

Distributed Systems - Project Report

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1 Design Choices

1.1 System Layout

The main classes of our system are the Nodes, the Clients, and the Coordinator.

The nodes and clients serve their roles as described in the project's assignment, while the coordinator is tasked to issue commands and enforce the project's assumptions.

To keep track of ongoing operations we implemented a "rounds system" in which the coordinator issues a group of operations, waits for their conclusion, and repeats the process.

1.2 Messages

The system's components communicate through messages, divided into two main categories: control messages and service messages.

Control messages are exchanged instantaneously between the coordinator and the other actors to issue commands (requests and management operations) and to get their results. With this information the coordinator can guarantee that nodes join and leave, crash and recover one at a time, and only when there are no ongoing operations.

Service messages implement the actual functionalities of the system. They simulate the messages that would be exchanged in a real world scenario, hence they are only sent between nodes and clients (not the coordinator). To make their behaviour more realistic they are sent with a random delay, mimicking the propagation delay of packets.¹

In **Fig.1** we illustrate all the messages of the system. To reduce the number of messages we adopted the following strategies:

1. **Get** and **Set**: only the nodes responsible for the interested data item are contacted.

¹The random delays *could* break FIFO, but we decided to ignore this as per the project's given assumptions

2. **Join:** the system only asks the joining node's clockwise neighbor for the data items that it is going to be responsible for, avoiding a number of unnecessary message exchanges. The latest version of these data items is then obtained through the Get operation. As stated above, reads already use the least amount of required messages.
3. **Leave:** the leaving node must transfer its data items to their new responsible nodes. If multiple data items are sent to the same node, they are bundled into the same message.
4. **Crash:** When a node crashes it sends no messages to the other nodes, only setting an internal flag. This operation is triggered by a control message.
5. **Recovery:** when a node enters recovery, it sends a data request to the other nodes to get updated on the status of the system. These messages are only sent to the $N - 1^2$ nodes in front and the $N - 1$ nodes behind the recovering one. Only these nodes may have the desired data items.

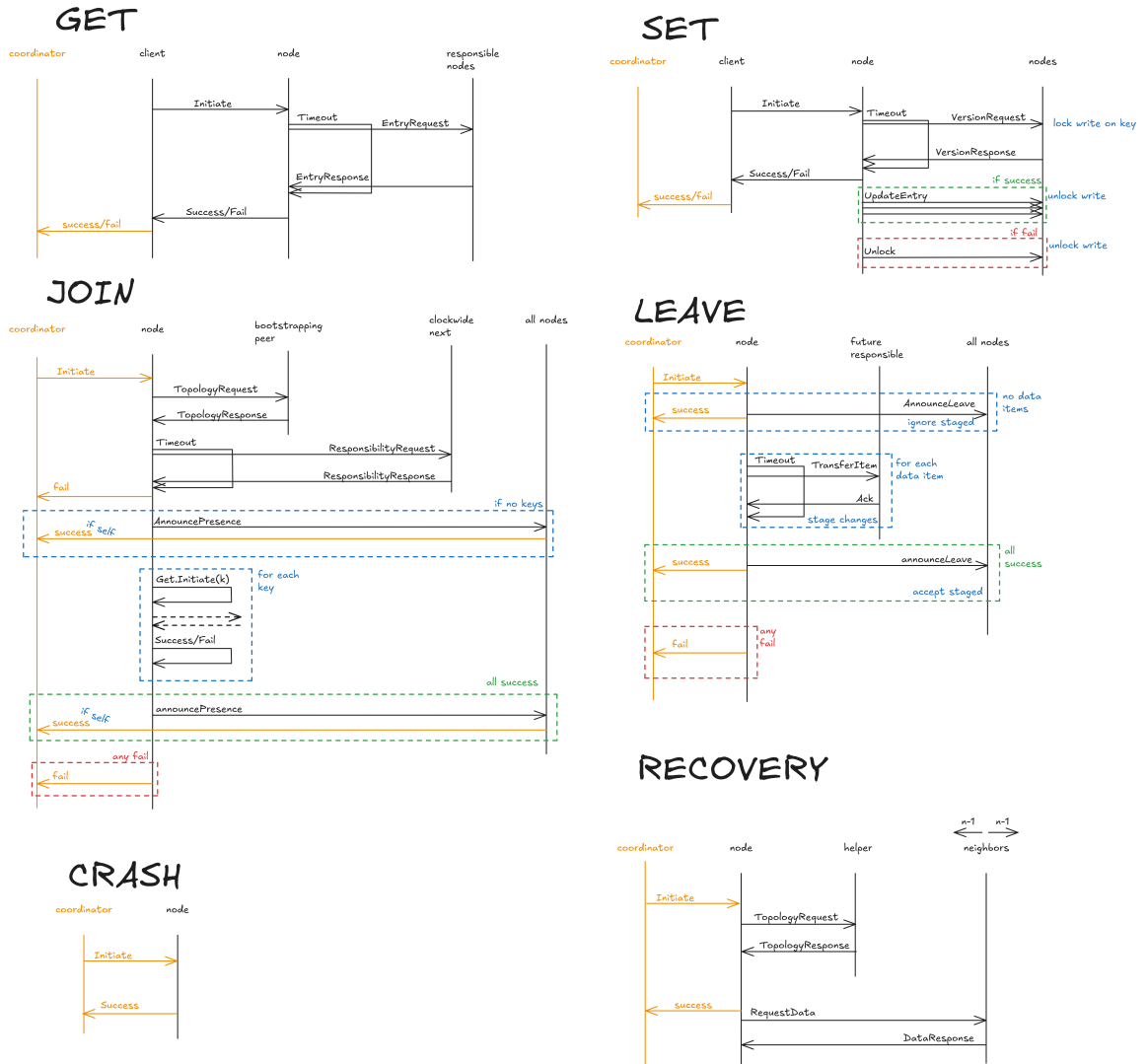


Figure 1: System messages

²N denotes the system's replication factor

1.3 Round system

There are two types of rounds: ones in which the system resolves a request (read or write) for each client, and ones in which a node performs management operations (join/leave, crash/recover).

Fig. shows the flowchart of a system round. The first diagram represents the simulation core: the coordinator continues issuing operations until it reaches a stopping criterion and decides which type of round it must begin. The second scheme is the round final part: the coordinator waits for the operations results and an additional time delay to let the system settle. Only then it will start a new round.

In the diagrams appear fundamentals variables:

- **ROUNDS**: global variable indicating how many rounds the coordinator must perform.
- **ongoing_actions**: number of pending operations for which the coordinator must receive a result (success or fail). It is set based on the type of round performed.
- **nodes_in**: list of nodes in the network.
- **nodes_out**: list of nodes out from the network from which the coordinator chooses a joining node and put the leaving nodes.
- **crashed_nodes**: list of crashed nodes.

The coordinator updates the above lists based on the operations performed, thus at the begin of each round the coordinator knows the nodes state and it is able to perform actions respecting the system requirements and assumptions.

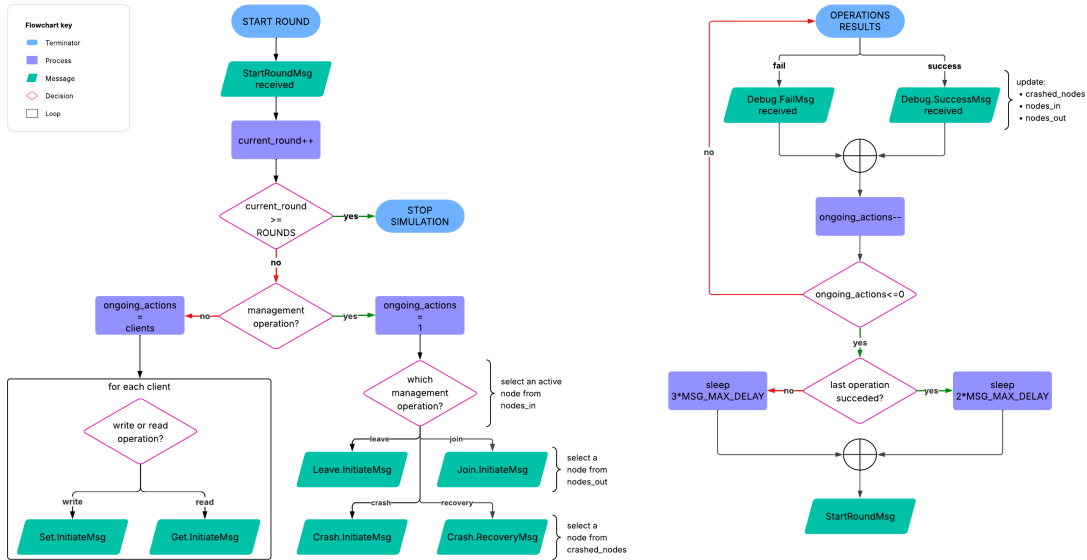


Figure 2: Round System

1.4 Testing Though Simulation

We perform two kinds of test on the system, both performed by the AppDebug class. Both tests rely on a log file containing a sequence of events in their global order.

The events stored in the file are:

- **node storage modification**: whenever data items are written or deleted from a node's storage, an entry describing the change is written to the file.

- operations: whenever an operation succeeds or fails, it is registered to the file as a single atomic entry.

First Test: Sequential Consistency A validator reads the log file and keeps track of all the successful read and write operations, storing each one as a node in a graph. The nodes are identified by the operation performed, the key of the item, its value, and its version.

Edges are then added between nodes to represent the happens-before relations between them:

1. Write nodes are linked to all the read nodes with the same key and value, since a value has to be written before being read
2. If two read events for the same key happen on the same client, an edge is created to represent this ordering
3. Each time a client writes something, an edge between all preceding read nodes (from the same client) and the newly formed write node is formed

Finally, the system checks for the existence of a topological order of this graph, and signals an error if it can't find any.

If none is found, it must be because the graph contains at least one loop, which shouldn't happen since the edges represent the happens-before relation which is acyclic.

If an ordering is found instead, the system enforced data-centric sequential consistency. Client-centric sequential consistency is guaranteed by the quorum instead.

Second Test: Mirroring Execution For the second test, two replicas of the system are created. Each replica tracks the individual storages of each node.

The first replica perfectly mirrors the execution of the real system. Data items are added or removed from the nodes if and only if the log file states that an alteration happened to the node's storage.

The second replica only reads the entries of the log file that report a successful operation (be it a management one or a read/write request) and simulates it.

The simulation keeps track of which nodes are in the system, which ones are crashed, and updates their storages accordingly.

At the end of each round the storage of each node in the first replica is compared with the corresponding one in the second replica. If no divergence between the two systems is found we can confirm the actual system behaves as assumed.

2 Assumptions and Requirements

3 Implementation Features