Distributed Algorithms

Consistent Snapshots

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Overview

> Snapshot problem

> Consistency criterion for snapshots

> Snapshot algorithms
>> Chandy and Lamport
>> Lai and Yang

Motivation

- Determine “current” *snapshot* of the global state (local states + messages) *without* stopping the system
- Consistent snapshots important
  - Checkpoints of a distributed database
  - Current load of a distributed system
  - Does a deadlock exist?
  - Has the algorithm terminated?
  - Can an object be collected?

  Stable predicates

- How can a “consistent” snapshot be determined?

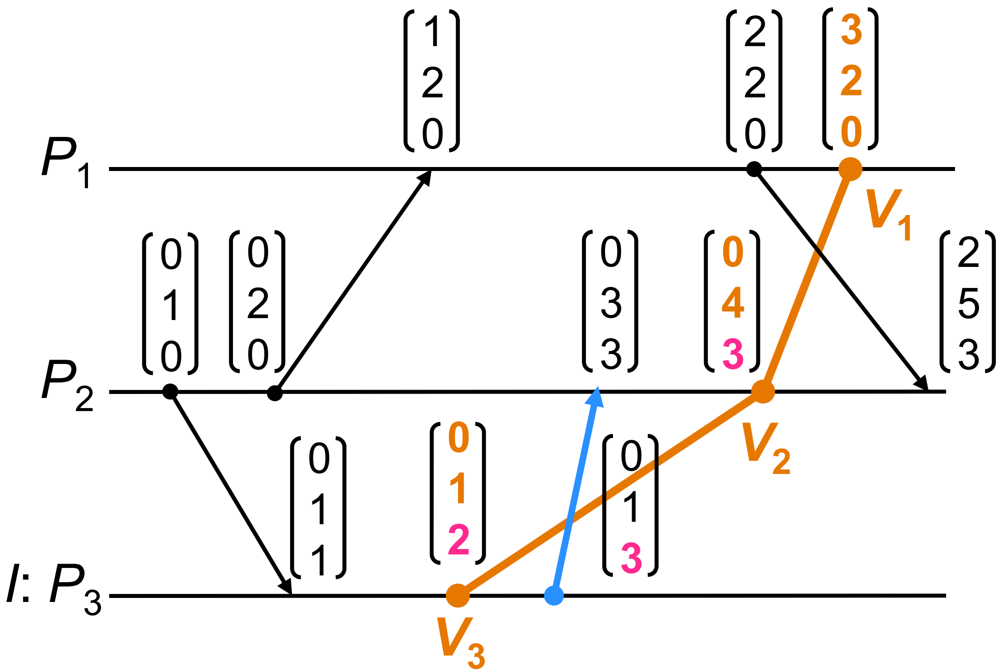
Snapshot Problem

- It is impossible to save the state of all processes at exactly the same time
- Saved state
  - will generally be out of date
  - has most likely never “really” been like that and
  - is probably inconsistent, because of messages from the future
- Requirement: snapshots should be consistent
  - saved state should not be influenced by messages from the future, i.e., sent after the state has been saved at the sender
- Consistent snapshots can be used to detect stable predicates
  - If a stable predicate holds for a consistent snapshot, it also holds for sure in reality

Consistency Criterion for Cuts

- Cut is a matrix comprising the processes' vector timestamps
  - $X = \{V_1, \ldots, V_n)$
- Vector of matrix row maximums
  - $t_x = (\max(V_1[1], \ldots, V_n[1])), \ldots, \max(V_1[n], \ldots, \mathrm{V}_n[n]))$
- Vector of matrix diagonal elements
  - $d_x = (V_1[1], \ldots, V_n[n])$
- X is consistent if and only if $t_x = d_x$
  - Each element of the matrix diagonal must be equal to the maximum of the respective row
  - If $t_x[\,i\,] > d_x[\,i\,]$ applies, some P_j received a message from P_i that was sent after the state was saved at P_i, but before it was saved at P_j
  - $t_x[\,i\,] < d_x[\,i\,]$ cannot occur

Consistency Criterion for Cuts



$$
\begin{array}{ccc} V_1 & V_2 & V_3 \\ \end{array}
\begin{pmatrix} 3 & 0 & 0 \\ 2 & 4 & 1 \\ 0 & 3 & 2 \end{pmatrix}
$$

$$
\begin{aligned}
t_x &= (3, 4, 3)^T \\
&\neq \\
d_x &= (3, 4, 2)^T
\end{aligned}
$$

Cut is not consistent due to blue message

Algorithm by Chandy and Lamport, 1985

- Requires reliable FIFO-channels
- Uses flooding as basic wave procedure
- Uses the flushing principle for communication channels
  - A flush message “pushes” the basic messages that are still in transit out of the FIFO-channels
  - If a node has received a flush message over a channel, it knows that it will receive no more basic messages over that channel

Algorithm by Chandy and Lamport

- Each process *P* receives exactly one flush message from each of its neighbors

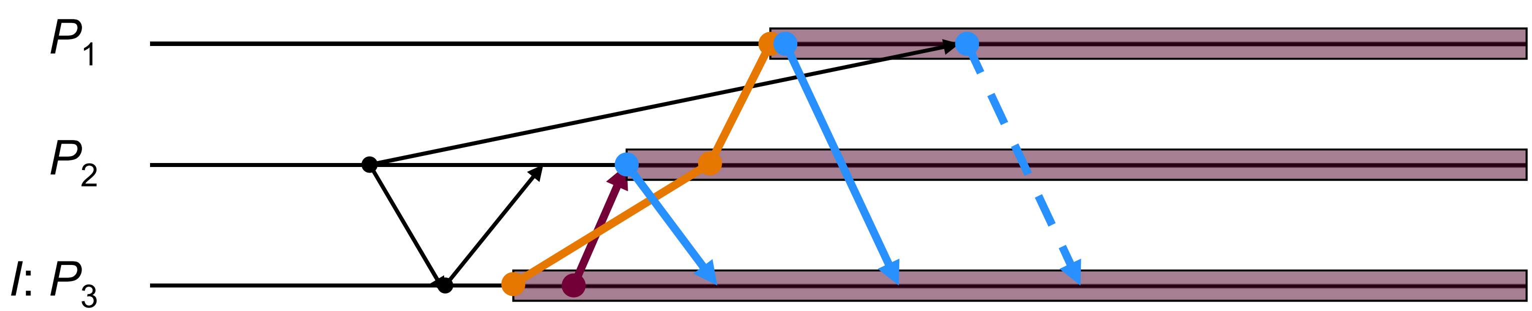
- Case 1: *P* receives for the first time a flush message
  - Let *Q* be the process, *P* received the flush message from
  - *P* saves its state and notes the channel <*Q*, *P*> as empty
  - *P* sends a flush message to all its neighbors

- Case 2: *P* receives further flush messages
  - Let *R* (≠ *Q*) be the process, *P* received that flush message from
  - *P* notes for the channel <*R*, *P*> the sequence of basic messages it received from *R* since the receipt of the first flush message

- Snapshot consists of all local states and messages saved

Algorithm by Lai and Yang, 1987

- Initially, all nodes are black and send black messages
- Initiator of snapshot algorithm gets red and saves local state
- Red nodes only send red messages
- Nodes get red if they are visited or received a red message
- When a node becomes red, it saves its local state and sends it to the initiator
- Red nodes send a copy of all black messages they receive to the initiator → termination detection?



Algorithm by Lai and Yang, 1987

- Snapshot is complete
  - if initiator received the local states of all nodes *and*
  - a copy of each black message that was still in transit
- How does the initiator know that it has all black messages?
- Solution: deficit counter similar to counting algorithm
  - Each node counts the messages sent and received
  - Counter reading is saved along with snapshot
  - Difference of both counters indicates number of black messages in transit

Exemplary Exam Questions

1. What is a consistent snapshot?
2. Explain the consistency criterion for consistent snapshots!
3. Describe the snapshot algorithm of Lai and Yang as well as the snapshot algorithm of Chandy and Lamport!

Literature

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Thank you for your kind attention!

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