Distributed Snapshot

Feb 16th & 17th, 2022
What is a Global Snapshot?

- A global snapshot captures the **global state** of a distributed system:
  - Local state of each process within the distributed system
  - Local state of each communication channel
- These local states are instantaneous
  - e.g., messages in transit one node to another
Global Snapshots are Useful

- **Checkpointing**
  - Recover more quickly after failures

- **Garbage Collection**
  - Remove objects that are not referenced any more by other objects/processes at any other servers

- **Deadlock Detection**
  - Examine the global application state and identify any deadlocks, useful in transactional DB systems

- And many others …
System Model

- N processes in the system
  - Each process keeps track of some state

- There are two unidirectional communication channels between each pair of processes P and Q
  - FIFO-ordered (i.e. first-in-first-out)
  - Message arrives intact and is unduplicated
  - Each channel also has some state

- No failures
Messages and States

● What are the messages?
  ○ Application messages that differ across systems (e.g. “sending $10 from A to B”, “read value at memory address X and write back with a new value”)
  ○ Special messages (e.g. marker message) that should not interfere with application messages

● What are the states?
  ○ Process state: application-defined state, or the classic notion of state which includes heap, registers, program counters and etc
  ○ Channel state: the set of messages inside

● Tips for Assignment 2
  ○ See *.top, *.events, *.snap files under ./test_data to understand what states and messages mean in this assignment
  ○ Read test_common.go to understand the syntax of the above files, and their relationships with the simulator
Distributed Snapshot


Key Idea: Servers send marker messages to each other

Marker messages

1. Mark the beginning of the snapshot process on the server
2. Act as a barrier (stopper) for recording messages
Chandy-Lamport Algorithm

Any process can initiate the snapshot

- Record local state
- Create marker messages and send them to all outbound channels
- Start recording messages from all incoming channels
Chandy-Lamport Algorithm Continued

When receiving a marker message from channel C

If this is the first marker message that this process has even seen:
- Record the local state
- Record the state of C as “empty sequence”
- Send out the marker message on all outbound channels
- Start recording messages from all of its other incoming channels

If it has already seen a marker message (e.g. from some other channel)
- Record the state of C as the sequence of messages received since the process’s local state has been recorded
- Stop recording messages on C (i.e. done with recording the channel’s state)

See Section 3 of the original paper for more details
Chandy-Lamport Algorithm Continued

When is the algorithm terminated?
- All processes have received marker messages (i.e. have recorded their local states)
- All processes have received marker messages from all of their incoming channels (i.e. have recorded the local states of all channels)
- Both need to satisfy

What happens after the termination?
- Optional and out of the scope of Chandy-Lamport algorithm
- Usually, there will be a central server that collects local snapshots from all servers to build a global snapshot (e.g. the simulator in Assignment 2) and maybe run some computations (e.g. deadlock detection) on it
Token passing example 1

1 Token 0 Tokens

A B
Token passing example 1

Event order:

1. A sends 1 token
Token passing example 1

Event order:
1. A sends 1 token
2. A starts snapshot, sends marker
Token passing example 1

Event order:

1. A sends 1 token
2. A starts snapshot, sends marker
3. B receives 1 token
**Token passing example 1**

**Event order:**

1. A sends 1 token
2. A starts snapshot, sends marker
3. B receives 1 token
4. B receives marker, starts snapshot
We did not record the token message because B received it before B started the snapshot process.
Token passing example 2

A

0 Tokens

B

1 Token
Token passing example 2

Event order:
1. B sends 1 token
**Token passing example 2**

*Event order:*

1. B sends 1 token
2. A starts snapshot, sends marker
Token passing example 2

Event order:
1. B sends 1 token
2. A starts snapshot, sends marker
3. A receives 1 token, records message
Token passing example 2

Event order:
1. B sends 1 token
2. A starts snapshot, sends marker
3. A receives 1 token, records message
4. B receives marker, starts snapshot
Token passing example 2

**Event order:**
1. $B$ sends 1 token
2. $A$ starts snapshot, sends marker
3. $A$ receives 1 token, records message
4. $B$ receives marker, starts snapshot
5. $A$ receives marker, ends snapshot

*We recorded the token message because $A$ received it after it has already started the snapshot process*
Token passing example 3

Which messages are definitely recorded*?

Which messages are definitely *not* recorded?

Which messages *might* be recorded?

* recorded as in-flight messages, i.e., as part of channel state rather than process state
Which messages are definitely recorded*?

m7

Which messages are definitely *not* recorded?

m1, m3

Which messages *might* be recorded?

m2, m4, m5, m6

*recorded as in-flight messages
Assignment 2 Overview

- You will implement the Chandy-Lamport snapshot algorithm
- Application is a token passing system
  - Number of tokens must be preserved in your snapshots
- Implementation uses *discrete time* simulator to order events
  - Simulator manages servers and injects events into the system
  - Server implements the snapshot algorithm (See slide 7 and 8)
- Allow multiple active snapshot processes
  - E.g., The second snapshot can start before the first snapshot completes in the system
Assignment 2 Interfaces

```go
func (sim *Simulator) Tick()

func (sim *Simulator) StartSnapshot(serverId string)

func (sim *Simulator) NotifySnapshotComplete(serverId string, snapshotId int)

func (sim *Simulator) CollectSnapshot(snapshotId int) *SnapshotState
```

- What kind of state does the simulator need to keep track of?
  - Time
  - Topology
  - Channels to signal the completion of snapshots
  - ...
Assignment 2 Interfaces

```go
cfunc (server *Server) SendToNeighbors(message interface{})

cfunc (server *Server) SendTokens(numTokens int, dest string)

cfunc (server *Server) HandlePacket(src string, message interface{})

cfunc (server *Server) StartSnapshot(snapshotId int)
```

- What kind of state does the server need to keep track of?
  - Local state
  - Neighbors
  - Which channels received markers
  - Recorded messages
  - ...

A Note on Channels and Goroutines

- Using channels is easy, debugging them is hard...
  
  Bullet-proof way: Keep track of how many things go in and go out

  Always ask yourself: is this channel buffered?

- In general, don’t use locks or atomic operations with channels (awkward)
- Try not to nest goroutines (hard to reason about)
Assignment 2

Start Early 😊

Due 02/24 (Thursday) at 11:59pm!