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Systems Support For Efficient State-Machine Replication

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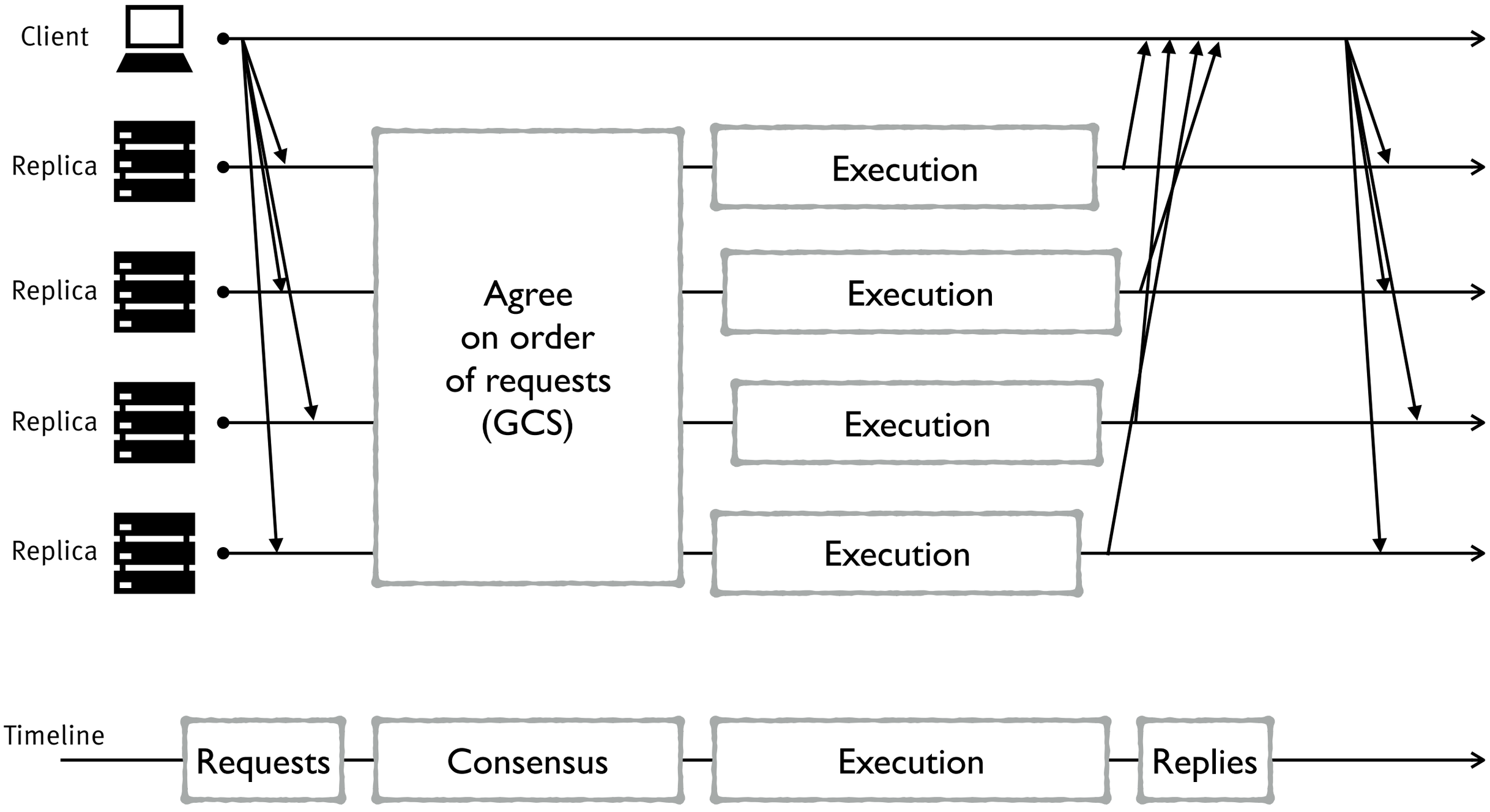
SMR

- Service modelled as deterministic finite state machine
- DSFM replicated across multiple servers (“replicas”)
- Incoming requests have to be totally ordered

➡ All replicas yield same state after receiving the same requests

➡ Can tolerate Byzantine faults

SMR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Agree on order of requests (GCS)
Execution
Execution
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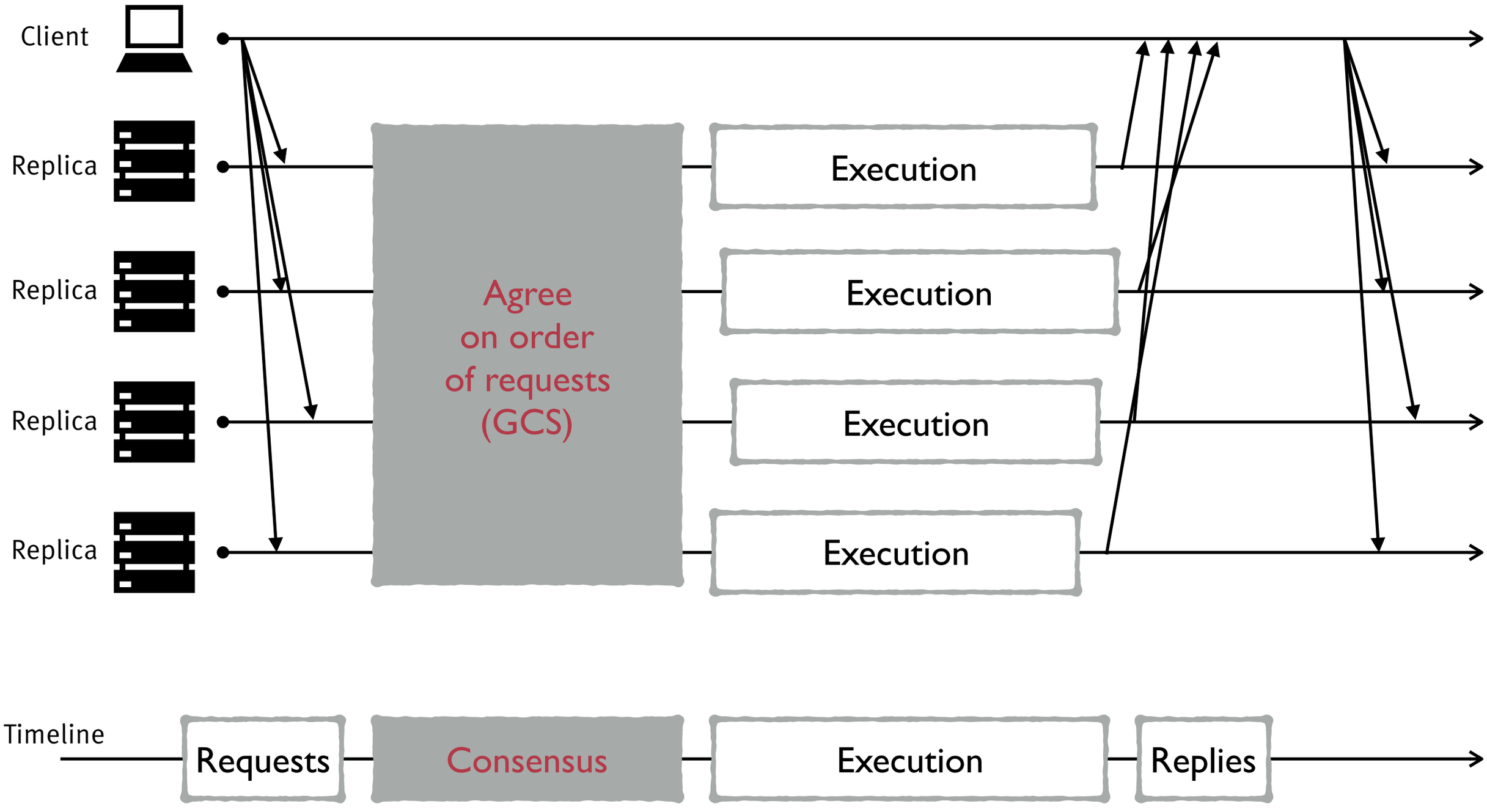
Execution
Timeline
Requests
Consensus
Execution
Replies

Efficient SMR

- Topics we are looking at:
- GCS —› Consensus with trusted components
- Execution —› Parallelized request handling; multithreading
- Variable request arrival rates —› Adapt to current load
- Checkpointing/Recovery —› Re-enable for parallel execution

SMR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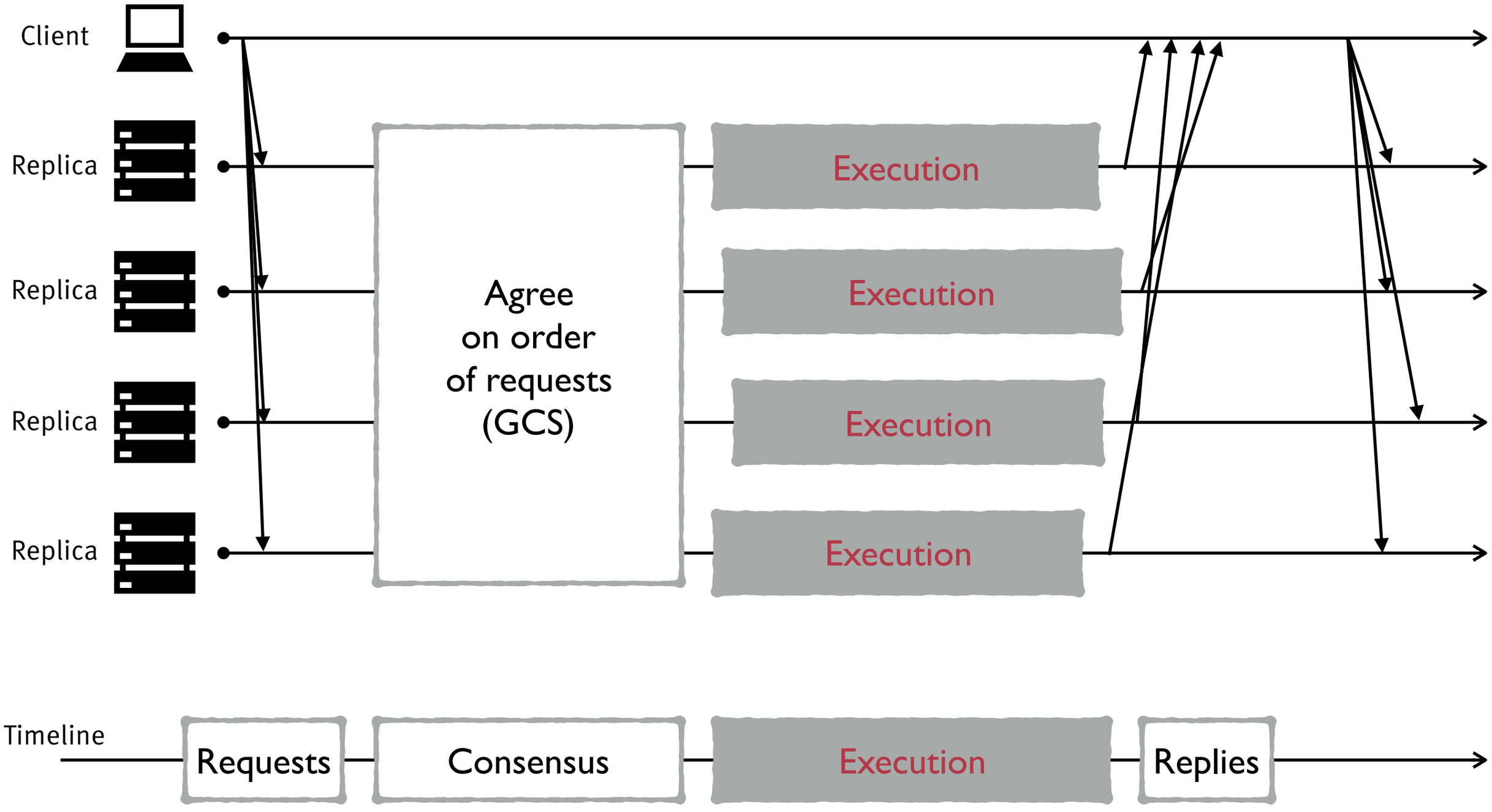
Trusted Components

- Deploying trusted components in the GCS can reduce overhead and increase performance
- Example: EBAWA
  - Contains several liveness and safety bugs we detected and fixed
  - New algorithm supporting trusted components: *Aphousia* (not yet published)
- Additional problem: Swapping of consensus algorithms in current systems hard (usually hardwired)
  - Research on modularizing SMR

SMR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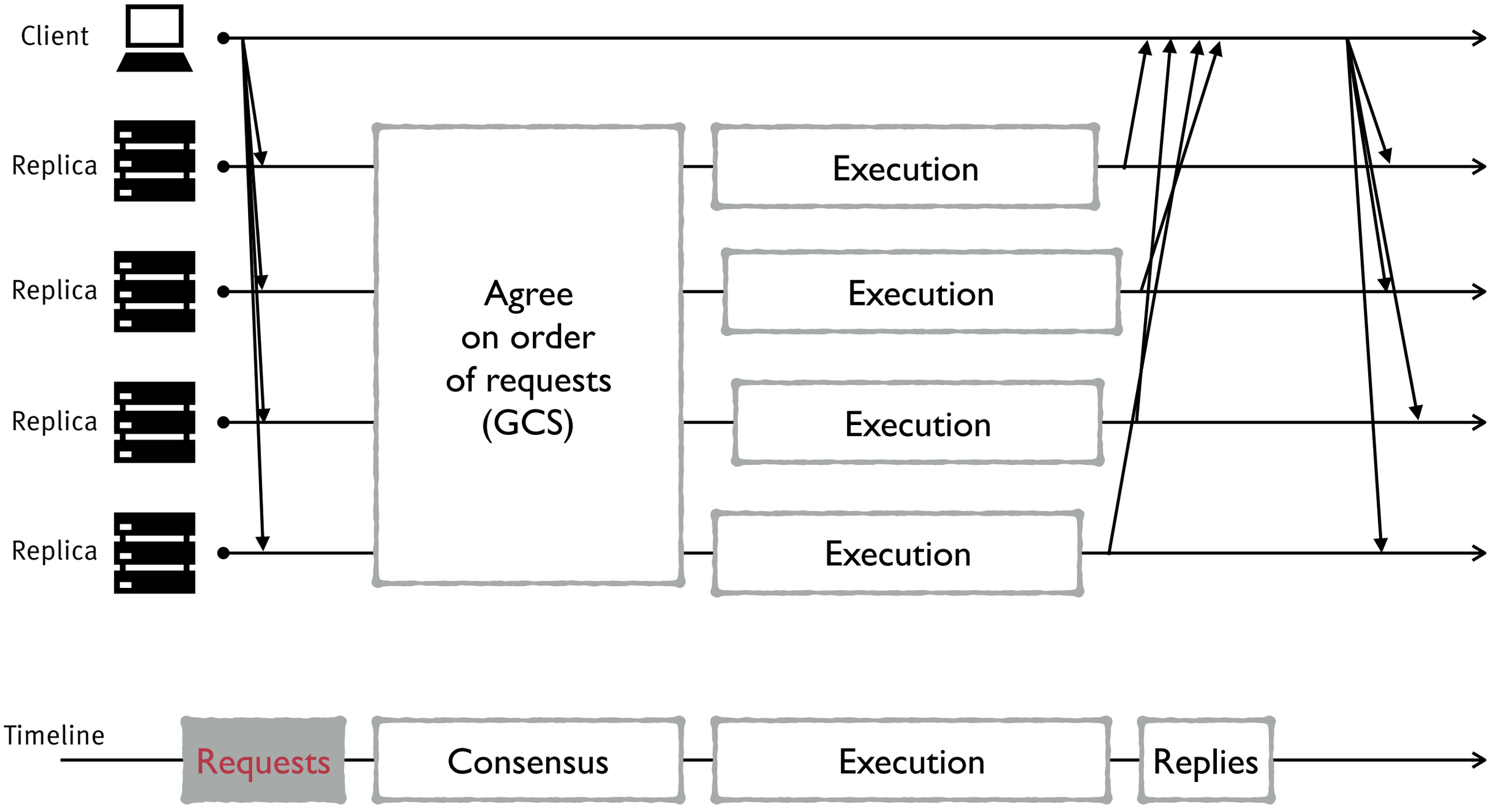
Parallel Request Handling

- Main approaches:
  - Distinguish (in-)dependent requests, sequentialize remaining ones
  - Deterministic multithreading (DetMT)
- We use DetMT with Unified Deterministic Scheduler (UDS)
  - Parametrized deterministic scheduler
  - Allows reconfiguration during runtime

F. J. Hauck, G. Habiger, and J. Domaschka. 2016. UDS: A Novel and Flexible Scheduling Algorithm for Deterministic Multithreading. In 2016 IEEE 35th Symposium on Reliable Distributed Systems (SRDS). 177– 186.

SMR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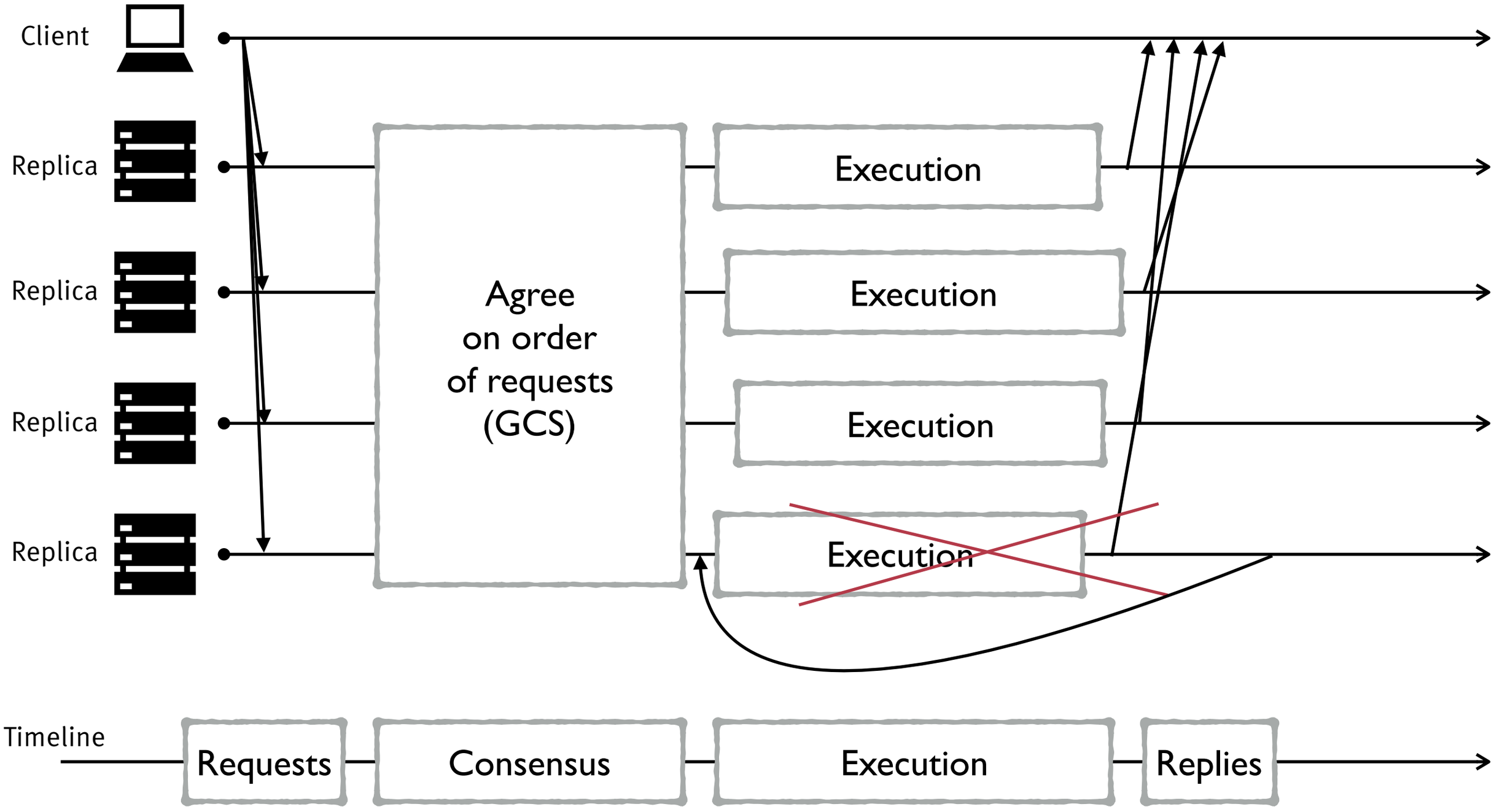
Variable Load

- Request arrival rate usually not uniform over time
- But: Provisioning of resources (number of replicas, hardware of each replica, software configuration) usually fixed
- Scaling horizontally is difficult/pointless due to Consensus
- ➡ Scale hardware vertically
- ➡ Reconfigure system during runtime

G. Habiger, F. J. Hauck, J. Köstler, and H. P. Reiser. 2018. Resource-Efficient State-Machine Replication with Multithreading and Vertical Scaling. In 2018 14th European Dependable Computing Conference (EDCC). 87–94. https://doi.org/10. 1109/EDCC.2018.00024

SMR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Checkpointing

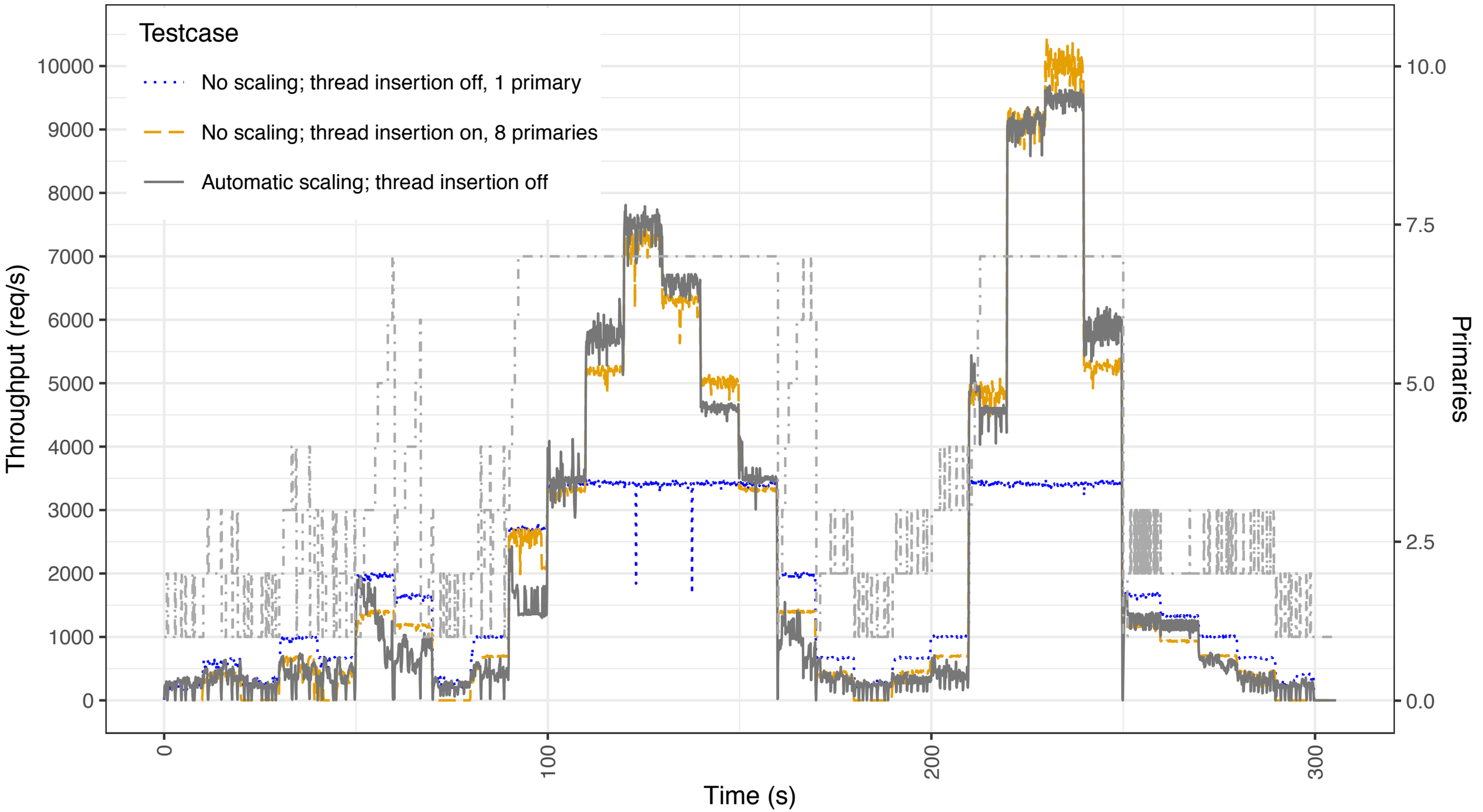
- Parallelizing request handling significantly complicates checkpointing
- Simplest approach: Stop-the-world (implemented)
- Advanced approaches: E.g. rolling snapshots during execution
  - tbd … still in the works

Reconfiguration Benefits

- Reconfiguring deterministic scheduler during runtime yields throughput and latency improvements
- Allows for best case performance in all scenarios
- Optimal resource usage in combination with dynamic vertical hardware scaling

(Publication currently in submission)

Reconfiguration Benefits



Conclusion

- Several parts of SMR can be improved
- Our goal: Easy (self-)configuring SMR system, including dynamic runtime adaptation
- 4 main topics we are looking at to achieve this:
  - Parallelized request handling via DetMT
  - GCS with trusted components
  - Dynamic vertical scaling and reconfiguration
  - Checkpointing during parallel execution