Cluster Consensus

When Aeron Met Raft

Martin Thompson - @mjpt777

Simple Testing Can Prevent Most Critical Failures: An Analysis of Production Failures in Distributed Data-Intensive Systems

Ding Yuan, Yu Luo, Xin Zhuang, Guilherme Renna Rodrigues, Xu Zhao, Yongle Zhang, Pranay U. Jain, and Michael Stumm, *University of Toronto*

https://www.usenix.org/conference/osdi14/technical-sessions/presentation/yuan

What does “Consensus” mean?

con•sen•sus

noun \ kən-ˈsen(t)-səs \

: **general agreement : <u>unanimity</u>**

Source: http://www.merriam-webster.com/

con•sen•sus

noun \ kən-ˈsen(t)-səs \

: **general agreement : unanimity**

: **the judgment arrived at by most of those concerned**

Source: http://www.merriam-webster.com/

Consensus on what?

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,

https://www.cl.cam.ac.uk/~ms705/pub/papers/2015-osr-raft.pdf

Raft Refloated: Do We Have Consensus?

Heidi Howard Malte Schwarzkopf Anil Madhavapeddy Jon Crowcroft

University of Cambridge Computer Laboratory
first.last@cl.cam.ac.uk

ABSTRACT

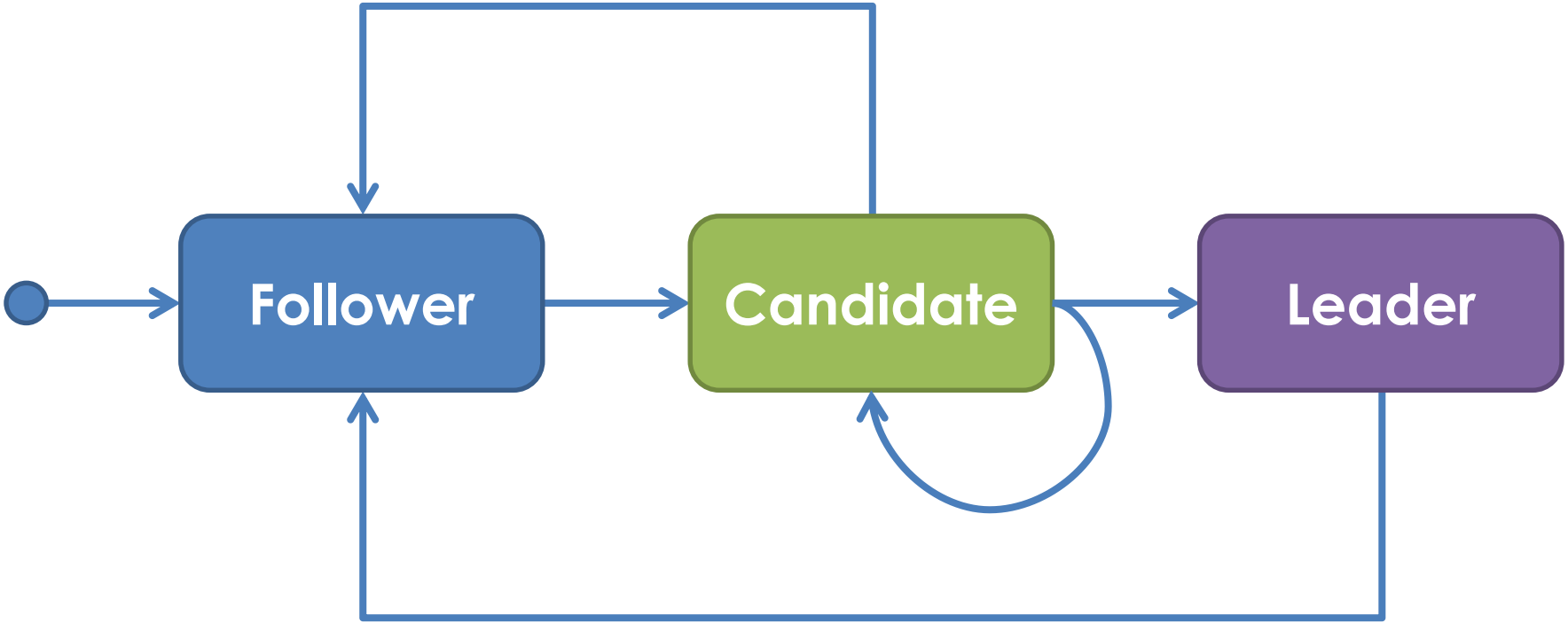
The Paxos algorithm is famously difficult to reason about and even more so to implement, despite having been synonymous with distributed consensus for over a decade. The recently proposed Raft protocol lays claim to being a new, understandable consensus algorithm, improving on Paxos without making compromises in performance or correctness.

ation ought to be far easier than with Multi-Paxos. Our study in this paper evaluates the claims about Raft made by its designers. Is it indeed easily understandable, and can the encouraging performance and correctness results presented by Ongaro and Ousterhout be independently confirmed?

In the endeavour to answer this question, we re-implemented Raft in a functional programming language (OCaml) and repeat the

Raft in a Nutshell

Roles



RPCs

1. **RequestVote RPC**
   Invoked by candidates to gather votes

2. **AppendEntries RPC**
   Invoked by leader to replicate and heartbeat

Safety Guarantees

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

Monotonic Functions

Version all the things!

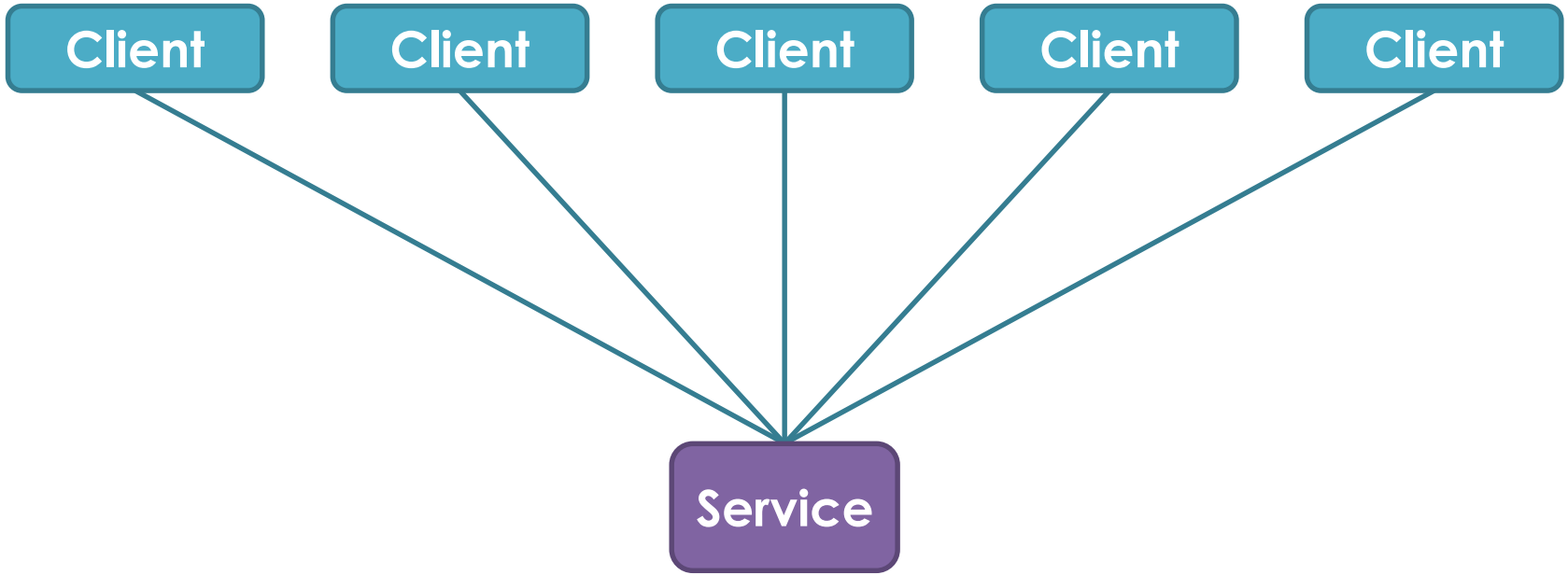
Clustering Aeron

Is it Guaranteed Delivery™ ???

What is the “Architect” really looking for?

Need to know...

“Guaranteed Processing™”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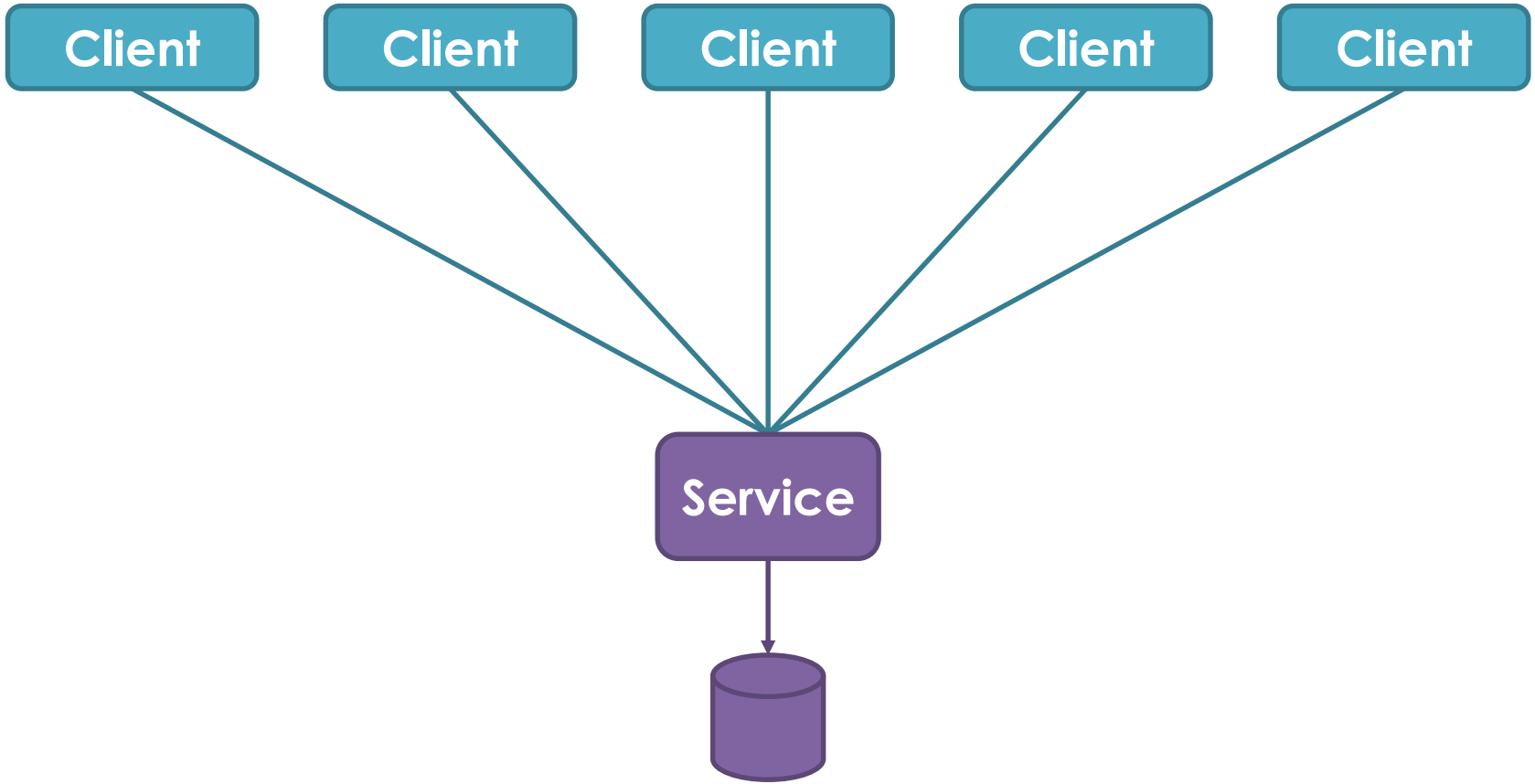
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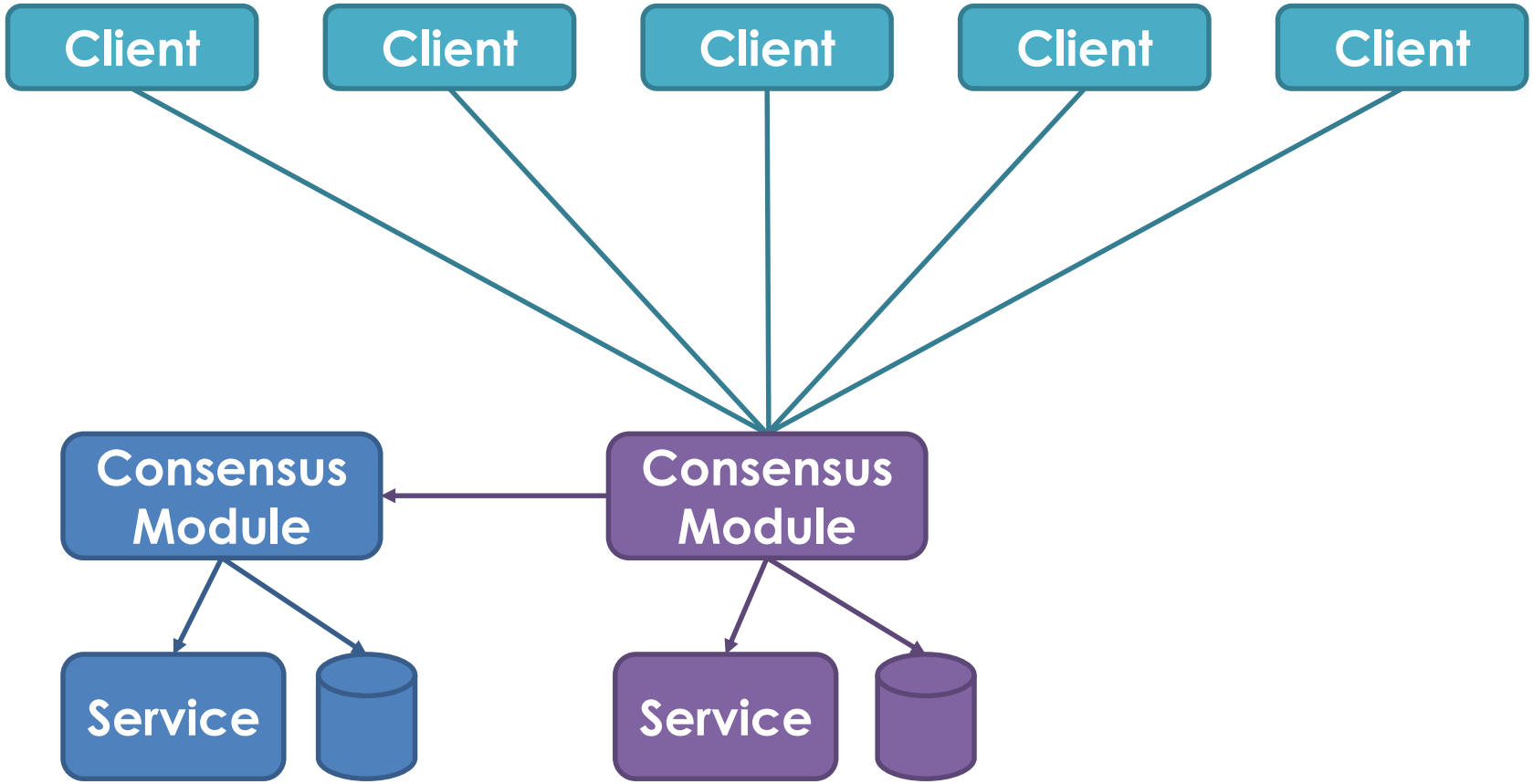
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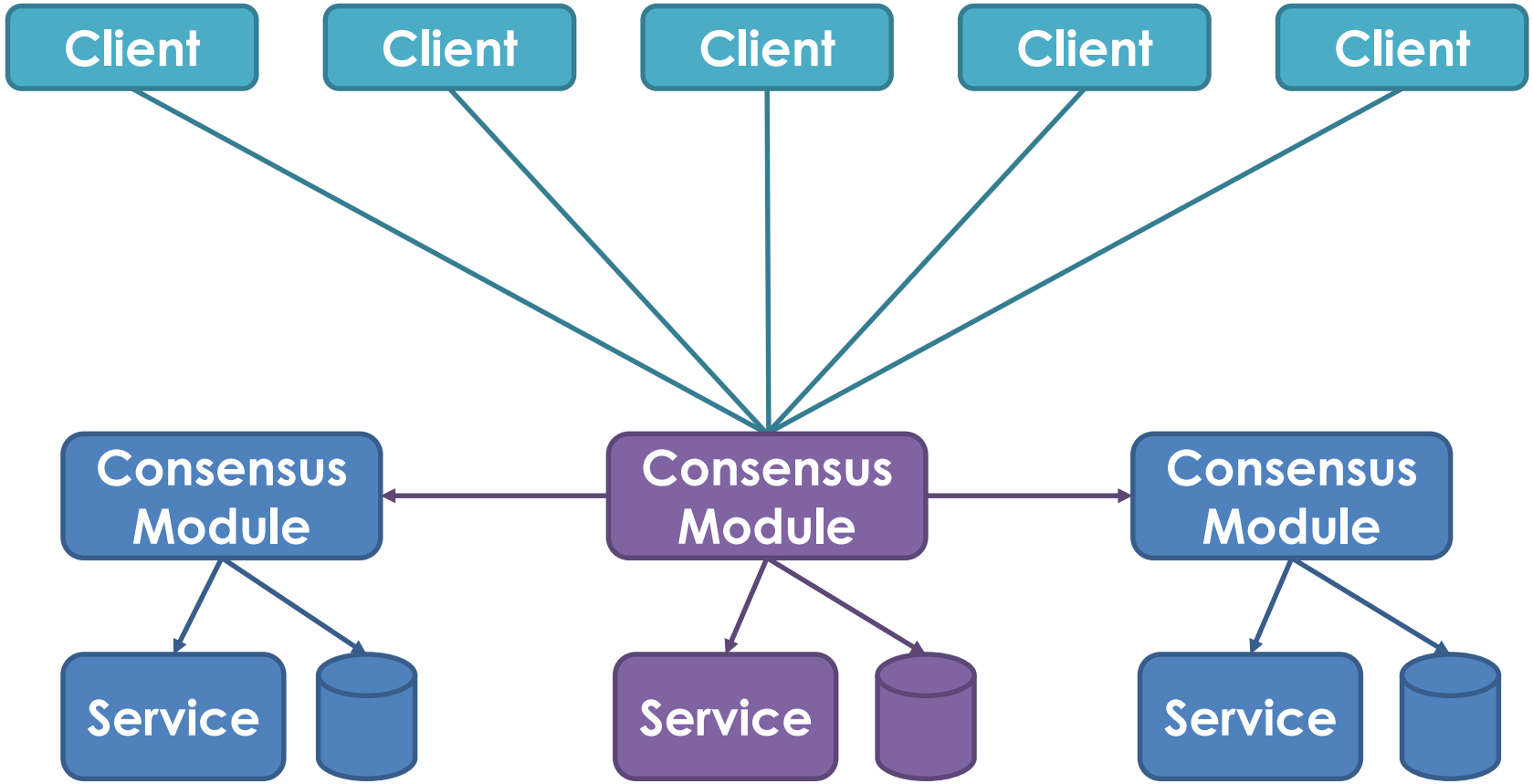
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NIO Pain!

Do servers crash?

```
FileChannel channel = null;
try
{
    channel = FileChannel.open(directory.toPath());
}
catch (final IOException ignore)
{
}

if (null != channel)
{
    channel.force(true);
}
```

```
FileChannel channel = null;
try
{
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catch (final IOException ignore)
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}
```

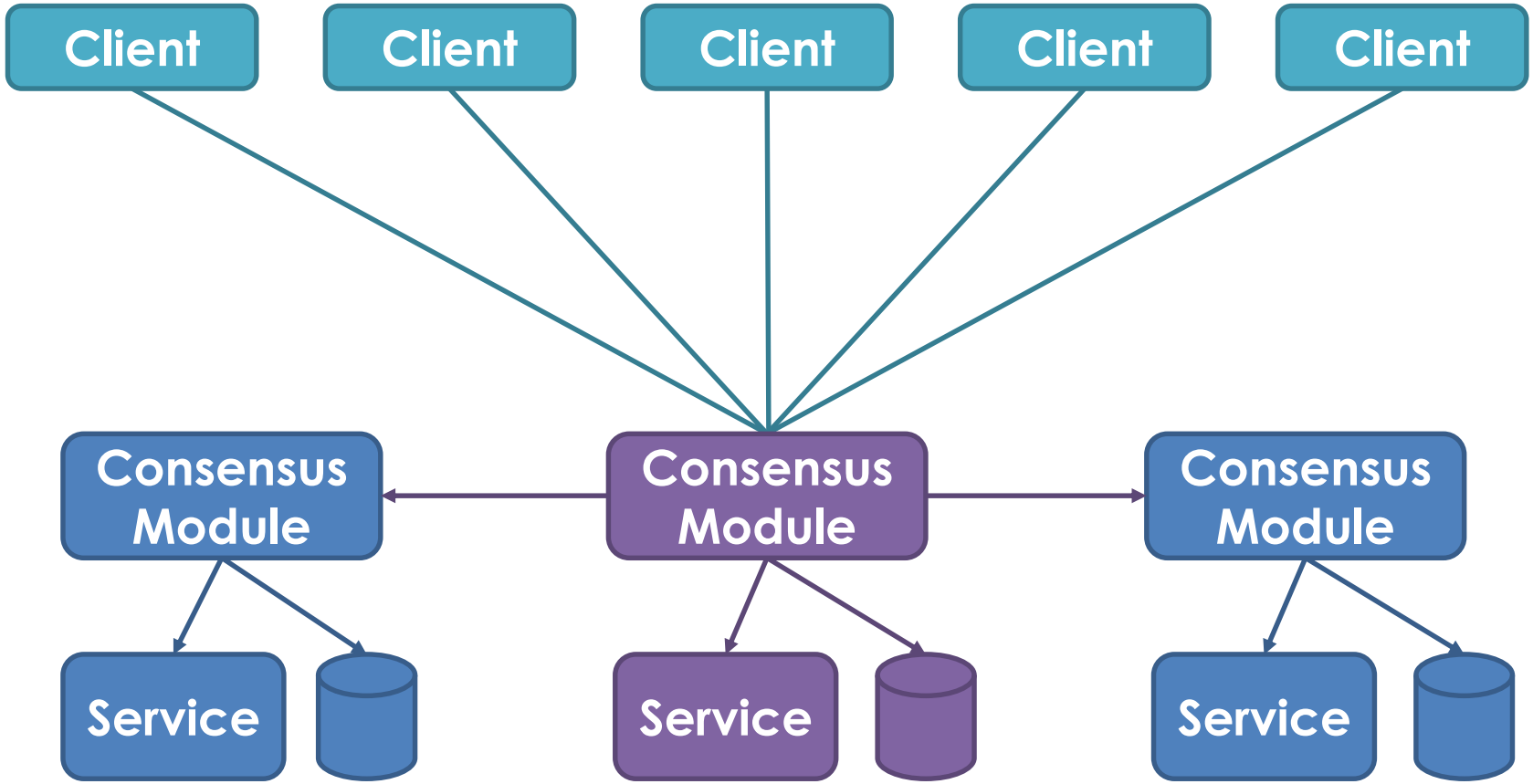
```
if (null != channel)
{
    channel.force(true);
}
```

Directory Sync

```
Files.force(directory.toPath(), true);
```

Performance

Let’s consider an RPC design approach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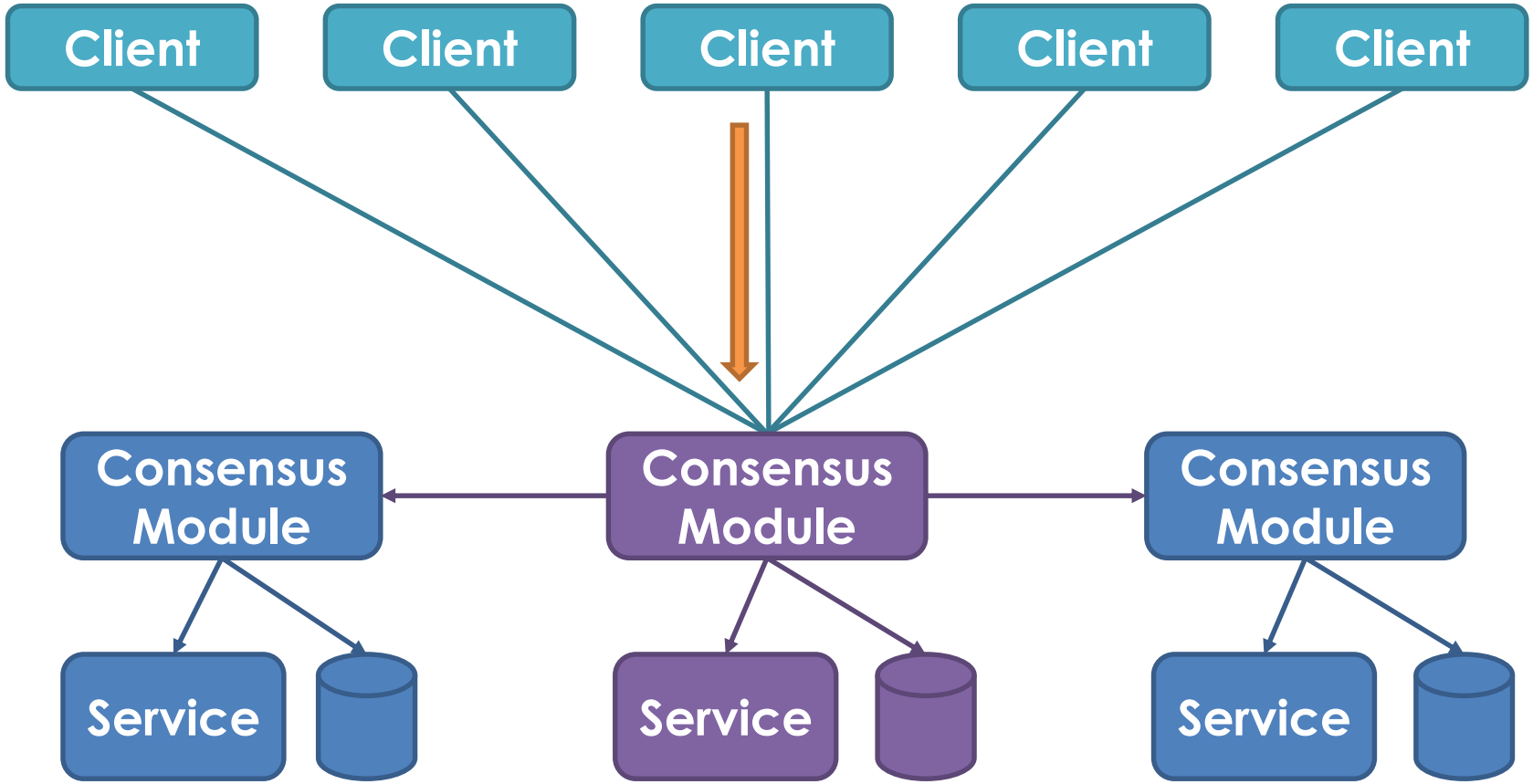
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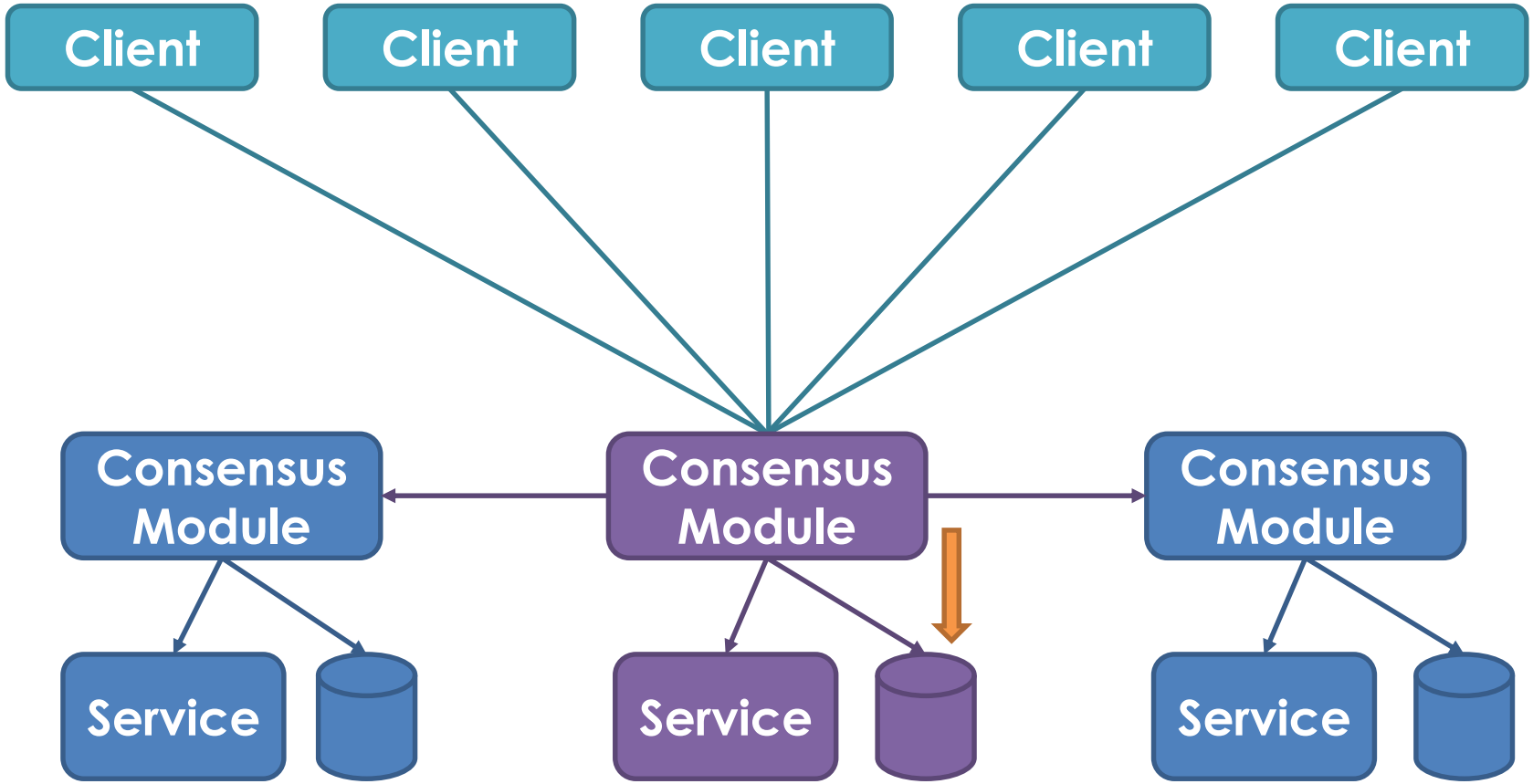
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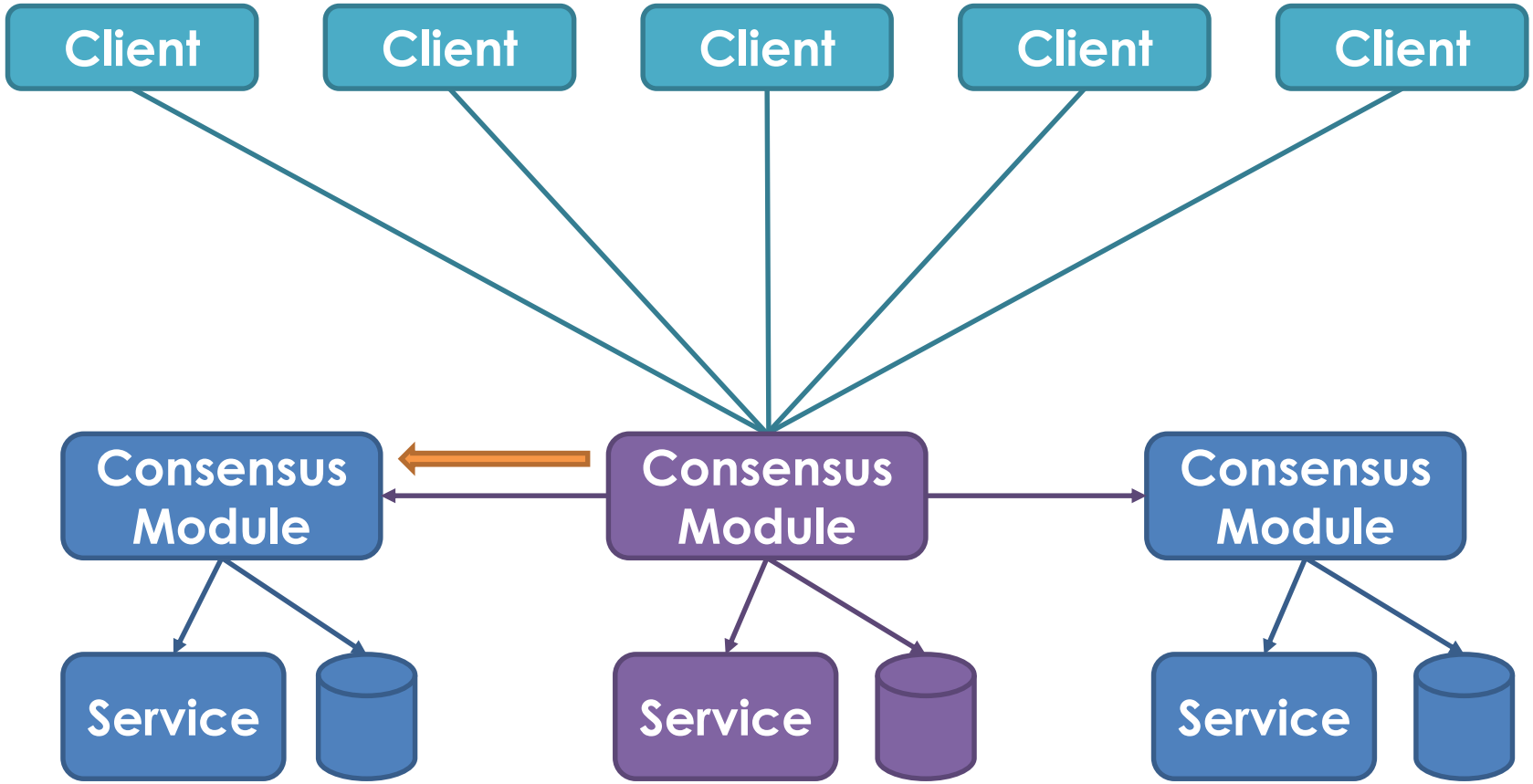
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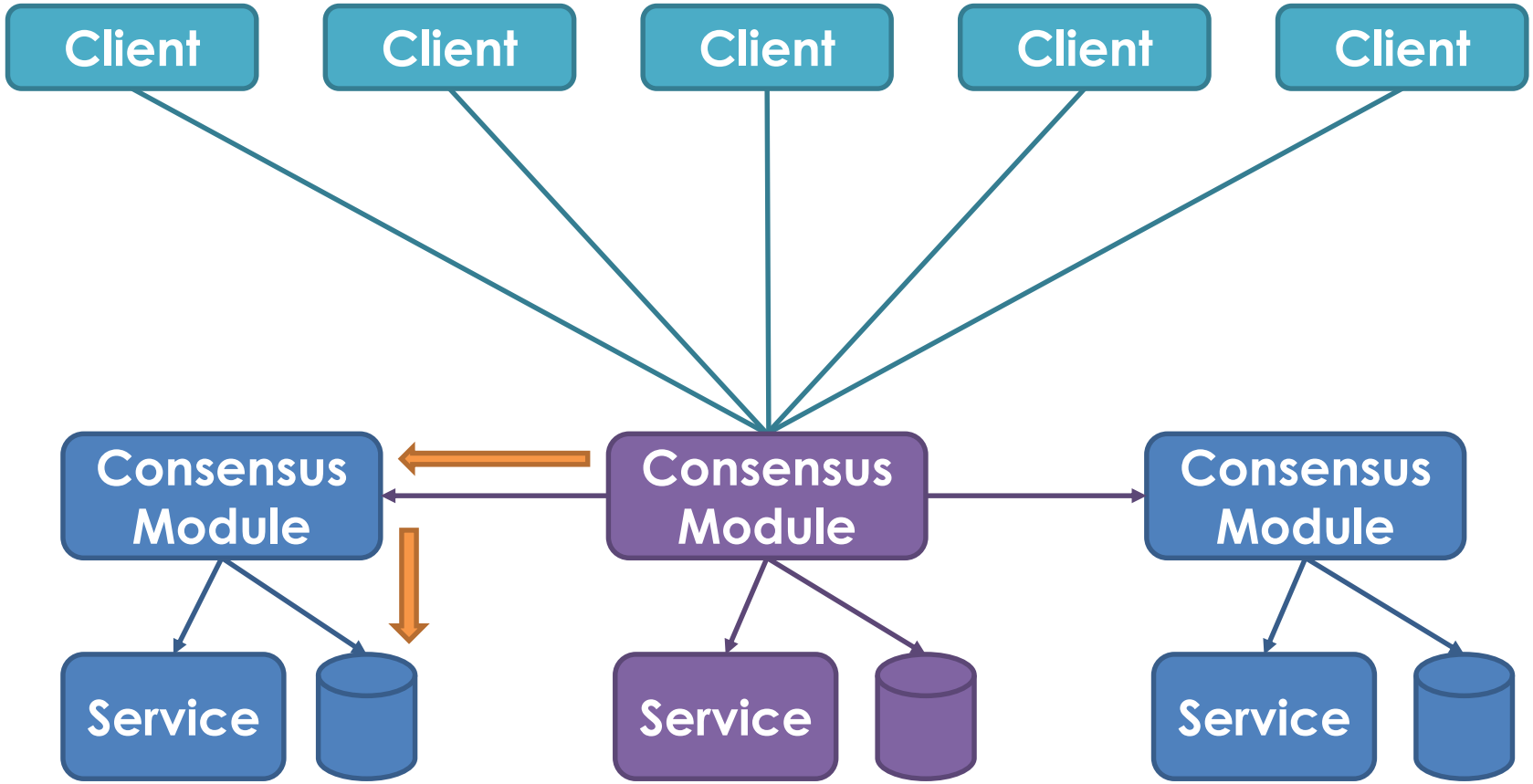
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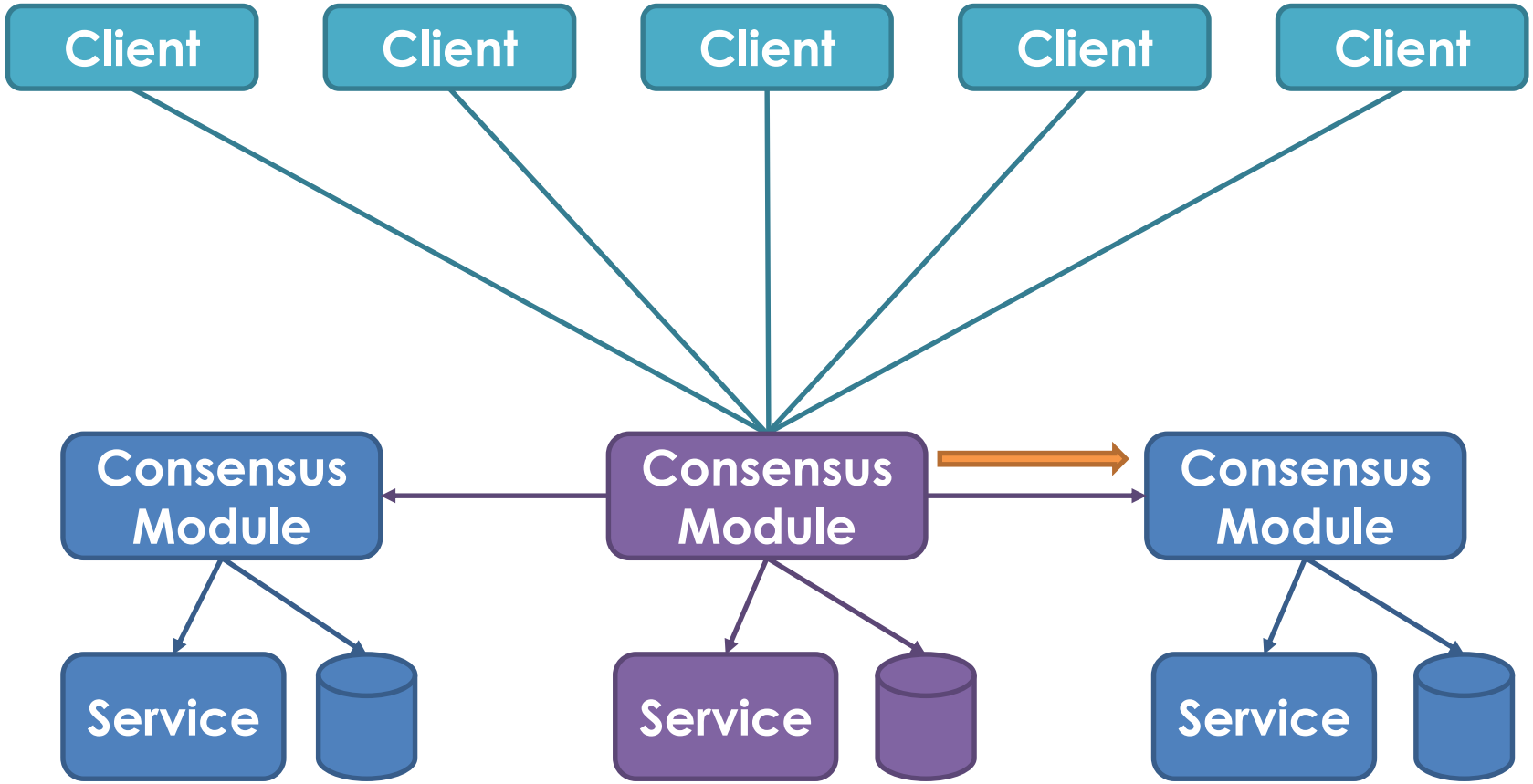
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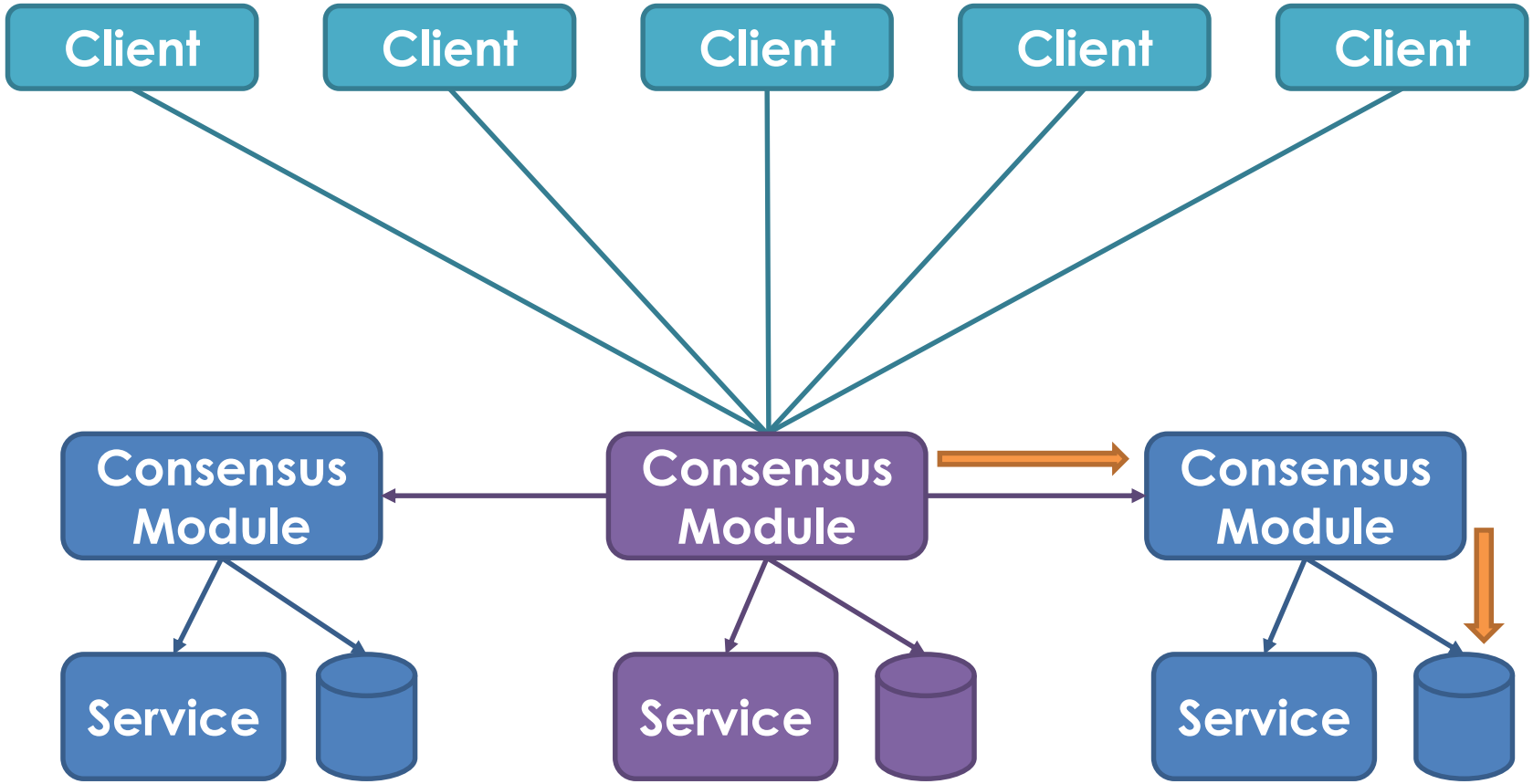
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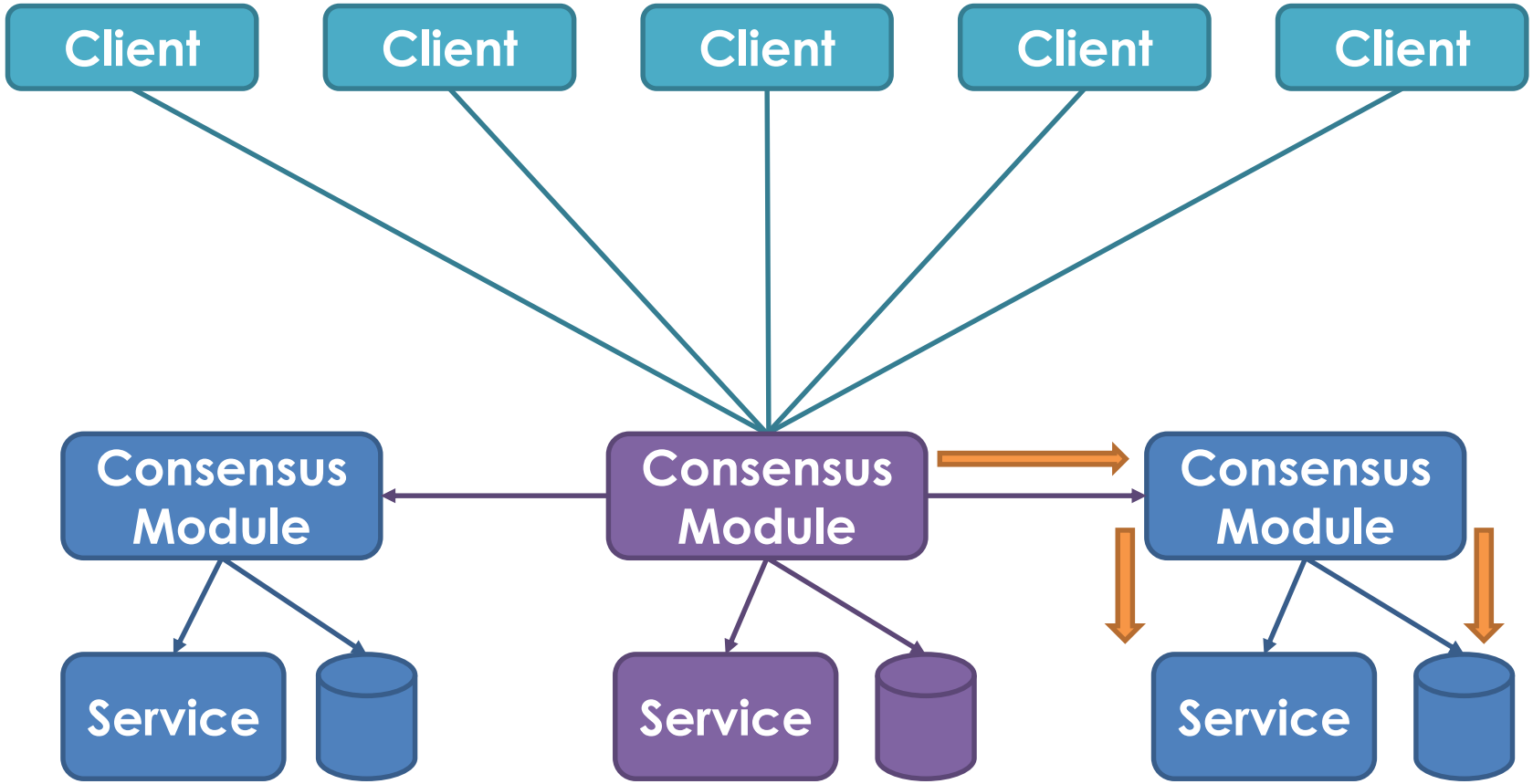
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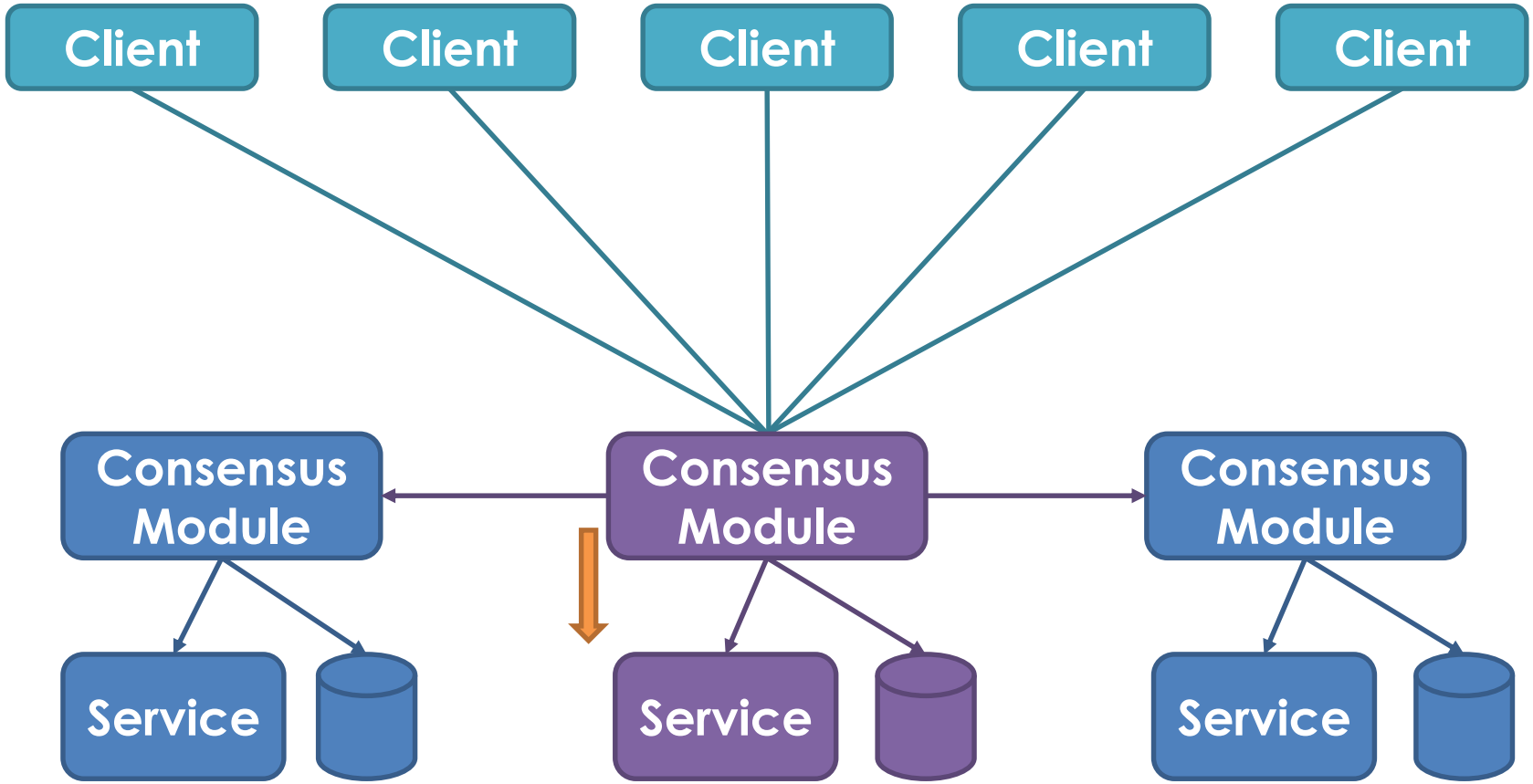
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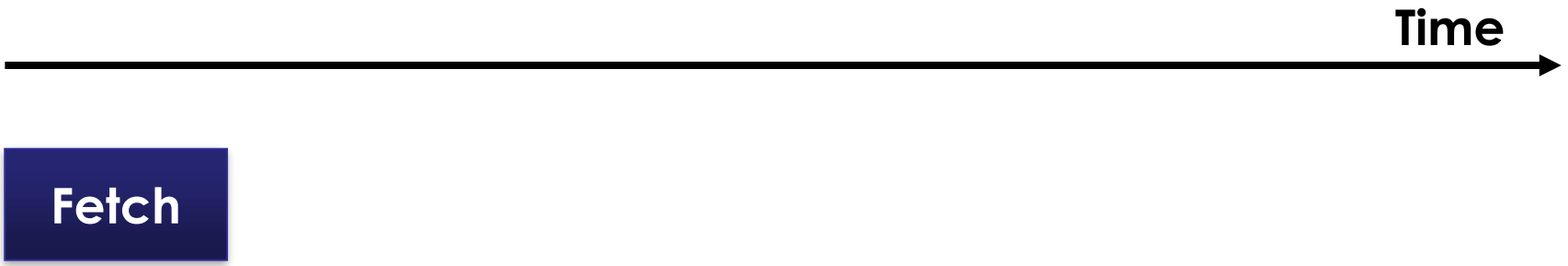
Concurrency and parallelism with Replicated State Machines?

1. ***Parallel*** *is the opposite of* ***Serial***
2. ***Concurrent*** *is the opposite of* ***Sequential***
3. ***Vector*** *is the opposite of* ***Scalar***

– John Gustafson

Instruction Pipelining



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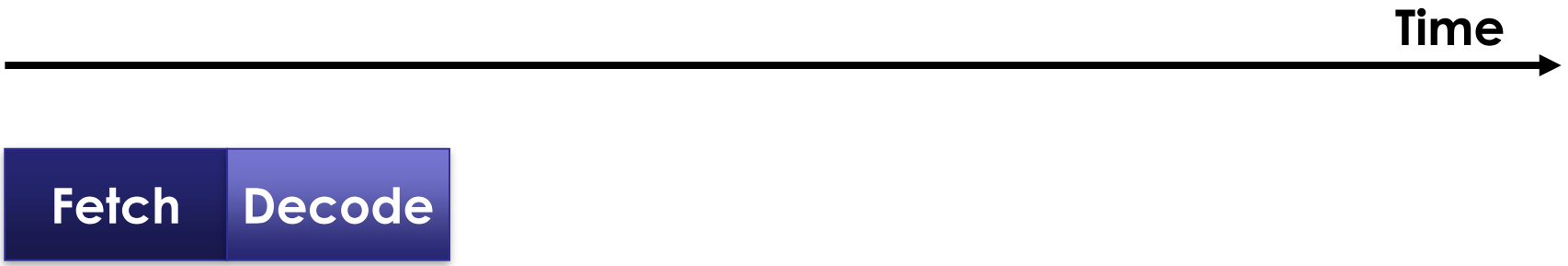

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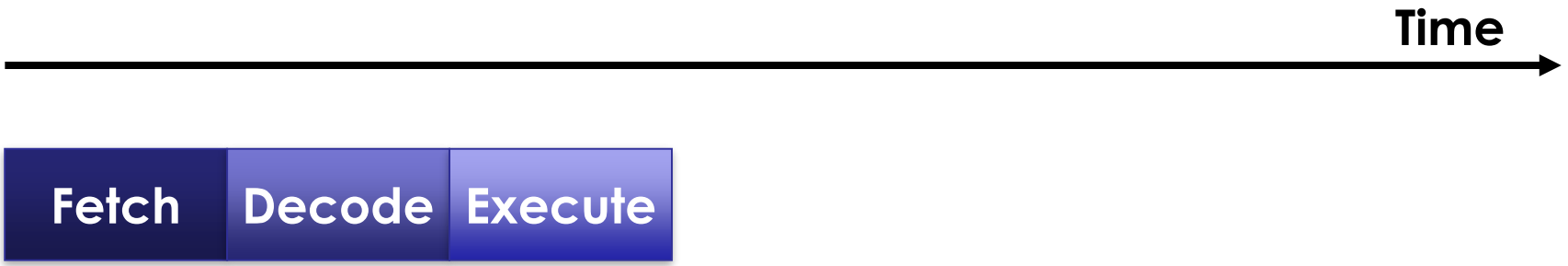

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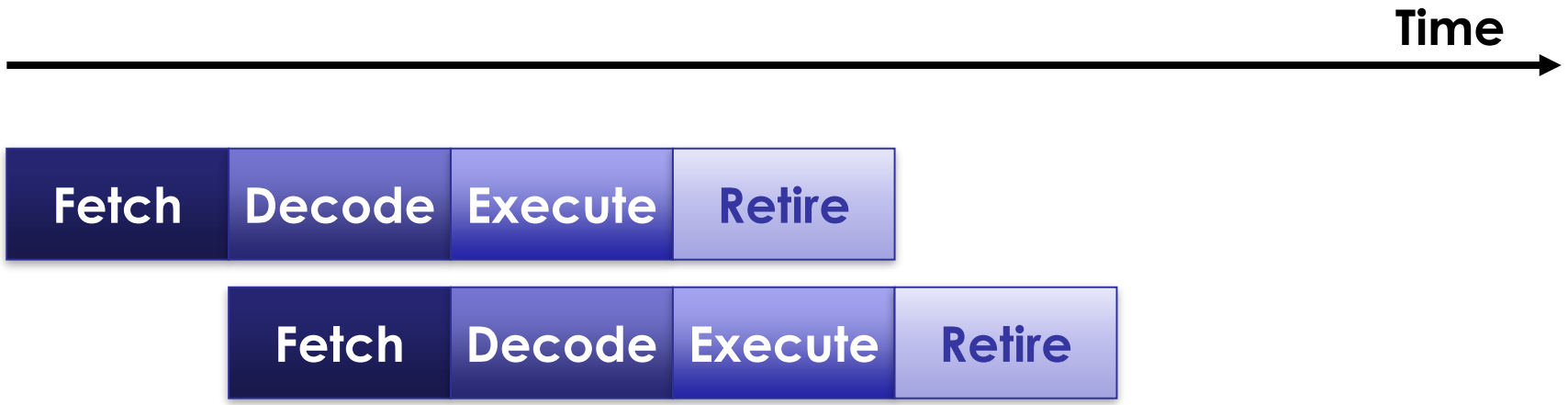

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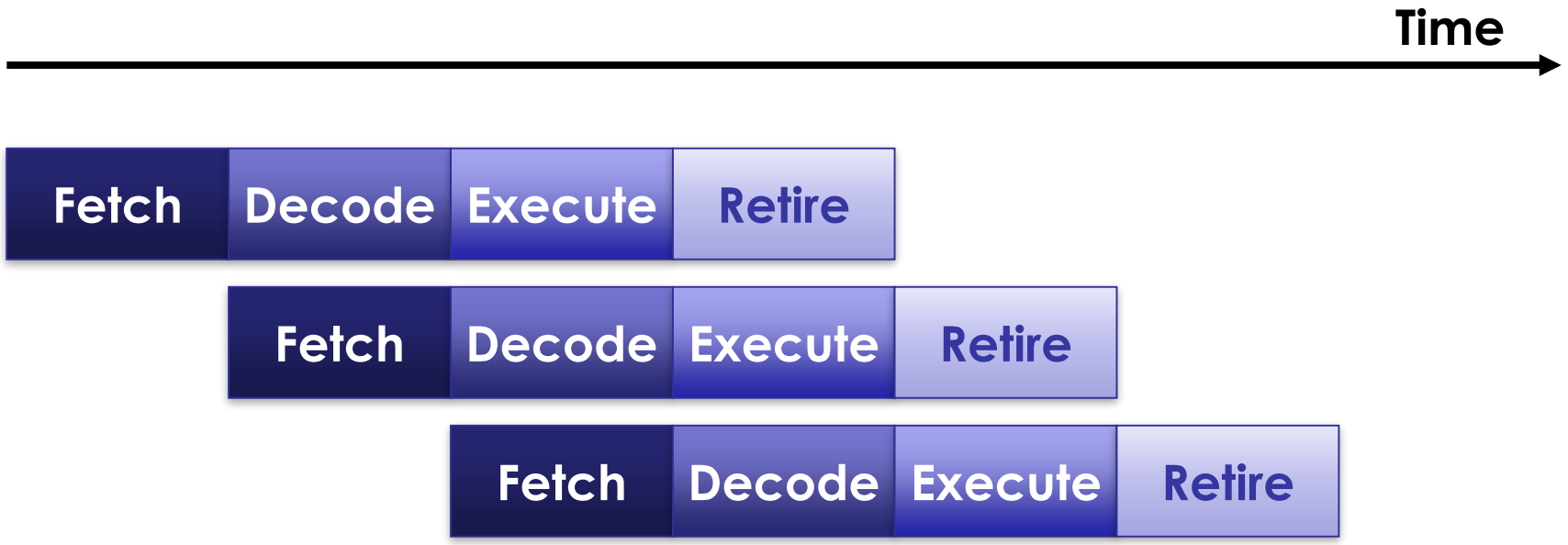

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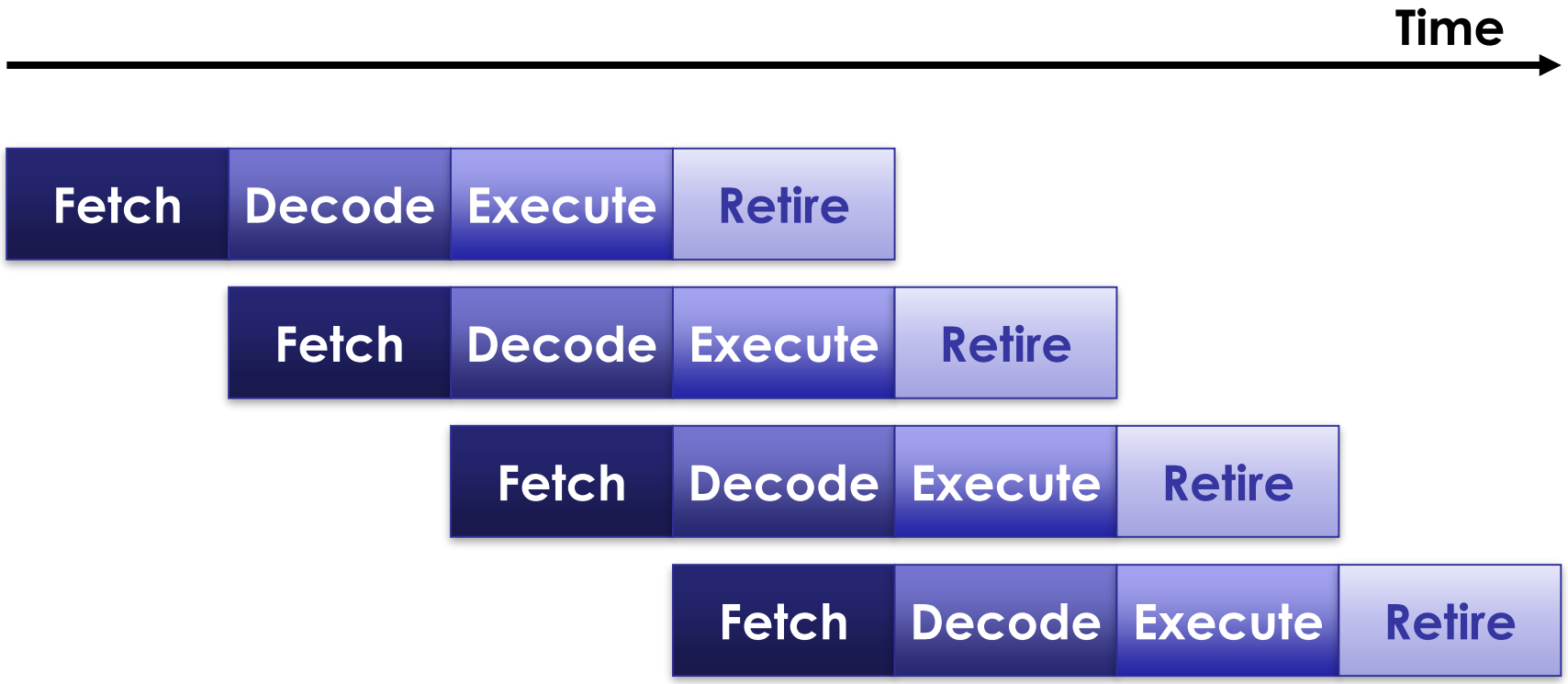

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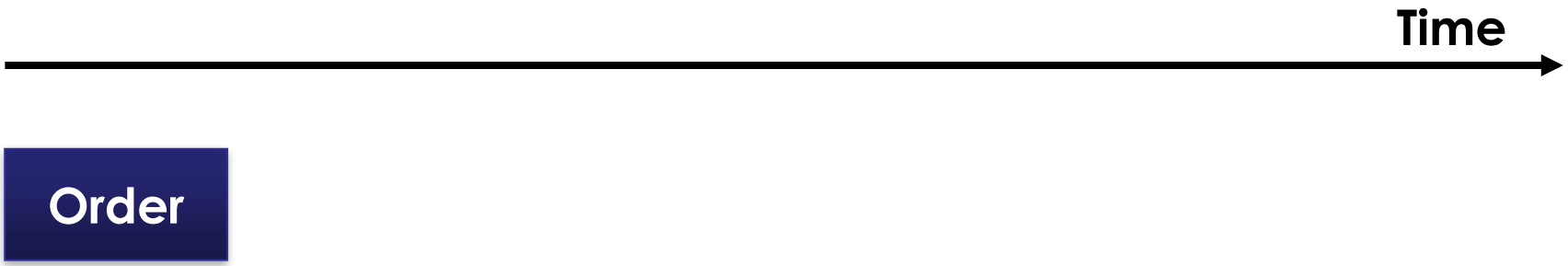

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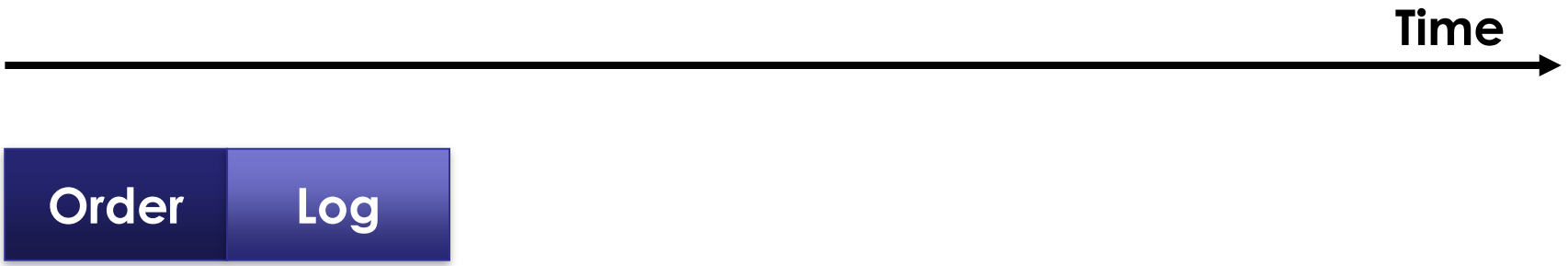

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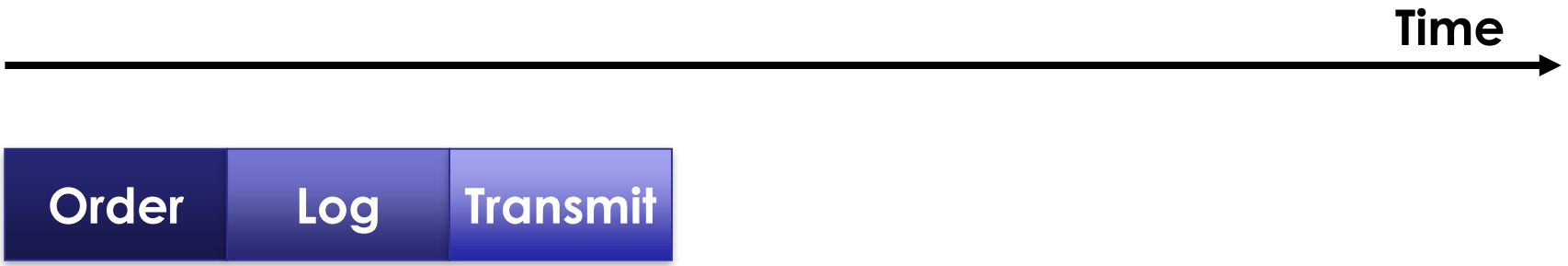

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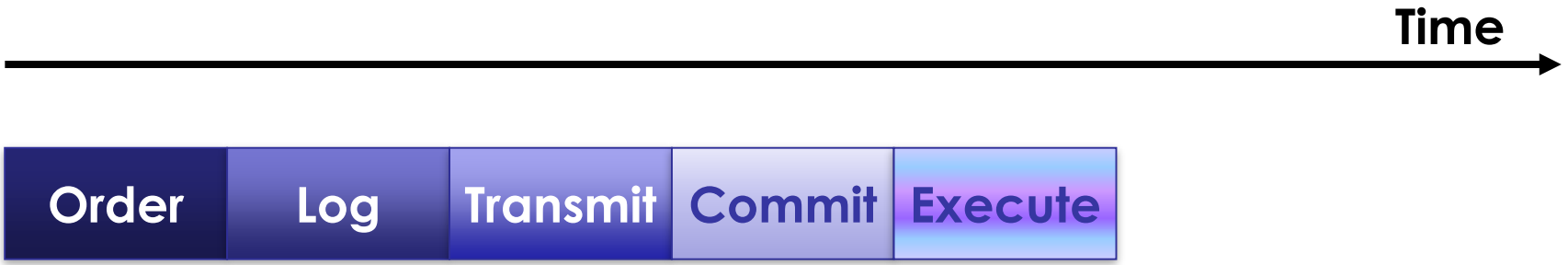

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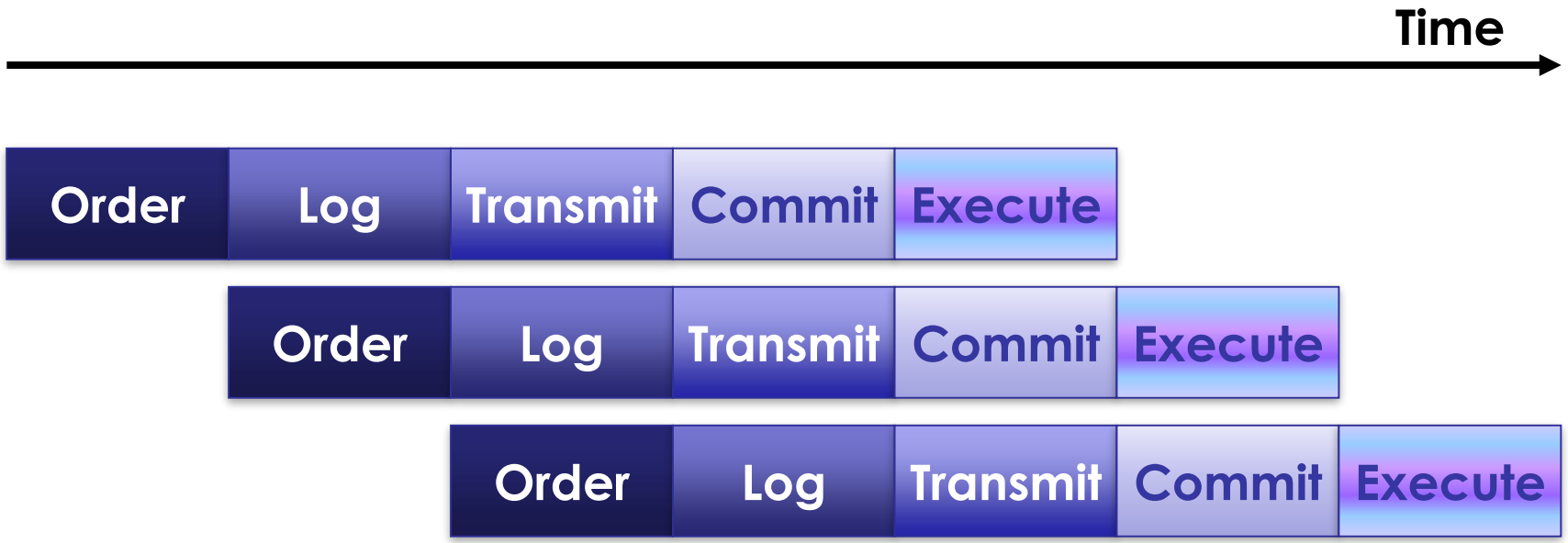

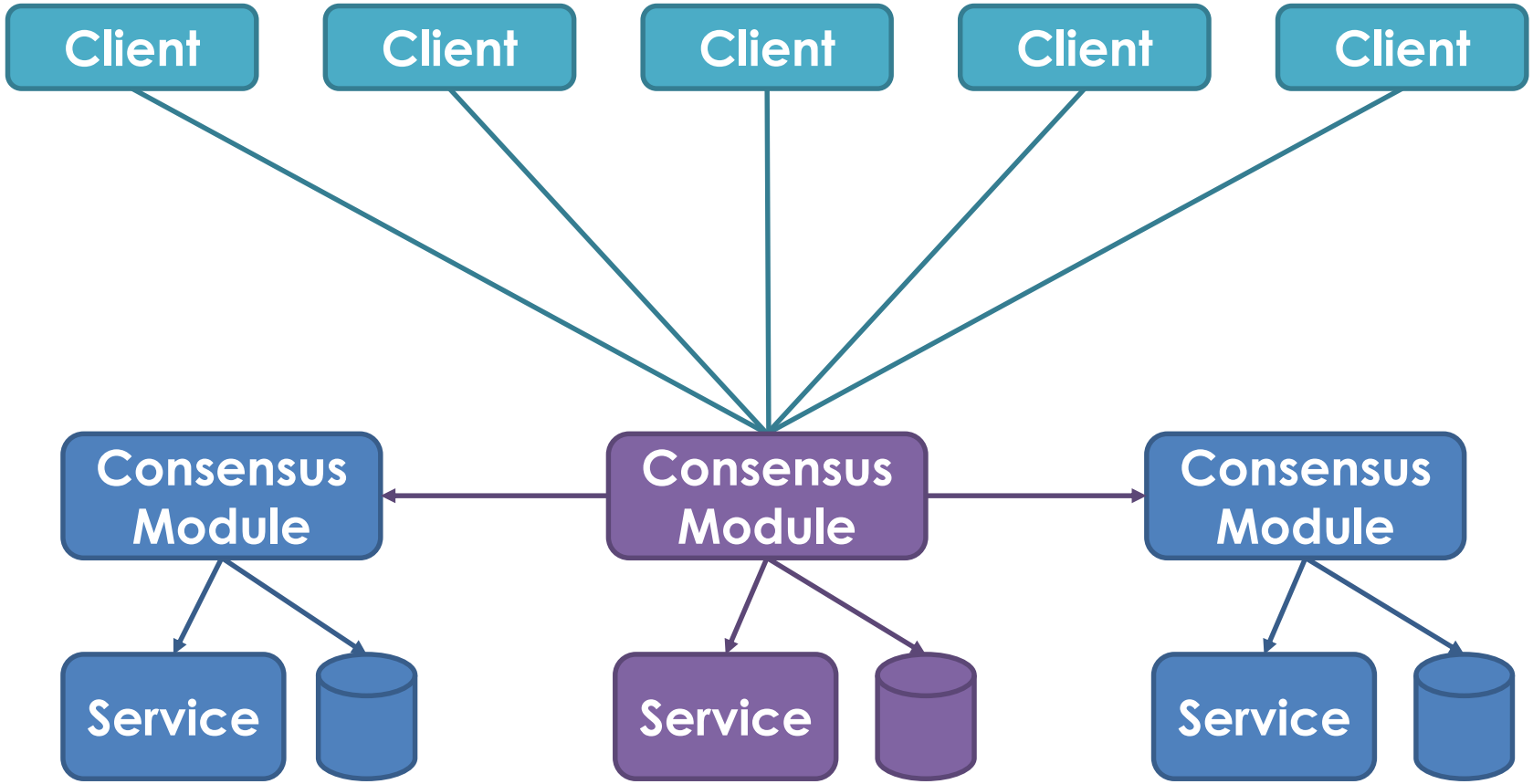
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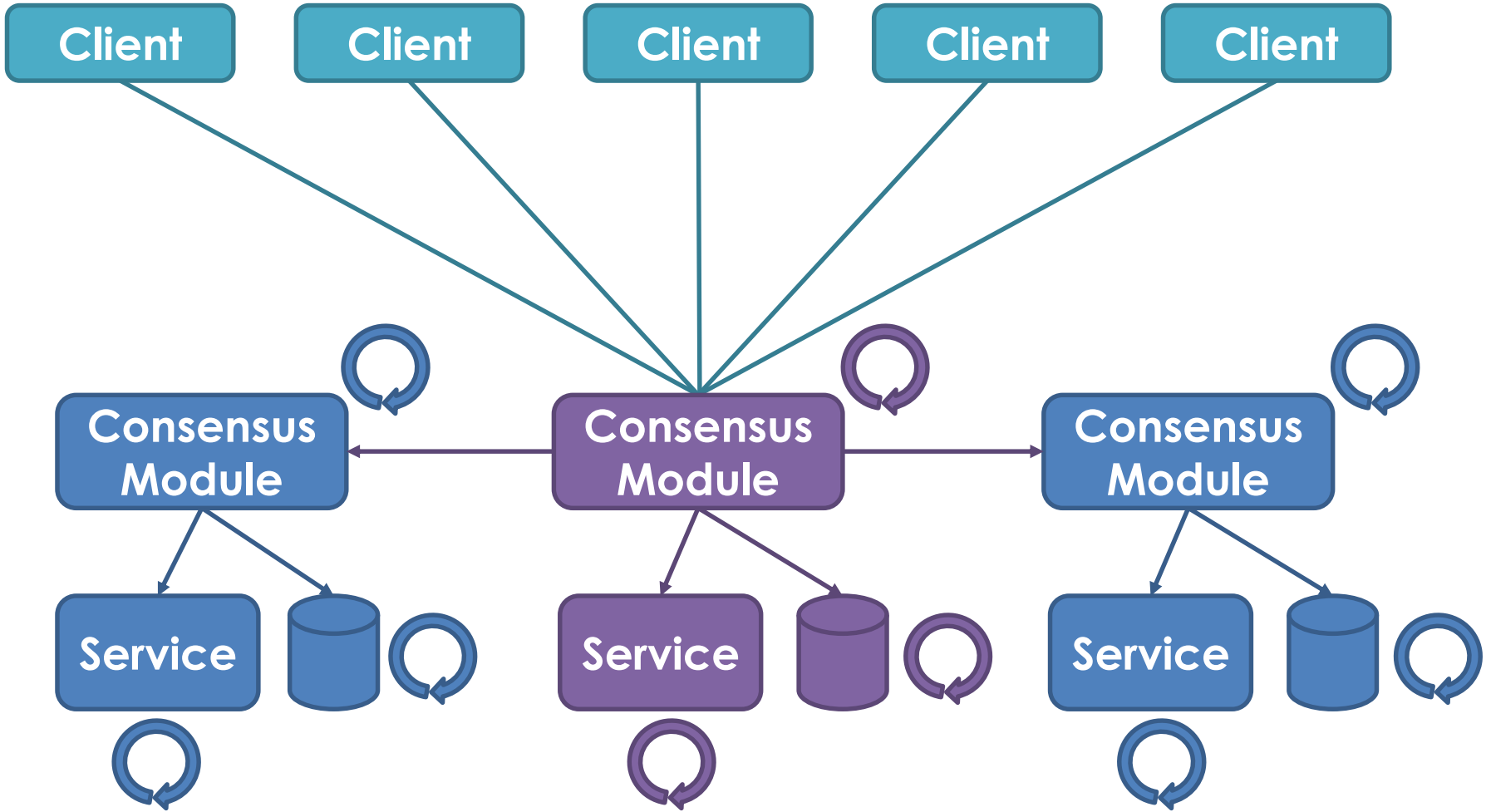
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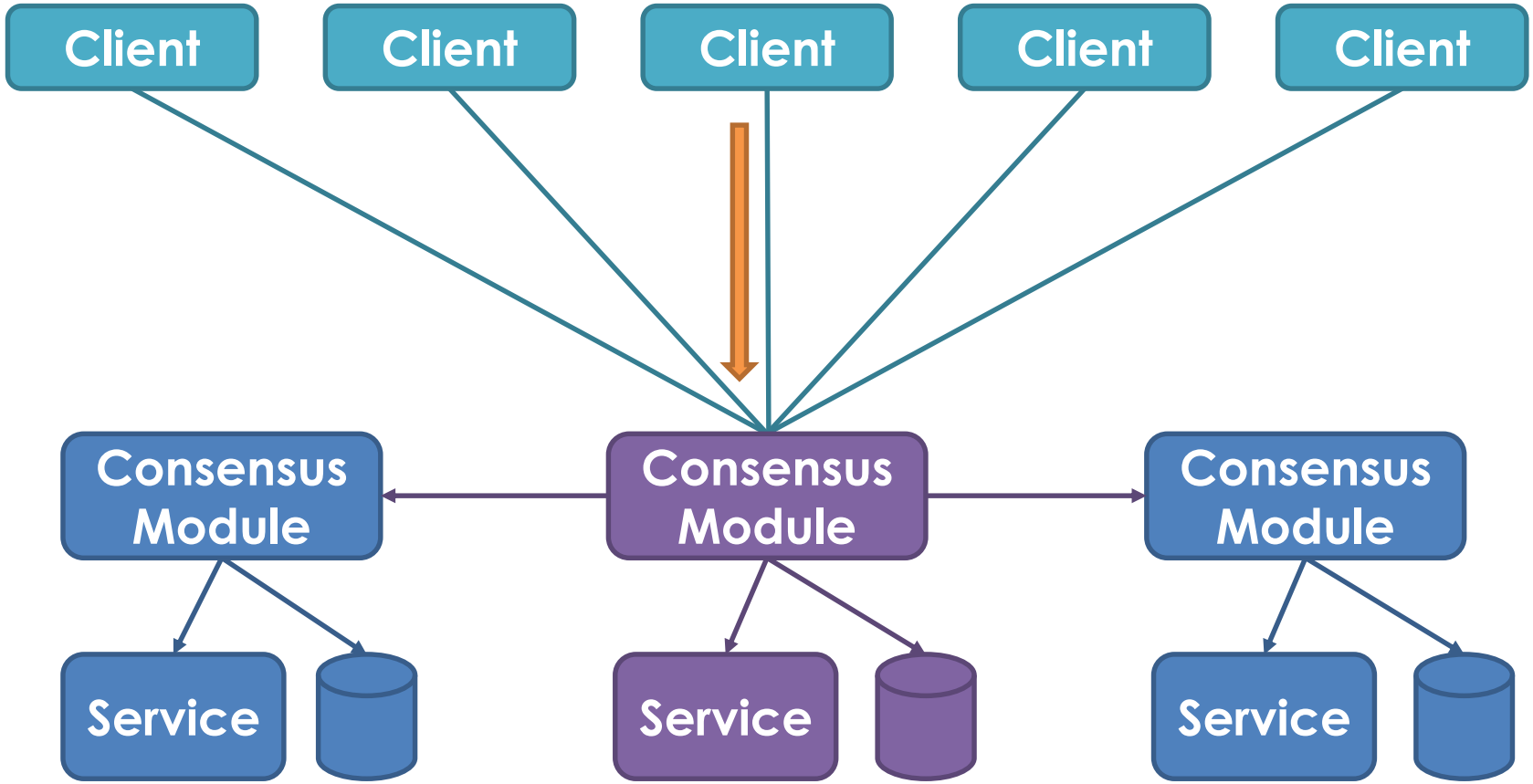
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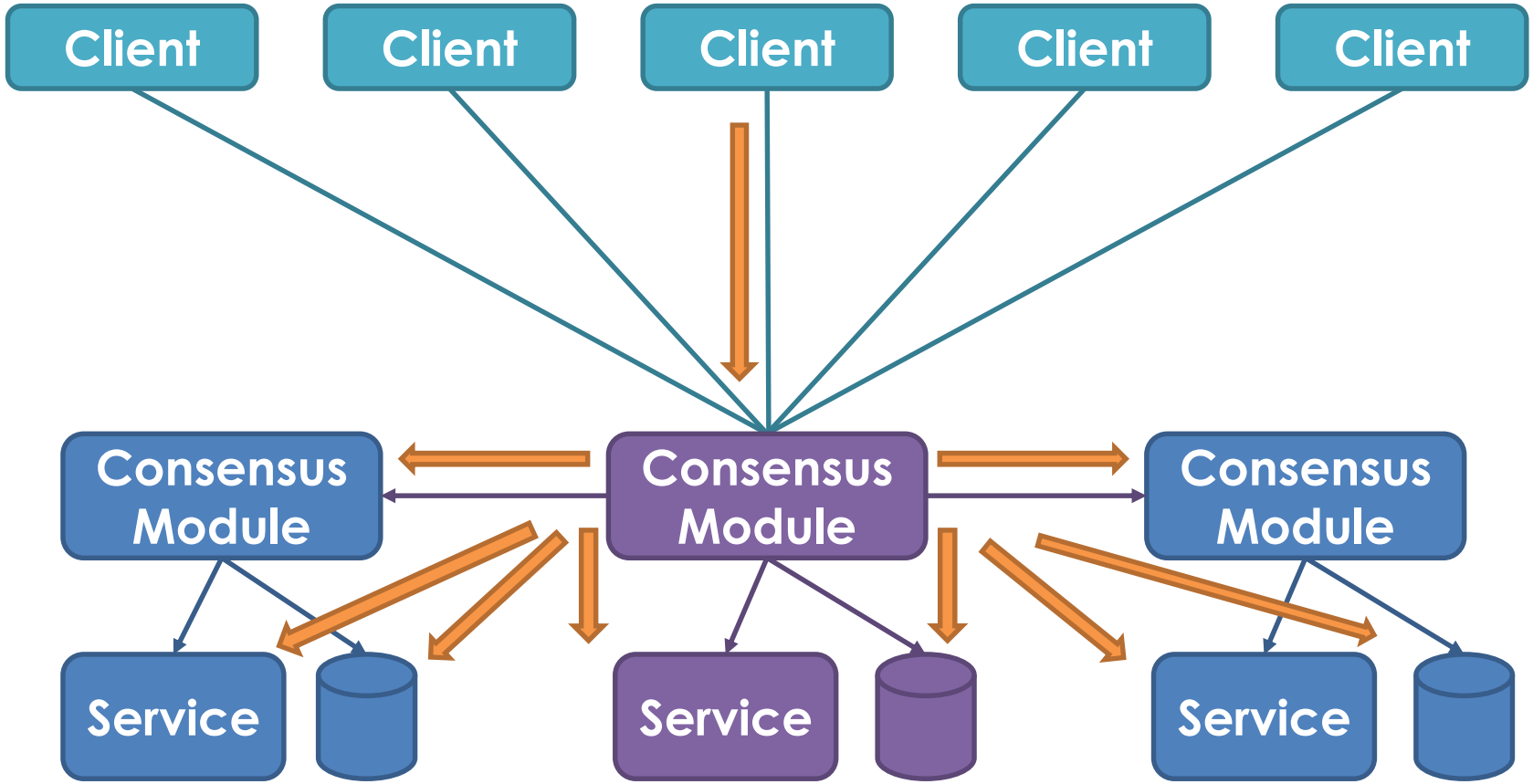
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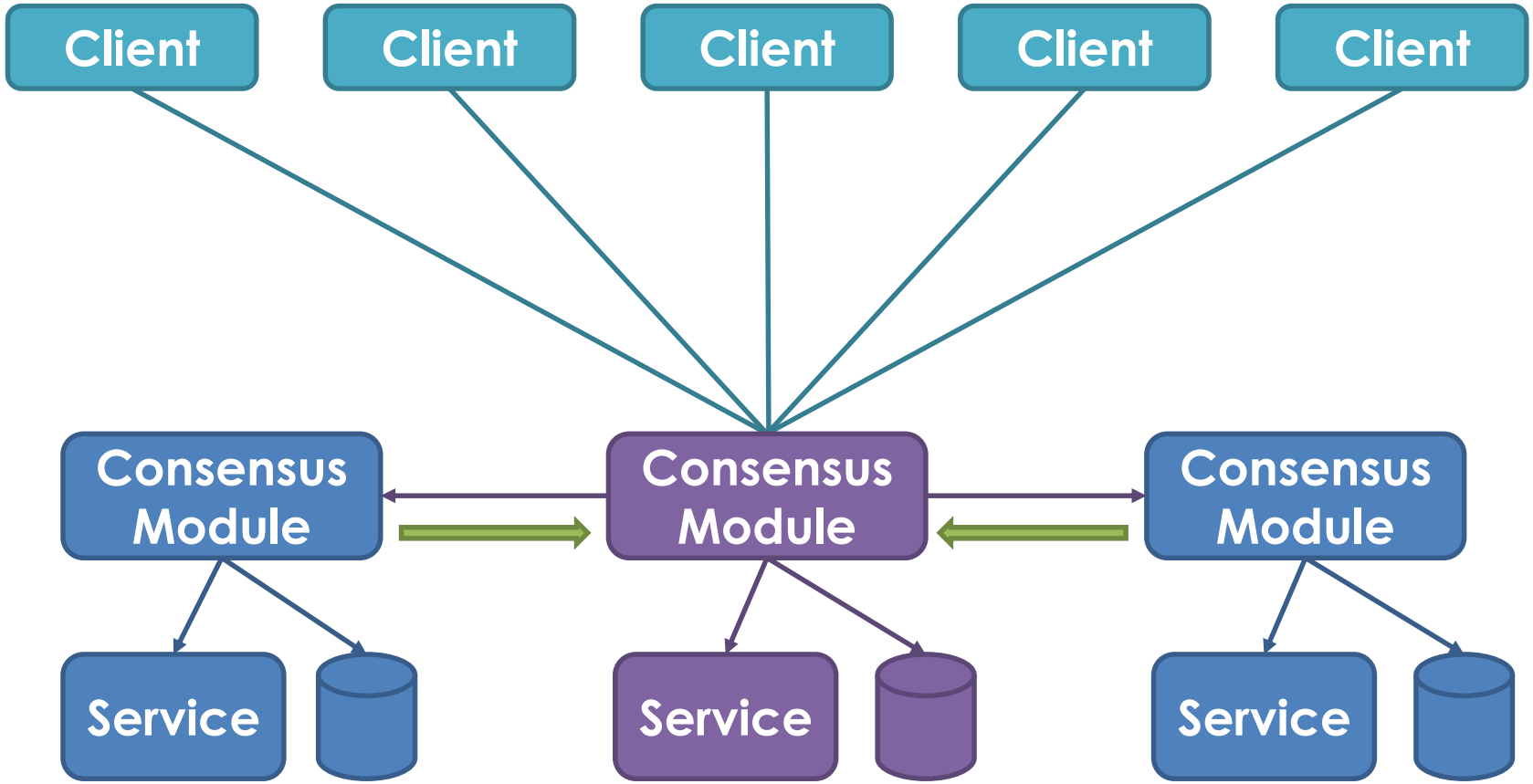
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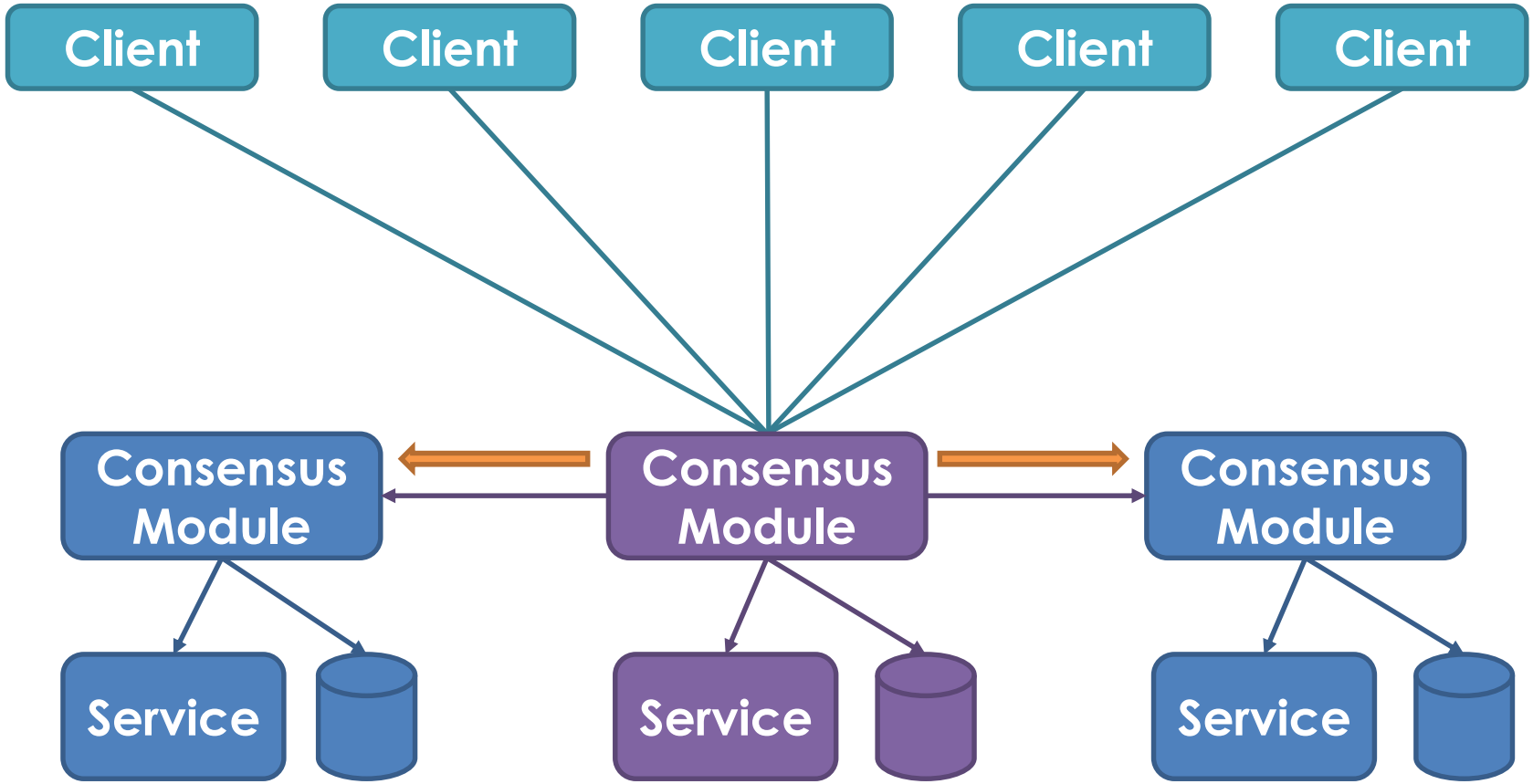
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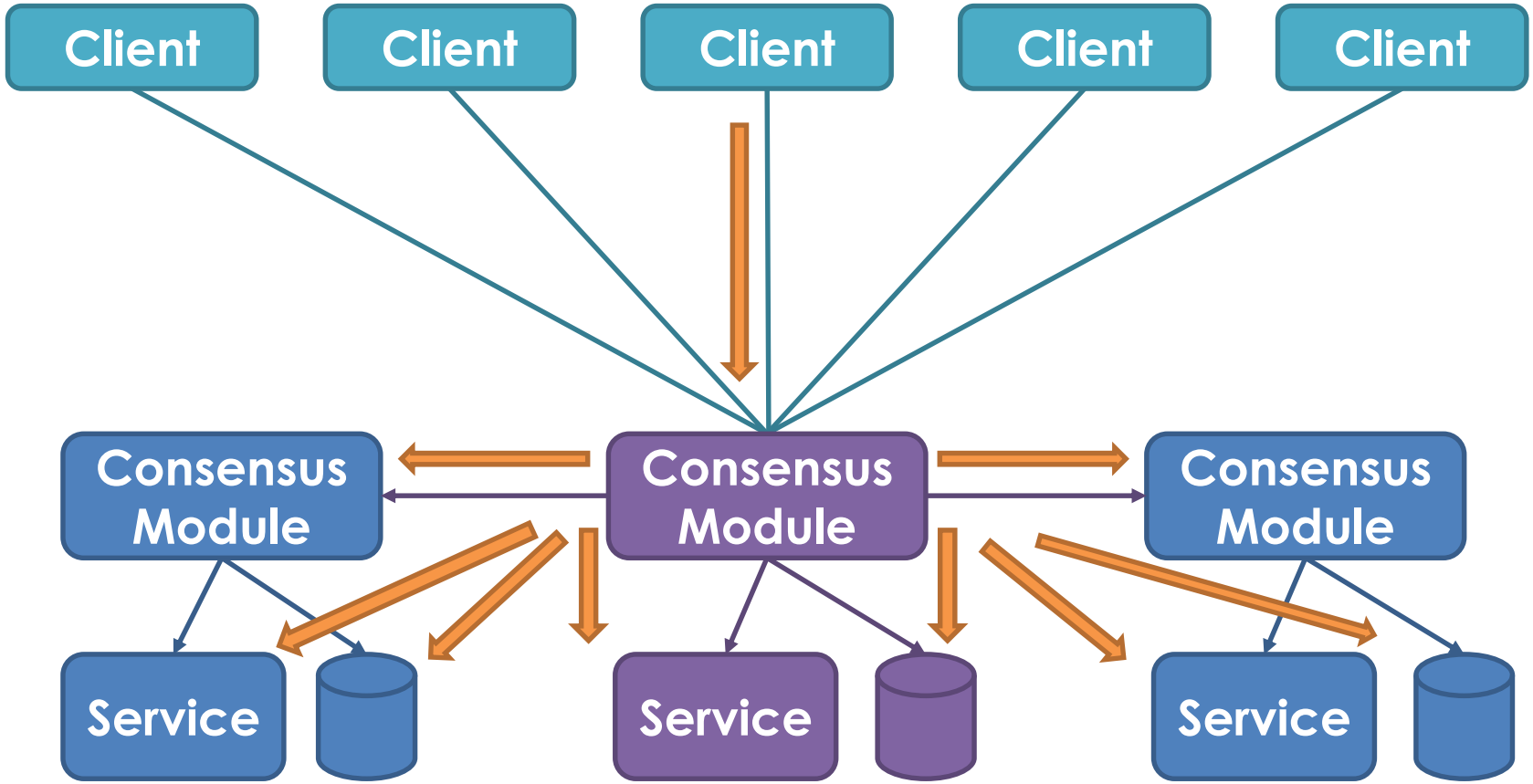
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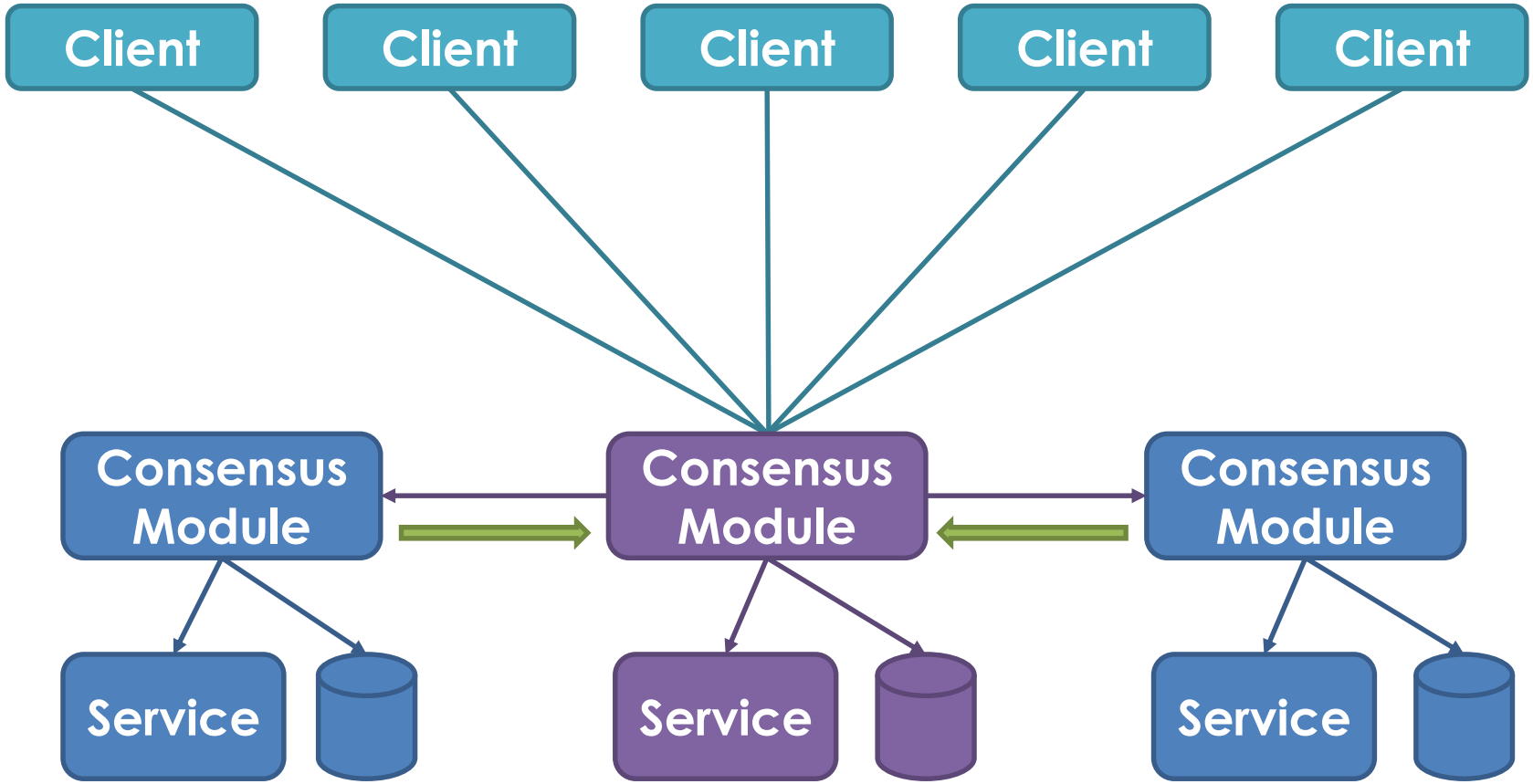
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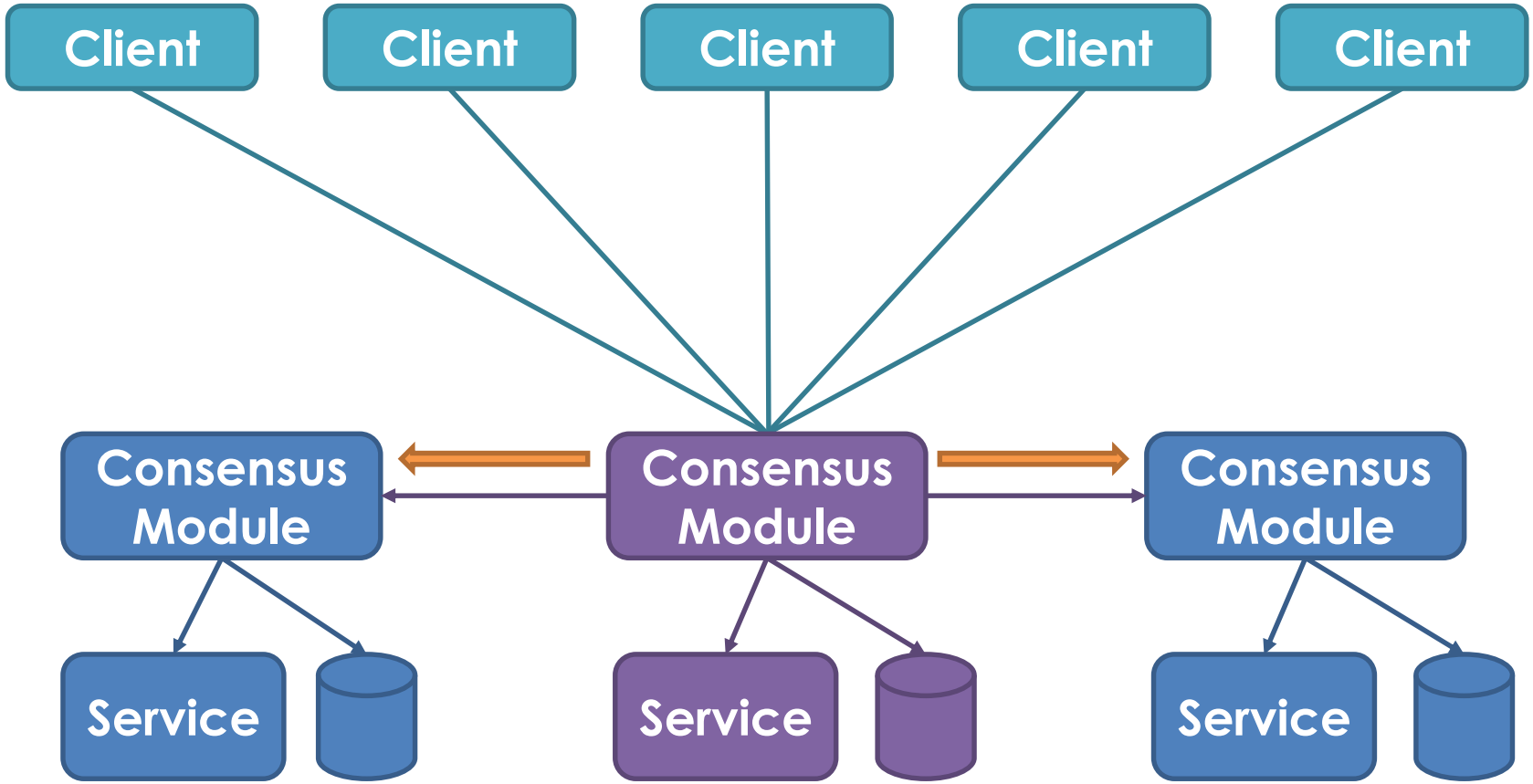
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NIO Pain!

ByteBuffer byte[] copies

```
ByteBuffer byteBuffer = ByteBuffer.allocate(64 * 1024);

byteBuffer.putInt(index, value);
```

ByteBuffer byte[] copies

```
ByteBuffer byteBuffer = ByteBuffer.allocate(64 * 1024);

byteBuffer.putBytes(index, bytes);
```

ByteBuffer byte[] copies

```
ByteBuffer byteBuf                    ocate(64 * 1024);

byteBuffe                             es);
```

https://bugs.openjdk.java.net/browse/JDK-5029431

2004-04-08 20:46

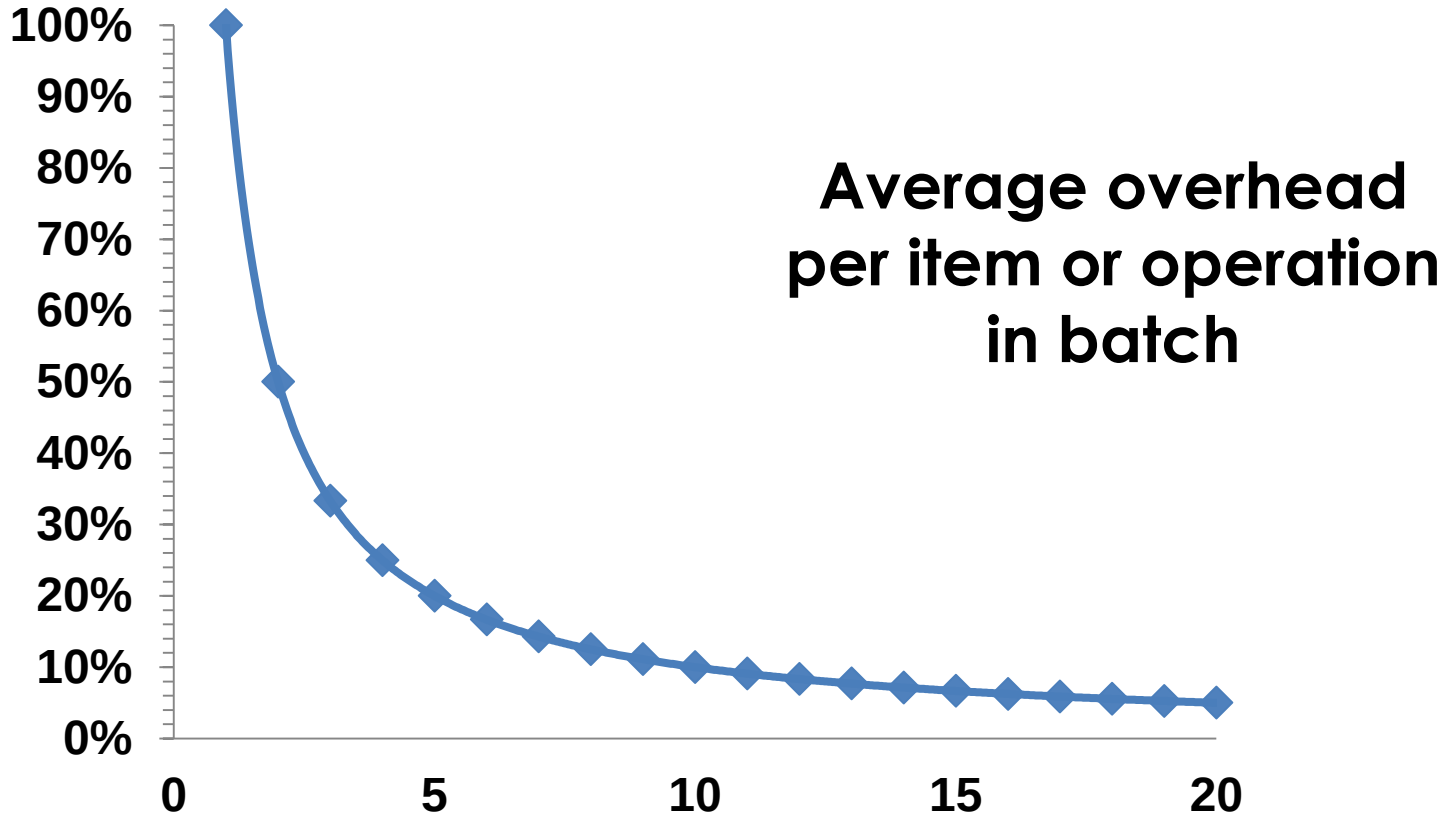
How can Aeron help?

Message Index => Byte Index

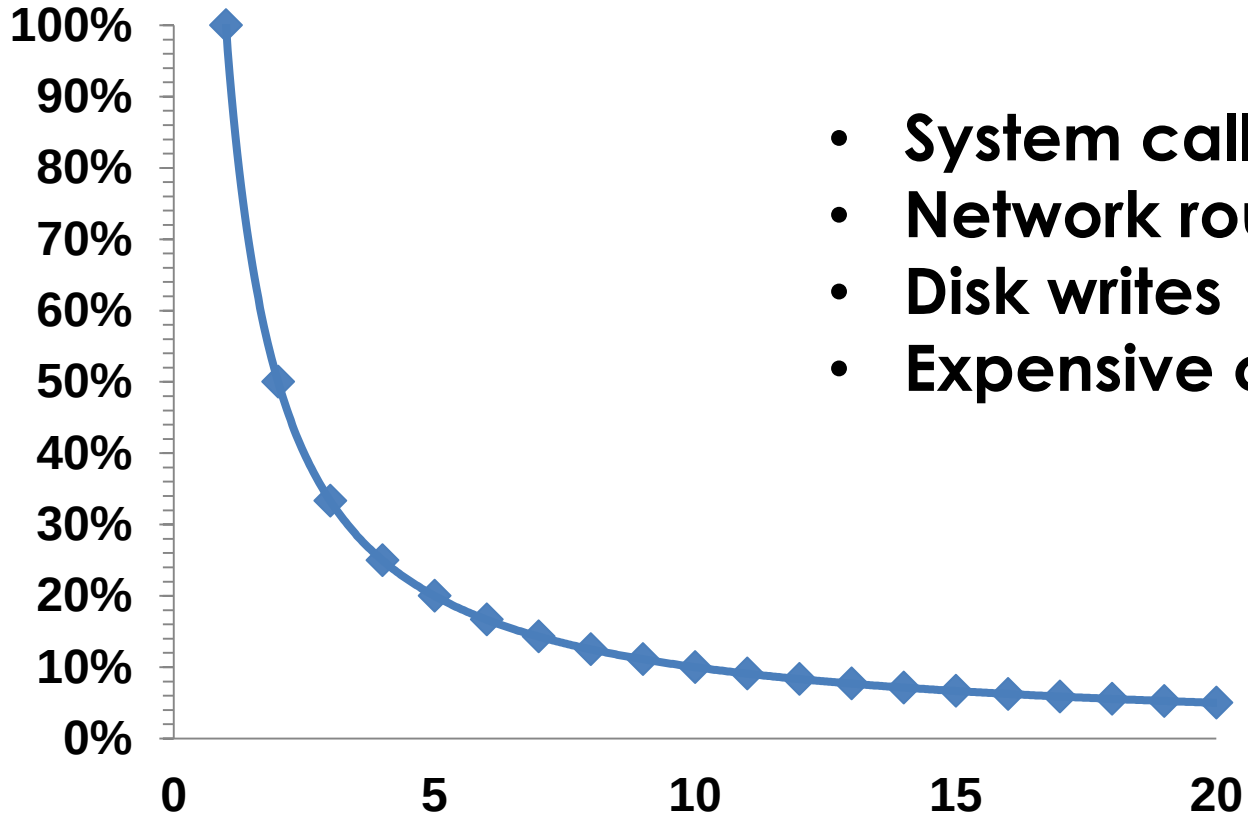
Multicast, MDC, and Spy based Messaging

Counters
=>
Bounded Consumption

Batching – Amortising Costs



Batching – Amortising Costs



- System calls
- Network round trips
- Disk writes
- Expensive computations

Interesting Features

Timers

All state must enter the system as a message!

Timers

```
public void foo()
{
    // Decide to schedule a timer

    cluster.scheduleTimer(correlationId, cluster.timeMs() + TimeUnit.SECONDS.toMillis(5));
}

public void onTimerEvent(final long correlationId, final long timestampMs)
{
    // Look up the correlationId associated with the timer
}
```

Timers

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```

Back Pressure and Stashed Work

Back Pressure

```
public ControlledFragmentAssembler.Action onSessionMessage(
    final DirectBuffer buffer,
    final int offset,
    final int length,
    final long clusterSessionId,
    final long correlationId)
{
    final ClusterSession session = sessionByIdMap.get(clusterSessionId);
    if (null == session || session.state() == CLOSED)
    {
        return ControlledFragmentHandler.Action.CONTINUE;
    }

    final long nowMs = cachedEpochClock.time();
    if (session.state() == OPEN && logPublisher.appendMessage(buffer, offset, length, nowMs))
    {
        session.lastActivity(nowMs, correlationId);
        return ControlledFragmentHandler.Action.CONTINUE;
    }

    return ControlledFragmentHandler.Action.ABORT;
}
```

Back Pressure

```
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    return ControlledFragmentHandler.Action.ABORT;
}
```

Back Pressure

```
public ControlledFragmentAssembler.Action onSessionMessage(
    final DirectBuffer buffer,
    final int offset,
    final int length,
    final long clusterSessionId,
    final long correlationId)
{
    final ClusterSession session = sessionByIdMap.get(clusterSessionId);
    if (null == session || session.state() == CLOSED)
    {
        return ControlledFragmentHandler.Action.CONTINUE;
    }

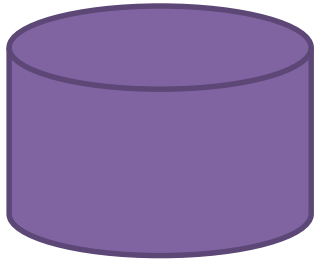
    final long nowMs = cachedEpochClock.time();
    if (session.state() == OPEN && logPublisher.appendMessage(buffer, offset, length, nowMs))
    {
        session.lastActivity(nowMs, correlationId);
        return ControlledFragmentHandler.Action.CONTINUE;
    }

    return ControlledFragmentHandler.Action.ABORT;
}
```

Log Replay and Snapshots

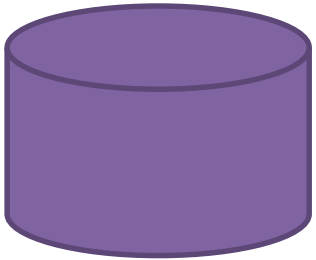
Log Replay and Snapshots

Distributed File System?



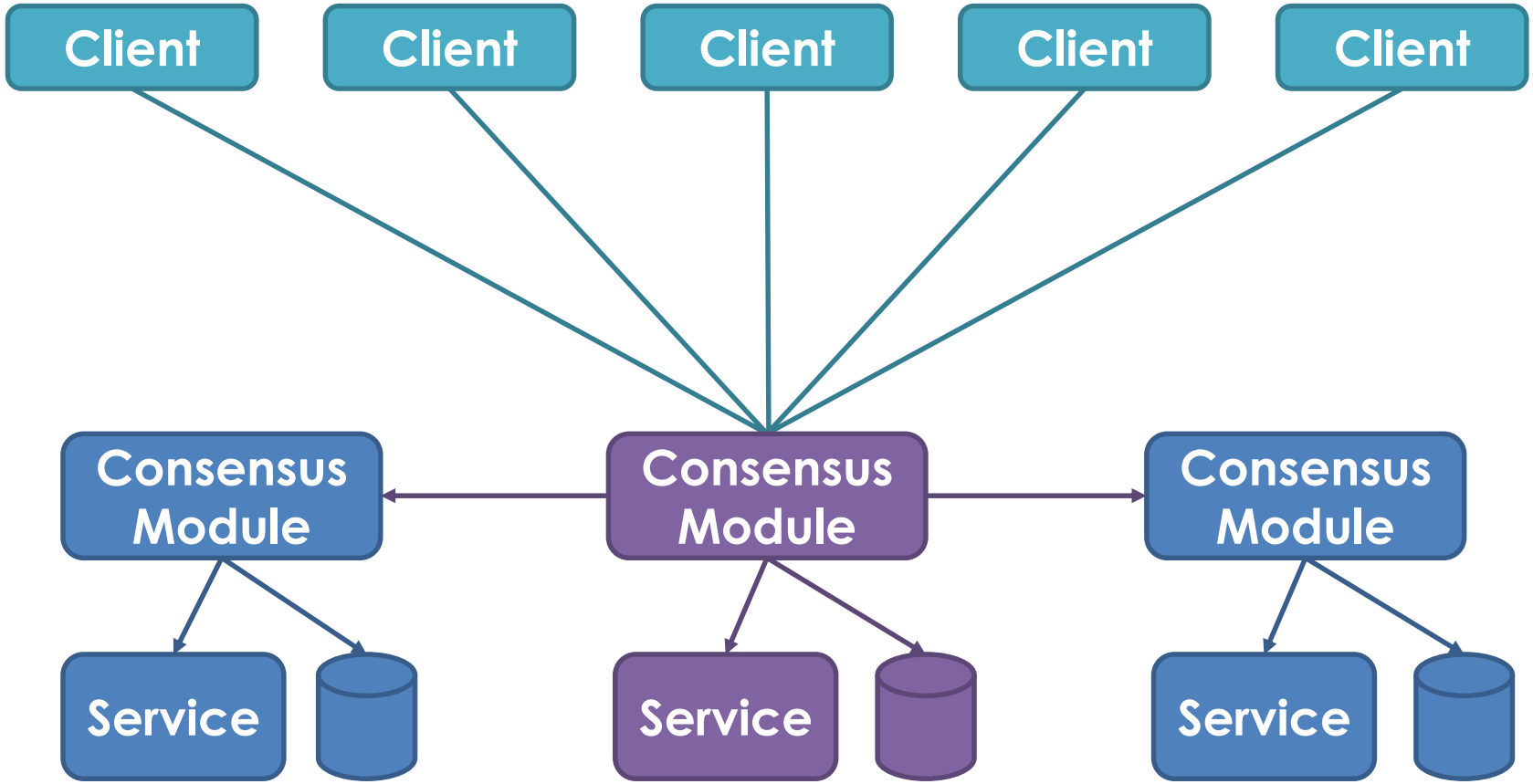
Log Replay and Snapshots

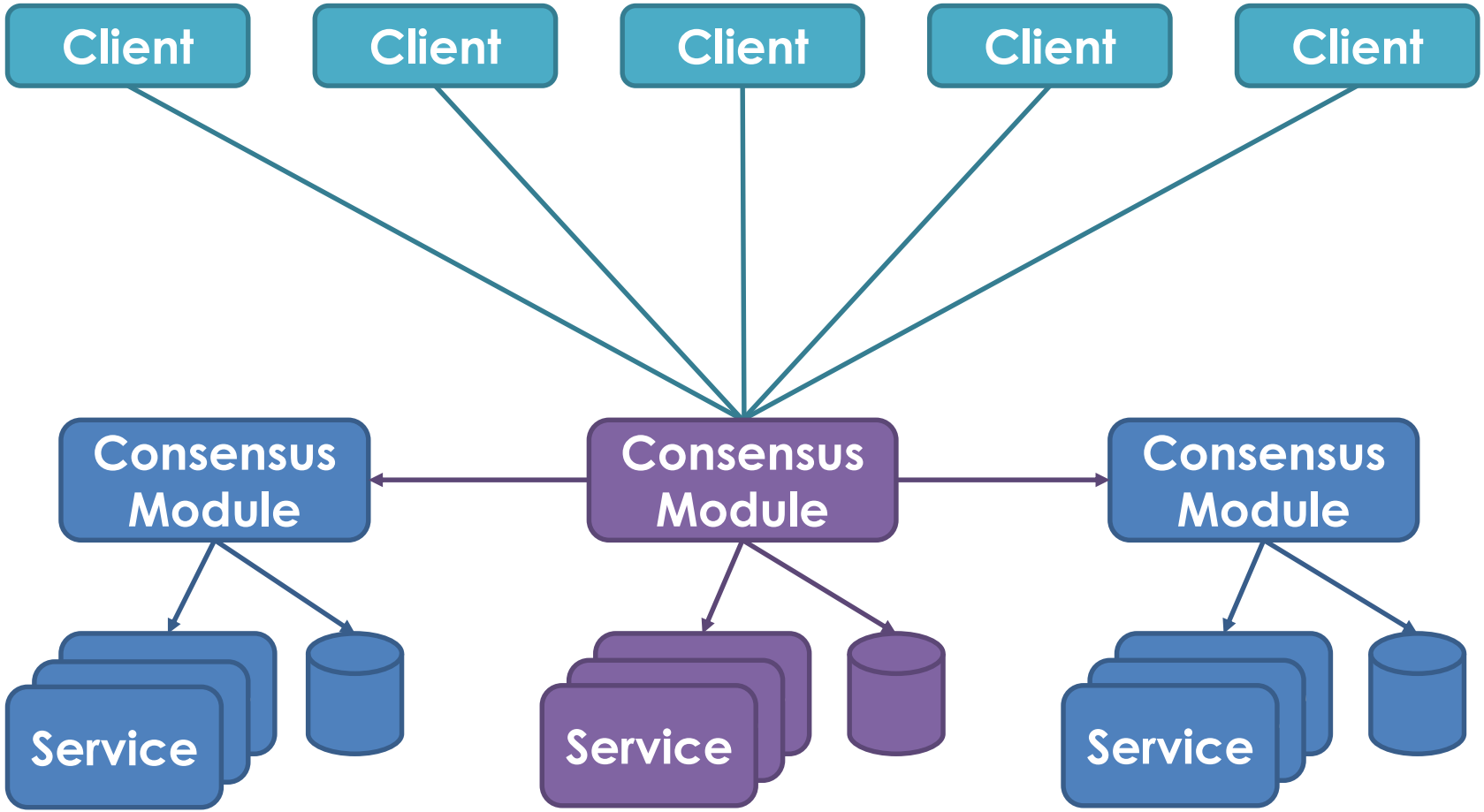
Distributed File System?



Aeron Archive
Recorded Streams

Multiple Services on the same stream


Client
Client
Client
Client
Client
Consensus Module
Consensus Module
Consensus Module
Service
Service
Service


Client
Client
Client
Client
Client
Consensus Module
Consensus Module
Consensus Module
Service
Service
Service

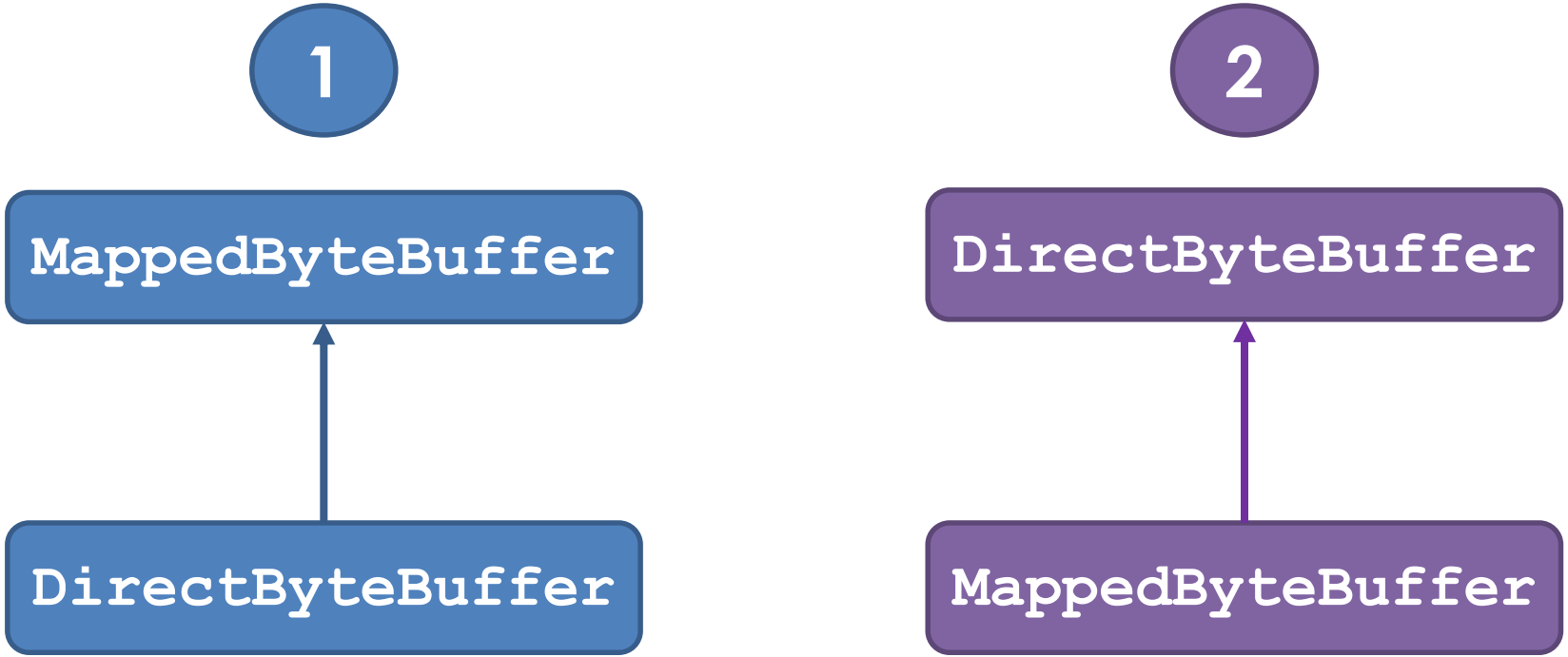
NIO Pain!

1

`MappedByteBuffer`

2

`DirectByteBuffer`


1
MappedByteBuffer
DirectByteBuffer
2
DirectByteBuffer
MappedByteBuffer

In Closing

What’s the Roadmap?


Do epic shit,
or die trying.

Questions?

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

Twitter: @mjpt777

"A distributed system is one in which the failure of a computer you didn't even know existed can render your own computer unusable."

- Leslie Lamport