Algorithms and protocols for distributed systems

We have defined process groups as having peer or hierarchical structure and have seen that a coordinator may be needed to run a protocol such as 2PC.

With peer structure, an external process may send an update request to any group member, which then functions as coordinator. We have seen that deadlock may occur.

If the group has hierarchical structure, one member is elected as coordinator.
That member must manage group protocols, and external requests must be sent on to it.
Note that this solves the potential deadlock problem of concurrent updates.
But a *single point of failure* is created, and a potential *bottleneck*, so this is only suitable for small groups.

If the coordinator fails, a new one must be elected.
For the election algorithm:

assume that: - each process has a unique ID known to all members
- the process with highest ID is coordinator

Election algorithm - Bully

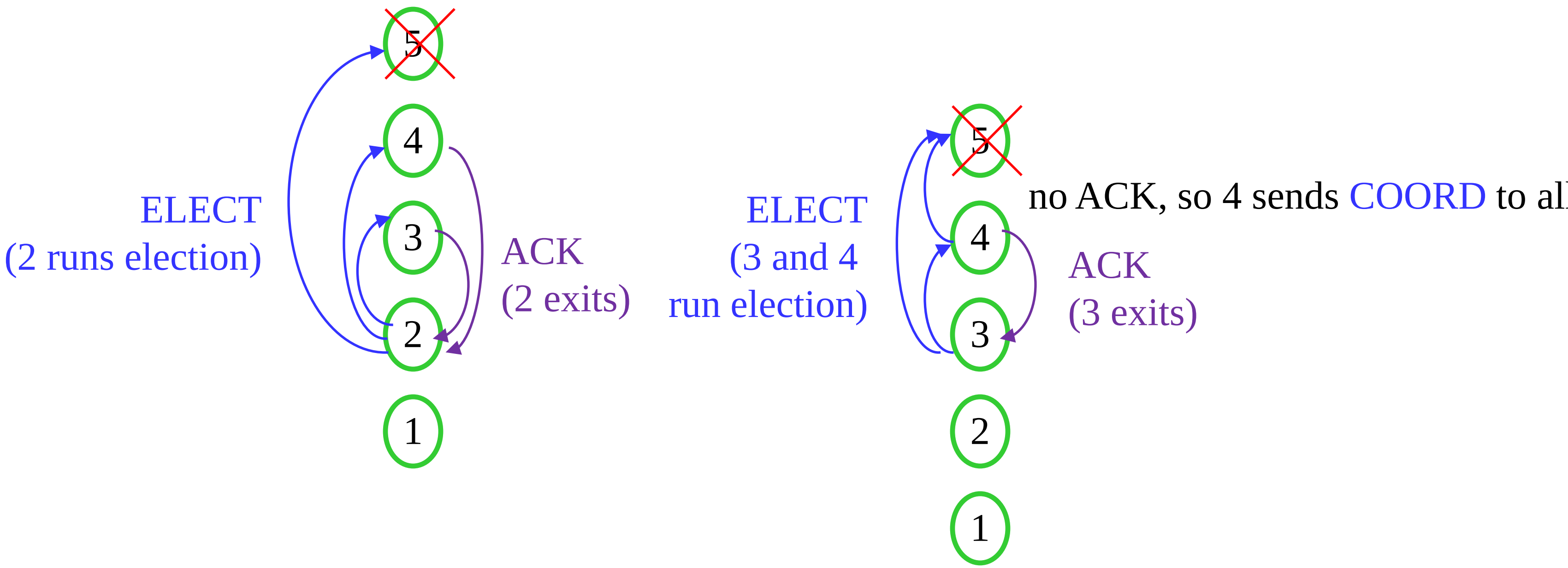
P notices no reply from coordinator

P sends ELECT message to all processes with higher IDs

If any reply, P exits. Any process that replies must itself run an election.

If none reply, P wins – gets any required state from persistent storage

– P sends COORD message to the group



(i) (ii)

Election algorithm - Ring

Processes are ordered into a ring structure that is known to all.
A failed process can be bypassed, provided that the ordering around the ring is known and that messages are acknowledged, so that a no-ACK can be detected.

The election algorithm:
P notices that the coordinator is not functioning.

P sends an ELECT message to the next process in the ring, tagged with its own (P's) ID

On receipt of ELECT by any process:

- without receiver's (its own) ID:
  append receiver's ID to message and send to next process in ring
- with receiver's ID (it's been all round):
  look for highest ID in list of appended IDs and send COORD (highest ID) message

Many election algorithms can run concurrently
All should agree on the same highest ID

Distributed mutual exclusion

Suppose N processes hold an object replica and it is required that
only one-at-a-time may access its replica.

Examples: - ensuring coherence of distributed shared memory
- distributed games
- distributed whiteboard

i.e. for use by *simultaneously running*, *tightly coupled components* managing object replicas in main memory. We have already seen the approach of LOCKING *persistent object replicas* for consistent, transactional update.

Assume that - processes update in place
- then the update is propagated (not shown as part of the algorithm)

Each process executes code of the form:

entry protocol

access object under exclusion, in a critical region

exit protocol

Distributed mutex 1. centralised algorithm

One process is the elected coordinator

entry protocol

send ***request*** message to coordinator

wait for ***reply (OK-to-enter)*** from coordinator

access object under exclusion

exit protocol

send ***finished*** message to coordinator

+ fair FCFS or priority if coordinator re-orders
+ economical (3 messages in basic protocol, but need more ....)
– coordinator is single point of failure (need to elect a new one if it fails)
– what does no reply mean? waiting for exclusive access – OK
  but coordinator could have failed

Improve/solve by using extra messages:

- coordinator ACKs request and sends again when process can proceed?
- heartbeat protocol between coordinator and processes awaiting object access

Distributed mutex 2 – Token Ring

A token giving permission to access the object circulates indefinitely

entry protocol

wait for token to arrive

access object under exclusion

exit protocol

pass on token

- Not controllable – ring order, not request order or priority order
- Quite efficient, but token circulates when no process wants object access
- Must handle loss of token and regeneration, ensuring one token only
- crashes? Use ACKs, reconfigure, bypass failed processes

3. Distributed peer-to-peer algorithm

entry protocol

send a timestamped ***request*** to all processes including oneself
(there is a convention for ordering timestamps: earliest timestamp wins + tiebreaker)
only when ALL processes have sent ***reply*** can the object be accessed
Any process executing the protocol, so wanting access, sends a ***reply*** to
all processes whose request messages have earlier timestamps than its own message

access object under exclusion

exit protocol

reply to any deferred requests

+ fair FCFS
– not economical, 2N messages + any ACKs
– N points of failure
– N bottlenecks
– no reply? Failure or deferring?

A bad idea – requiring ALL processes to act before any one can proceed.