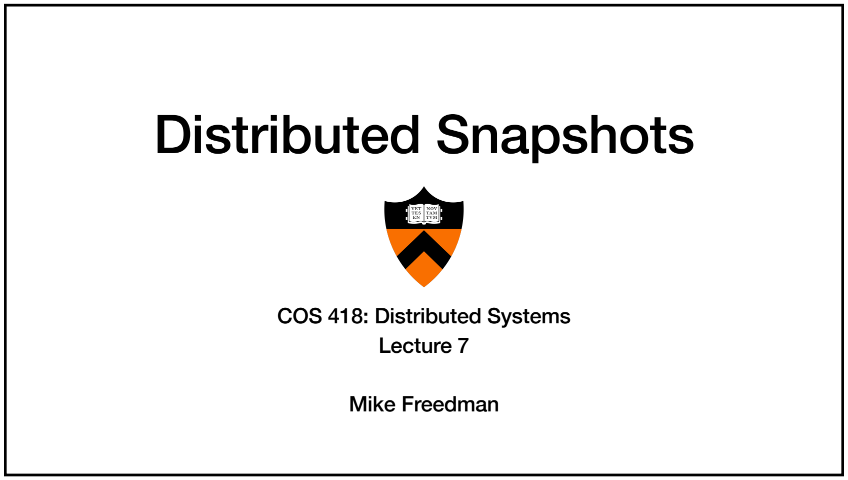

# Distributed Snapshots

COS 418: Distributed Systems
Lecture 7

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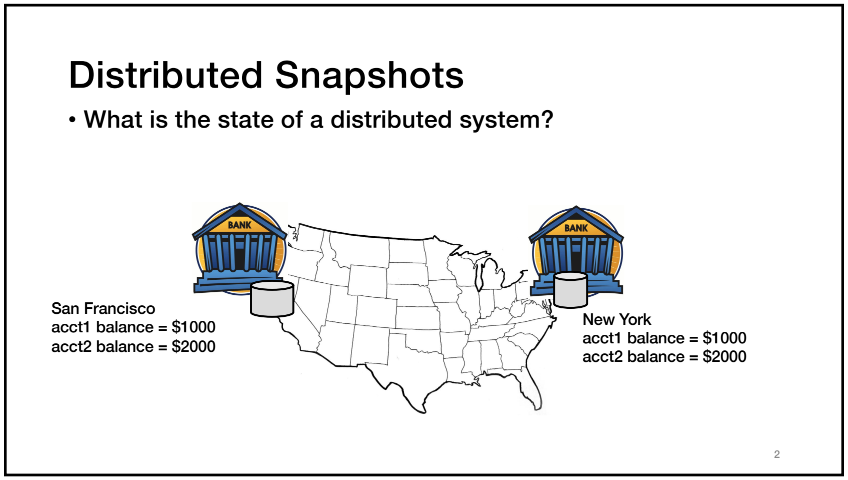

## Distributed Snapshots

- What is the state of a distributed system?

San Francisco
acct1 balance = $1000
acct2 balance = $2000

New York
acct1 balance = $1000
acct2 balance = $2000

2

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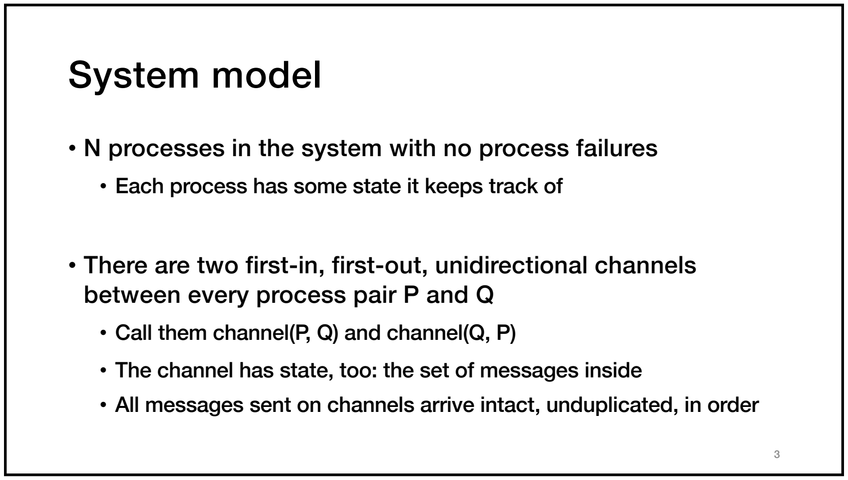

## System model

- N processes in the system with no process failures
  - Each process has some state it keeps track of
- There are two first-in, first-out, unidirectional channels between every process pair P and Q
  - Call them channel(P, Q) and channel(Q, P)
  - The channel has state, too: the set of messages inside
  - All messages sent on channels arrive intact, unduplicated, in order

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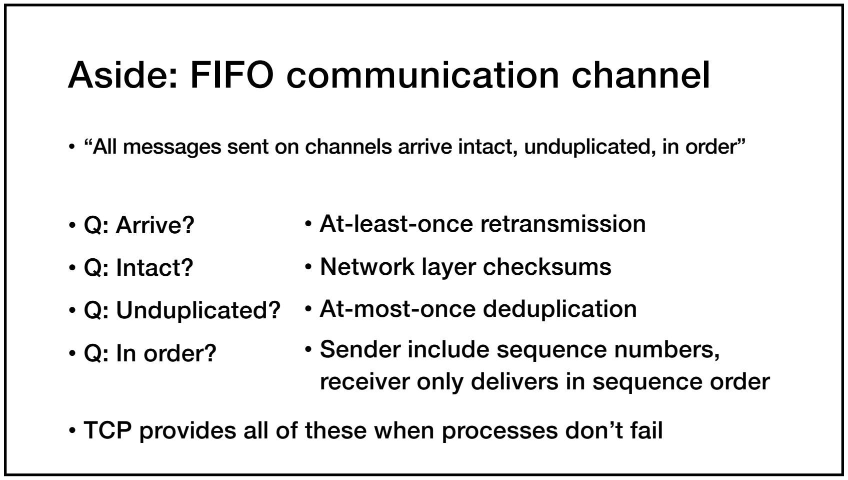

## Aside: FIFO communication channel

- "All messages sent on channels arrive intact, unduplicated, in order"

| | |
|---|---|
| • Q: Arrive? | • At-least-once retransmission |
| • Q: Intact? | • Network layer checksums |
| • Q: Unduplicated? | • At-most-once deduplication |
| • Q: In order? | • Sender include sequence numbers, receiver only delivers in sequence order |

- TCP provides all of these when processes don't fail

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## Global snapshot is global state

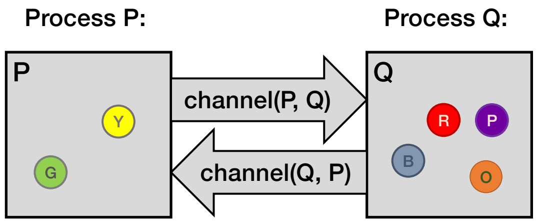
- Each distributed application has a number of processes running on a number of physical servers
- These processes communicate with each other via channels
- A global snapshot captures
  1. The local states of each process (e.g., program variables), and
  2. The state of each communication channel

## Why do we need snapshots?

- Checkpointing: Restart if the application fails
- Collecting garbage: Remove objects that aren't referenced
- Detecting deadlocks: The snapshot can examine the current application state
  - Process A grabs Lock 1, B grabs 2, A waits for 2, B waits for 1... ... ...
- Other debugging: A little easier to work with than printf…

## System model: Graphical example

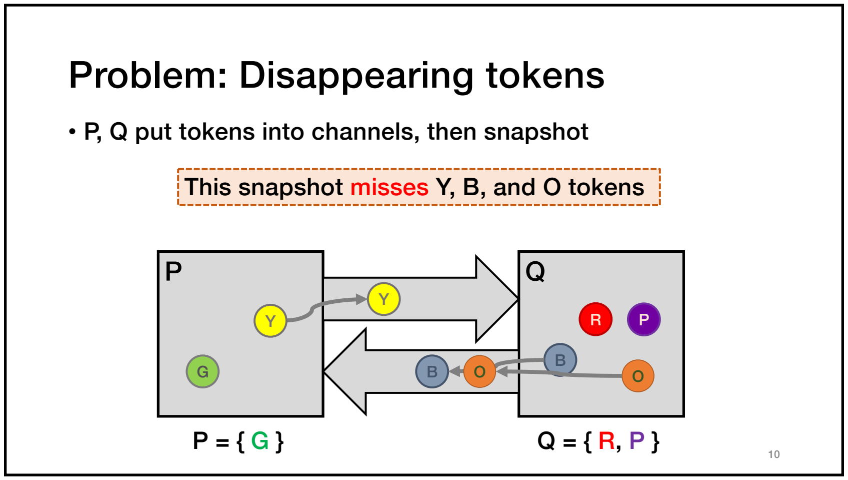
- Let's represent process state as a set of colored tokens
- Suppose there are two processes, P and Q:



Correct global snapshot = Exactly one of each token

## When is inconsistency possible?

- Suppose we take snapshots only from a process perspective
- Suppose snapshots happen independently at each process
- Let's look at the implications…



## Problem: Disappearing tokens

- P, Q put tokens into channels, then snapshot

This snapshot misses Y, B, and O tokens

P = { G }

Q = { R, P }

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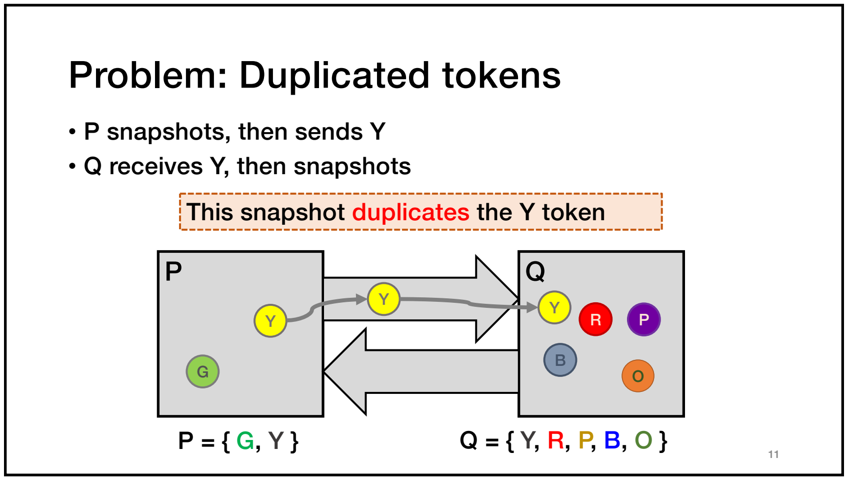

## Problem: Duplicated tokens

- P snapshots, then sends Y
- Q receives Y, then snapshots

This snapshot duplicates the Y token

P = { G, Y }

Q = { Y, R, P, B, O }

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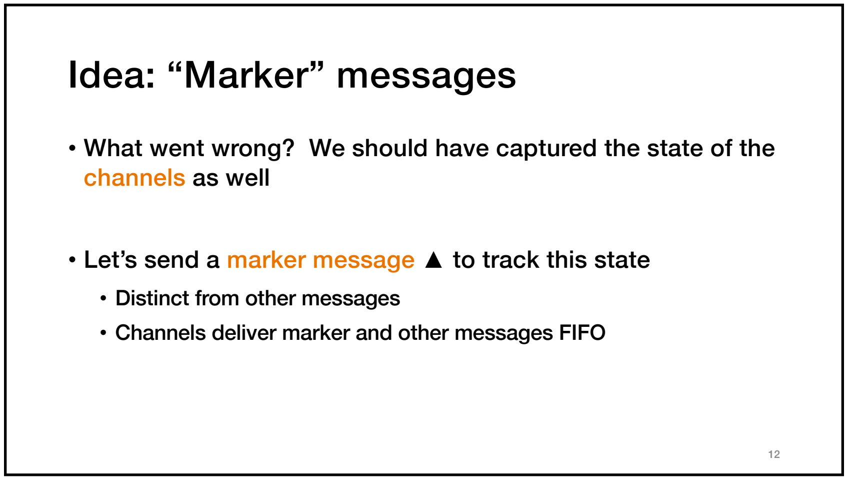

## Idea: “Marker” messages

- What went wrong? We should have captured the state of the channels as well

- Let’s send a marker message ▲ to track this state
  - Distinct from other messages
  - Channels deliver marker and other messages FIFO

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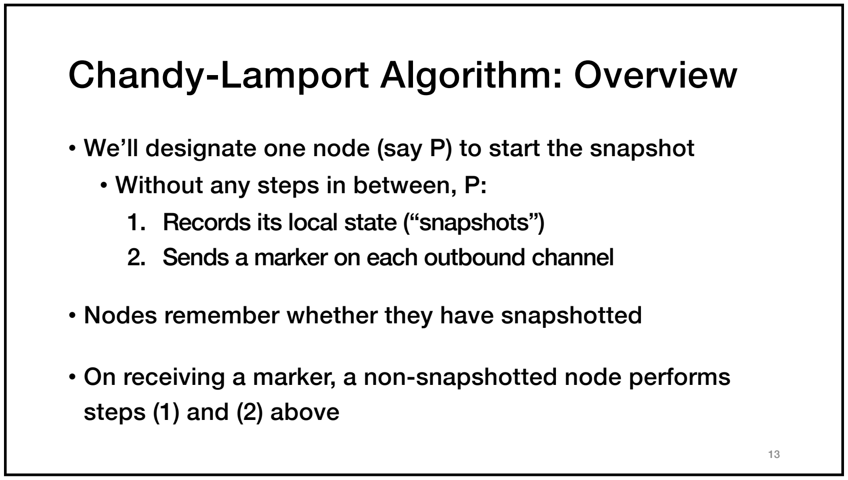

## Chandy-Lamport Algorithm: Overview

- We’ll designate one node (say P) to start the snapshot
  - Without any steps in between, P:
    1. Records its local state (“snapshots”)
    2. Sends a marker on each outbound channel

- Nodes remember whether they have snapshotted

- On receiving a marker, a non-snapshotted node performs steps (1) and (2) above

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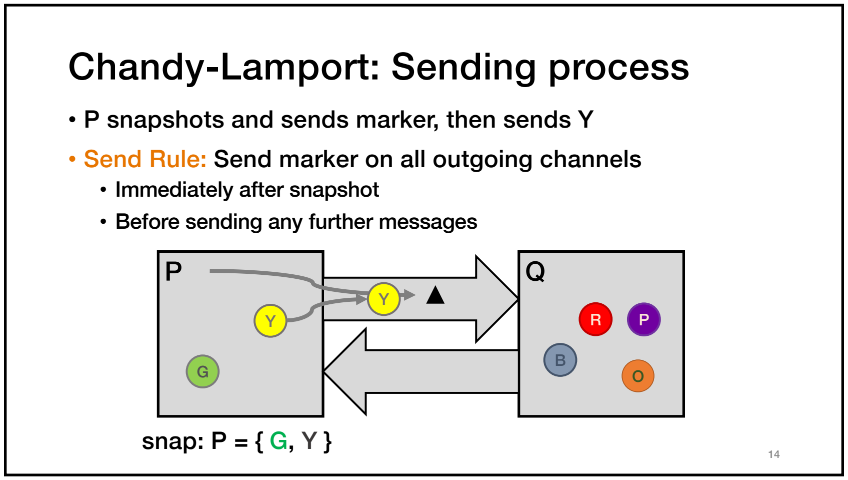

## Chandy-Lamport: Sending process

- P snapshots and sends marker, then sends Y
- Send Rule: Send marker on all outgoing channels
  - Immediately after snapshot
  - Before sending any further messages

snap: P = { G, Y }

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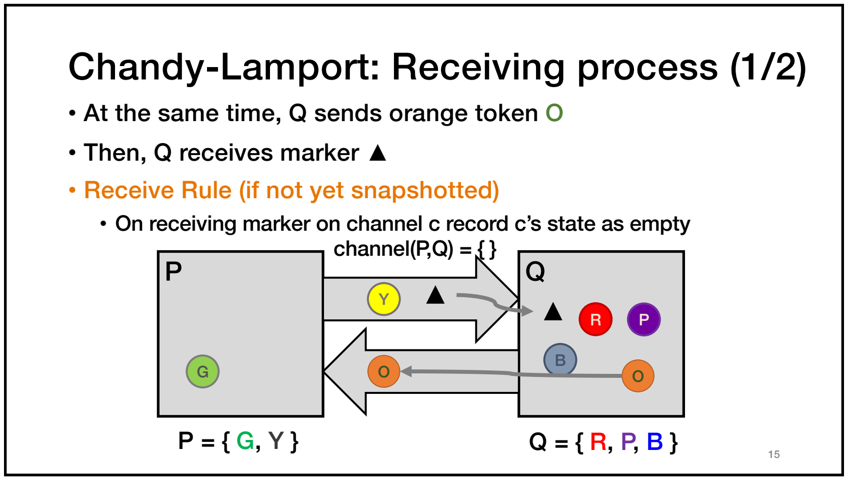

## Chandy-Lamport: Receiving process (1/2)

- At the same time, Q sends orange token O
- Then, Q receives marker ▲
- Receive Rule (if not yet snapshotted)
  - On receiving marker on channel c record c's state as empty

channel(P,Q) = { }

P = { G, Y }

Q = { R, P, B }

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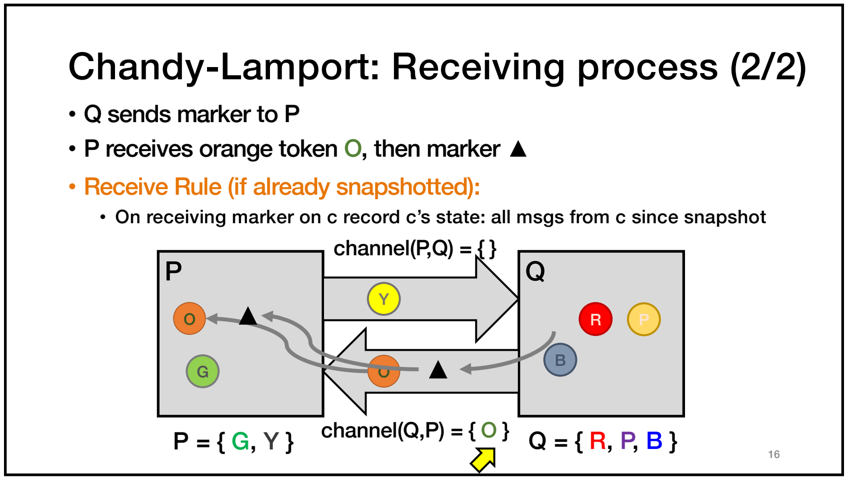

## Chandy-Lamport: Receiving process (2/2)

- Q sends marker to P
- P receives orange token O, then marker ▲
- Receive Rule (if already snapshotted):
  - On receiving marker on c record c's state: all msgs from c since snapshot

channel(P,Q) = { }

P = { G, Y }

channel(Q,P) = { O }

Q = { R, P, B }

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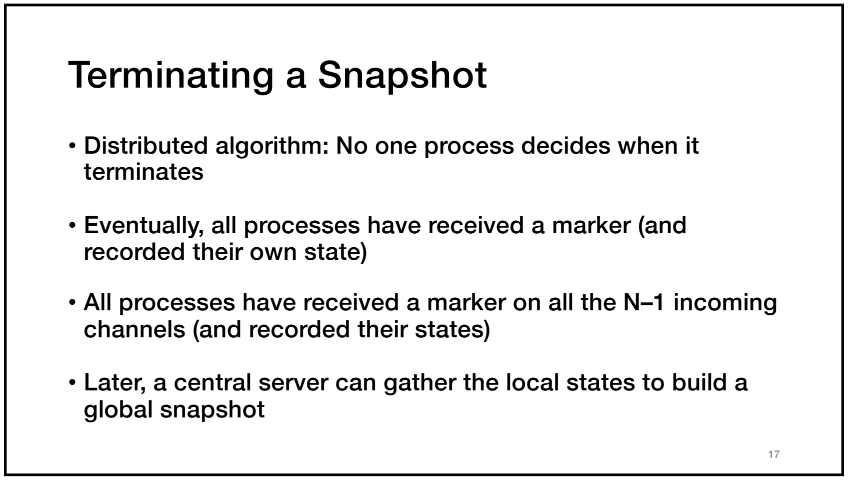

## Terminating a Snapshot

- Distributed algorithm: No one process decides when it terminates
- Eventually, all processes have received a marker (and recorded their own state)
- All processes have received a marker on all the N–1 incoming channels (and recorded their states)
- Later, a central server can gather the local states to build a global snapshot

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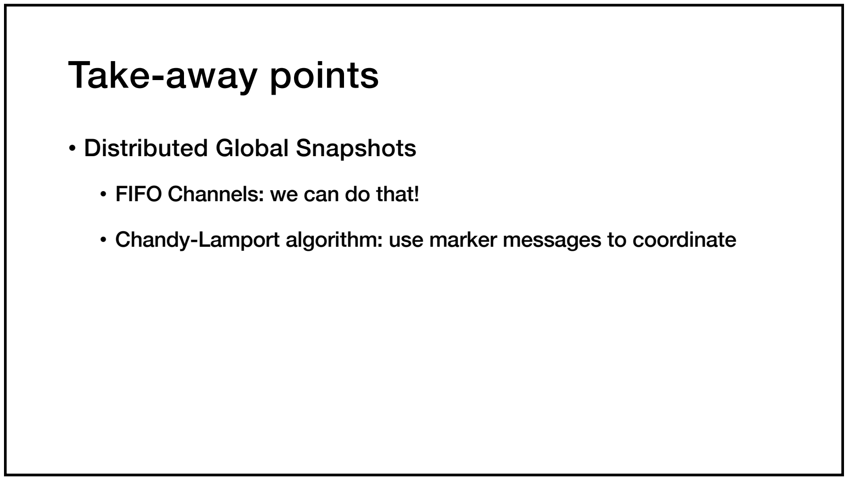

## Take-away points

- Distributed Global Snapshots
  - FIFO Channels: we can do that!
  - Chandy-Lamport algorithm: use marker messages to coordinate

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