Self-Management for Large Scale Distributed Systems

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Swedish Institute of Computer Science

Outline

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Dealing with Complexity

Problem

All computing systems need to be managed

Dealing with Complexity

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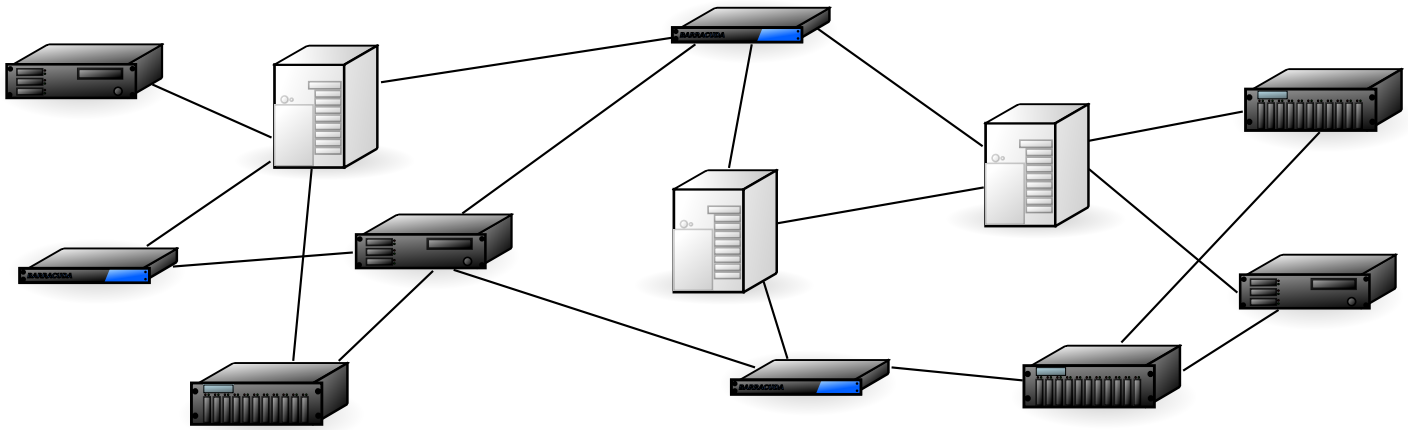
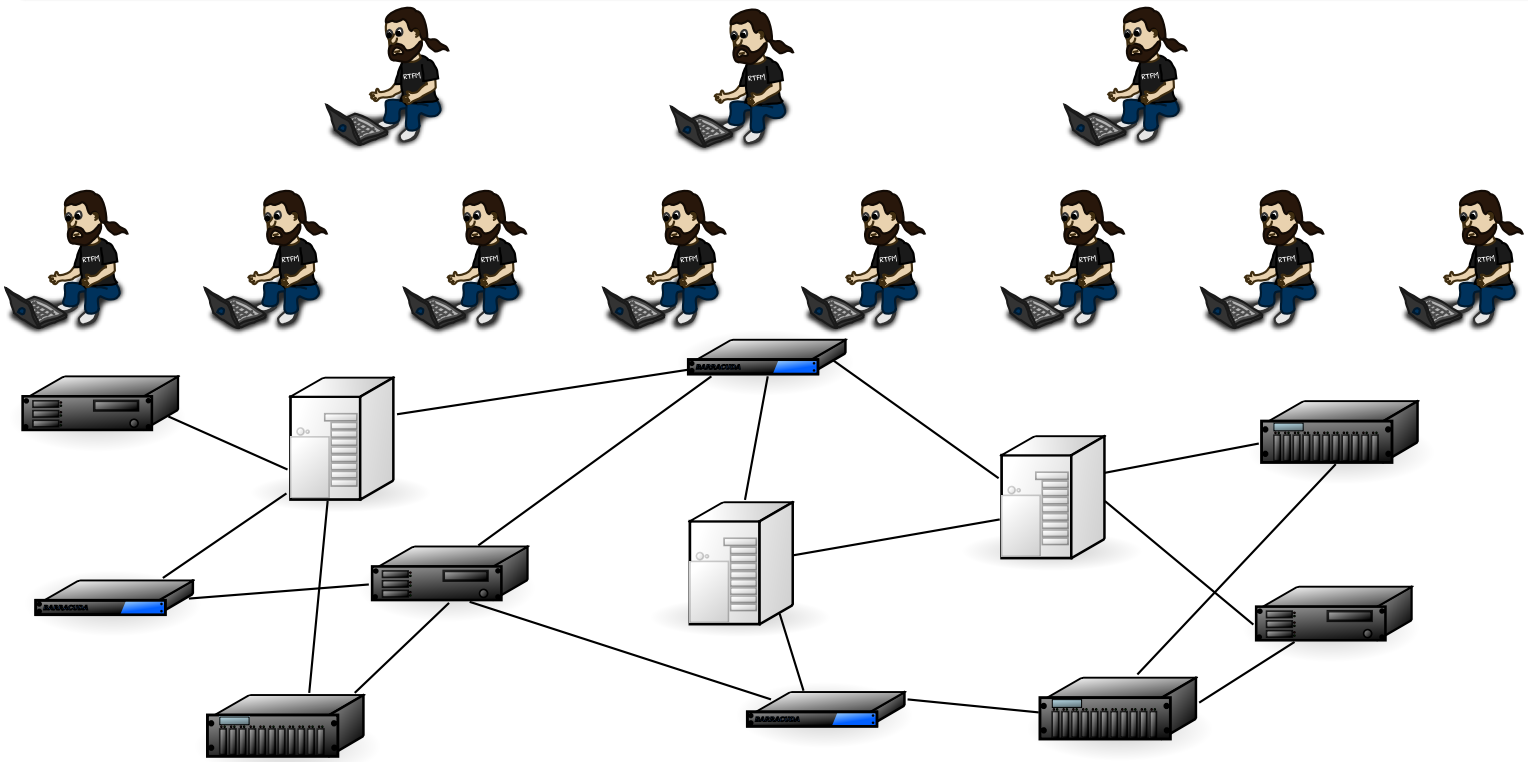
Computing systems are getting more and more complex



Dealing with Complexity

Problem

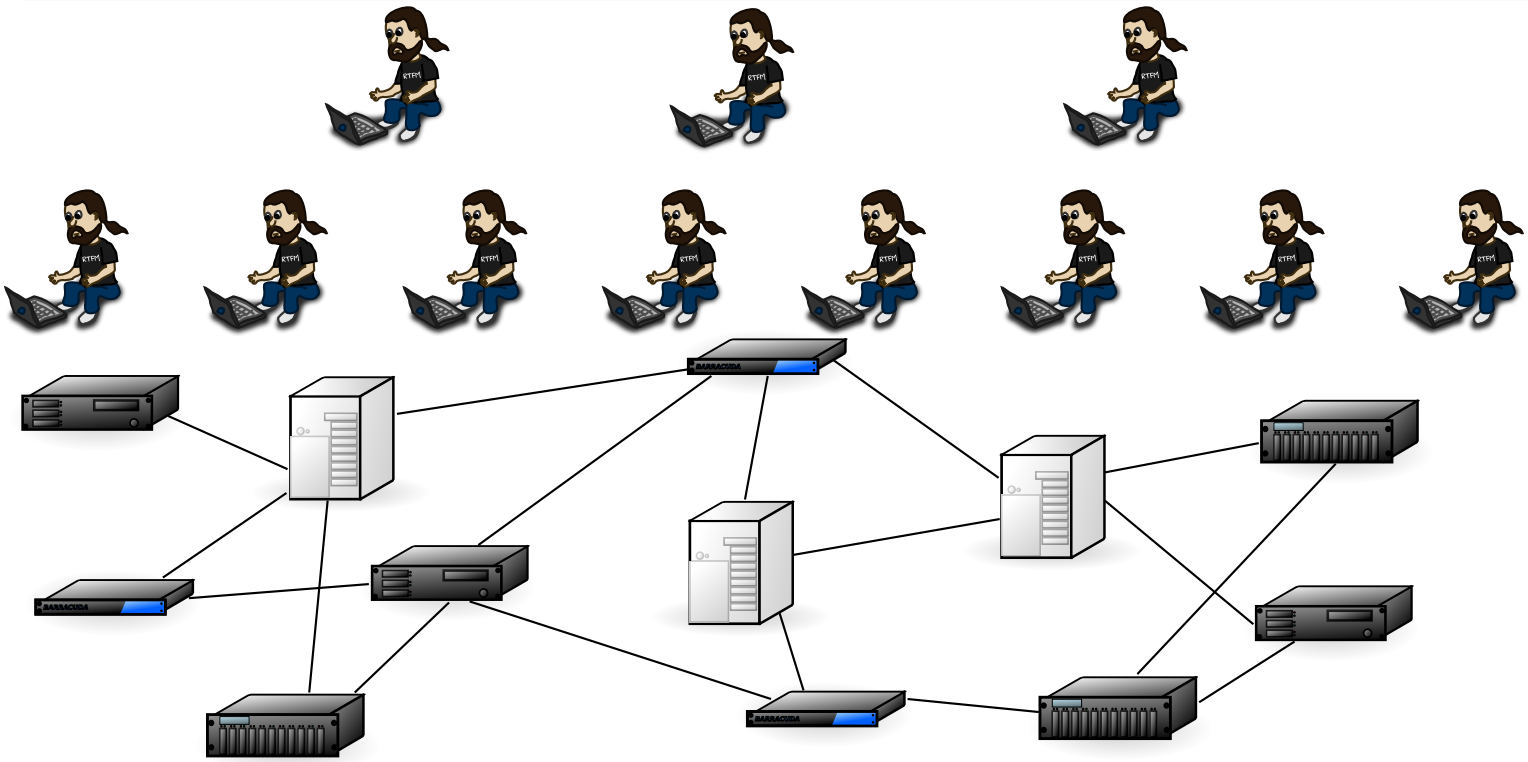
Complexity means higher administration overheads



Dealing with Complexity

Problem

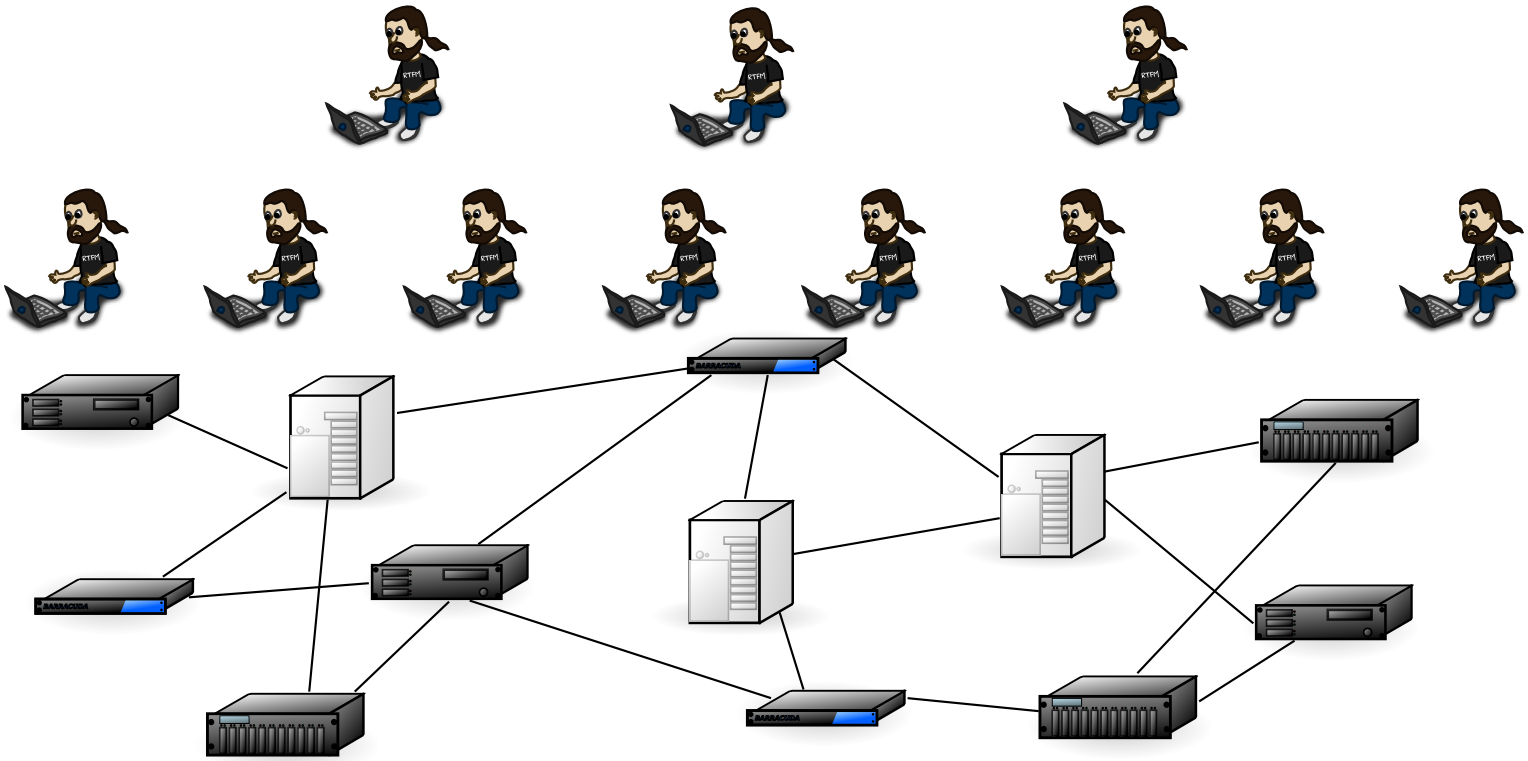
Complexity poses a barrier on further development



Dealing with Complexity

Solution

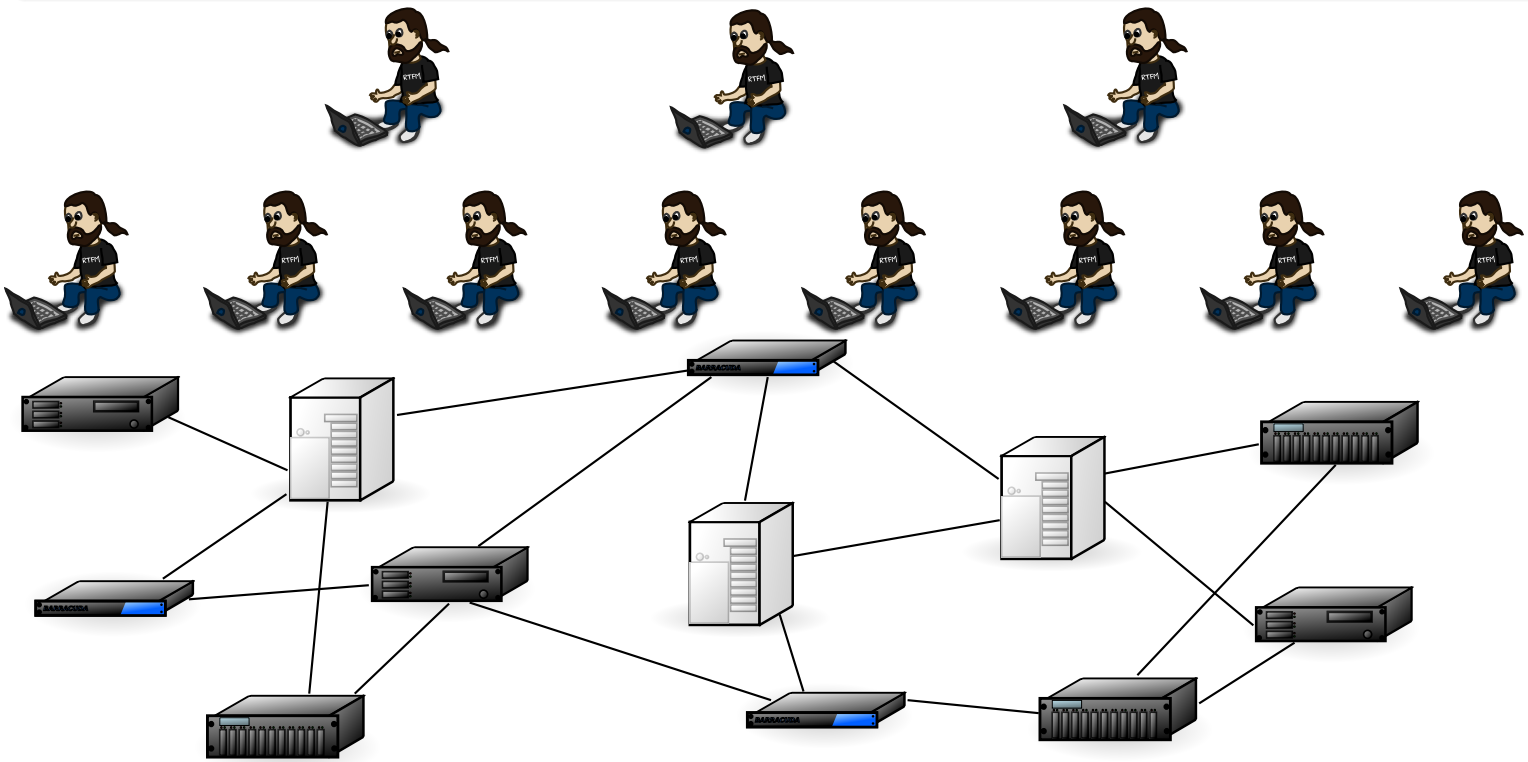
The Autonomic Computing initiative by IBM



Dealing with Complexity

Solution

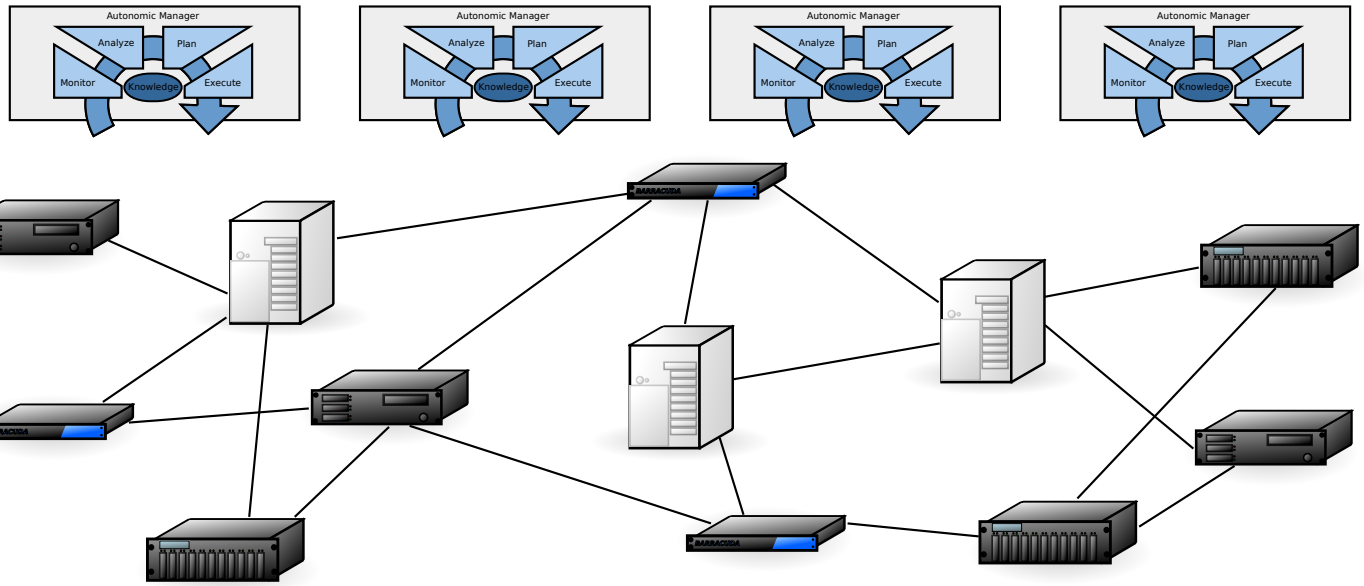
Self-Management: Systems capable of managing themselves



Dealing with Complexity

Solution

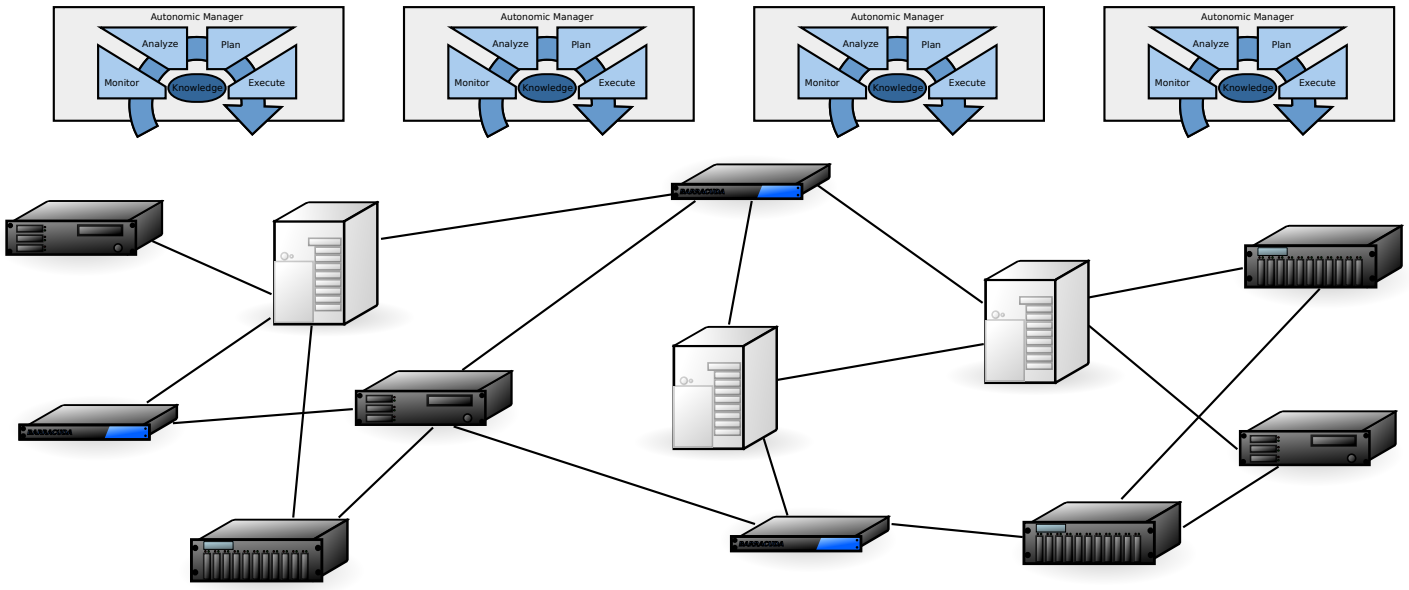
Use Autonomic Managers



Dealing with Complexity

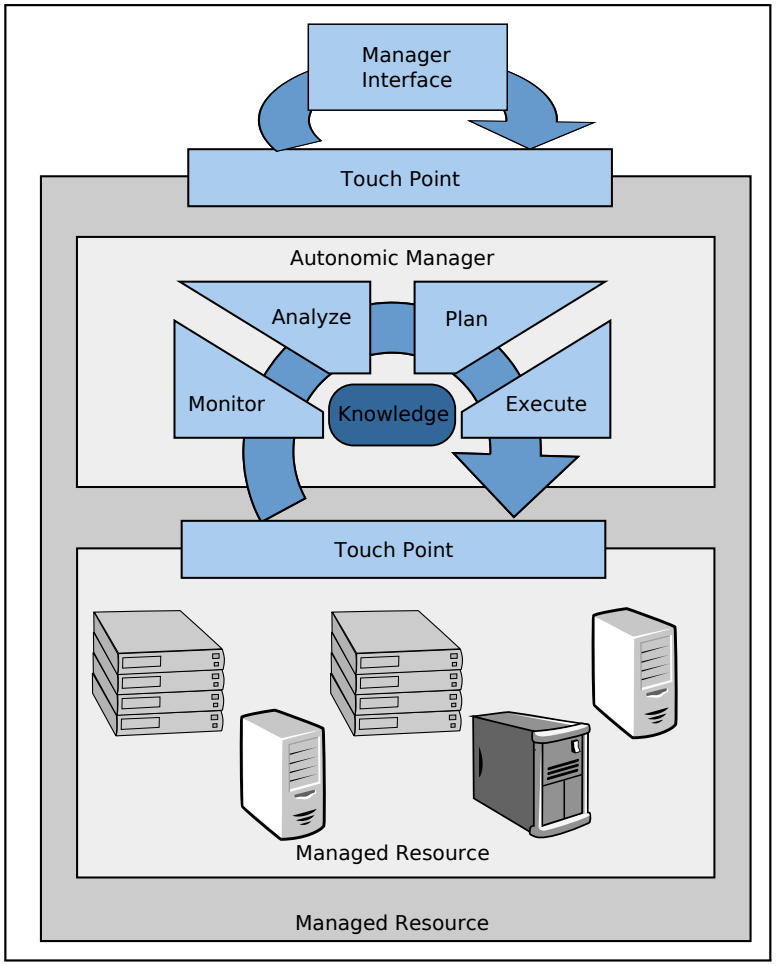
Open Question

How to achieve Self-Management?



The Autonomic Computing Architecture

- Managed Resource
- Touchpoint (Sensors & Actuators)
- Autonomic Manager
  - Monitor
  - Analyze
  - Plan
  - Execute
- Knowledge Source
- Communication
- Manager Interface



The Goal

Large-scale distributed systems

- Complex and require self-management
- May run on unreliable resources
- Major sources of complexity:
  - Scale (resources, events, users, . . .)
  - Dynamism (resource churn, load changes, . . .)

Goal

- A platform (concepts, abstractions, algorithms. . .) that facilitates development of self-managing applications in large-scale and/or dynamic distributed environment.
- A methodology that help us to achieve self-management.

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Research Plan

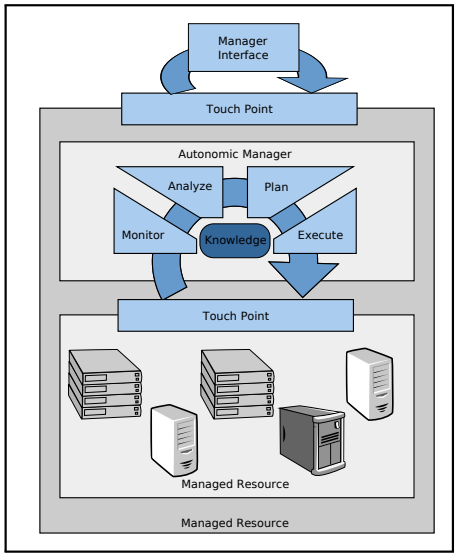
Self-Management in large-scale distributed systems. Consists of four main parts:

- Part 1: Touchpoints and feedback loops in distributed systems
- Part 2: Robust Management
- Part 3: Improve management logic
- Part 4: Integrate previous parts in a self-managing system.

Outline

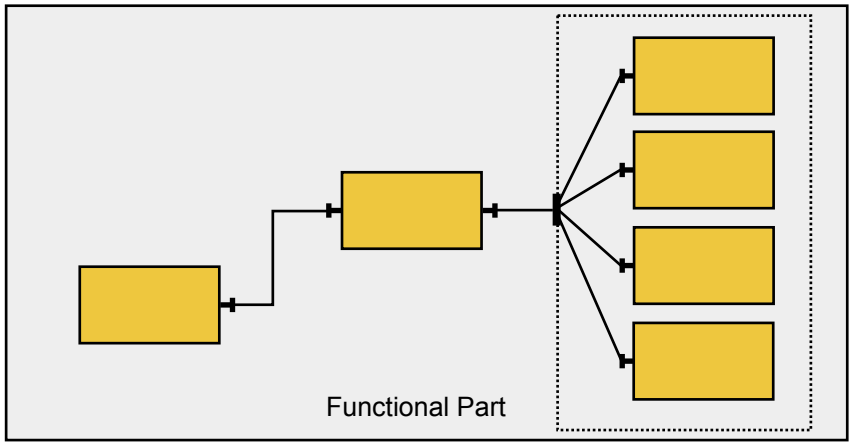
Niche

- Niche is a Distributed Component Management System
- Niche implements the Autonomic Computing Architecture for large-scale distributed environment
- Niche leverages Structured Overlay Networks for communication and for provisioning of basic services (DHT, Publish/Subscribe, Groups, etc.)



Management Part

- Management Elements
  - Watchers
  - Aggregators
  - Managers
  - Executors
- Communicate through events
- Publish/Subscribe
- Autonomic Managers (control loops) built as network of MEs
- Sensors and Actuators for components and groups
- Actuation API



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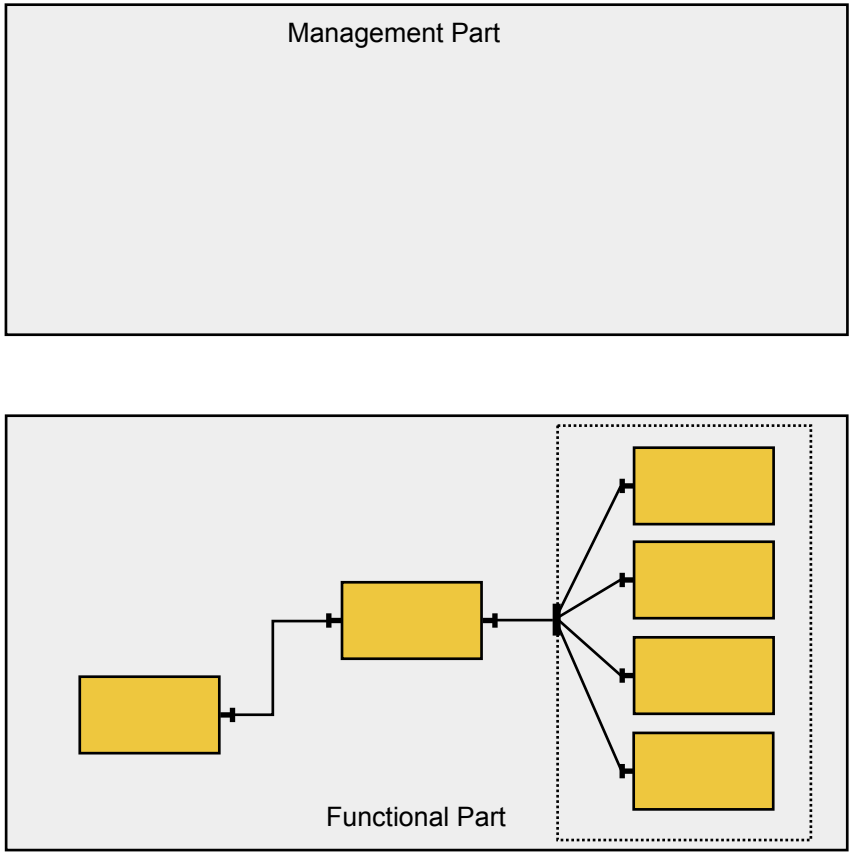

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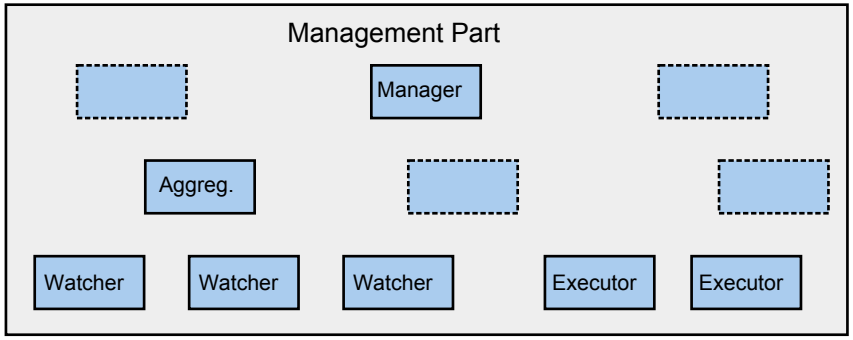

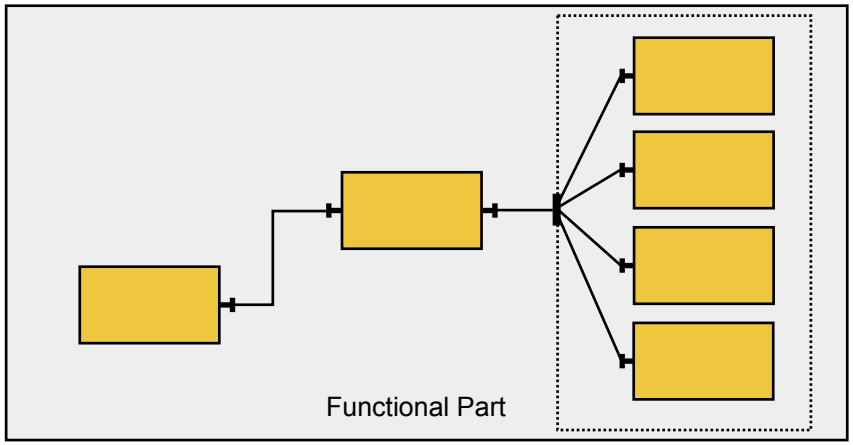

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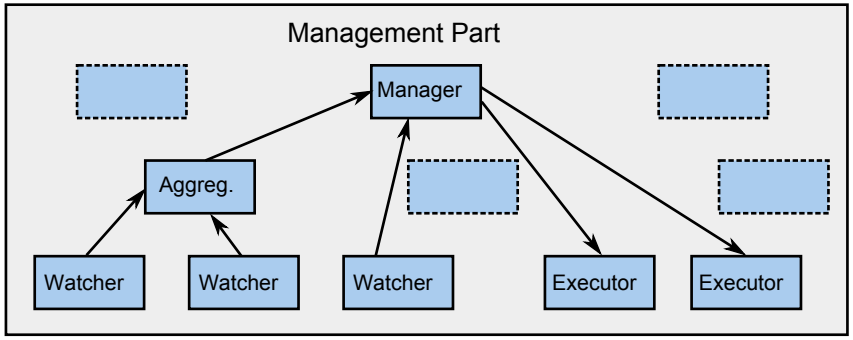

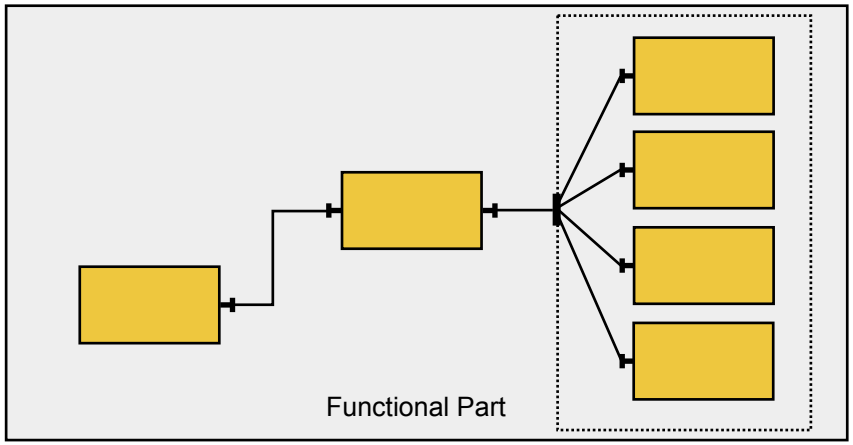

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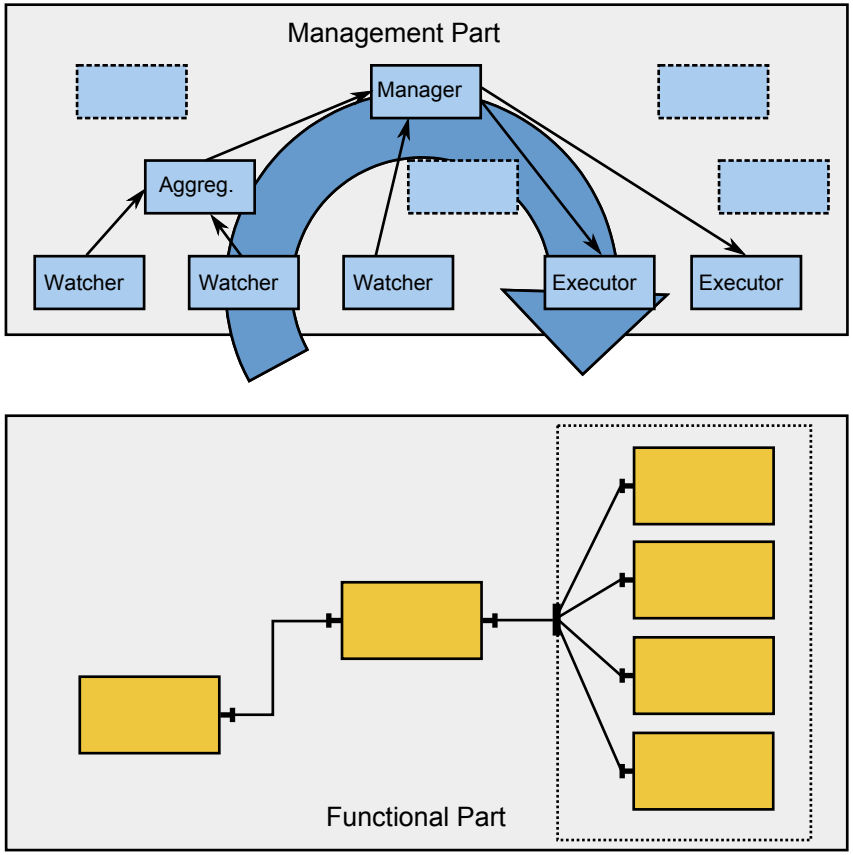

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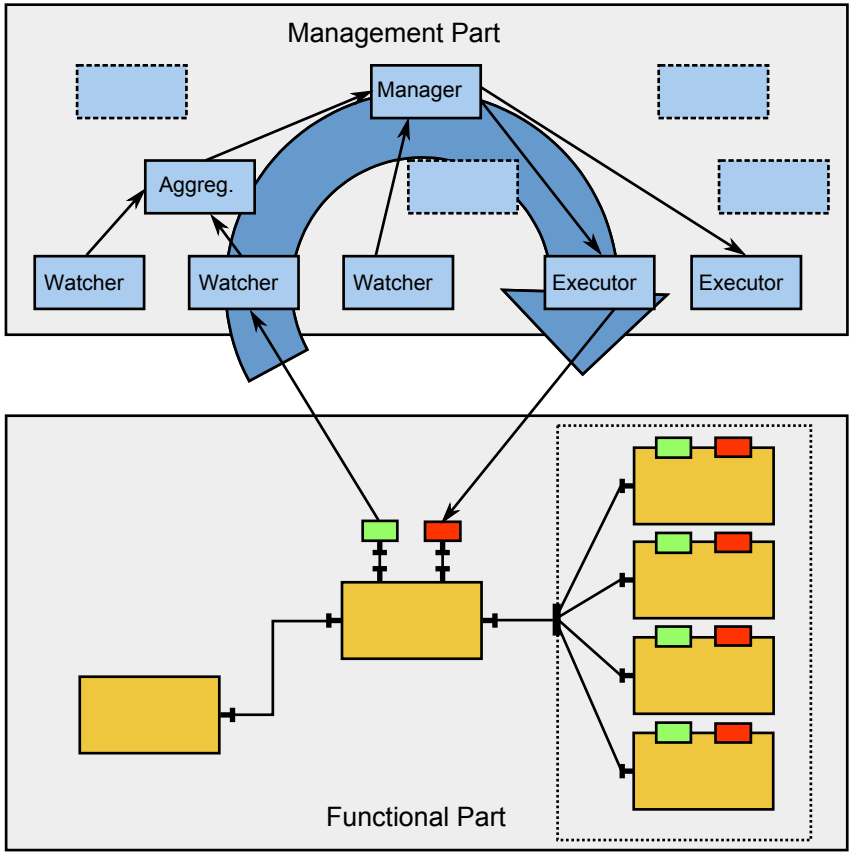
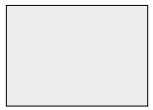


Runtime Environment

- Containers that host components and MEs
- Use a Structured Overlay Network for communication
- Provide overlay services

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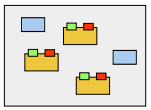
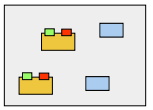
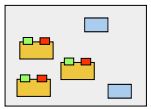
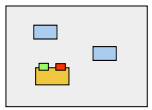

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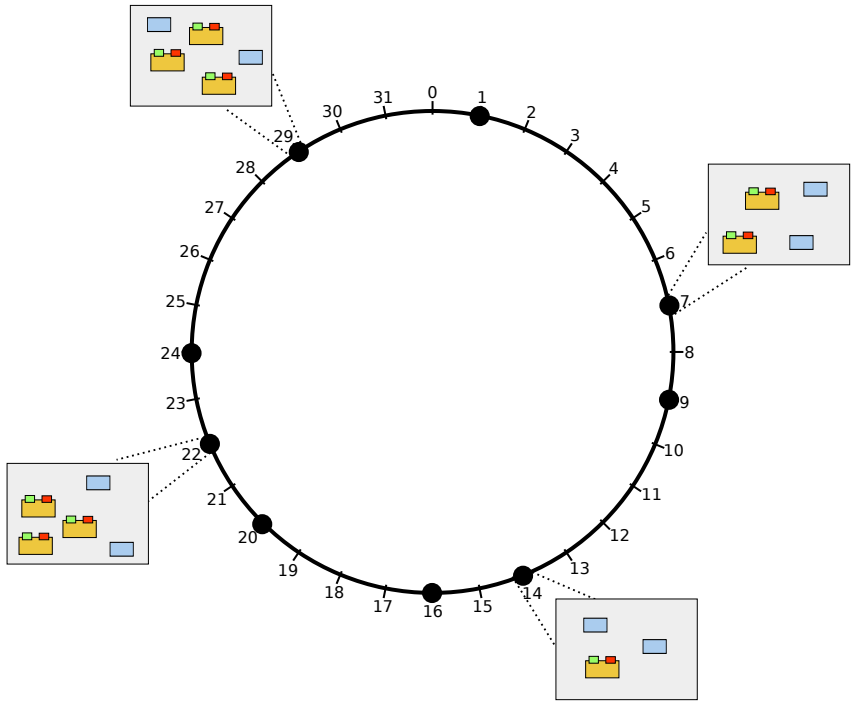
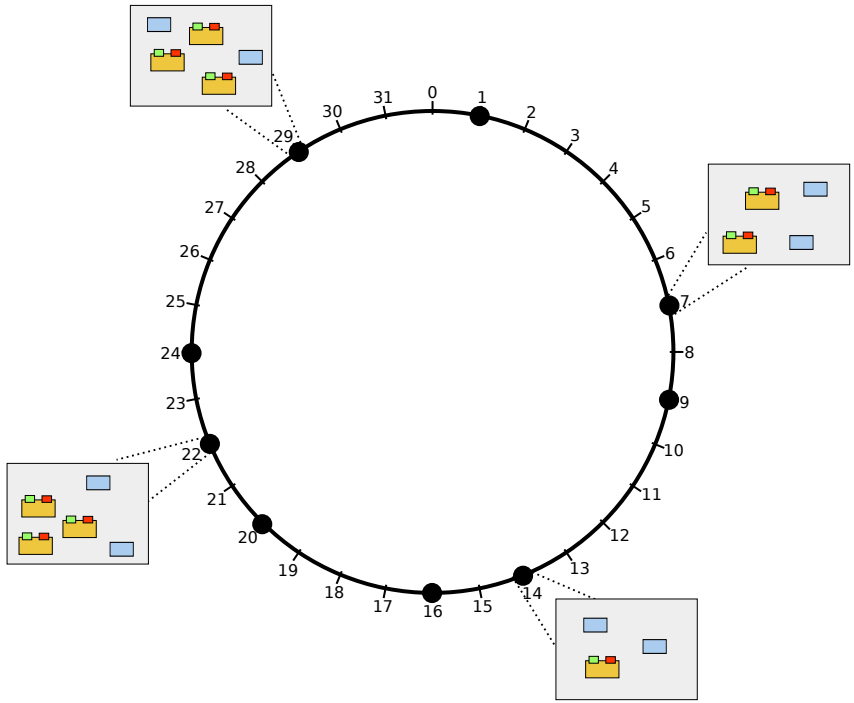


Dealing with Resource Churn

How to deal with failures?

- MEs heal the functional part
- How to heal failed MEs?
  - Programmatically in the management logic
  - Transparently by the platform



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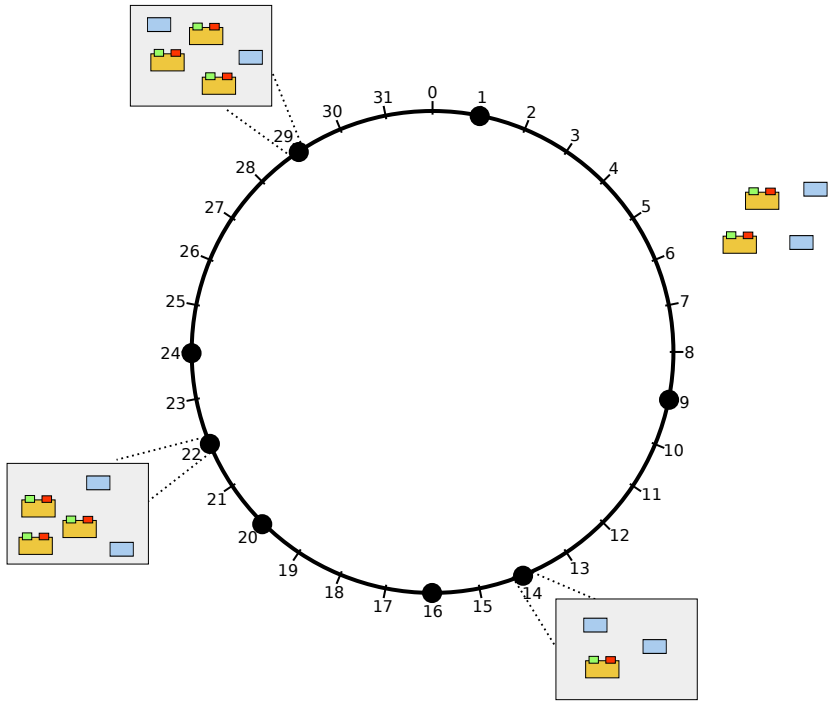

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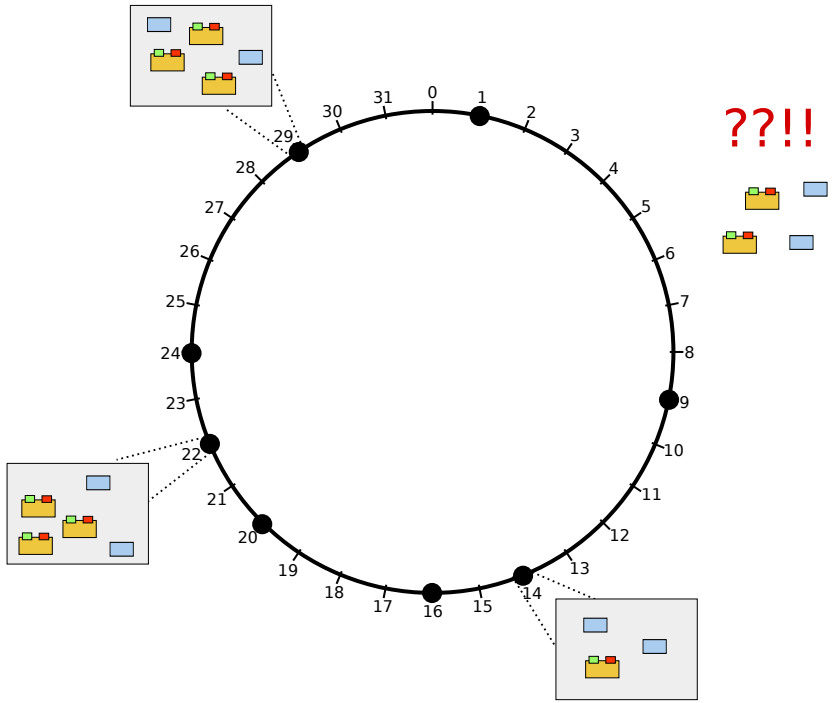

Outline

Robust Management Elements

A Robust Management Element (RME):

- is replicated to ensure fault-tolerance
- tolerates continuous churn by automatically restoring failed replicas on other nodes
- maintains its state consistent among replicas
- provides its service with minimal disruption in spite of resource churn (high availability)
- is location transparent, i.e., RME clients communicate with it regardless of current location of its replicas

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Solution Outline

- Replicated state machine
- An algorithm to reconfigure the replicated state machine. (We used the SMART algorithm)
- Our decentralized algorithm to automate reconfiguration

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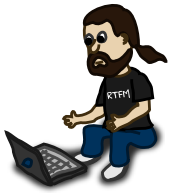

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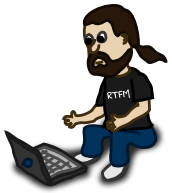

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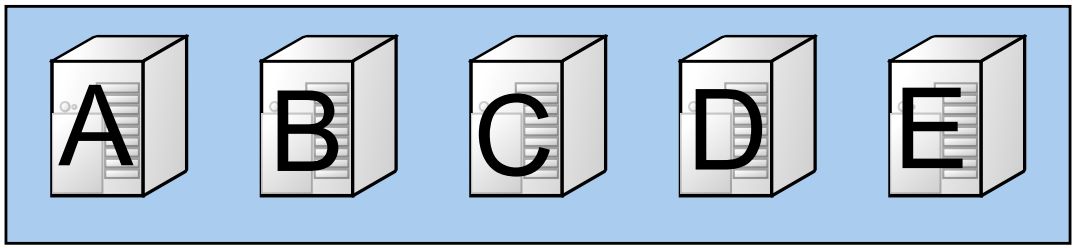

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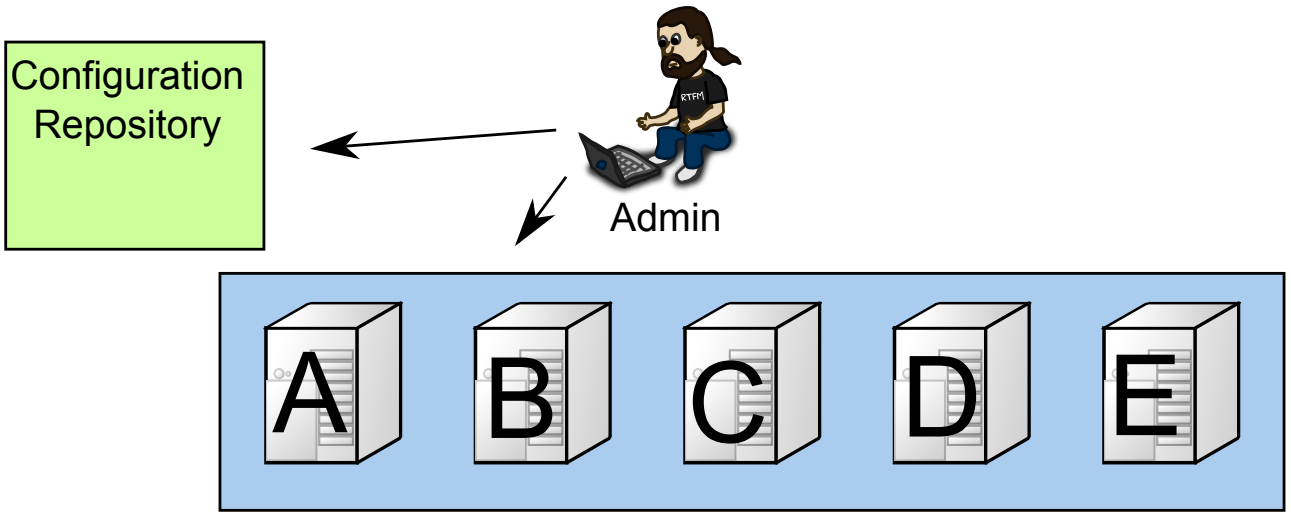

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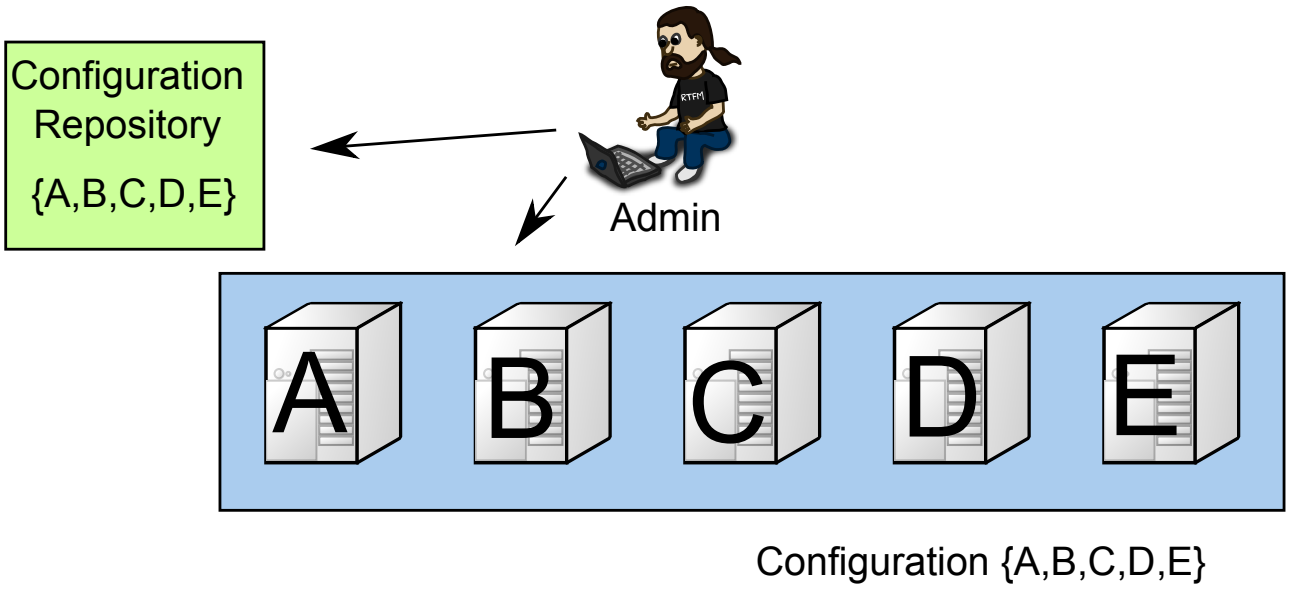
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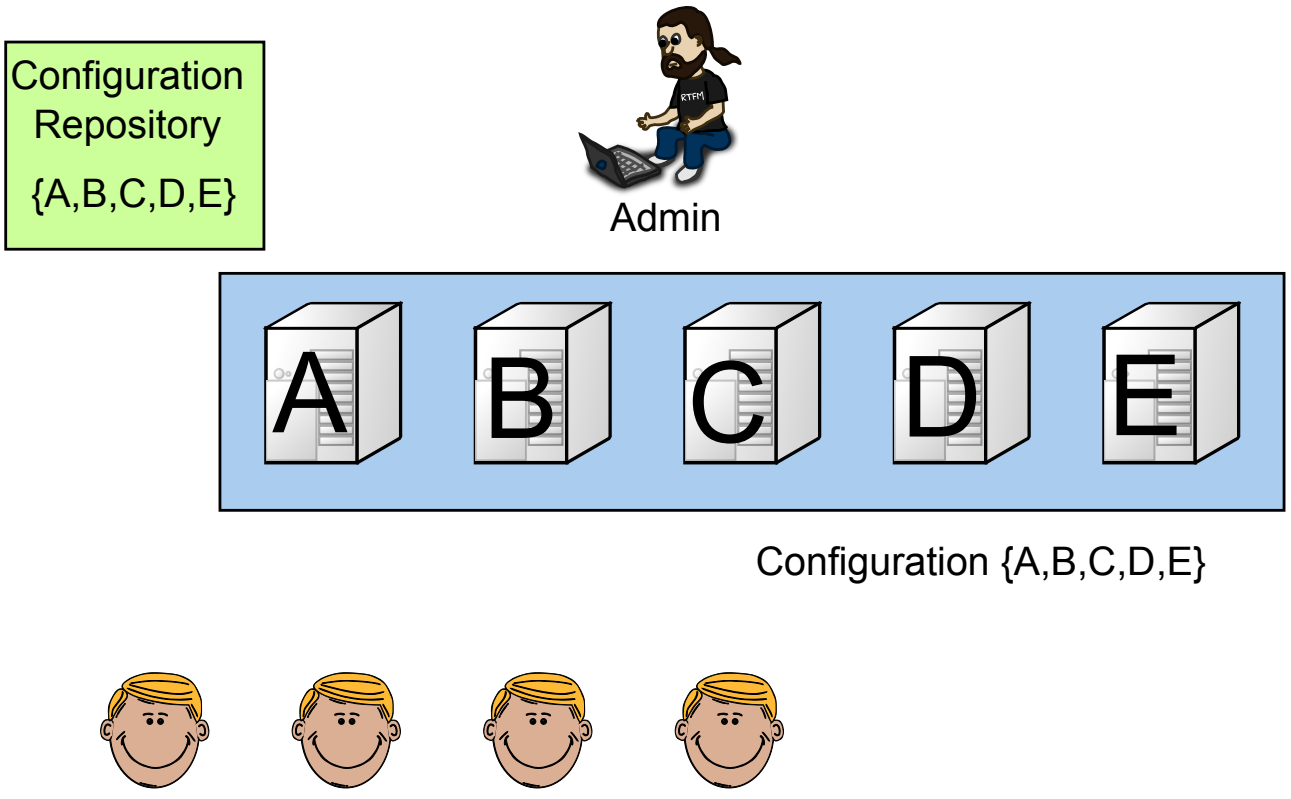
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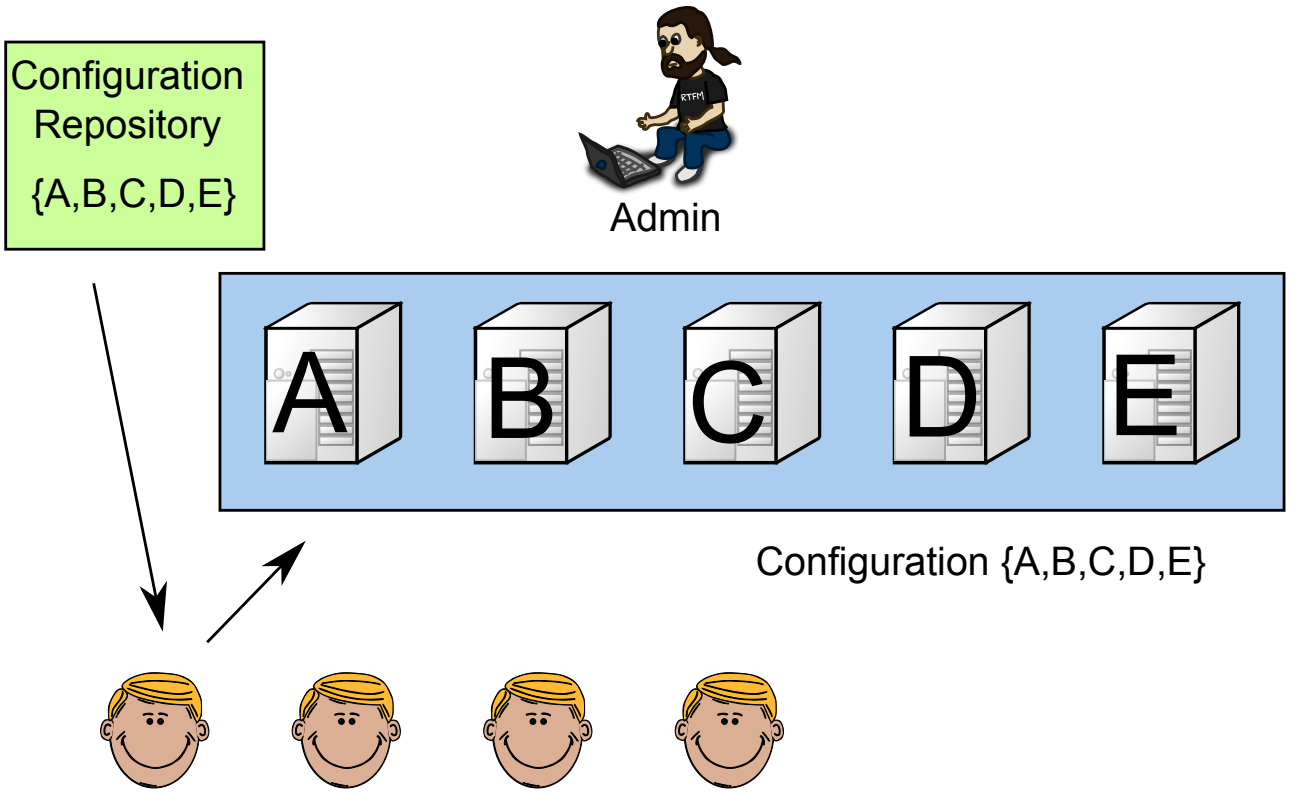
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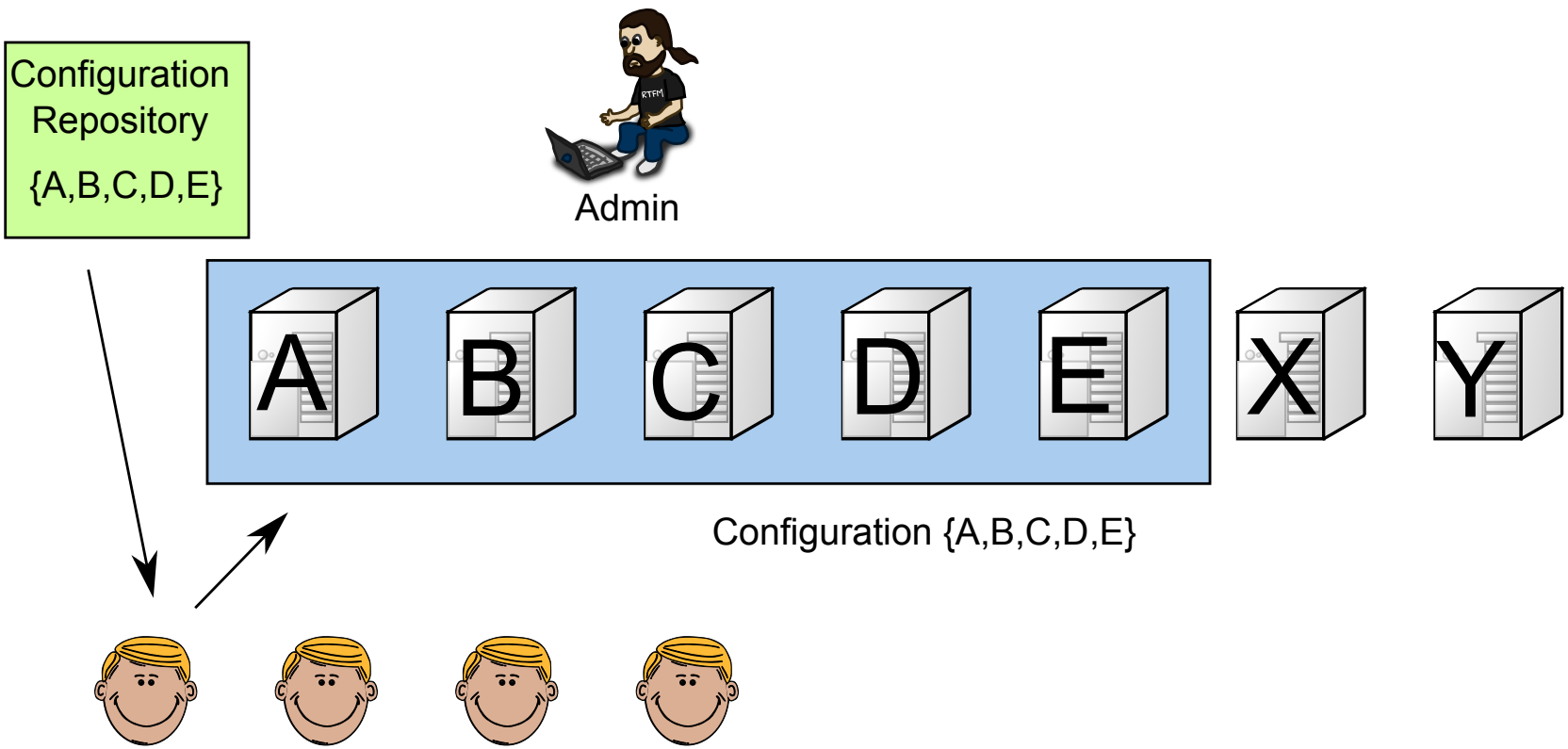
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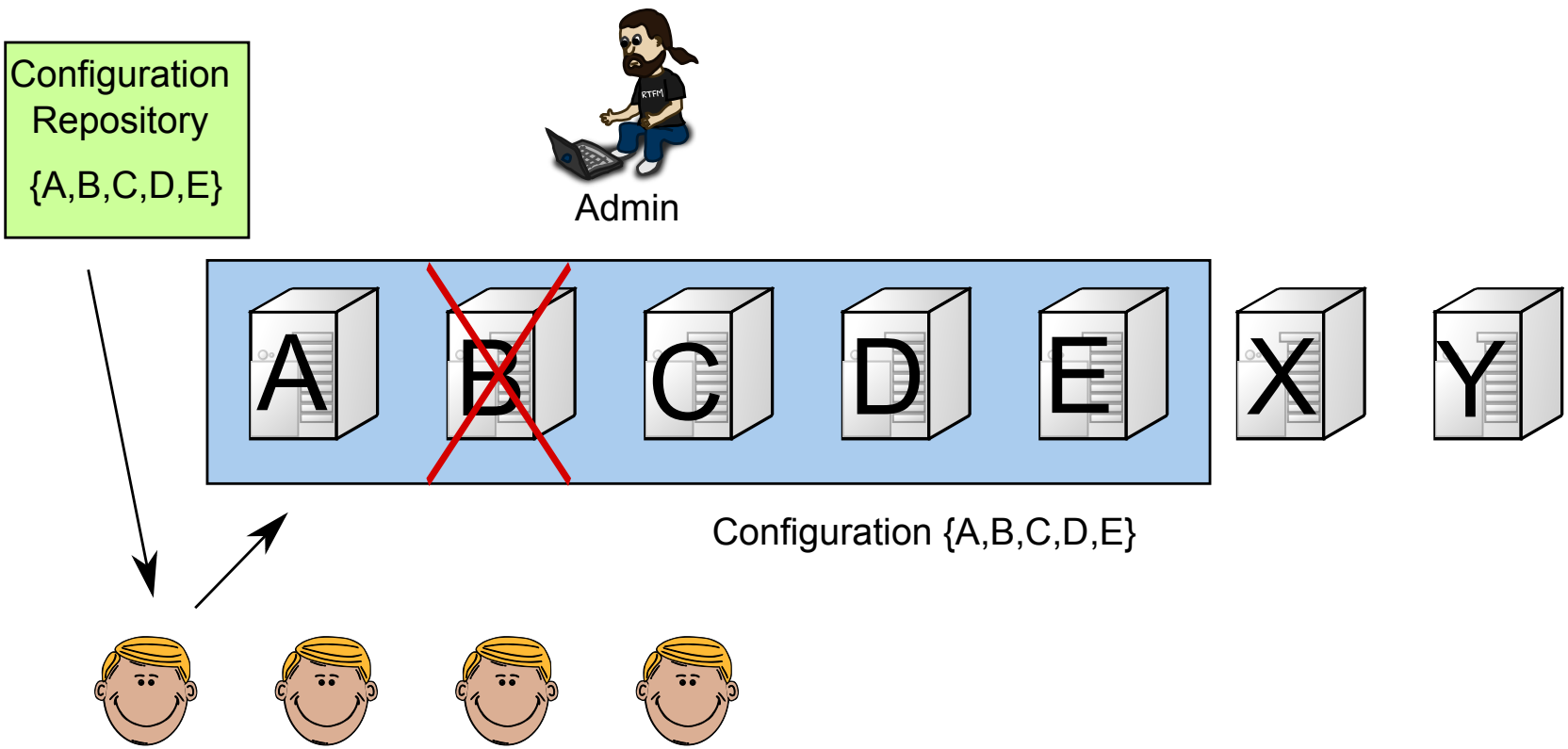
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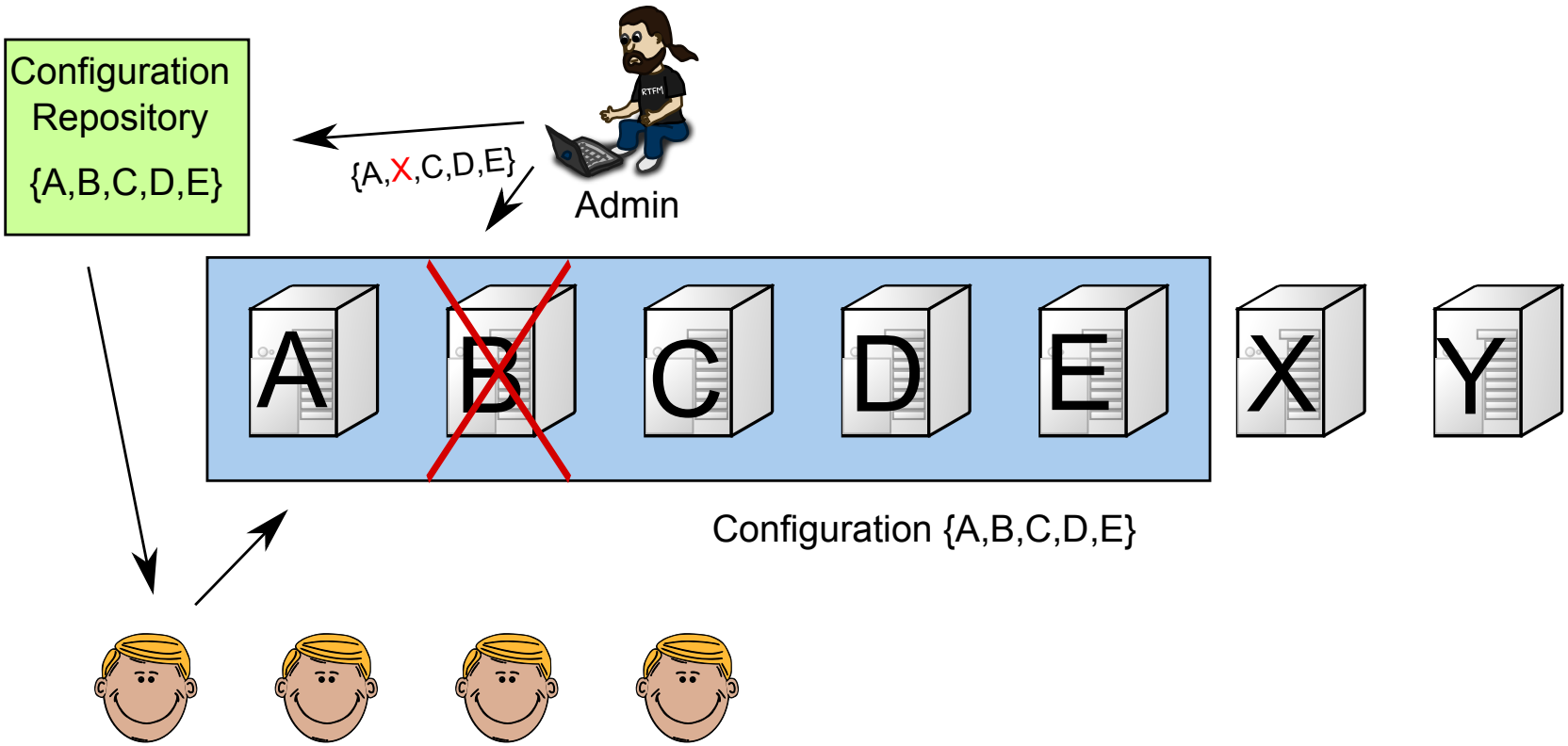
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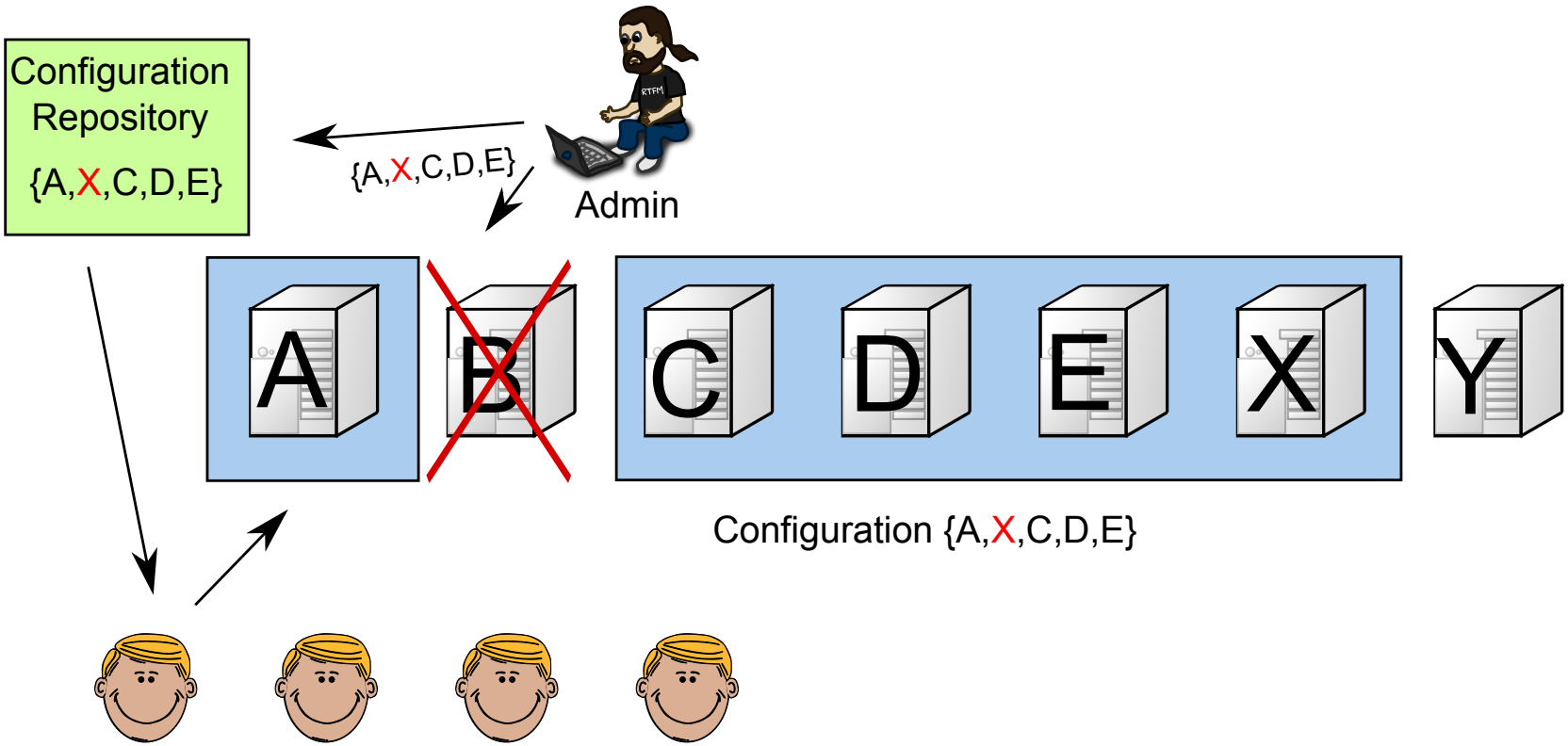
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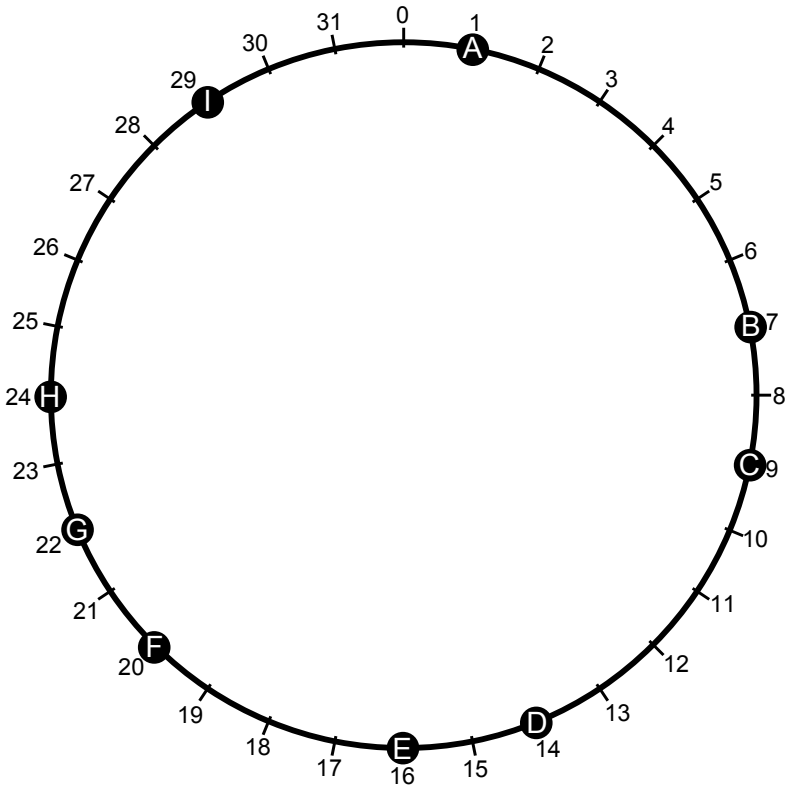
Creating a Replicated State Machine (RSM)

Any node can create a RSM. Select ID and replication degree



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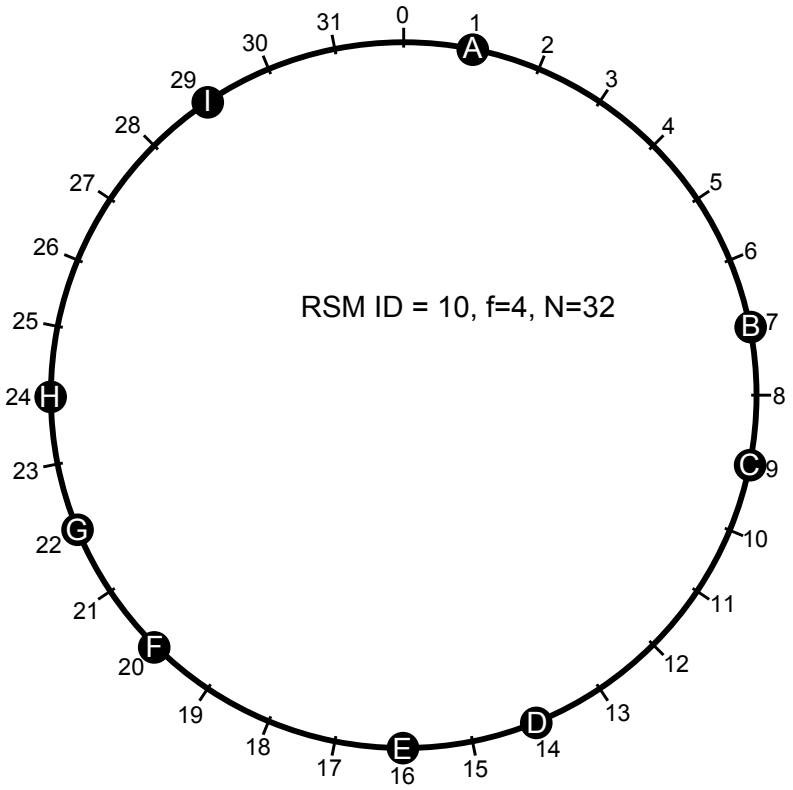
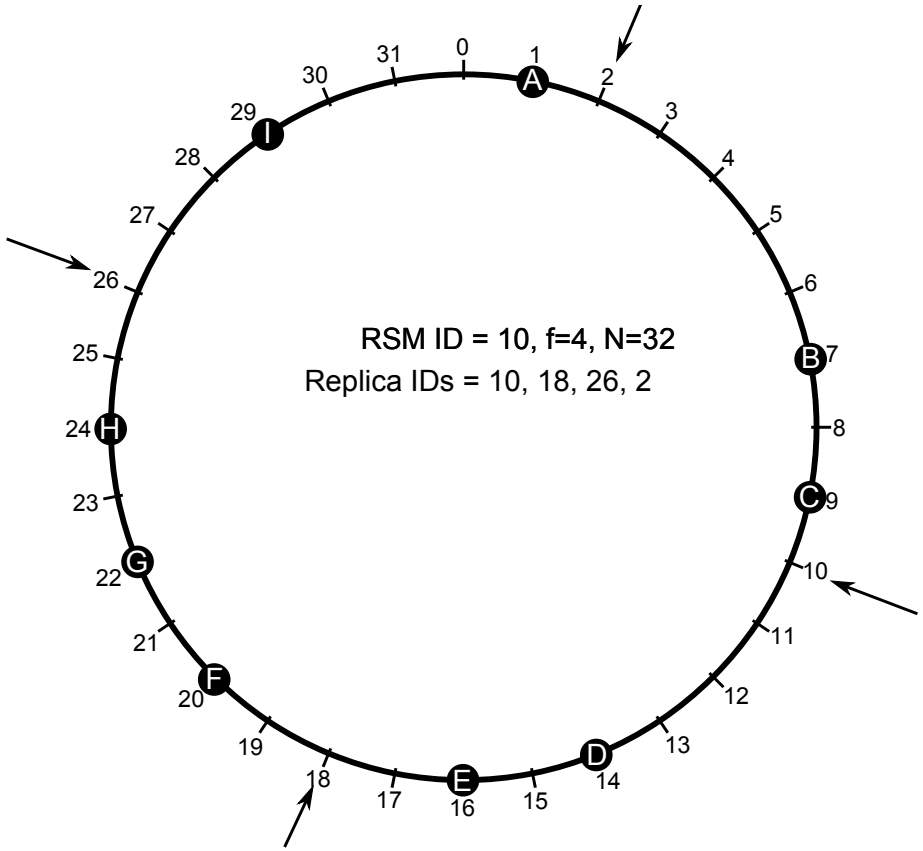


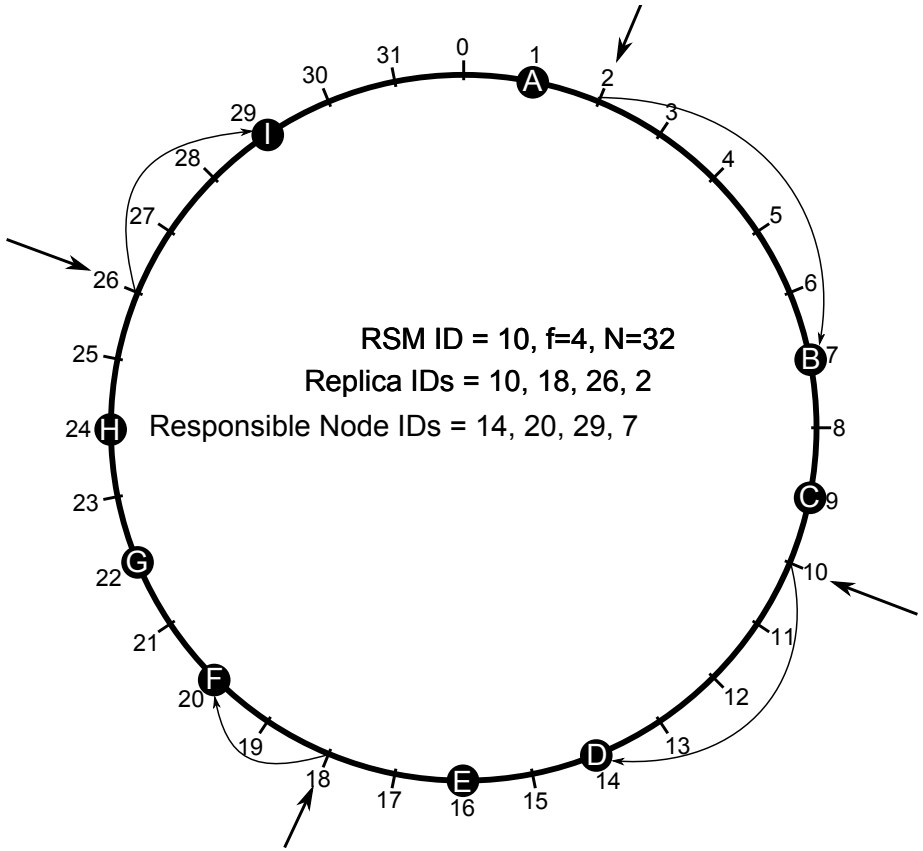
Creating a Replicated State Machine (RSM)

The node uses symmetric replication scheme to calculate replica IDs



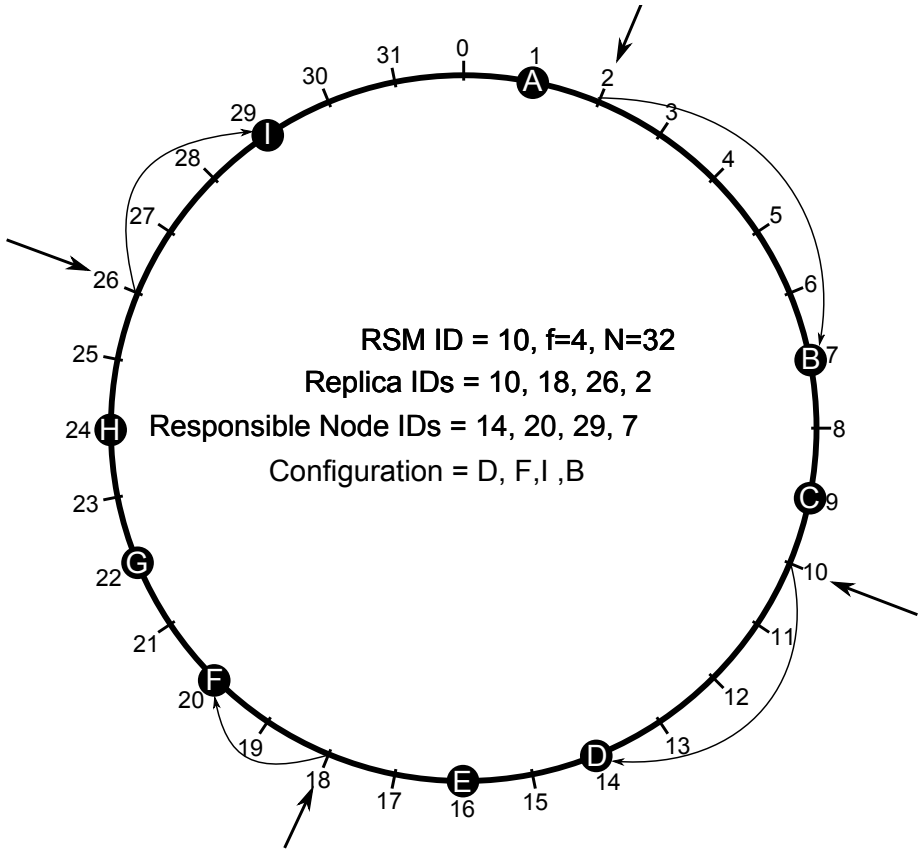
Creating a Replicated State Machine (RSM)

The node uses lookups to find responsible nodes . . .



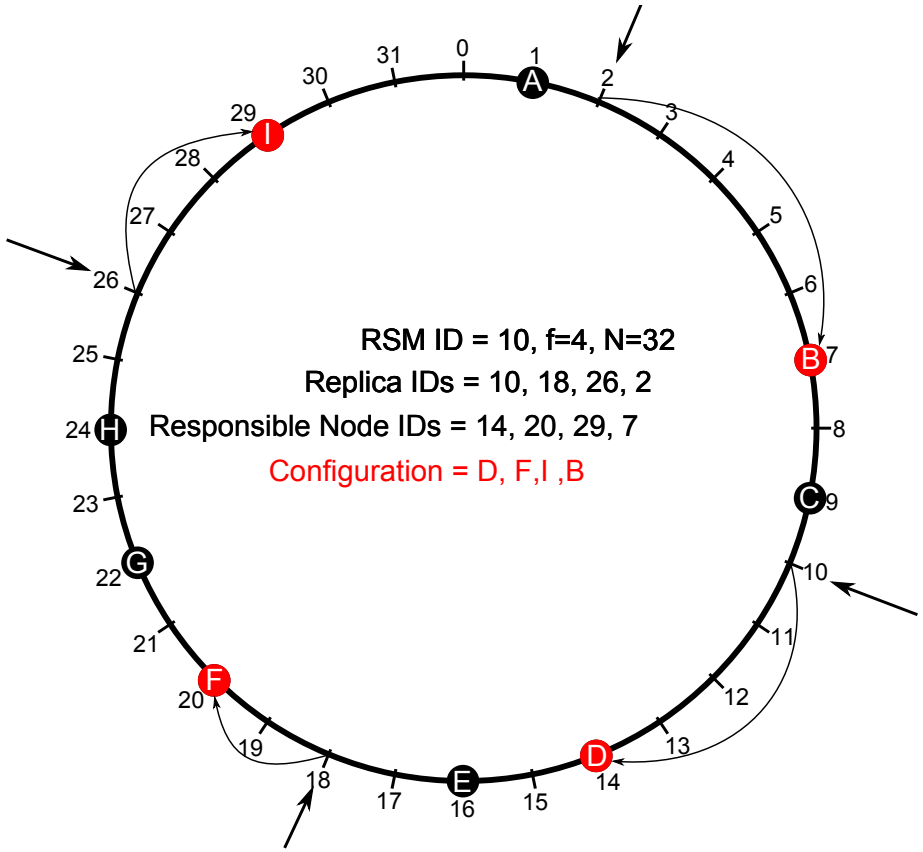
Creating a Replicated State Machine (RSM)

. . . and gets direct references to them



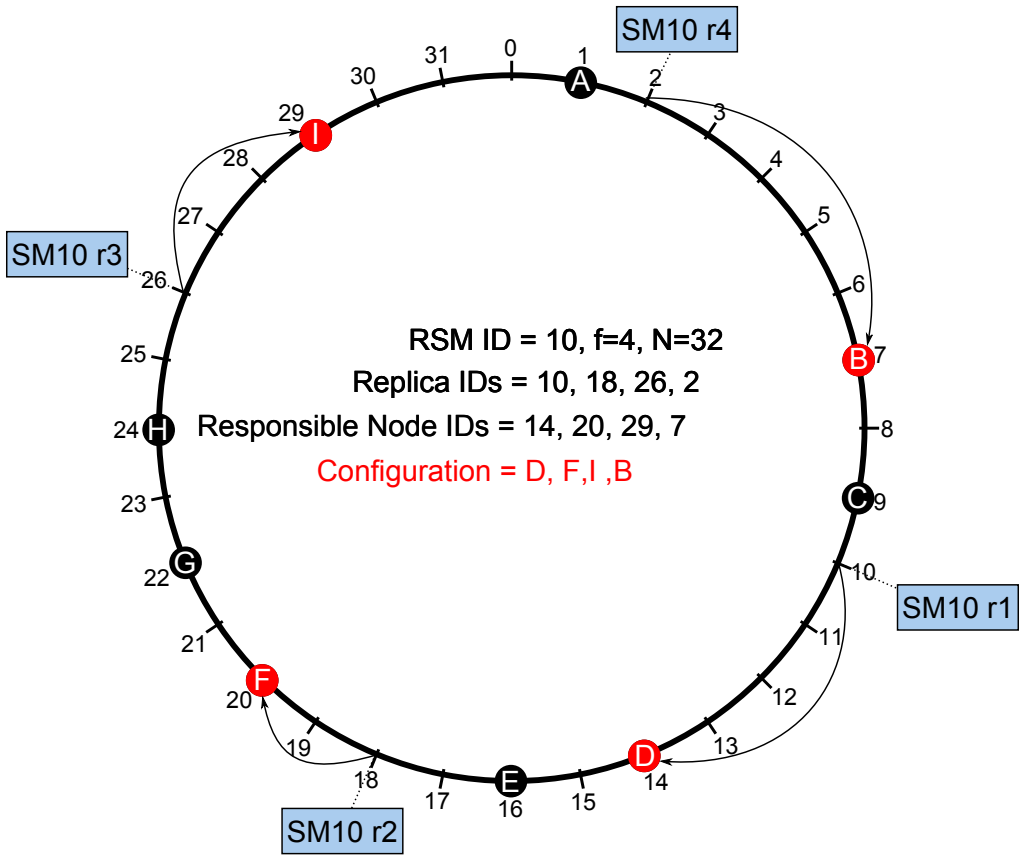
Creating a Replicated State Machine (RSM)

The set of direct references forms the configuration



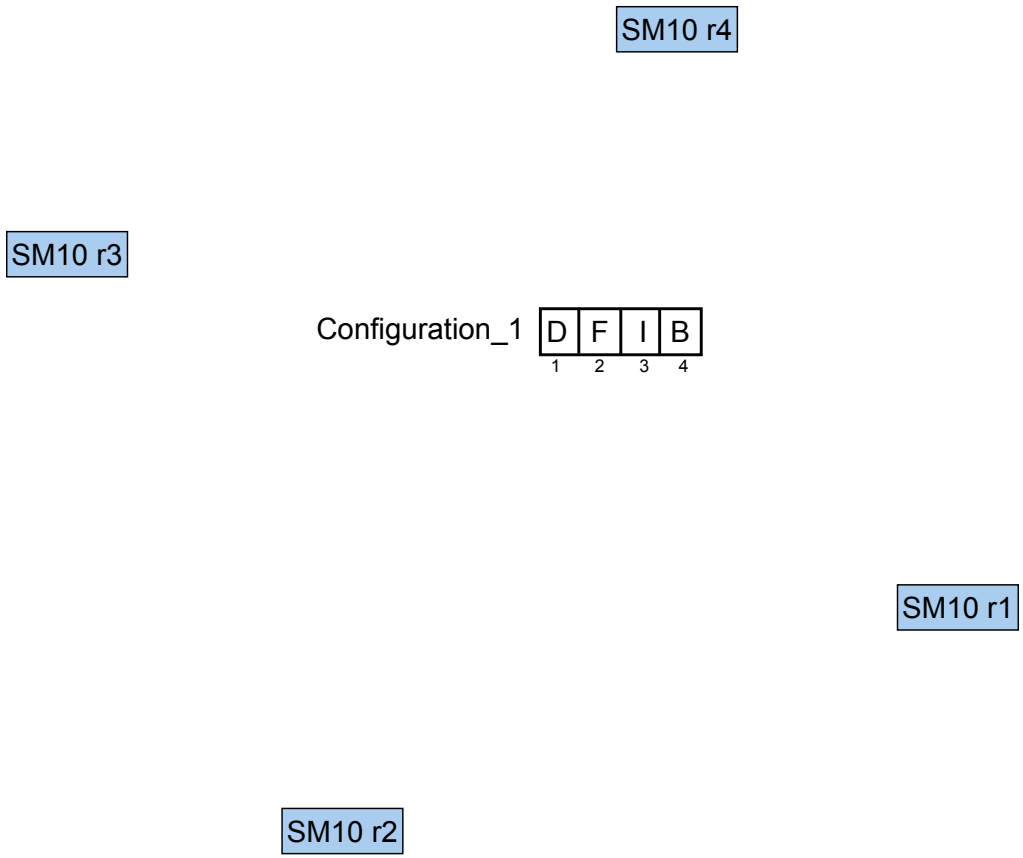
Creating a Replicated State Machine (RSM)

The node sends a *Create* message to the configuration

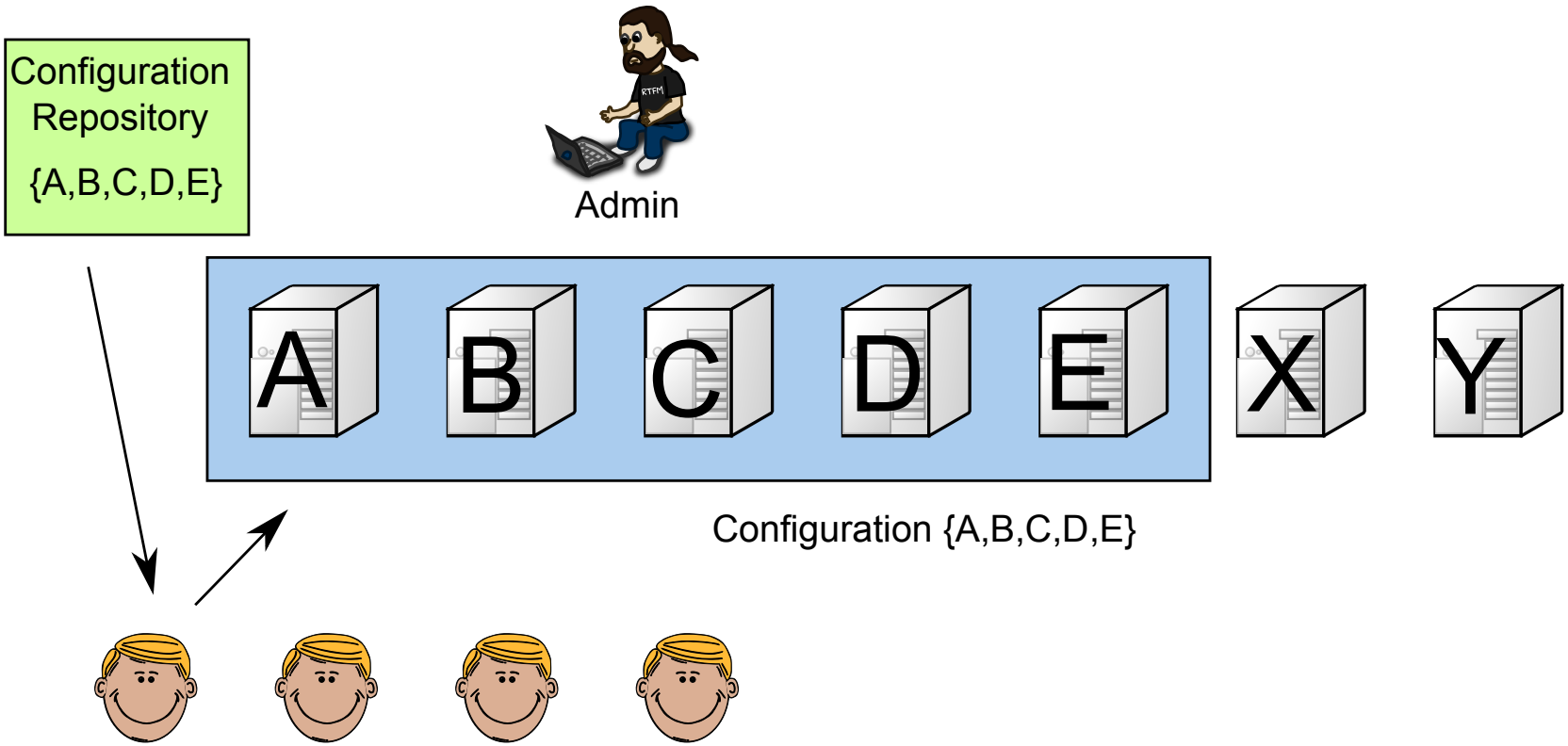


Creating a Replicated State Machine (RSM)

Now replicas communicate directly using the configuration



SMART with Multiple Admins



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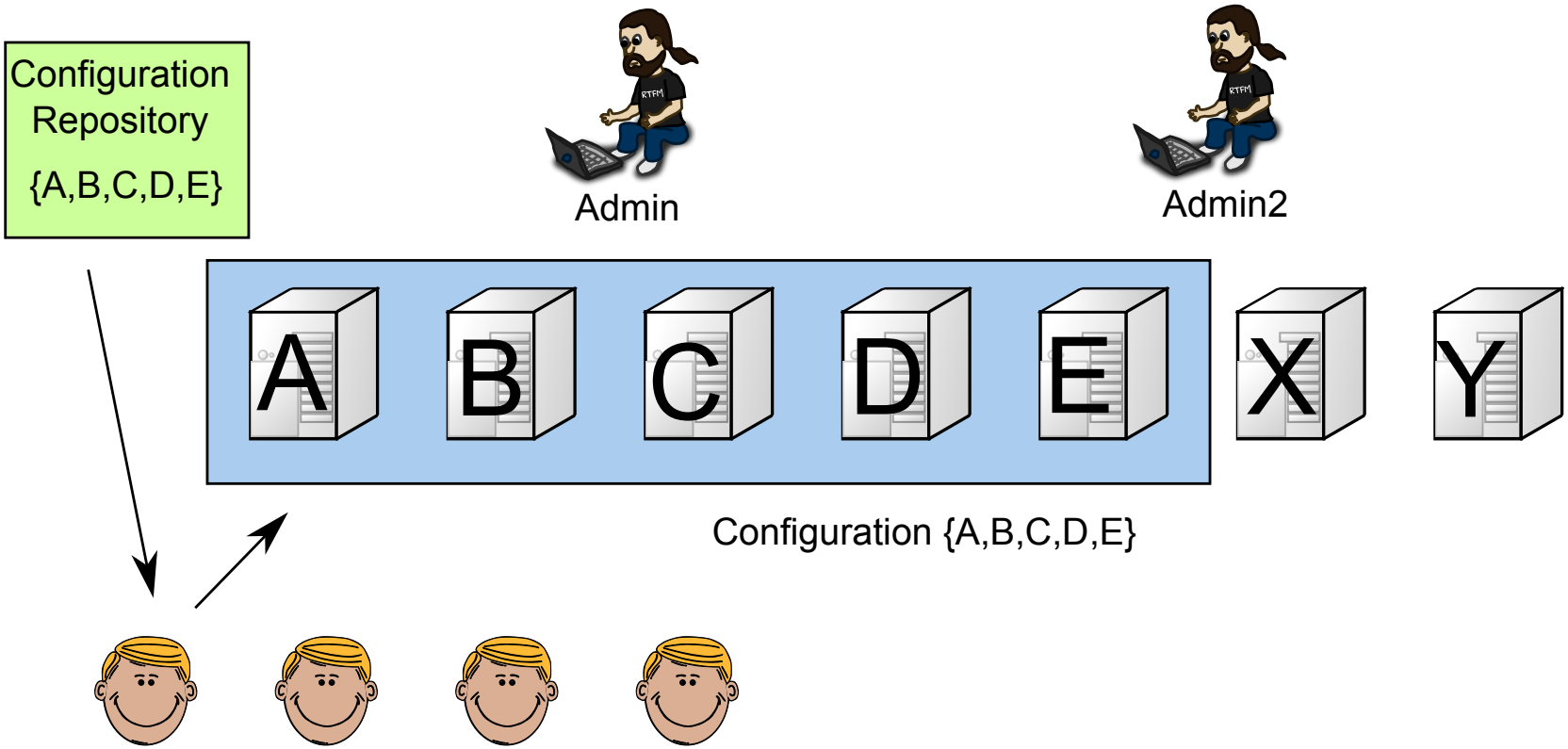

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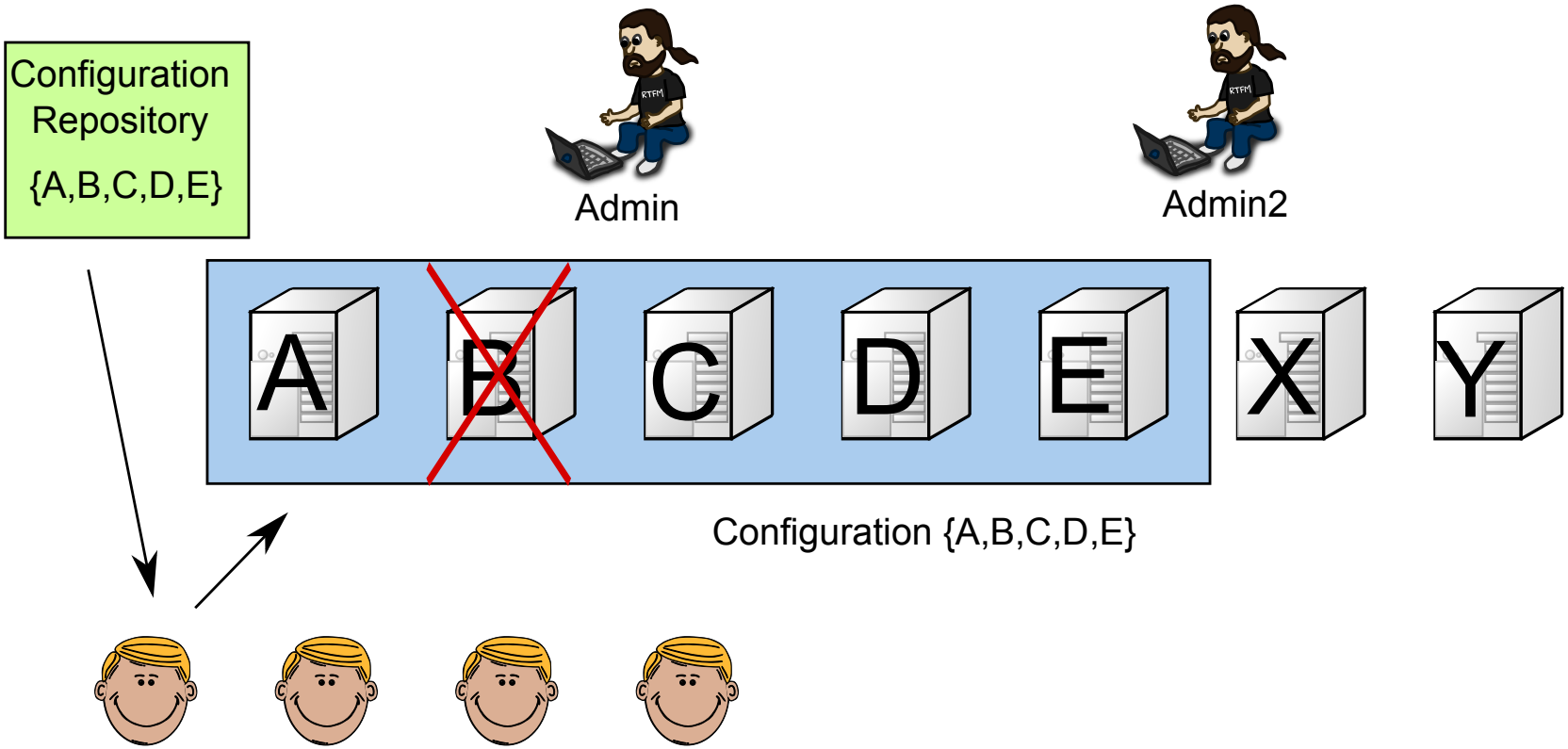

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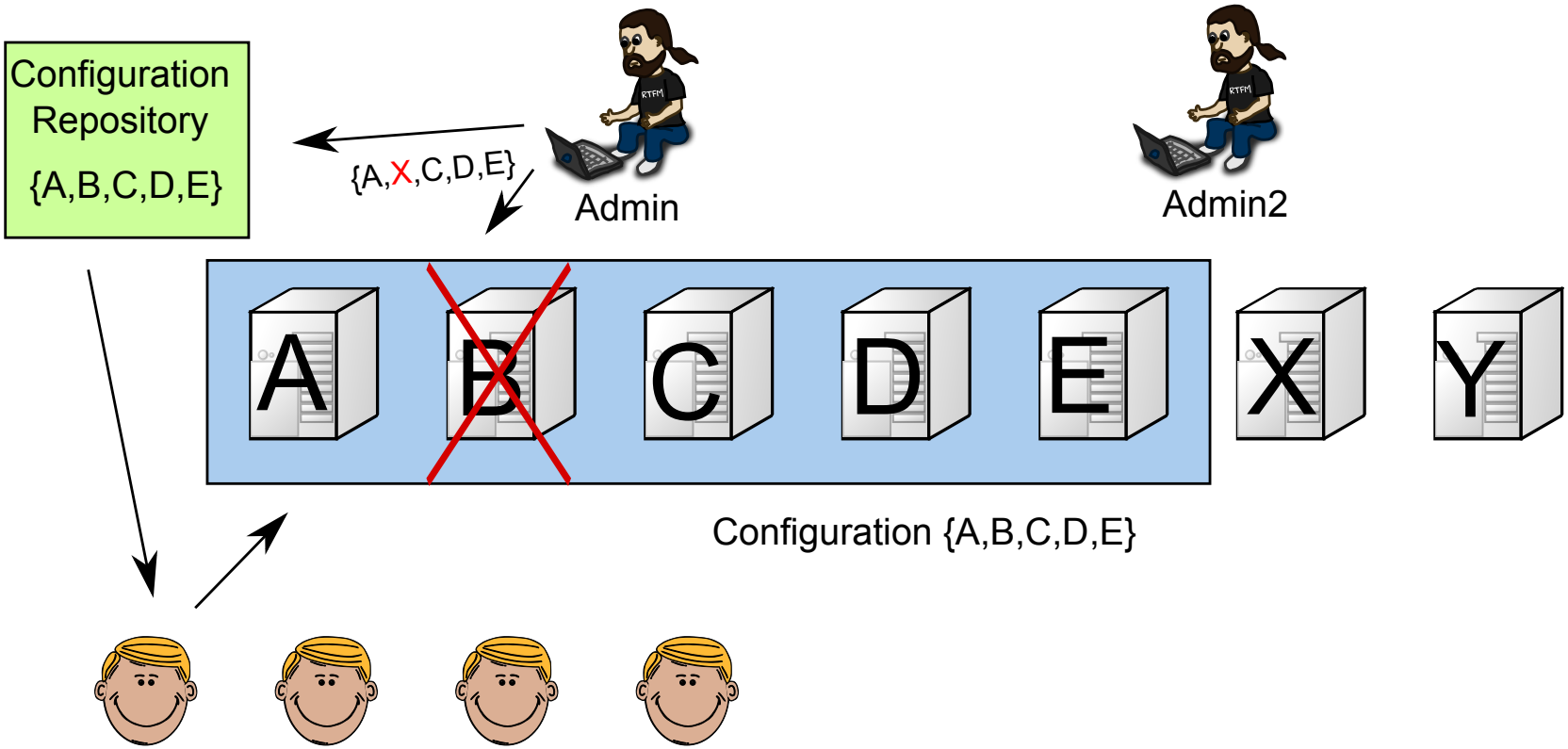

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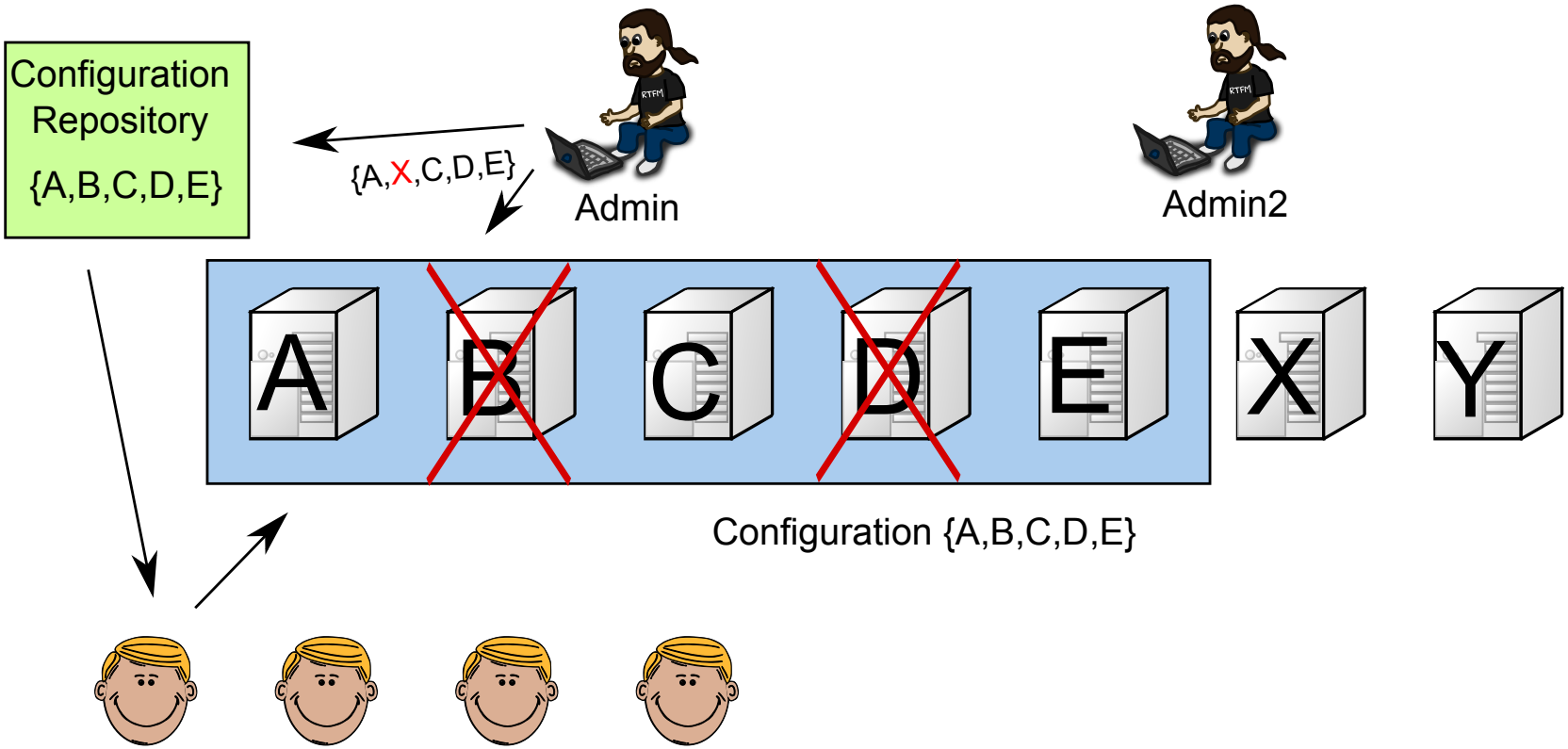

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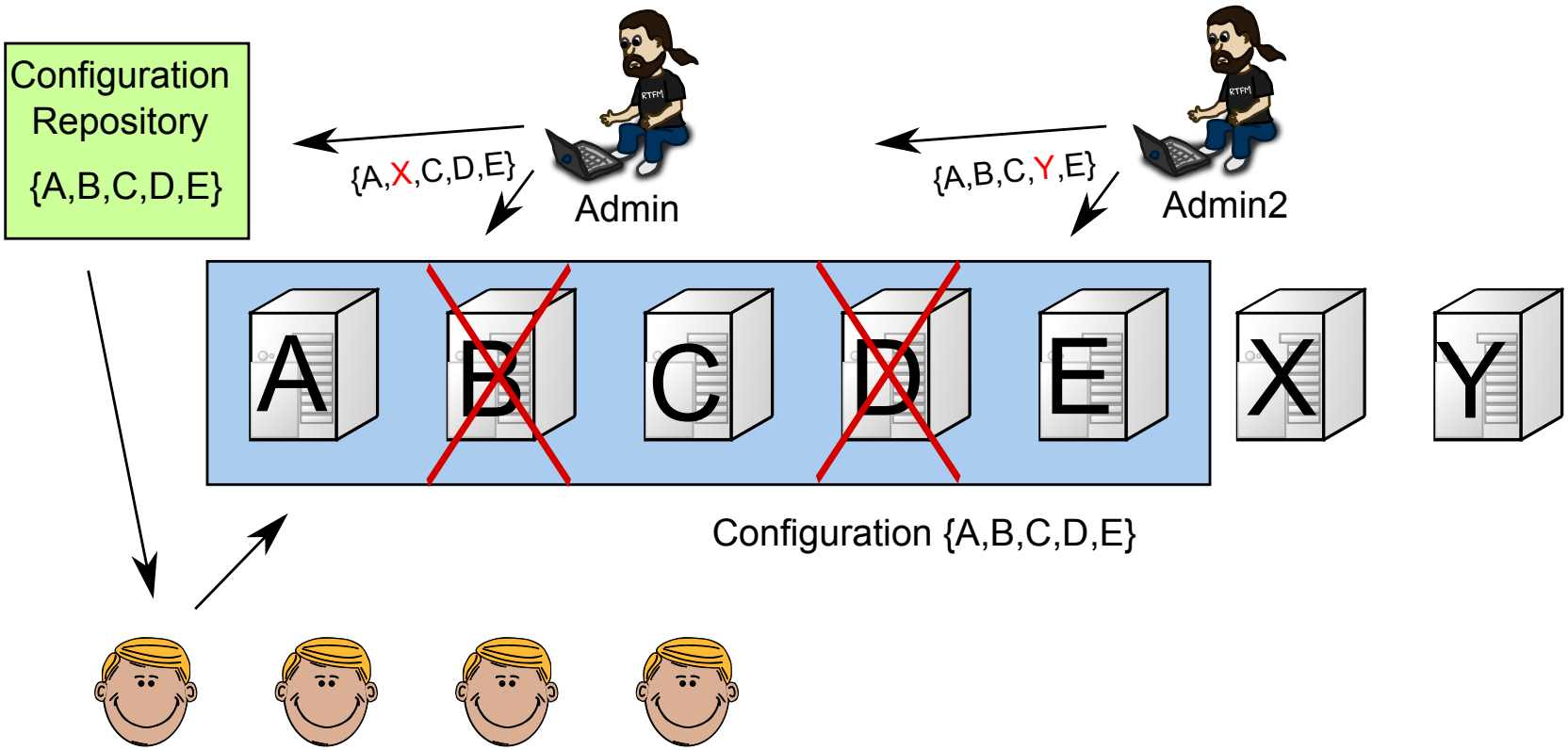

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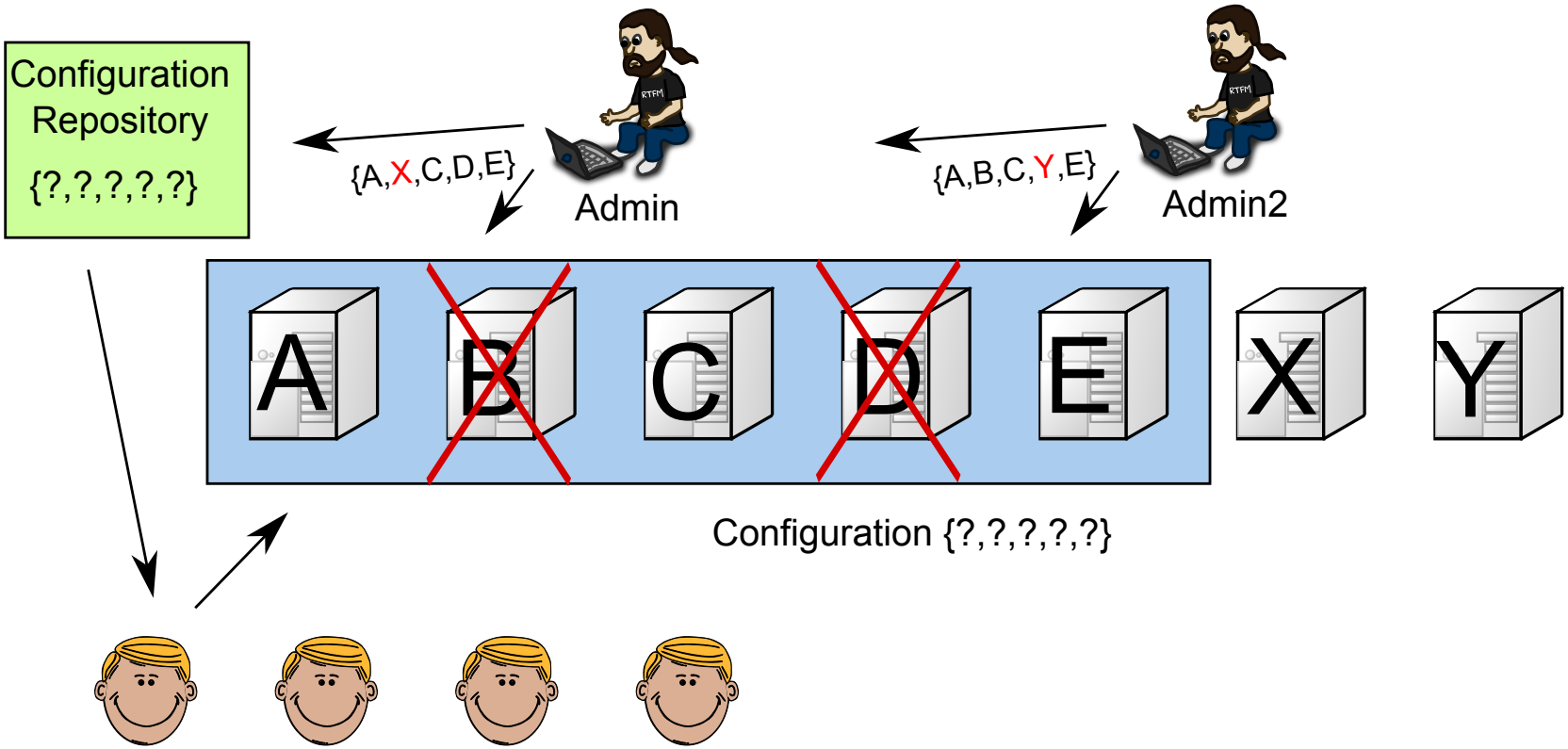

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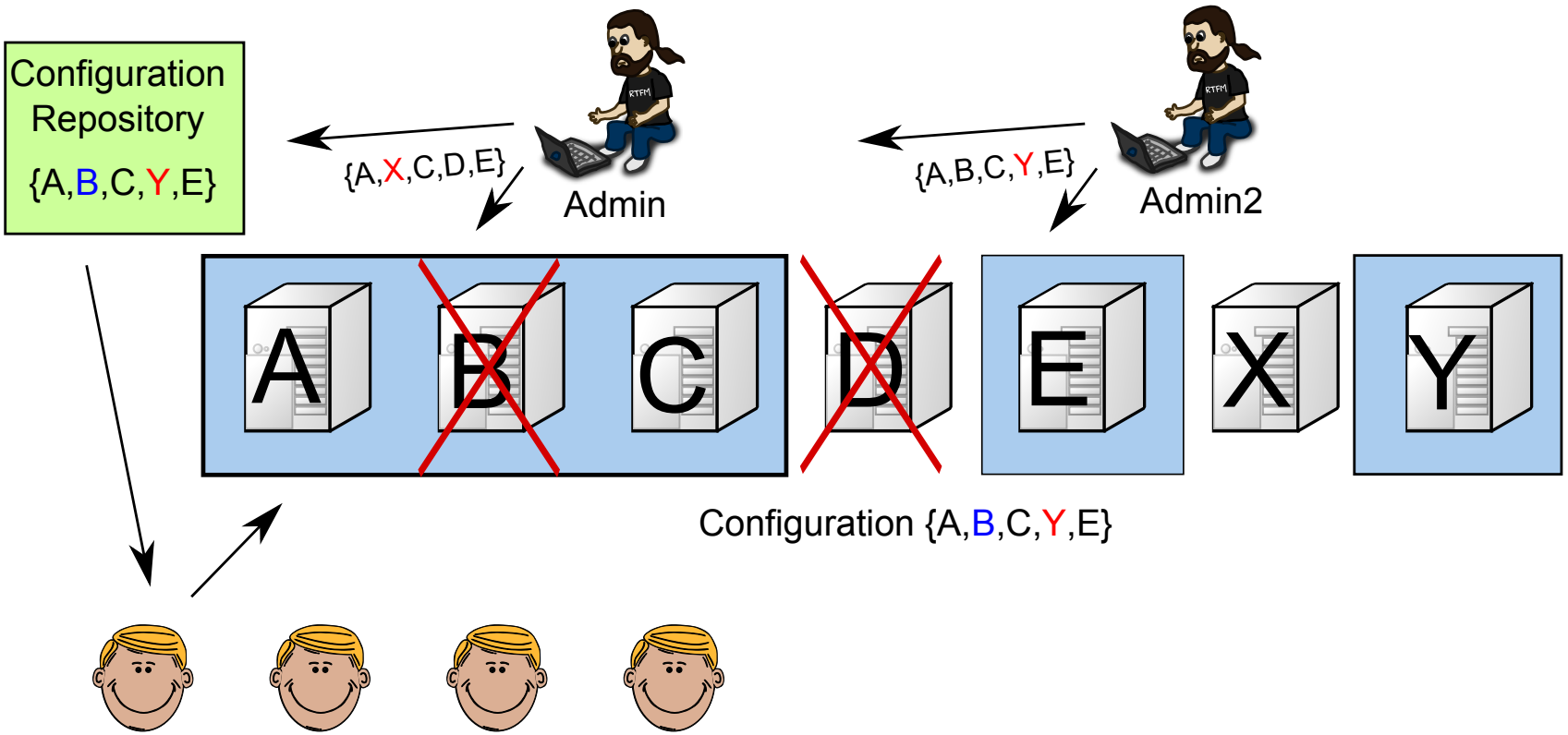

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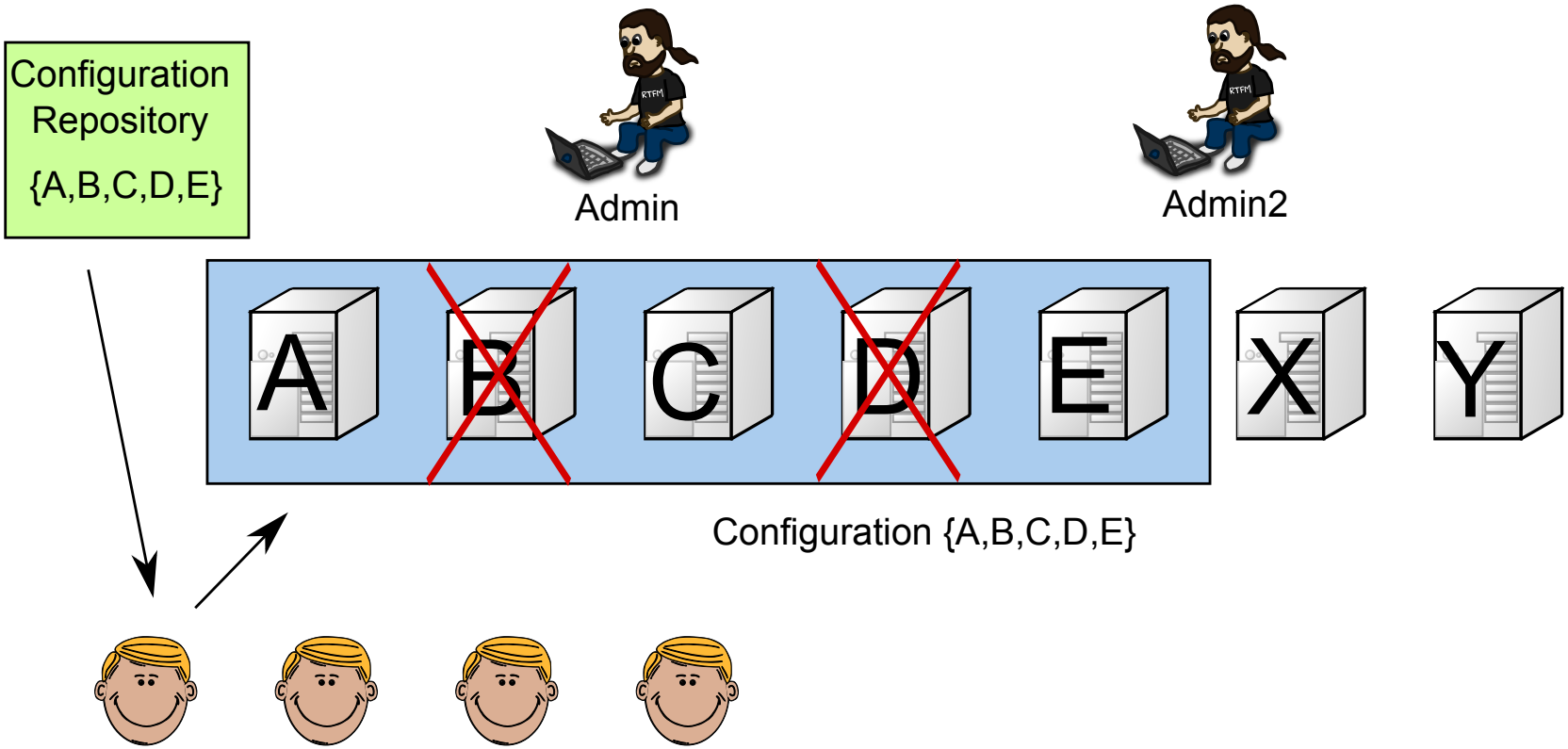

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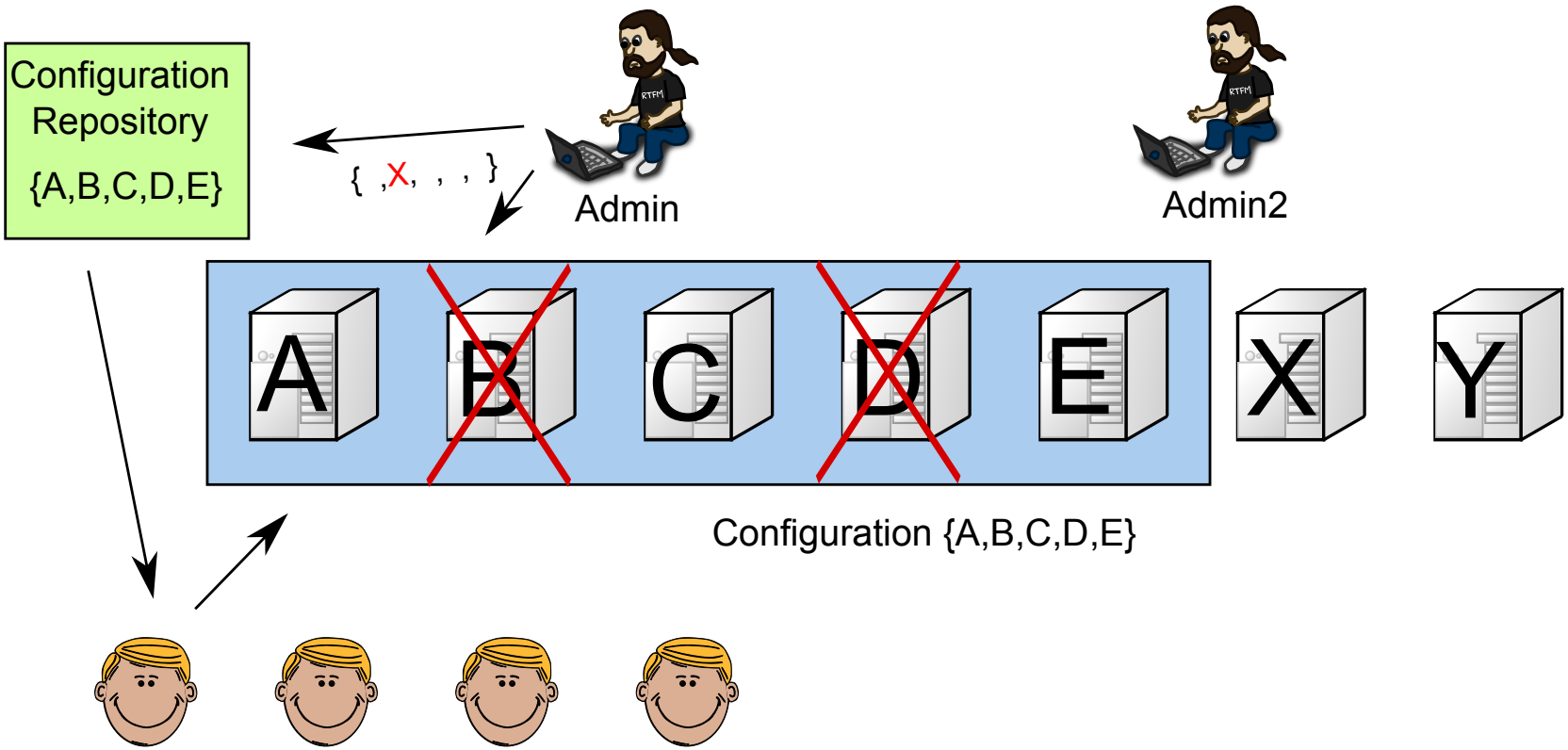

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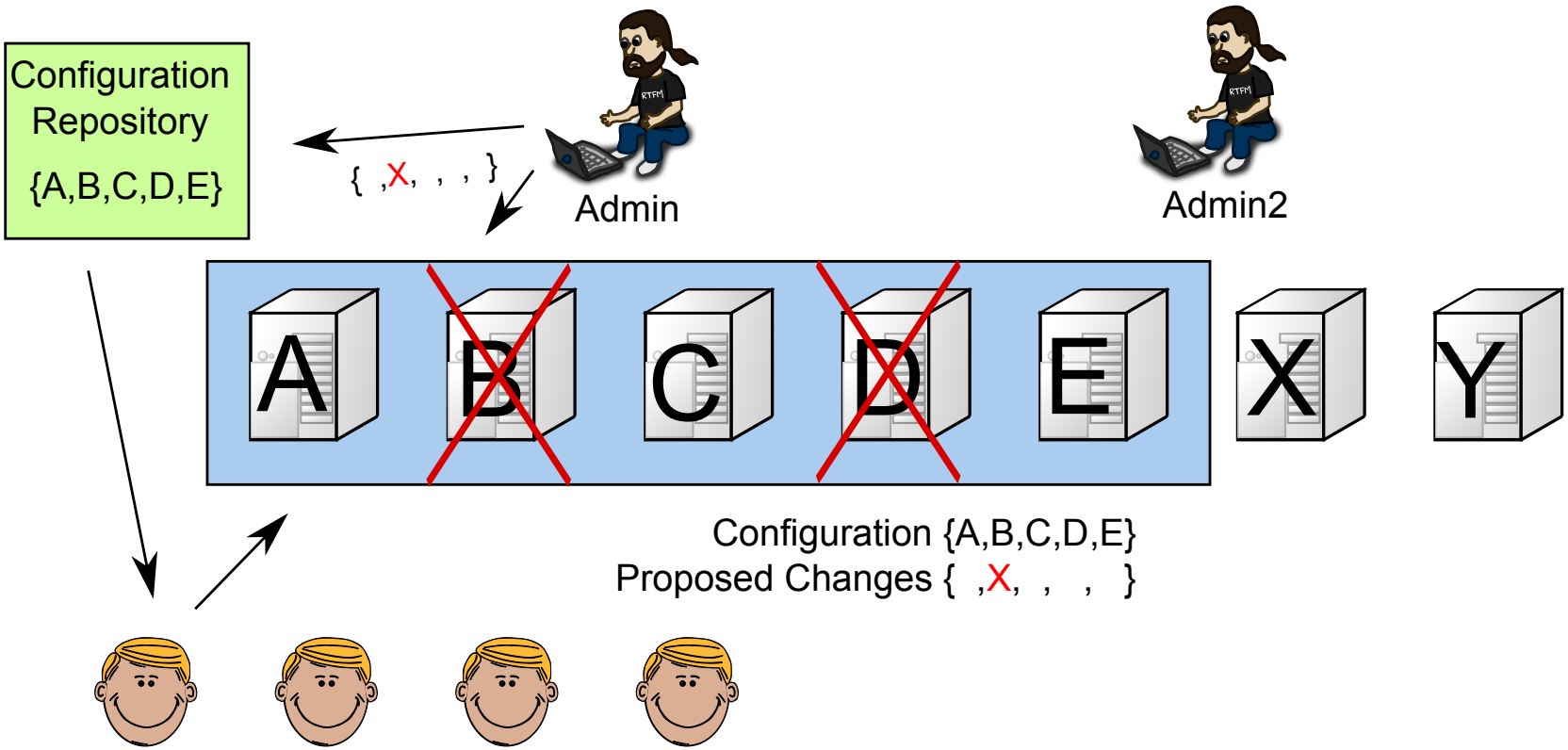

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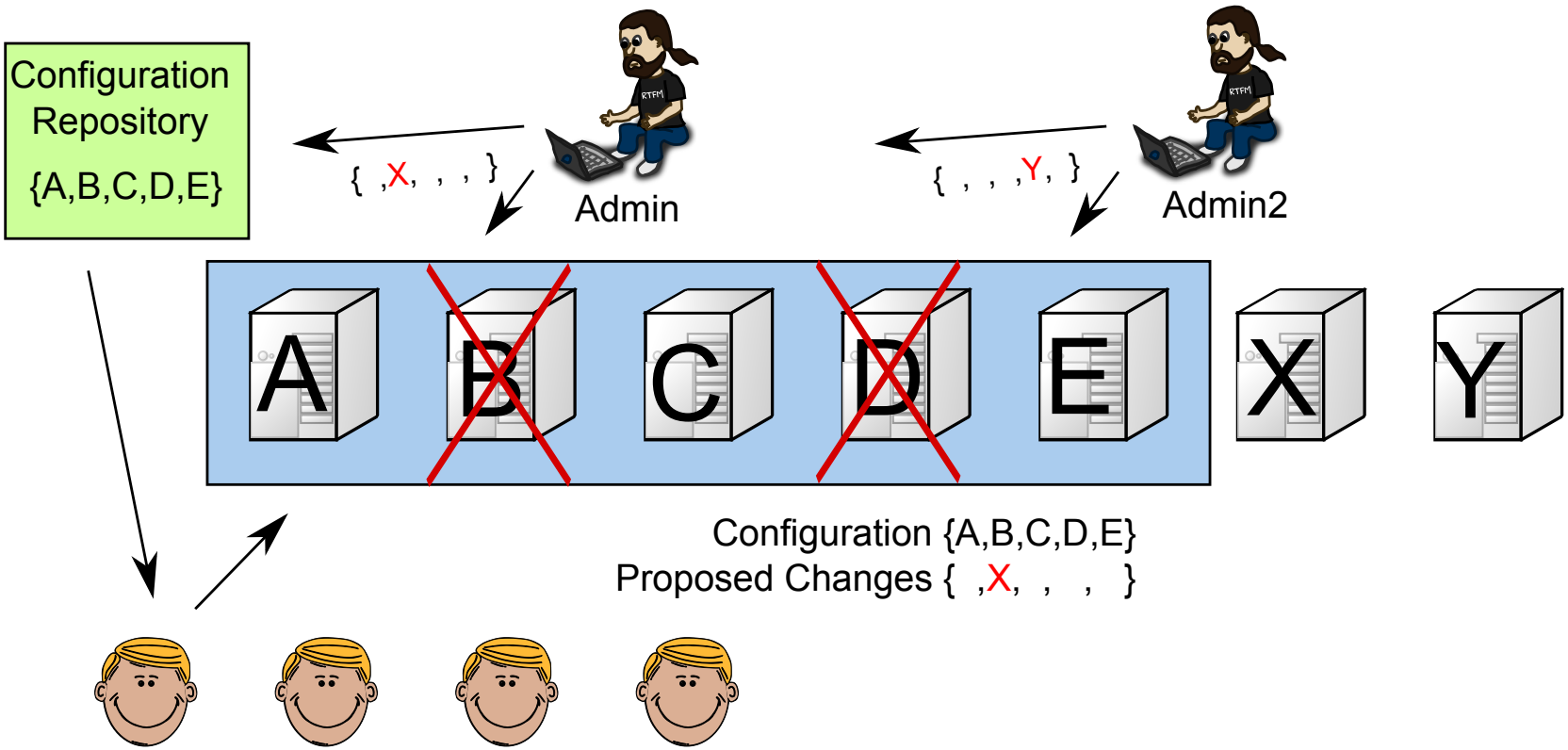

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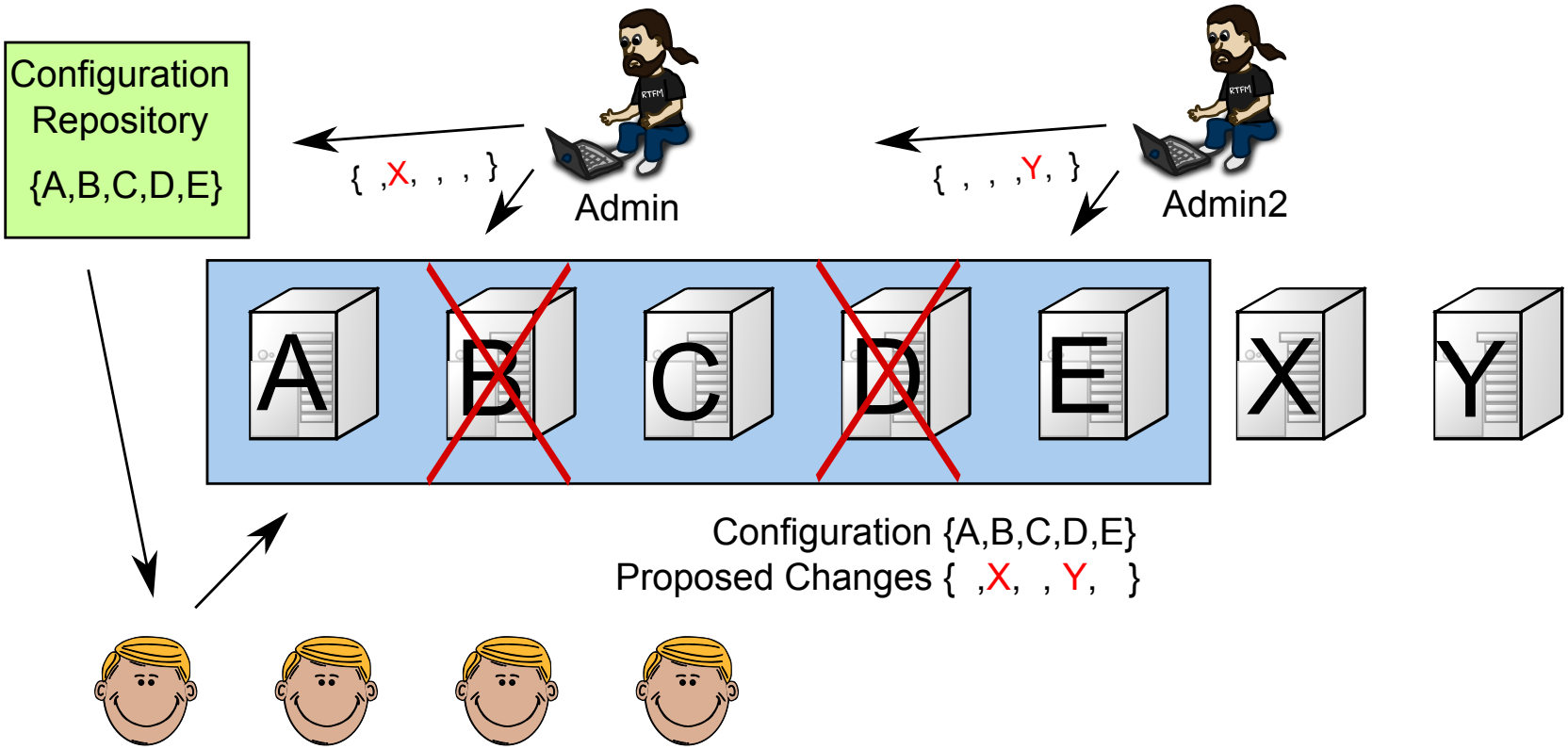

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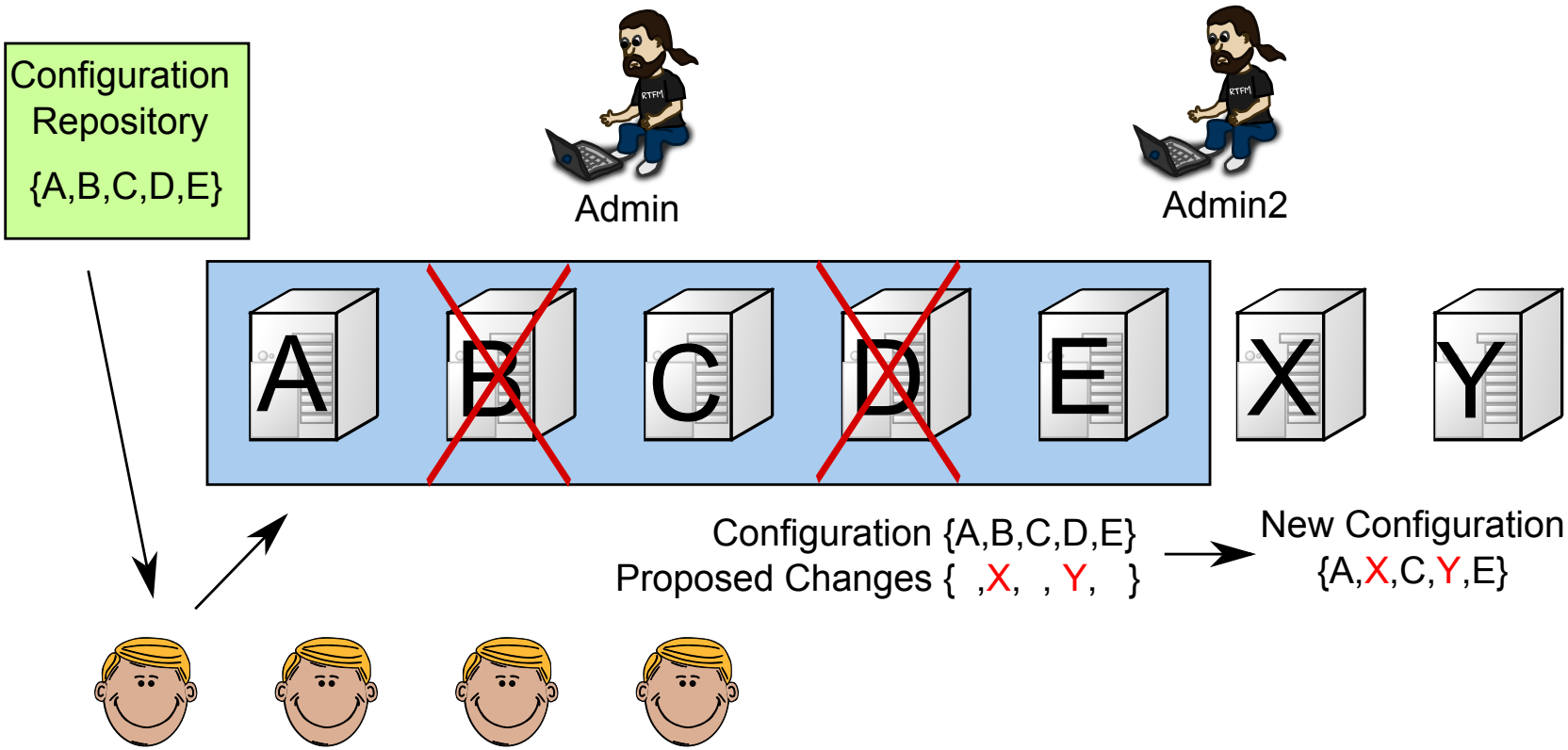

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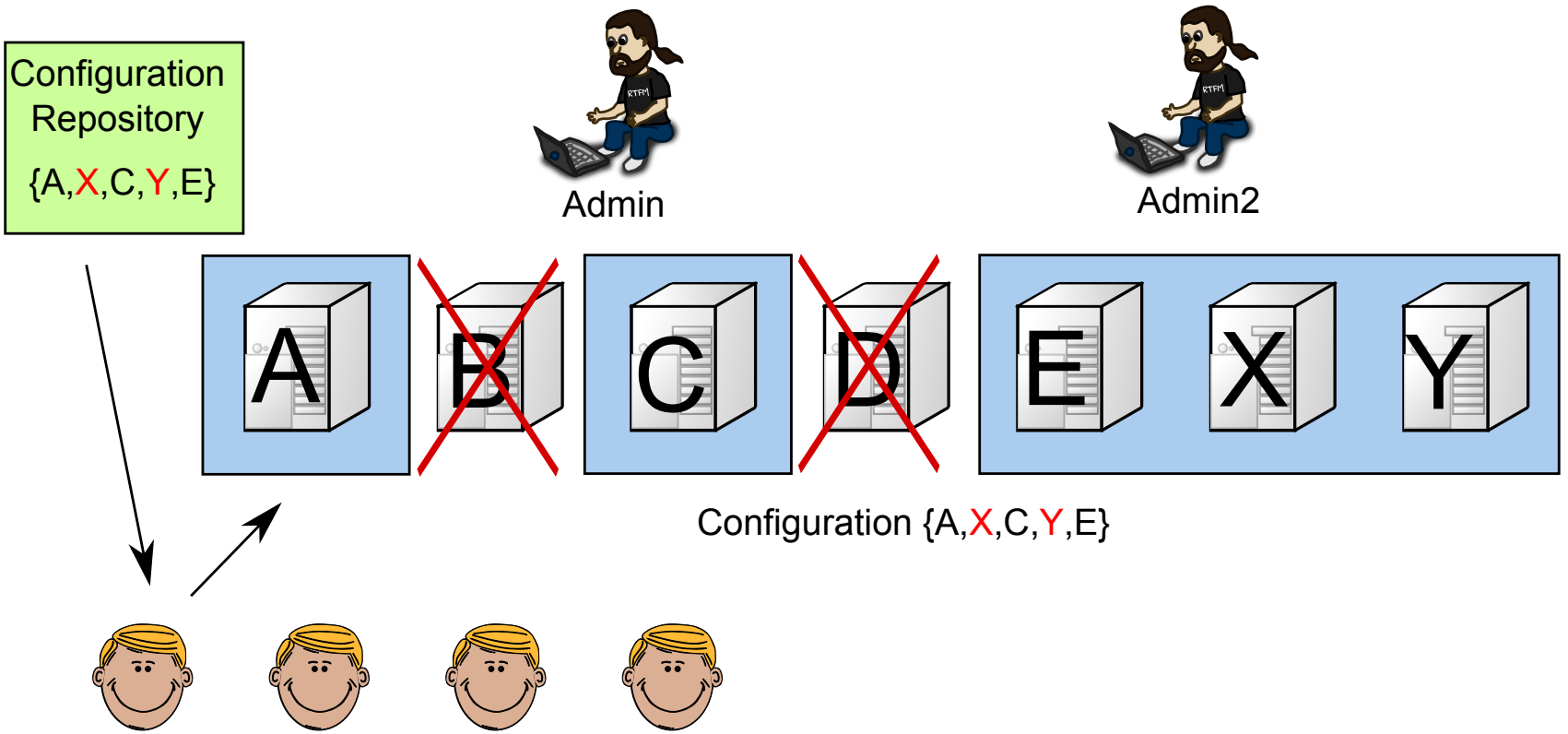
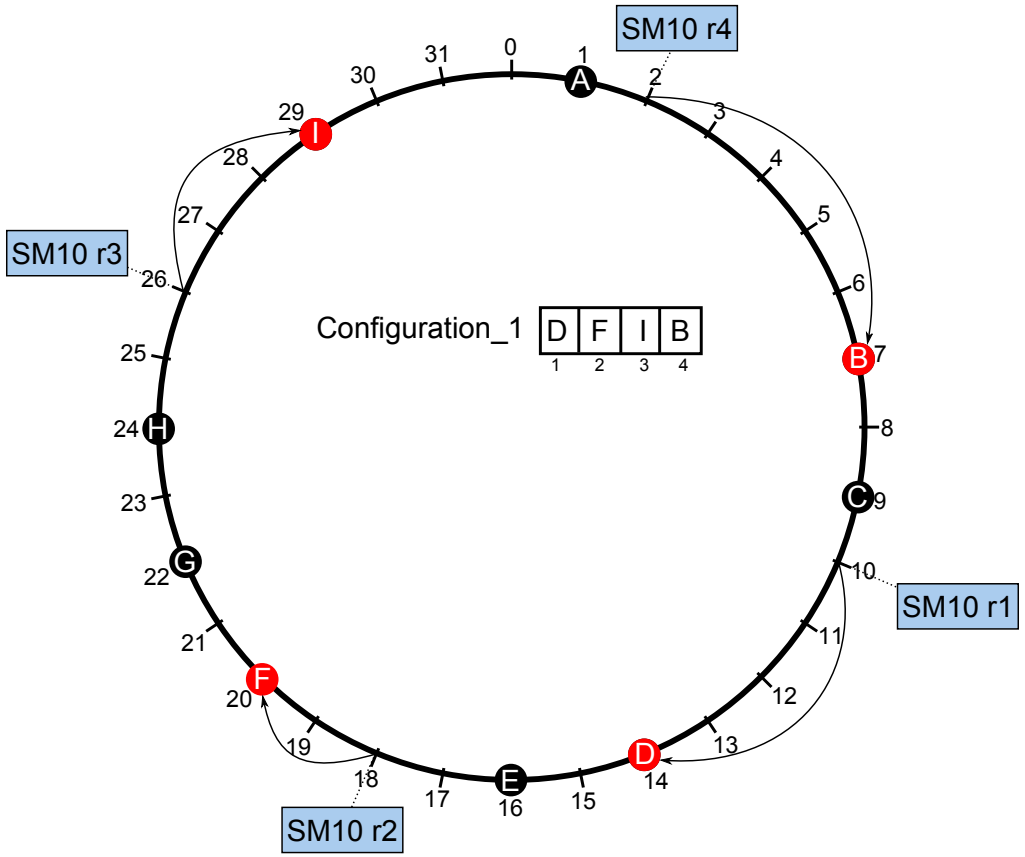
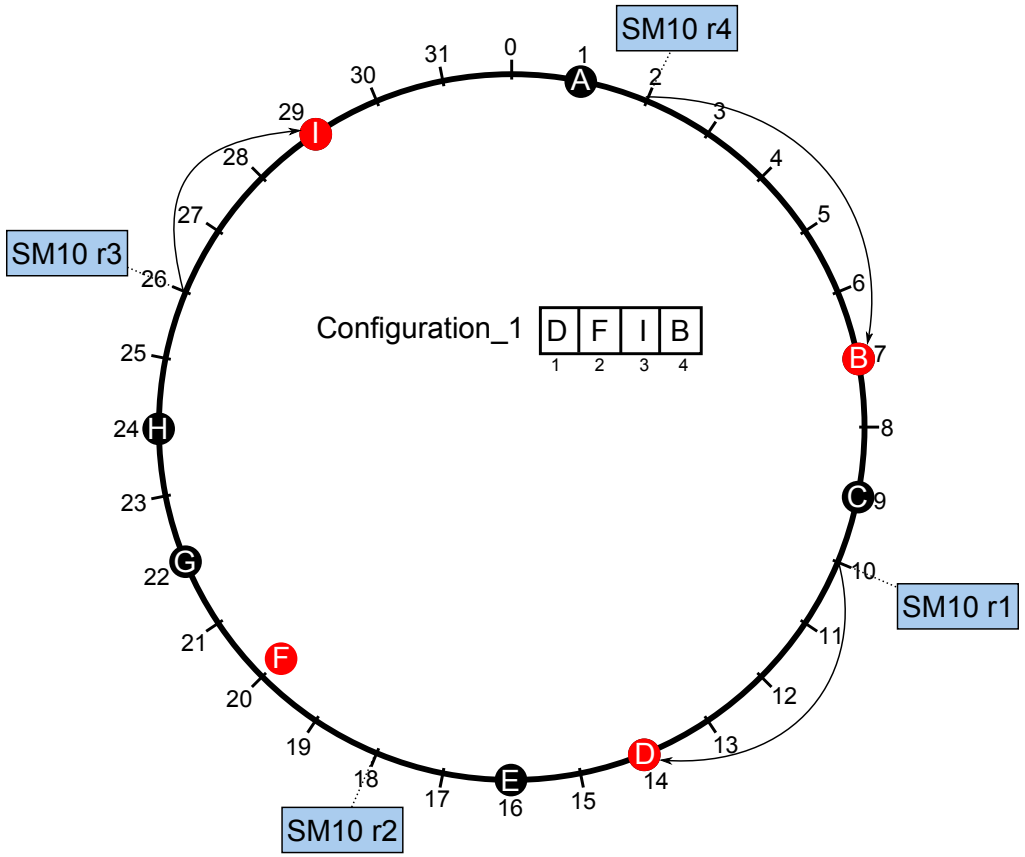


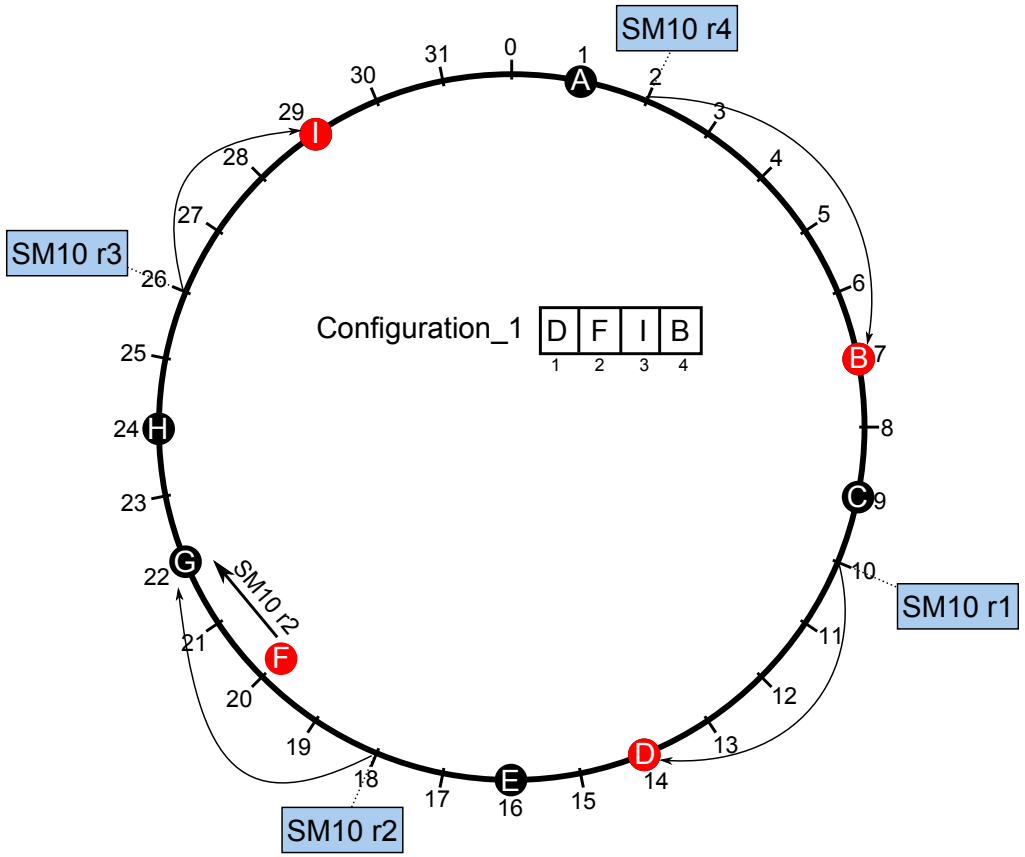
Handling Churn



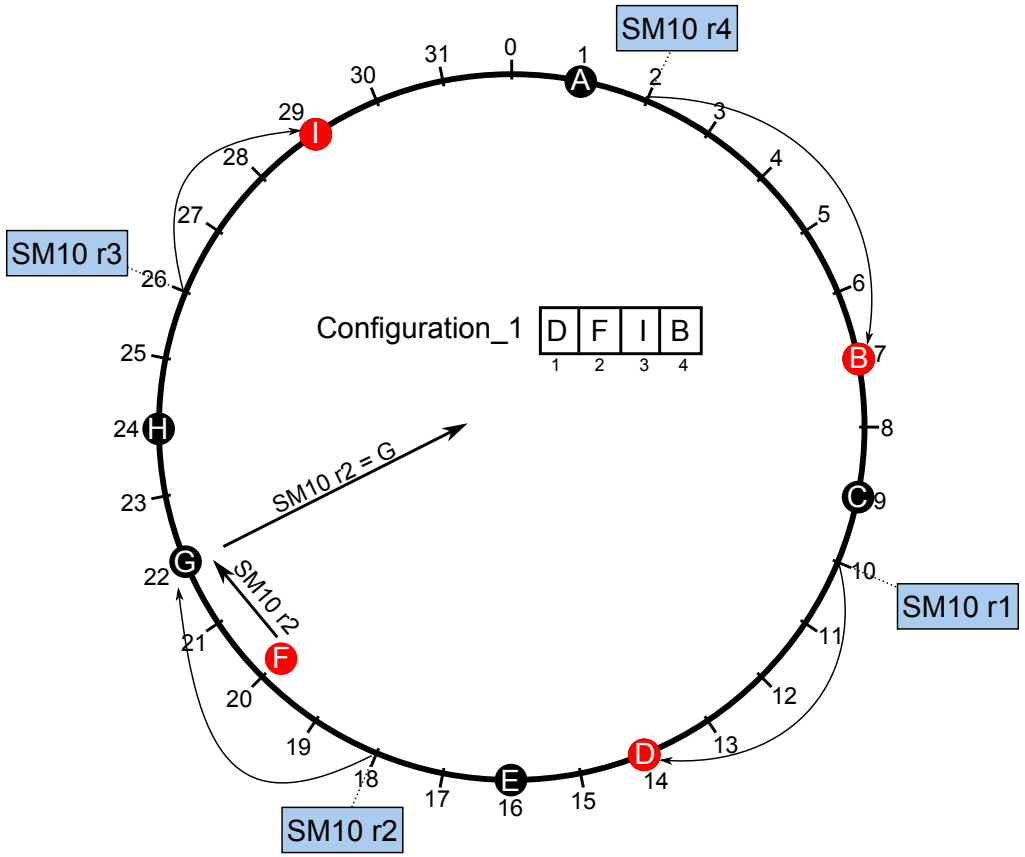
Handling Churn



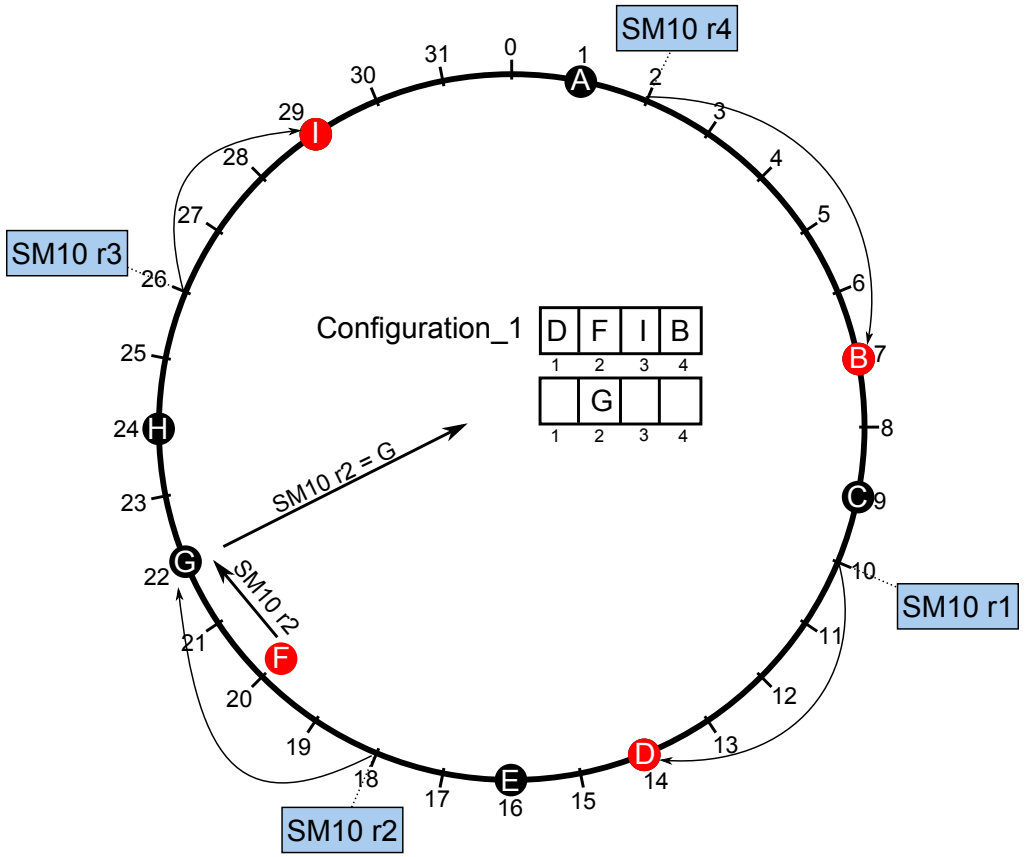
Handling Churn



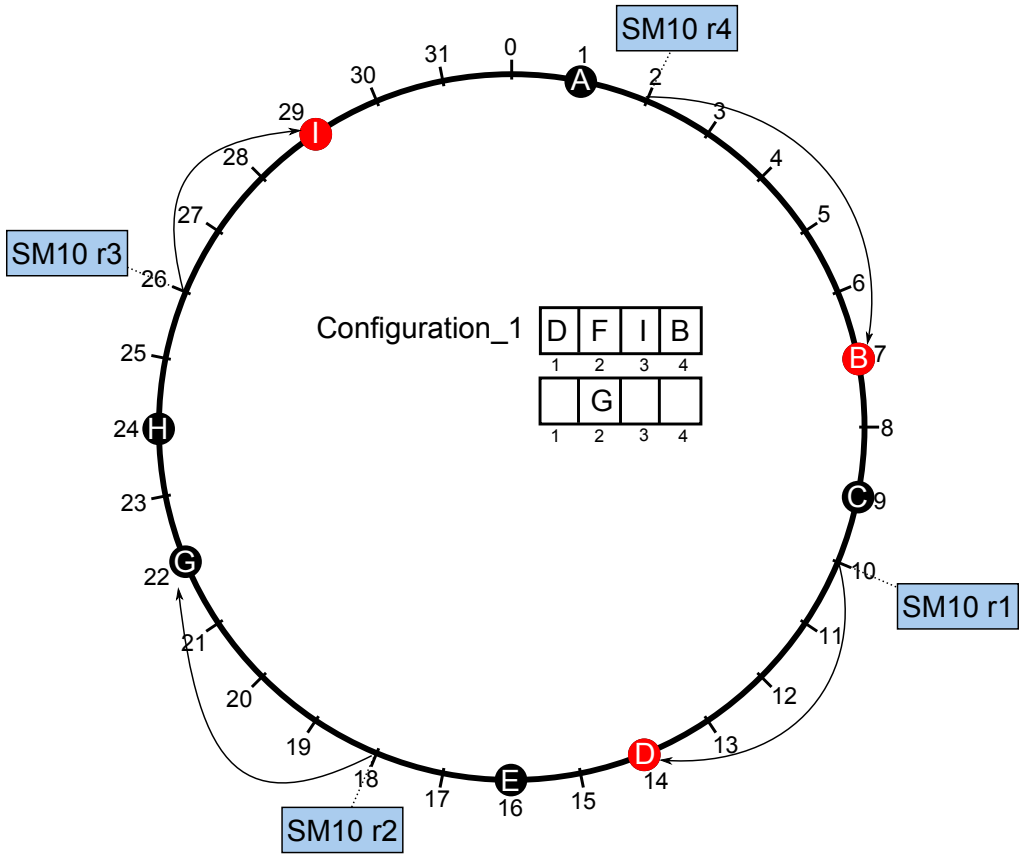
Handling Churn



Handling Churn



Handling Churn



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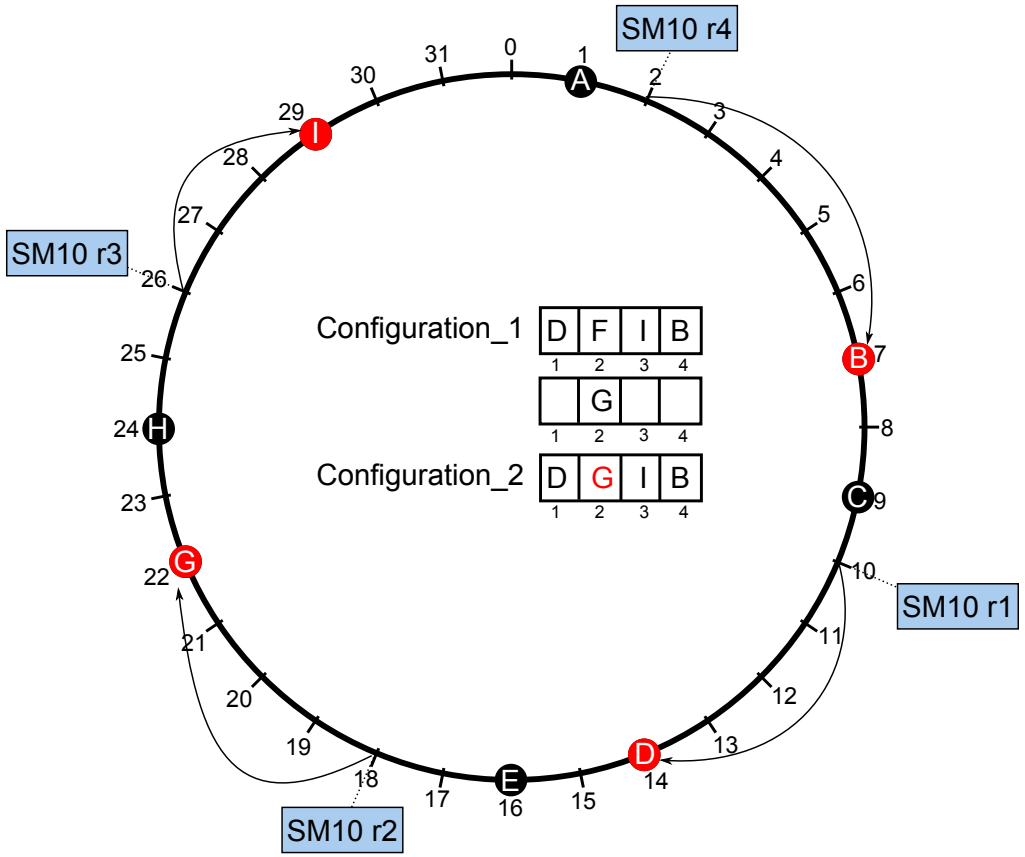

Outline

Improve Management Logic

- Apply control theory to distributed systems
- Distributed optimization
- Reinforcement Learning

Self-Management in Cloud Applications

- Study elastic services in the Cloud
- Develop self-management techniques for Cloud applications
- Integrate all pieces into an elastic storage system