKeeper

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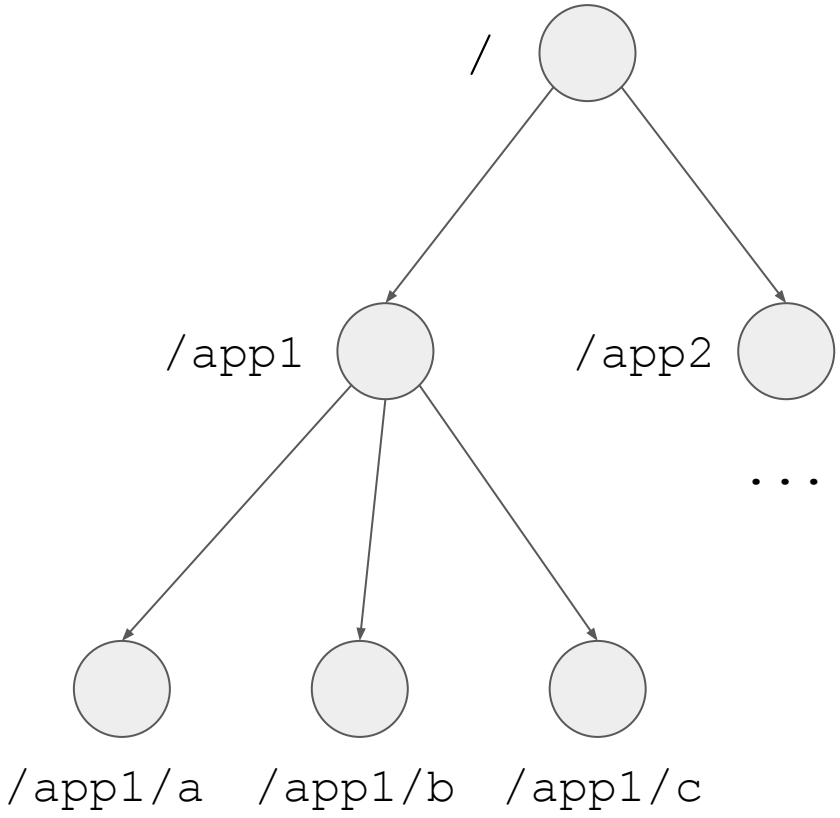
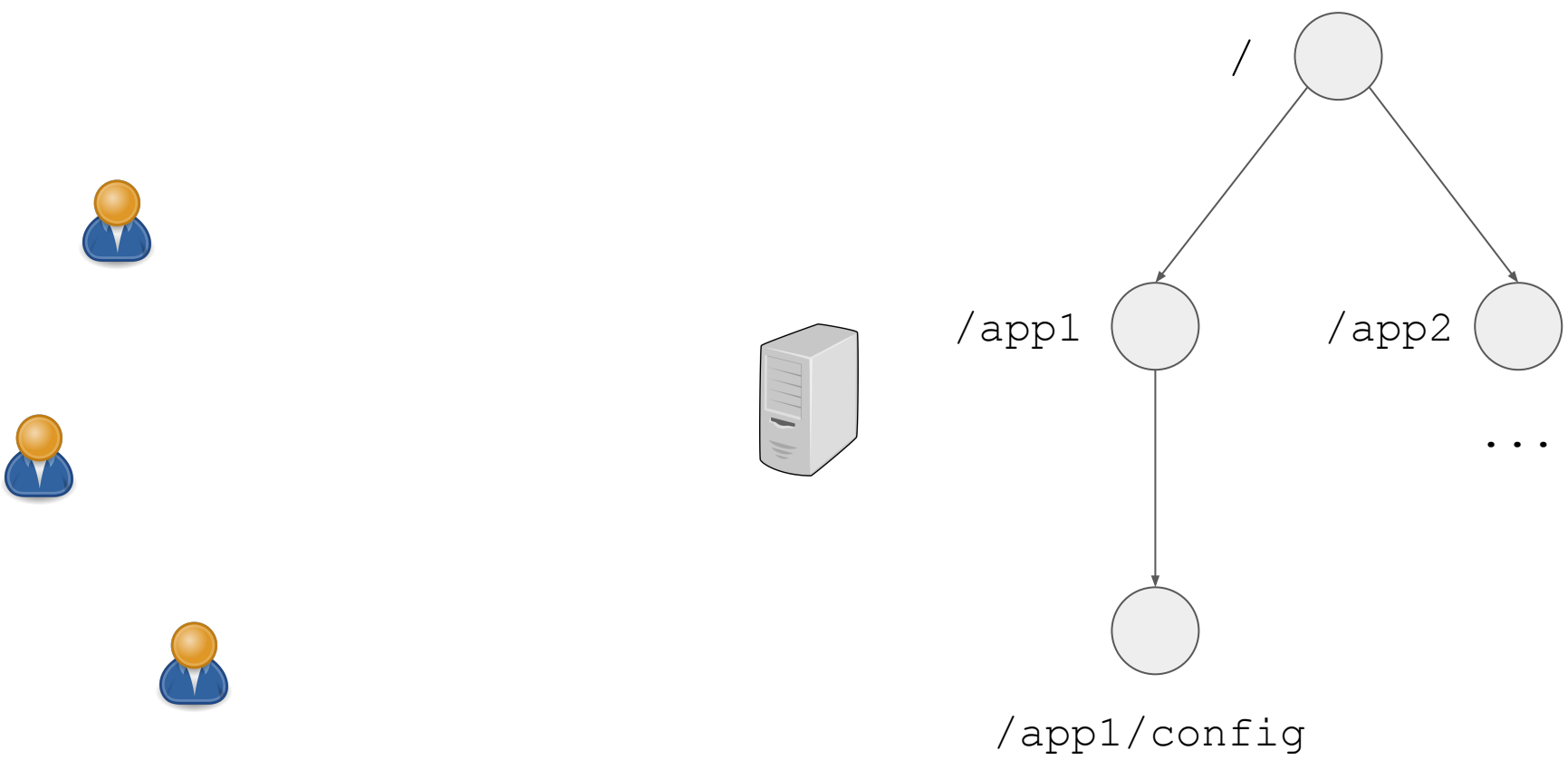


ZooKeeper

ZooKeeper gives clients the abstraction of a set of data nodes arranged in a hierarchical namespace.

- **Watches** notify clients when nodes change.
- **Performance**
  - Wait-free
  - Optimized for reads
- **Consistency**
  - Linearizable writes
  - FIFO ordering for a given client

Configuration Management



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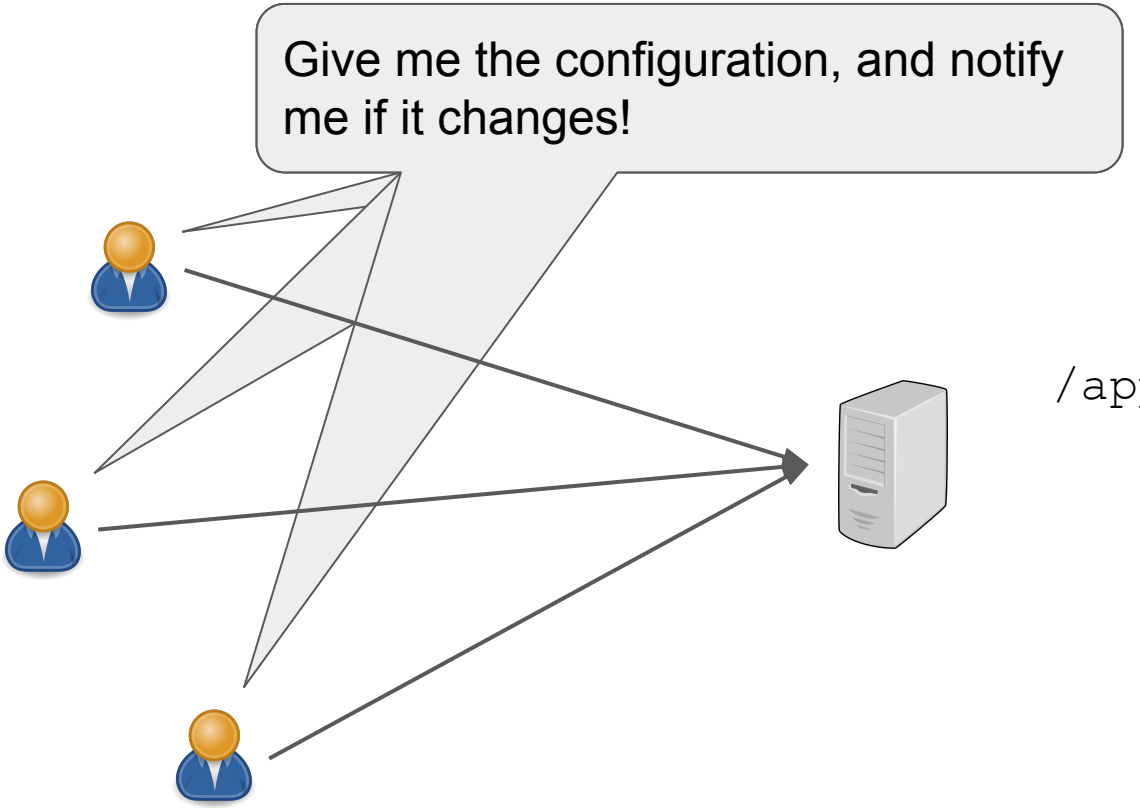

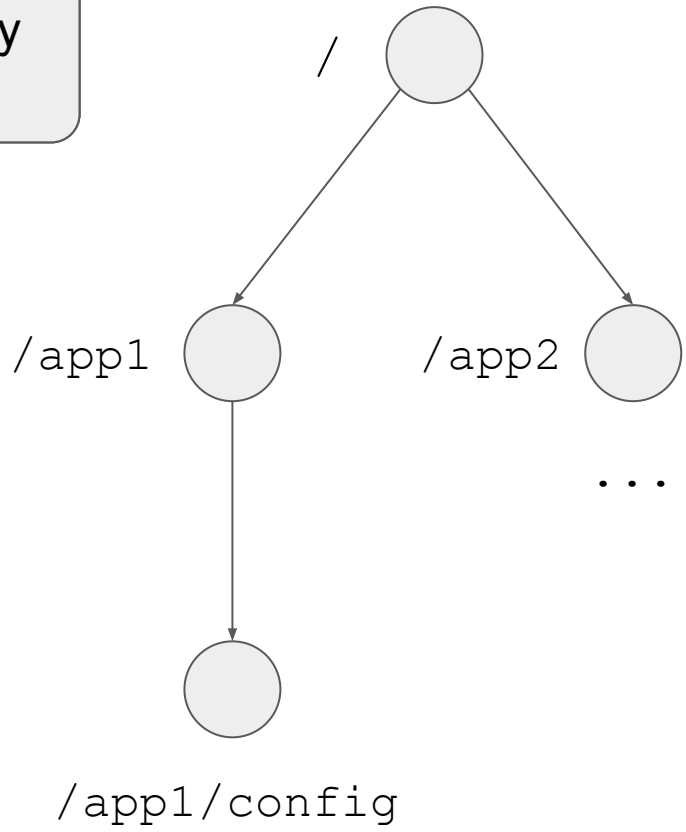

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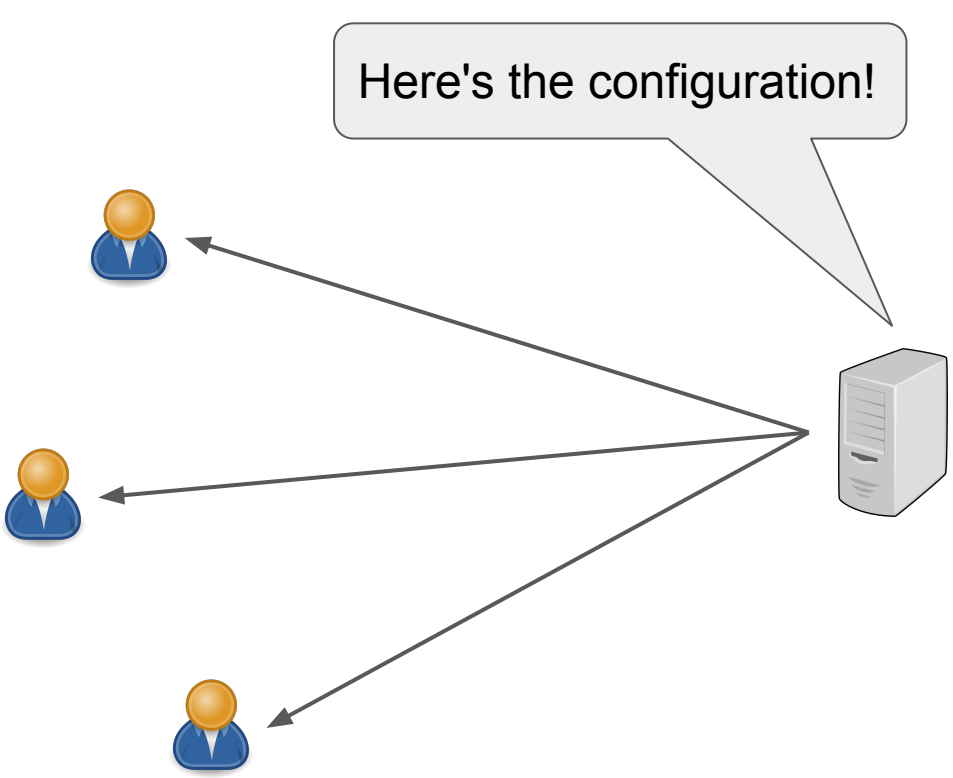

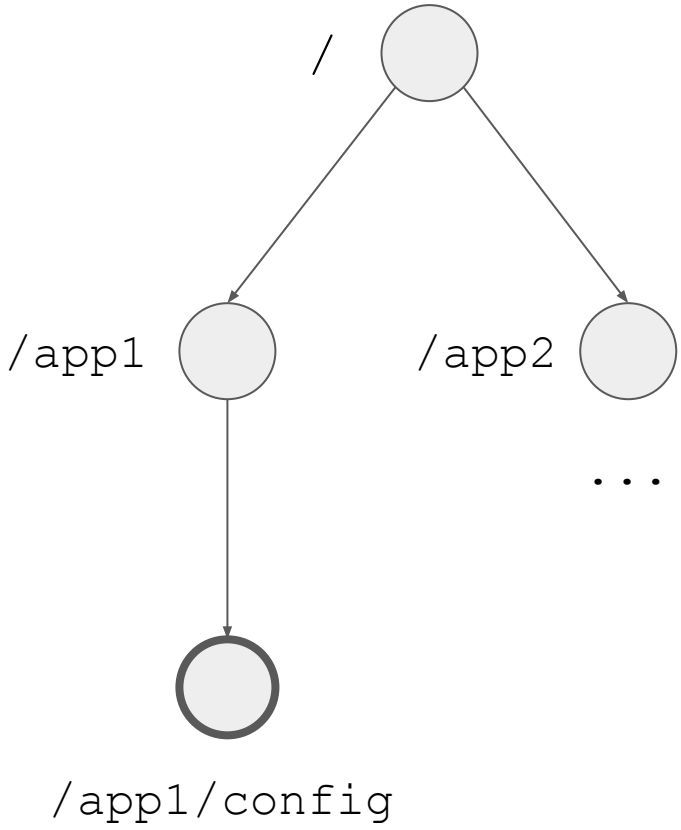

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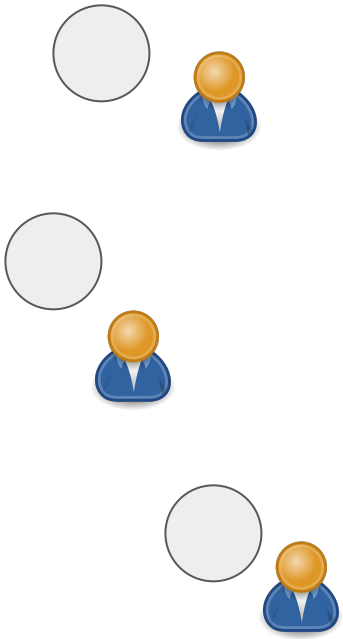

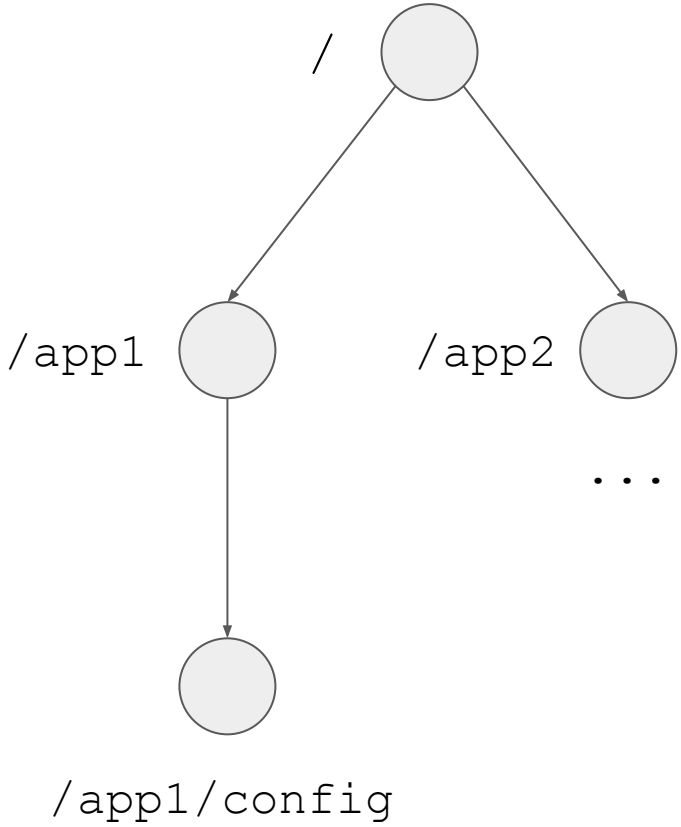

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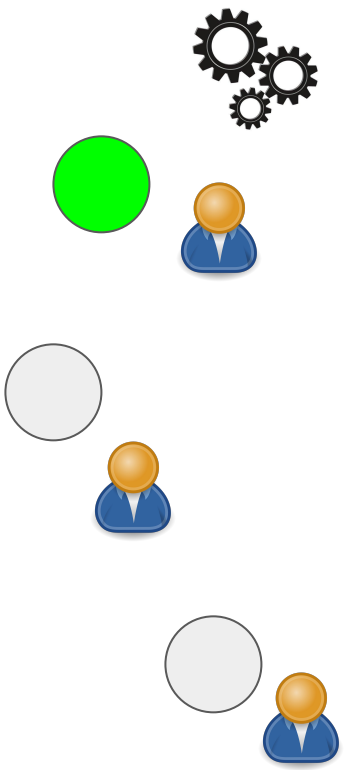

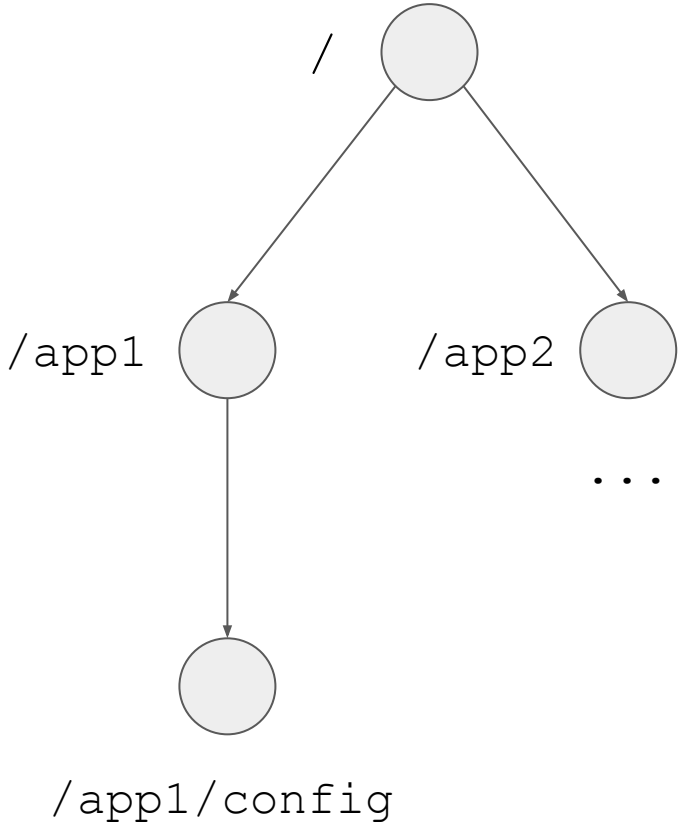

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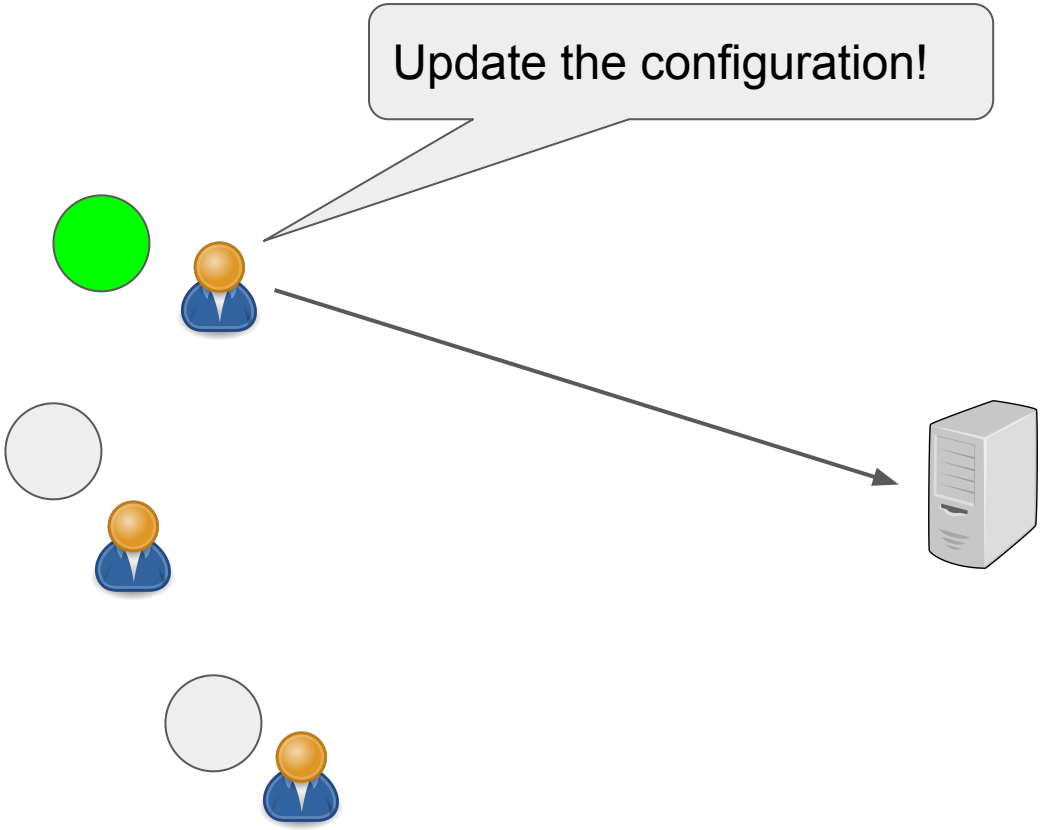

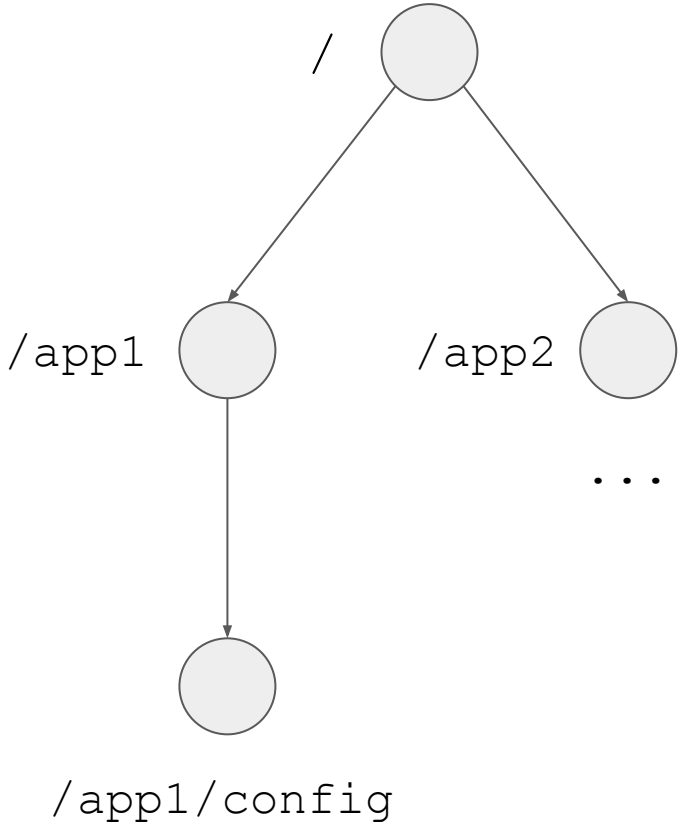

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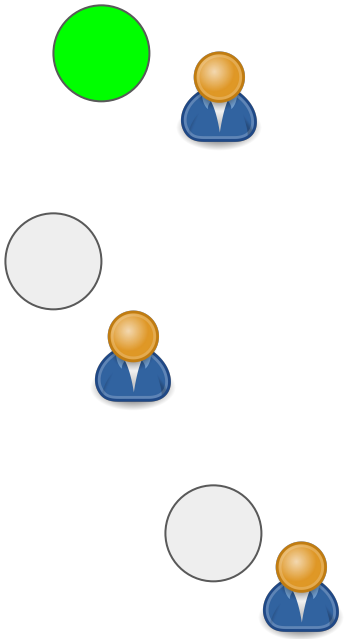

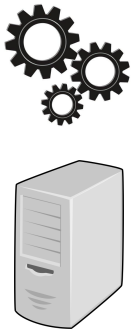

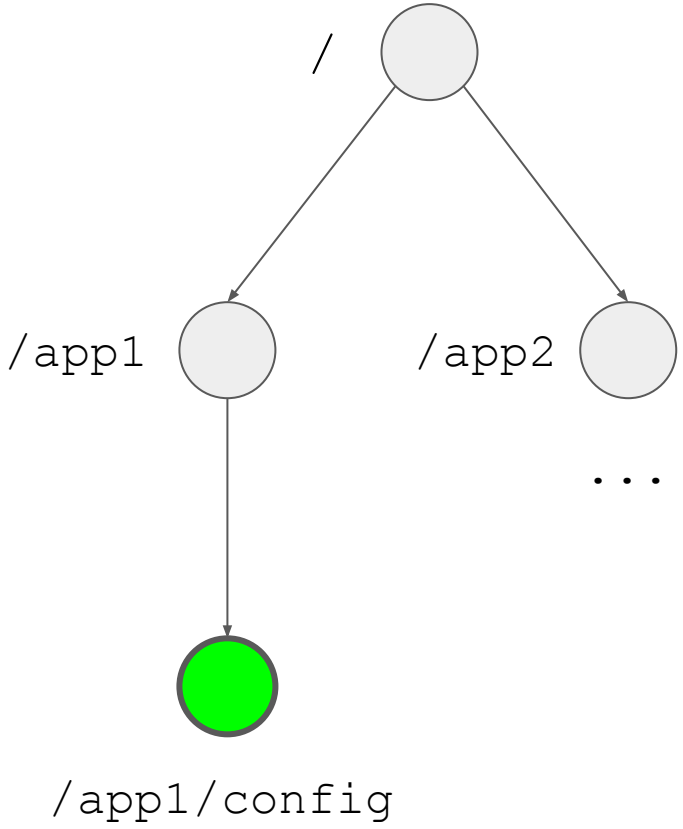

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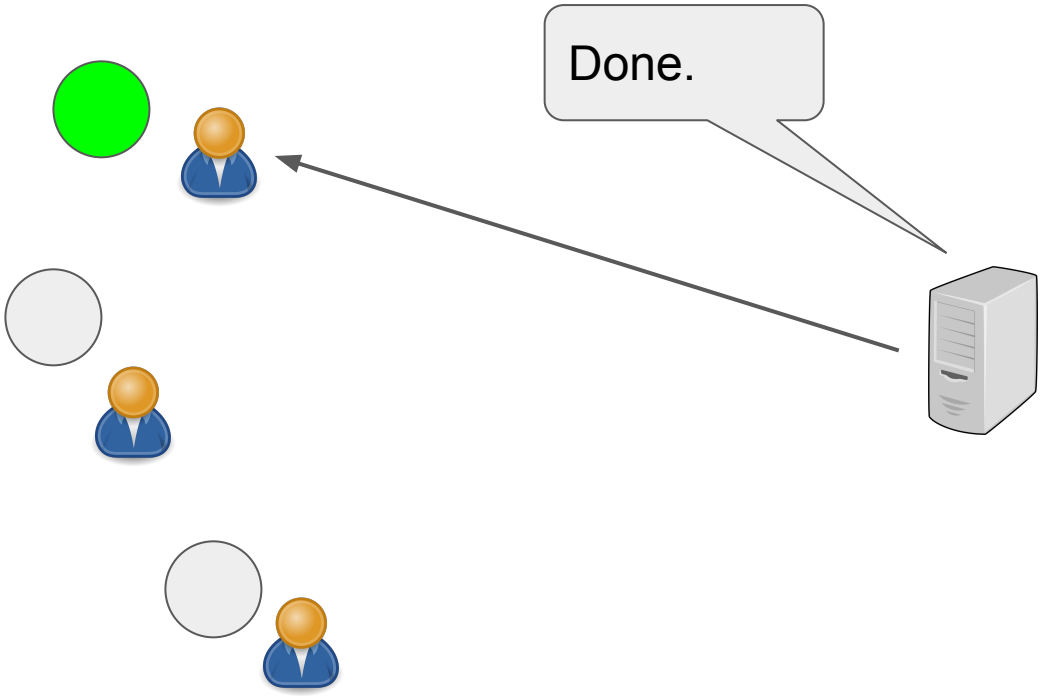

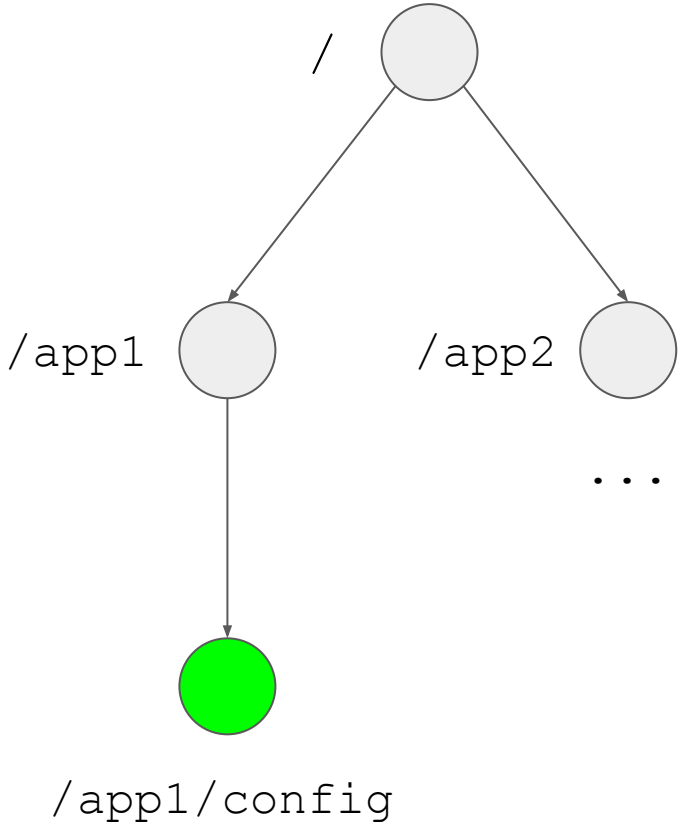

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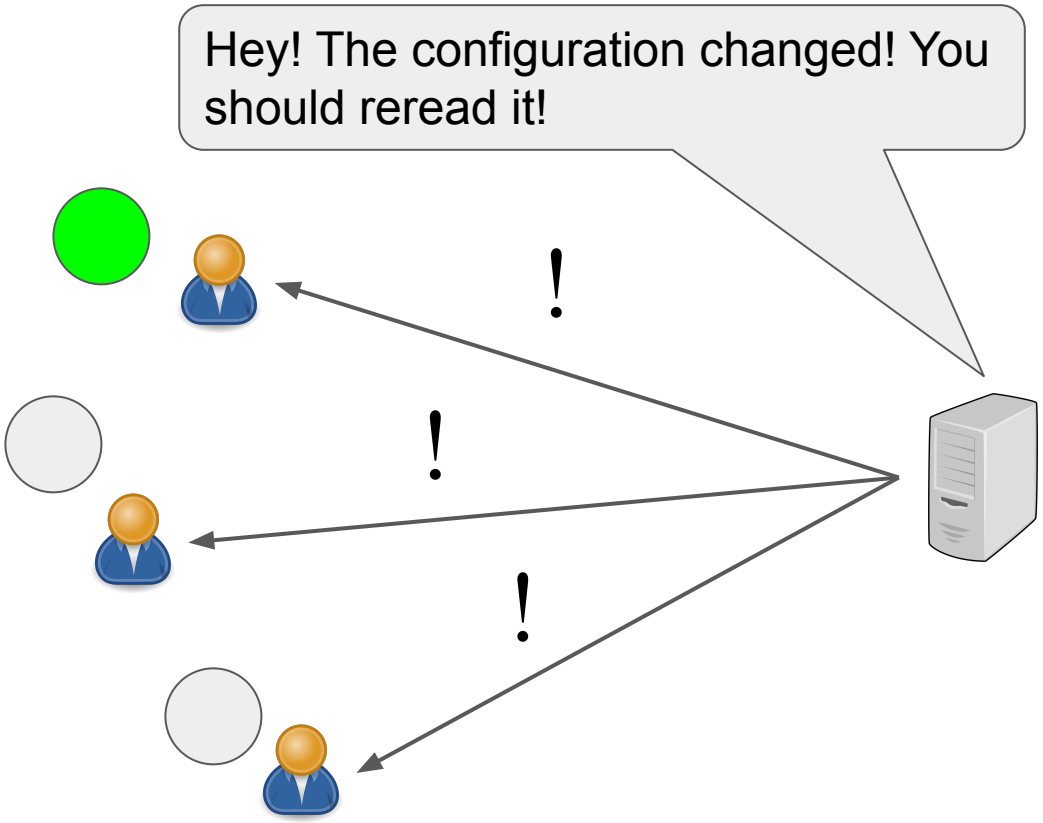

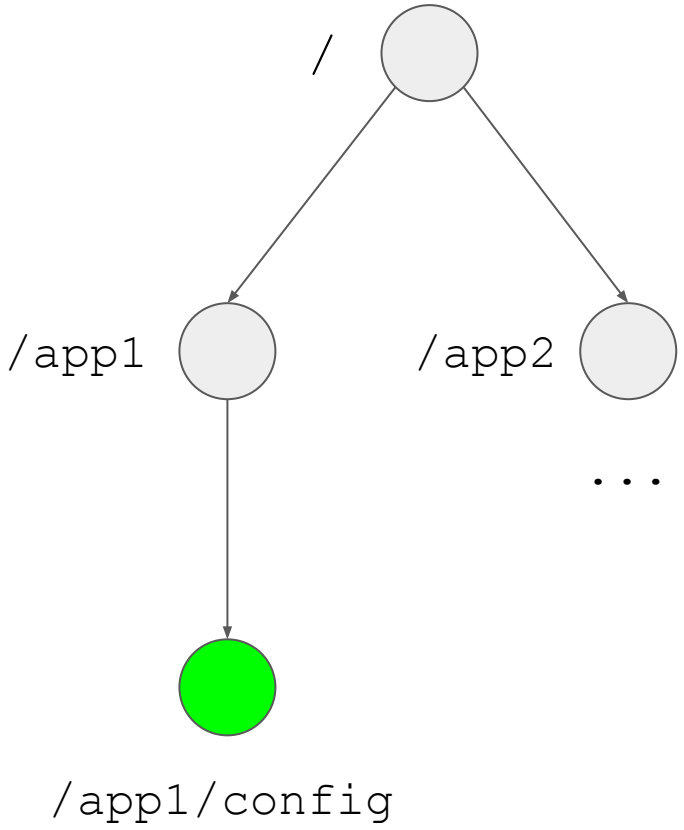

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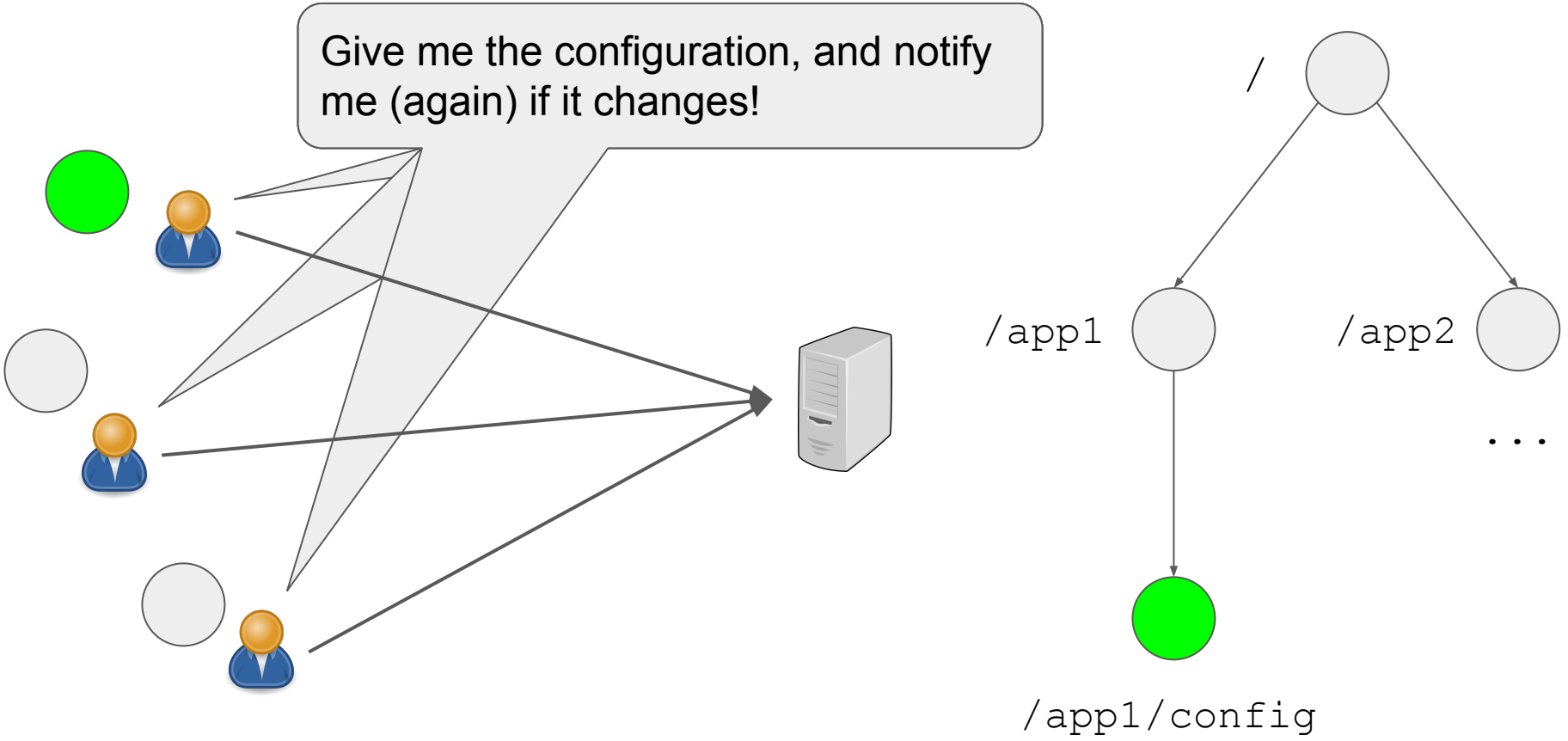

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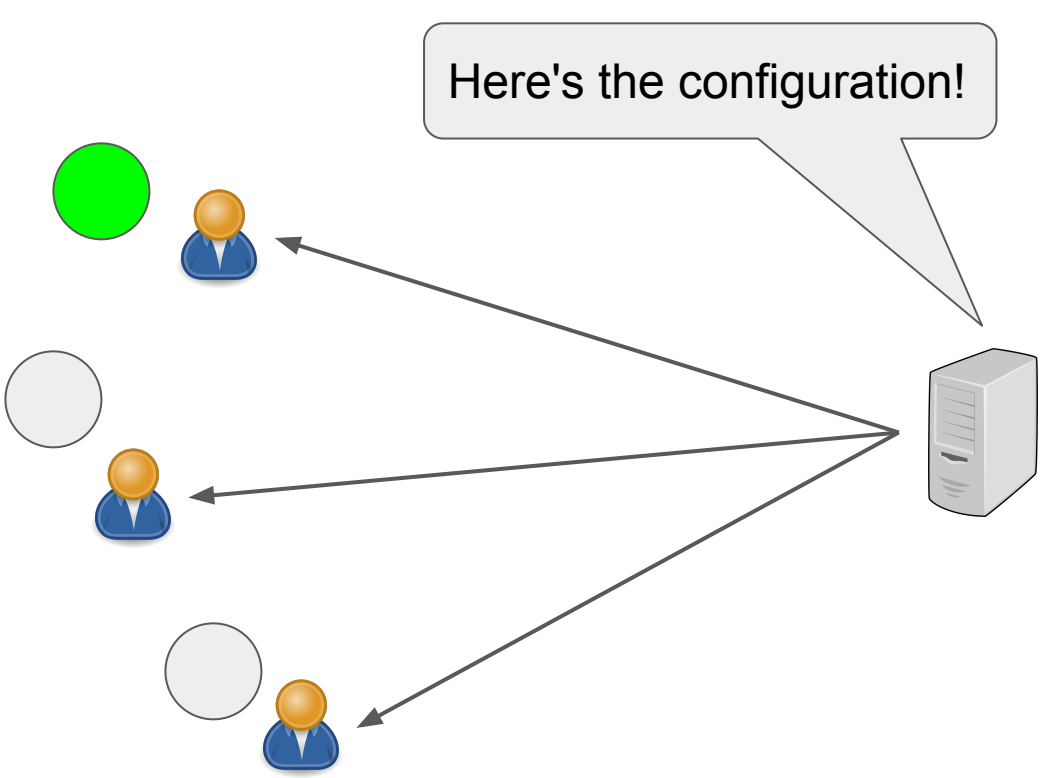

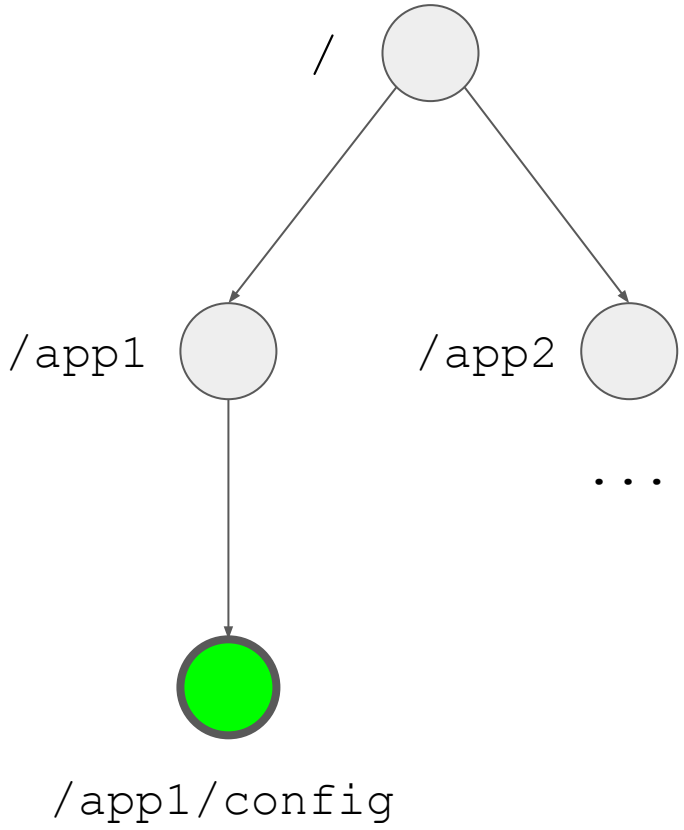

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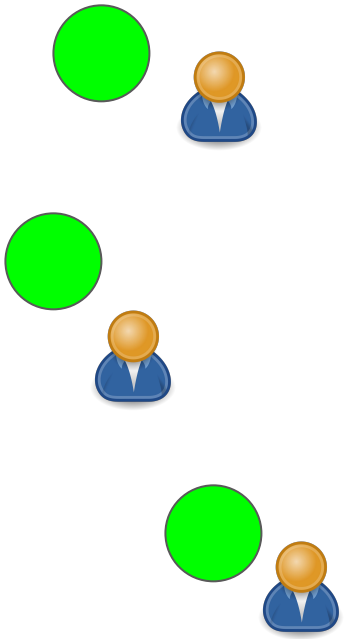

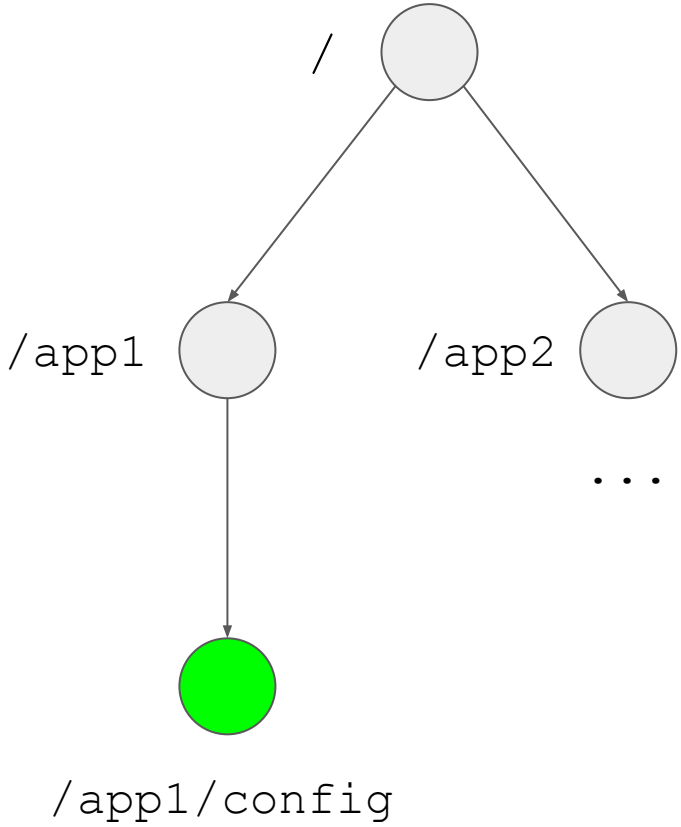

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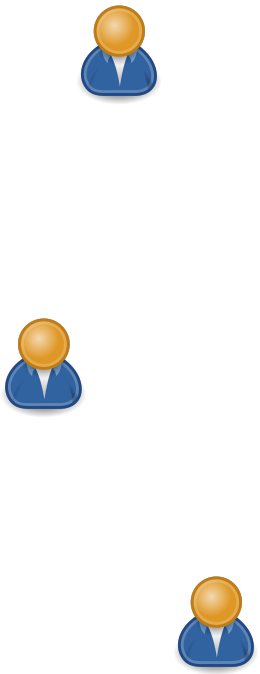

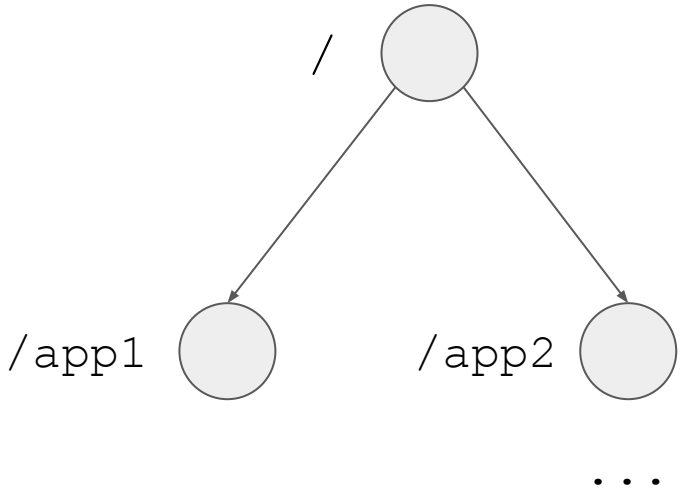

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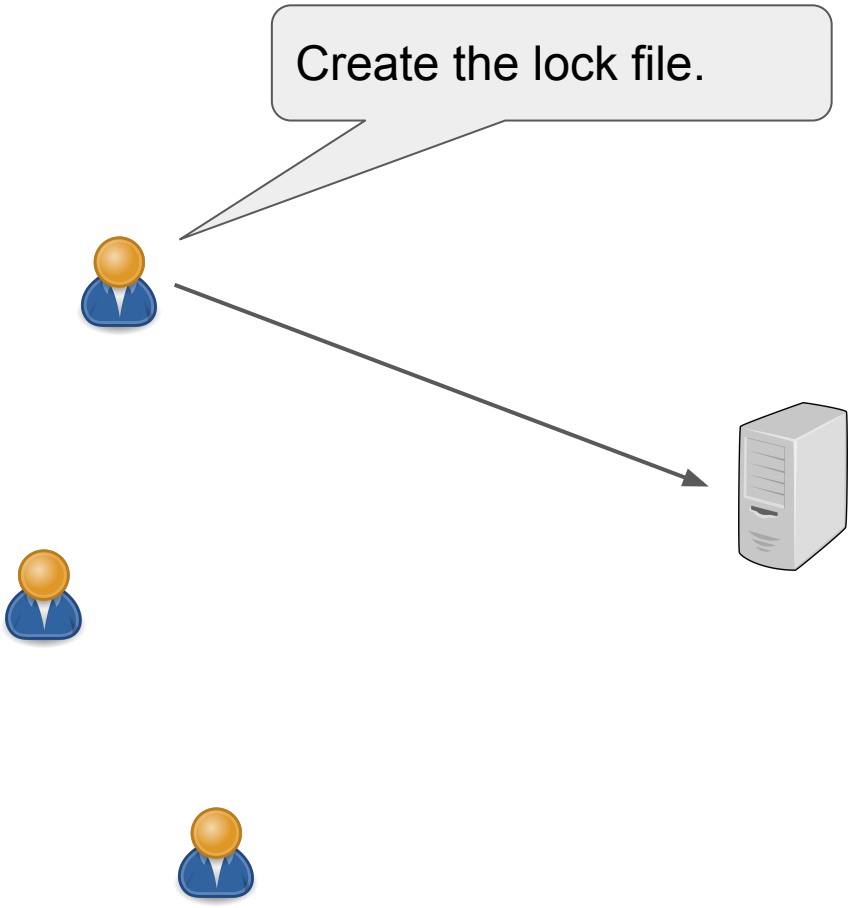

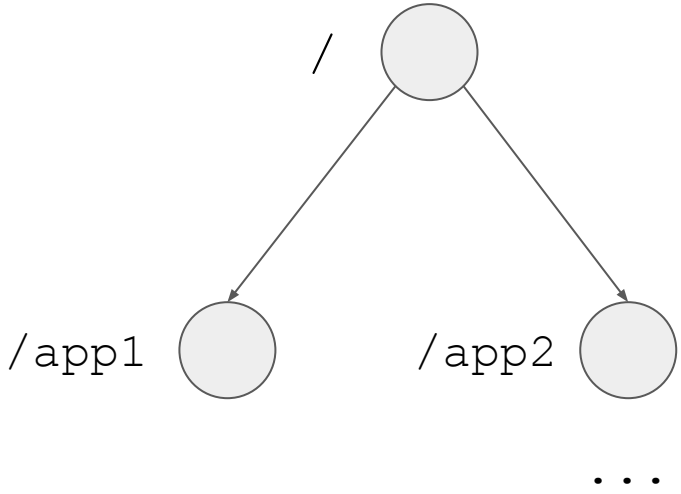

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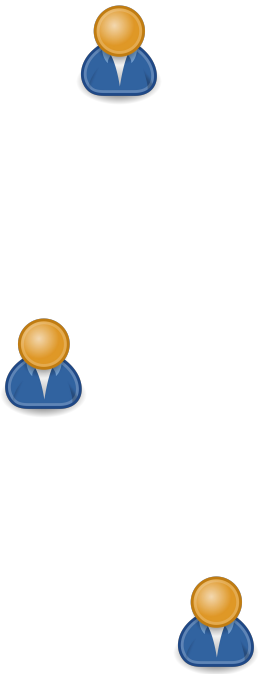

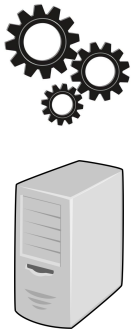

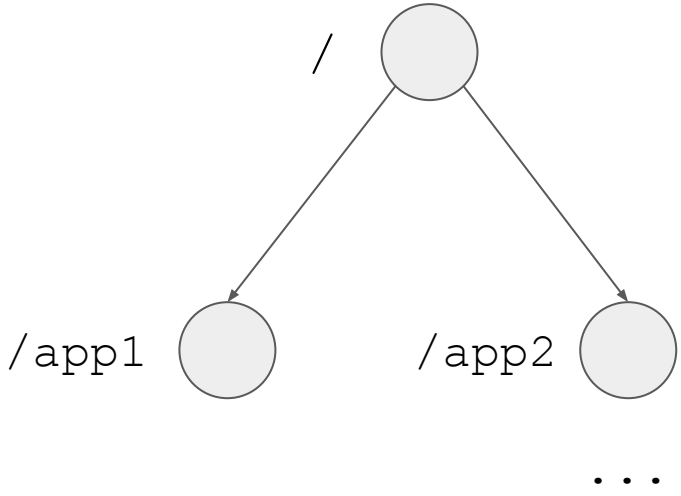

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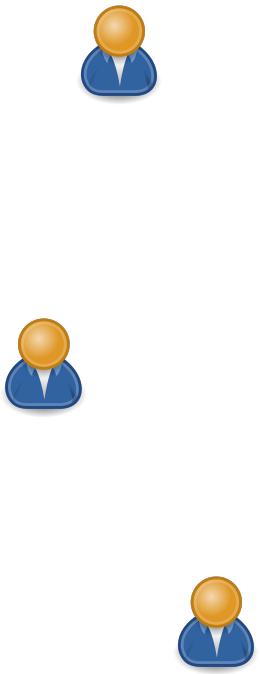

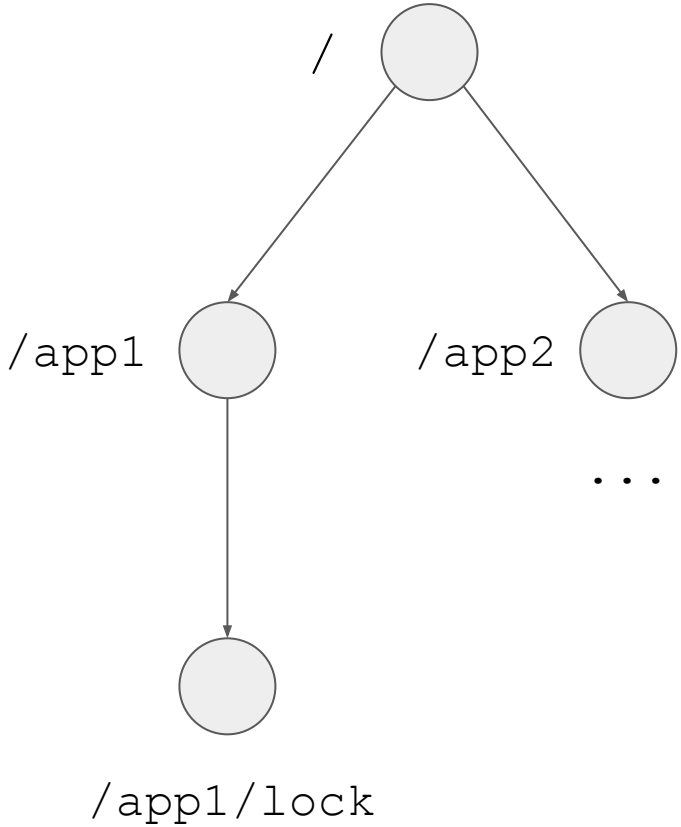

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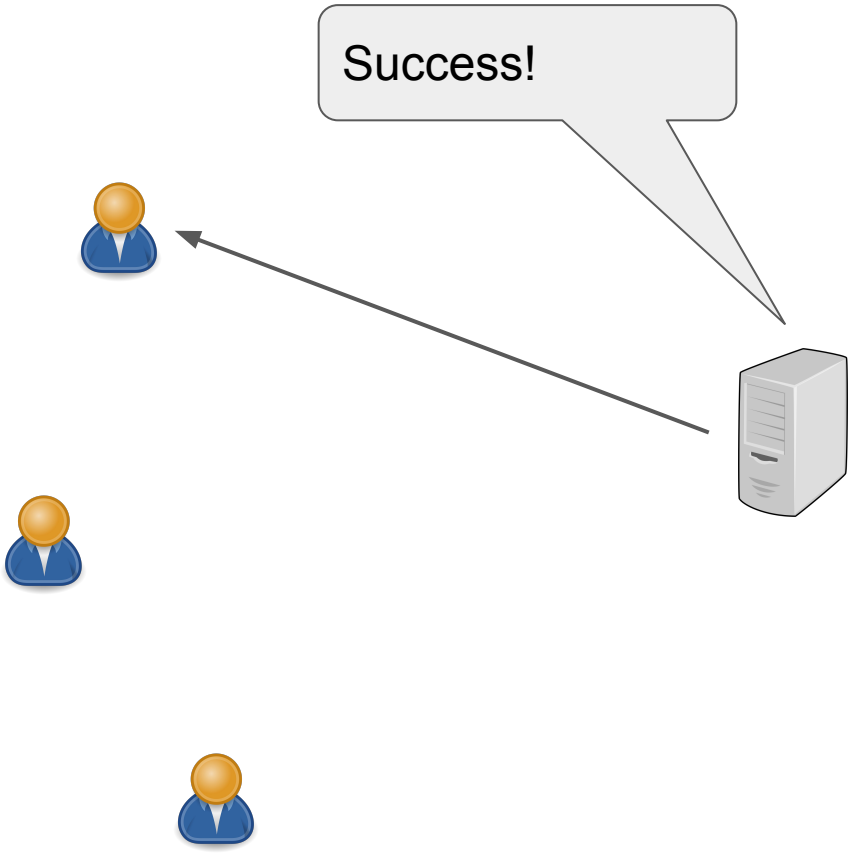

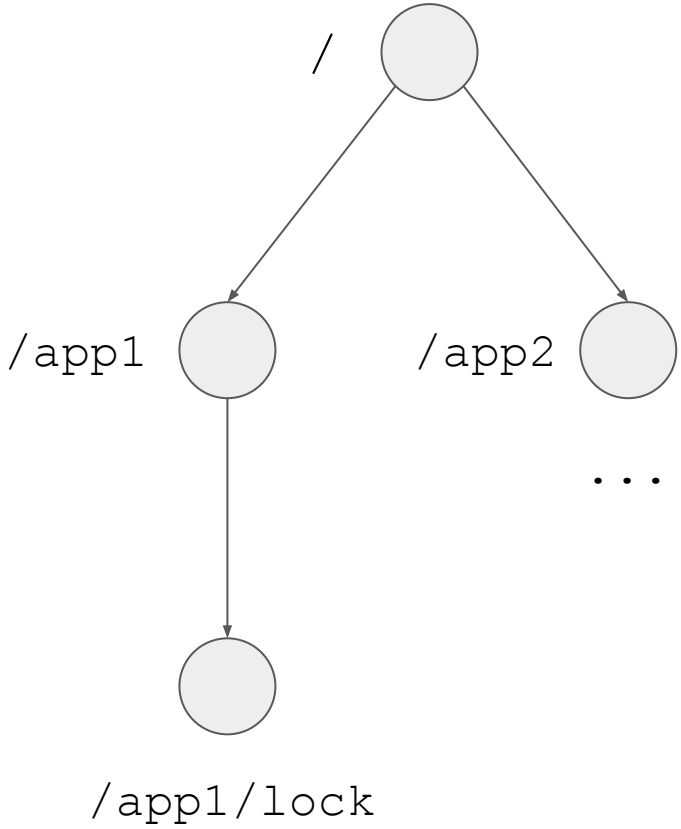

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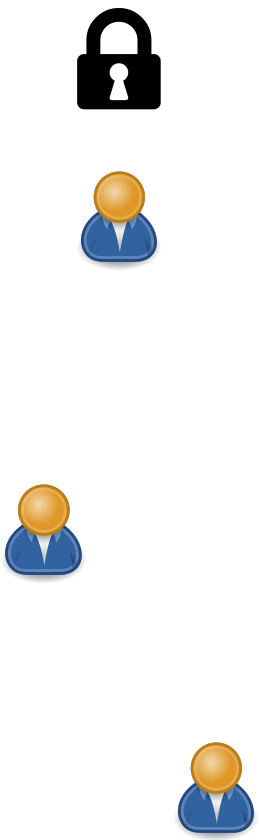

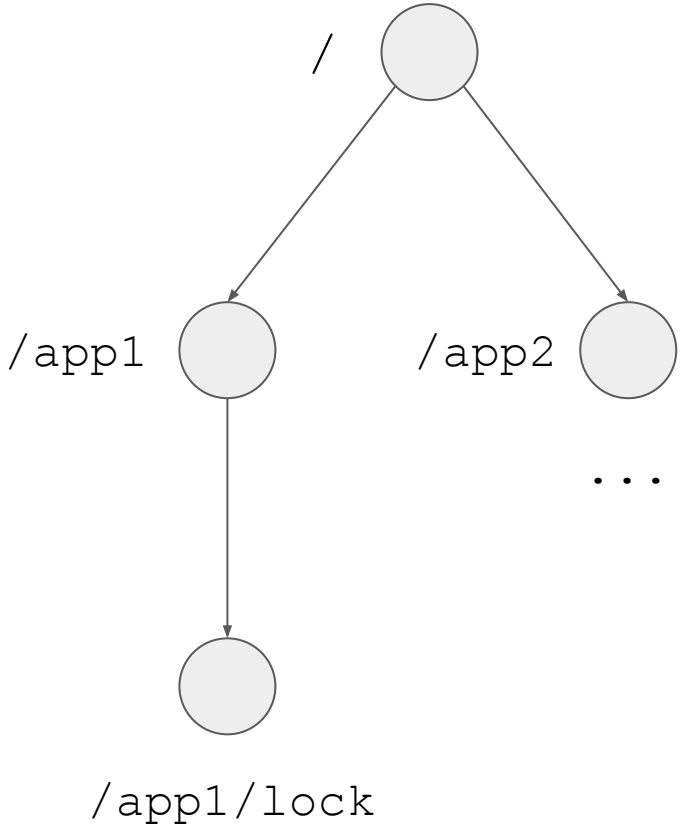

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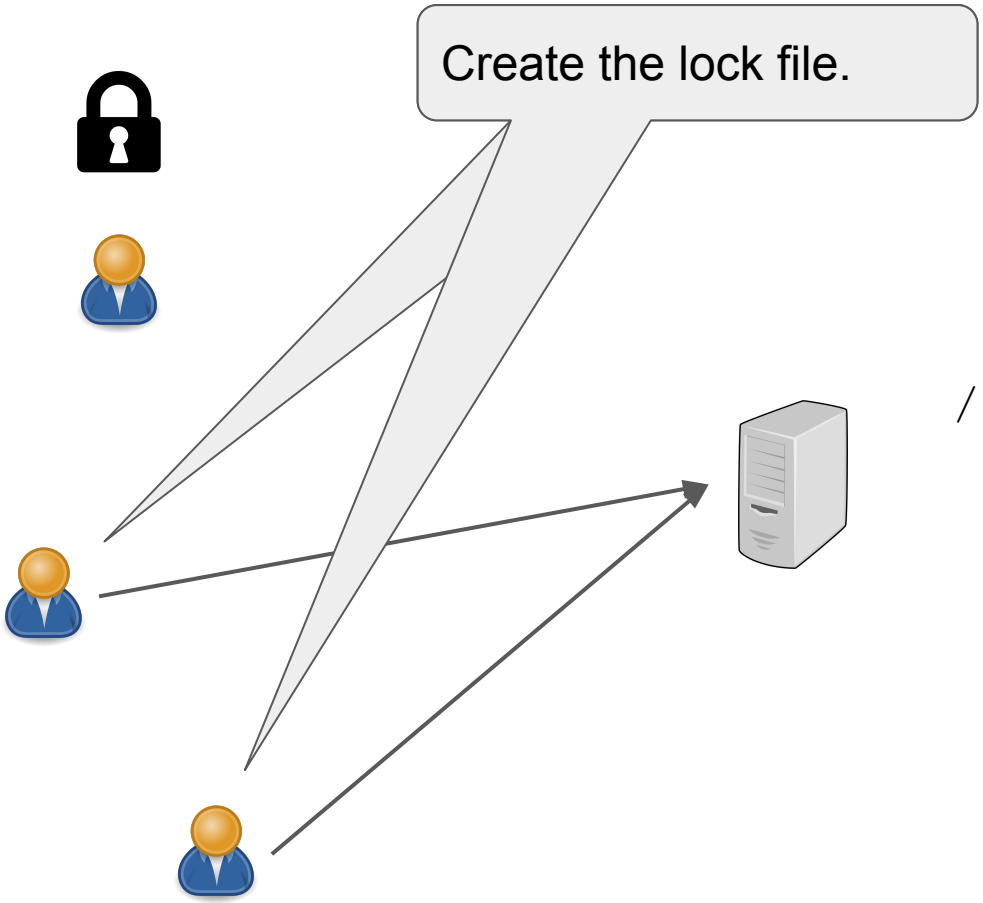

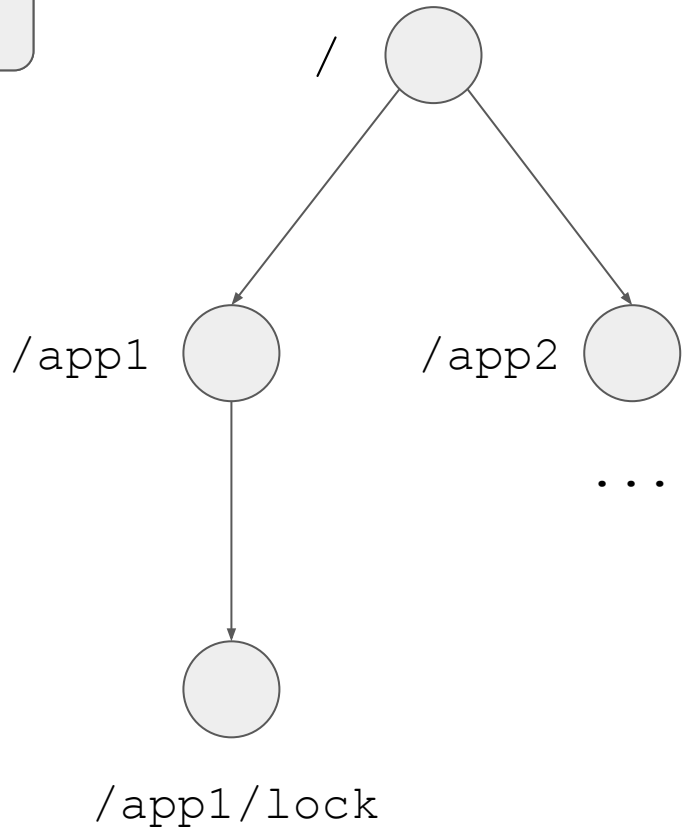

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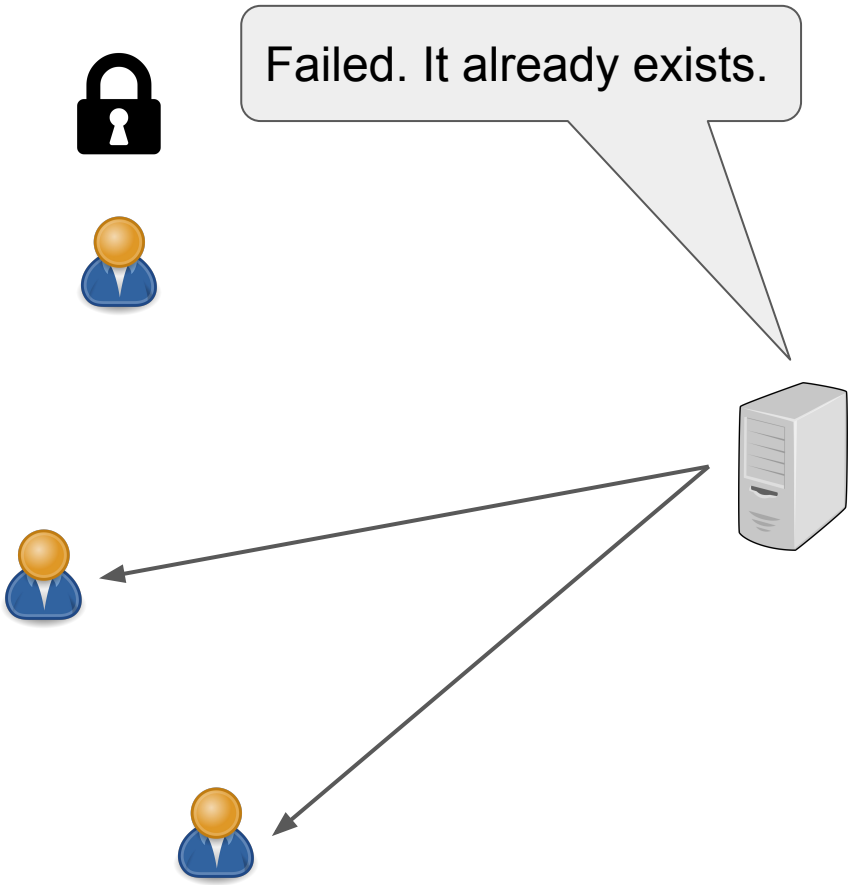

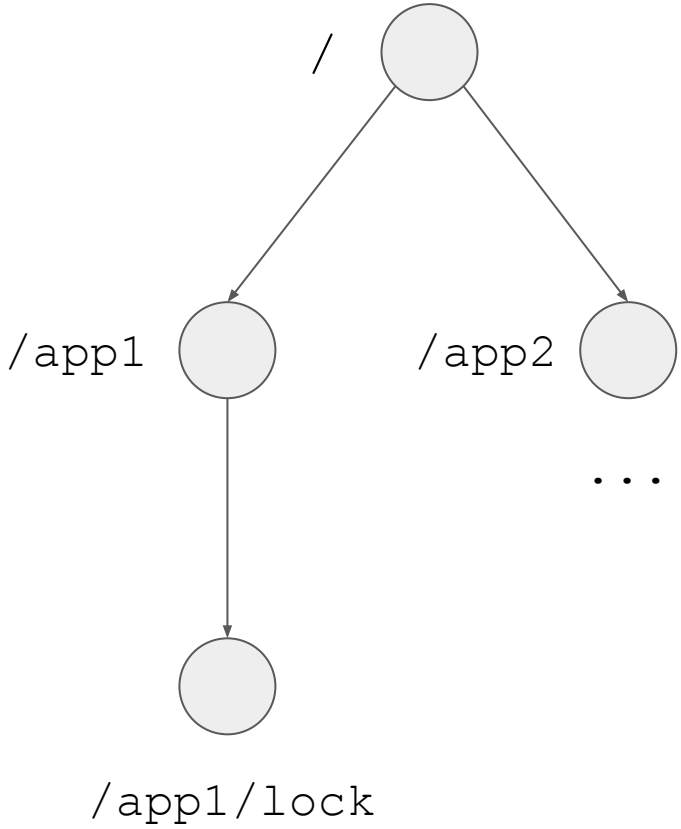

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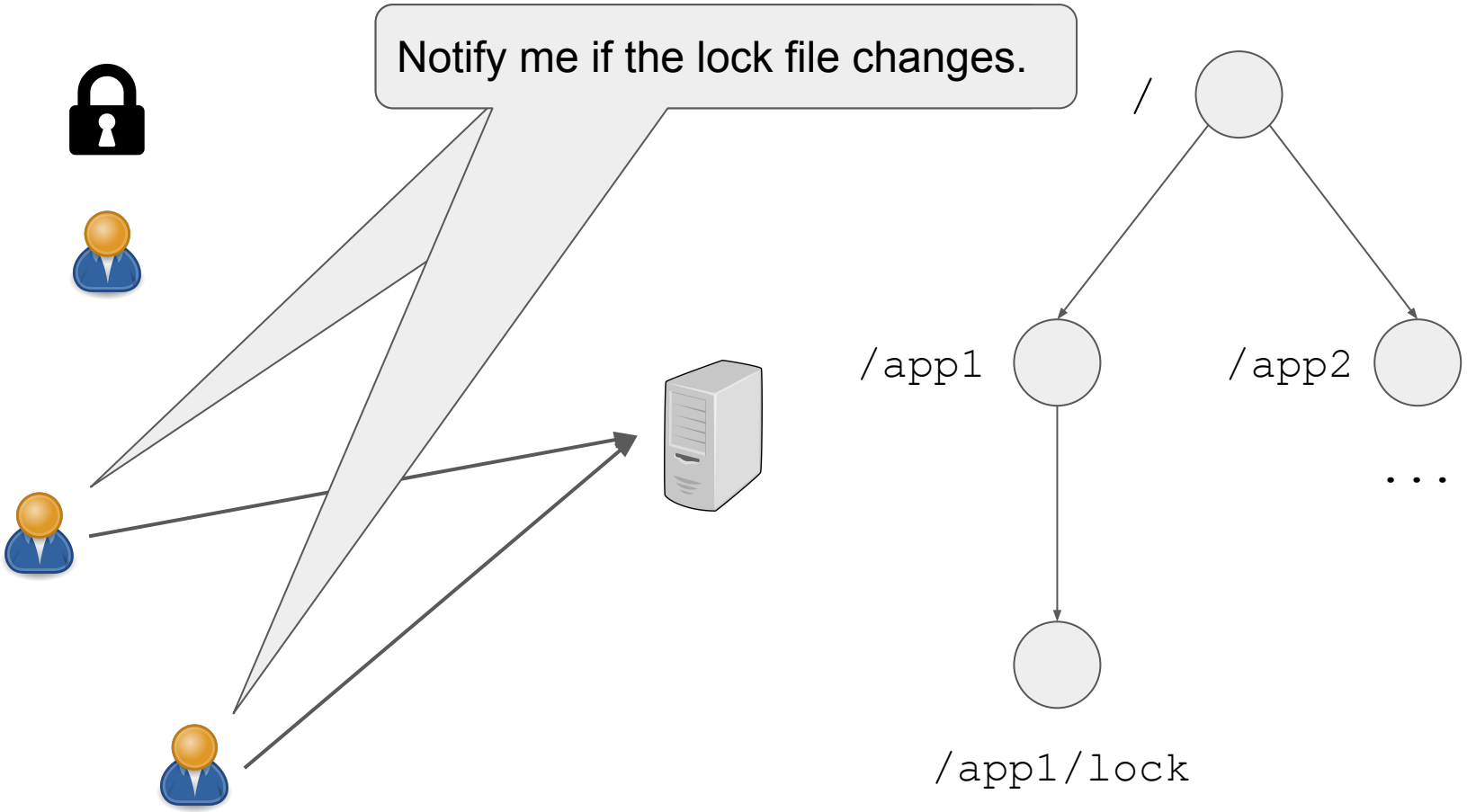

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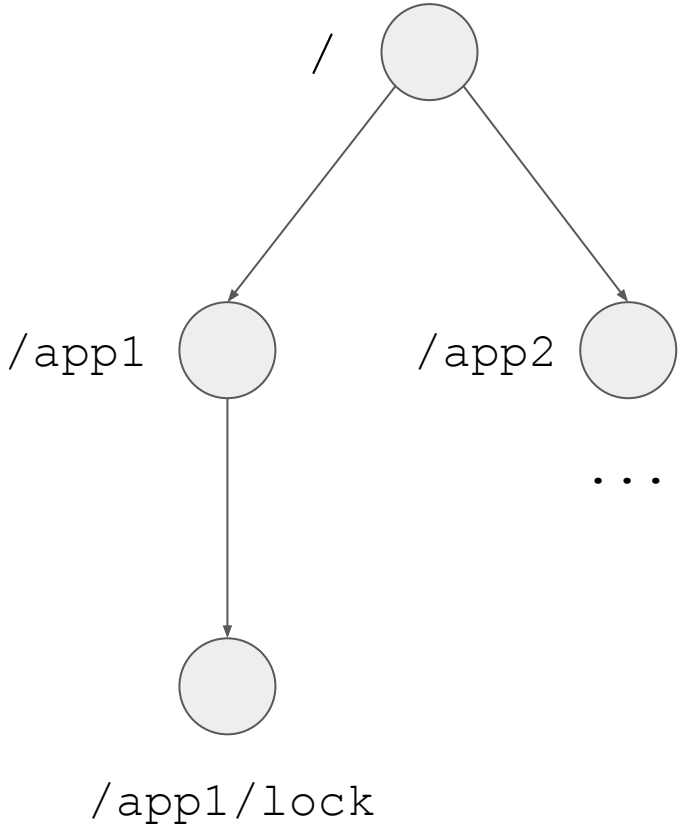

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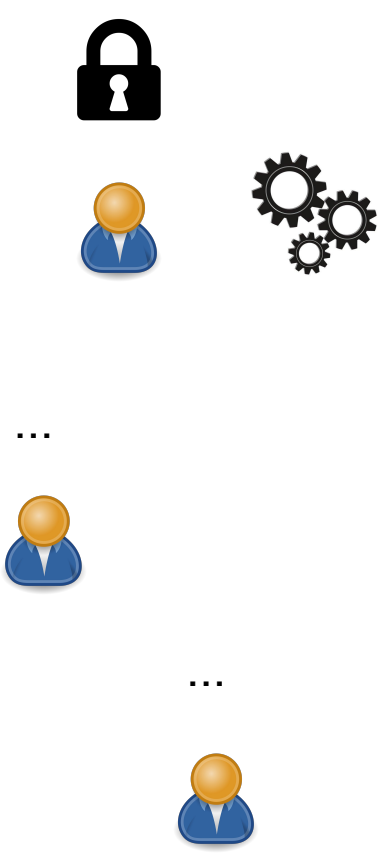

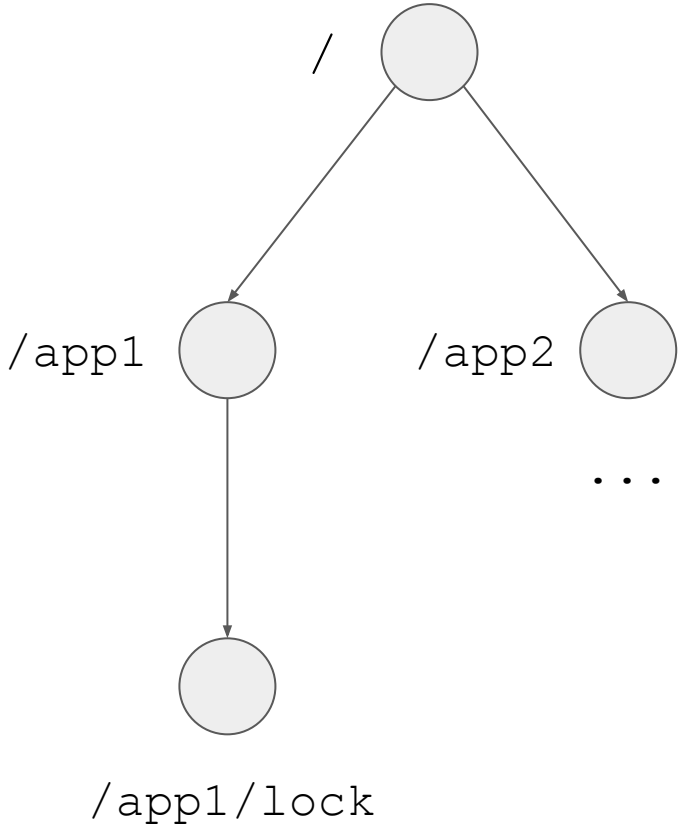

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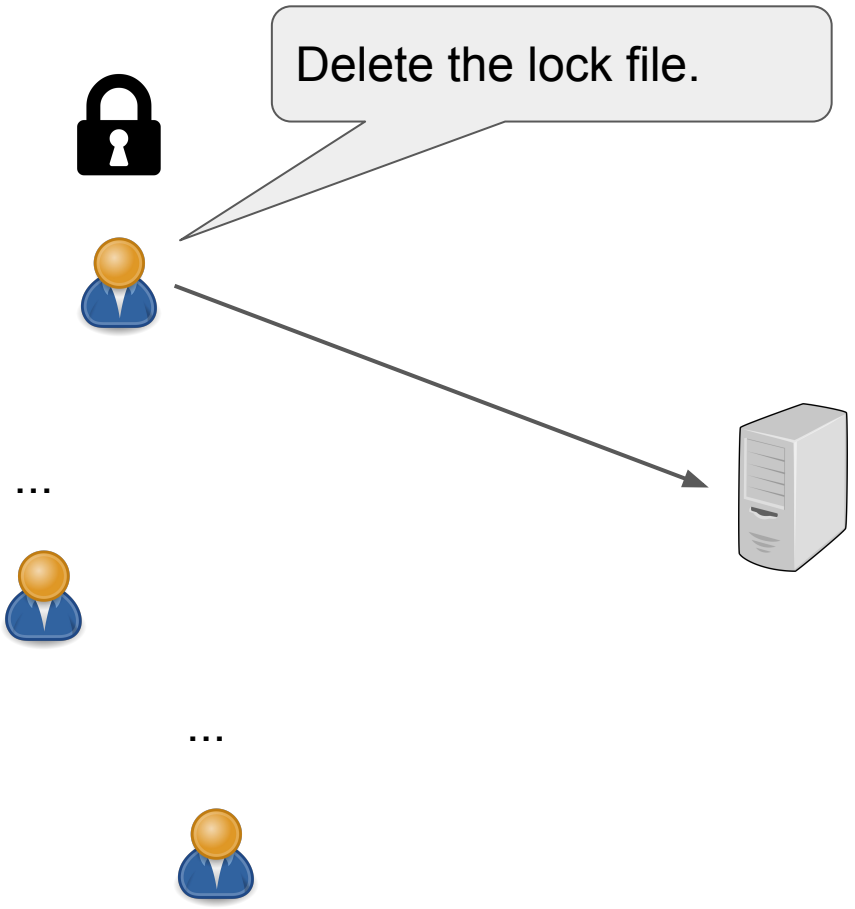

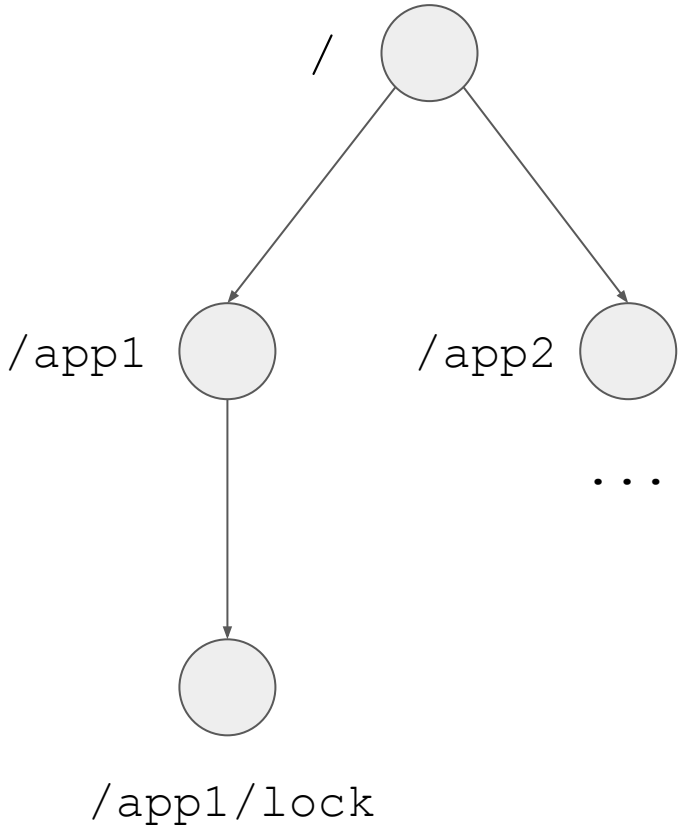

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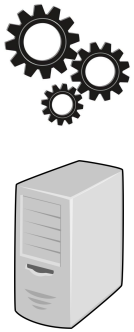

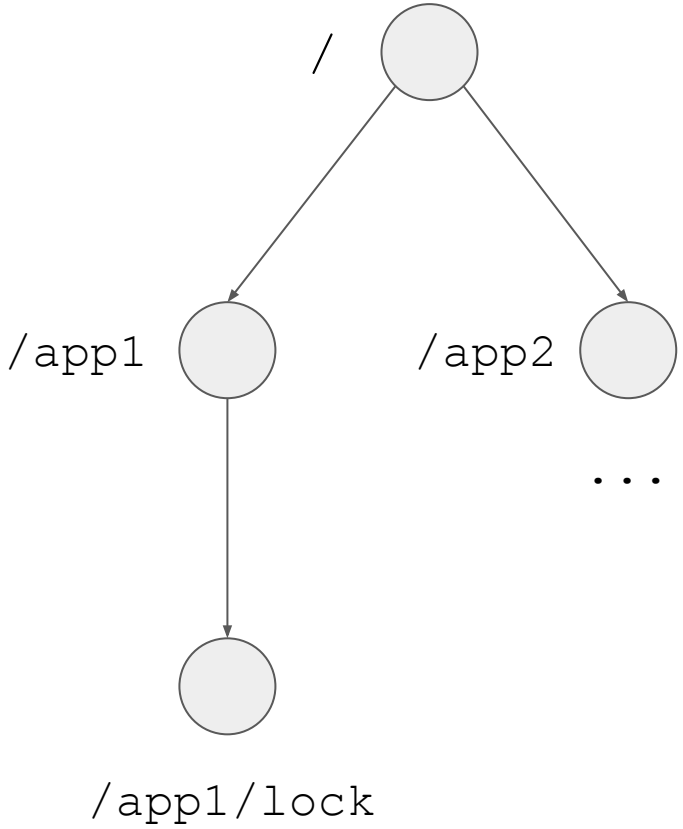

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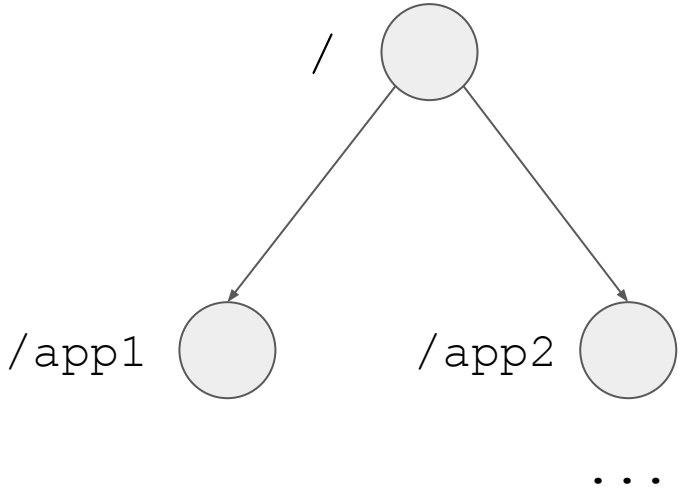

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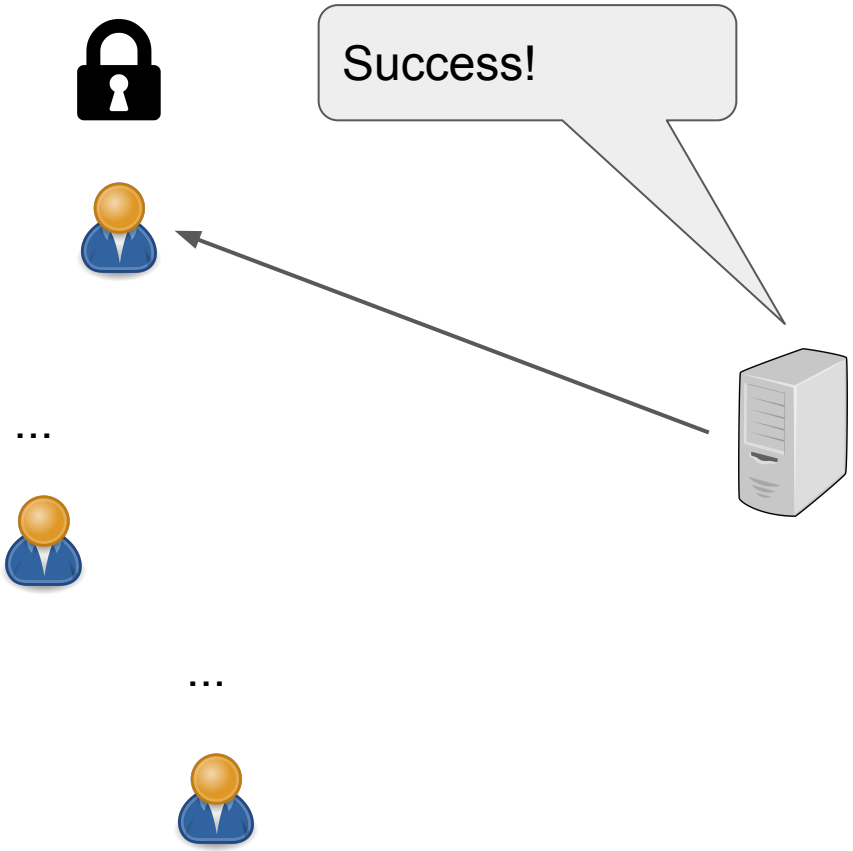

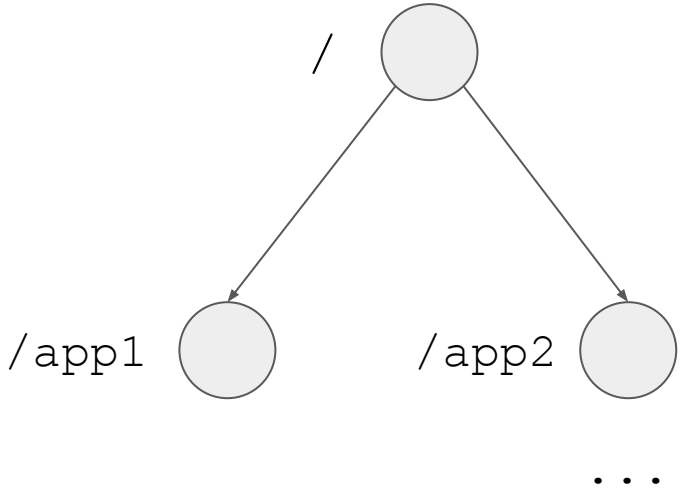

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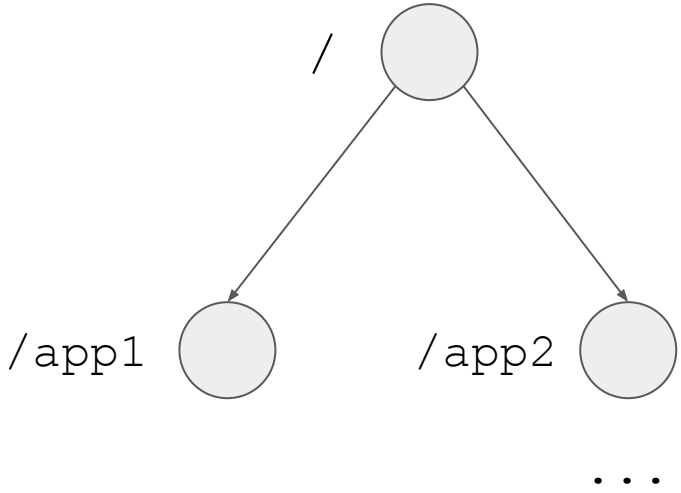

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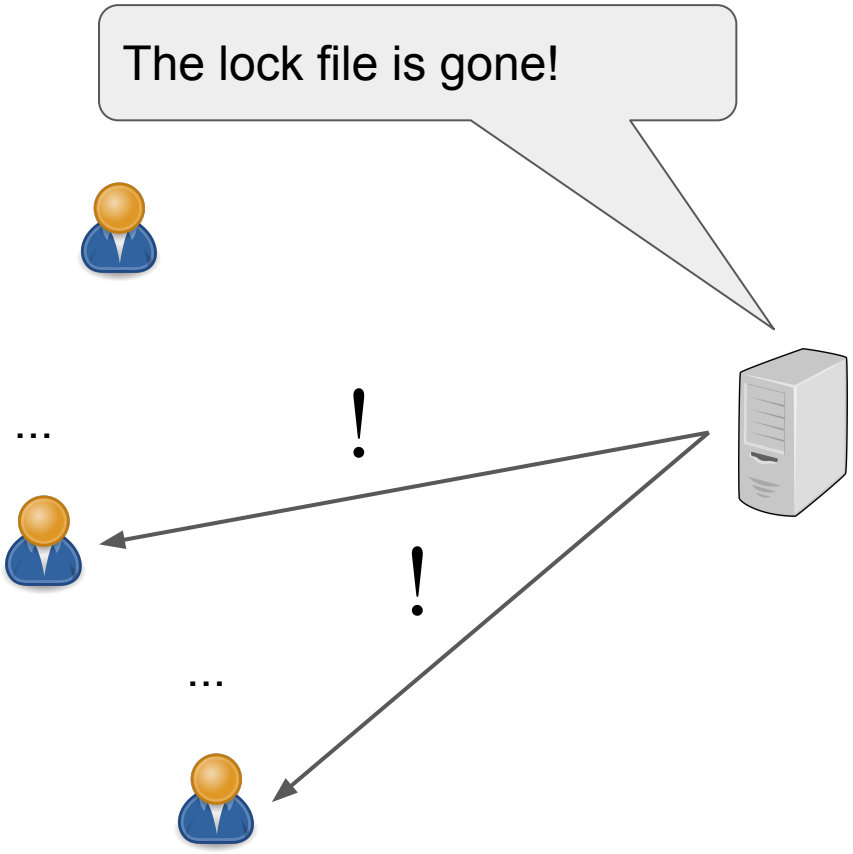

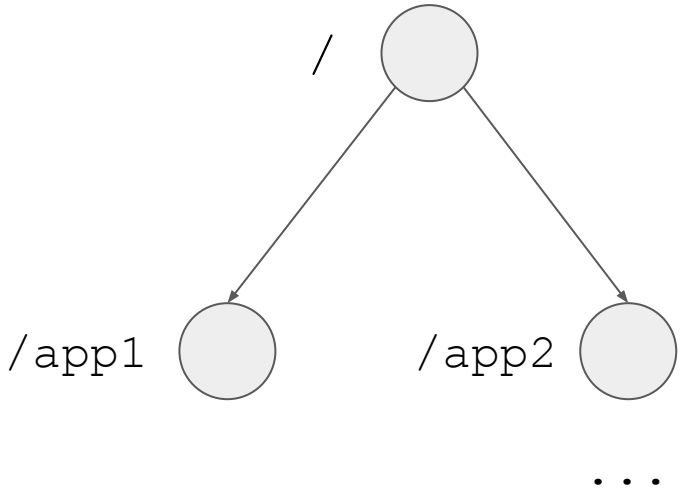

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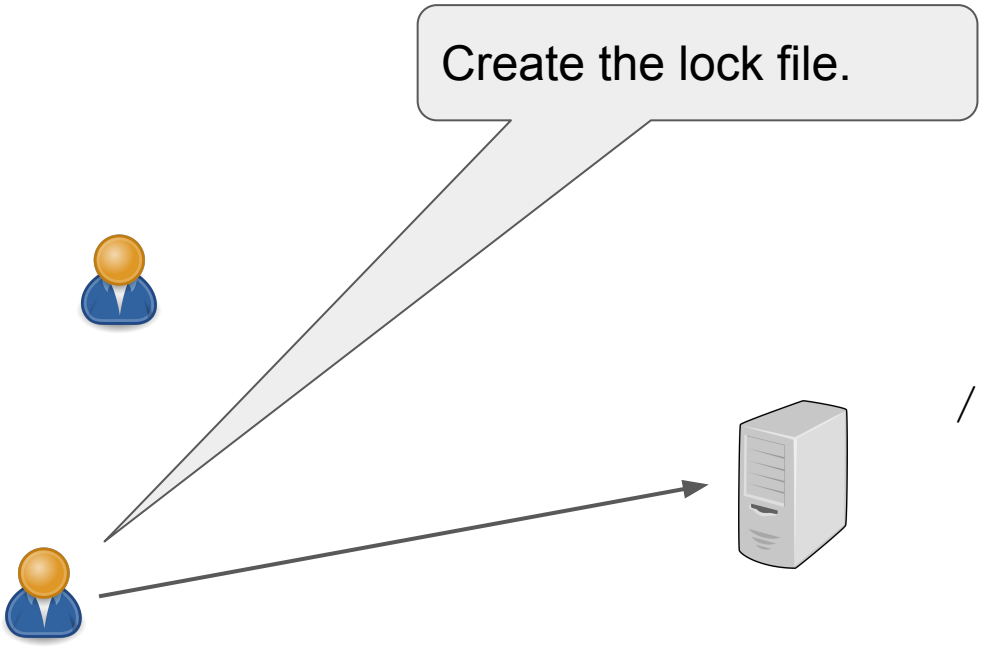

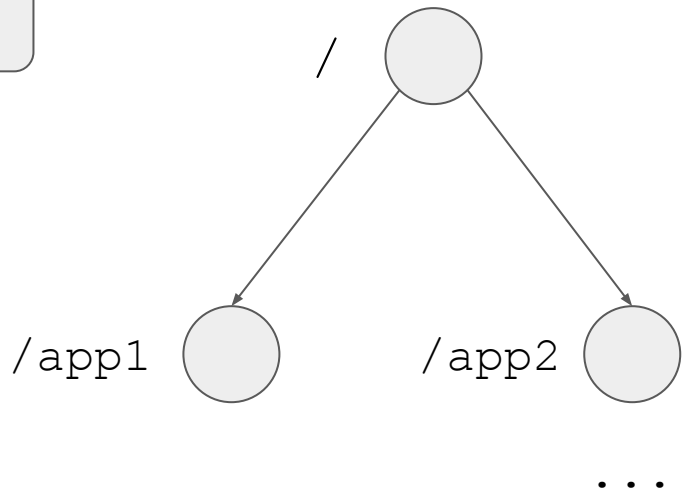

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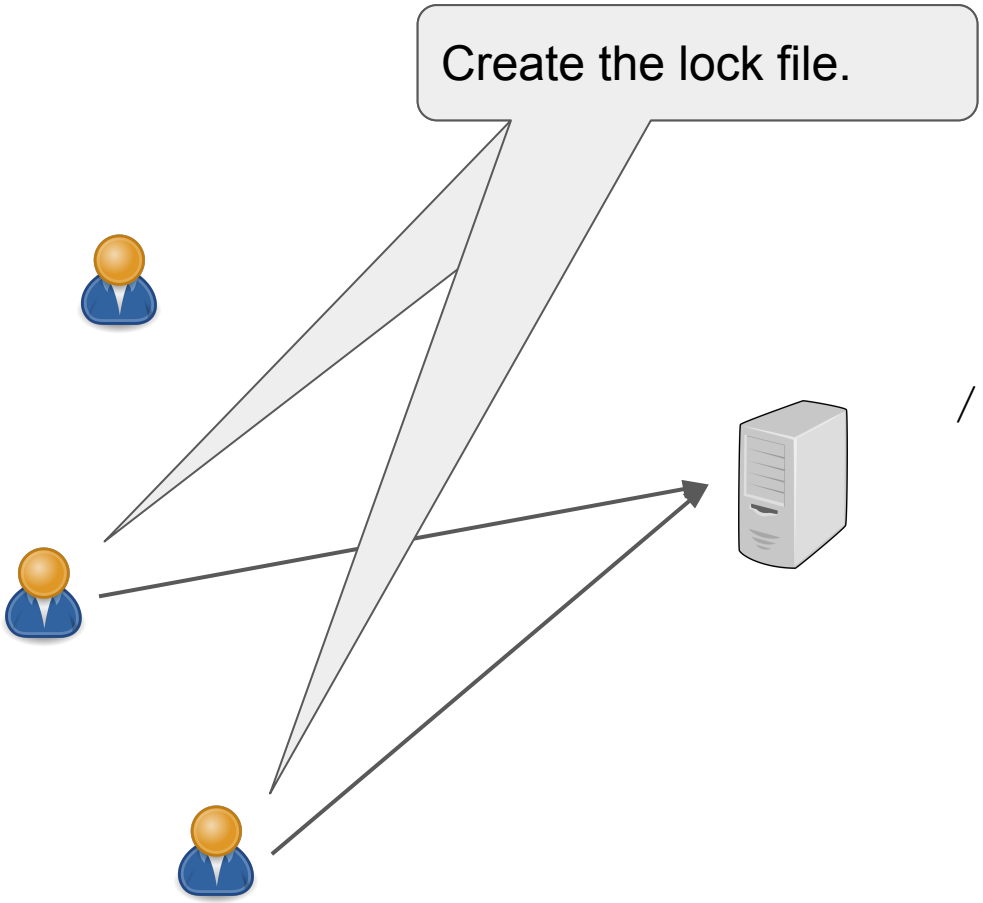

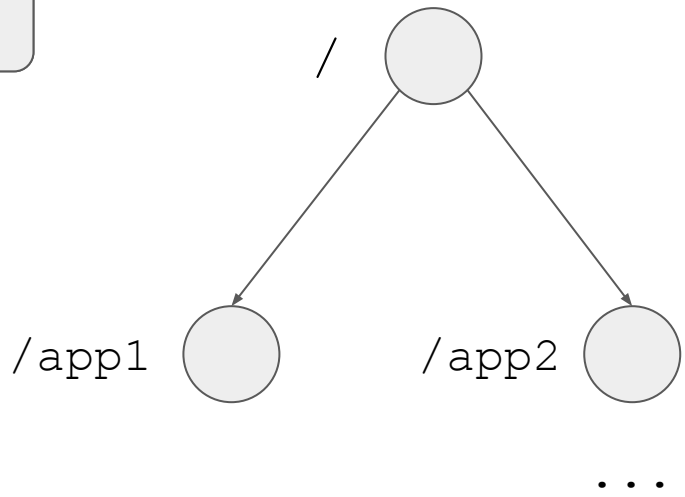

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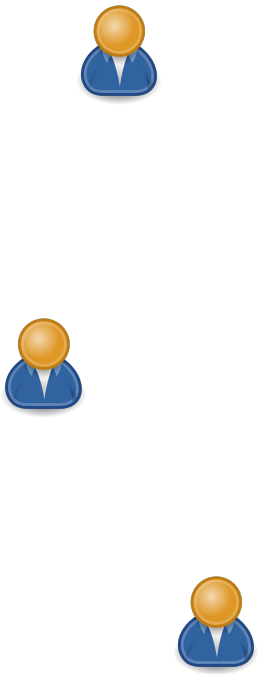

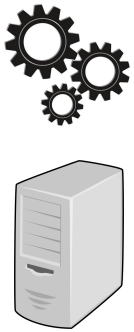

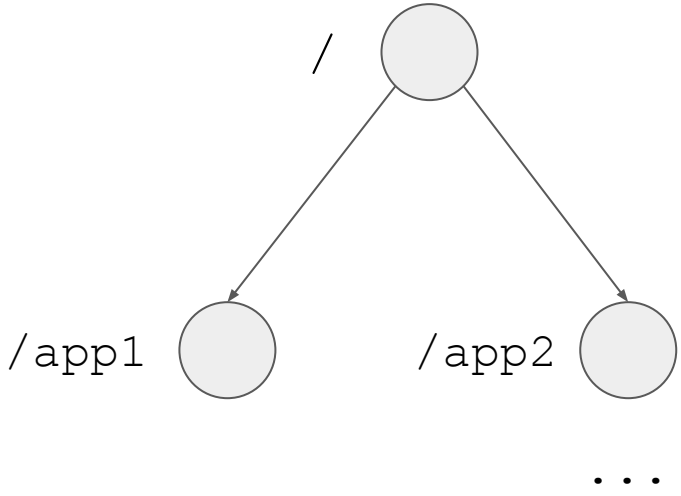

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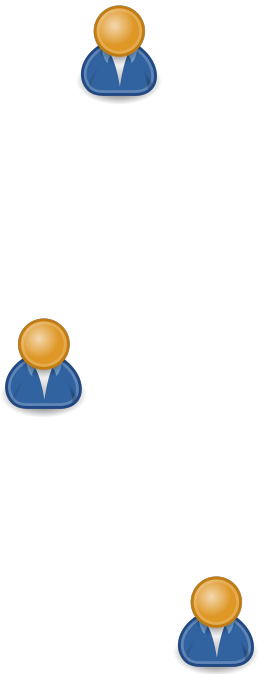

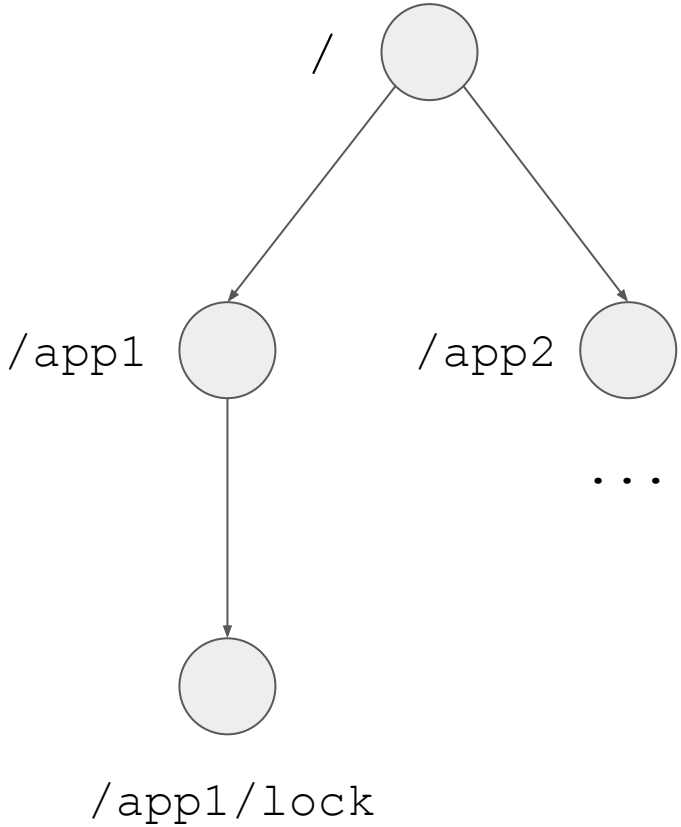

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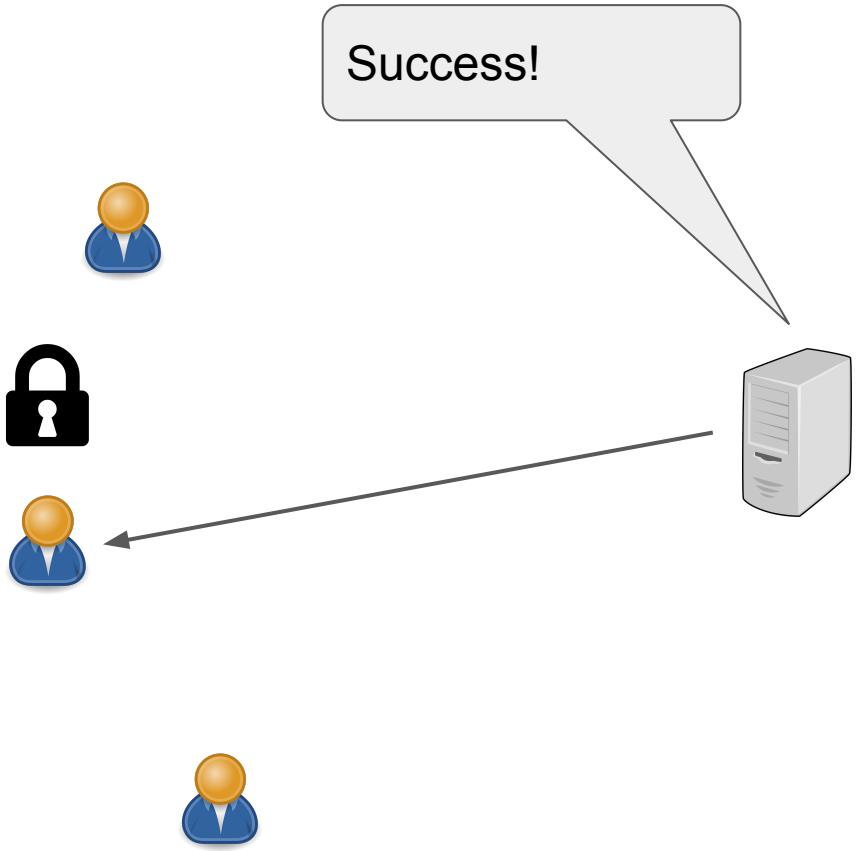

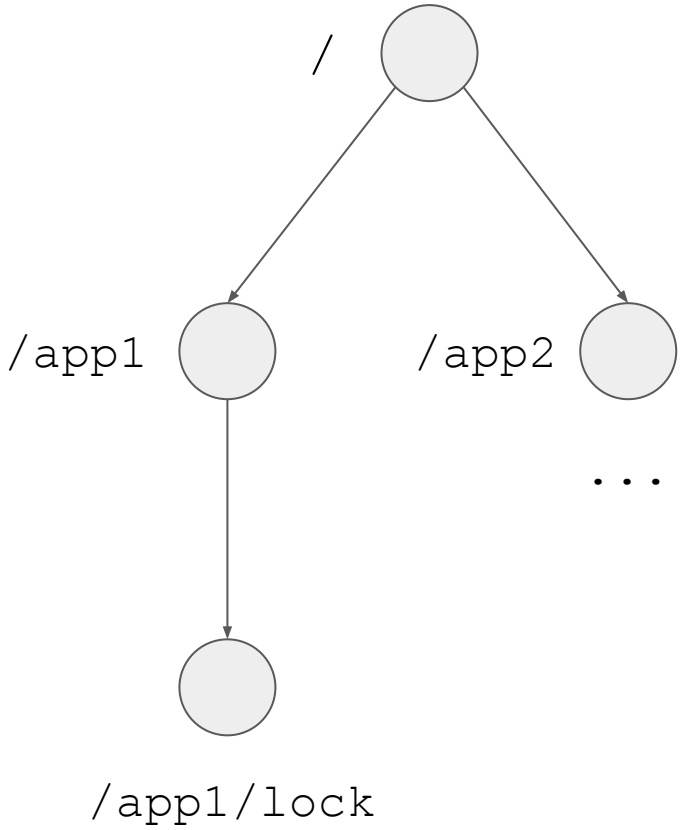

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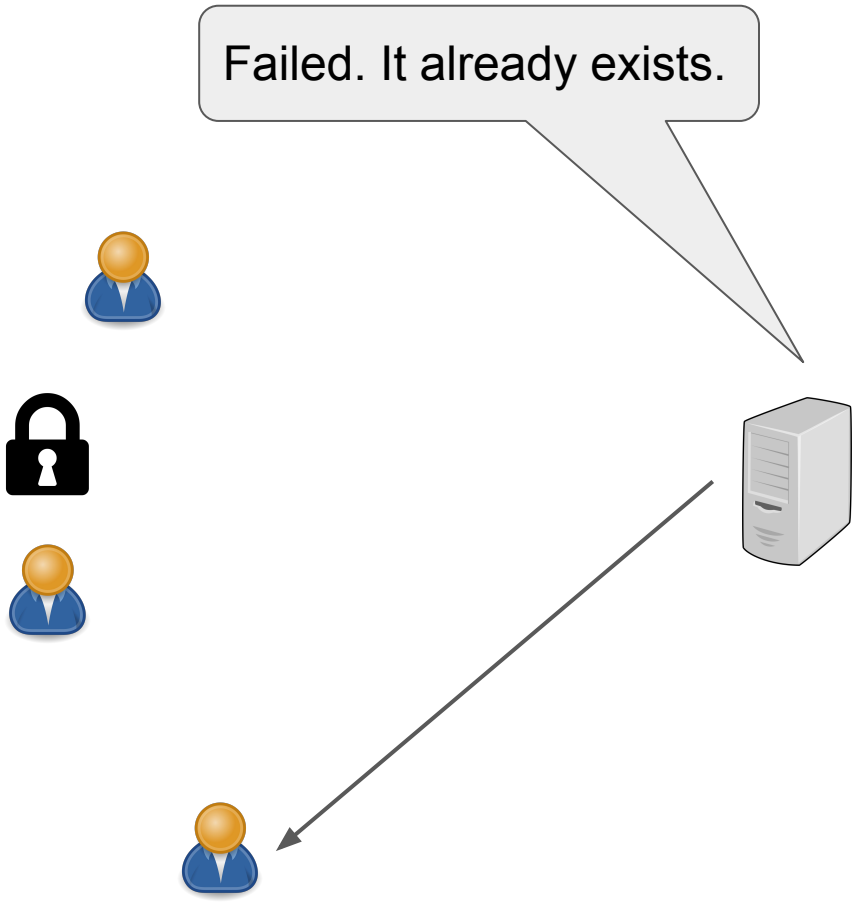

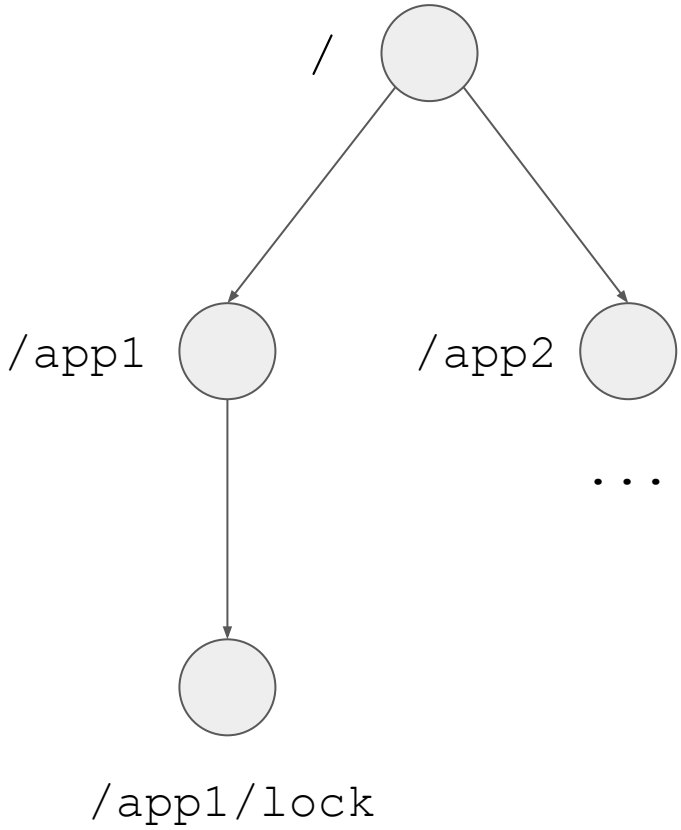

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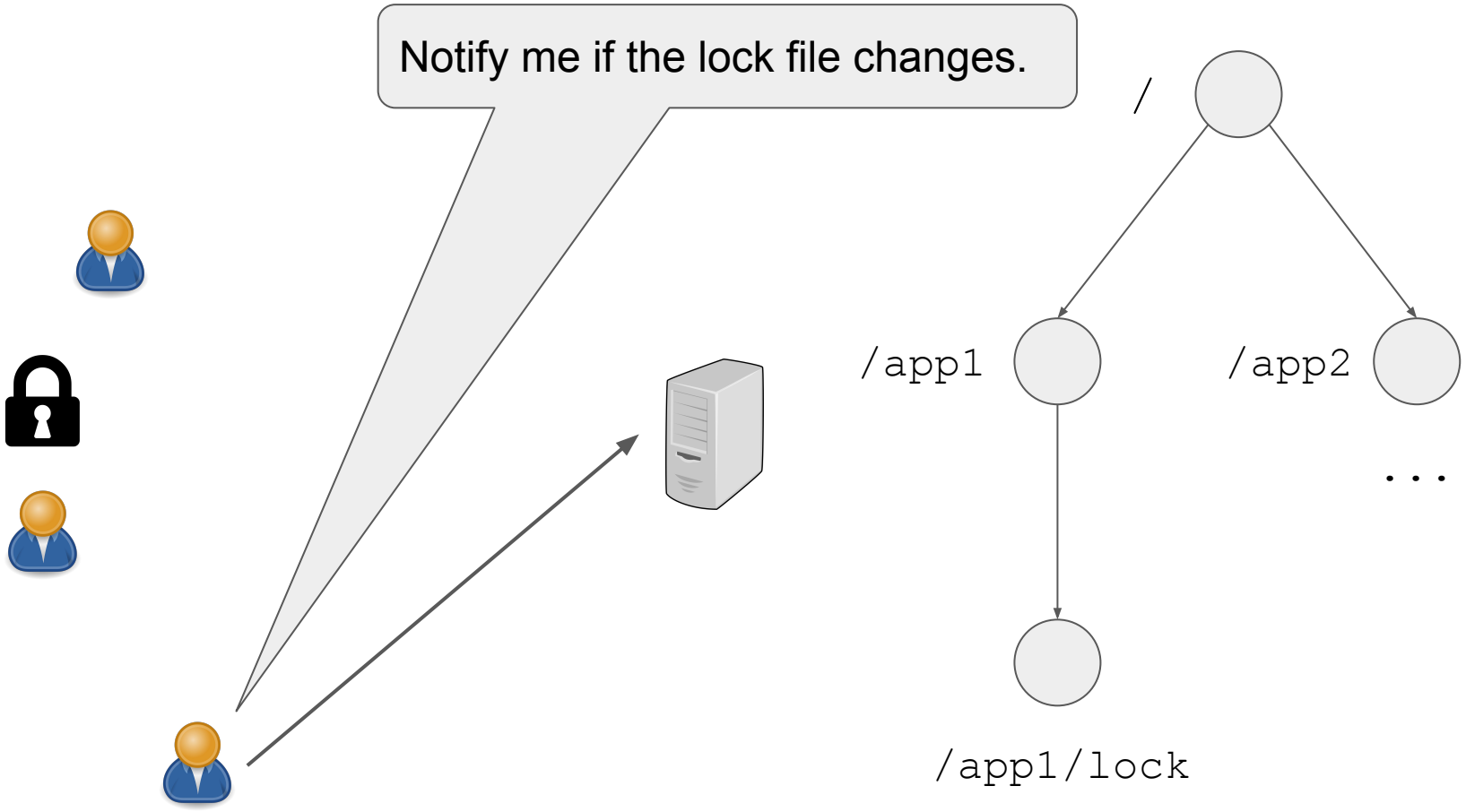

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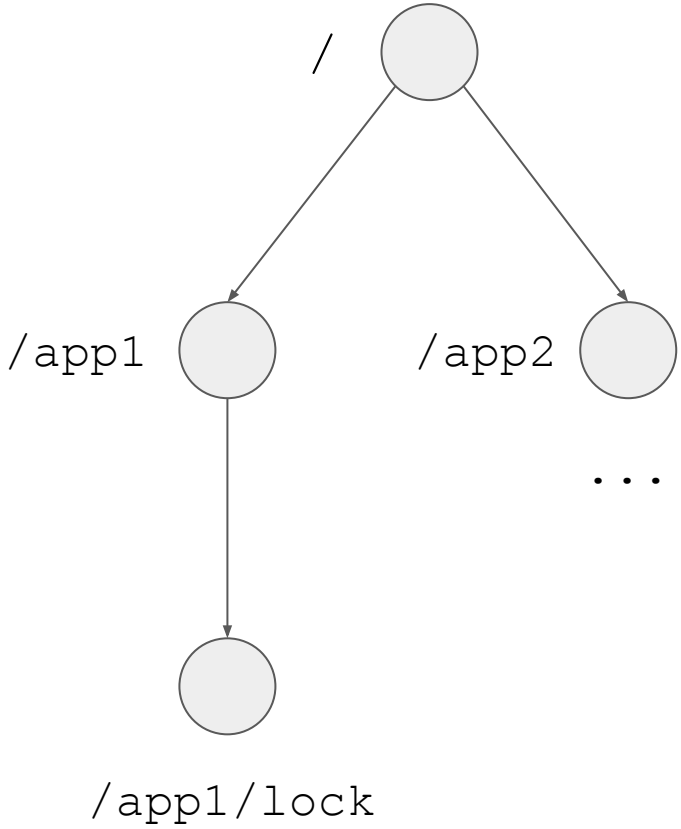
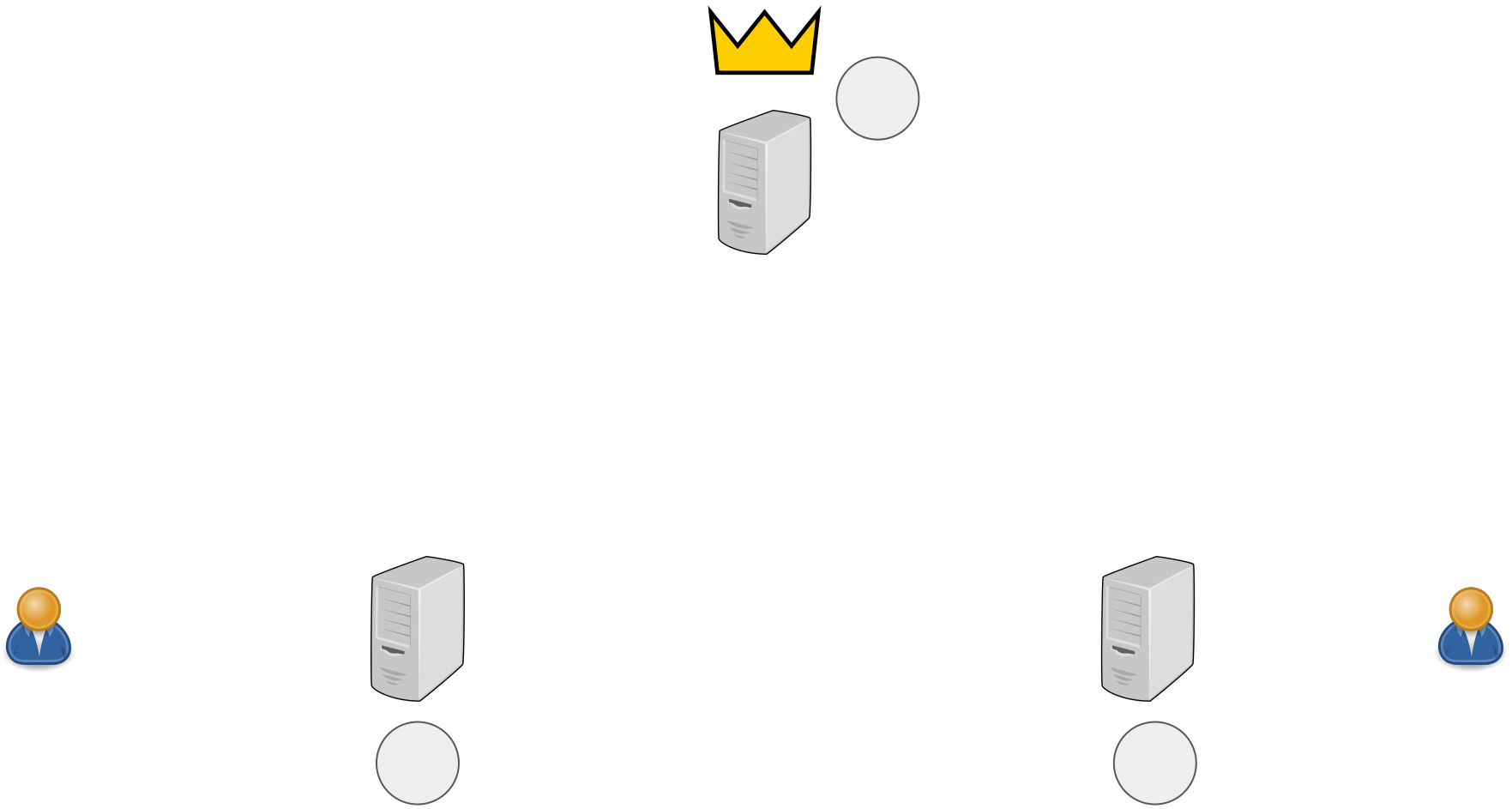


How does ZooKeeper achieve consistency?

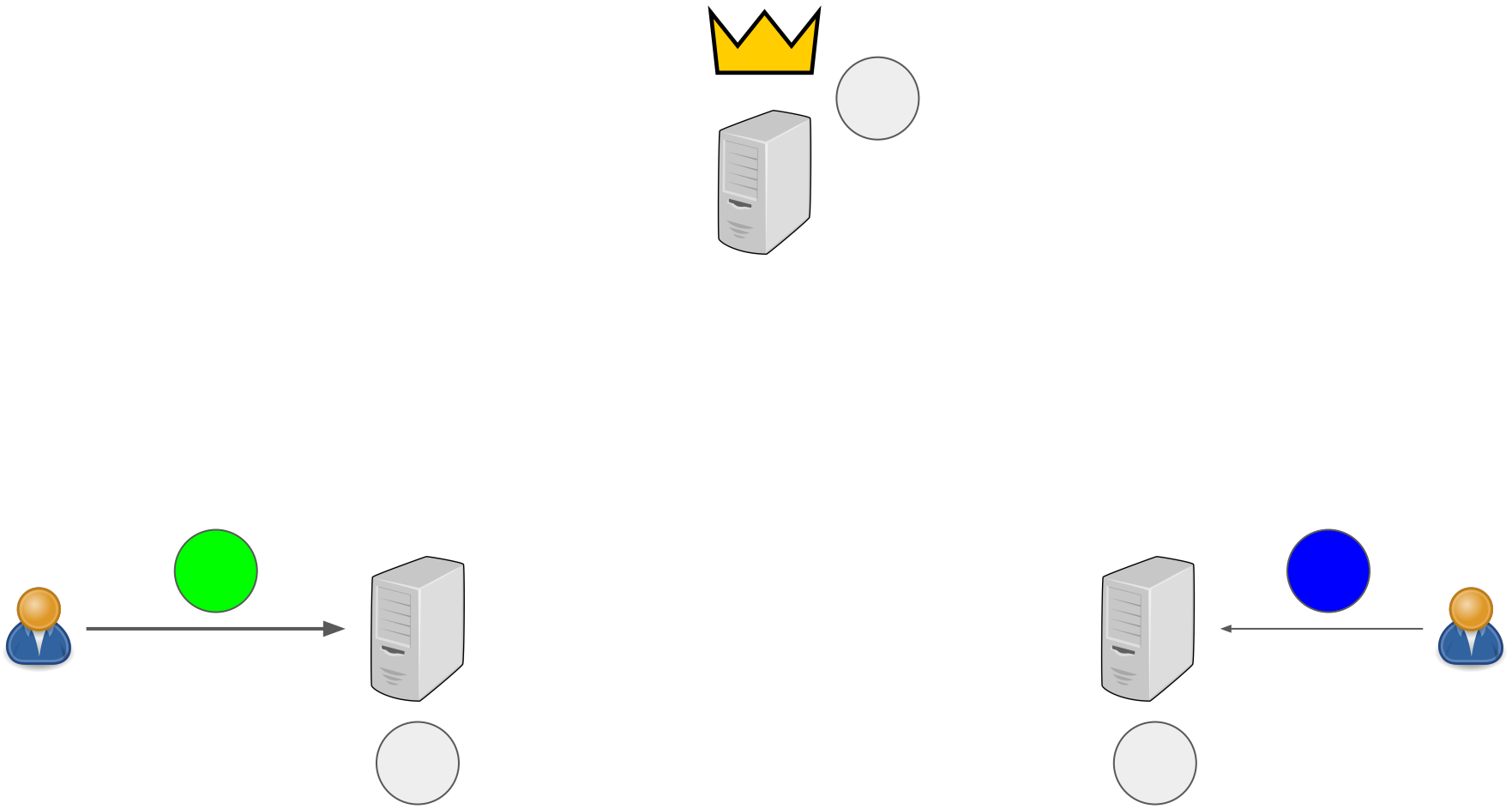
Write requests are funneled through a single leader process, which determines consistent total order via an **atomic broadcast** protocol.

Request processing is **pipelined**, naturally providing FIFO ordering for each client.

Linearizable Writes



Linearizable Writes



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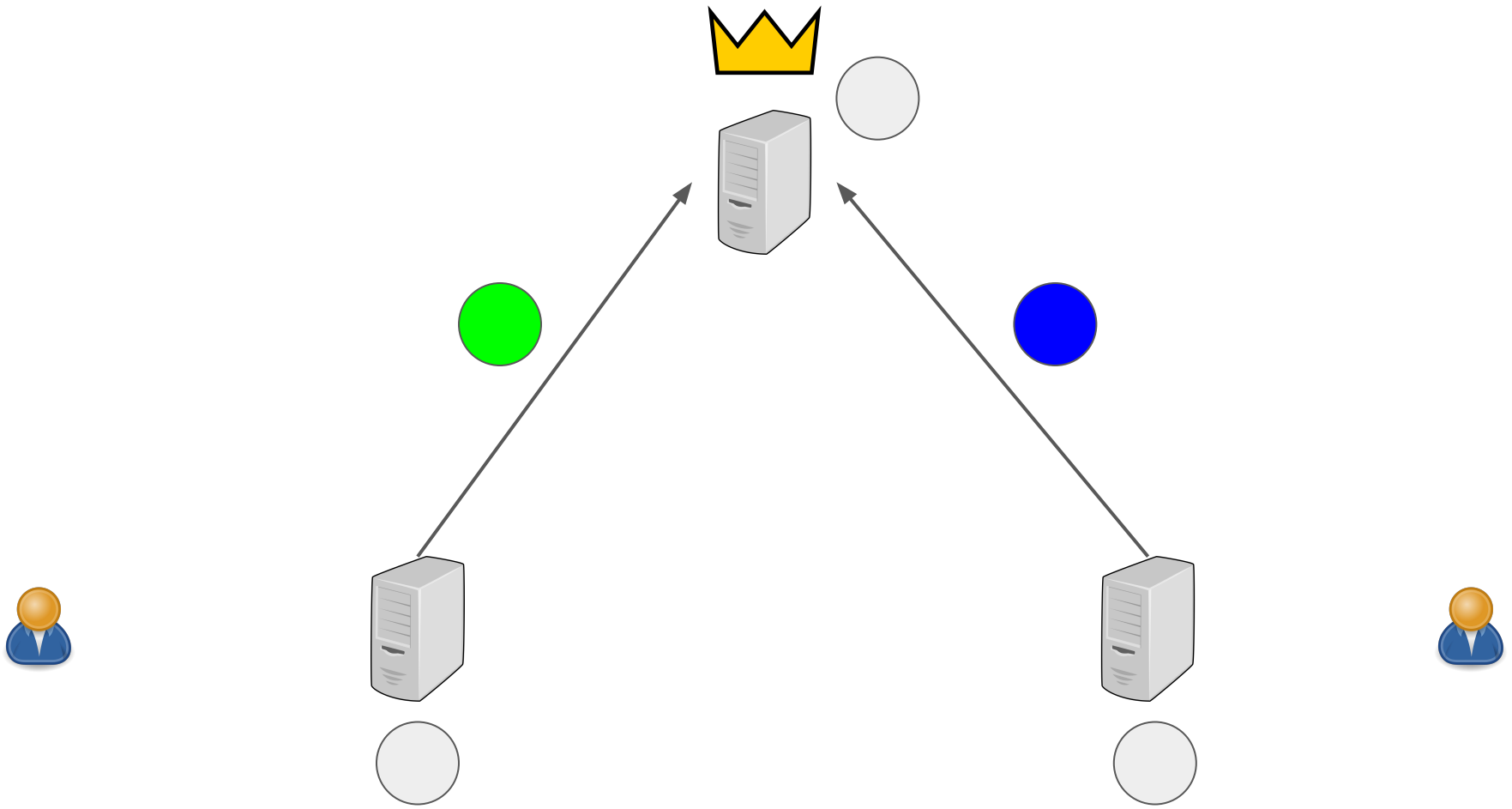

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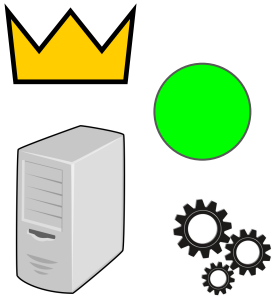

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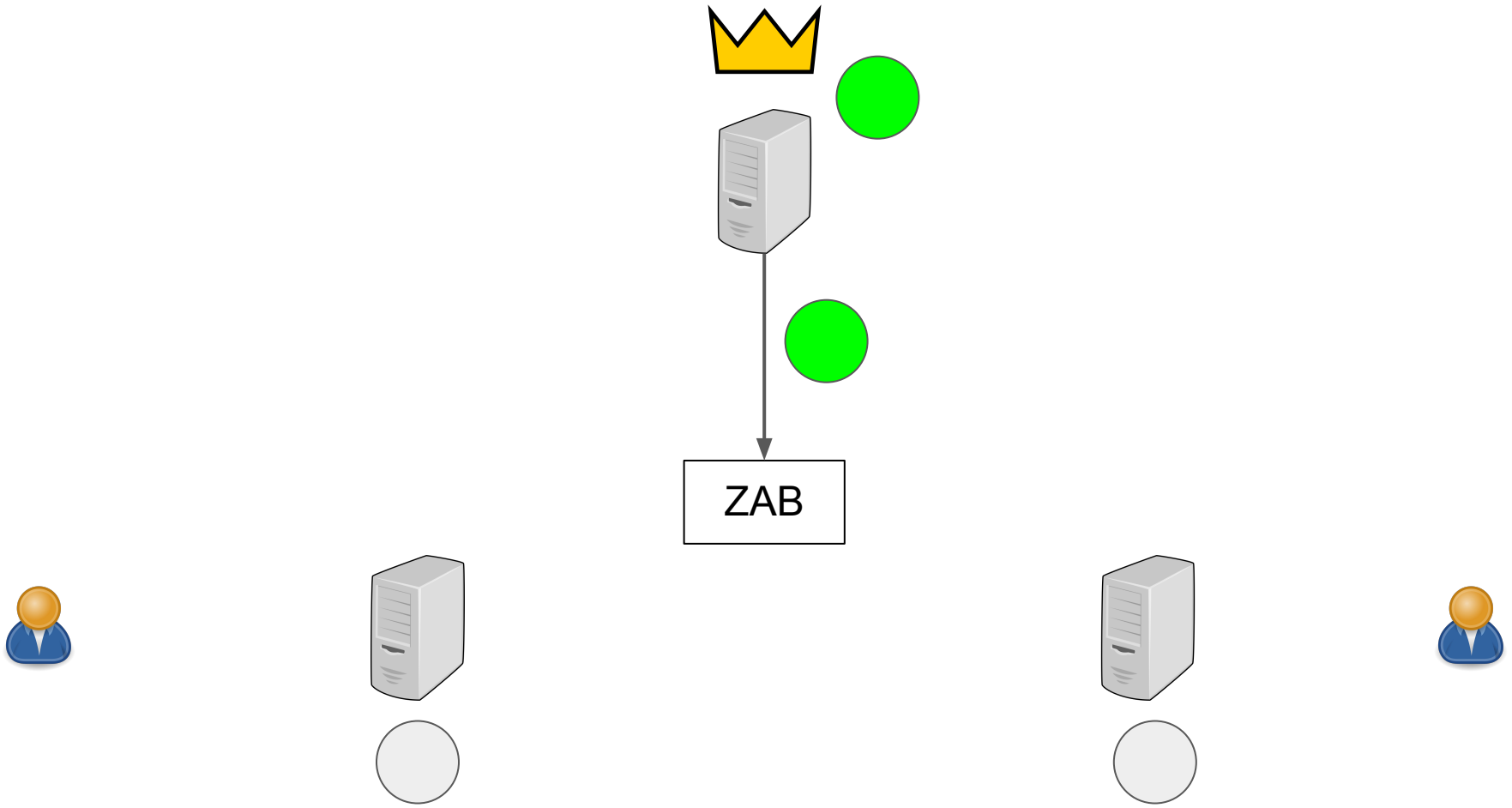

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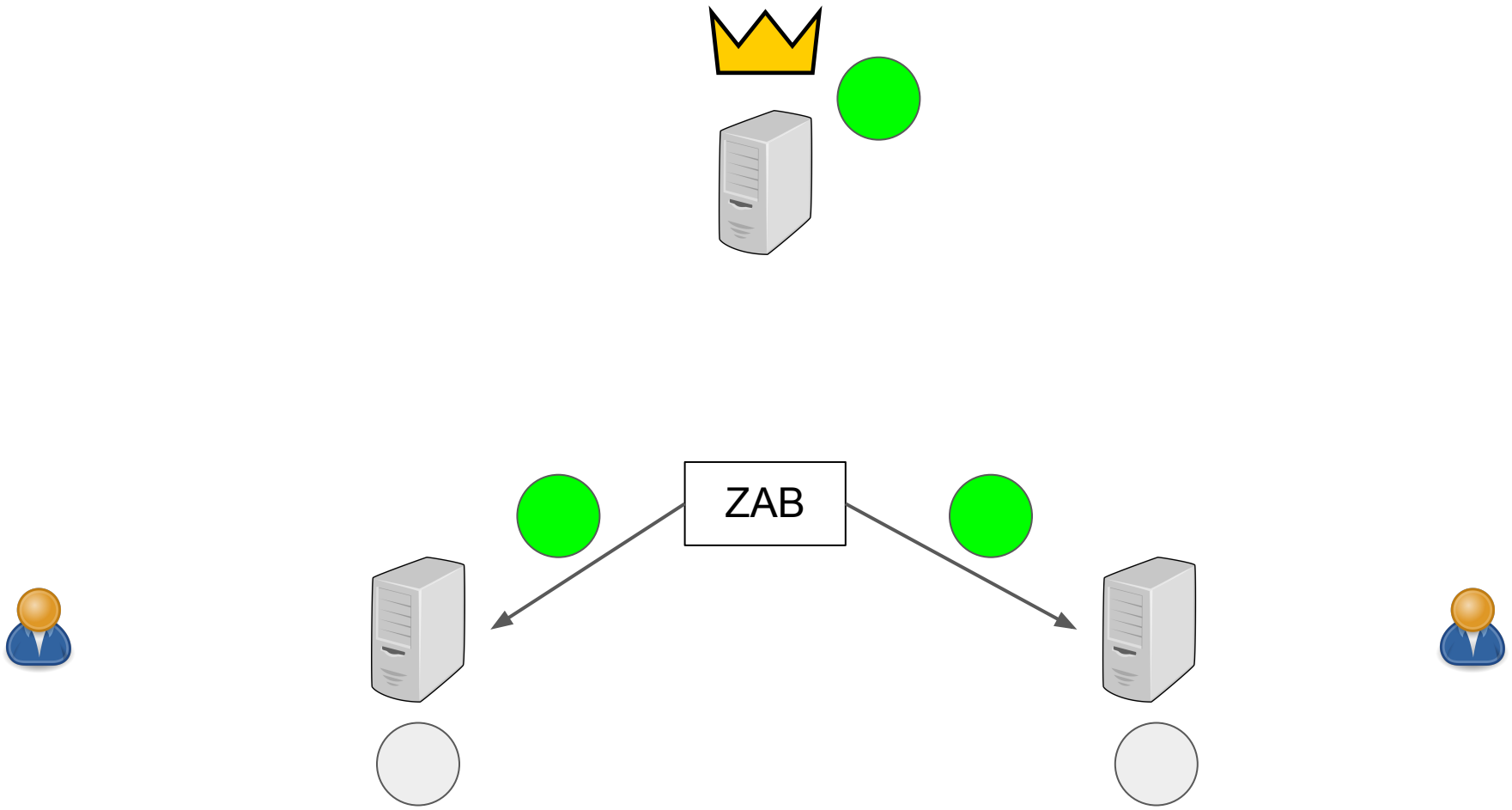

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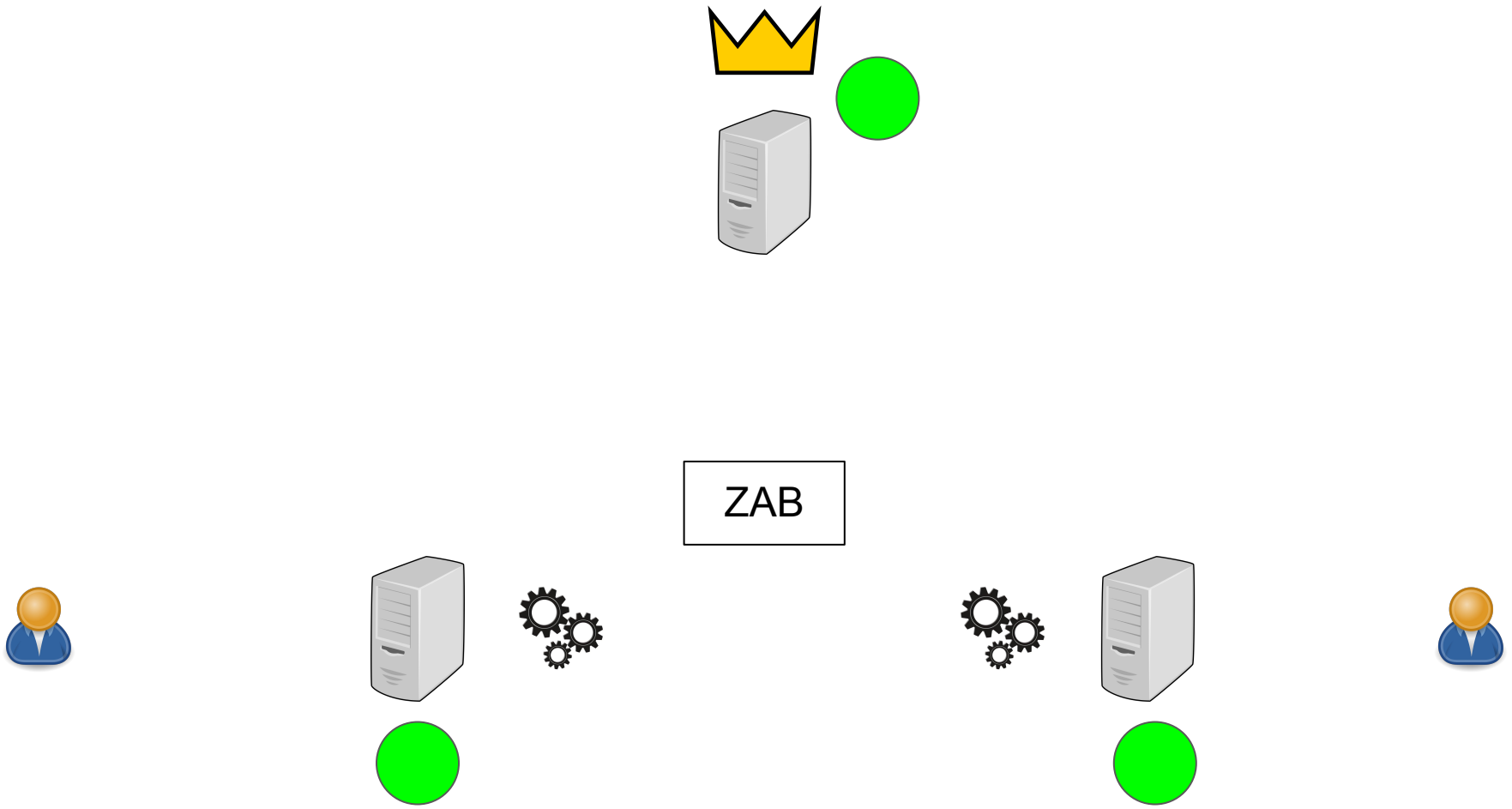

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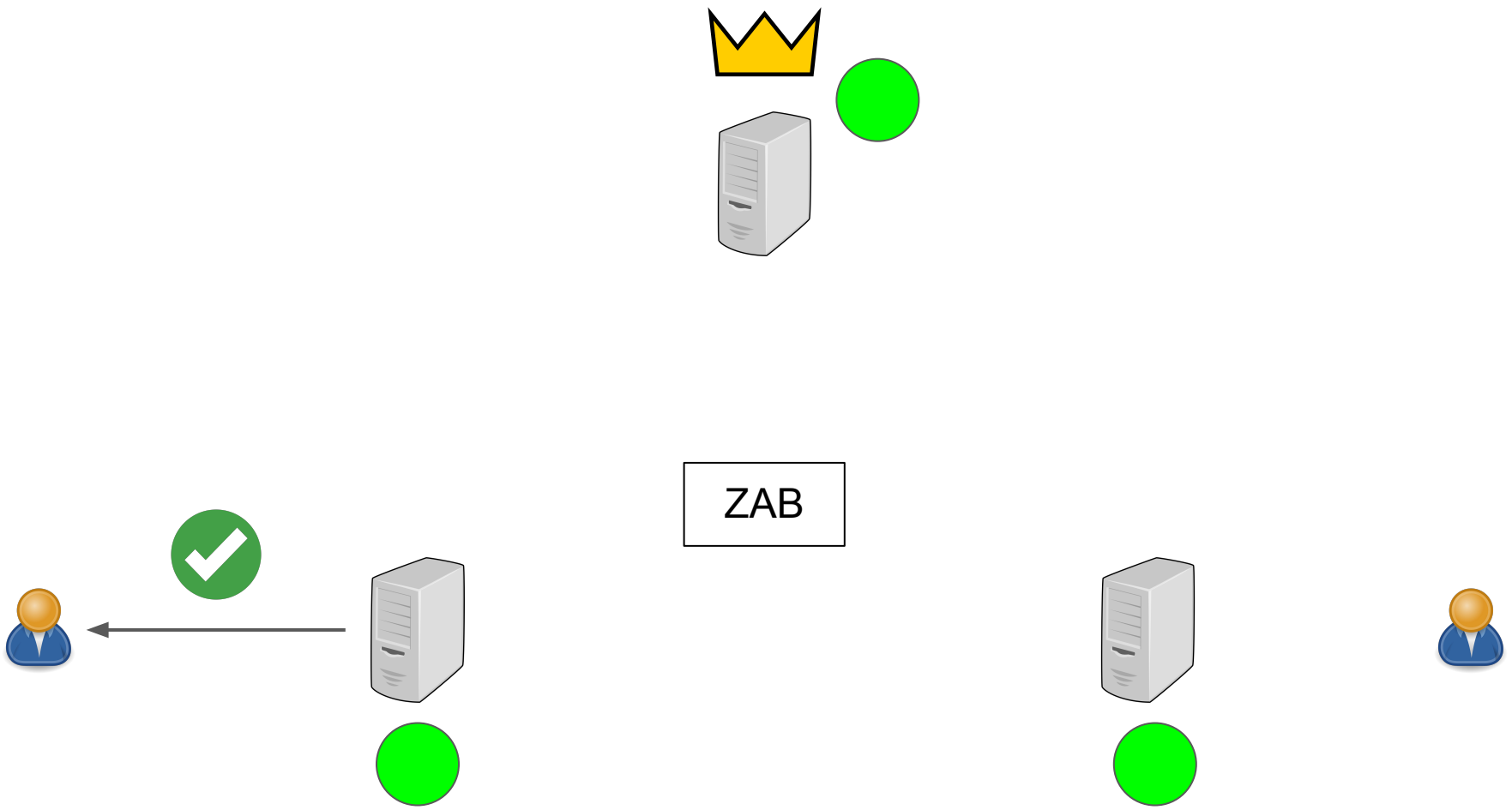
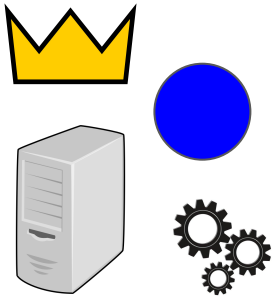
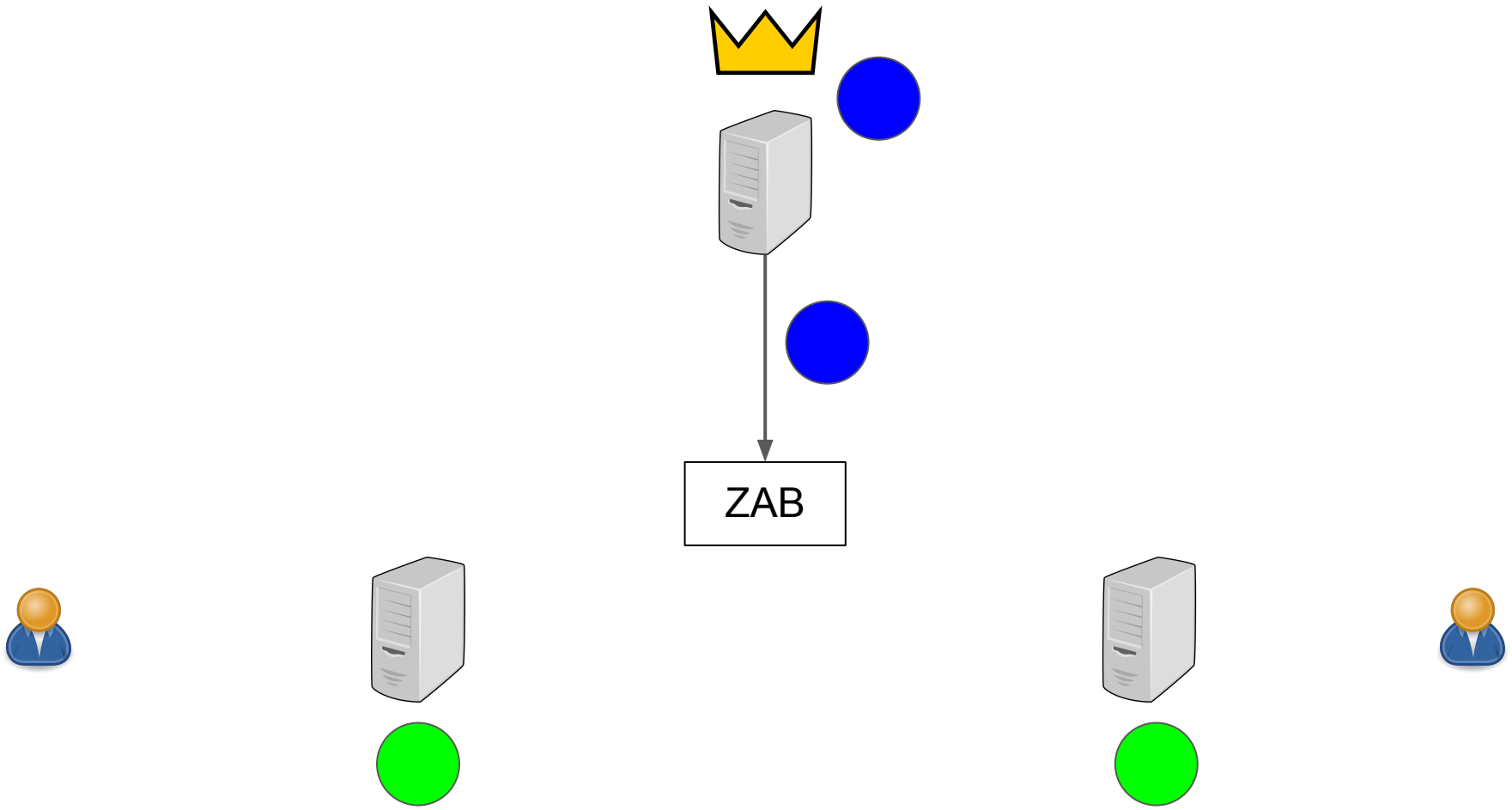


Linearizable Writes



ZAB

Linearizable Writes



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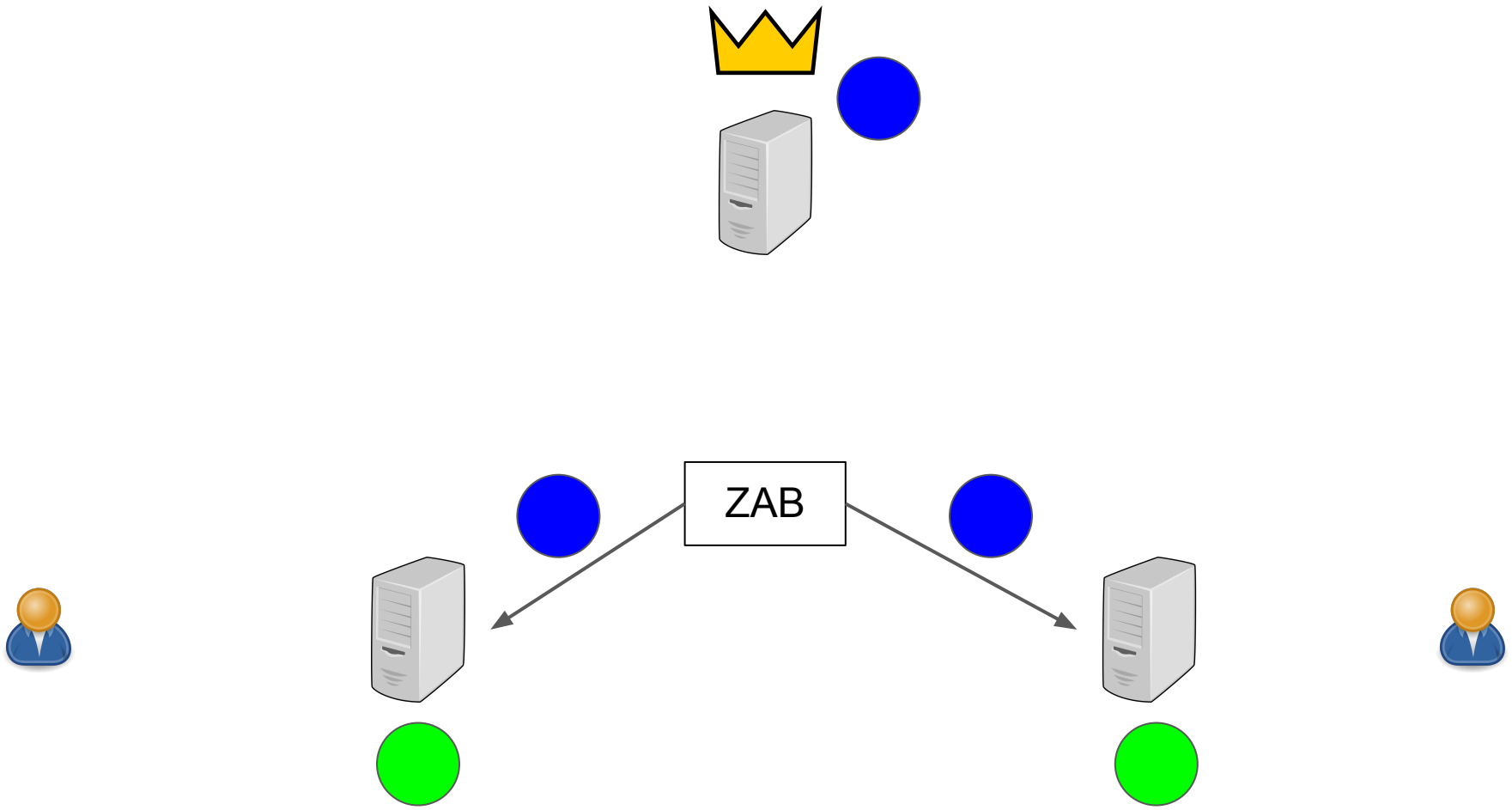

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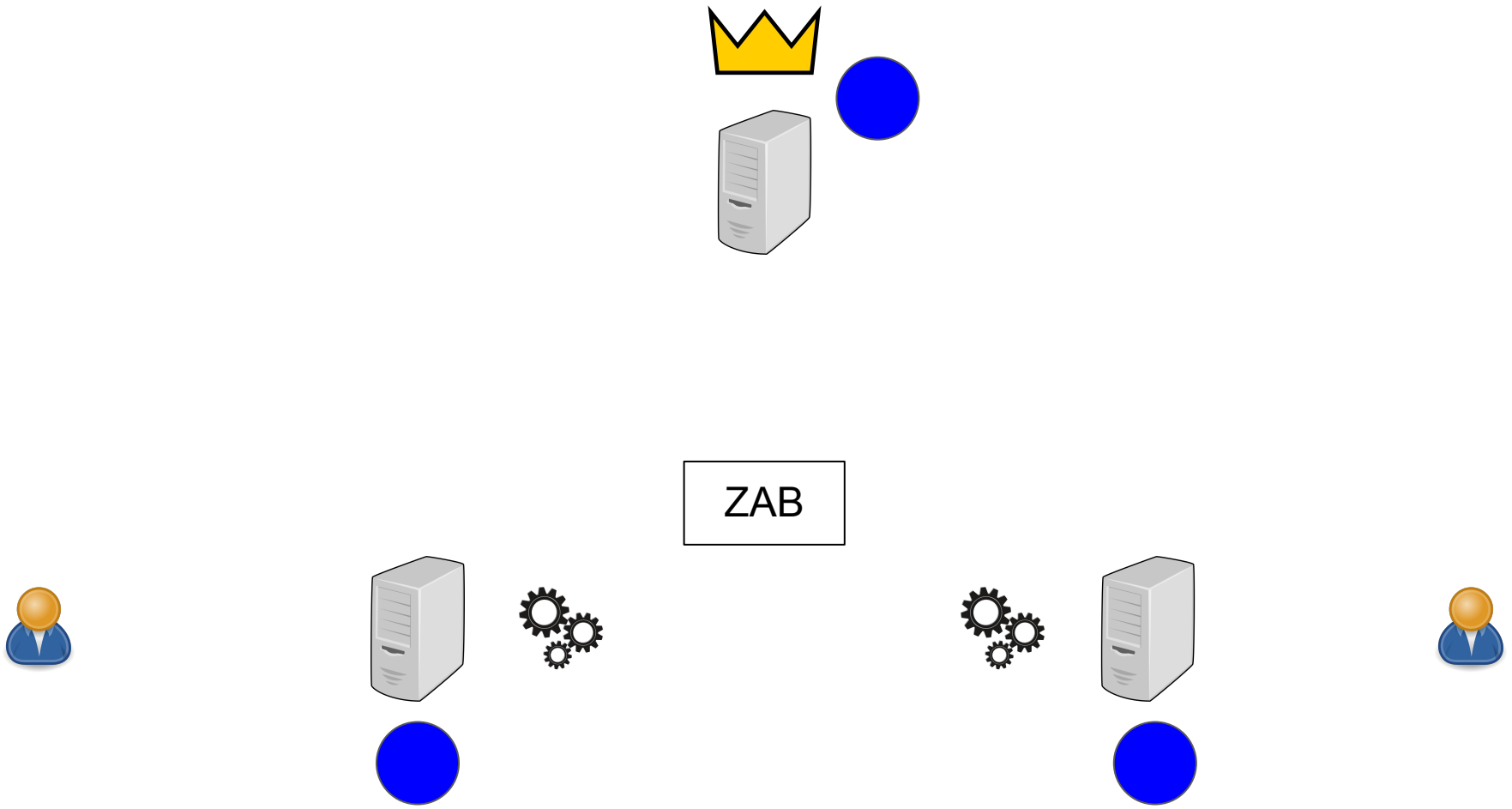

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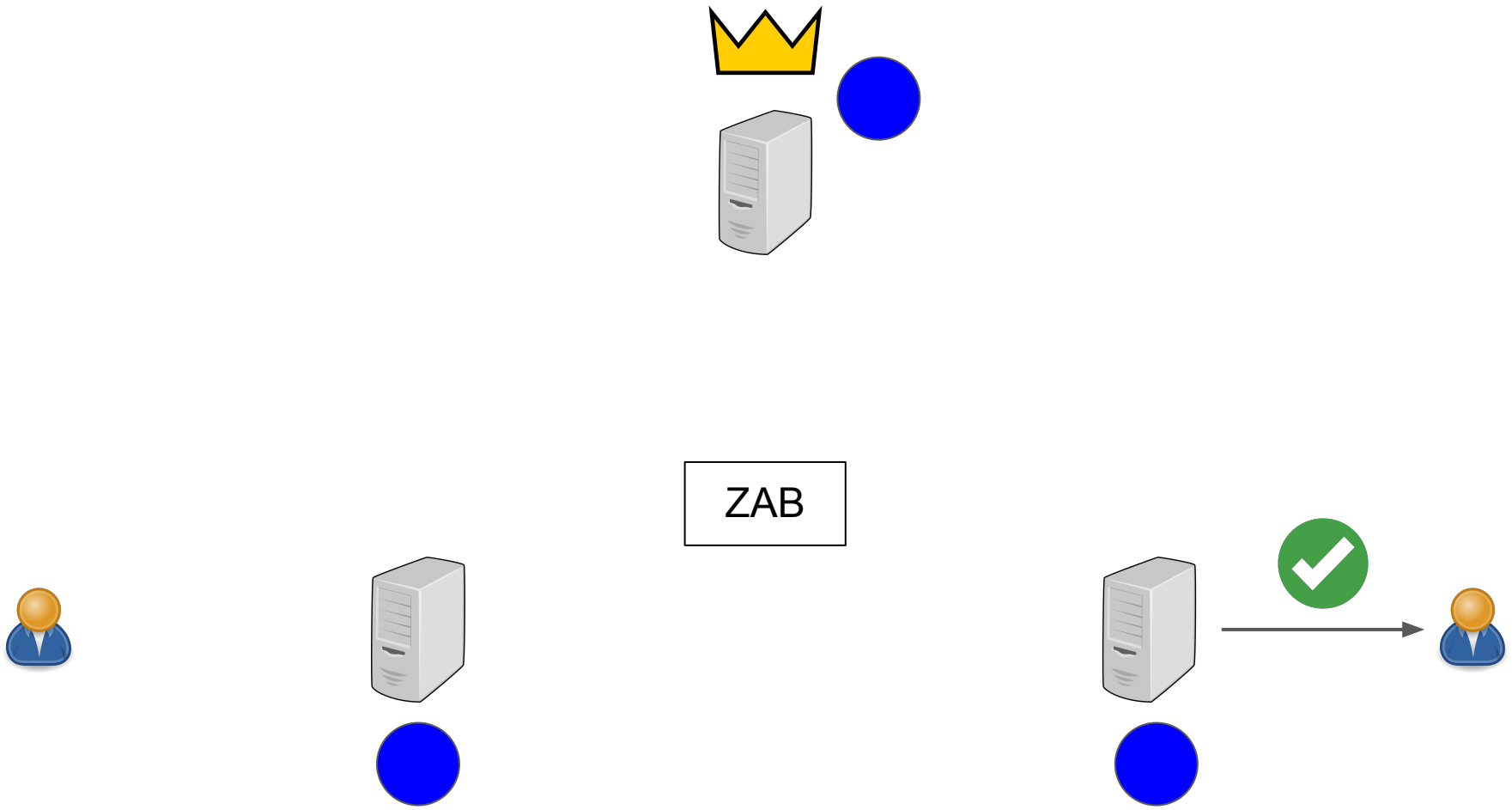
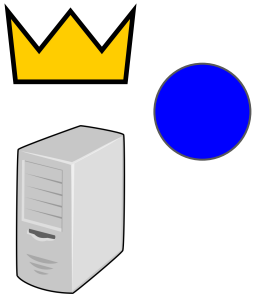


Linearizable Writes

Atomic Broadcast guarantees that writes are applied in the same total order at all replicas



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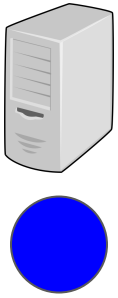
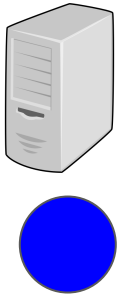


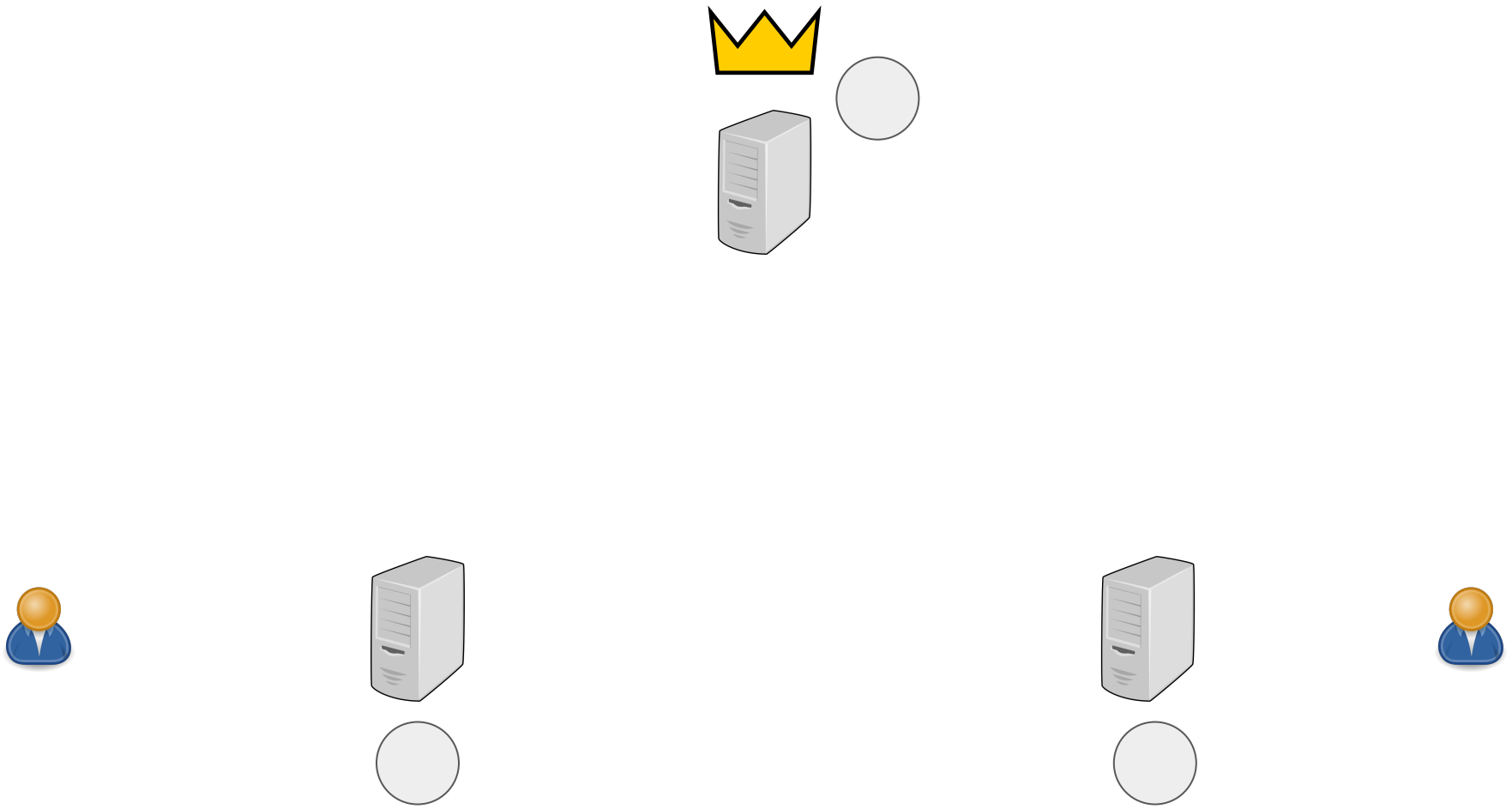


How does ZooKeeper achieve performance?

All ZooKeeper operations are **wait-free**.

Read requests are processed **locally**, by the individual replica that communicates with the client.

Fast Reads



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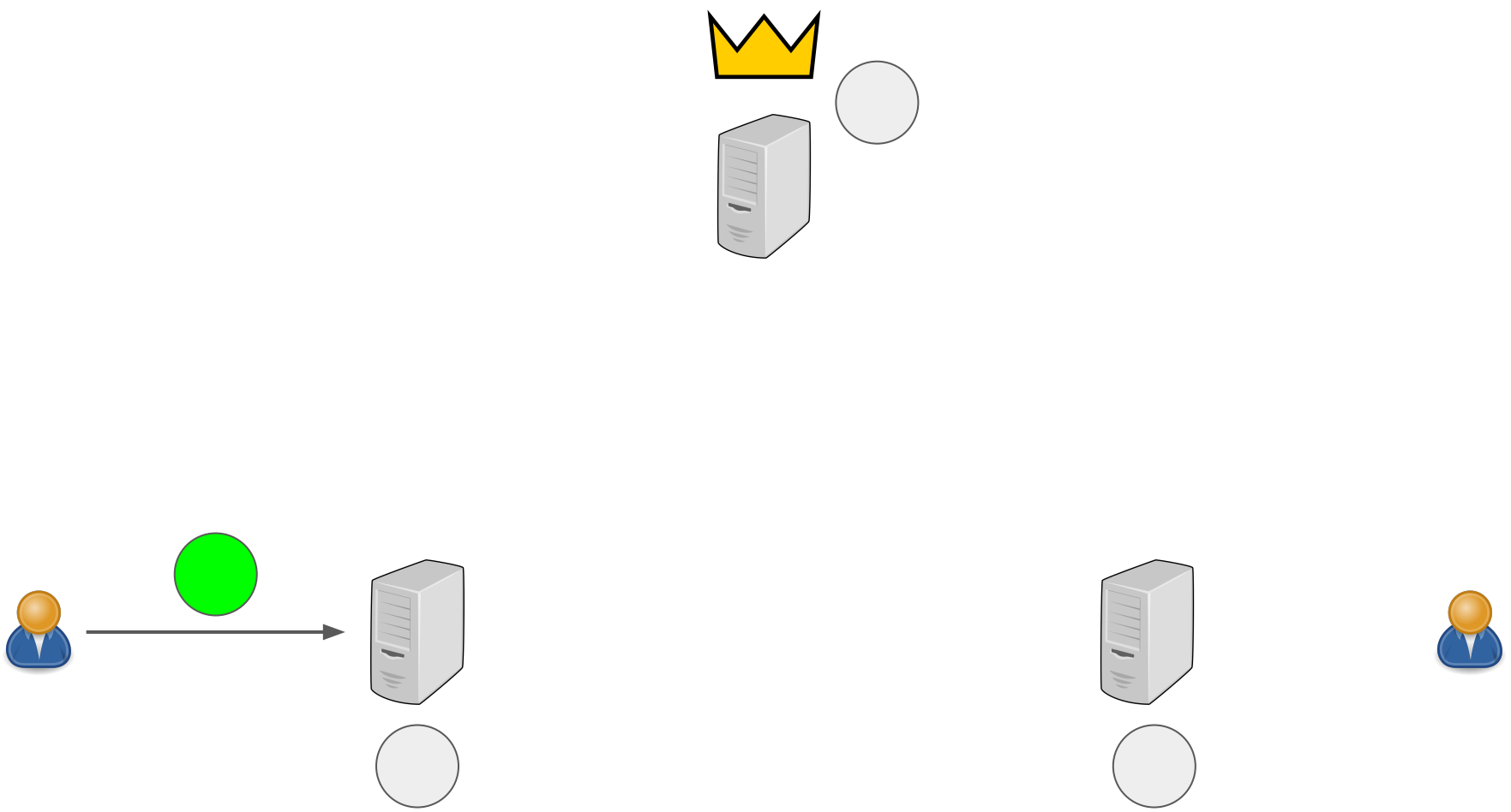

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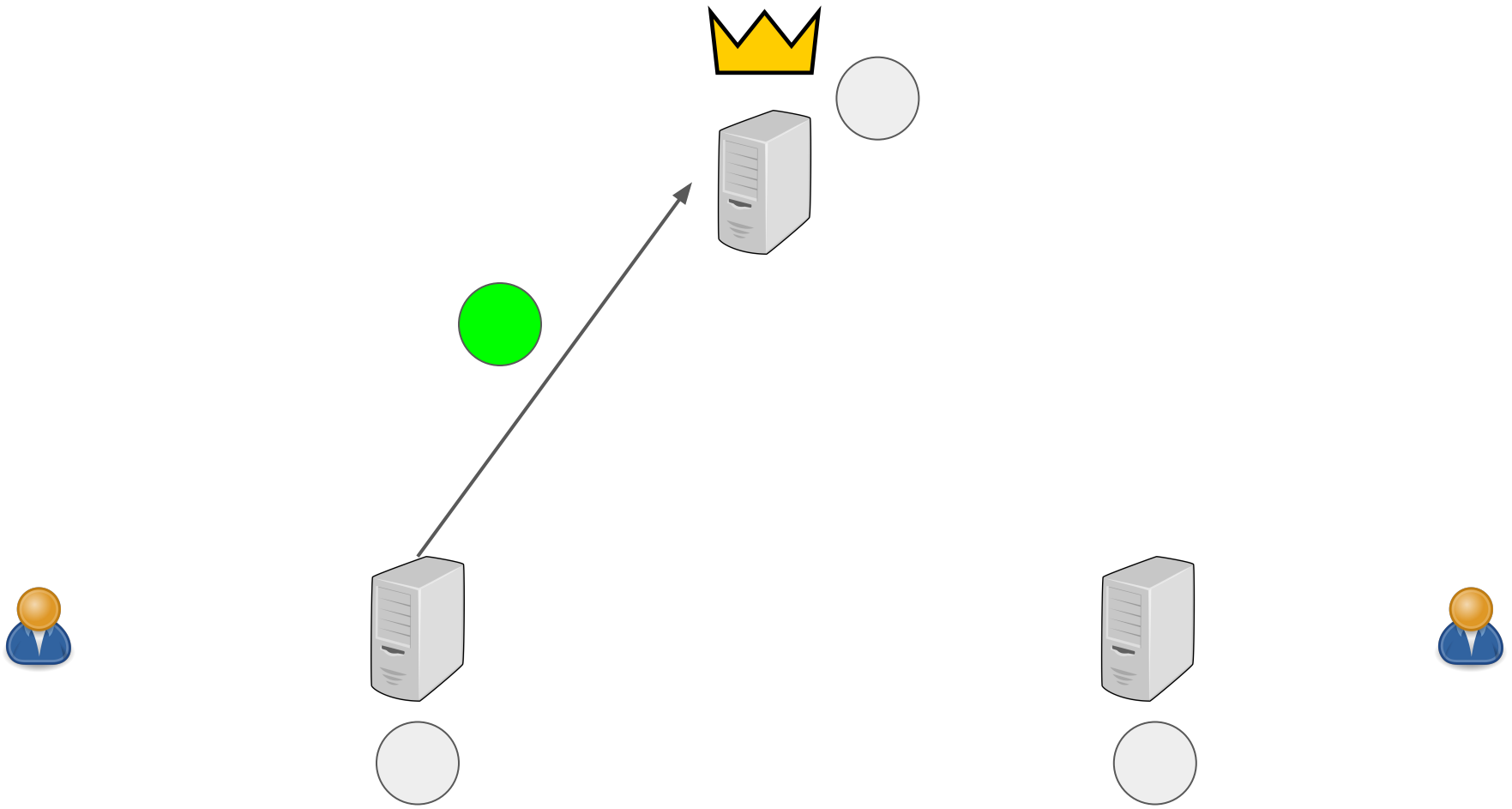

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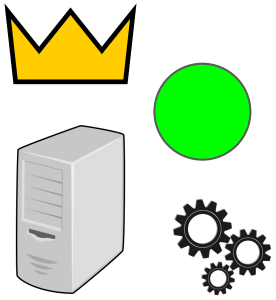

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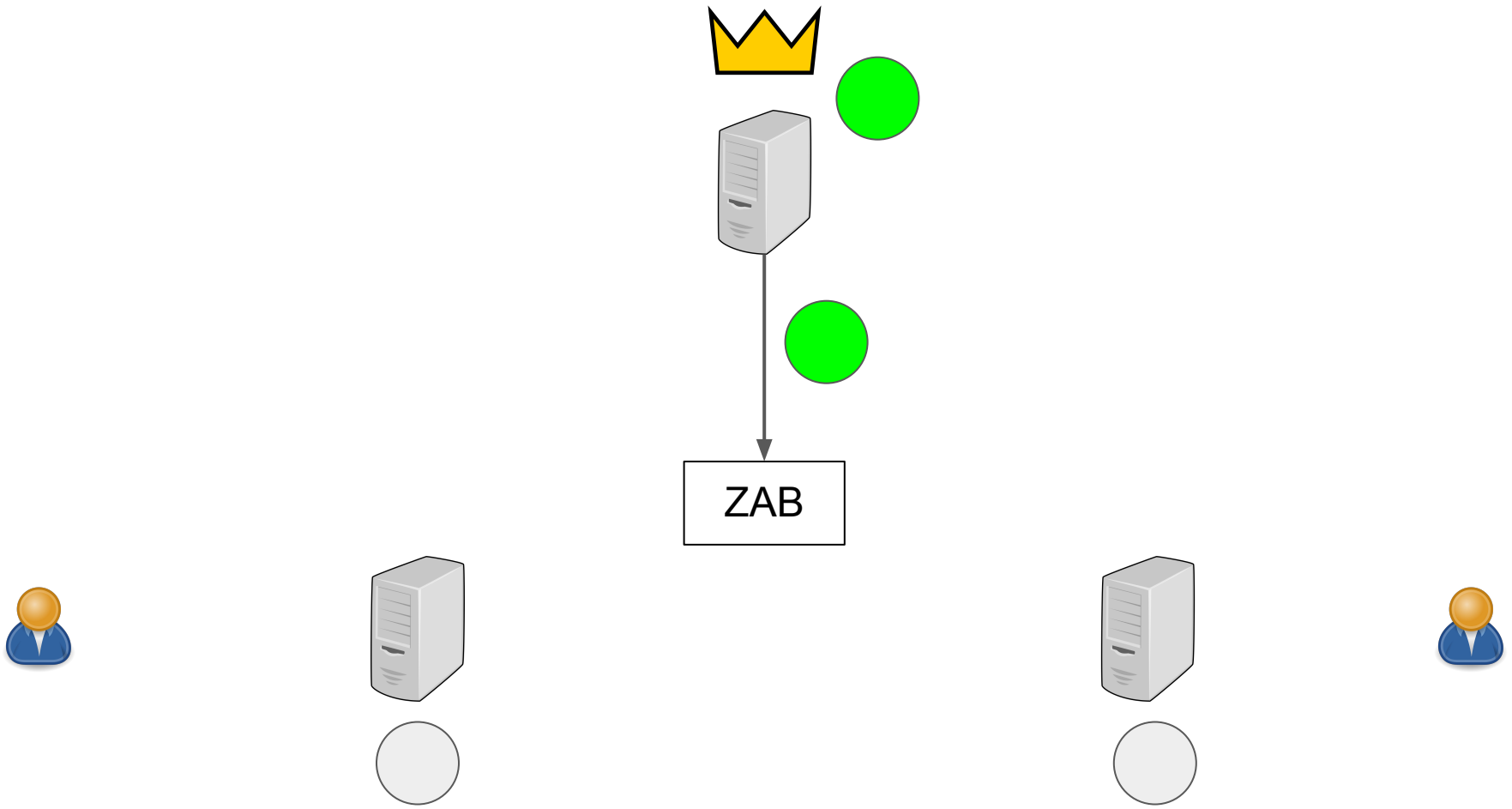

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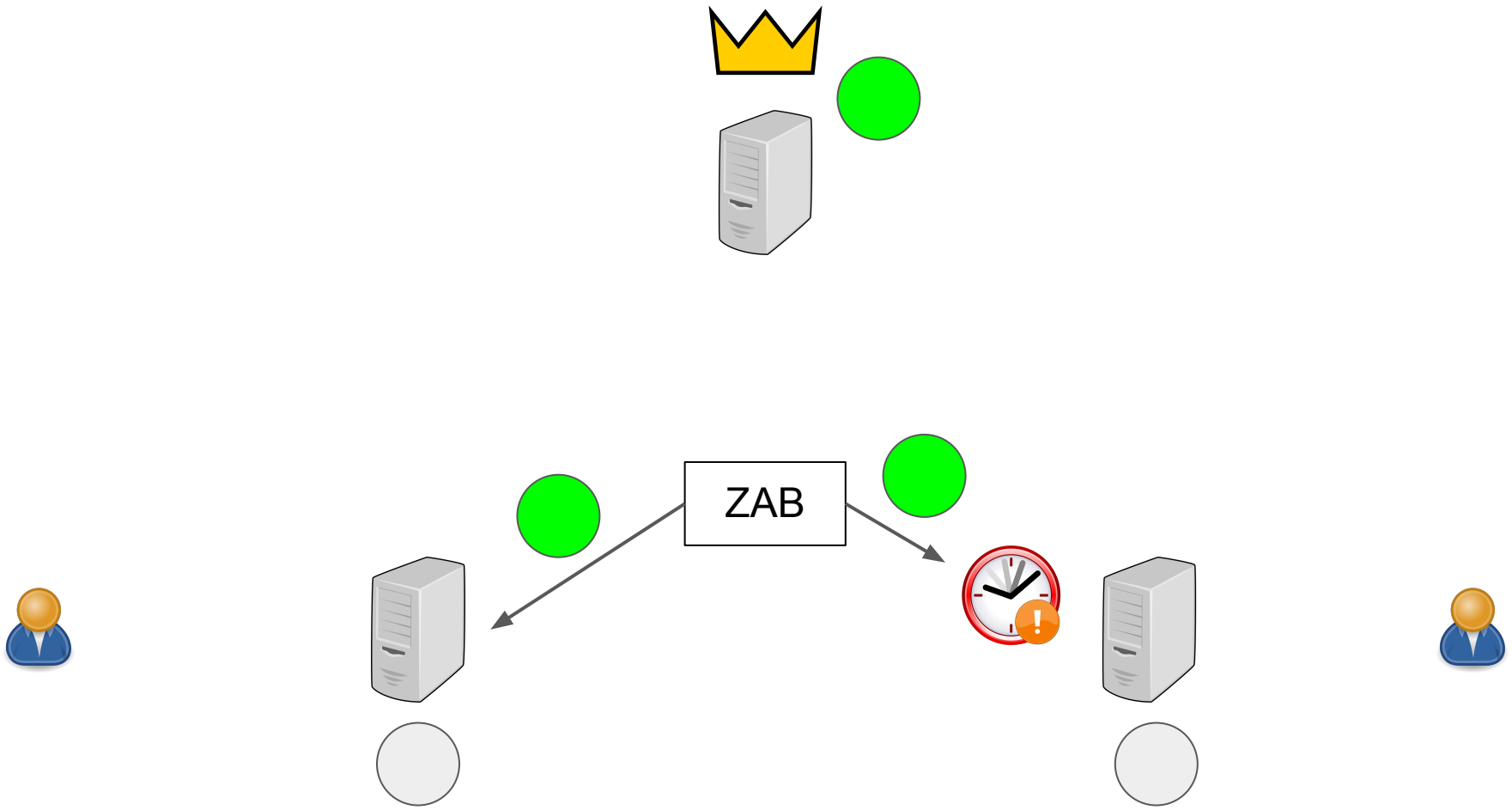

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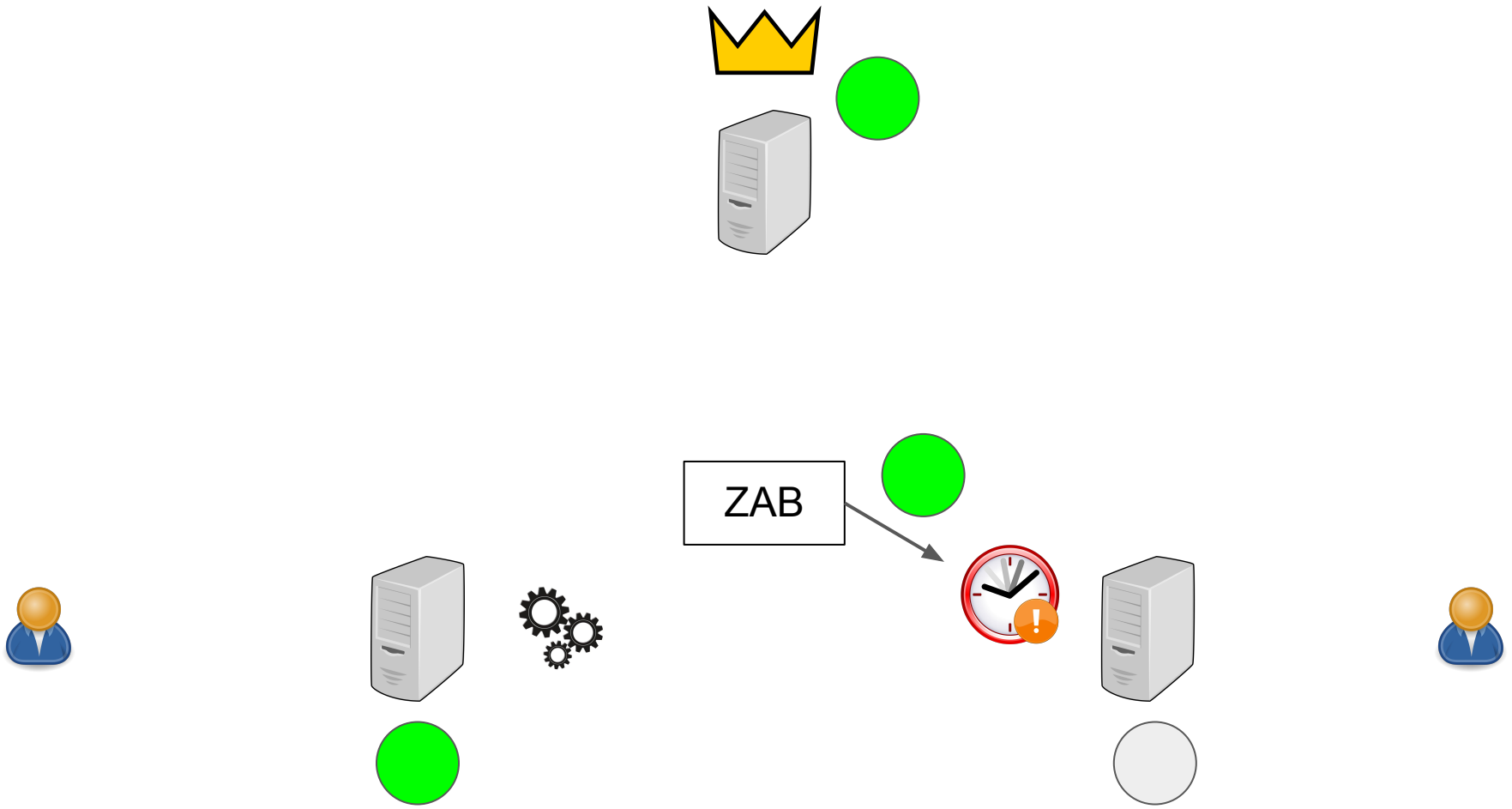

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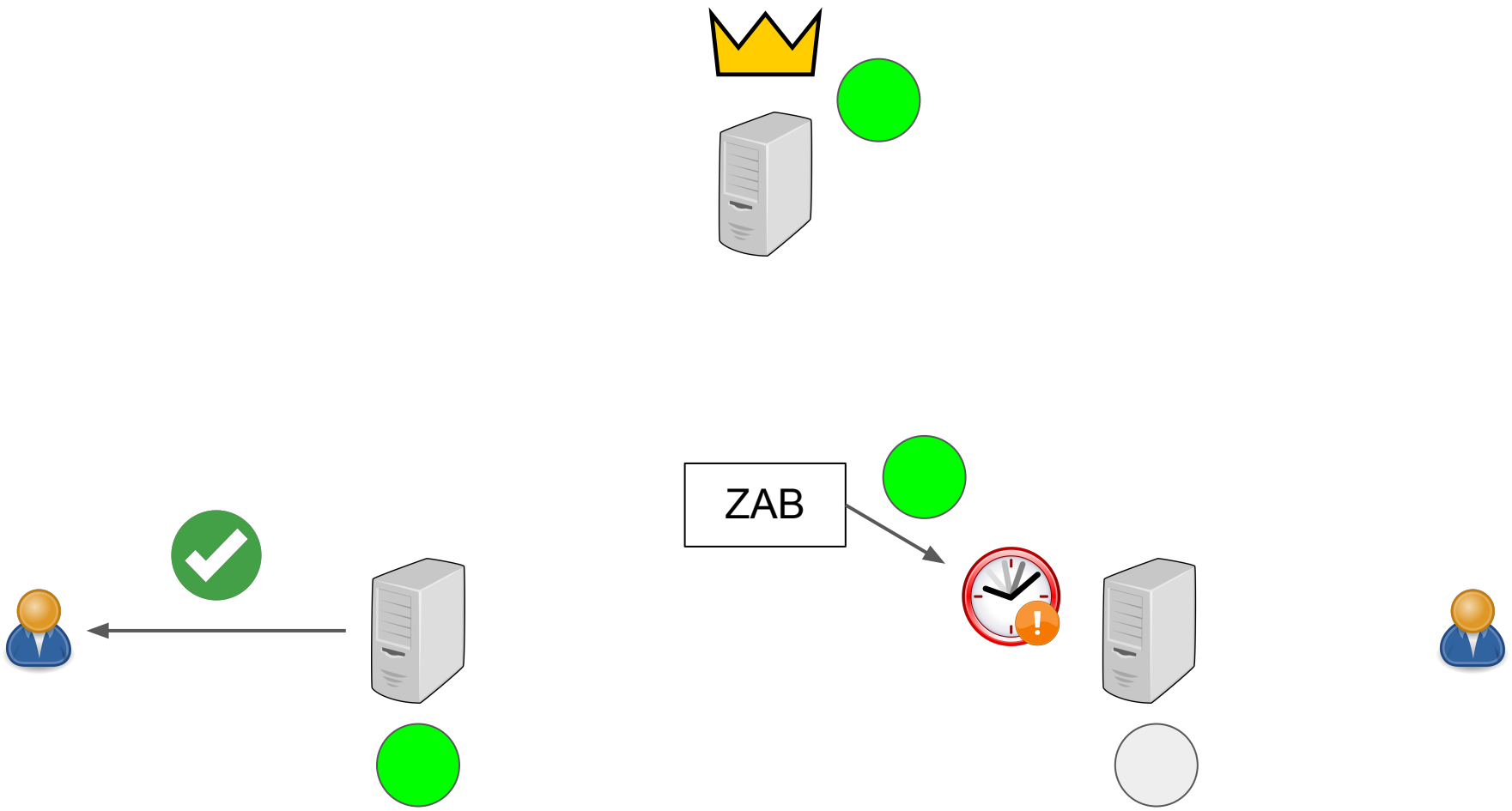

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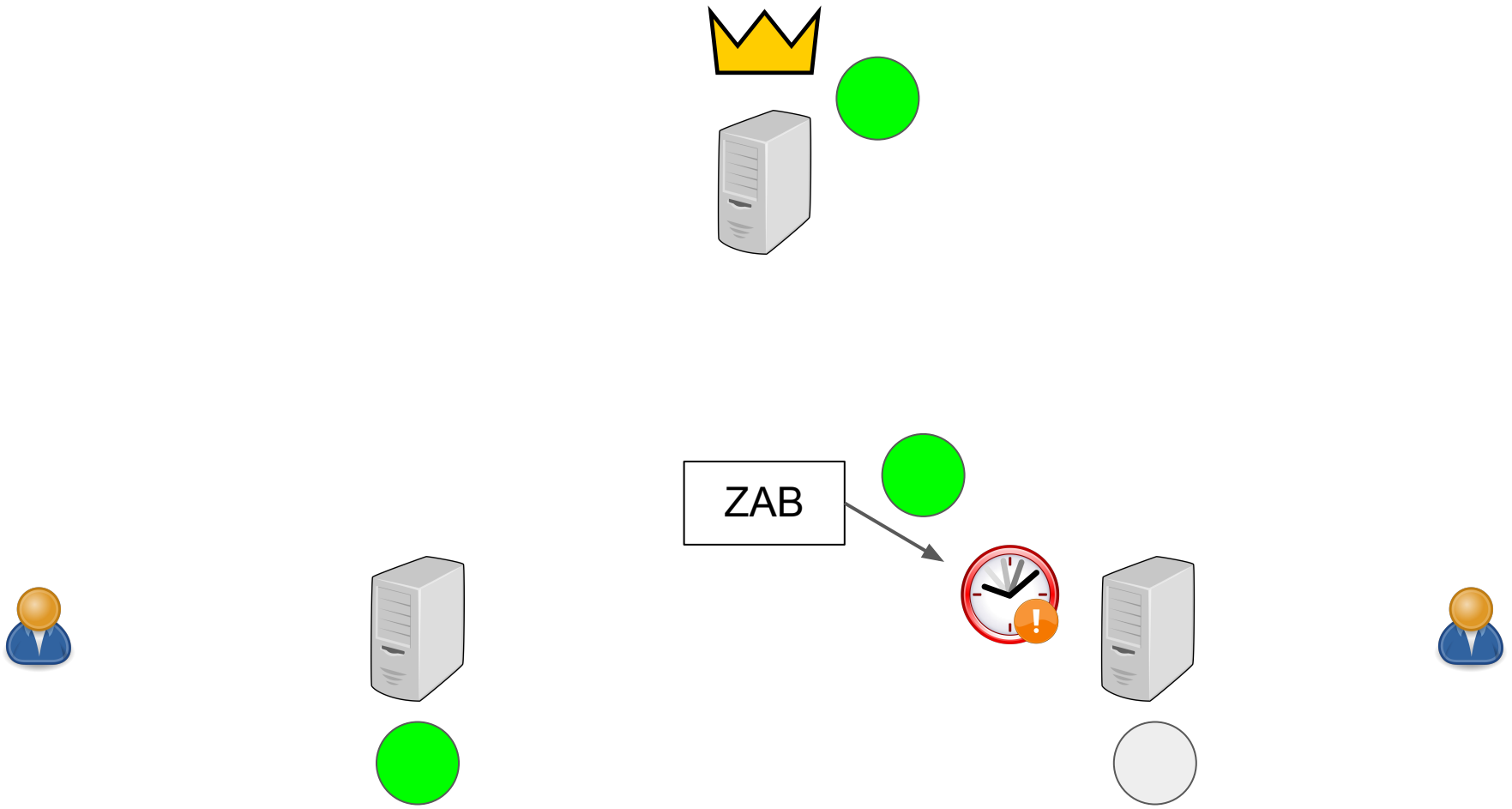

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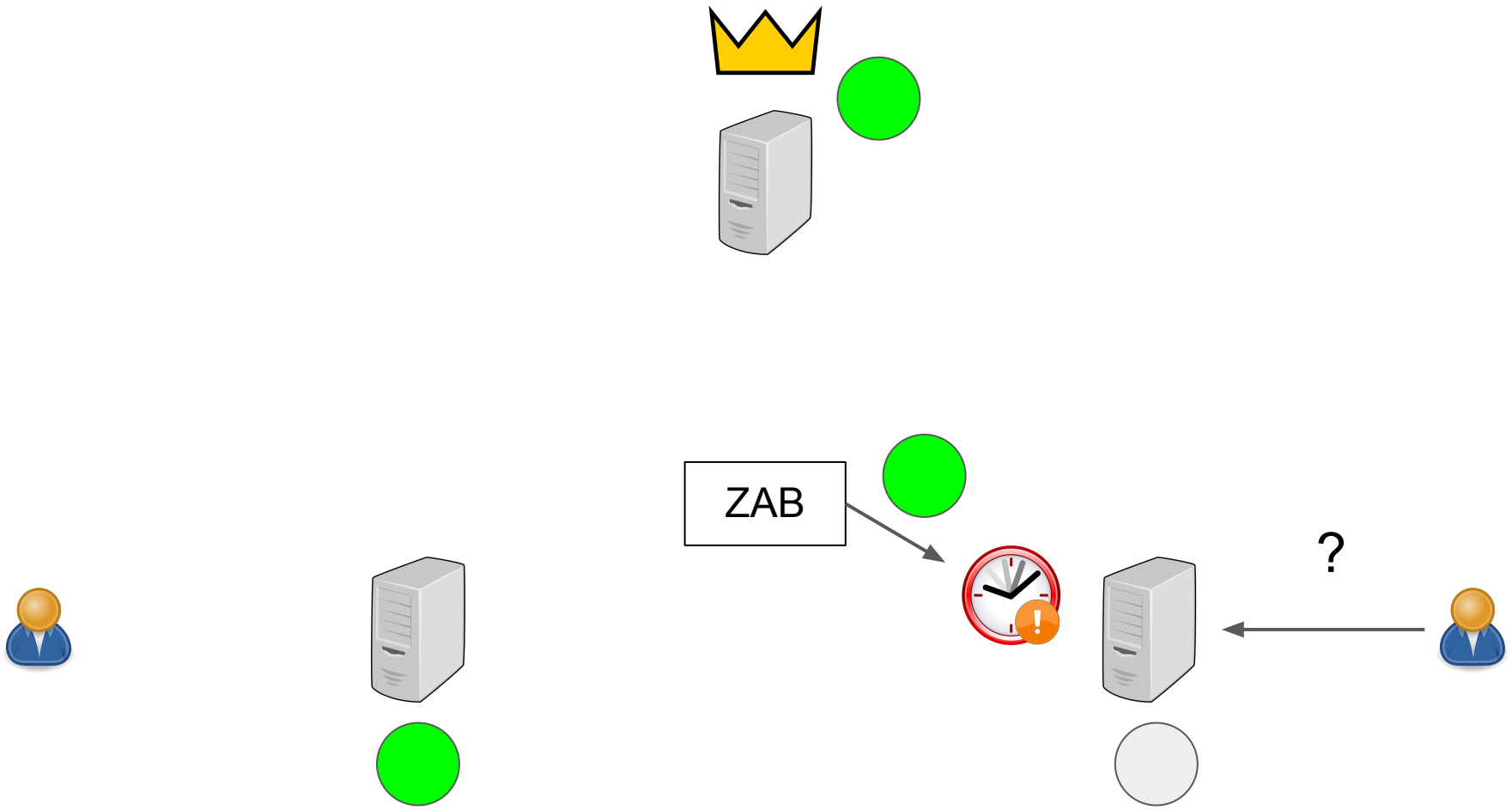

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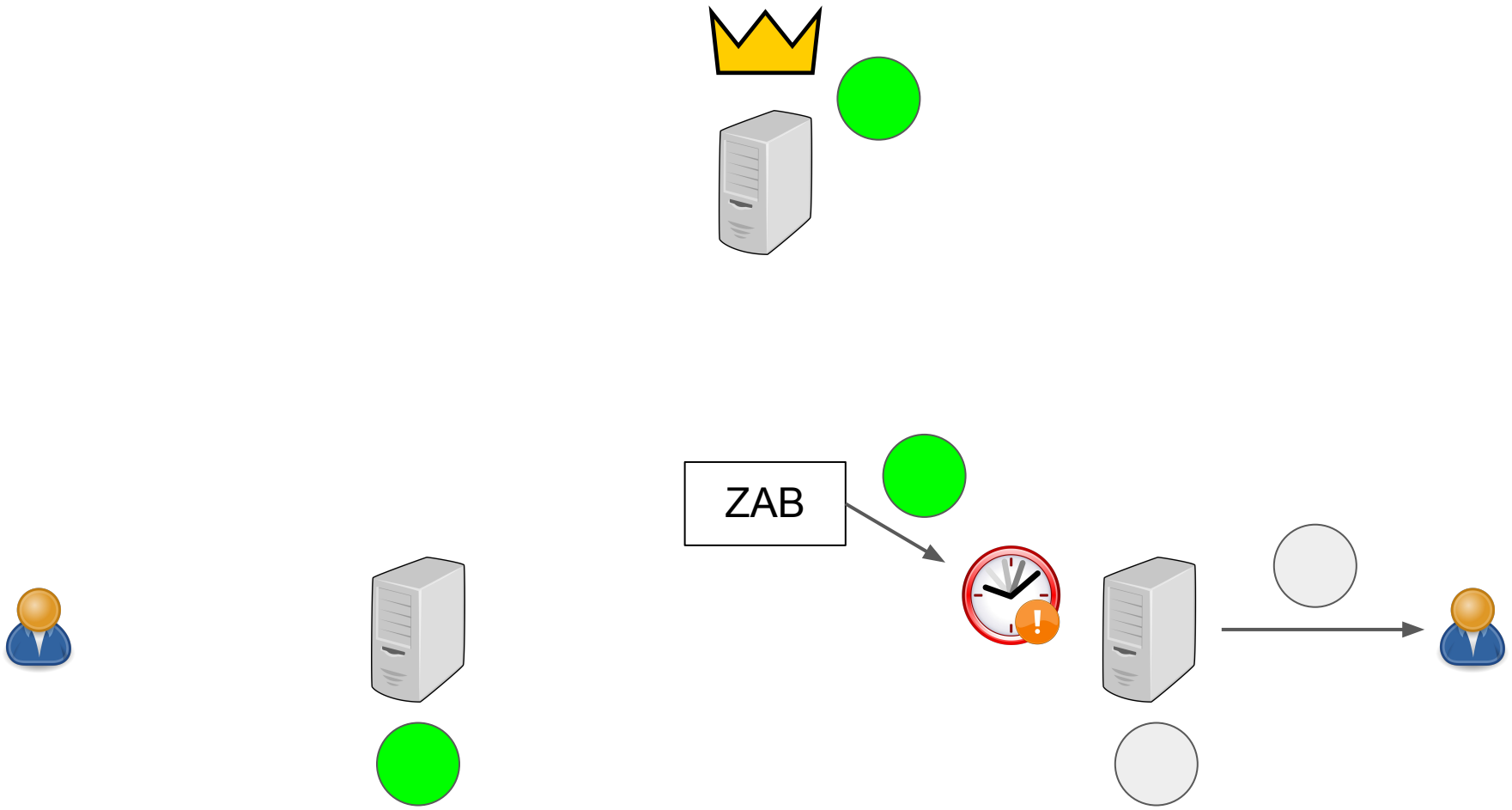

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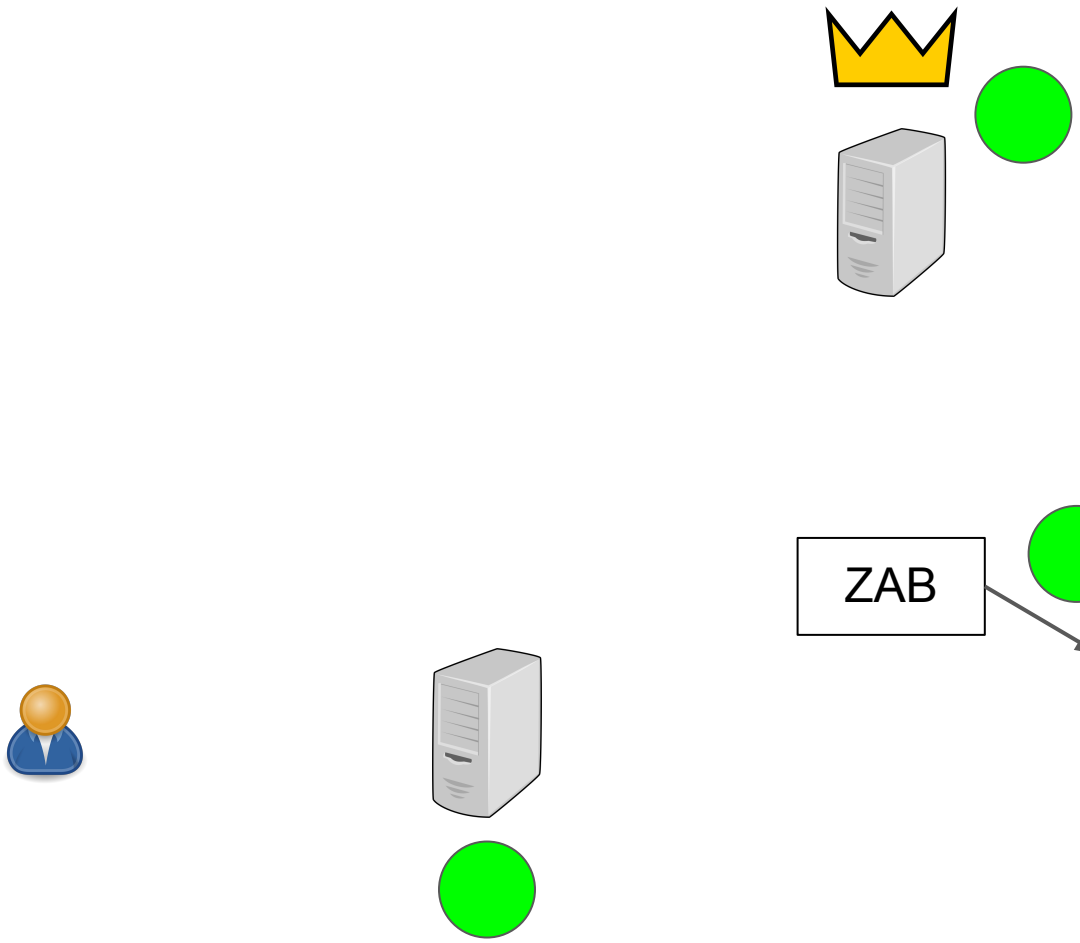


A read may return a stale value, even though a write request has completed!

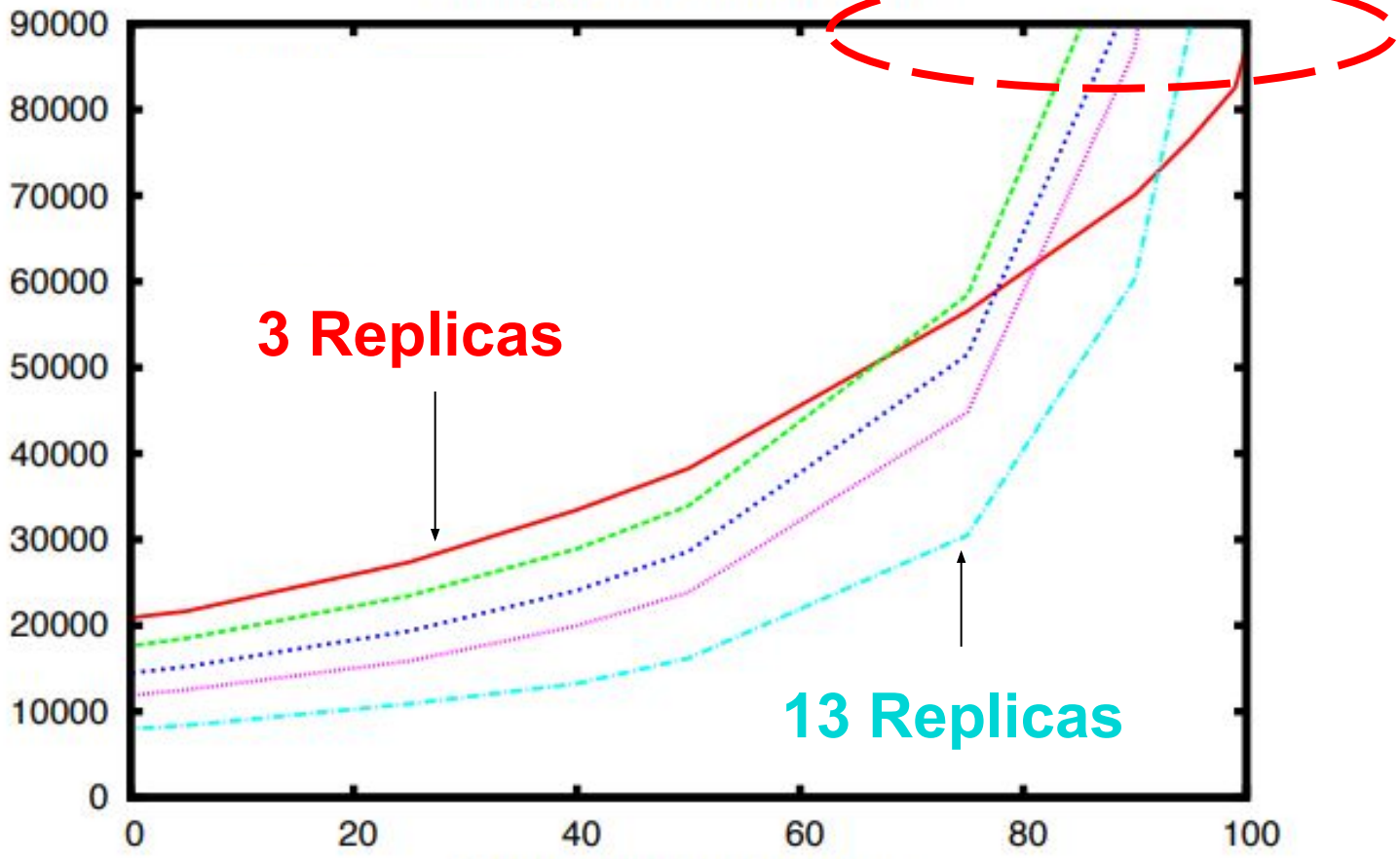
How does it Perform?

To evaluate ZooKeeper's performance, the throughput was measured for a fully-saturated system.

- 250 clients
- 1K Data for read/write requests
- Read:Write ratio varied from 0 to 1
- Experiment repeated for different numbers of ZooKeeper replicas

Throughput

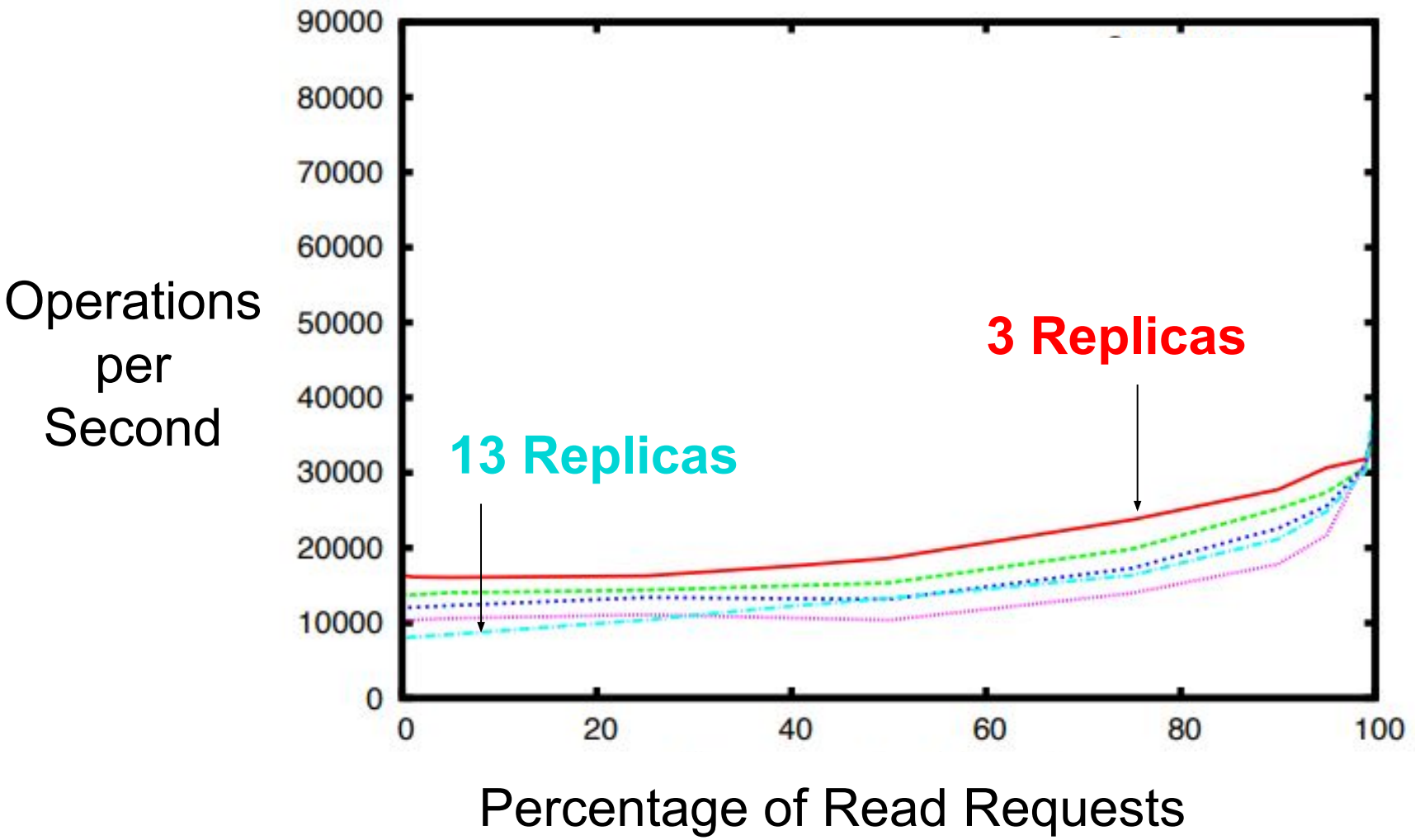
Throughput for 13 replicas, 100% reads: 460k



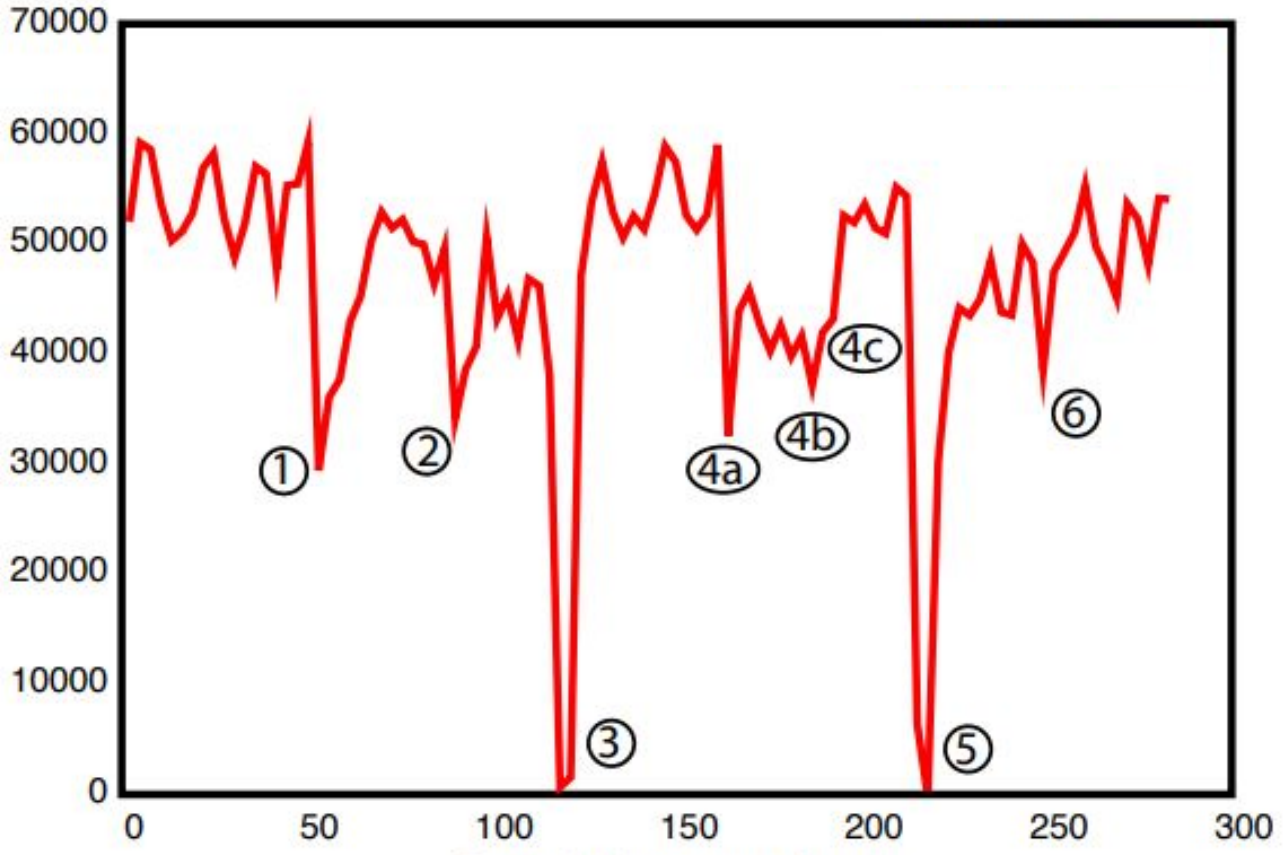
Operations per Second

Percentage of Read Requests

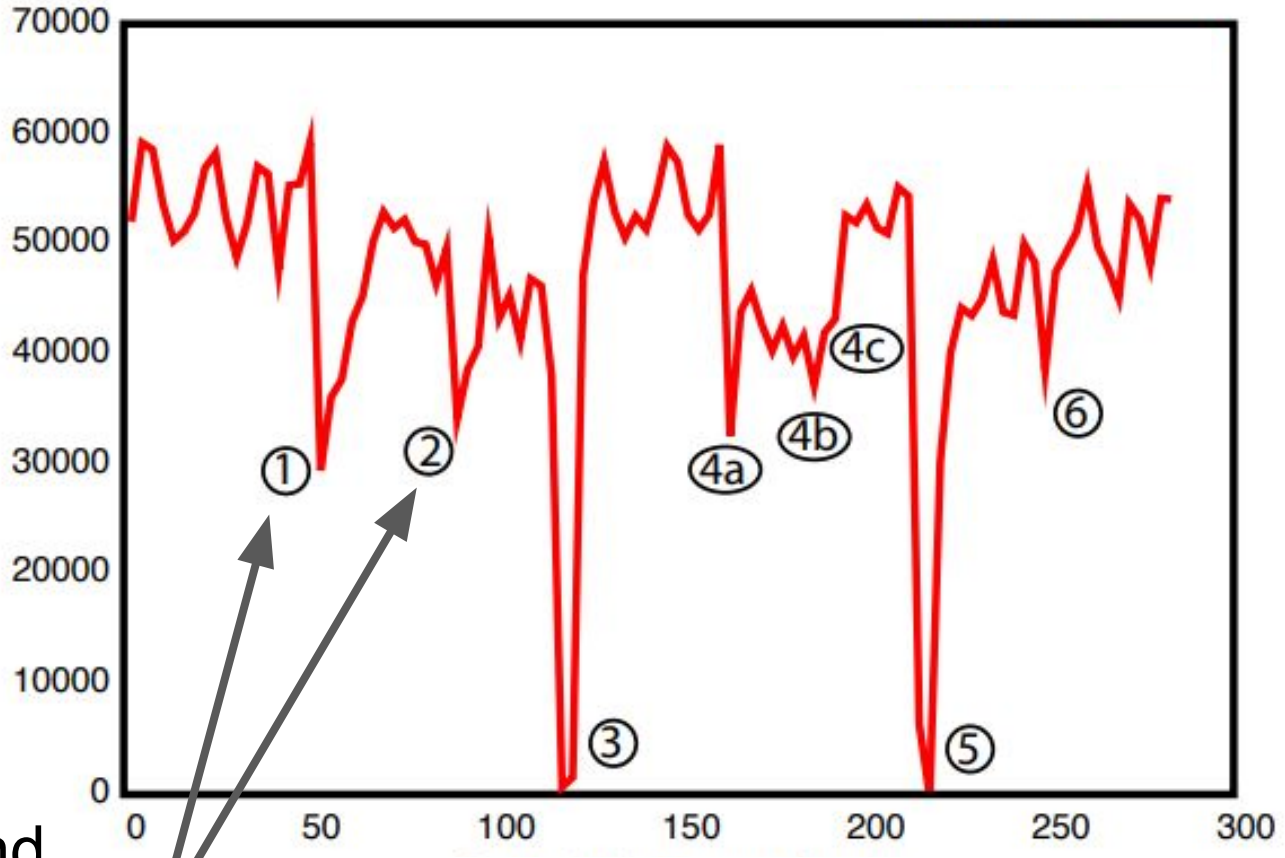
Throughput (All Requests to Leader)



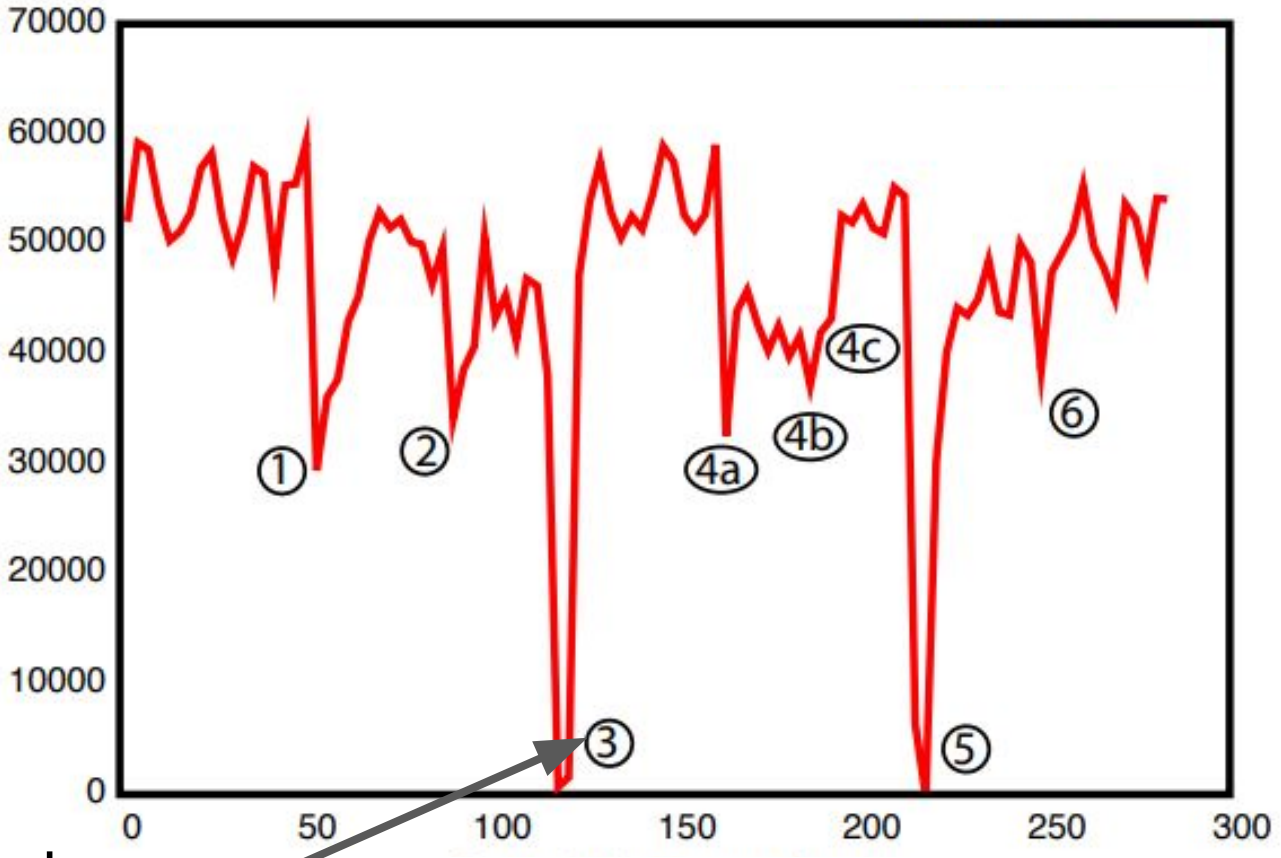
Throughput with Failures



Throughput with Failures



Throughput with Failures



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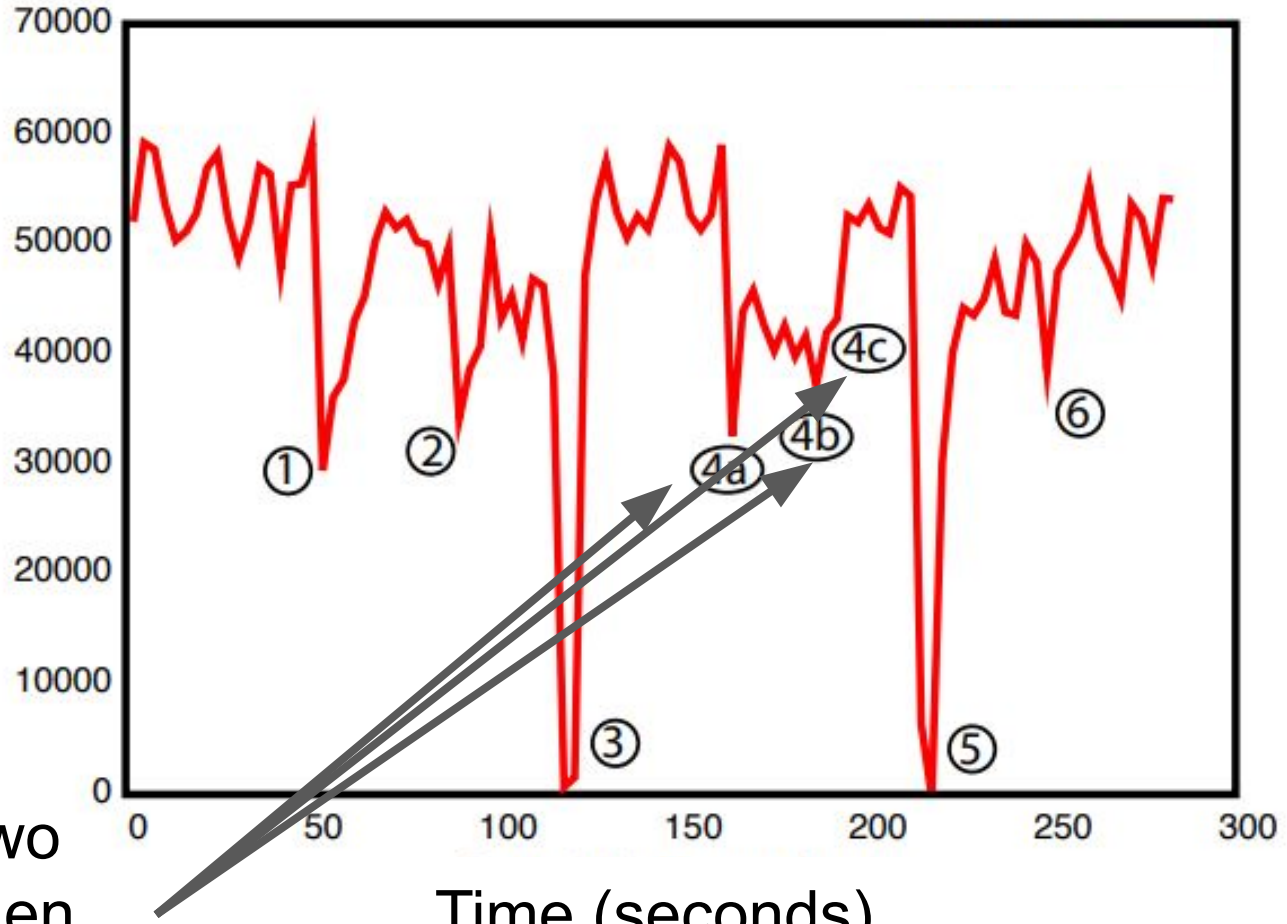

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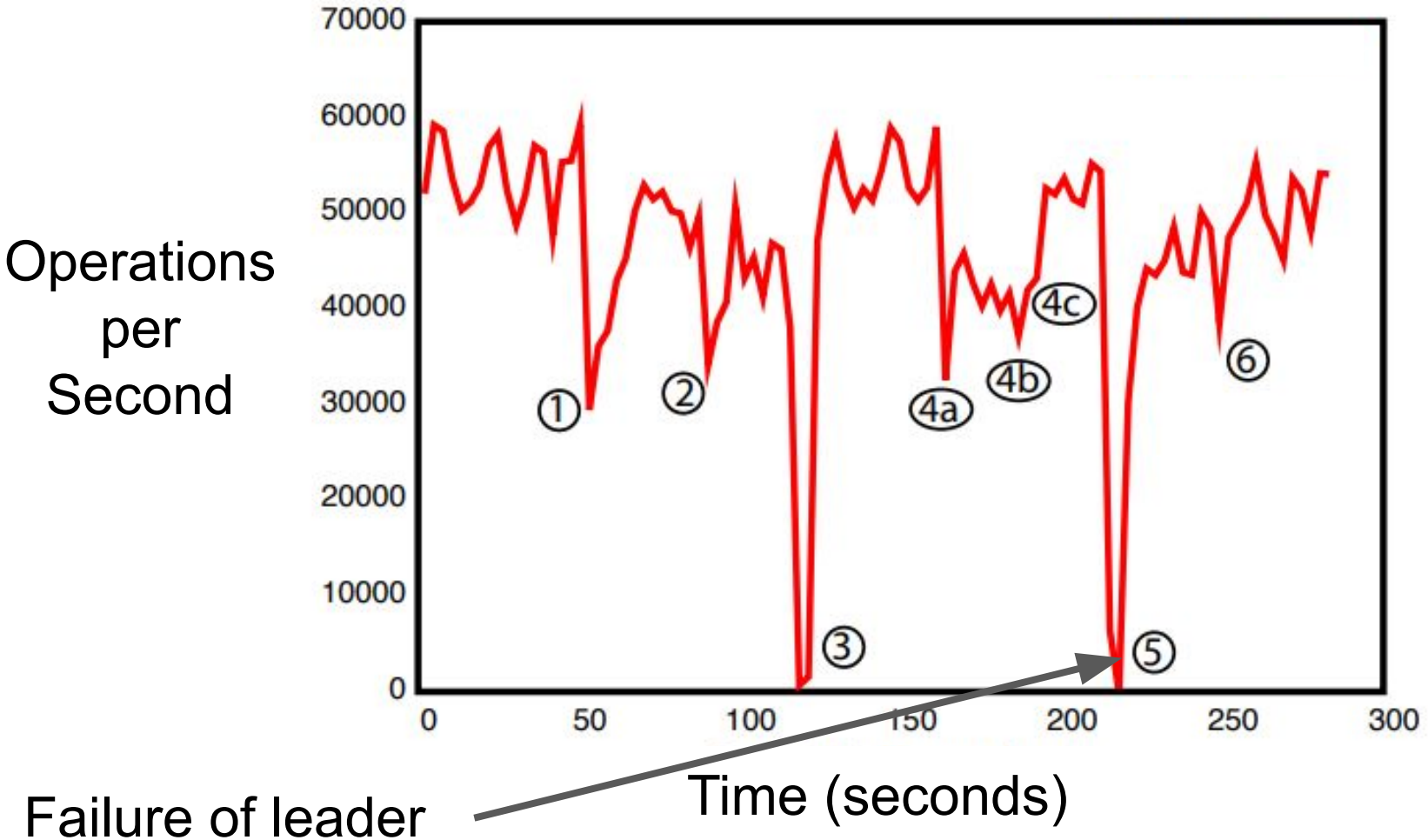

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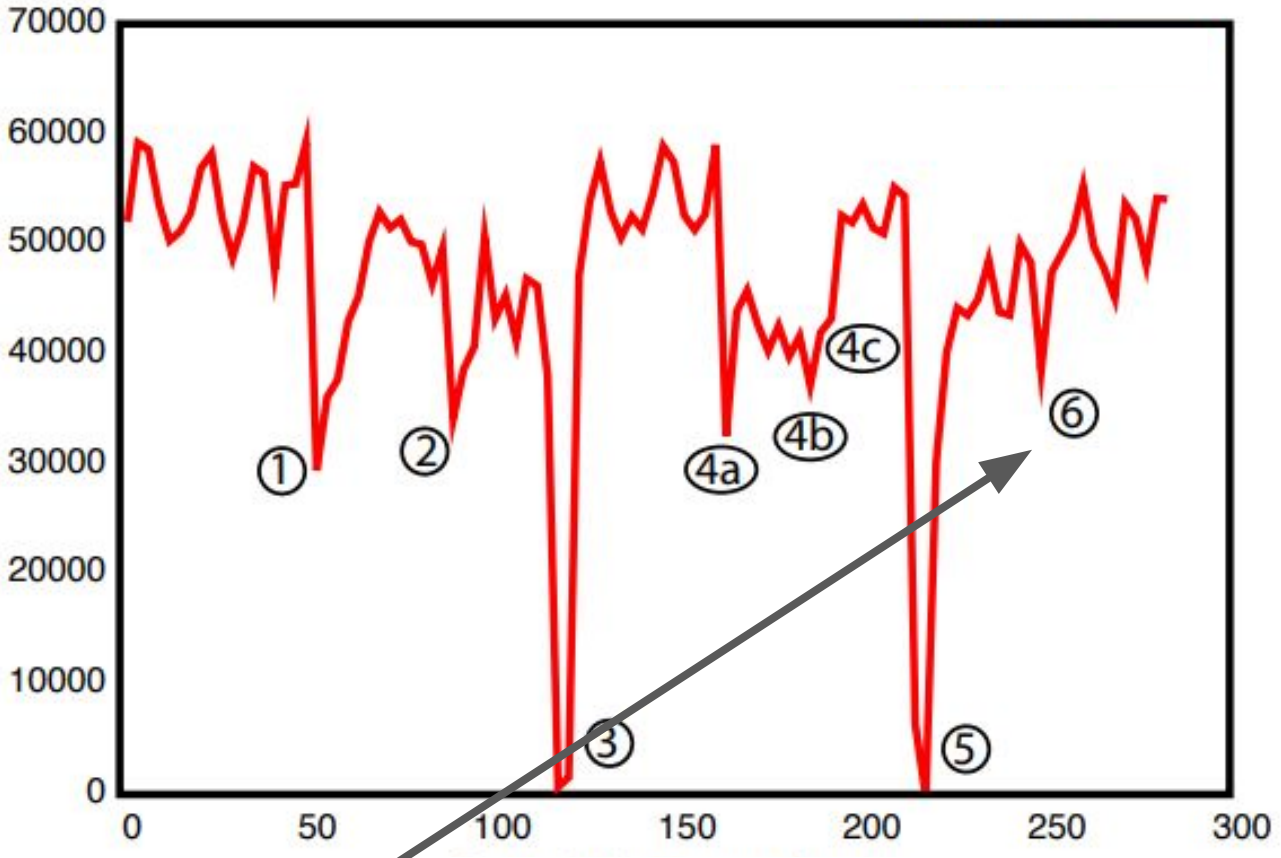

Latency

	Number of servers			
Workers	3	5	7	9
1	776	748	758	711
10	2074	1832	1572	1540
20	2740	2336	1934	1890

Table 2: Create requests processed per second.

Thank you! Questions?