Sharing Memory with semi-Byzantine Clients and Faulty Storage Servers

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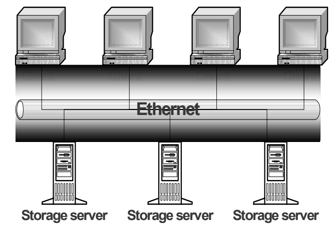
Storage Systems

- **storage servers**
  - disks
  - active disks
  - object stores …
- **clients**
- **complete network**
  - asynchronous
  - reliable



Our Contributions

- **Fault-tolerant simulations of a single-writer multi-reader regular register in storage systems, tolerating**
  - Semi-Byzantine failures of clients, resulting in erroneous write operations
  - Fail-stop failures of storage servers
    - requires a majority of nonfaulty servers
  - Byzantine failures of storage servers
    - requires that two-thirds of the servers are nonfaulty
- **Use the simulations to improve the fault-tolerance of the Paxos algorithm**
  [Lamport]

Talk Outline

- Model
- Simulations
- Application:
  The Paxos Algorithm
- Conclusion

Client Failures

- Well-debugged applications do not suffer malicious failures

Still… corrupted data may be written to shared storage:
  - A client fails during an update operation, leaving a corrupted disk block
  - Failures of network switches and storage hardware cause loss / re-ordering of messages from the client to the storage servers

Semi-Byzantine Clients

- Memory objects are protected by access control lists
  - Only specified client may access the object
- Clients fail by stopping or executing some memory access operations incorrectly

Modeling Semi-Byzantine Clients

- Use the faulty shared memory model

  [Afek, Greenberg, Merritt and Taubenfeld]
- A faulty register experiences erroneous writes
  - A sequence of write / read operations (to the same register) is f-faulty if inserting *f* arbitrary write operations makes it legal
  - An algorithm is f-reliable if it is correct in any f-faulty execution

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Handling Semi-Byzantine Clients

Algorithm 1

An f reliable simulation of a SWMR register with semi Byzantine clients

- **An f reliable SWMR atomic register**
  [Afek et al.]
- **Using 20f+8 atomic SWMR registers**

Handling Fail-Stop Storage Servers

Algorithm 2

A simulation of a SWMR register with semi-Byzantine clients and fail-stop servers
  - assume a majority of storage servers do not fail

- **Shared-memory simulation**
  [Attiya, Bar-Noy and Dolev]
- **Message complexity 2n*(20f+8)**
  - Message aggregation reduces complexity to 2n.
- **Time complexity 20f+8**

Simulation with Byzantine Storage Servers

```
WRITE(X)
send STORE(x) to all servers
loop
  receive ack from server S
until ack is received from n-t servers

READ()
loop
  send READ to all servers
  loop
     answer[S] = receive VAL(x) from server S
  until received from n-t servers
until (one value appears n-t times in answer[])
```

Simulation Properties

- **A read operation returns the value of the latest preceding or overlapping write operation**
  - Safety is always guaranteed
- **A read operation terminates if it overlaps a finite number of write operations**
  - May block if overlaps an infinite number of writes
- **Requires n > 3t**
  - t is the number of faulty storage servers.

Handling Byzantine Storage Servers

Algorithm 3

A simulation of SWMR *regular* register with n>3t Byzantine storage servers

Algorithm 4

A simulation of SWMR *regular* register with semi-Byzantine clients and n>3t Byzantine storage servers

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- **Simulations**
- **Application:**
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Shared-Memory Paxos

- **A weak consensus algorithm using SWMR regular registers.**
  [Gafni and Lamport]
- **Phases of the Synod consensus algorithm**
  - **Agreement is always guaranteed**
- **Terminates when a single process executes a phase**
  - **Use unreliable leader election algorithm**
  - **When the system is stable, only one process executes the algorithm**

Fail-Stop Storage Servers and Semi-Byzantine Clients

- **Use Algorithm 2**
- **Tolerates f erroneous writes executed by the client in a single phase**
- **Masks invalid values written by clients**
- **Message and time complexity is 20f+8 times the complexity of Paxos.**
- **Self-checking allows to use only 28 registers (f=1)**
  - **client stops writing after the first faulty operation**

Byzantine Storage Servers and Semi-Byzantine Clients

- Use Algorithm 4
- Paxos attempts to terminate only when a single process executes the algorithm

⇨ There are no overlapping writes

⇨ Reads terminate

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Other Simulations

[Martin, Alvisi and Dahlin]

- Clients fail only by stopping
  - Can be combined with Algorithm 1 to handle semi-Byzantine clients
- Assume n > 3t
- May block when there are overlapping writes
- Storage servers push updates to clients
  - Maintain data about each client

Other Simulations

[Chockler, Keidar and Malkhi]

- Clients fail only by stopping
  - Can be combined with Algorithm 1 to handle semi-Byzantine clients
- Assume n > 3t
- Give a terminating simulation
  - Write take two rounds
  - Reads take t+1 rounds
- Show this is optimal
- Fairly complex
  - But termination is not always necessary!

Byzantine Paxos

[Castro and Liskov]

- Tolerates Byzantine clients
- Does not tolerate faulty storage servers
- Specially-tailored and not modular

What Else?

- Find other applications
- Improve on the 28f+1 bound
- More practical simulation?

THANK YOU !