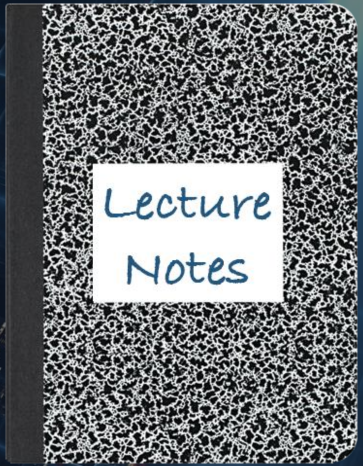
CS 417 – DISTRIBUTED SYSTEMS

Week 5: Part 2

Leader Election



Paul Krzyzanowski

Leader Election

- Purpose
  - Need to pick one process to act as coordinator

- Assumptions
  - Processes have no distinguishing characteristics
  - Each process has a unique ID to identify itself
  - Reliable message delivery

Bully algorithm

Goal: Select the process with the largest ID as the leader

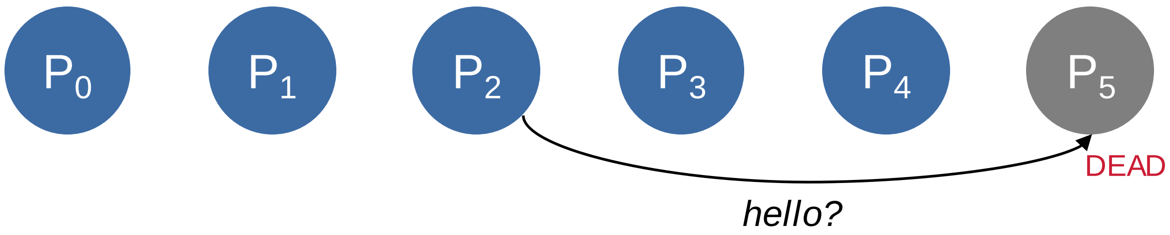
- Holding an election: when process P_i detects a dead leader:
  - Send ***election*** message to all processes with higher IDs
    - If nobody responds, **P_i wins** and takes over
    - If any process responds, *P*'s job is done
  - Optional: Let all nodes with lower IDs know an election is taking place

- If a process receives an ***election*** message
  - Send an ***OK*** message back
  - Hold an election (unless it is already holding one)

Bully algorithm

- A process announces victory:
  - Sends all processes a message telling them that it is the new leader
- If a dead process recovers
  - It holds an election to find the leader

Bully algorithm

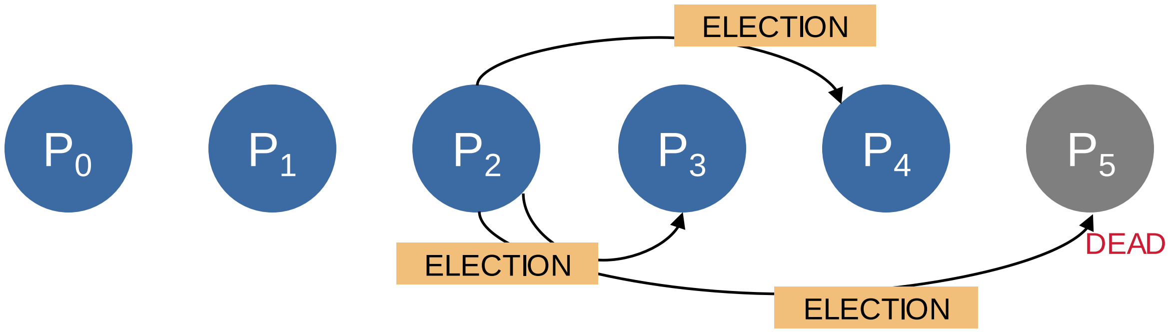


Rule: highest # process is the leader

Suppose P_5 dies

P_2 detects P_5 is not responding

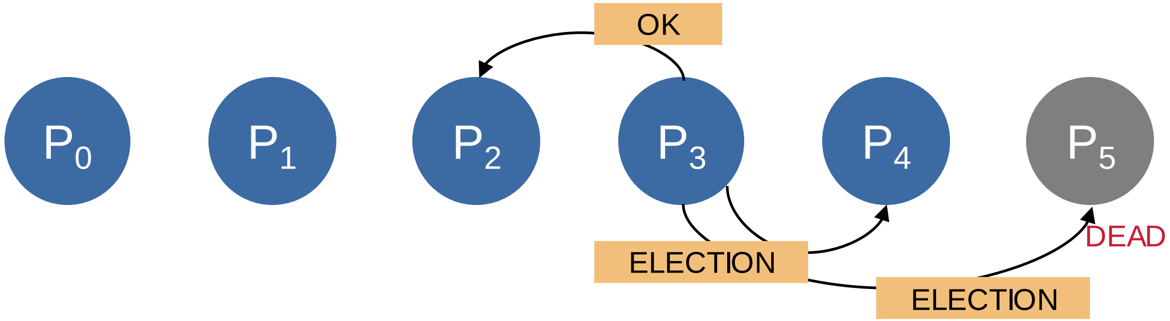
Bully algorithm



P_2 starts an election

Contacts all higher-numbered systems

Bully algorithm



Everyone who receives an ***election*** message responds

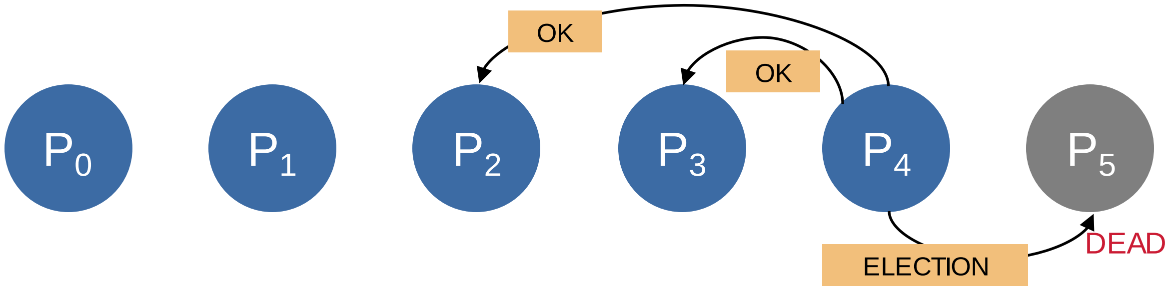
… and holds their own election, contacting higher # processes

Example: P_3 receives the message from P_2

Responds to P_2

Sends ***election*** messages to P_4 and P_5

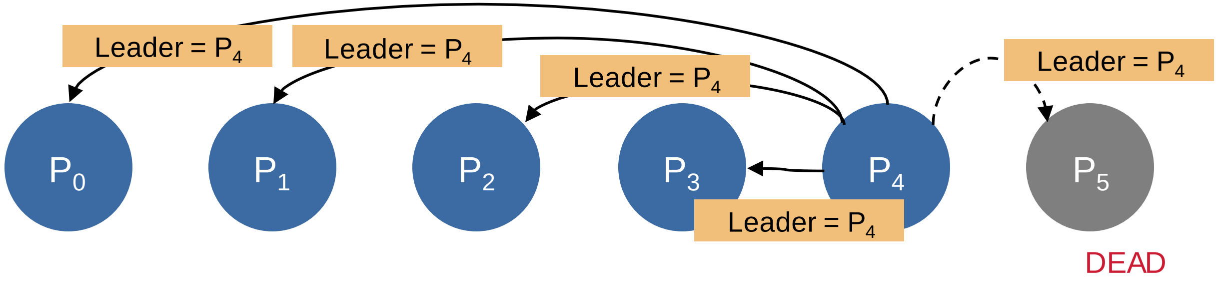
Bully algorithm



P_4 responds to P_3 and P_2's messages

… and holds an election

Bully algorithm



Nobody responds to P_4

After a timeout, P_4 declares itself the leader

Ring election algorithm

Ring arrangement of processes

- **Holding an election**: if any process P_i detects failure of leader
  - Construct an ***election*** message containing the ID of P_i and send it to the clockwise neighbor (the successor)
  - If the successor is down, skip over it and try the process after that
  - Repeat until a running process is located
- Upon receiving an ***election*** message
  - Process forwards the message, adding its process ID to the body

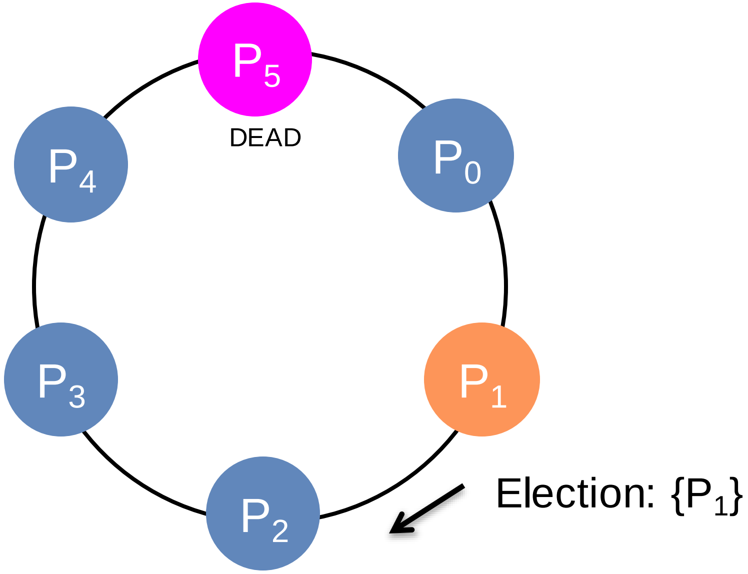
Eventually message returns to originator

- The process receives an ***election*** message and sees its ID is at the head of the list
- Multicast a **leader** message announcing the new leader
  - E.g., highest numbered process

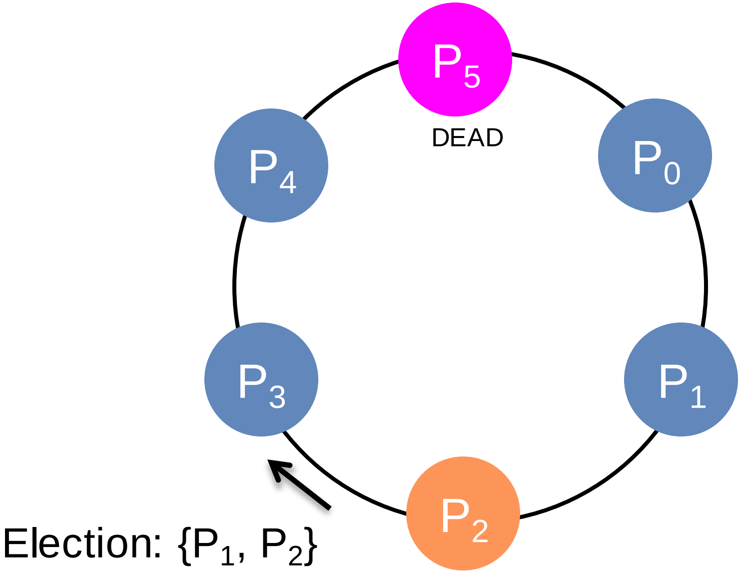
Ring algorithm

Assume P_1 discovers that the leader, P_5, is dead

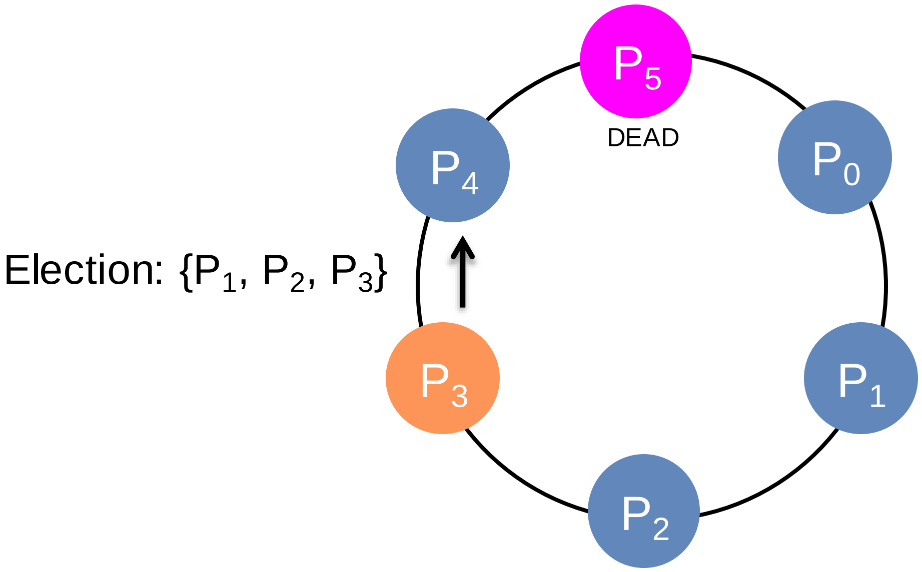
P_1 starts an election



Ring algorithm



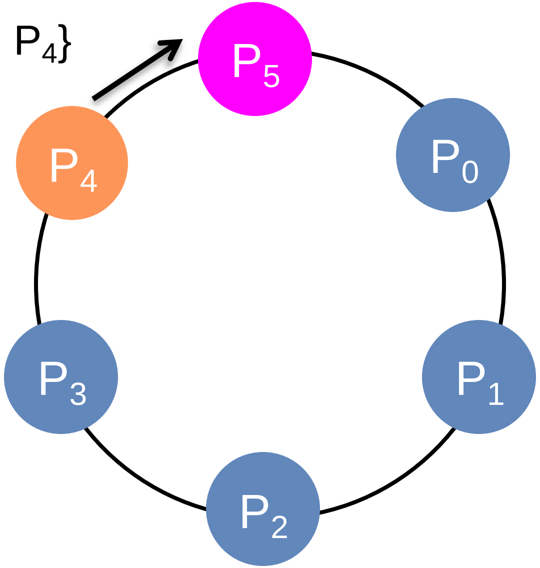
Ring algorithm



Ring algorithm

Election: {P_1, P_2, P_3, P_4}

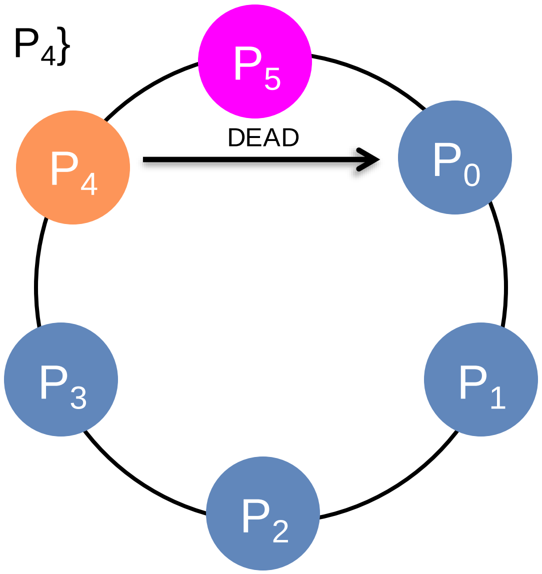
Fails: P_5 is dead



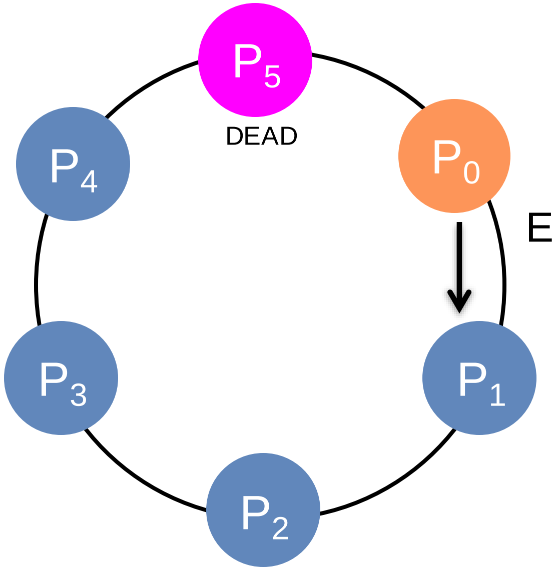
Ring algorithm

Election: {P_1, P_2, P_3, P_4}

Skip to P_0



Ring algorithm

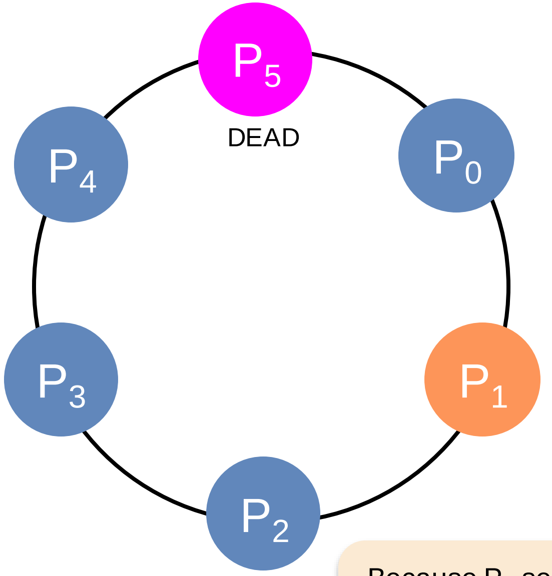


Election: $\{P_1, P_2, P_3, P_4, P_0\}$

Ring algorithm

P_2 receives the election message that it initiated

P_2 now picks a leader (e.g., highest ID)



This is me! *Winner!*

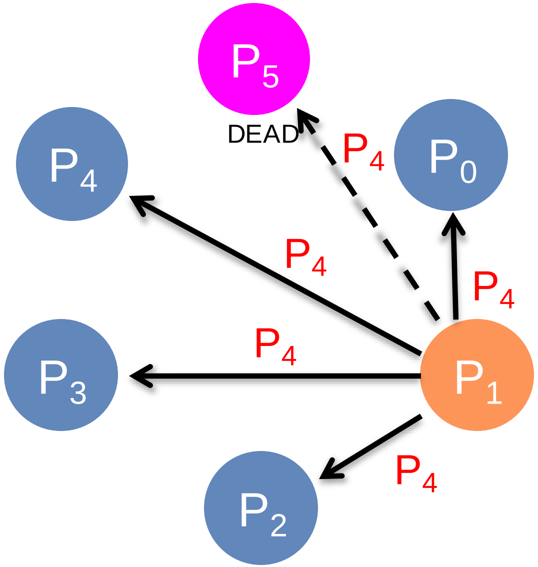
Election: $\{P_1, P_2, P_3, P_4, P_0\}$

Because P_1 sees its ID at the head of the list, it knows that this is the election that it started.

We might have multiple concurrent elections. Everyone must choose the same leader. Here, we agree to pick the **highest ID** in the list.

Ring algorithm

P_1 announces that P_4 is the new leader to the group



Many other election algorithms that target other topologies: mesh, torus, hypercube, trees, …

Chang & Roberts Ring Algorithm

Optimize the ring election algorithm

- The message always contains *one* process ID (PID)
- Try to avoid multiple circulating elections

- If a process sends an ***election*** message, it marks its state as a *participant*
  - This allows it to cut off extra elections
- Assume highest # PID is the winner

Chang & Roberts Ring Algorithm

Upon receiving an election message:

If PID(message) > PID(process) – *higher ID will always win over a lower one*
    forward the message

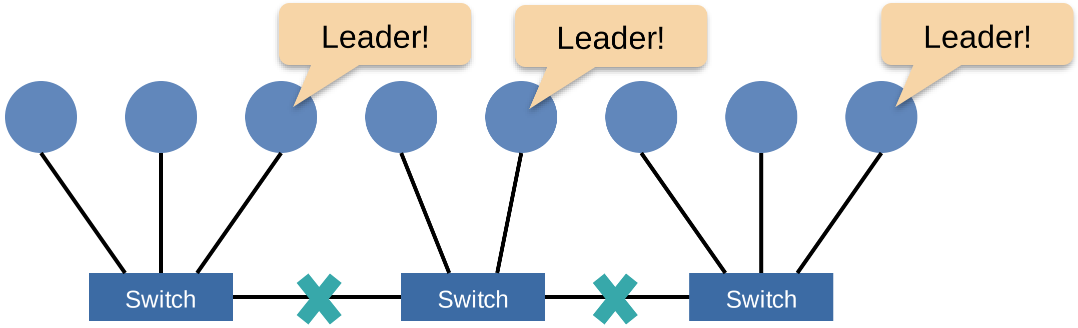
If PID(message) < PID(process) AND process is not a *participant* – *we are a higher ID number; use ours*
    replace PID in message with PID(process) and forward the new message
    set the process state to *participant*

If PID(message) < PID(process) AND process is *participant*
    discard the message
    – *we're already circulating our ID and it's a higher number than this one*

If PID(message) == PID(process)
    the process is now the leader
    – *message fully circulated to the one who started: announce winner*

Elections & Network Partitions

- Network **partitions** (segmentation)
  - Multiple nodes may decide they're the leader
  - Leads to multiple groups, each with a leader & diverging data among them → **split brain**



- Dealing with partitions
  - Insist on a majority → if no majority, the system will not function
    - Quorum = minimum # of participants required for a system to function)
  - Rely on alternate communication mechanism to validate failure
    - Redundant network, shared disk (but that can also fail)

The End