Coordinator Election Algorithms in Ring Topology

Chang Roberts and Franklin's Algorithms

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Outline of the Presentation

Agenda

Distributed coordinator/leader election

Imagine a network of data storage servers arranged in a closed loop, like a digital RING. Each server in this ring holds a piece of crucial information.
However, a critical task arises: the servers need to agree on a single coordinator to manage updates and ensure data consistency across the entire ring. Without a designated leader, conflicts could occur. Different servers might update the same information simultaneously, leading to inconsistencies and errors.

The Ring Election Problem

The Ring Election problem asks: how can these servers elect a single coordinator from within the ring itself? The chosen coordinator will be responsible for coordinating updates, ensuring all servers possess the same, up-to-date information. This seemingly simple task requires a **sophisticated algorithm** to function efficiently within the closed-loop structure of the ring network.

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Chang-Roberts Algorithm: Efficient Leader Election in Directed Rings

The Chang-Roberts algorithm offers a **ROBUST** approach to leader election in directed ring networks, characterized by the following key strengths:

- Directed Rings: Works best in directed ring networks for optimized communication.
- ID-based Election: Uses process IDs (highest wins) for efficient leader selection.
- Guaranteed Termination: Ensures the election concludes with a single leader.
- Scalable Messages: Message complexity scales proportionally with the network size.

Agenda

Franklin's Algorithm: Leader Election in Bidirectional Rings

Franklin's algorithm tackles leader election in **BIDIRECTIONAL** ring networks, offering these key advantages:

- Bidirectional Communication: Leverages communication in both directions within the ring, potentially accelerating leader selection compared to unidirectional algorithms.
- Probabilistic Selection: Introduces an element of randomness to potentially break ties and avoid deadlocks in scenarios with identical process IDs.
- Scalable Messages: Message complexity scales proportionally with the network size, similar to Chang-Roberts.
- Guaranteed Termination: Ensures the election concludes with a single leader, even in the presence of process failures.

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Ring Leader Election: Keeping Order Flowing

“Order from Chaos: Electing a Leader in Ring Networks”

Ring networks struggle without a leader. Tasks clash, data conflicts, and messages meander. Leader election establishes a coordinator: streamlining tasks, ensuring data consistency, and optimizing communication.
This is crucial for distributed systems like databases and blockchains, ensuring a smooth flow within the ring.

Agenda

Model, Definitions

Distributed coordinator/leader election

Ring Networks - Leader Election Imagine a circle of computers (processes) talking to their neighbors. This is a ring network.

- Chang-Roberts works in directed rings (one-way talk) while Franklin's tackles bidirectional rings (two-way talk).
- Leader election picks a coordinator (leader) for the ring to manage tasks, data, and communication.

Background

Leader election in ring networks has been extensively studied. Several algorithms exist, each with trade-offs. Here's a comparison of Chang-Roberts and Franklin's:

- Chang-Roberts (1979) is a simple and efficient algorithm for directed rings, but limited to unidirectional communication.
- Franklin's (1982) builds on Chang-Roberts, introducing bidirectional communication and probabilistic tie-breaking. Both algorithms guarantee termination and message complexity scales with the network size.

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Coordinator Election in Rings

Chang Roberts Algorithm

Designed for rings where processes have unique identifiers. Messages with process IDs are circulated, and a process remains active if its own ID is larger than the IDs it receives. The process with the largest ID eventually becomes the leader.

Coordinator Election Algorithm in a Ring Topology

Chang Roberts

Chang Roberts on a ring topology is presented in Algorithm 1.

1: Initialize process ID and state

OnMessageFromBottom: (m) **do**
2: **if** $m.id > self.id$ **then**
  Become passive
end
else
  Continue as active
end
3: Broadcast m

OnMessageFromTop: (m) **do**
4: **if** $m.id > self.id$ **then**
  Become passive
end
else
  Continue as active
end
5: Broadcast m

Algorithm 1: Chang Roberts algorithm

Advantages

Efficiency Improvement

Notably enhances message complexity compared to basic flooding algorithms, contributing to more streamlined communication in ring networks.

Advantages

Straightforward Implementation

Relatively straightforward to implement due to its clear-cut logic and reliance on simple message circulation principles.

Disadvantages

Message Complexity

Despite being an improvement over basic flooding algorithms, it still exhibits a worst-case message complexity of $O(n^2)$, which can become prohibitive for larger networks.

Disadvantages

Dependency on Unique Identifiers

The algorithm heavily relies on the existence of unique identifiers for each process, limiting its applicability in scenarios where such identifiers are not readily available.

Coordinator Election in Rings

Franklin’s Algorithm

Designed for bidirectional rings. It uses the concept of “waves” of messages, where a process can start a wave if its ID is larger than its neighbors. Waves travel in both directions, and collisions resolve in favor of the larger ID. Eventually, the largest ID prevails.

Coordinator Election Algorithm in a Ring Topology

Franklin's

Franklin's on a ring topology is presented in Algorithm 2.

1: Initialize process ID and state

OnMessageFromBottom: (m) **do**
2: **if** $m.id > self.id$ **then**
Start wave
end
3: Broadcast m

OnMessageFromTop: (m) **do**
4: **if** $m.id > self.id$ **then**
Start wave
end
5: Broadcast m

Algorithm 2: Franklin's algorithm

Advantages

Optimized Message Complexity

Offers a significant improvement in terms of message complexity with a worst-case scenario of O(n log n), particularly beneficial for larger ring networks.

Advantages

Scalability

Due to its efficient message complexity, it scales well with increasing network size, making it suitable for a wide range of applications.

Disadvantages

Complex Implementation

Implementation of Franklin's algorithm can be considerably more complex compared to simpler algorithms like Chang and Roberts, requiring a deeper understanding of bidirectional message propagation and collision resolution.

Disadvantages

Communication Channel Requirements

Relies on bidirectional communication channels between neighboring processes, which may pose challenges in certain network architectures where such channels are not readily available or feasible.

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Number of Messages based on Number of Nodes

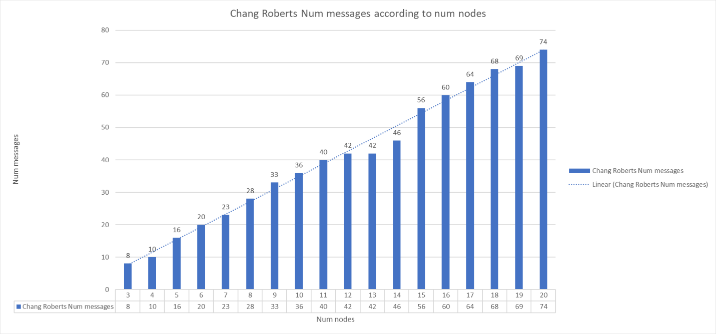


Figure: Chang Roberts Algorithm

Number of Messages based on Number of Nodes

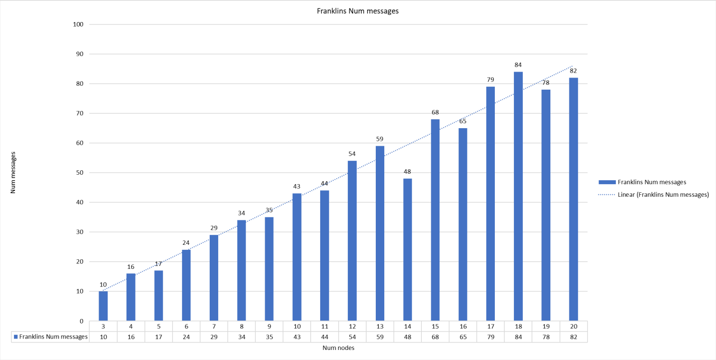


Figure: Franklin's Algorithm

How do those algorithms find the leader?

Let's proceed with the ring election dance.

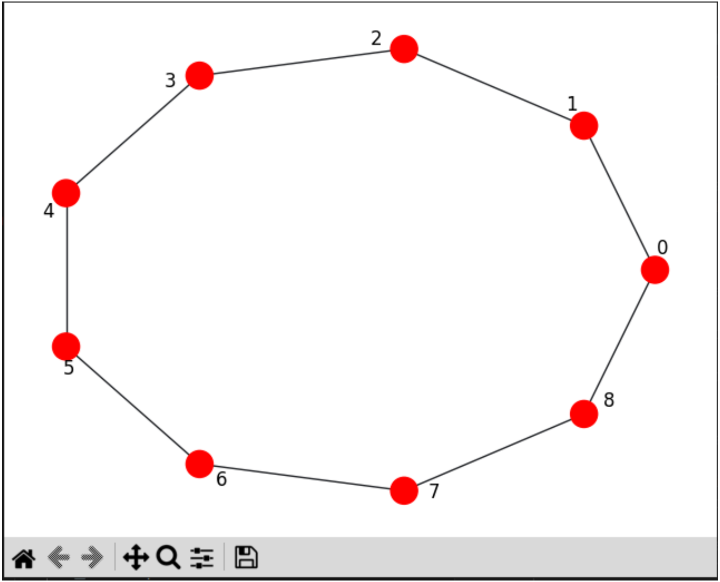


Figure: Chang Roberts Algorithm

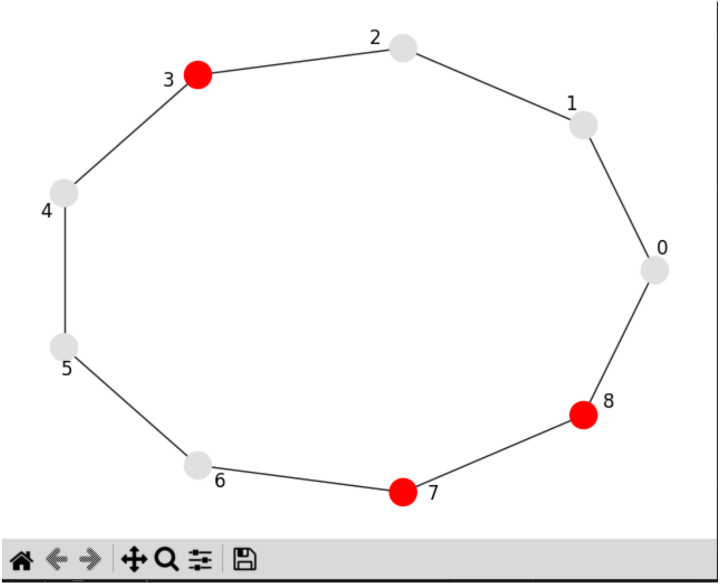


Figure: Chang Roberts Algorithm

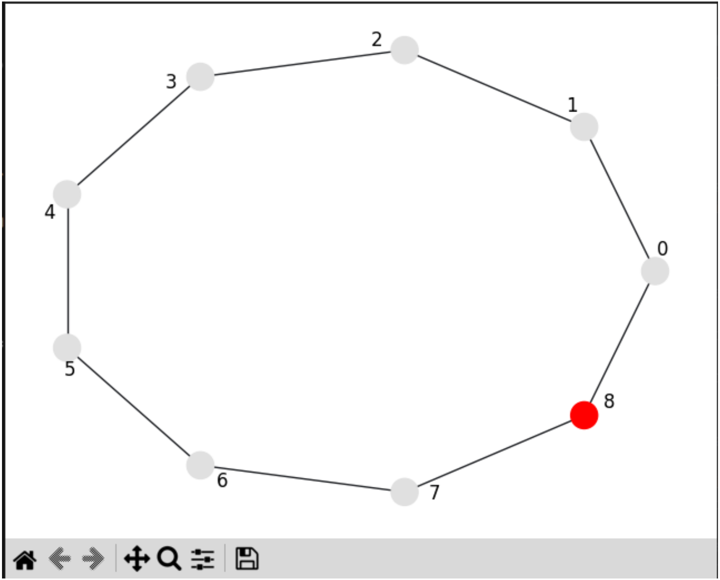


Figure: Chang Roberts Algorithm

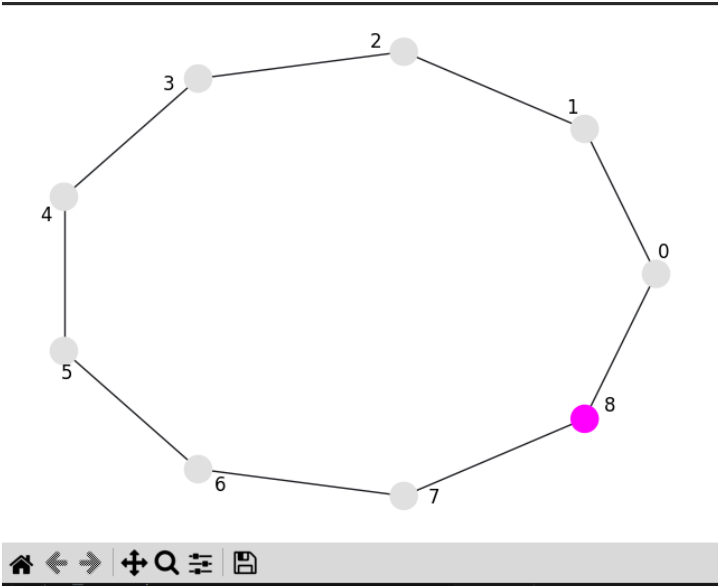


Figure: Chang Roberts Algorithm

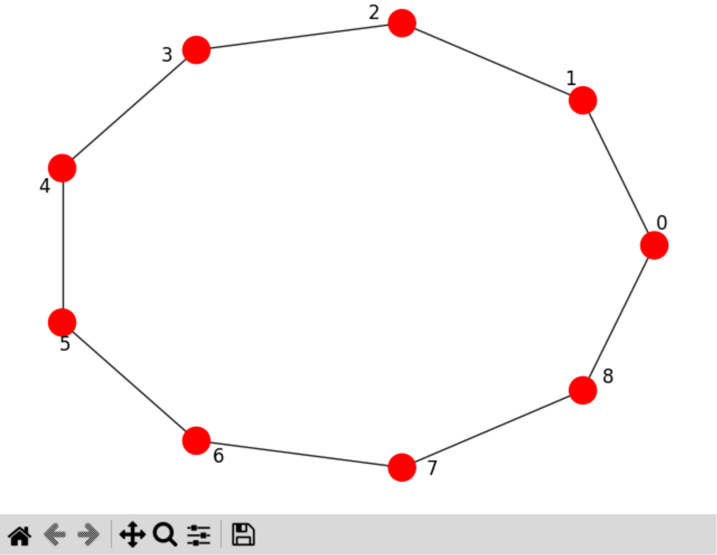
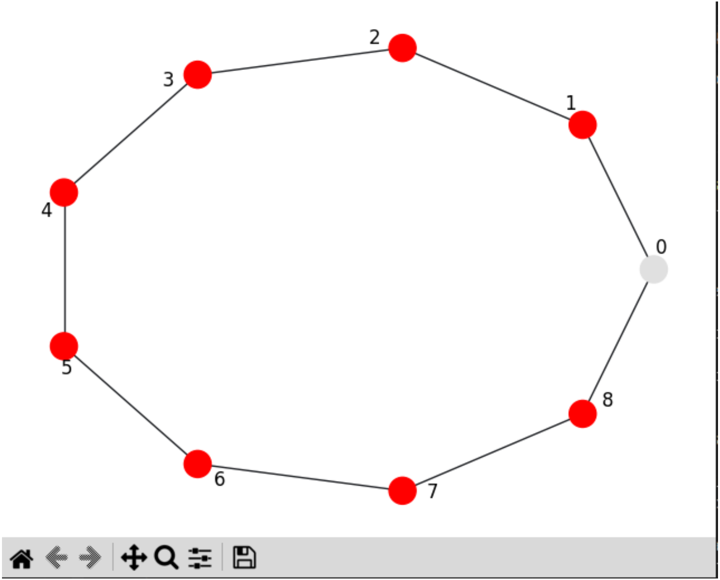


Figure: Franklin's Algorithm



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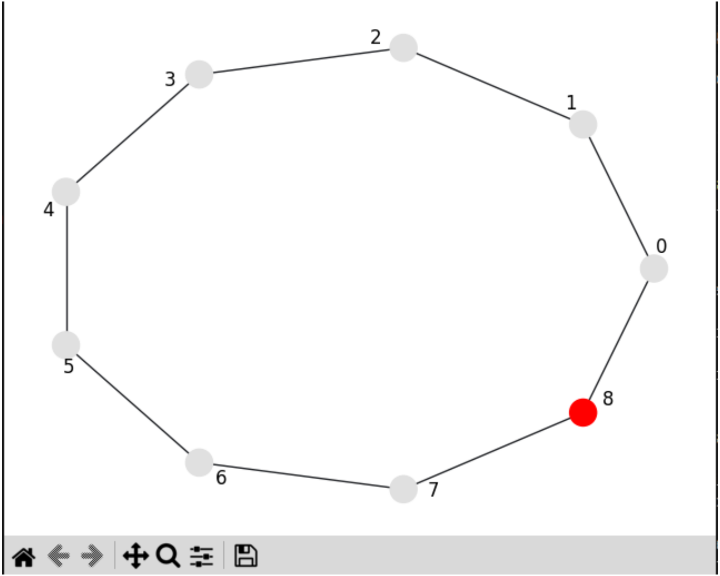

Figure: Franklin's Algorithm

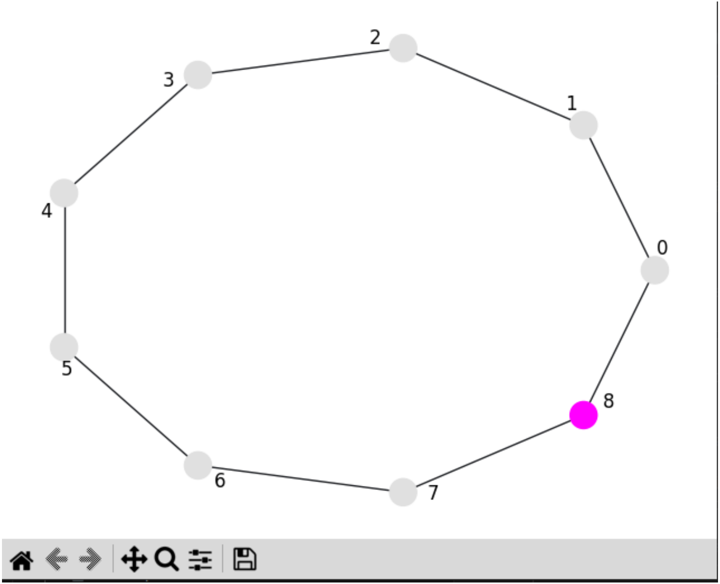

Figure: Franklin's Algorithm

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Conclusions

Selecting the Right Leader Election Algorithm for Distributed Systems

- Thorough analysis and comparison of Chang and Roberts Algorithm and Franklin's Algorithm for leader election in ring networks within distributed systems.
- Both algorithms demonstrated effectiveness in leader election, each with its own advantages and disadvantages.
- Findings provide insights into selecting appropriate leader election algorithm based on network characteristics and resource constraints.
- Future research could explore hybrid approaches or optimizations to address limitations and enhance applicability in diverse distributed system environments.

References

Questions

THANK YOU

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