Basil: Breaking up BFT with ACID (transactions)

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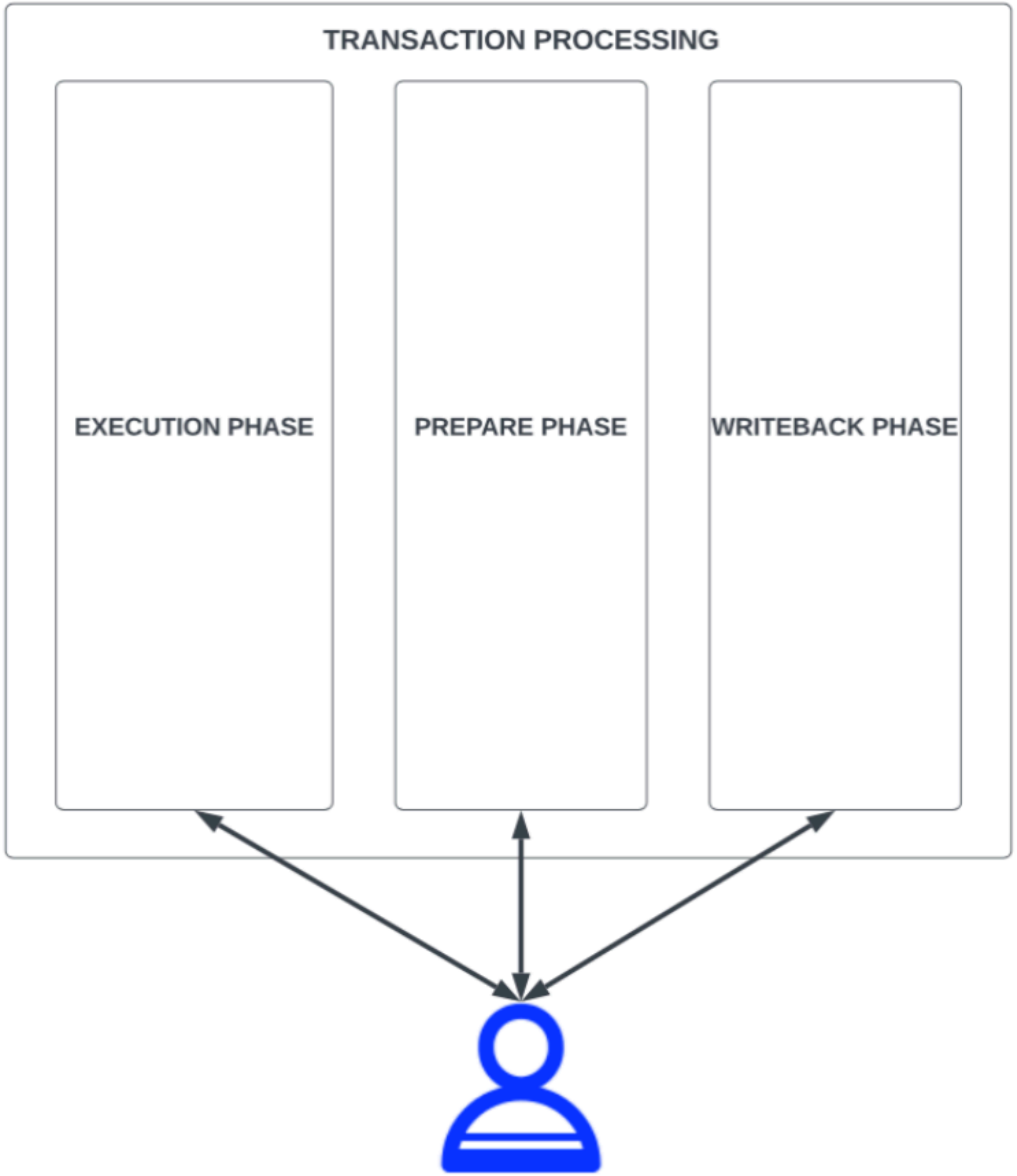
What is Basil?

- Transactional
- Leaderless
- Byzantine Fault Tolerant Key-value Store

Goal : Addressing drawbacks of traditional BFT systems

How does the Basil System Work



Client Driven Abstraction Layer

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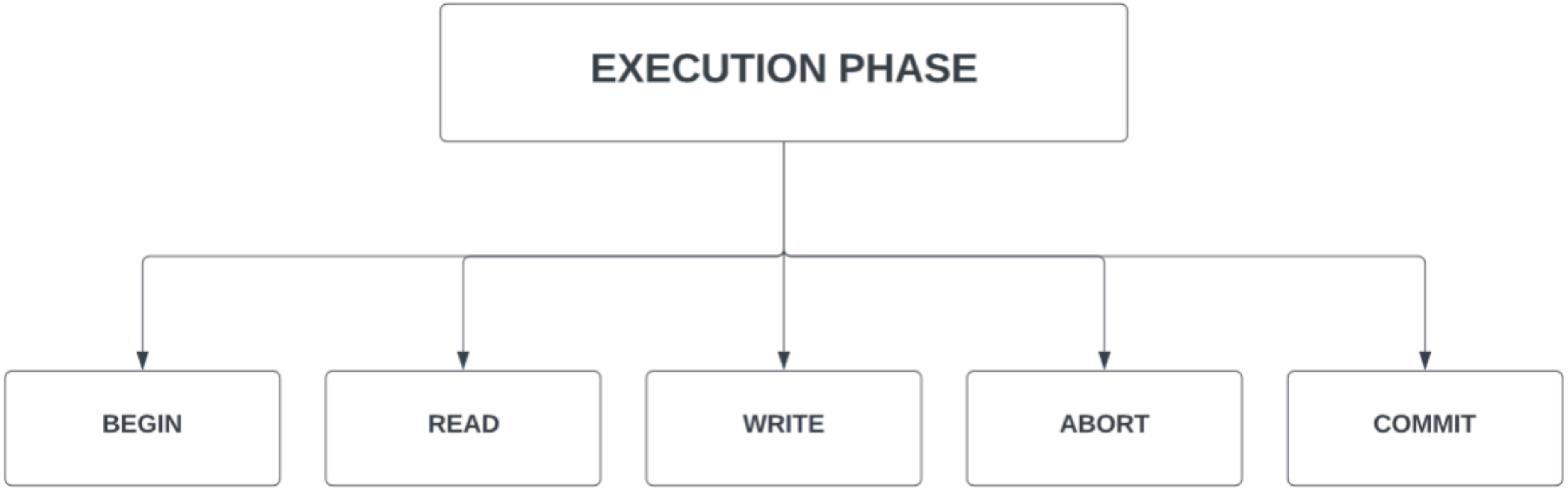
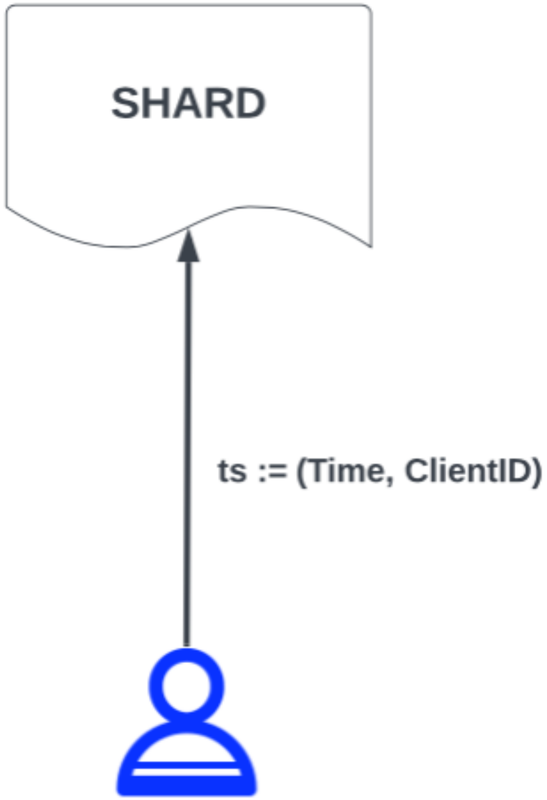
Execution Phase



Begin( )



Begin( )

ts <= Replica Time + Some well chosen time period (δ)

- Avoid Byzantine clients from giving high timestamps
- Improved system throughput

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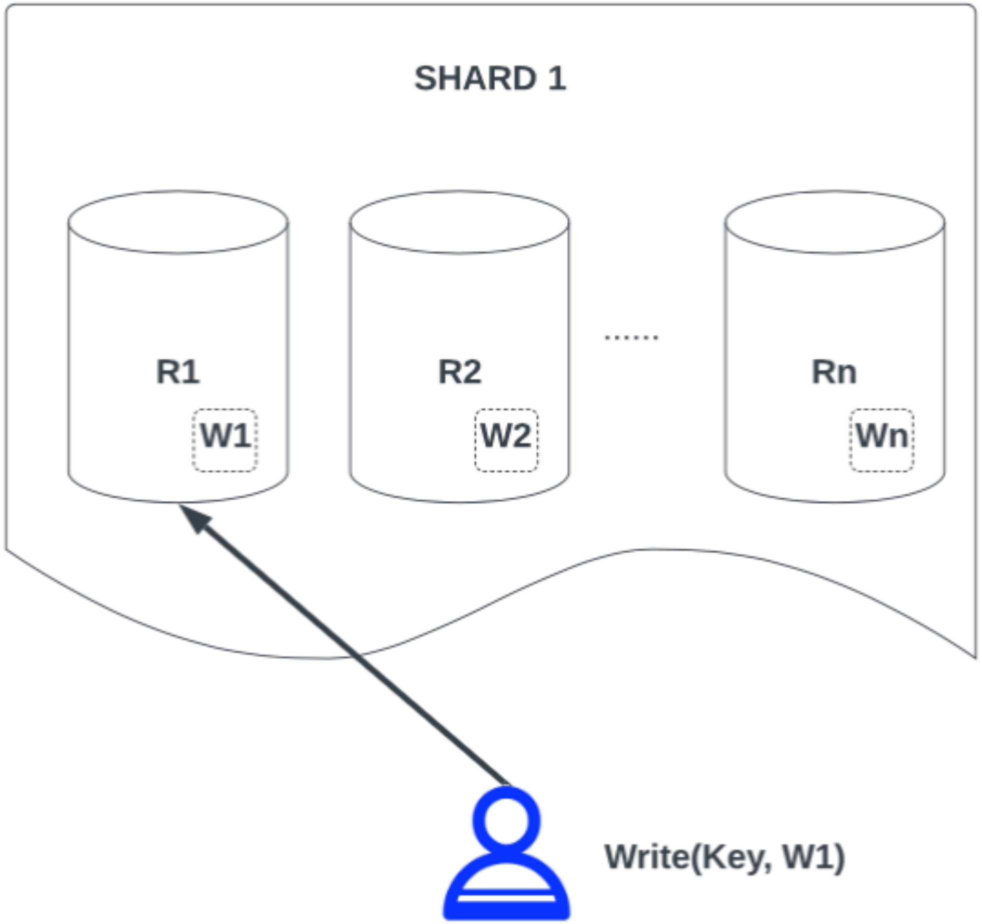
Write(key, value)



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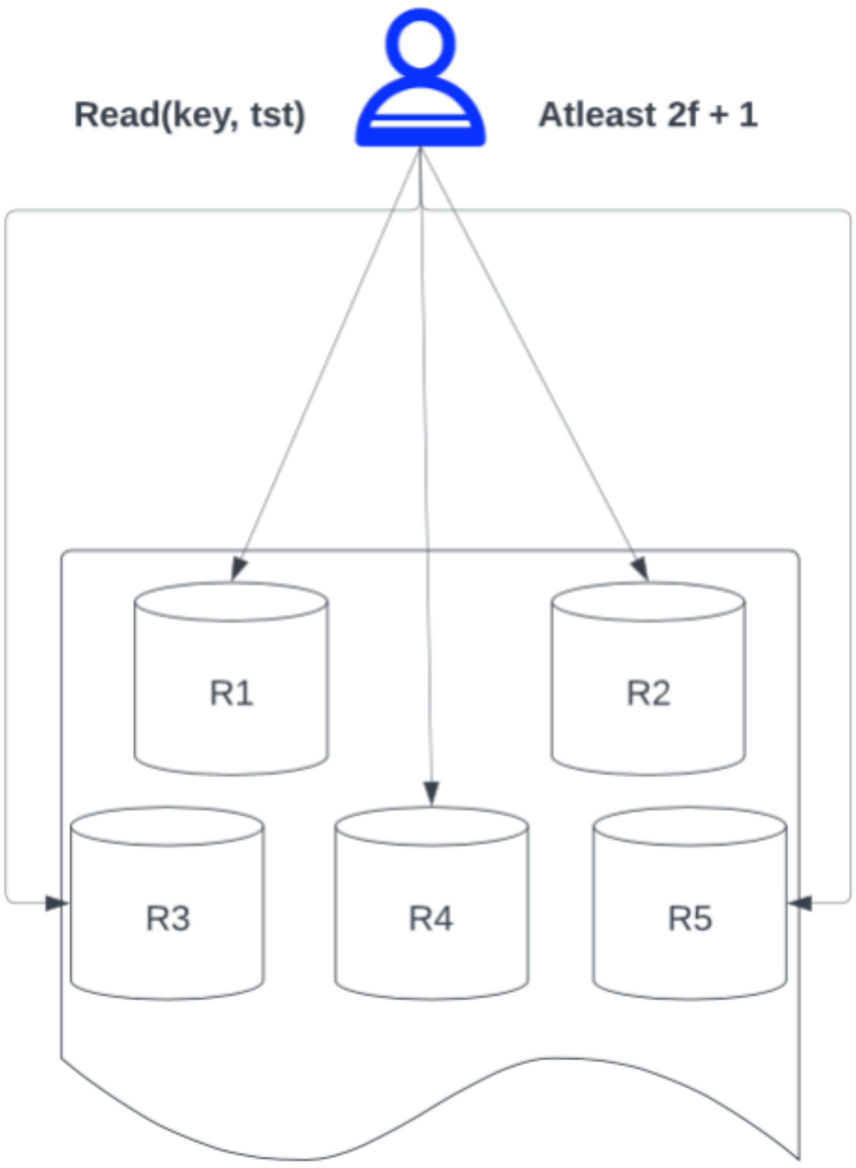
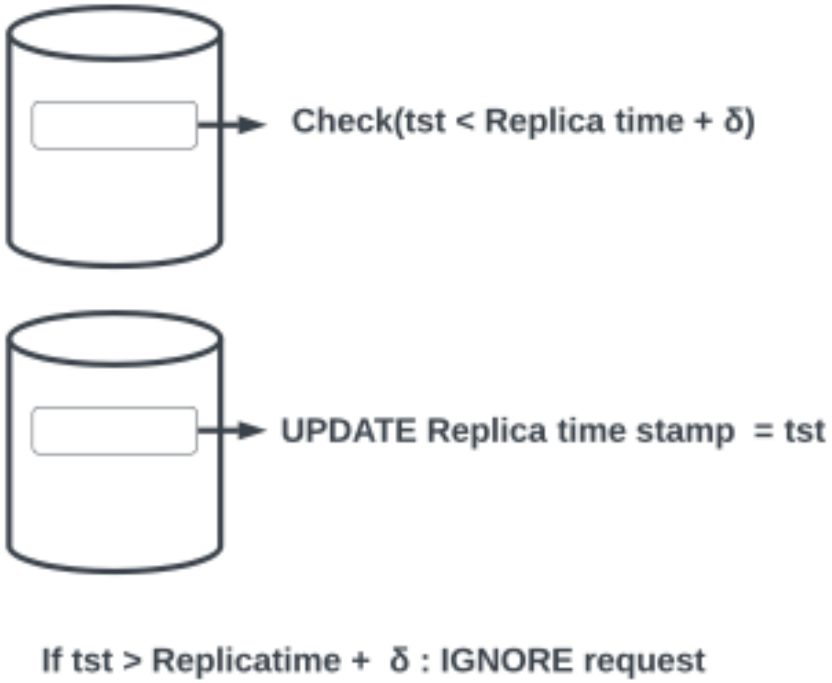
Read(key)

1: Client send read request to at-least 2f+1 replicas



Read(key)

2: Replica processes client requests



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Read(key)

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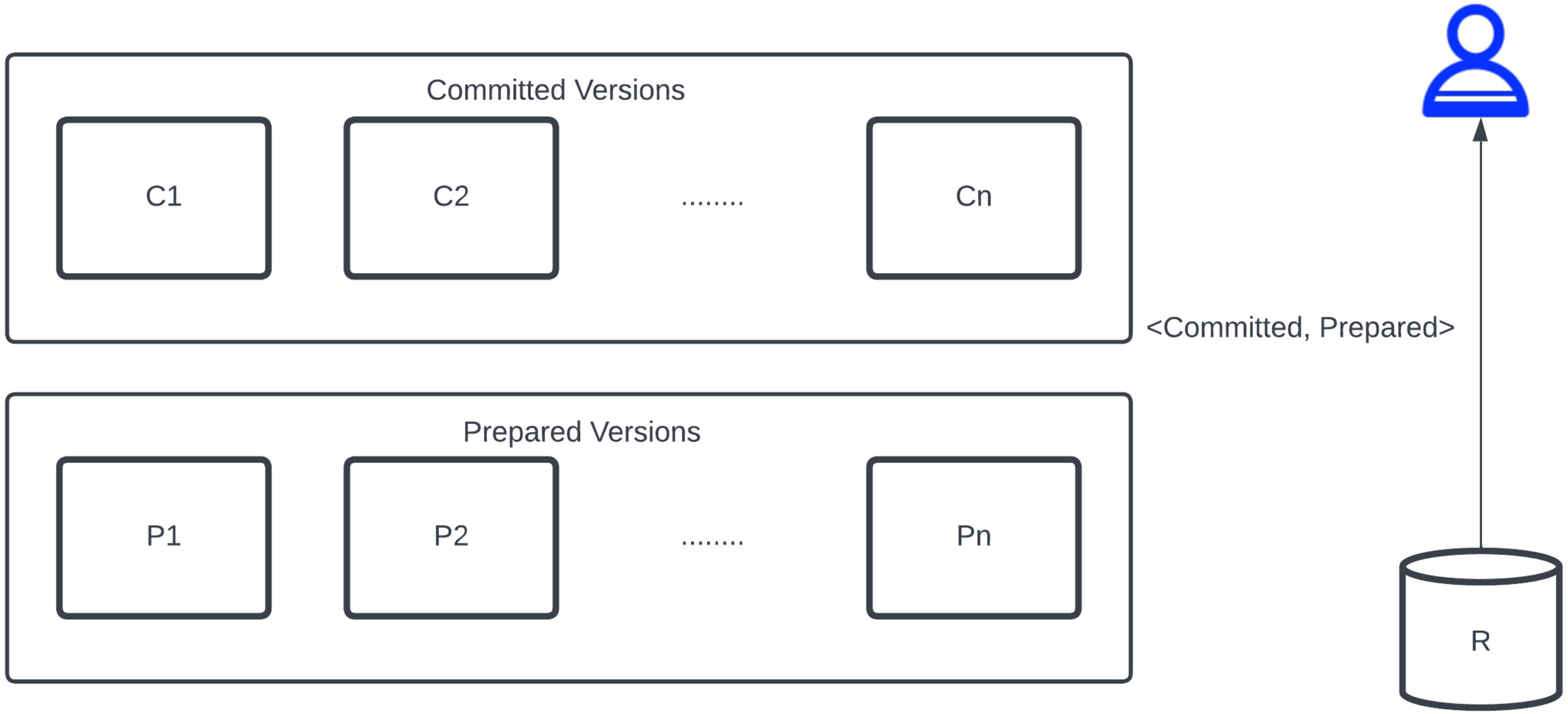
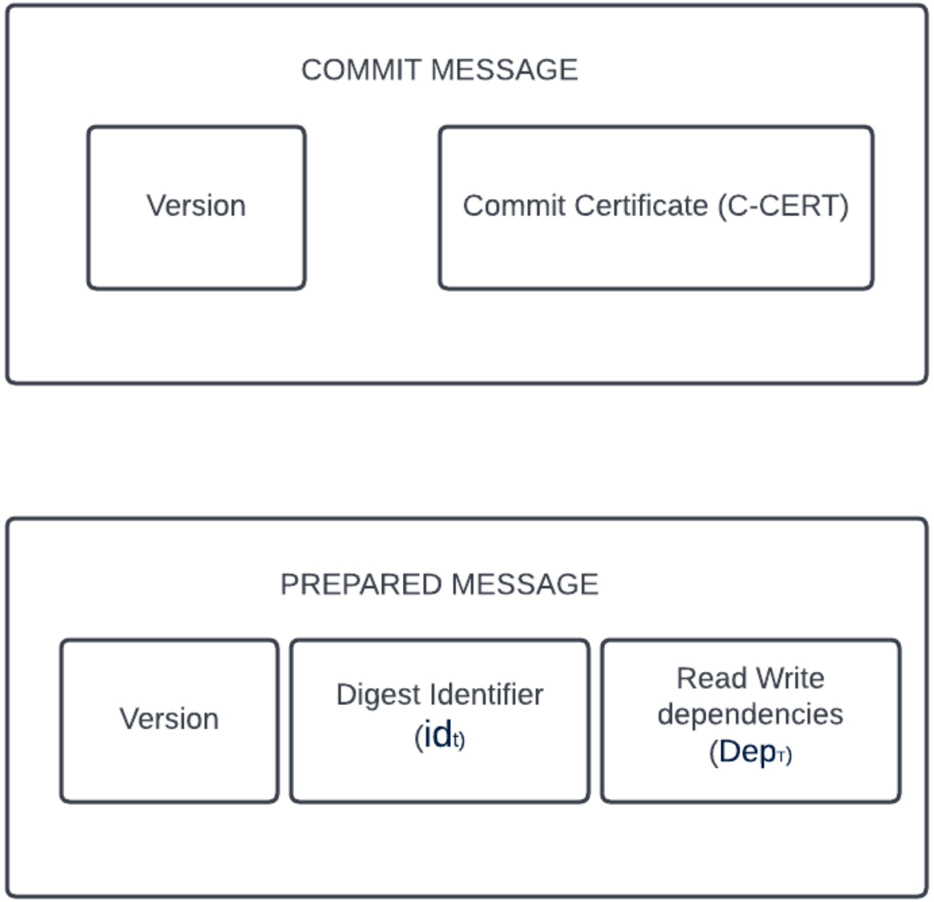


Read(key)

2: Replica processes client requests



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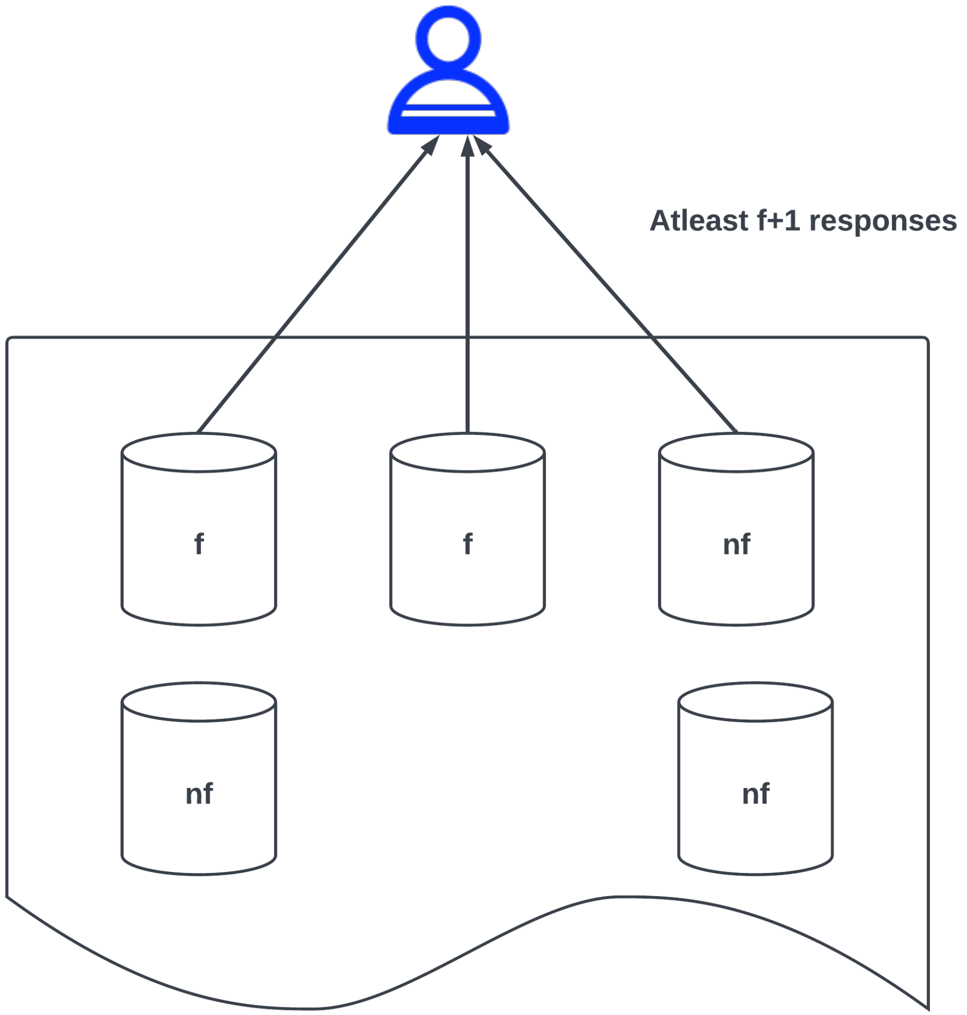
Read(key)

3: Client receives read replies



Read(key)

3: Client receives read replies

For commit messages

- At least f+1 responses
- Valid C-CERT
- Highest timestamp considered

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Read(key)

3: Client receives read replies

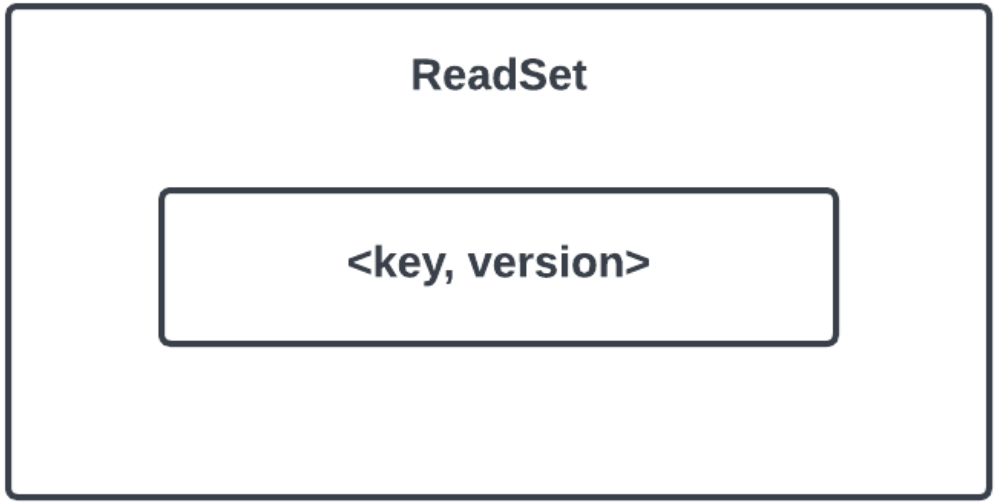
For prepared messages

- At least f+1 responses
- Same version

Read(key)

Client abstraction after reading

If committed version is picked up



Read(key)

Client abstraction after reading

If prepared version is picked up

Dependency Set

(version, id_T)

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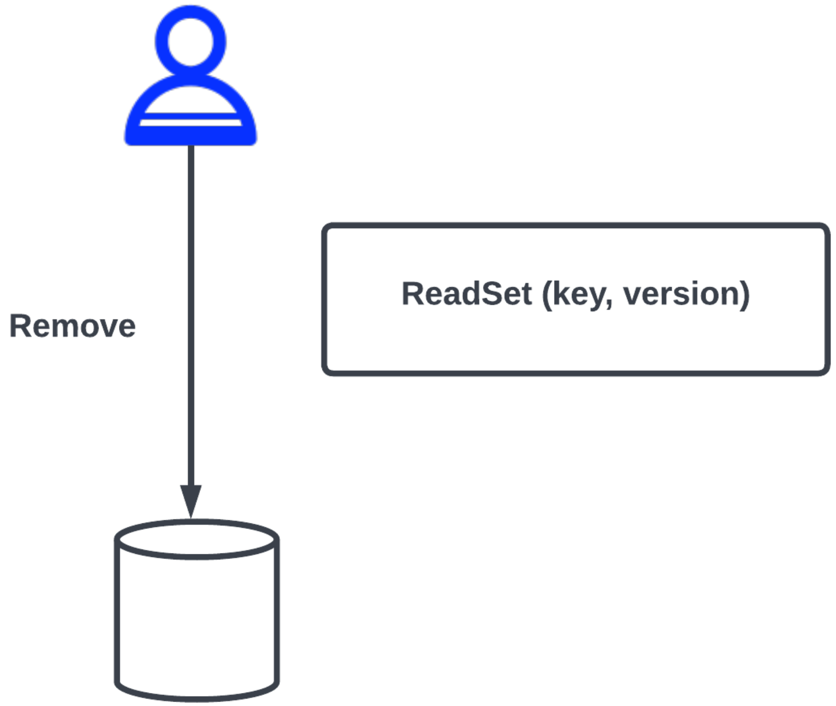
Abort()

Read



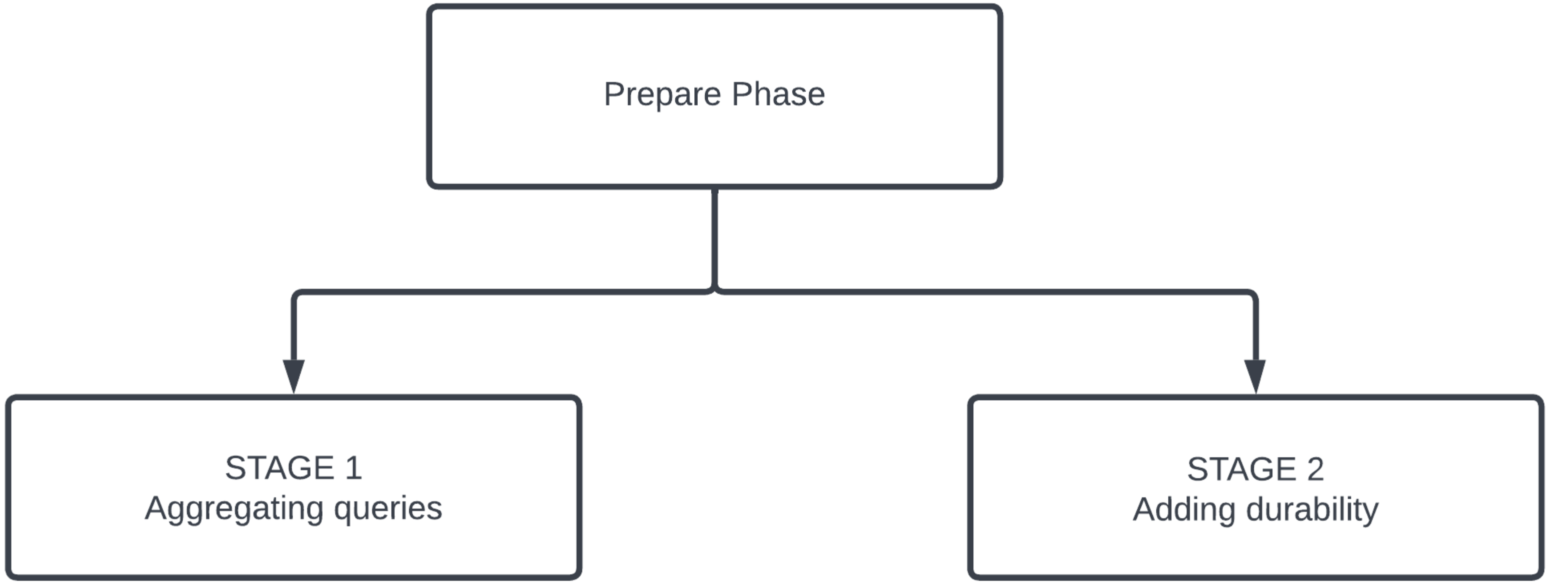
Write

No action needed

Commit()

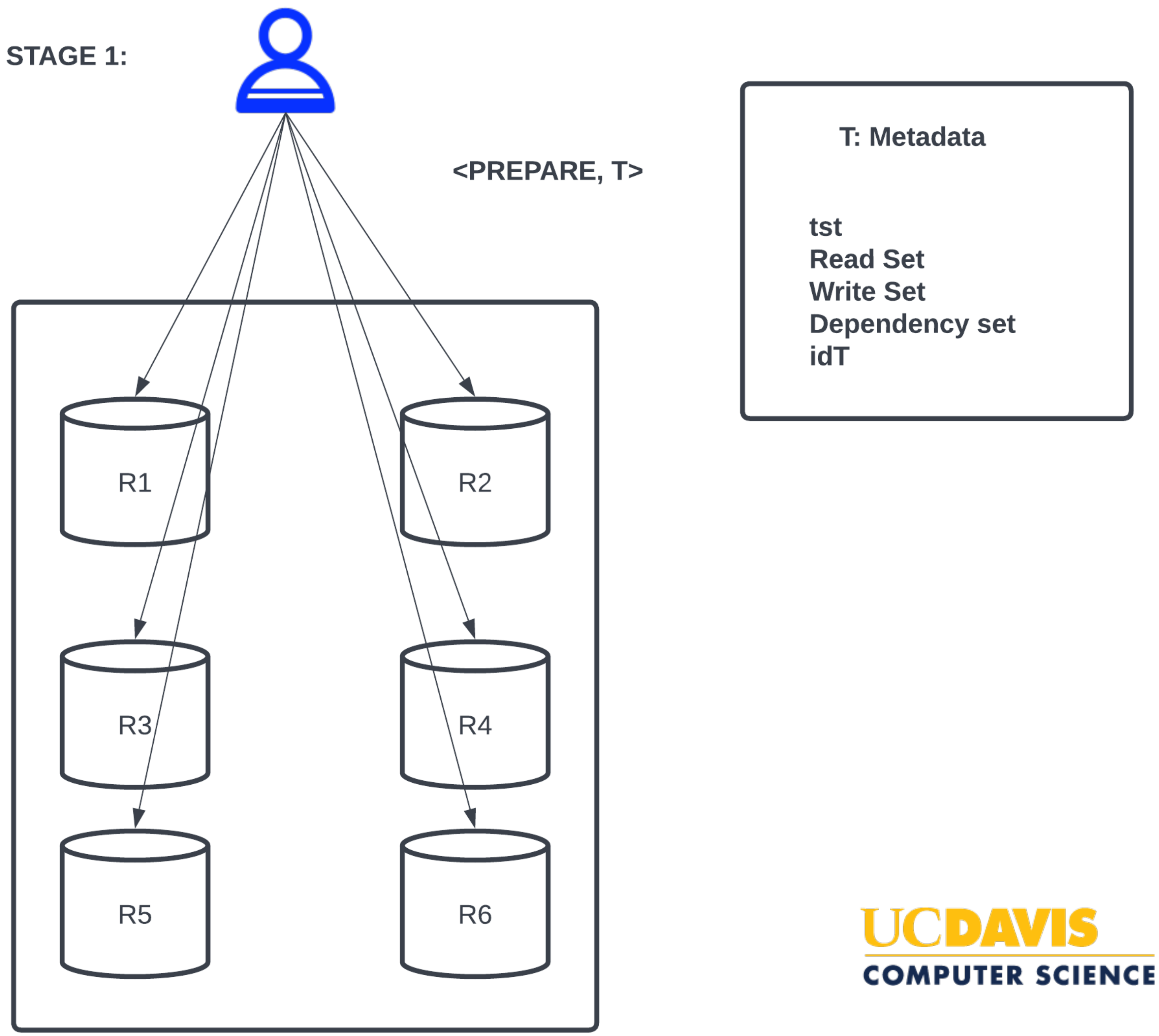
Client initiates the Prepare phase

Prepare Phase



Prepare Phase

1: Client sends an authenticated ST1 request to all replicas in shard S



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Prepare Phase

2: Replica R receives a ST1 request and executes the concurrency control check.

Additional commit check before committing T

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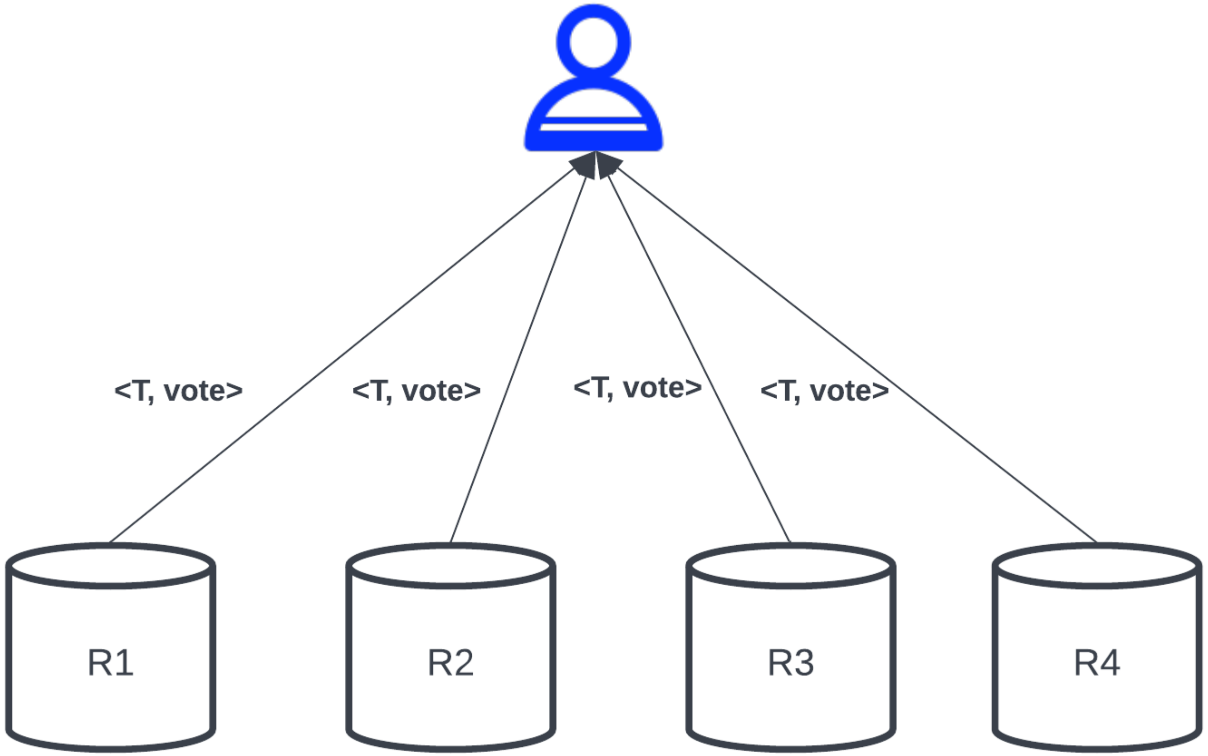
Prepare Phase

3: Replica returns its vote in a ST1R message.



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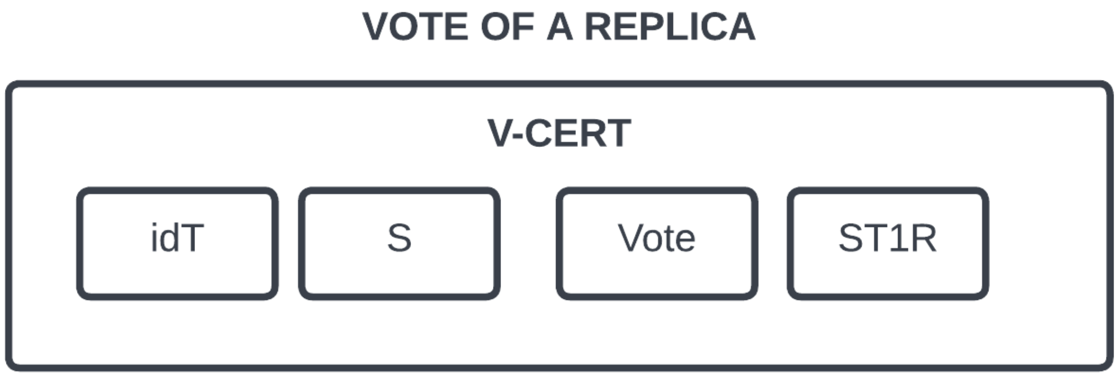
Prepare Phase

4: The client receives replicas votes.

- At client level : Shard S → Commit / Abort



Prepare Phase

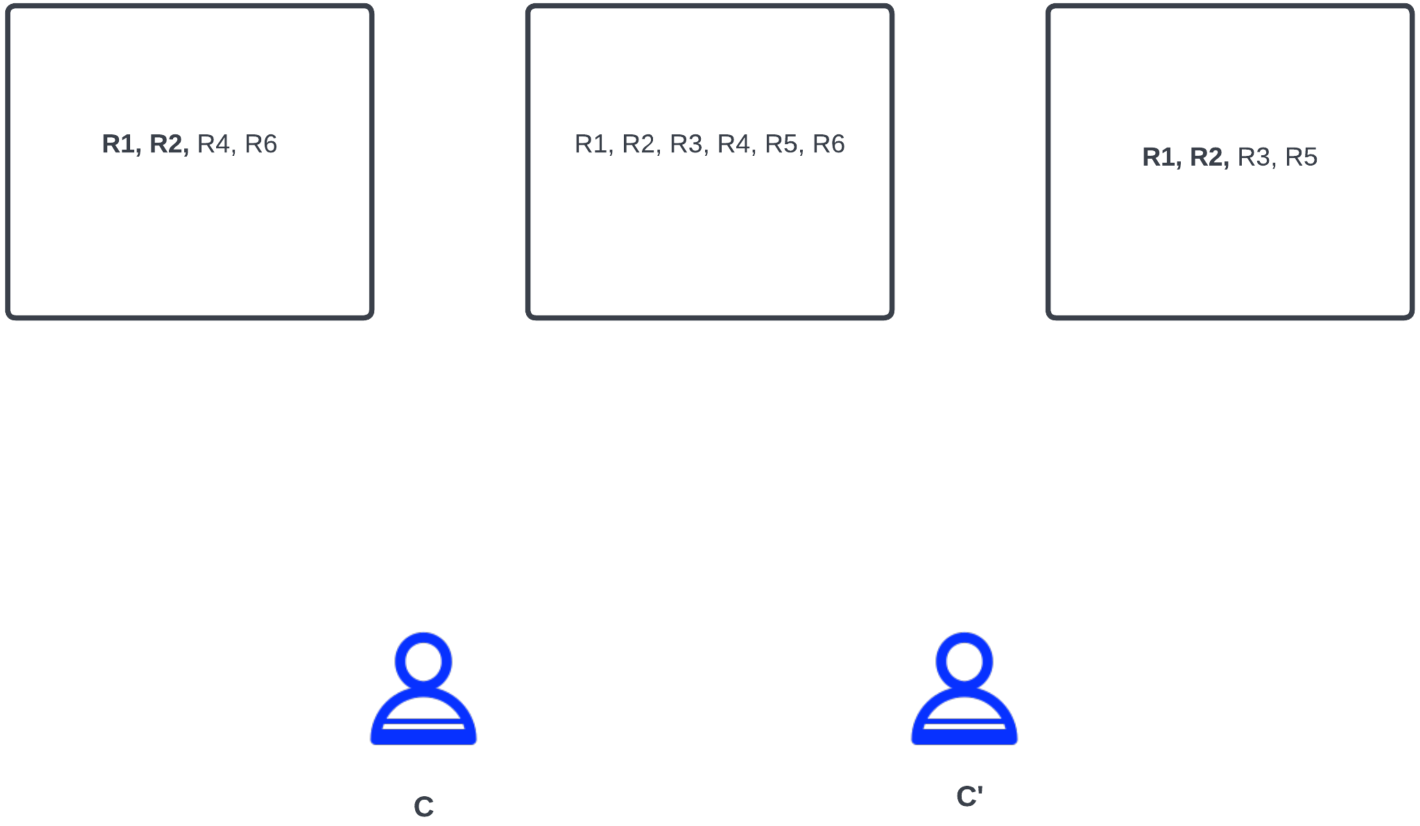
4: The client receives replicas votes.

- Votes from fast shards contribute to V-CERT
- Votes from slow shards contribute to *vote tally*

Prepare Phase

4: The client receives replicas votes.

1) Commit Slow Path

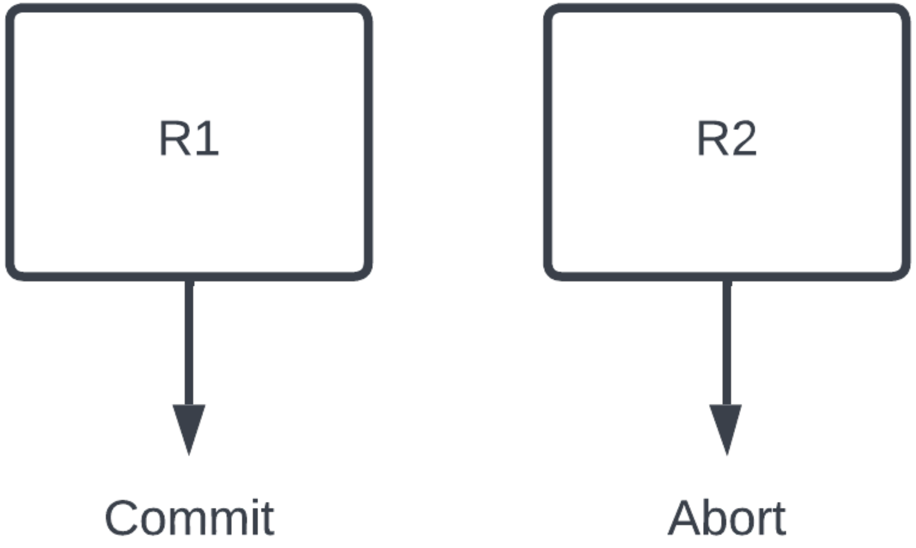


- $3f + 1 \leq$ Commit votes $< 5f + 1$
- Isolation guaranteed

Prepare Phase

4: The client receives replicas votes.

2) Abort Slow Path



- f+1 ≤ Abort votes < 3 f +1)
- Votes from prepared replicas
- Byzantine replica wont be able to abort
- Not durable

Prepare Phase

4: The client receives replicas votes.

3) Commit Fast Path

- All replicas vote to commit
- Generate V-CERT

Prepare Phase

4: The client receives replicas votes.

4) Abort Fast Path

- $3f + 1 \leq$ Abort votes
- $3f + 1$ or more vote not to commit : **COMMIT NOT POSSIBLE AT ALL**

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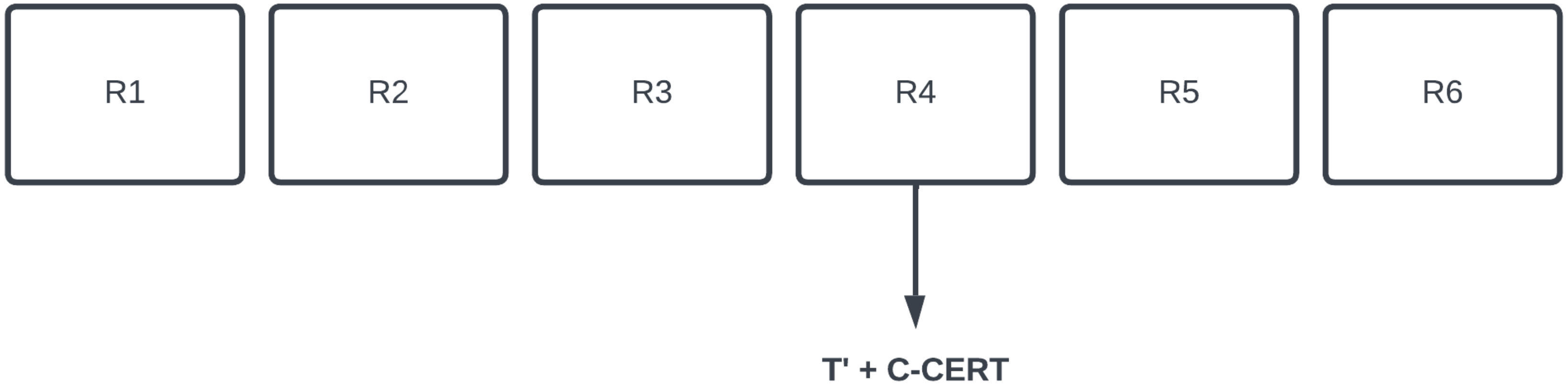
Prepare Phase

4: The client receives replicas votes.

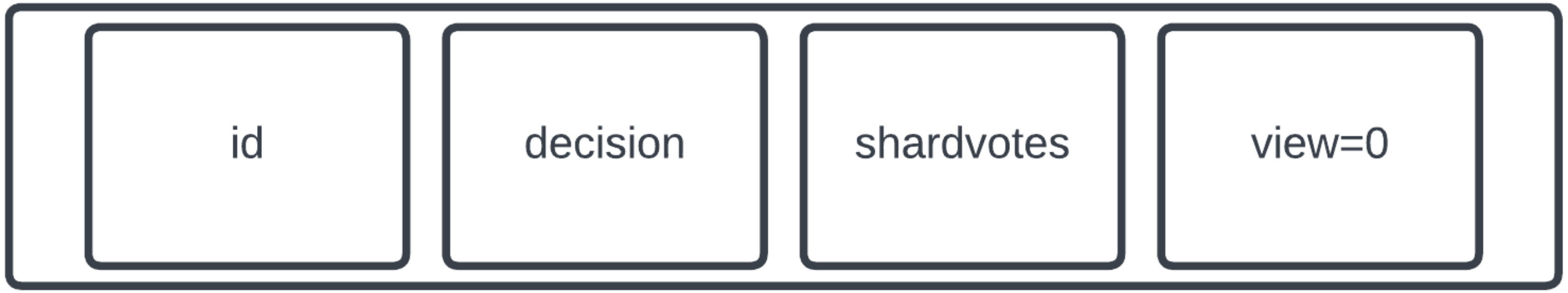
5) Abort Fast Path



Prepare Phase

Stage 2

5: The client attempts to make its tentative 2PC decision durable.

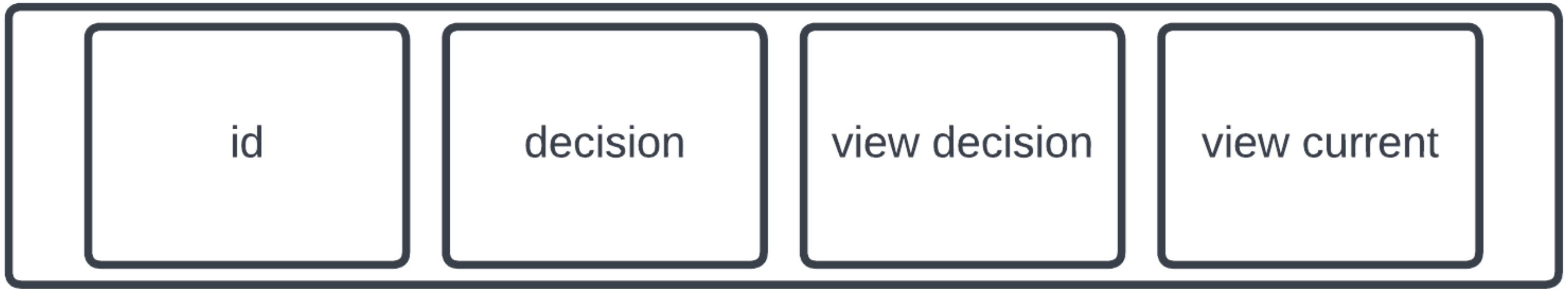


Id - Unique Identifier
Decision - Commit/abort
Shard votes - vote tally
View =0 -> ST2 message was issued by client C

Prepare Phase

Stage 2

6: Replicas in $Slog$ receive the ST2 message and return ST2R responses.



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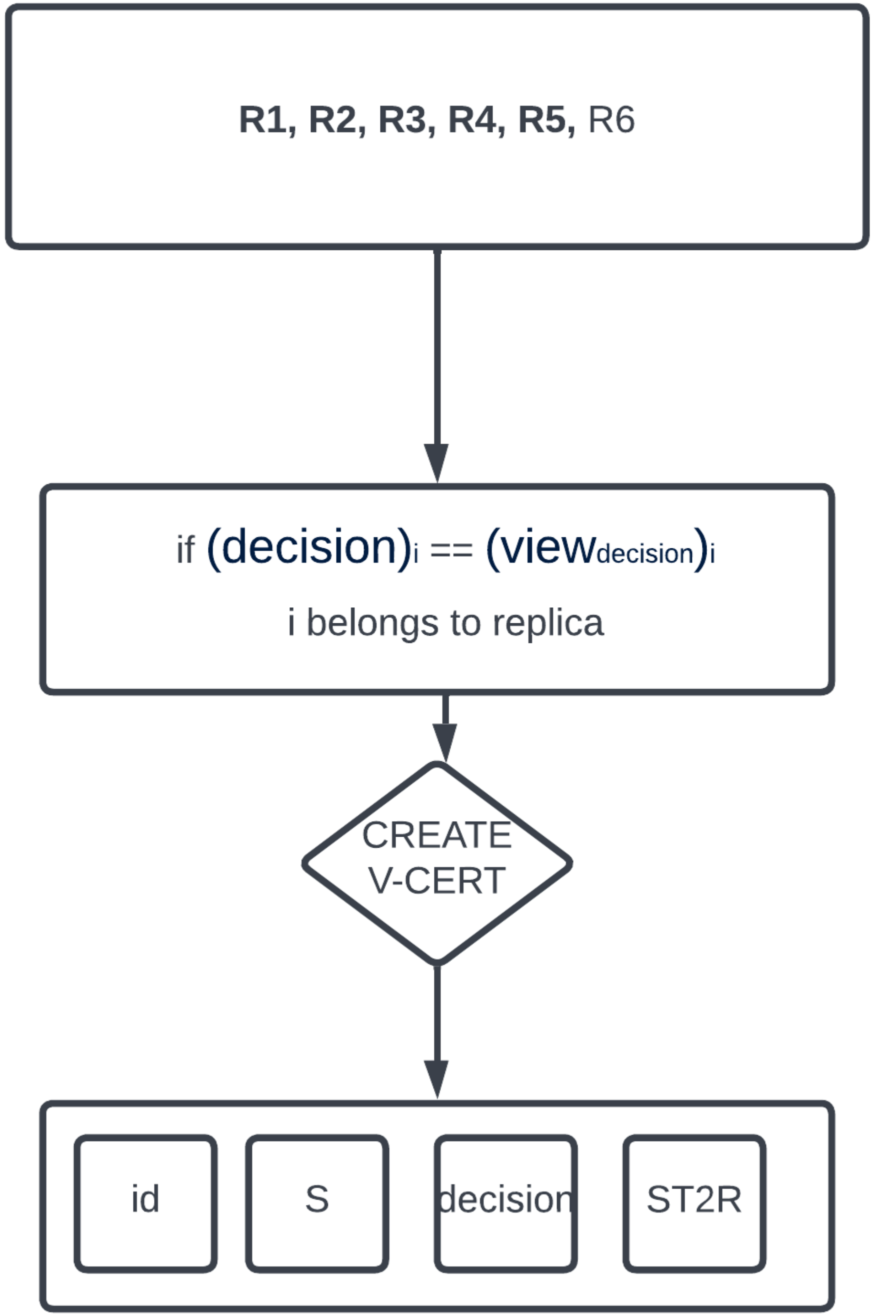
Prepare Phase

n = 6, f = 1; n-f = 5

Stage 2

7: The client receives a sufficient number of matching replies to confirm a decision was logged.



Prepare Phase

Why $5f + 1$ replicas per shard?

Prepare Phase

- Clients should observe either commitment quorum or abort quorum
- No overlap

n = 3f + 1, f = 1 (R4 is faulty), n-2f = 2

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Writeback Phase

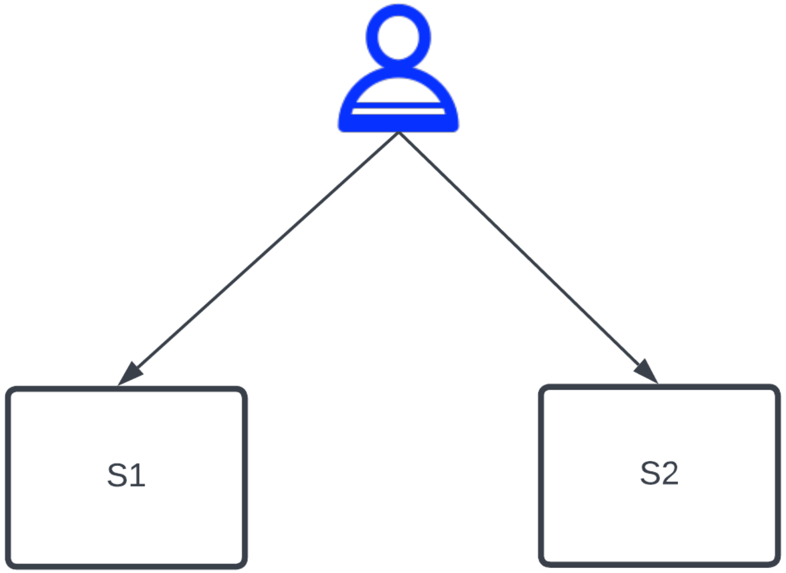
1: The client asynchronously forwards decision certificates to all participating shards.

C- CERT: $\langle idT$, $Commit$, {V-CERT S }

For a commit decision

A- CERT: $\langle idT$, $Abort$, {V-CERT S }$\rangle$

For abort decision



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Writeback Phase

2: Replica validates C-CERT or A-CERT and updates store accordingly.

- Updates all local data structures
- Writes to the datastore on commit
- Notifies pending dependencies

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Evaluation Results

- Basil improves throughput over traditional BFT systems by four to five times
- Basil's novel recovery mechanism further minimizes the impact of failures: with 30% Byzantine clients, throughput drops by less than 25% in the worst-case.

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How is Basil better than traditional BFT systems?

Implementing the totally ordered distributed ledgers abstraction in a scalable way is challenging

To construct the totally ordered ledger we need to run the byzantine fault tolerant agreement protocols between all replicas

While executing transaction sequentially is safe and acid compliant, that can become obvious super bottleneck

What does correctness for transactional application means in a BFT setting

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Basil strives to guarantee is that the execution that appears to a correct client should be indistinguishable from a serialisable execution that involves only read and write operations issued by the correct clients.

Byzantine Independence

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No group that contains only byzantine participants should be able to single handedly decide the outcome of our operations.

Client driven design

Three core components of Basil

Concurrency Control Mechanism

Commit protocol that is integrated with the concurrency control protocol

Fallback protocol

References

Suri-Payer, Florian, et al. "Basil: Breaking up BFT with ACID (transactions)." Proceedings of the ACM SIGOPS 28th Symposium on Operating Systems Principles. 2021.

https://youtu.be/RKZvsW-p4P0

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