CS7610: Lab 4 report

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This program implements the Paxos consensus protocol in a distributed system without a designated leader, where multiple proposers compete to push their proposals. The system consists of peers configured as either proposers, acceptors, or learners, with communication established over TCP to ensure reliable message exchange. Each peer reads from a configuration file to understand its role within the Paxos process, enabling dynamic coordination among nodes.

Initialization

Peers are initialized from a configuration (hostsfile) that defines their roles:

- **Proposers:** Nodes proposing values, starting from the peer with the lowest ID.
- **Acceptors:** Nodes receiving proposals and responding based on protocol rules.
- **Learners:** Nodes that observe the chosen value after consensus is reached.

Each peer establishes connections over TCP on port 8080, with roles specified by the configuration file.

Key System Components

- **Message Handling:** Each message (prepare, accept, acknowledge) is managed as a JSON object, ensuring standard format across peers.
- **Synchronization:** Mutexes are used to coordinate proposal rounds and prevent race conditions.
- **Fault Tolerance:** The system handles delays and missing acknowledgments by ensuring the proposal process restarts when conflicts occur.

Design Decisions and Challenges

1. **Role-Based Messaging:** The role-based design reduces unnecessary message traffic by ensuring proposers only communicate with specific acceptors.
2. **Concurrent Message Handling:** Goroutines are used to handle incoming and outgoing messages concurrently, allowing each peer to participate in multiple proposal rounds without blocking on I/O operations.
3. **Consistent State Management:** Mutexes are employed to protect shared resources like the proposal number, accepted values, and response maps, ensuring consistency in each peer's state, even under concurrent proposal attempts.

Testcase 1

Output from peer1:

{"peer_id":1,"action":"sent","message_type":"prepare","message_value":"","proposal_num":1}

{"peer_id":2,"action":"received","message_type":"prepare_ack","message_value":"","proposal_num":1}
{"peer_id":3,"action":"received","message_type":"prepare_ack","message_value":"","proposal_num":1}

{"peer_id":1,"action":"sent","message_type":"accept","message_value":"X","proposal_num":1}

{"peer_id":2,"action":"received","message_type":"accept_ack","message_value":"X","proposal_num":1}
{"peer_id":3,"action":"received","message_type":"accept_ack","message_value":"X","proposal_num":1}

{"peer_id":1,"action":"chose","message_type":"chose","message_value":"X","proposal_num":1}

{"peer_id":4,"action":"received","message_type":"prepare_ack","message_value":"","proposal_num":1}
{"peer_id":4,"action":"received","message_type":"accept_ack","message_value":"X","proposal_num":1}

Output from peer2:

{"peer_id":1,"action":"received","message_type":"prepare","message_value":"","proposal_num":1}
{"peer_id":2,"action":"sent","message_type":"prepare_ack","message_value":"","proposal_num":1}

{"peer_id":1,"action":"received","message_type":"accept","message_value":"X","proposal_num":1}
{"peer_id":2,"action":"sent","message_type":"accept_ack","message_value":"X","proposal_num":1}

{"peer_id":2,"action":"chose","message_type":"chose","message_value":"X","proposal_num":1}

Output from peer3:

{"peer_id":1,"action":"received","message_type":"prepare","message_value":"","proposal_num":1}
{"peer_id":3,"action":"sent","message_type":"prepare_ack","message_value":"","proposal_num":1}

{"peer_id":1,"action":"received","message_type":"accept","message_value":"X","proposal_num":1}
{"peer_id":3,"action":"sent","message_type":"accept_ack","message_value":"X","proposal_num":1}

{"peer_id":3,"action":"chose","message_type":"chose","message_value":"X","proposal_num":1}

Output from peer4:

{"peer_id":1,"action":"received","message_type":"prepare","message_value":"","proposal_num":1}
{"peer_id":4,"action":"sent","message_type":"prepare_ack","message_value":"","proposal_num":1}

{"peer_id":1,"action":"received","message_type":"accept","message_value":"X","proposal_num":1}
{"peer_id":4,"action":"sent","message_type":"accept_ack","message_value":"X","proposal_num":1}

{"peer_id":4,"action":"chose","message_type":"chose","message_value":"X","proposal_num":1}

Output from peer5:

Empty

Combined output:

```
Attaching to peer1, peer2, peer3, peer4, peer5
peer1  |
{"peer_id":1,"action":"sent","message_type":"prepare","message_value":"","proposal_num":1}
peer2  |
{"peer_id":1,"action":"received","message_type":"prepare","message_value":"","proposal_num":1}
peer1  |
{"peer_id":2,"action":"received","message_type":"prepare_ack","message_value":"","proposal_num":1}
peer3  |
{"peer_id":1,"action":"received","message_type":"prepare","message_value":"","proposal_num":1}
peer4  |
{"peer_id":1,"action":"received","message_type":"prepare","message_value":"","proposal_num":1}
peer2  |
{"peer_id":2,"action":"sent","message_type":"prepare_ack","message_value":"","proposal_num":1}
peer1  |
{"peer_id":3,"action":"received","message_type":"prepare_ack","message_value":"","proposal_num":1}
peer3  |
{"peer_id":3,"action":"sent","message_type":"prepare_ack","message_value":"","proposal_num":1}
peer4  |
{"peer_id":4,"action":"sent","message_type":"prepare_ack","message_value":"","proposal_num":1}
peer2  |
{"peer_id":1,"action":"received","message_type":"accept","message_value":"X","proposal_num":1}

peer1  |
{"peer_id":1,"action":"sent","message_type":"accept","message_value":"X","proposal_num":1}
peer3  |
{"peer_id":1,"action":"received","message_type":"accept","message_value":"X","proposal_num":1}
peer4  |
{"peer_id":1,"action":"received","message_type":"accept","message_value":"X","proposal_num":1}
peer2  |
{"peer_id":2,"action":"sent","message_type":"accept_ack","message_value":"X","proposal_num":1}
peer1  |
{"peer_id":2,"action":"received","message_type":"accept_ack","message_value":"X","proposal_num":1}
peer3  |
{"peer_id":3,"action":"sent","message_type":"accept_ack","message_value":"X","proposal_num":1}
peer4  |
{"peer_id":4,"action":"sent","message_type":"accept_ack","message_value":"X","proposal_num":1}
peer2  |
{"peer_id":2,"action":"chose","message_type":"chose","message_value":"X","proposal_num":1}
peer1  |
{"peer_id":3,"action":"received","message_type":"accept_ack","message_value":"X","proposal_num":1}
peer3  |
{"peer_id":3,"action":"chose","message_type":"chose","message_value":"X","proposal_num":1}
peer4  |
{"peer_id":4,"action":"chose","message_type":"chose","message_value":"X","proposal_num":1}

peer1  |
{"peer_id":1,"action":"chose","message_type":"chose","message_value":"X","proposal_num":1}
peer1  |
{"peer_id":4,"action":"received","message_type":"prepare_ack","message_value":"","proposal_num":1}
peer1  |
{"peer_id":4,"action":"received","message_type":"accept_ack","message_value":"X","proposal_num":1}
```

Testcase 2

Output from peer1:

{"peer_id":1,"action":"sent","message_type":"prepare","message_value":"","proposal_num":1}

{"peer_id":4,"action":"received","message_type":"prepare_ack","message_value":"","proposal_num":1}
{"peer_id":3,"action":"received","message_type":"prepare_ack","message_value":"","proposal_num":1}

{"peer_id":1,"action":"sent","message_type":"accept","message_value":"X","proposal_num":1}

{"peer_id":3,"action":"received","message_type":"accept_ack","message_value":"X","proposal_num":1}
{"peer_id":4,"action":"received","message_type":"accept_ack","message_value":"X","proposal_num":1}

{"peer_id":1,"action":"chose","message_type":"chose","message_value":"X","proposal_num":1}

{"peer_id":2,"action":"received","message_type":"prepare_ack","message_value":"","proposal_num":1}
{"peer_id":2,"action":"received","message_type":"accept_ack","message_value":"X","proposal_num":1}

Output from peer2:

{"peer_id":1,"action":"received","message_type":"prepare","message_value":"","proposal_num":1}
{"peer_id":2,"action":"sent","message_type":"prepare_ack","message_value":"","proposal_num":1}

{"peer_id":1,"action":"received","message_type":"accept","message_value":"X","proposal_num":1}
{"peer_id":2,"action":"sent","message_type":"accept_ack","message_value":"X","proposal_num":1}

{"peer_id":2,"action":"chose","message_type":"chose","message_value":"X","proposal_num":1}

{"peer_id":5,"action":"received","message_type":"prepare","message_value":"","proposal_num":2}
{"peer_id":2,"action":"sent","message_type":"prepare_ack","message_value":"X","proposal_num":1}

{"peer_id":5,"action":"received","message_type":"accept","message_value":"X","proposal_num":2}
{"peer_id":2,"action":"sent","message_type":"accept_ack","message_value":"X","proposal_num":2}

{"peer_id":2,"action":"chose","message_type":"chose","message_value":"X","proposal_num":2}

Output from peer3:

{"peer_id":1,"action":"received","message_type":"prepare","message_value":"","proposal_num":1}
{"peer_id":3,"action":"sent","message_type":"prepare_ack","message_value":"","proposal_num":1}

{"peer_id":1,"action":"received","message_type":"accept","message_value":"X","proposal_num":1}
{"peer_id":3,"action":"sent","message_type":"accept_ack","message_value":"X","proposal_num":1}

{"peer_id":3,"action":"chose","message_type":"chose","message_value":"X","proposal_num":1}

{"peer_id":5,"action":"received","message_type":"prepare","message_value":"","proposal_num":2}
{"peer_id":3,"action":"sent","message_type":"prepare_ack","message_value":"X","proposal_num":1}

{"peer_id":5,"action":"received","message_type":"accept","message_value":"X","proposal_num":2}
{"peer_id":3,"action":"sent","message_type":"accept_ack","message_value":"X","proposal_num":2}

{"peer_id":3,"action":"chose","message_type":"chose","message_value":"X","proposal_num":2}

Output from peer4:

{"peer_id":1,"action":"received","message_type":"prepare","message_value":"","proposal_num":1}
{"peer_id":4,"action":"sent","message_type":"prepare_ack","message_value":"","proposal_num":1}

{"peer_id":1,"action":"received","message_type":"accept","message_value":"X","proposal_num":1}
{"peer_id":4,"action":"sent","message_type":"accept_ack","message_value":"X","proposal_num":1}

{"peer_id":4,"action":"chose","message_type":"chose","message_value":"X","proposal_num":1}

{"peer_id":5,"action":"received","message_type":"prepare","message_value":"","proposal_num":2}
{"peer_id":4,"action":"sent","message_type":"prepare_ack","message_value":"X","proposal_num":1}

{"peer_id":5,"action":"received","message_type":"accept","message_value":"X","proposal_num":2}
{"peer_id":4,"action":"sent","message_type":"accept_ack","message_value":"X","proposal_num":2}

{"peer_id":4,"action":"chose","message_type":"chose","message_value":"X","proposal_num":2}

Output from peer5:

{"peer_id":5,"action":"sent","message_type":"prepare","message_value":"","proposal_num":2}

{"peer_id":4,"action":"received","message_type":"prepare_ack","message_value":"X","proposal_num":1}
{"peer_id":2,"action":"received","message_type":"prepare_ack","message_value":"X","proposal_num":1}

{"peer_id":5,"action":"sent","message_type":"accept","message_value":"X","proposal_num":2}

{"peer_id":4,"action":"received","message_type":"accept_ack","message_value":"X","proposal_num":2}
{"peer_id":2,"action":"received","message_type":"accept_ack","message_value":"X","proposal_num":2}

{"peer_id":5,"action":"chose","message_type":"chose","message_value":"X","proposal_num":2}

{"peer_id":3,"action":"received","message_type":"prepare_ack","message_value":"X","proposal_num":1}
{"peer_id":3,"action":"received","message_type":"accept_ack","message_value":"X","proposal_num":2}

Combined Output:

peer1 |
{"peer_id":1,"action":"sent","message_type":"prepare","message_value":"","proposal_num":1}
peer4 |
{"peer_id":1,"action":"received","message_type":"prepare","message_value":"","proposal_num":1}
peer3 |
{"peer_id":1,"action":"received","message_type":"prepare","message_value":"","proposal_num":1}
peer1 |
{"peer_id":4,"action":"received","message_type":"prepare_ack","message_value":"","proposal_num":1}
peer2 |
{"peer_id":1,"action":"received","message_type":"prepare","message_value":"","proposal_num":1}
peer4 |
{"peer_id":4,"action":"sent","message_type":"prepare_ack","message_value":"","proposal_num":1}
peer3 |
{"peer_id":3,"action":"sent","message_type":"prepare_ack","message_value":"","proposal_num":1}
peer1 |
{"peer_id":3,"action":"received","message_type":"prepare_ack","message_value":"","proposal_num":1}
peer2 |
{"peer_id":2,"action":"sent","message_type":"prepare_ack","message_value":"","proposal_num":1}
peer4 |
{"peer_id":1,"action":"received","message_type":"accept","message_value":"X","proposal_num":1}
peer3 |
{"peer_id":1,"action":"received","message_type":"accept","message_value":"X","proposal_num":1}

peer1 |
{"peer_id":1,"action":"sent","message_type":"accept","message_value":"X","proposal_num":1}
peer2 |
{"peer_id":1,"action":"received","message_type":"accept","message_value":"X","proposal_num":1}
peer4 |
{"peer_id":4,"action":"sent","message_type":"accept_ack","message_value":"X","proposal_num":1}
peer3 |
{"peer_id":3,"action":"sent","message_type":"accept_ack","message_value":"X","proposal_num":1}
peer1 |
{"peer_id":3,"action":"received","message_type":"accept_ack","message_value":"X","proposal_num":1}
peer2 |
{"peer_id":2,"action":"sent","message_type":"accept_ack","message_value":"X","proposal_num":1}
peer4 |
{"peer_id":4,"action":"chose","message_type":"chose","message_value":"X","proposal_num":1}
peer3 |
{"peer_id":3,"action":"chose","message_type":"chose","message_value":"X","proposal_num":1}
peer1 |
{"peer_id":4,"action":"received","message_type":"accept_ack","message_value":"X","proposal_num":1}
peer2 |
{"peer_id":2,"action":"chose","message_type":"chose","message_value":"X","proposal_num":1}

peer1 |
{"peer_id":1,"action":"chose","message_type":"chose","message_value":"X","proposal_num":1}
peer1 |
{"peer_id":2,"action":"received","message_type":"prepare_ack","message_value":"","proposal_num":1}
peer1 |
{"peer_id":2,"action":"received","message_type":"accept_ack","message_value":"X","proposal_num":1}

peer5 |
{"peer_id":5,"action":"sent","message_type":"prepare","message_value":"","proposal_num":2}
peer4 |
{"peer_id":5,"action":"received","message_type":"prepare","message_value":"","proposal_num":2}
peer5 |
{"peer_id":4,"action":"received","message_type":"prepare_ack","message_value":"X","proposal_num":1
}
peer2 |
{"peer_id":5,"action":"received","message_type":"prepare","message_value":"","proposal_num":2}
peer3 |
{"peer_id":5,"action":"received","message_type":"prepare","message_value":"","proposal_num":2}
peer4 |
{"peer_id":4,"action":"sent","message_type":"prepare_ack","message_value":"X","proposal_num":1}
peer5 |
{"peer_id":2,"action":"received","message_type":"prepare_ack","message_value":"X","proposal_num":1
}
peer2 |
{"peer_id":2,"action":"sent","message_type":"prepare_ack","message_value":"X","proposal_num":1}
peer3 |
{"peer_id":3,"action":"sent","message_type":"prepare_ack","message_value":"X","proposal_num":1}
peer4 |
{"peer_id":5,"action":"received","message_type":"accept","message_value":"X","proposal_num":2}

peer5 |
{"peer_id":5,"action":"sent","message_type":"accept","message_value":"X","proposal_num":2}
peer2 |
{"peer_id":5,"action":"received","message_type":"accept","message_value":"X","proposal_num":2}
peer3 |
{"peer_id":5,"action":"received","message_type":"accept","message_value":"X","proposal_num":2}
peer4 |
{"peer_id":4,"action":"sent","message_type":"accept_ack","message_value":"X","proposal_num":2}
peer5 |
{"peer_id":4,"action":"received","message_type":"accept_ack","message_value":"X","proposal_num":2}
peer2 |
{"peer_id":2,"action":"sent","message_type":"accept_ack","message_value":"X","proposal_num":2}
peer3 |
{"peer_id":3,"action":"sent","message_type":"accept_ack","message_value":"X","proposal_num":2}
peer4 |
{"peer_id":4,"action":"chose","message_type":"chose","message_value":"X","proposal_num":2}
peer5 |
{"peer_id":2,"action":"received","message_type":"accept_ack","message_value":"X","proposal_num":2}
peer2 |
{"peer_id":2,"action":"chose","message_type":"chose","message_value":"X","proposal_num":2}
peer3 |
{"peer_id":3,"action":"chose","message_type":"chose","message_value":"X","proposal_num":2}

peer5 |
{"peer_id":5,"action":"chose","message_type":"chose","message_value":"X","proposal_num":2}
peer5 |
{"peer_id":3,"action":"received","message_type":"prepare_ack","message_value":"X","proposal_num":1
}

peer5 |
{"peer_id":3,"action":"received","message_type":"accept_ack","message_value":"X","proposal_num":2}