Distributed Systems

Mutual Exclusion & Election Algoritms

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Mutual Exclusion & Election Algorithms

Process Synchronization

Techniques to coordinate execution among processes

- One process may have to wait for another
- Shared resource (e.g. critical section) may require exclusive access

Centralized Systems

Mutual exclusion via:

- Test & set in hardware
- Semaphores
- Messages
- Condition variables

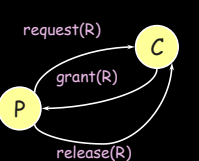
Distributed Mutual Exclusion

- Assume there is agreement on how a resource is identified
  - Pass identifier with requests
- Create an algorithm to allow a process to obtain exclusive access to a resource.

Centralized algorithm

- Mimic single processor system
- One process elected as coordinator

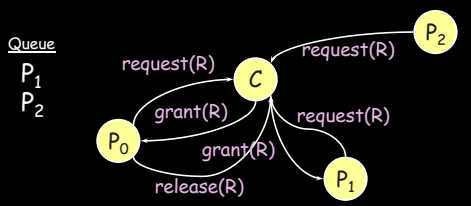
1. **Request** resource
2. Wait for response
3. **Receive grant**
4. *access resource*
5. **Release resource**



Centralized algorithm

If another process claimed resource:

- Coordinator does not reply until release
- Maintain queue
  - Service requests in FIFO order



Centralized algorithm

Benefits

- Fair
  - All requests processed in order
- Easy to implement, understand, verify

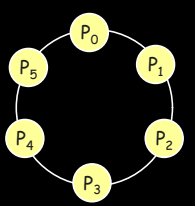
Problems

- Process cannot distinguish being blocked from a dead coordinator
- Centralized server can be a bottleneck

Token Ring algorithm

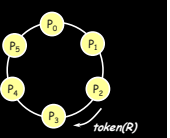
Assume known group of processes

- Some ordering can be imposed on group
- Construct logical ring in software
- Process communicates with neighbor



Token Ring algorithm

- Initialization
  - Process 0 gets token for resource R
- Token circulates around ring
  - From P_i to $P_{(i+1) \bmod N}$
- When process acquires token
  - Checks to see if it needs to enter critical section
  - If no, send ring to neighbor
  - If yes, access resource
    - Hold token until done



Token Ring algorithm

- Only one process at a time has token
  - Mutual exclusion guaranteed
- Order well-defined
  - Starvation cannot occur
- If token is lost (e.g. process died)
  - It will have to be regenerated
- Does not guarantee FIFO order
  - sometimes this is undesirable

Ricart & Agrawala algorithm

- Distributed algorithm using reliable multicast and logical clocks
- Process wants to enter critical section:
  - Compose message containing:
    - Identifier (machine ID, process ID)
    - Name of resource
    - Timestamp (totally-ordered Lamport)
  - Send request to all processes in group
  - Wait until everyone gives permission
  - Enter critical section / use resource

Ricart & Agrawala algorithm

- When process receives request:
  - If receiver not interested:
    - Send OK to sender
  - If receiver is in critical section
    - Do not reply; add request to queue
  - If receiver just sent a request as well:
    - Compare timestamps: received & sent messages
    - Earliest wins
    - If receiver is loser, send **OK**
    - If receiver is winner, do not reply, queue
- When done with critical section
  - Send OK to **all queued requests**

Ricart & Agrawala algorithm

- N points of failure
- A lot of messaging traffic
- Demonstrates that a fully distributed algorithm is possible

Lamport's Mutual Exclusion

Each process maintains request queue
- Contains **mutual exclusion requests**

Requesting critical section:
- Process P_i sends request(i, T_i) to all nodes
- Places request on its own queue
- When a process P_j receives a request, it returns a timestamped **ack**

Lamport time

Lamport's Mutual Exclusion

Entering critical section (accessing resource):
- P_i received a message (*ack* or *release*) from every other process with a timestamp larger than T_i
- P_i's request has the earliest timestamp in its queue

Difference from Ricart-Agrawala:
- Everyone responds (acks) … always - no hold-back
- Process decides to go based on whether its request is the earliest in its queue

Lamport's Mutual Exclusion

Releasing critical section:
- Remove request from its own queue
- Send a timestamped *release* message

- When a process receives a *release* message
  - Removes request for that process from its queue
  - This may cause its own entry have the earliest timestamp in the queue, enabling it to access the critical section

Election algorithms

Elections

- Need one process to act as coordinator
- Processes have no distinguishing characteristics
- Each process can obtain a unique ID

Bully algorithm

- Select process with largest ID as coordinator
- When process P detects dead coordinator:
  - Send *election* message to all processes with higher IDs.
    - If nobody responds, P 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 process receives an *election* message
  - Send **OK** message back
  - Hold election (unless it is already holding one)

Bully algorithm

- A process announces victory by sending all processes a message telling them that it is the new coordinator
- If a dead process recovers, it holds an election to find the coordinator.

Ring algorithm

- Ring arrangement of processes
- If any process detects failure of coordinator
  - Construct **election** message with process ID and send to next process
  - If successor is down, skip over
  - Repeat until a running process is located
- Upon receiving an election message
  - Process forwards the message, adding its process ID to the body

Ring algorithm

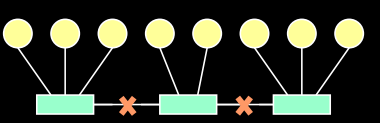
Eventually message returns to originator

- Process sees its ID on list
- Circulates (or multicasts) a **coordinator** message announcing coordinator
  - E.g. lowest numbered process

Problems with elections

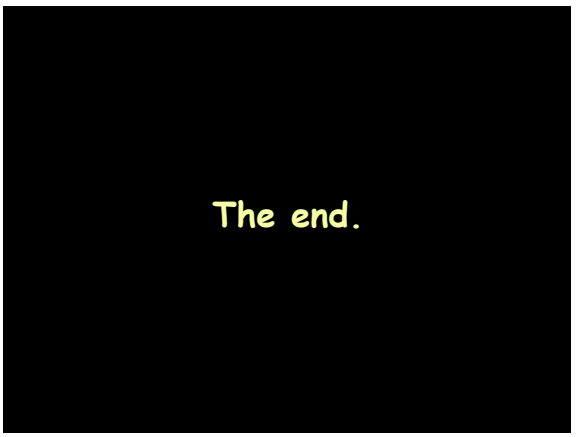
Network segmentation

- **Split brain**



Rely on alternate communication mechanism

- Redundant network, shared disk, serial line, SCSI


The end.