Zyzzyva, Proof of Execution, Practical Byzantine Fault Tolerance Discussion

PBFT

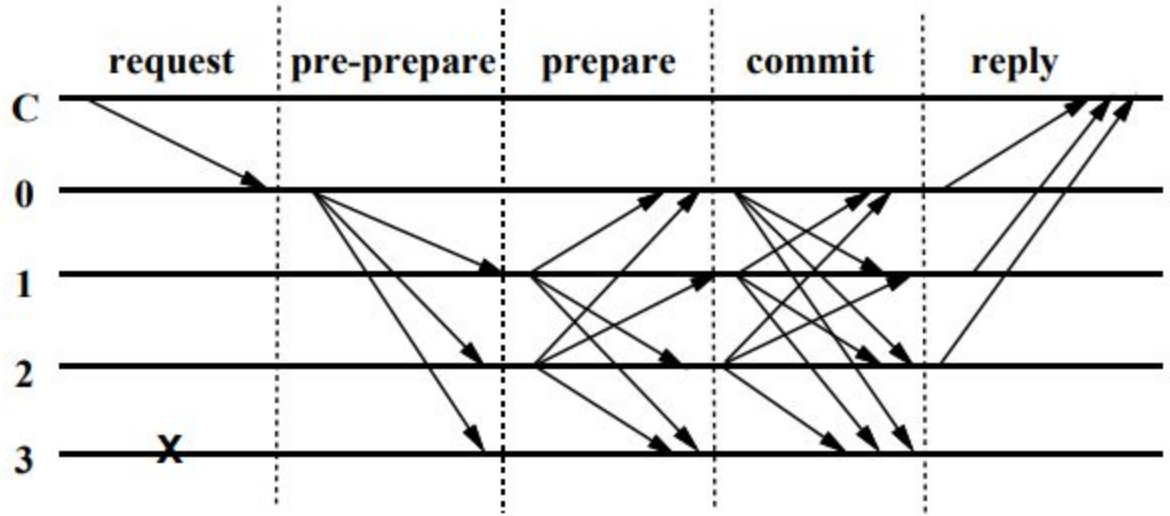

Figure 1: Normal Case Operation

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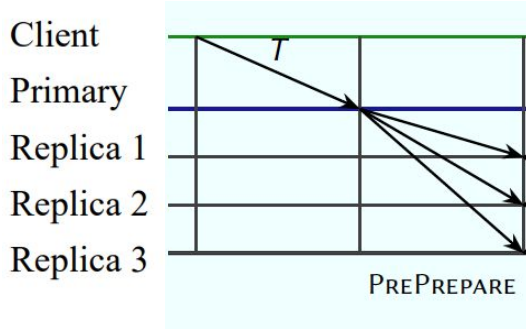

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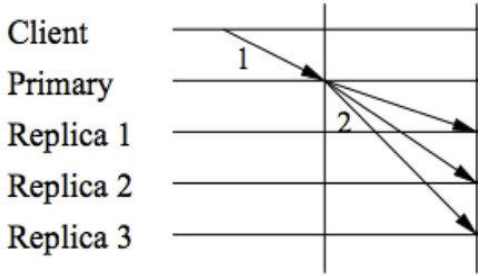

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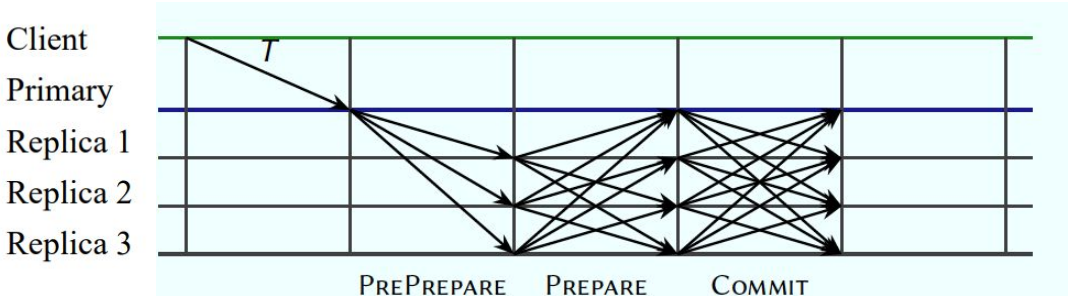

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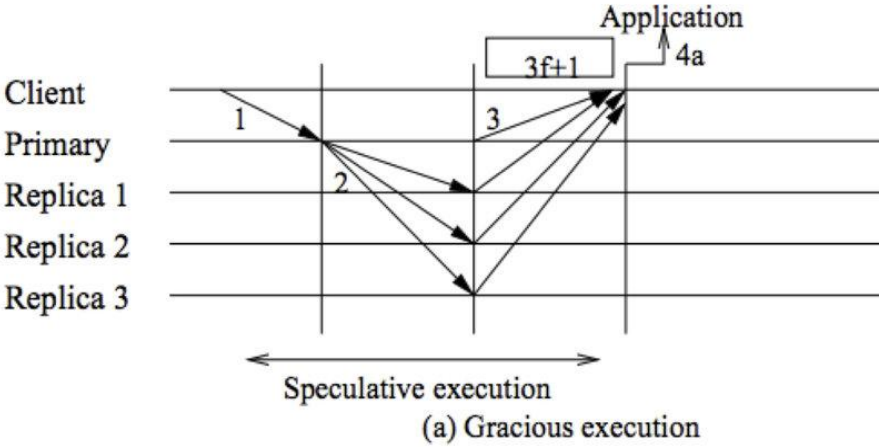

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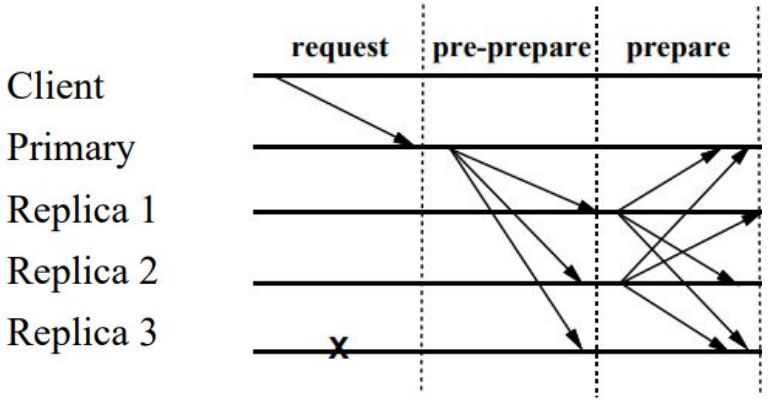

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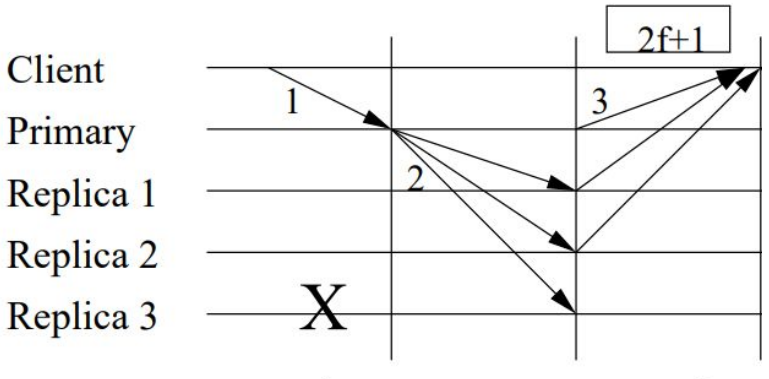

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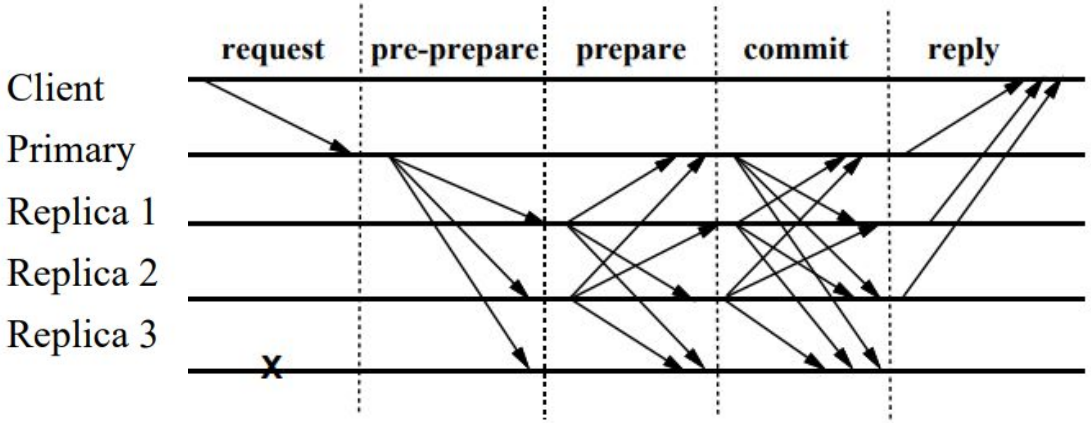

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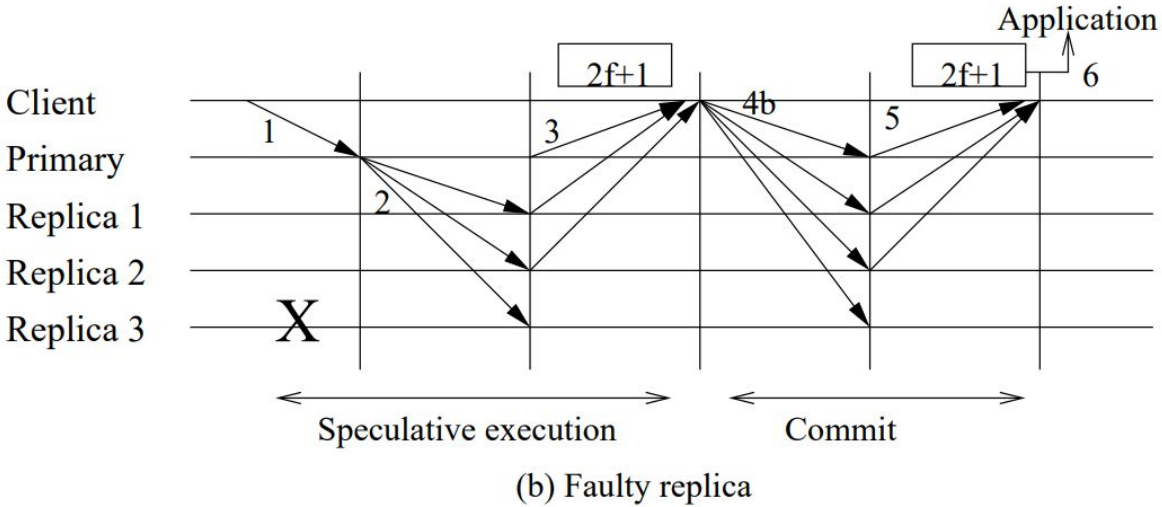

(b) Faulty replica

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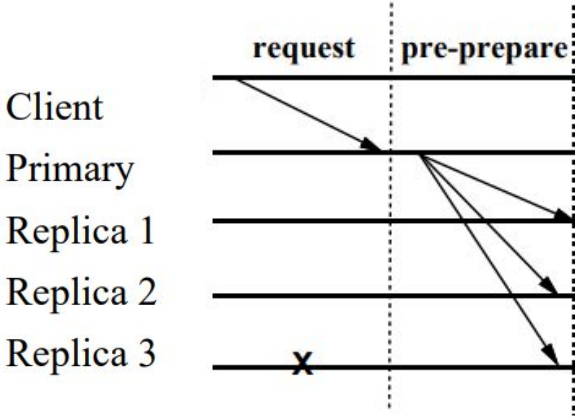

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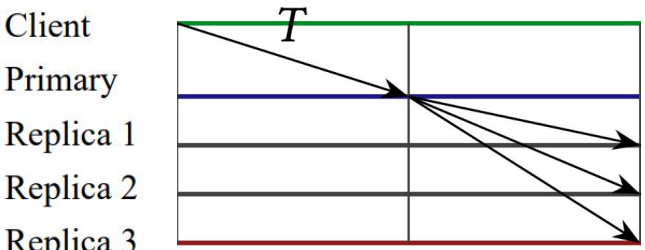

POE

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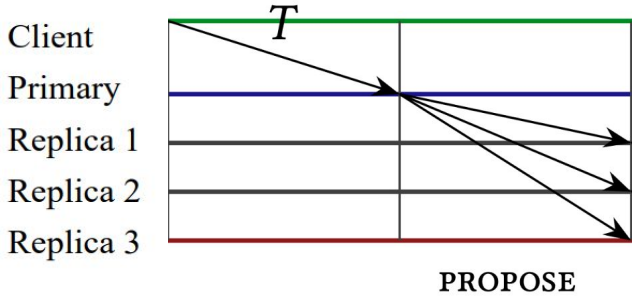

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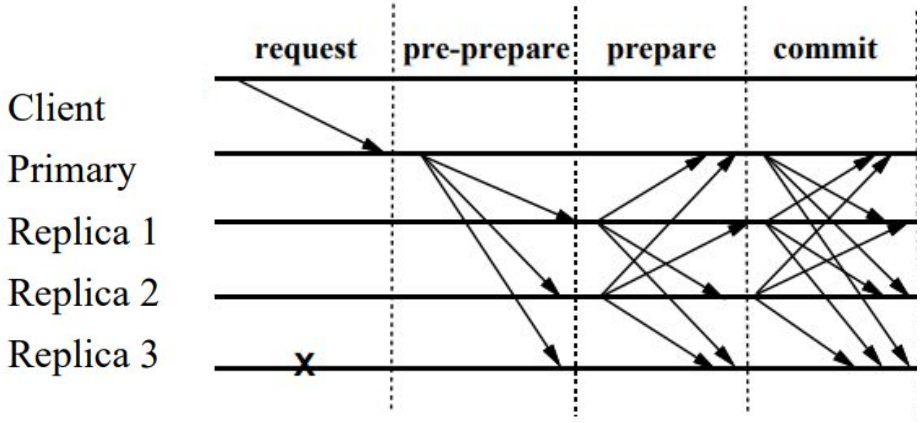

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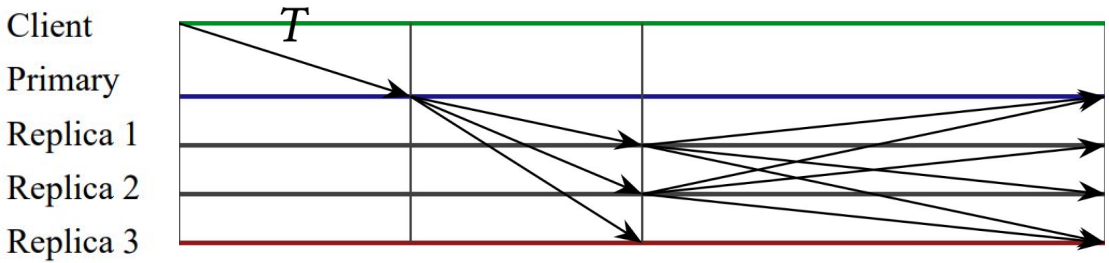

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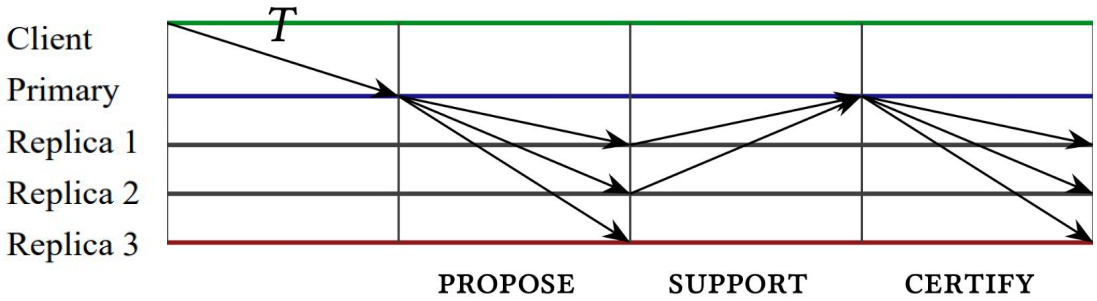

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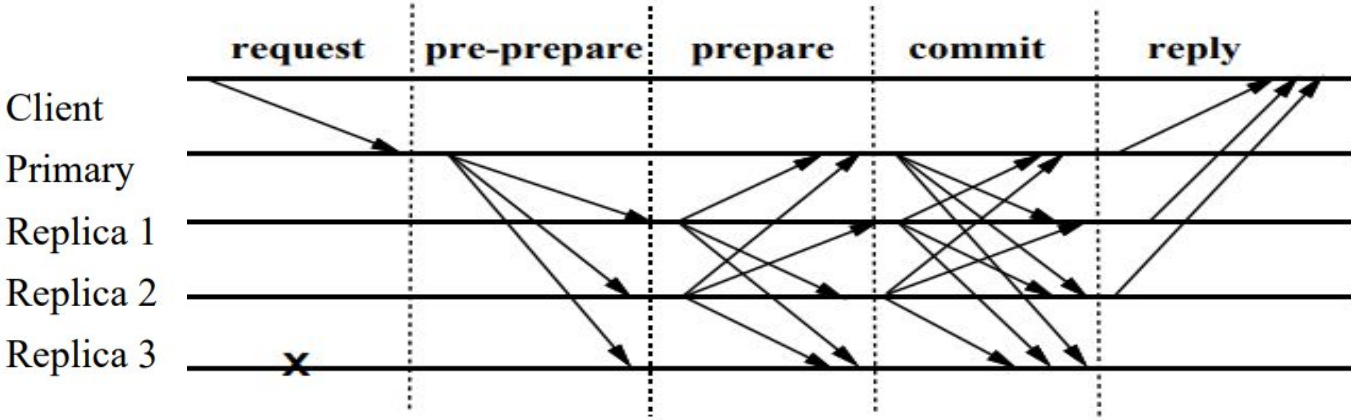

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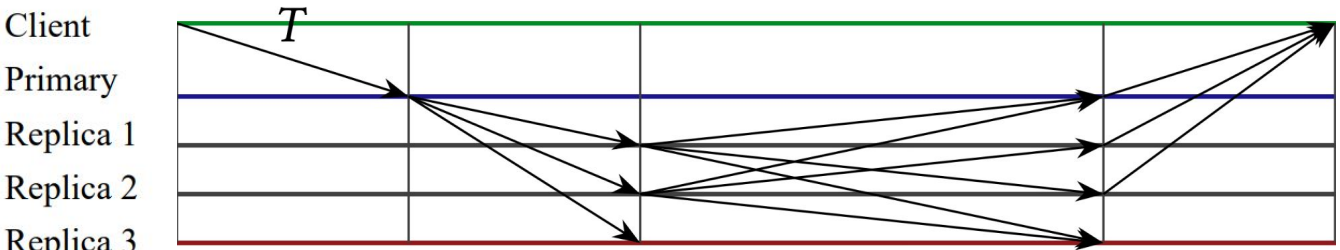

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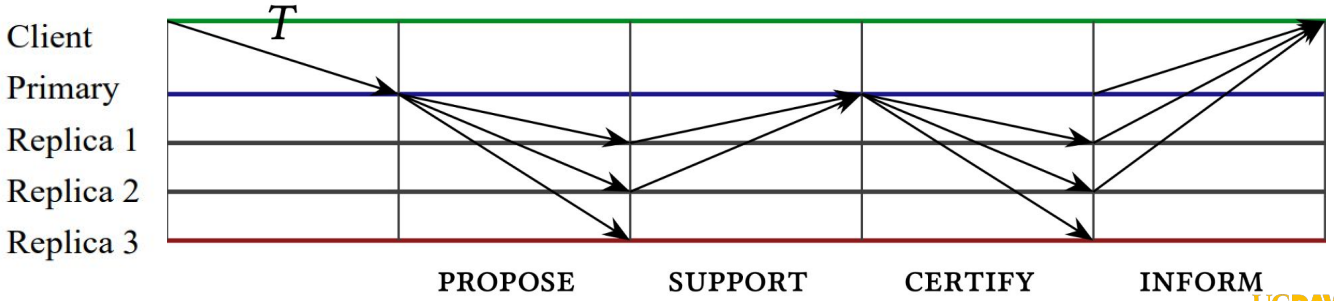
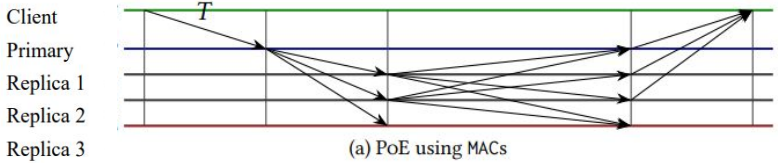
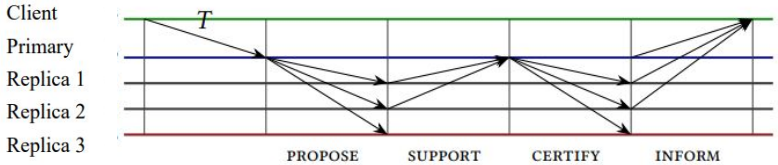


POE

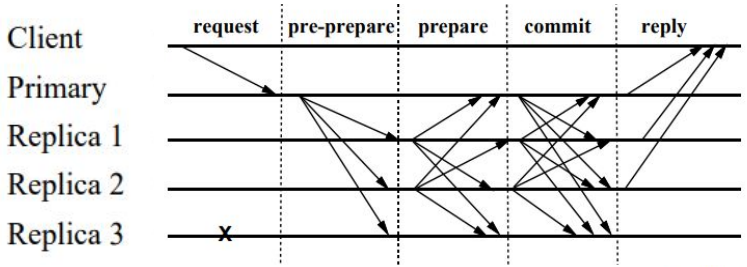


(a) PoE using MACs

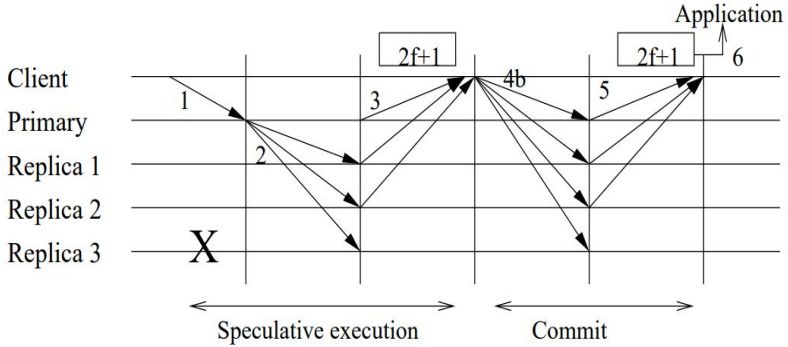


(b) PoE using TSs.

PBFT



Zyzzyva



(b) Faulty replica

Zyzzyva: View Change

View Change Protocol

- Guarantees of electing a **new primary**.
- It requires a **correct replica**
  - To observe the **primary as faulty**
  - Possess **evidence** that **f+1 replicas have committed** to a View-Change.
- Traditional methods (Byzantine) needs to **maintain the history** of the requests.
- Additional properties of View-Change Protocol in Zyzzyva
  - **Liveness**
  - **Safety**

Liveness: Missing Phase

- **Strengthens** commitment of correct replica by adding **“I hate new Primary” phase**.
- Liveness brings “Prepare” and “Commit” phase into one single phase (following PBFT).
- Every **correct** replica has to abandon a view for view-change.

- Procedure
  - A correct replica uses **voting system (no-confidence votes)** across other correct replica to identify faulty primary.
  - If atleast **f+1** votes, then View-Change is started to change the primary.
  - They use the rule **I-Hate-New-Primary** rule to elect for a faulty primary.

Safety: Uncommitted Request

- Weakens when request appears in the history included in the message.
- In case of **2f + 1** responses received by client
  - **Correct replica** has at least f+1 commit certificates
  - VIEW-CHANGE will contain all the commit certificates received from a LOCAL-COMMIT.

- In case of **3f + 1** responses received by client
  - **No commit** certificate in this case
  - All ORDER-REQ messages are saved in all the correct replicas.
  - **New Primary** would include all the ORDER-REQ messages into its history.

- There is no case where 2 completed requests can have the **same sequence number** by correct replica. This is a benign case of preserving safety.

Section 3: Correctness

1. **Safety**:
   a. **Agreement protocol is safe within single view**
      i. No Two requests complete with the same sequence number n
      ii. h_n is a prefix of $h_{n'}$ for n < n' and completed request r and r'
   b. **Agreement and view protocol together ensure safety across views**

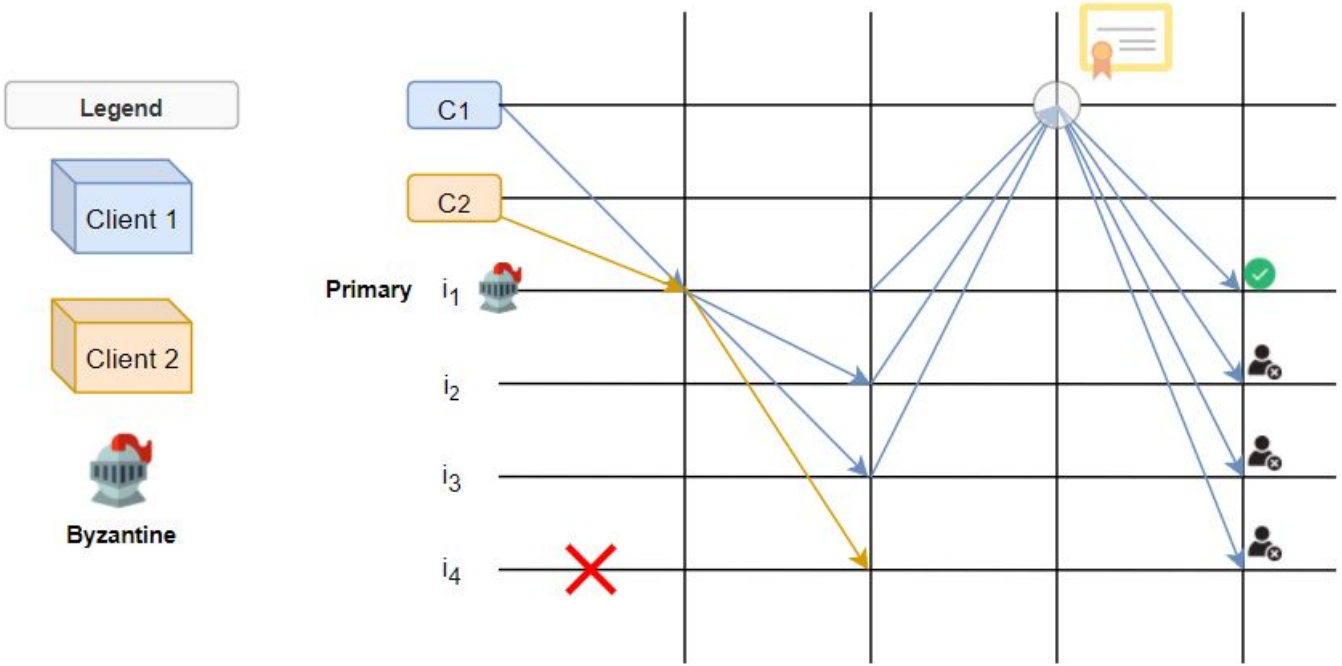
2. **Liveness**: **Zyzzyva guarantees liveness only during periods of synchrony**
   a. If **primary** is **correct** when a correct client issues the request, then the **request completes**
   b. If a request from a correct client **does not complete** during the **current view** then the **view change does not complete** during the **current view** then a view change occurs

Zyzzyva

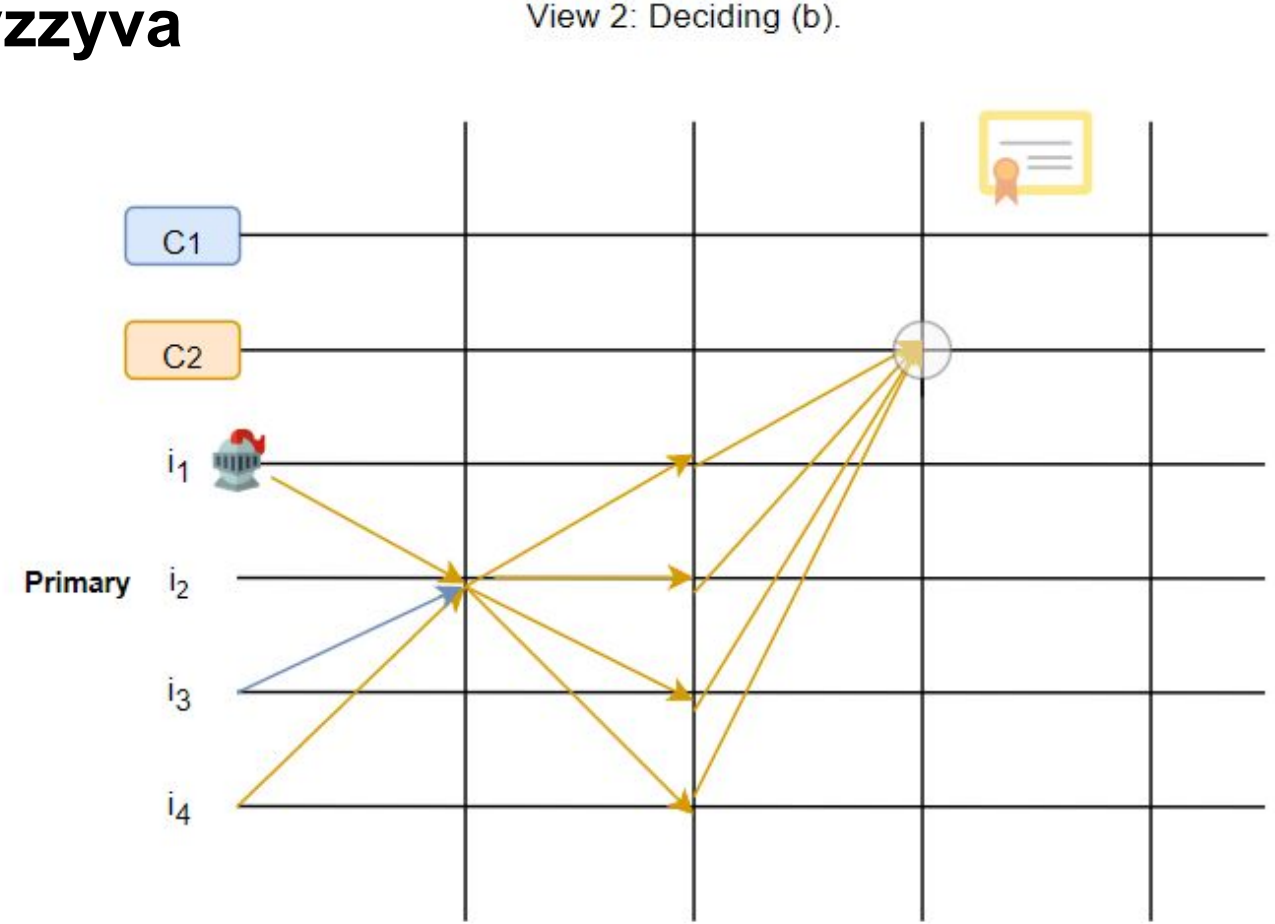
Breaking Safety

Scenario 1

View 1: Creating a commit-certificate for (a).

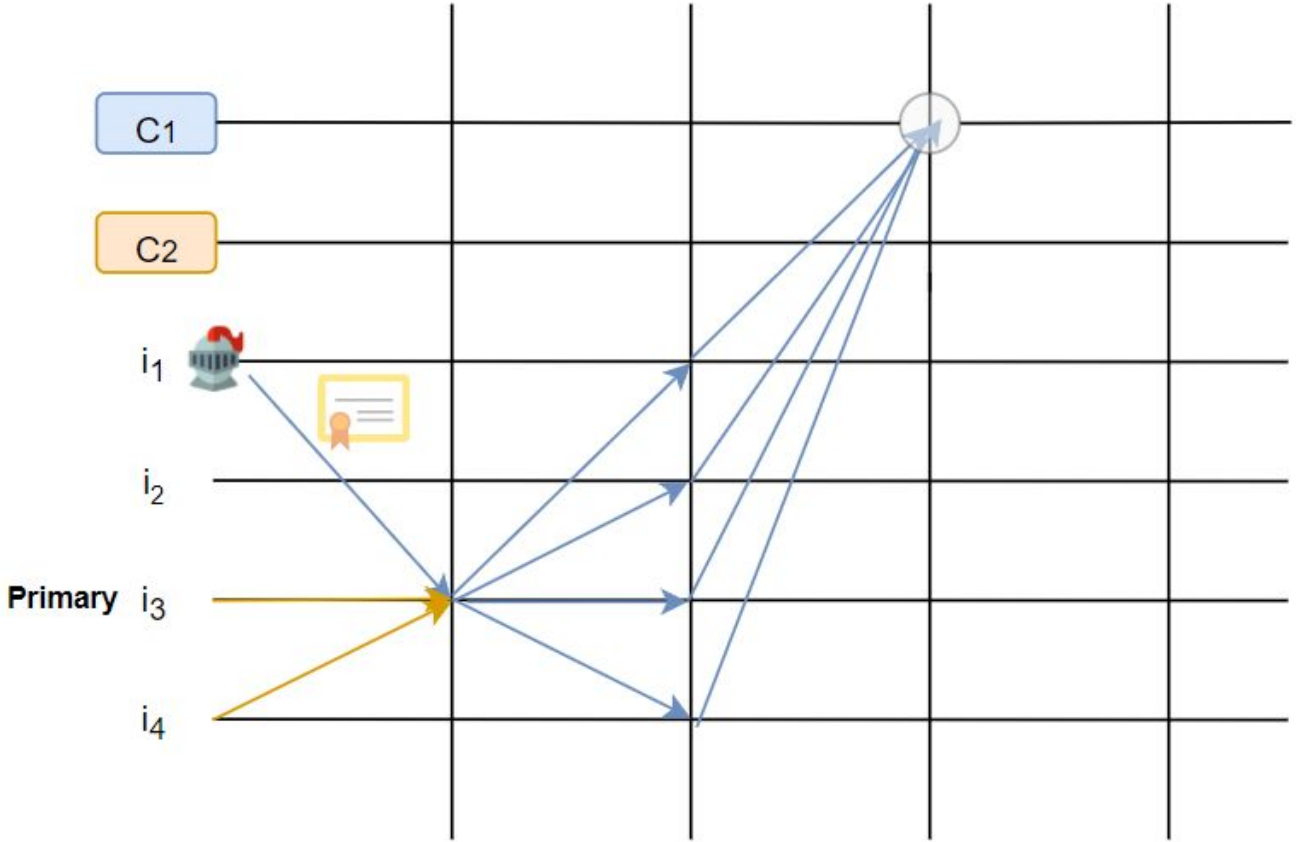


Zyzzyva



Zyzzyva

View 3: Choosing the wrong commit-certificate

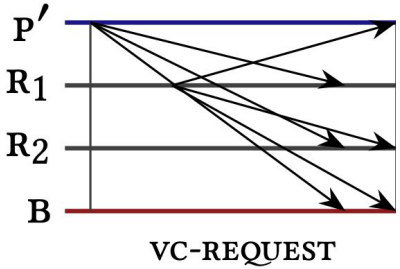


Proof of Execution: View Change

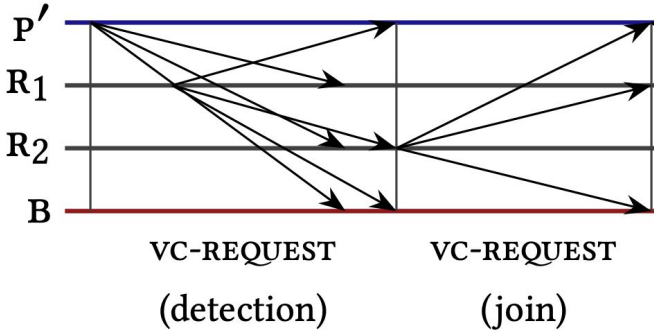
Proof of Execution - View Change

- Replicas elect new primary
- Needs to be detected by all non faulty replicas
- All replicas establish which transactions were included in view v
- A new primary proposes a new view.
  - If valid, the replicas switch over
  - If not, view change is initiated again

POE



POE



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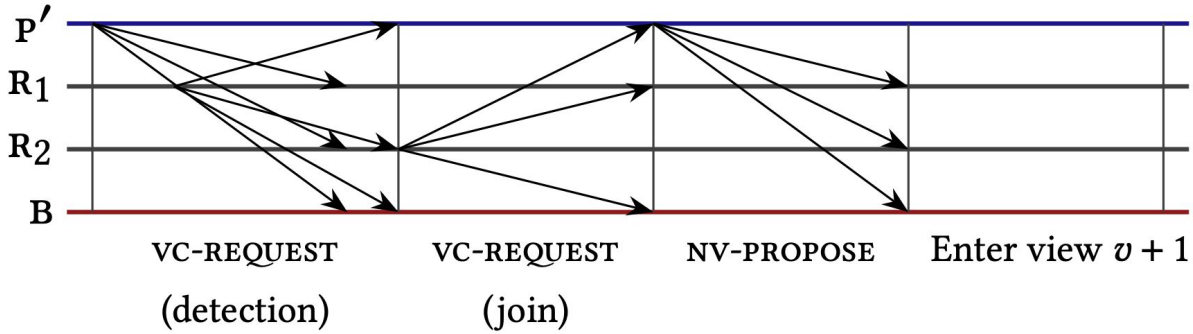


Discussion

Zyzzyva Uses Speculation

- Reduce cost of BFT
- Simplify design of BFT

Zyzzyva Advantages over QU (Query Update)

1. **Fewer** replicas
2. Improved throughput via **batching**
3. **Simpler** State Machine Replication Semantics
4. Ability to support **high** contention **workloads**

Zyzzyva Disadvantages over QU

1. Will this actually **resolve** the problem?
2. What if there is an **extra** work?
3. Simpler does **not** mean it works **all** the **time**.

Q/U sidesteps this lower bound by providing a slightly weaker service than state machine replication and optimizes cases without concurrent access to any state

Zyzzyva vs PBFT

Zyzzyva reduces cryptographic overheads and increases peak throughout by a factor of two to an order of magnitude for demanding workloads.

Discussion

Proof Of Execution

- Reduce cost of BFT
- Simplify design of BFT

POE Advantages

1. **Fewer Replicas**
2. **Out of order** processing
3. **Speculative Execution**
4. No **Response Aggregation**

POE vs PBFT

POE reduces the amount of communication between replicas and increases throughput across multiple factors

Zyzzyva Evaluation

Evaluation

The protocol was evaluated on the following:

1. **Throughput**
2. **Latency**
3. **Fault Scalability**
4. **Performance During Failures**

Protocols to be compared

Query/Update (Q/U)

Hybrid-Quorum replication (HQ Replication)

Practical Byzantine Fault Tolerance (PBFT)

Zyzzyva

Throughput

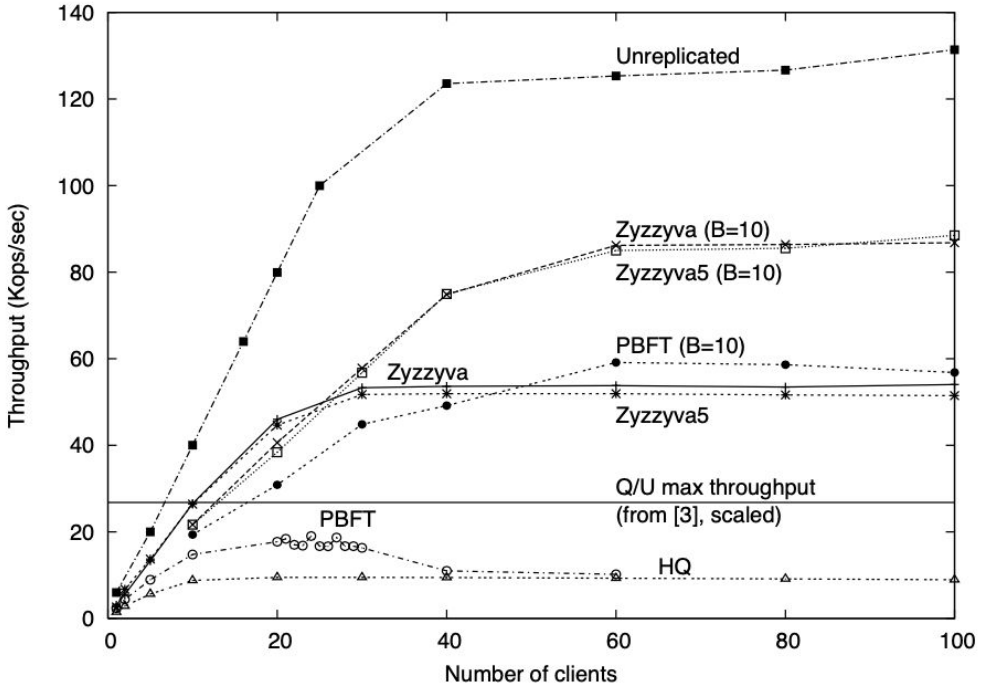


Figure 3: Realized throughput for the 0/0 benchmark as the number of client varies for systems configured to tolerate $f = 1$ faults.

Latency

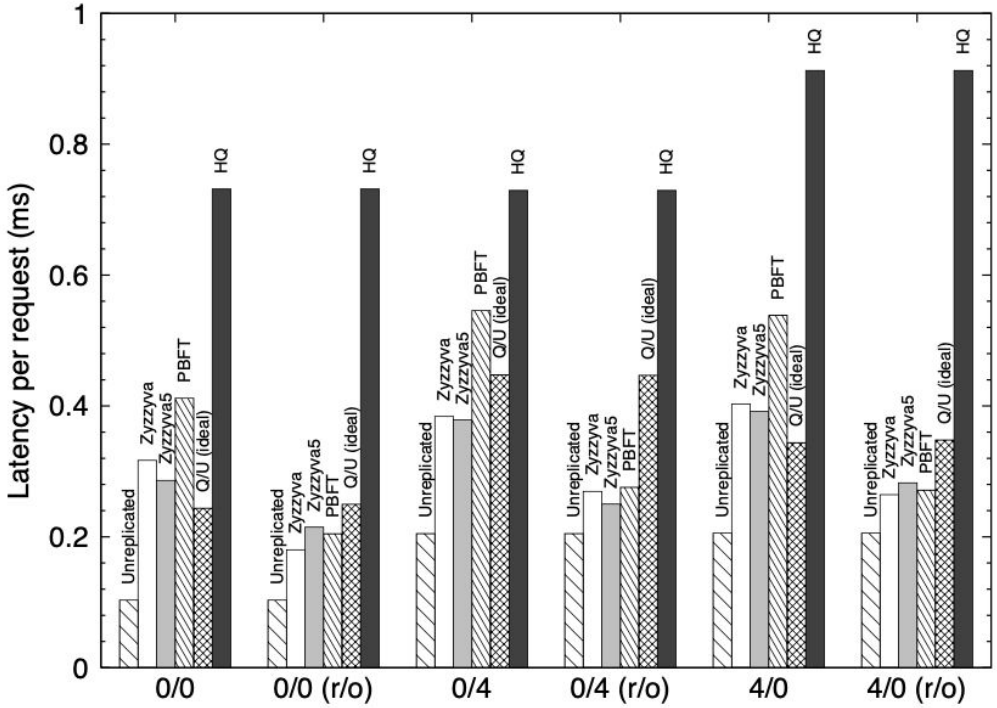


Figure 4: Latency for 0/0, 0/4, and 4/0 benchmarks for systems configured to tolerate $f = 1$ faults.

Fault Scalability

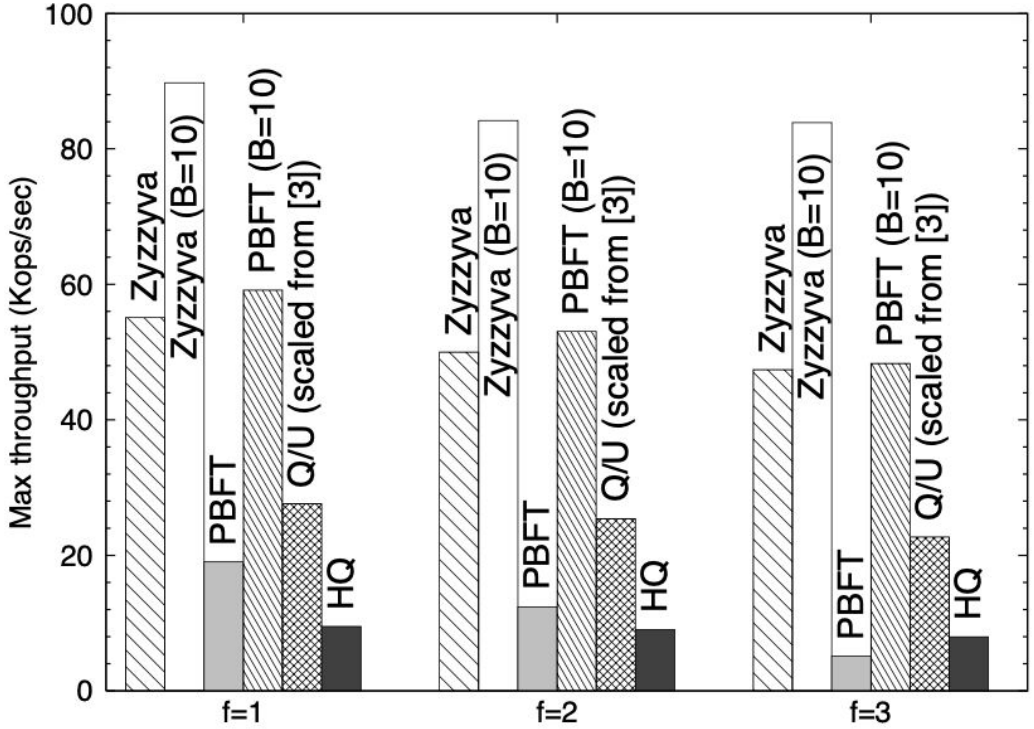


Figure 6: Fault scalability: Peak throughputs

Fault Scalability

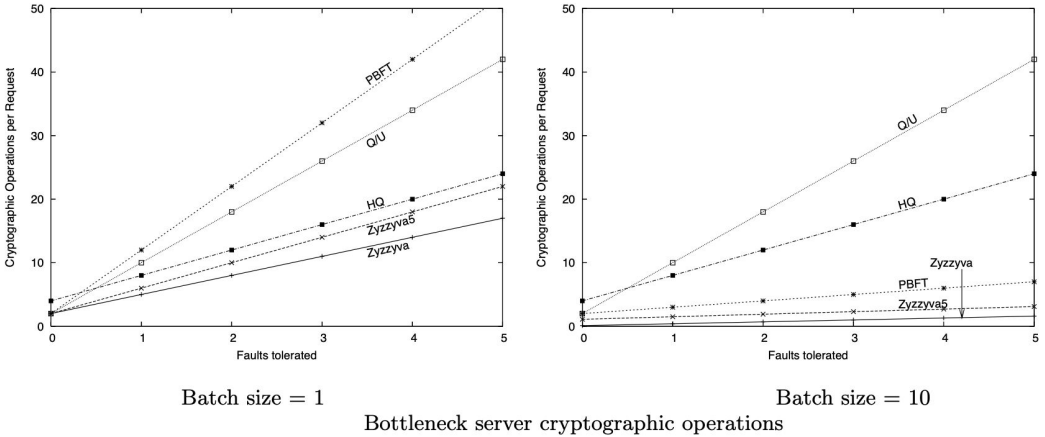


Figure 7: Fault scalability using analytical model

Performance During Failure

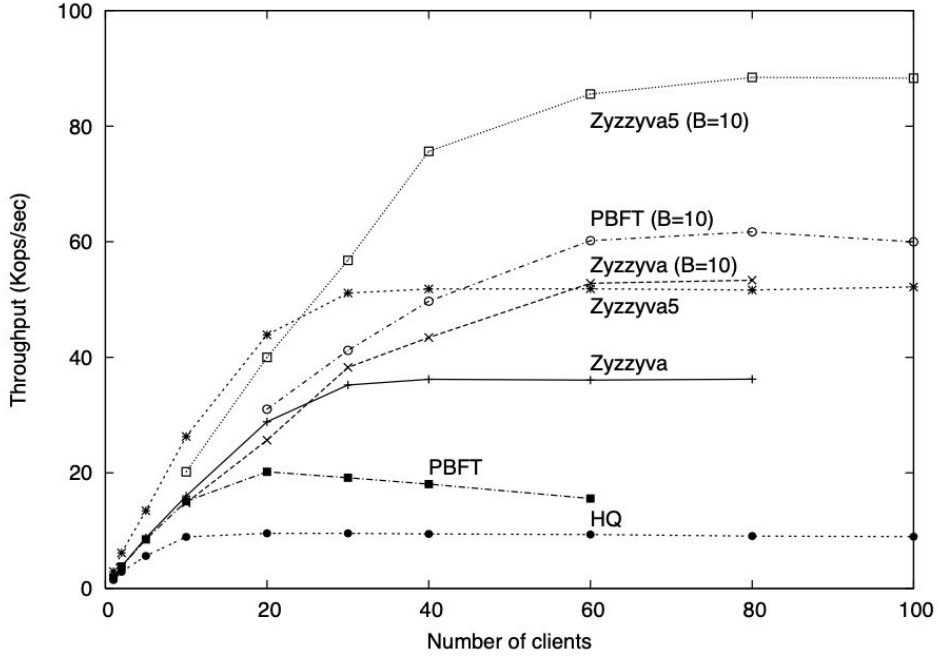


Figure 8: Realized throughput for the 0/0 benchmark as the number of client varies when f non-primary replicas fail to respond to requests.

Zyzzyva Implementation Optimizations

Implementation Optimizations

The protocol has 7 optimizations that were applied:

1. **Replacing Signatures with MACS**
2. **Separating Agreement from Execution**
3. **Request Batching**
4. **Caching Out of Order Requests**
5. **Read-Only Optimization**
6. **Single Execution Response**
7. **Preferred Quorums**

Proof of Execution: Evaluation

Evaluation

POE was evaluated against the following criteria

1. **Performance under failures**
2. **Benefit to batching client requests**
3. **Performance under zero payload**
4. **Scalability**

Protocols to be compared

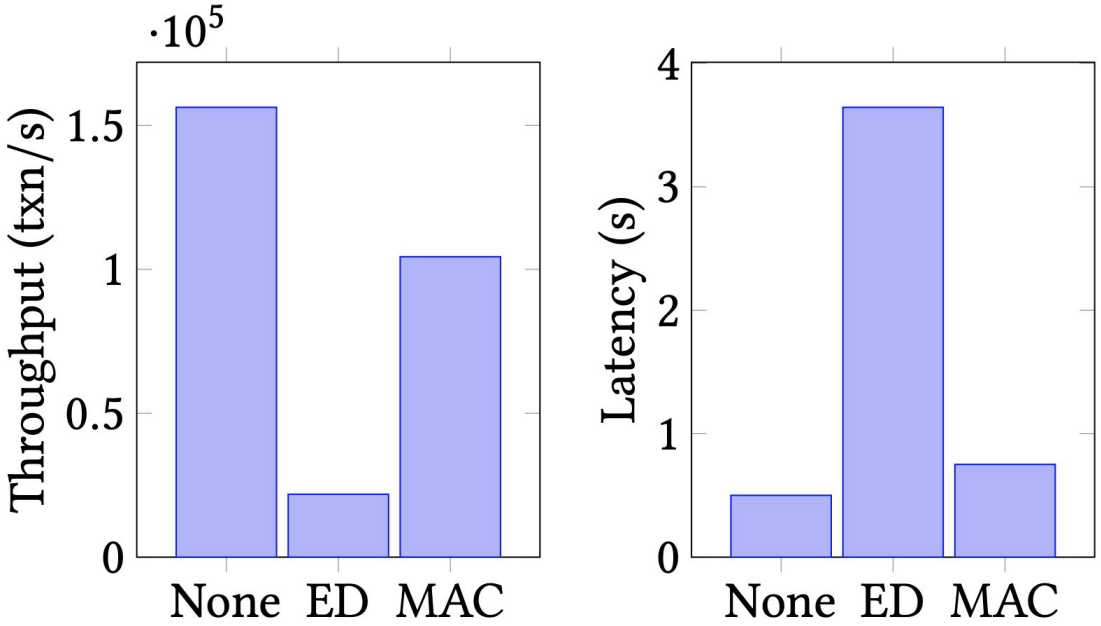
Practical Byzantine Fault Tolerance (PBFT)

Zyzzyva

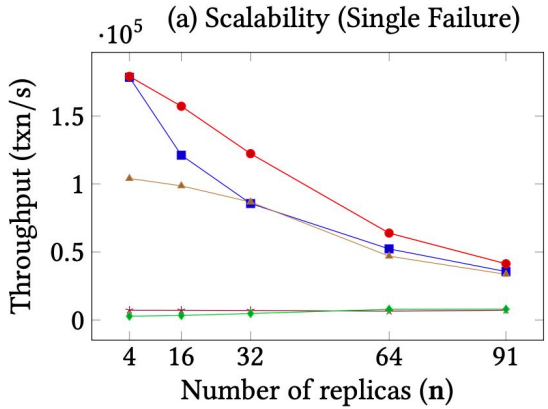
SBFT

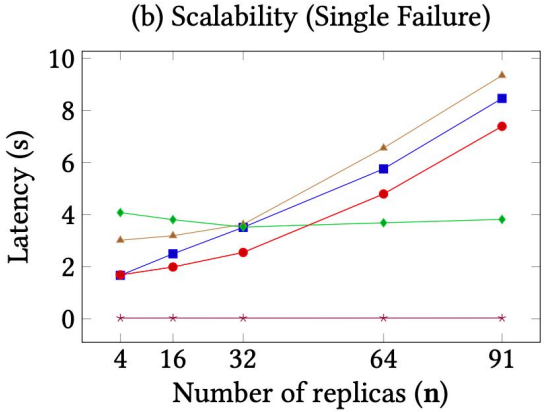
HotStuff

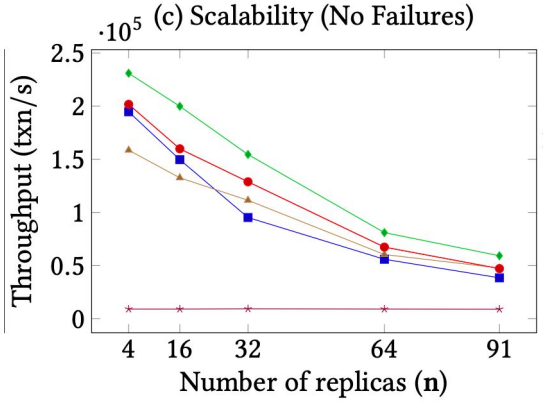
Evaluation - Performance with different signature schemes

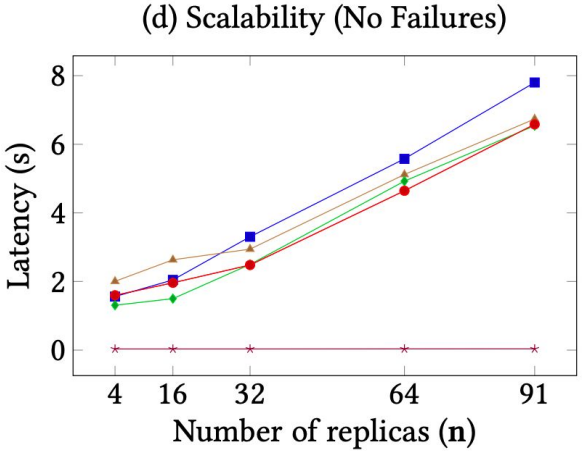


Evaluation - Scalability

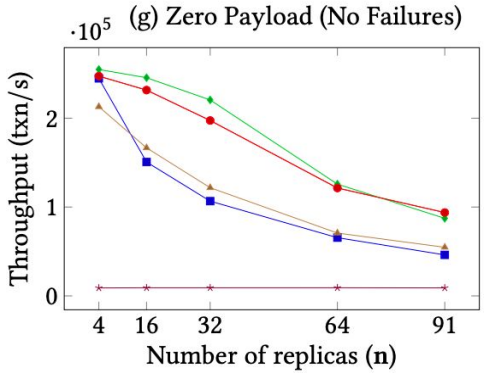


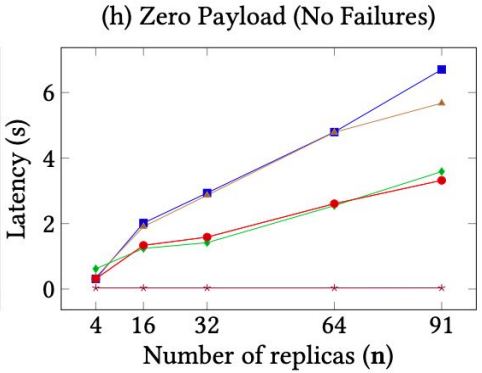


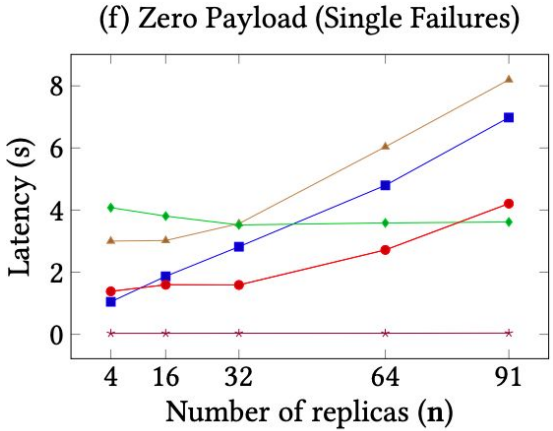


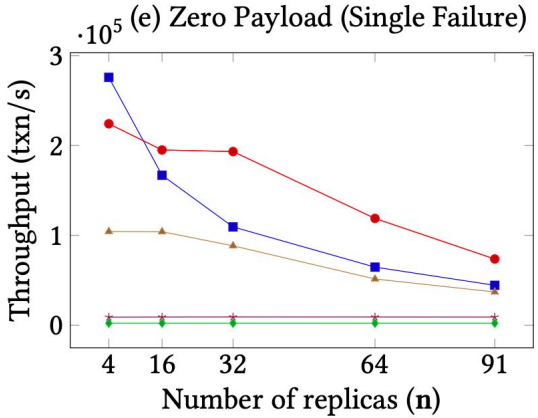


Evaluation - Zero Payload

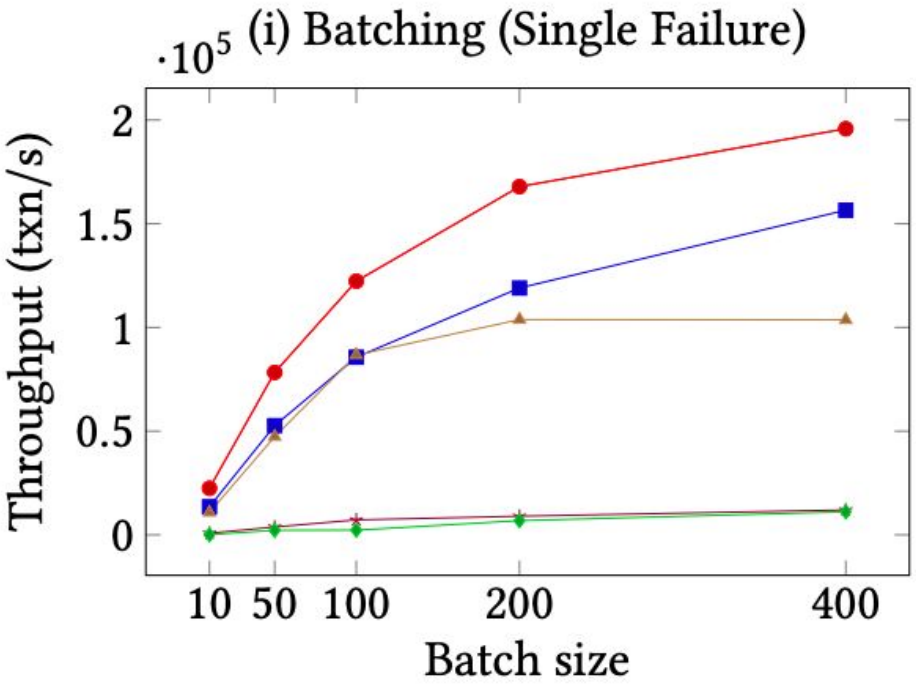


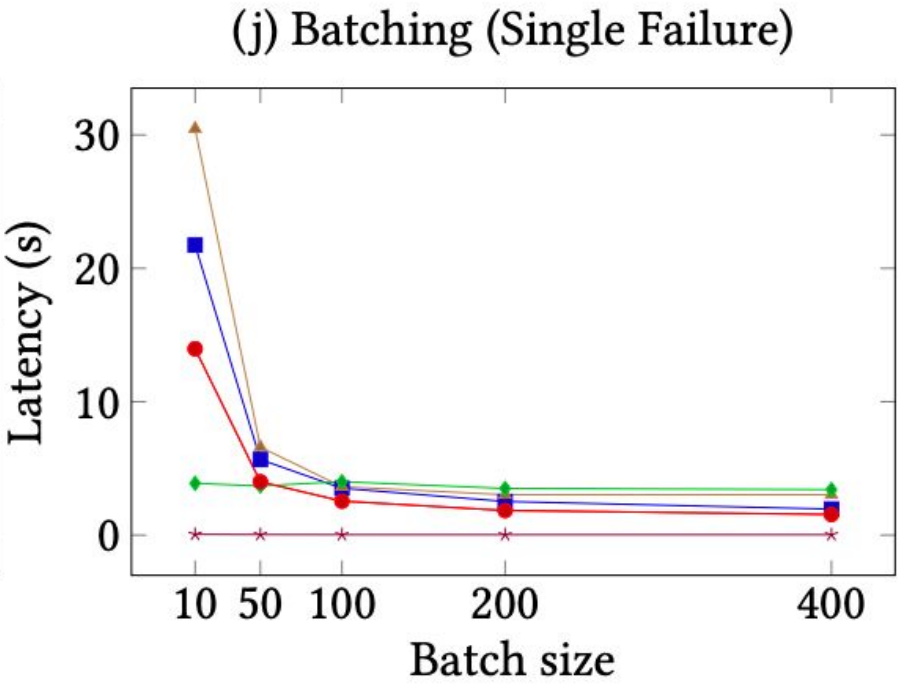




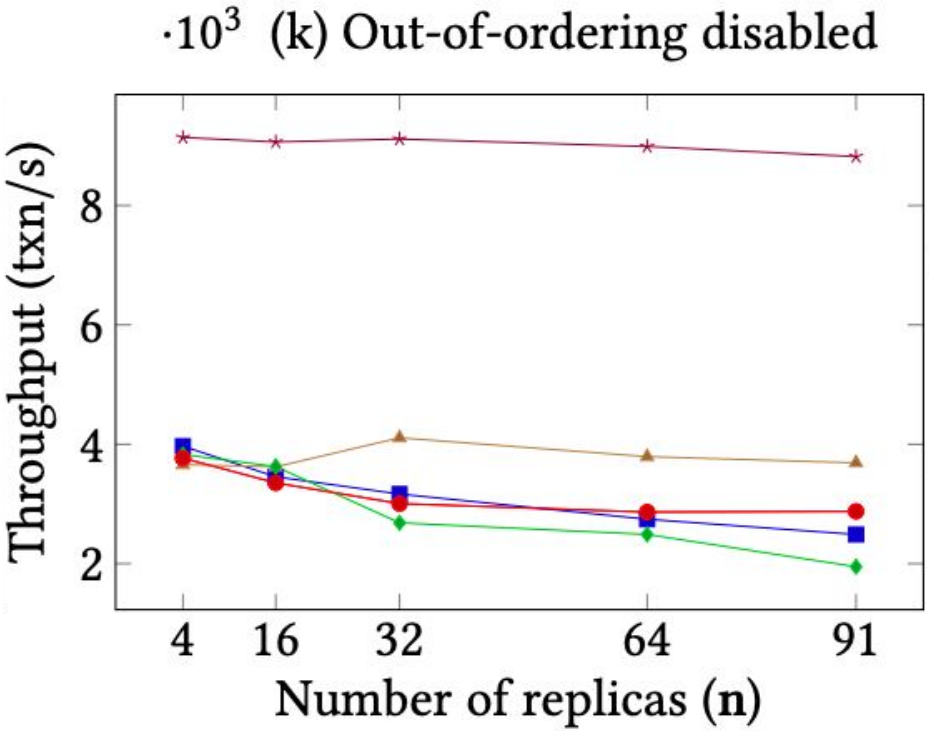


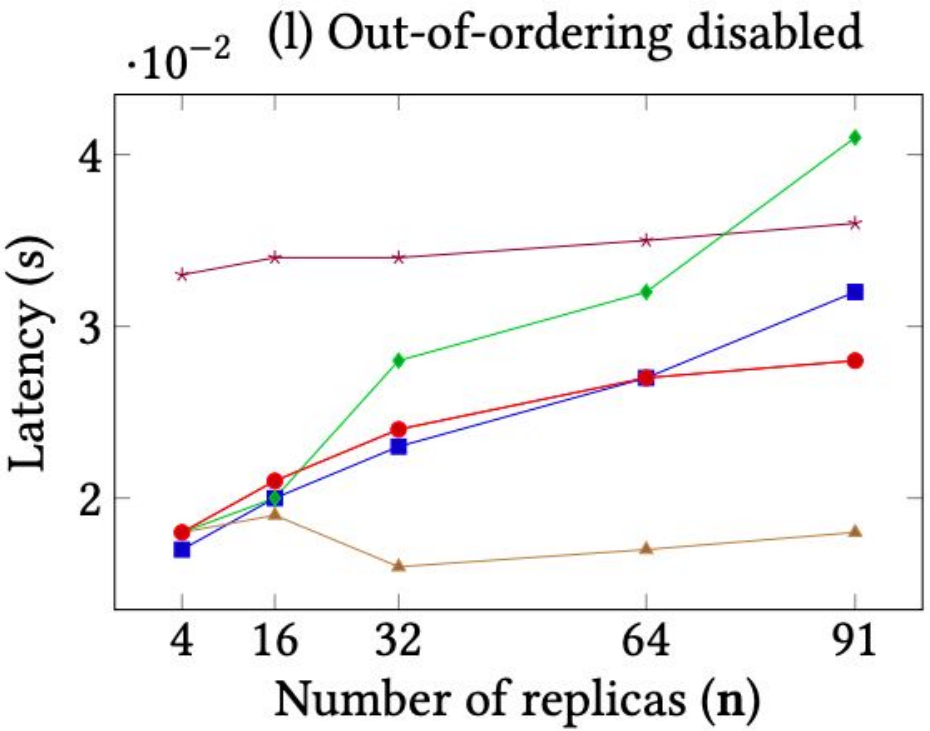
Evaluation - Batching





Evaluation - Out of Order Execution





Evaluation - Failures