Simulation for Paxos Voting System

Introduction

This document shows the outcomes of testing the implementation of the Paxos protocol for a council election system. As needed by the assignment, the tests were carried out to confirm that the system could manage a variety of scenarios. The test setup, situations tested, and related logs/simulations are explained in the following parts. Screenshots have been included to demonstrate proper functionality.

Scenarios Tested

I used a class named **CouncilElection_Test** to test the system's functionality. Three scenarios need to be tested.

1. **Simultaneous Proposals from Multiple Proposers**
    - Simulates the simultaneous submission of proposals by two proposers (M1 and M2).
    - Makes sure one proposer reaches quorum and tests the system's capacity to manage many proposals simultaneously.

The simulation of this scenario is handled using the runSimultaneousProposals() method.

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===Testing Multiple Simultaneous Proposals for Council Election===

Member 4 is listening on port 8004
Member 9 is listening on port 8009
Member 1 is listening on port 8001
Member 5 is listening on port 8005
Member 7 is listening on port 8007
Member 3 is listening on port 8003
Member 2 is listening on port 8002
Member 8 is listening on port 8008
Member 6 is listening on port 8006
Current Time[1732205228667]: M1 is sending proposal with vote number: 1732205228668
Current Time[1732205228667]: M2 is sending proposal with vote number: 1732205228669
Current Time[1732205228733]: M1 received a promise from M1
Current Time[1732205228729]: M2 received a promise from M1
Current Time[1732205228746]: M2 received a promise from M2
Current Time[1732205228747]: M1 received a promise from M2
Current Time[1732205228749]: M2 received a promise from M3
Current Time[1732205228750]: M1 received a promise from M3
Current Time[1732205228752]: M2 received a promise from M4
Current Time[1732205228753]: M1 received a promise from M4
Current Time[1732205228755]: M2 received a promise from M5
Current Time[1732205228756]: M1 received a promise from M5
Current Time[1732205228758]: M2 received a promise from M6
Current Time[1732205228759]: M1 received a promise from M6
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Current Time[1732205228765]: M1 received a promise from M8
Current Time[1732205228767]: M2 received a promise from M9
Current Time[1732205228768]: M1 received a promise from M9
Current Time[1732205228770]: M2 received a acceptance from M1
Current Time[1732205228774]: M1 received a acceptance from M2
Current Time[1732205228775]: M2 received a acceptance from M2
Current Time[1732205228777]: M1 received a acceptance from M3
Current Time[1732205228780]: M2 received a acceptance from M3
Current Time[1732205228780]: M1 received a acceptance from M4
Current Time[1732205228783]: M1 received a acceptance from M5
Current Time[1732205228783]: M2 received a acceptance from M4
Current Time[1732205228785]: M1 received a acceptance from M6
Current Time[1732205228785]: M2 received a acceptance from M5
Current Time[1732205228788]: M2 received a acceptance from M6
Current Time[1732205228788]: M1 received a acceptance from M7
Current Time[1732205228791]: M2 received a acceptance from M7
Current Time[1732205228791]: M1 received a acceptance from M8
Current Time[1732205228794]: M2 received a acceptance from M8
Current Time[1732205228794]: M1 received a acceptance from M9
Vote Counts:
Current Time[1732205228796]: M2 received a acceptance from M9
M1 gets: 8 votes
M2 gets: 9 votes
M3 gets: 0 votes
Current Time[1732205228805]: M2 is elected as council president
```

The screenshots display the logs in which M1 and M2 make simultaneous proposals, and M1 is elected council president.

2. **Immediate Response for All Members**
    - Simulates every member (M1–M9) responding immediately when asked for voting.
    - Ensures no delays or offline members and that the protocol finishes the voting system quickly.

The simulation of this scenario is handled using the runImmediatedResponse() method.

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===Testing Immediate Response for All Members===

Member 5 is listening on port 8005
Member 2 is listening on port 8002
Member 4 is listening on port 8004
Member 1 is listening on port 8001
Member 6 is listening on port 8006
Member 8 is listening on port 8008
Member 9 is listening on port 8009
Member 7 is listening on port 8007
Member 3 is listening on port 8003
Current Time[1732176343802]: M1 is sending proposal with vote number: 1732176343803
Current Time[1732176343802]: M2 is sending proposal with vote number: 1732176343804
Member M1 is responding immediately.
Member M1 is responding immediately.
Current Time[1732176343834]: M2 received a promise from M1
Current Time[1732176343836]: M1 received a promise from M1
Member M2 is responding immediately.
Current Time[1732176343842]: M1 received a promise from M2
Member M2 is responding immediately.
Current Time[1732176343842]: M2 received a promise from M2
Member M3 is responding immediately.
Current Time[1732176343843]: M1 received a promise from M3
Member M3 is responding immediately.
Current Time[1732176343844]: M2 received a promise from M3
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Current Time[1732176343861]: M1 received a acceptance from M5
Member M5 is responding immediately.
Current Time[1732176343861]: M2 received a acceptance from M5
Member M6 is responding immediately.
Current Time[1732176343862]: M1 received a acceptance from M6
Member M6 is responding immediately.
Current Time[1732176343863]: M2 received a acceptance from M6
Member M7 is responding immediately.
Current Time[1732176343864]: M1 received a acceptance from M7
Member M7 is responding immediately.
Current Time[1732176343865]: M2 received a acceptance from M7
Member M8 is responding immediately.
Current Time[1732176343865]: M1 received a acceptance from M8
Member M8 is responding immediately.
Member M9 is responding immediately.
Current Time[1732176343866]: M2 received a acceptance from M8
Current Time[1732176343866]: M1 received a acceptance from M9
Vote Counts:
Member M9 is responding immediately.
Current Time[1732176343867]: M2 received a acceptance from M9
M1 gets: 9 votes
M2 gets: 9 votes
M3 gets: 0 votes
Current Time[1732176343871]: M1 is elected as council president
```

The Screenshots display logs in which every member responds immediately, and the election is quickly concluded.

3. **Varied Response Time (Delayed or Offline)**
    - Immediate response, minor delays (up to 2 seconds), large delays (up to 5 seconds), and offline members (M2 or M3) are among the response patterns that are simulated for members.
    - Evaluates the protocol's resilience to member failures and real-life network conditions.

The simulation of this scenario is handled using the runDelayedOrNoResponse() method.

```
===Testing Responses for Each Member with immediate response, Delays or Going Offline===

Member 9 is listening on port 8009
Member 6 is listening on port 8006
Member 1 is listening on port 8001
Member 5 is listening on port 8005
Member 3 is listening on port 8003
Member 4 is listening on port 8004
Member 7 is listening on port 8007
Member 2 is listening on port 8002
Member 8 is listening on port 8008
Current Time[1732177737804]: M1 is sending proposal with vote number: 1732177737805
Current Time[1732177737804]: M3 is sending proposal with vote number: 1732177737807
Current Time[1732177737804]: M2 is sending proposal with vote number: 1732177737806
Member M1 is response immediately.
Member M1 is response immediately.
Member M1 is response immediately.
Current Time[1732177737846]: M1 received a promise from M1
Current Time[1732177737843]: M2 received a promise from M1
Current Time[1732177737845]: M3 received a promise from M1
Member M2 is going offline.
Member M2 is going offline.
Member M2 is going offline.
Current Time[1732177737852]: M2 received a promise from M3
Current Time[1732177737853]: M1 received a promise from M3
Member M3 is not responding (message dropped)
Current Time[1732177737854]: M3 received a promise from M3
Member M4 respond after a small delay in 2 seconds.
Current Time[1732177738972]: M2 received a promise from M4
Member M5 respond after a small delay in 2 seconds.
Current Time[1732177739961]: M2 received a promise from M5
Member M4 respond after a small delay in 2 seconds.
Current Time[1732177740557]: M1 received a promise from M4
Member M6 respond after a small delay in 2 seconds.
Current Time[1732177740782]: M2 received a promise from M6
Member M7 respond after a small delay in 2 seconds.
Current Time[1732177741378]: M2 received a promise from M7
Member M4 respond after a small delay in 2 seconds.
Current Time[1732177741606]: M3 received a promise from M4
Member M8 respond after a large delay upto 5 seconds.
Current Time[1732177742389]: M2 received a promise from M8
Member M5 respond after a small delay in 2 seconds.
Current Time[1732177742481]: M1 received a promise from M5
Member M9 respond after a large delay upto 5 seconds.
Current Time[1732177742601]: M2 received a promise from M9
Member M1 is response immediately.
Current Time[1732177742604]: M2 received a acceptance from M1
Member M2 is going offline.
Current Time[1732177742610]: M2 received a acceptance from M3
Member M5 respond after a small delay in 2 seconds.
Current Time[1732177742695]: M3 received a promise from M5
Member M4 respond after a small delay in 2 seconds.
```

```
Member M2 is going offline.
Member M3 is not responding (message dropped)
Member M9 respond after a large delay upto 5 seconds.
Current Time[1732177749441]: M3 received a promise from M9
Member M1 is response immediately.
Current Time[1732177749442]: M3 received a acceptance from M1
Member M2 is going offline.
Member M3 is not responding (message dropped)
Current Time[1732177749444]: M3 received a acceptance from M3
Member M4 respond after a small delay in 2 seconds.
Member M4 respond after a small delay in 2 seconds.
Current Time[1732177750532]: M3 received a acceptance from M4
Member M5 respond after a small delay in 2 seconds.
Member M9 respond after a large delay upto 5 seconds.
Current Time[1732177751627]: M2 received a acceptance from M9
Vote Counts:
M1 gets: 0 votes
M2 gets: 8 votes
M3 gets: 3 votes
Current Time[1732177751636]: M2 is elected as council president
Member M6 respond after a small delay in 2 seconds.
Member M5 respond after a small delay in 2 seconds.
Current Time[1732177751920]: M3 received a acceptance from M5
```

The screenshots illustrate fault tolerance by displaying logs with offline members (M2 and M3) and delayed responses.

Conclusion

The Paxos protocol implementation worked as intended when tested in a variety of scenarios:

- Maintained quorum and managed concurrent proposals with success.
- Finished swiftly, and every member responded right away.
- Showed resilience in managing offline members and delays.

These outcomes attest to the implementation's accuracy and robustness. Included screenshots show how the system behaves and how the elections turn out.