
# Evolution of Financial Exchange Architectures

Martin Thompson - @mjpt777

# 10 years ago…

# Evolution

Design

Resilience

Performance

Deployment

# Design

# State Machines

$$\text{Input} \times \text{State} \rightarrow \text{State}$$

# State Machines

$$\text{Input} \times \text{State} \rightarrow \text{State}$$

$$\text{Input} \times \text{State} \rightarrow \text{Output}$$

# Replicated State Machines

**Ordered Inputs**

**+**

**Deterministic Execution**

**=>**

**Same State & Outputs**

# Distributed Event Log

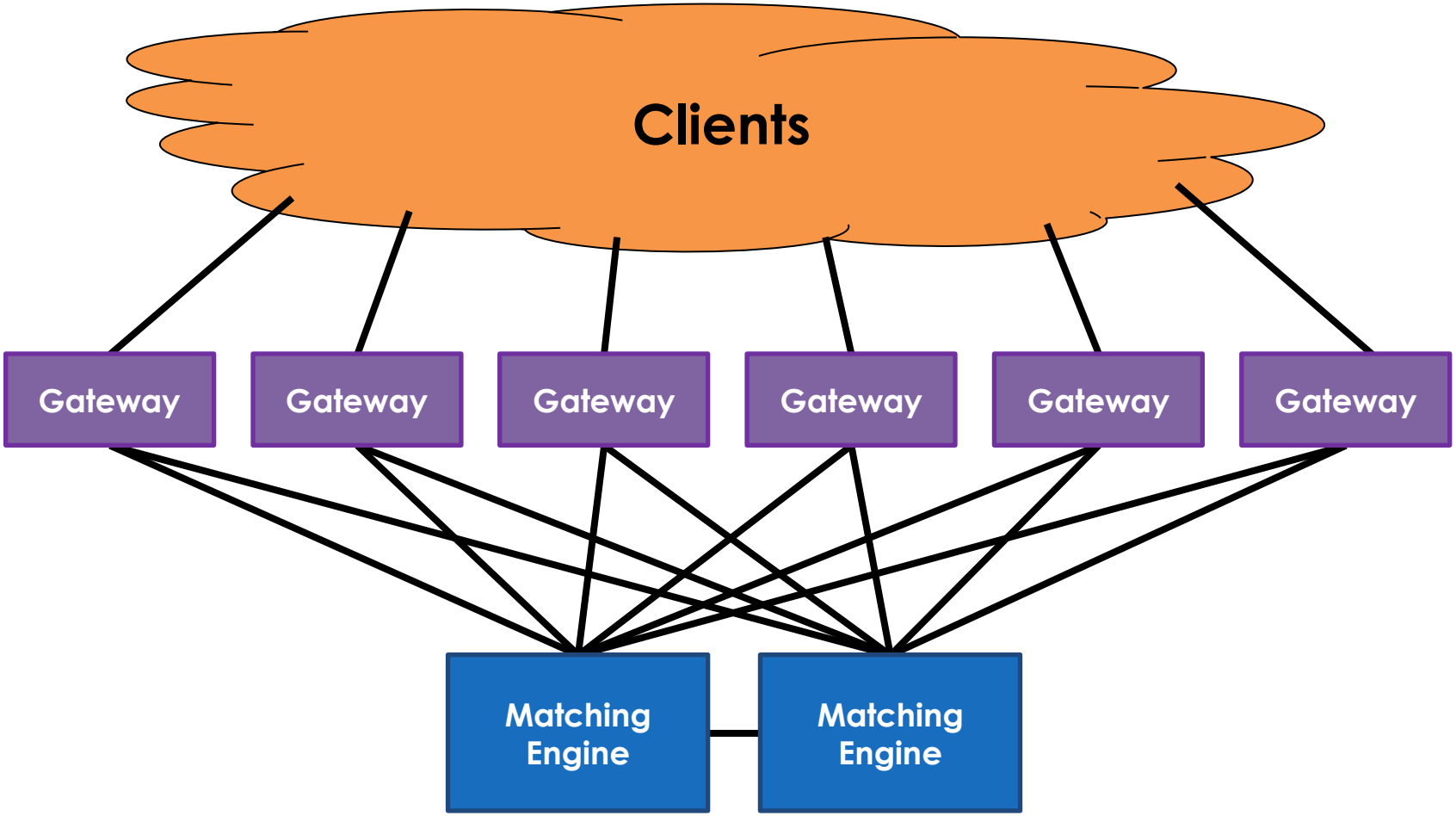
# Rich Domain Models (DDD)

# Rich Domain Models (DDD)

# Data Structures (CS)

# Time & Timers

# Fairness


Clients
Gateway
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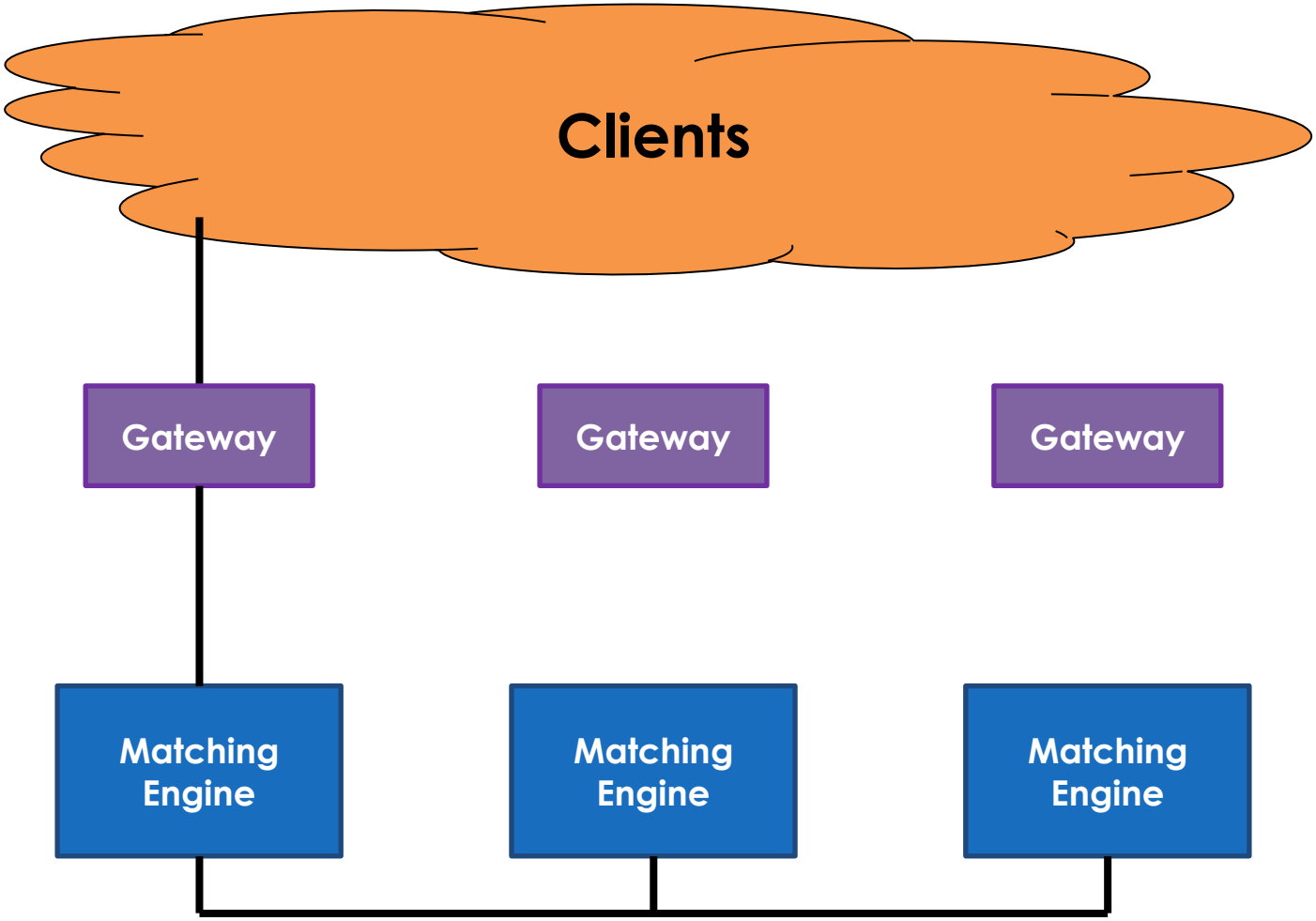
Matching Engine
Matching Engine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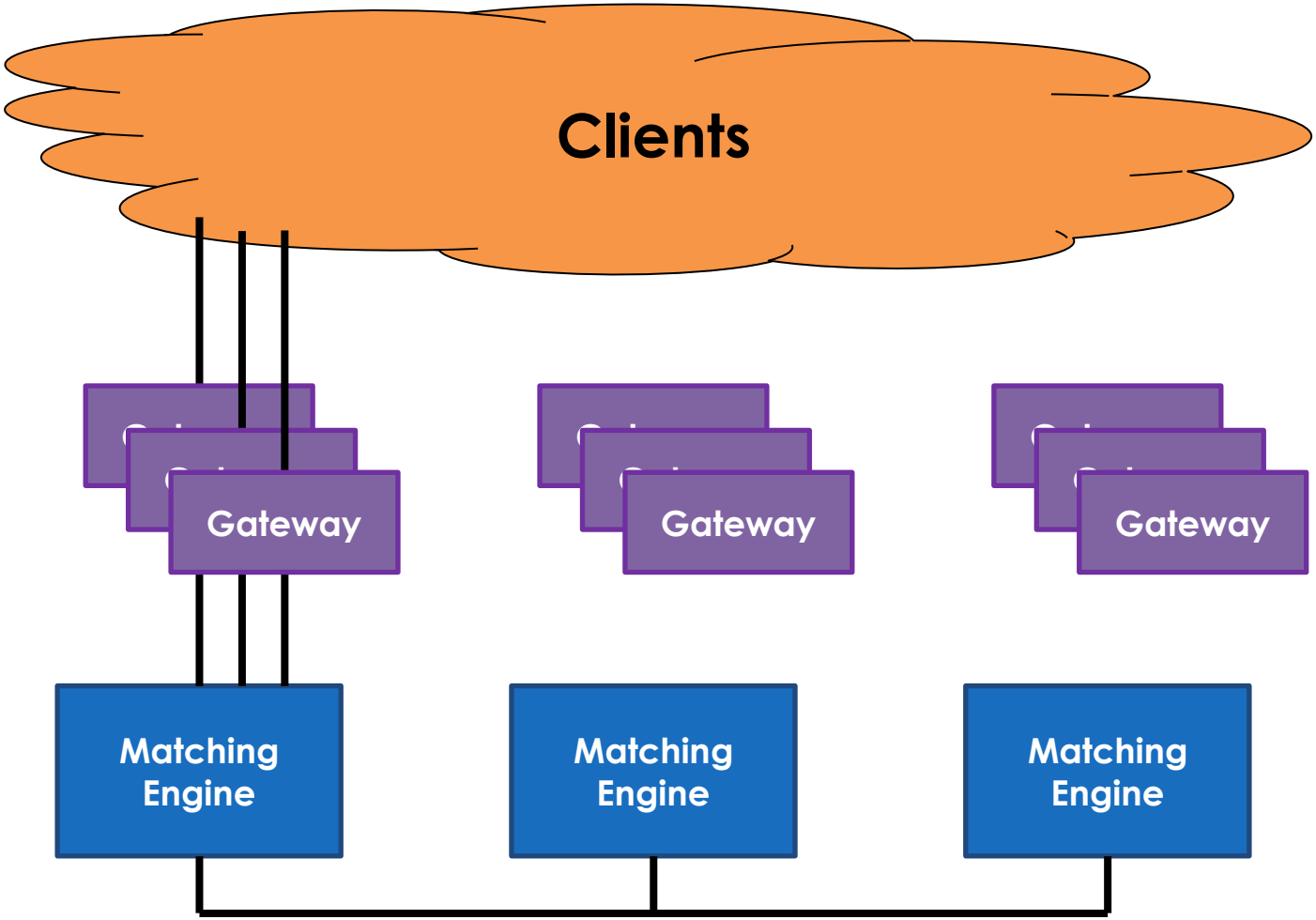
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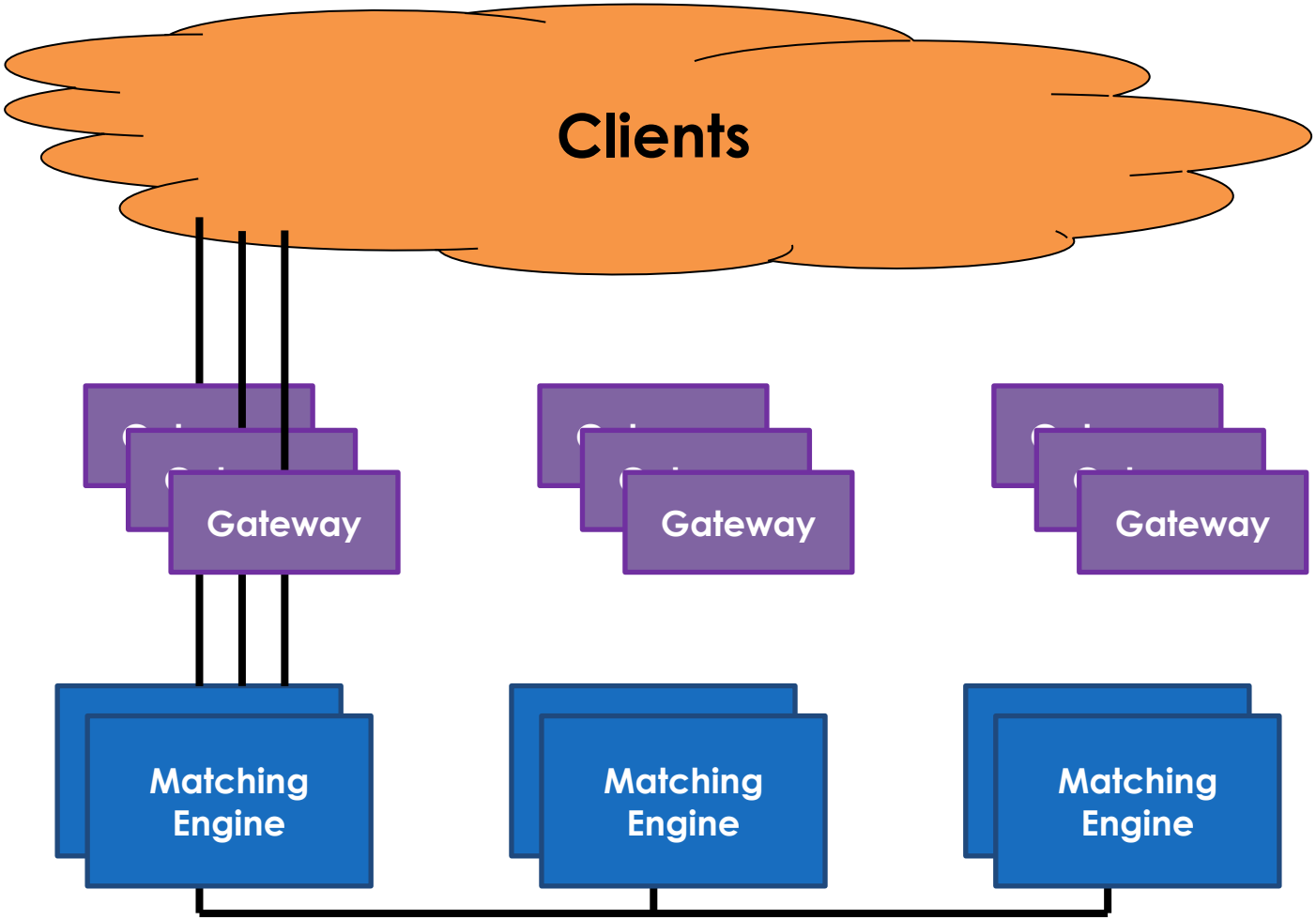

Clients
Gateway
Gateway
Gateway
Matching Engine
Matching Engine
Matching Engine

# Migration by Asset Class

# OTC => Exchange Traded

# Resilience

# Fault Tolerance

# Fault Tolerance

*Primary + Secondary*

*vs*

*Consensus*

*Leslie Lamport - Paxos*

*Barbara Liskov - Viewstamp Replication*

*Ken Birman - Virtual Synchrony*

https://raft.github.io/raft.pdf

# In Search of an Understandable Consensus Algorithm (Extended Version)

Diego Ongaro and John Ousterhout
Stanford University

## Abstract

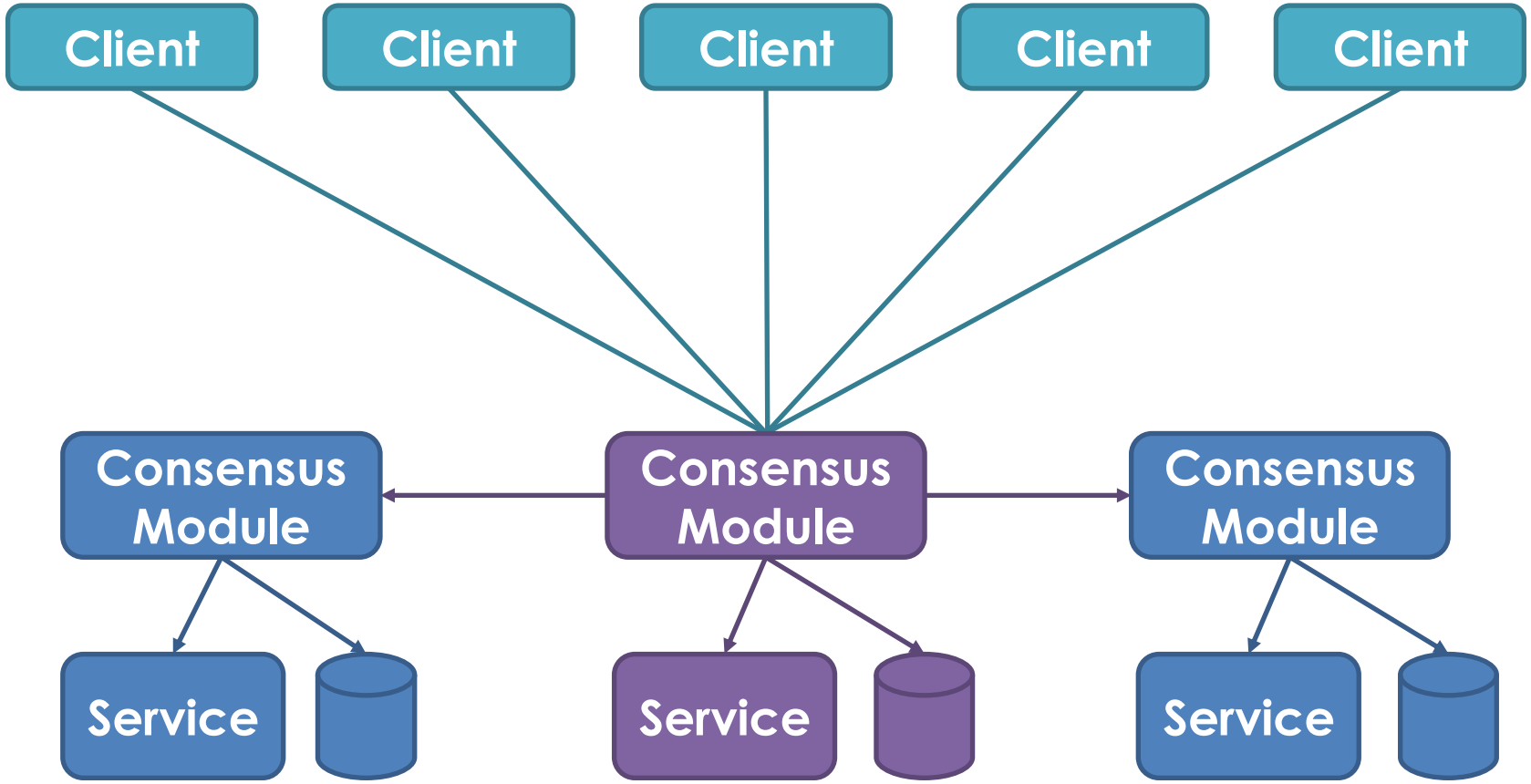
Raft is a consensus algorithm for managing a replicated log. It produces a result equivalent to (multi-)Paxos, and it is as efficient as Paxos, but its structure is different from Paxos; this makes Raft more understandable than Paxos and also provides a better foundation for building practical systems. In order to enhance understandability, Raft separates the key elements of consensus, such as leader election, log replication, and safety, and it enforces a stronger degree of coherency to reduce the number of states that must be considered. Results from a user study demonstrate that Raft is easier for students to learn than state space reduction (relative to Paxos, Raft reduces the degree of nondeterminism and the ways servers can be inconsistent with each other). A user study with 43 students at two universities shows that Raft is significantly easier to understand than Paxos: after learning both algorithms, 33 of these students were able to answer questions about Raft better than questions about Paxos.

Raft is similar in many ways to existing consensus algorithms (most notably, Oki and Liskov's Viewstamped Replication [29, 22]), but it has several novel features:

- **Strong leader:** Raft uses a stronger form of leadership than other consensus algorithms. For example,

# Raft Safety Guarantees

- Election Safety
- Leader Append-Only
- Log Matching
- Leader Completeness
- State Machine Safety


Client
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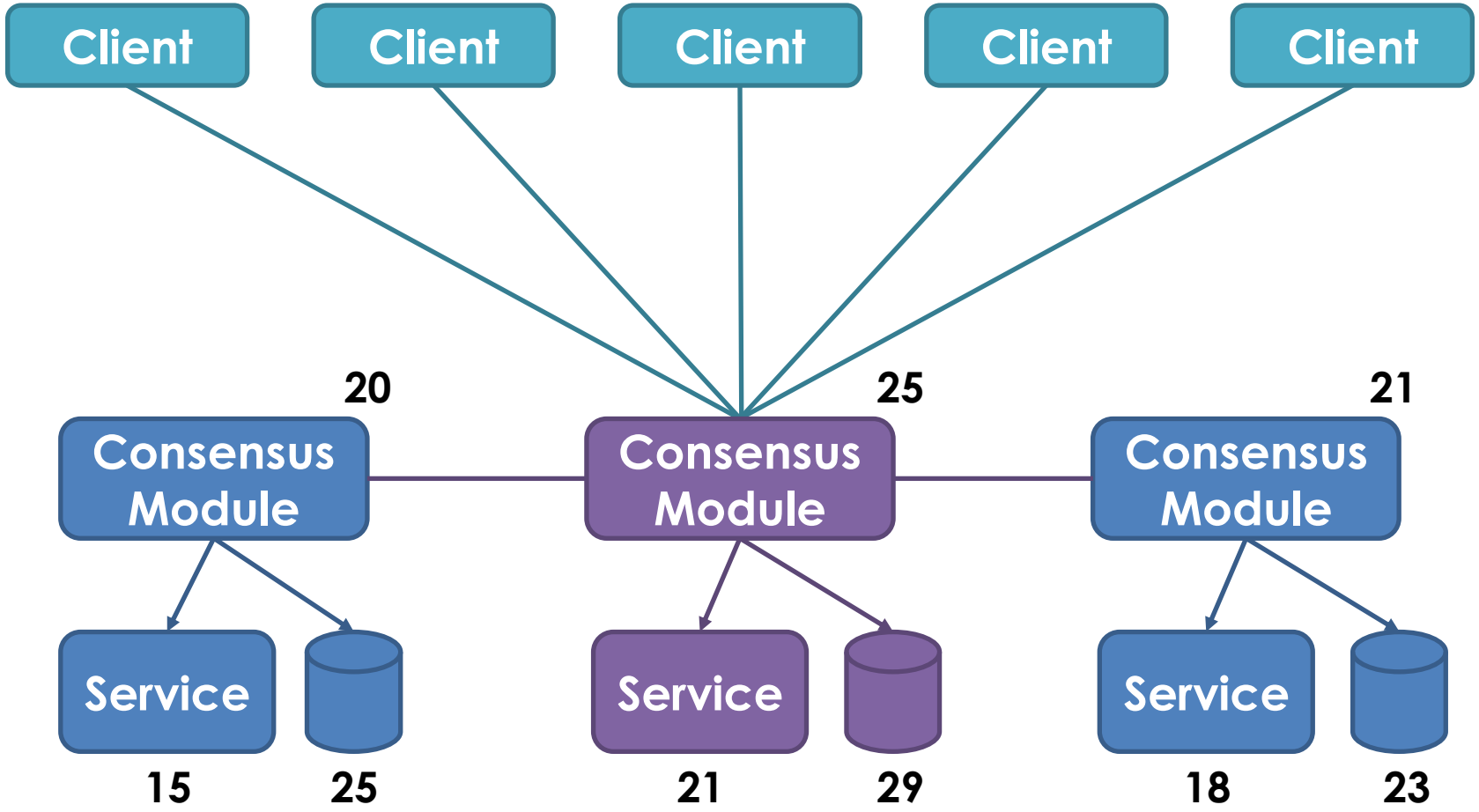
Consensus Module
Consensus Module
Consensus Module
Service
Service
Service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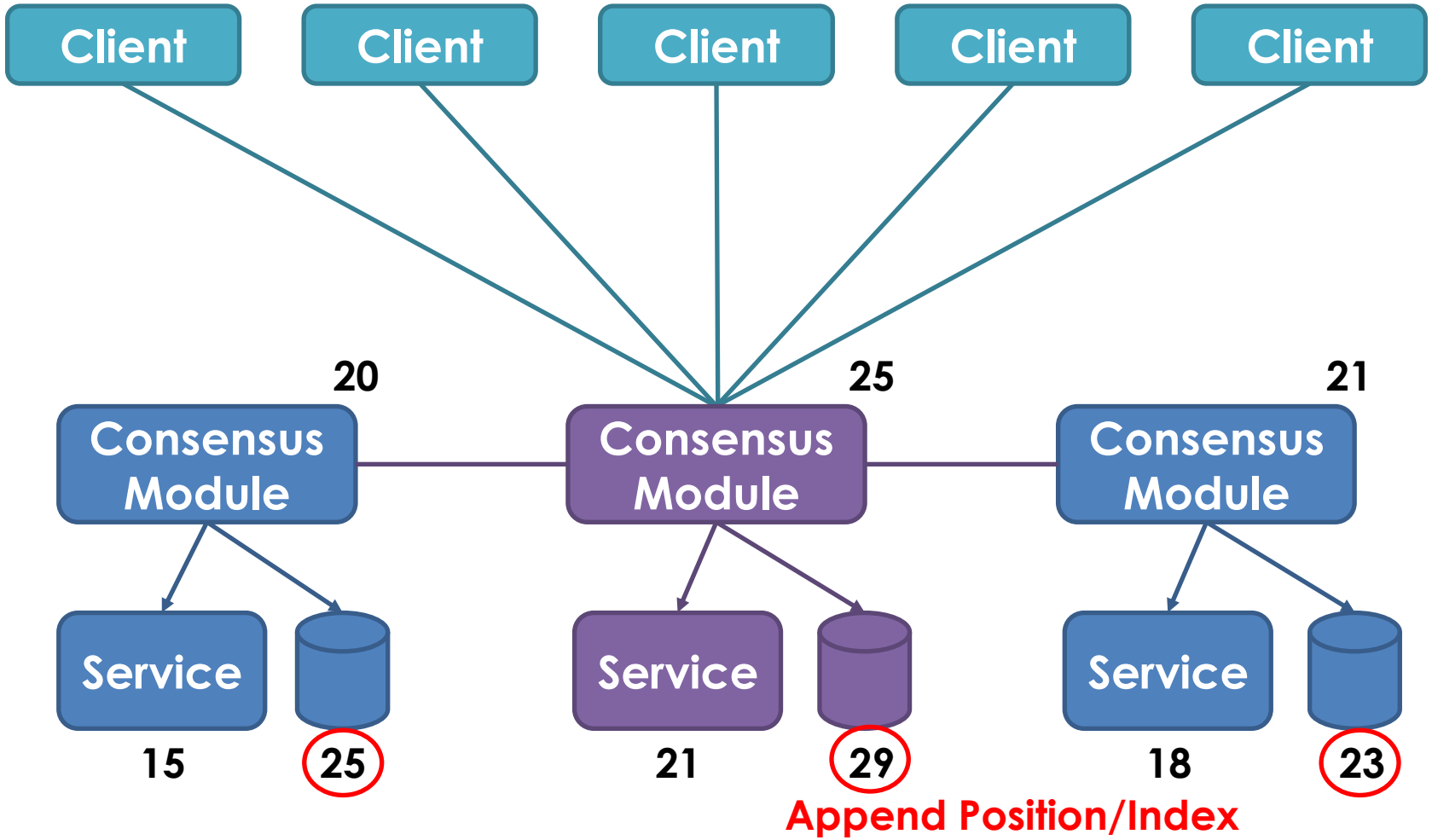
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Consensus Module
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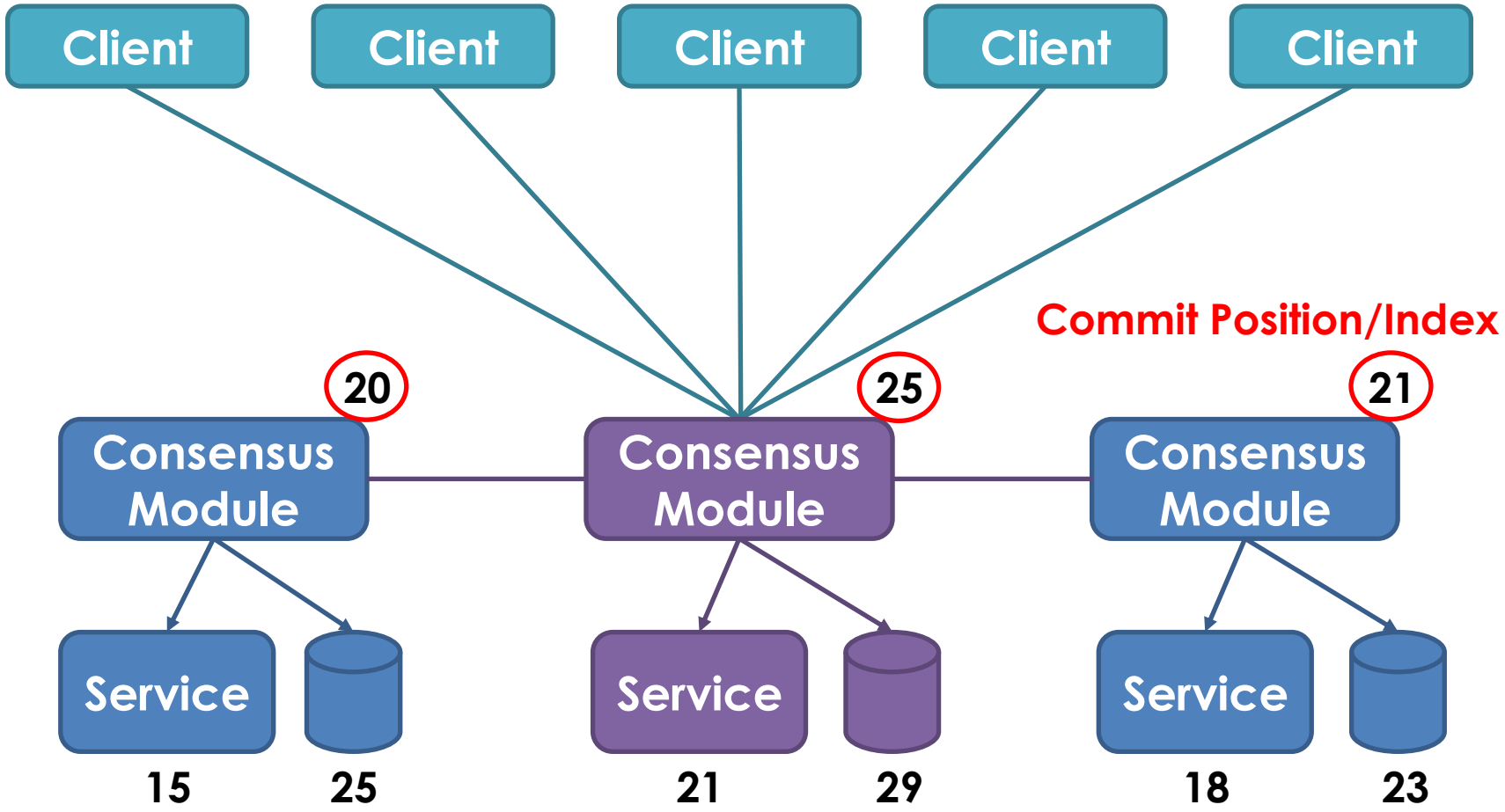
Append Position/Index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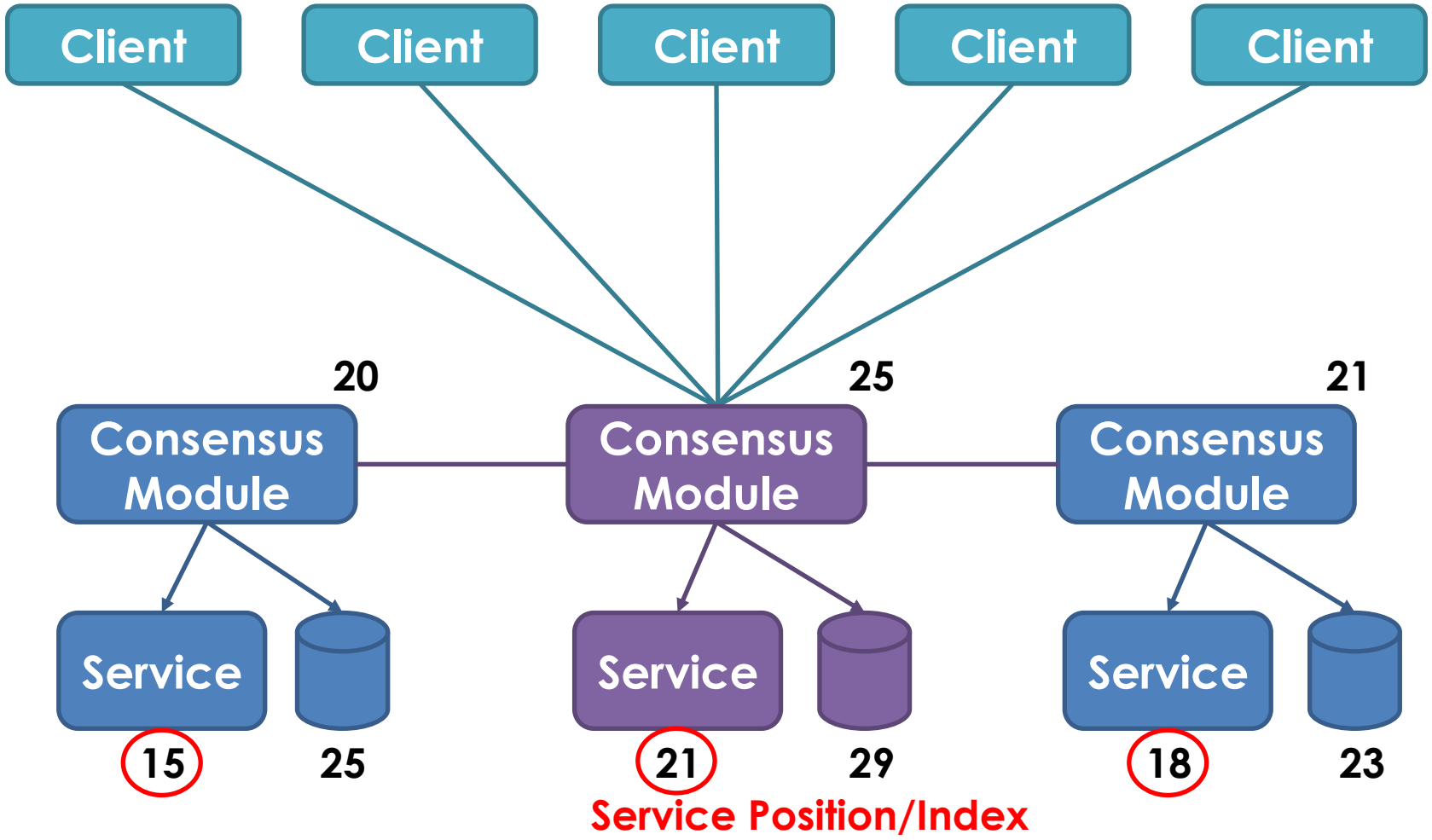
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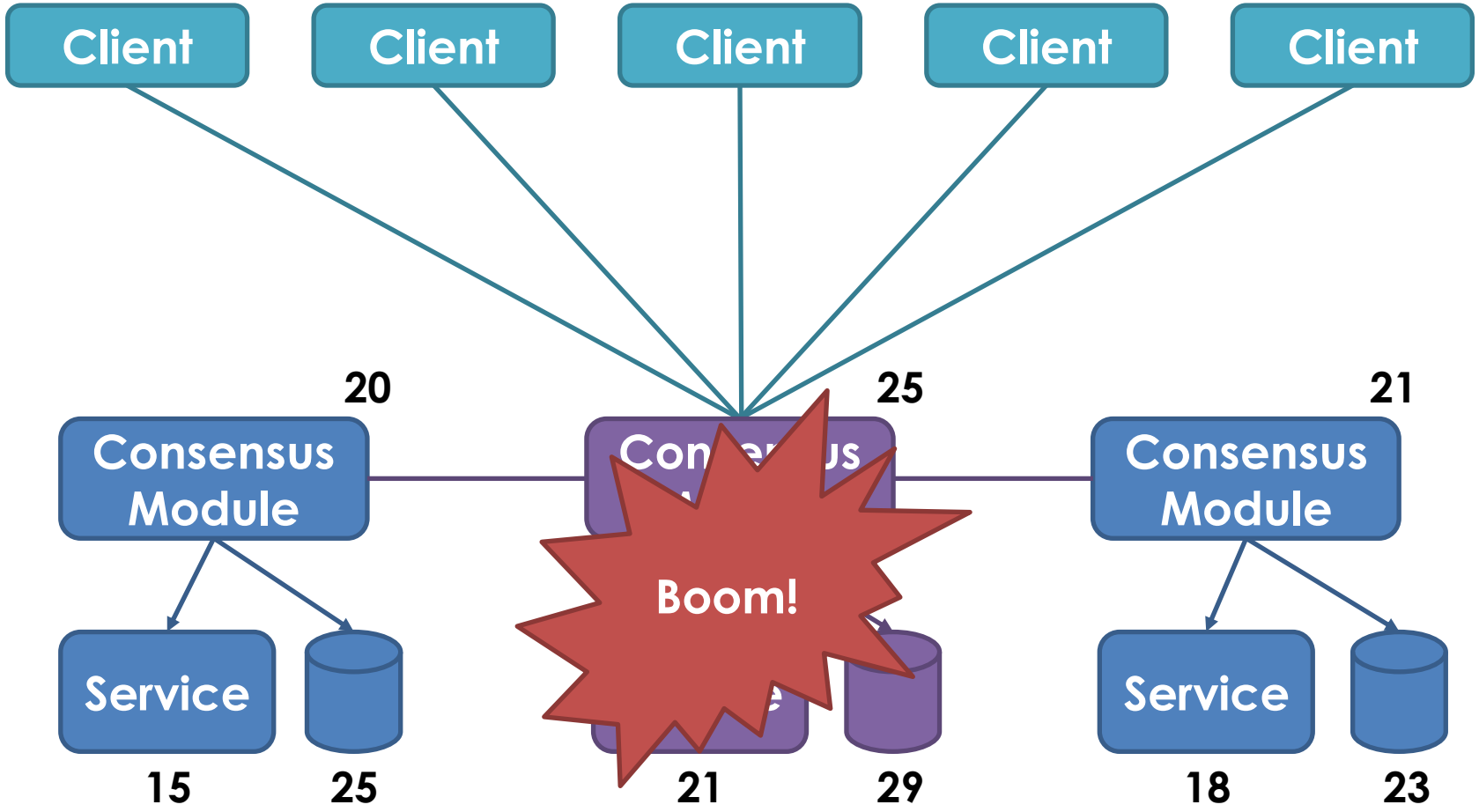
Service Position/Index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Consensus Module
Consensus Module
Boom!
Service
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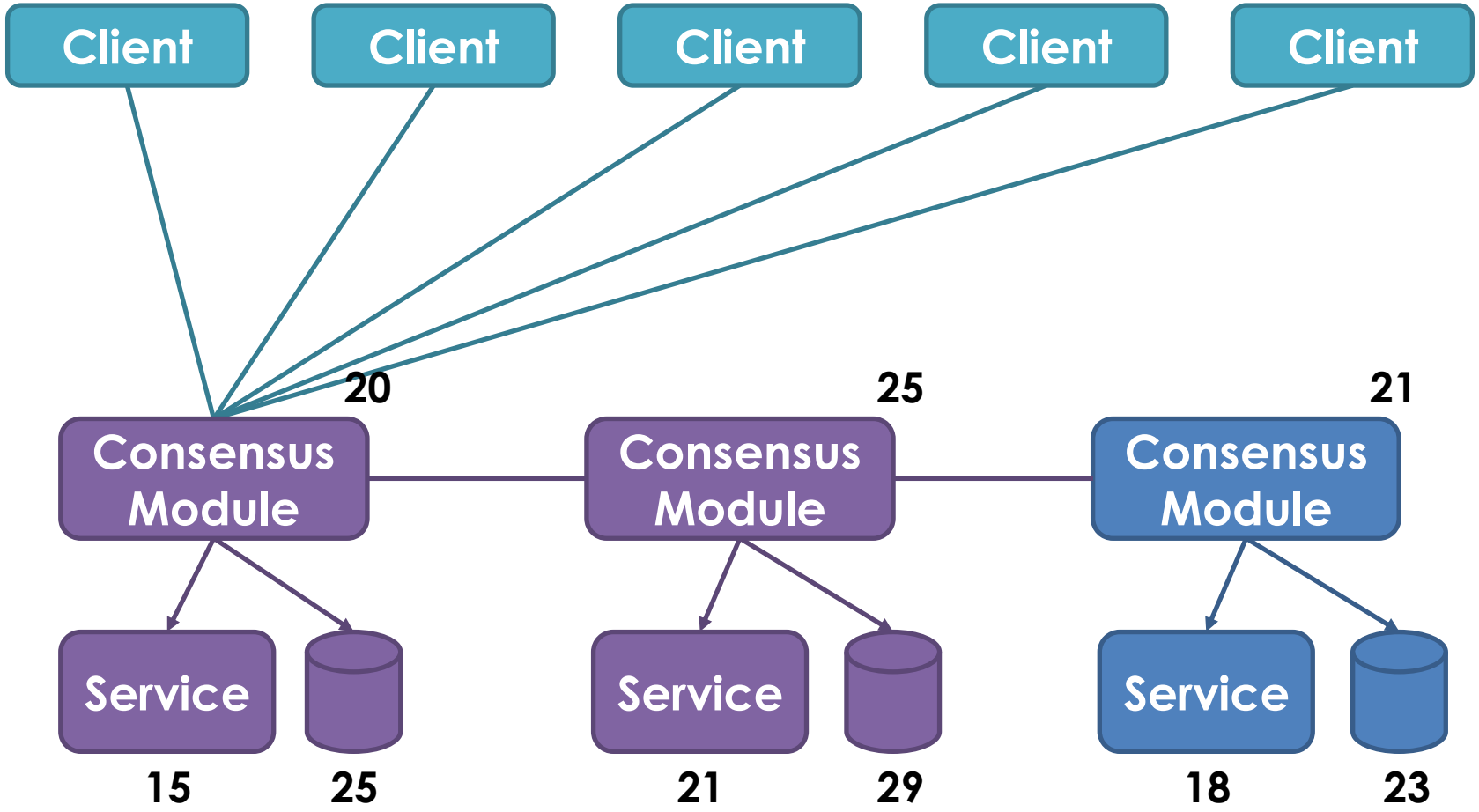
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Consensus Module
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Consensus Module
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23

# Importance of
# Code Quality & Model Fidelity

# Robustness

*How well does your application handle errors?*

# Performance

# Latency distribution awakening

# Systemic & queueing events

# Garbage Collectors

# Memory Access Patterns
# &
# Data Structures

# Binary Codecs

# Spectre & Meltdown

**Greatly increased cost for system calls, page faults, and context switching**

# Advances in Hardware

# New IO APIs

# Mechanical Sympathy

# Does programming language choice matter?

# Deployment

# Continuous Delivery

# 24 * 7 Operations

# Flexible Scaling

# Wrapping up…

# What will the next 10 years hold?

@mjpt777

https://github.com/real-logic/aeron

*“The future is already here – it's just not evenly distributed”*

- William Gibson