Low End-to-End Latency atop a Speculative Shared Log with Fix-Ante Ordering






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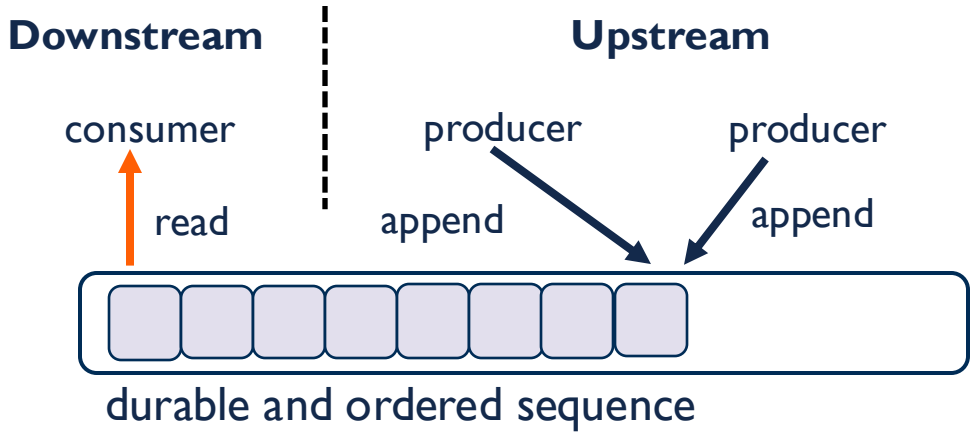

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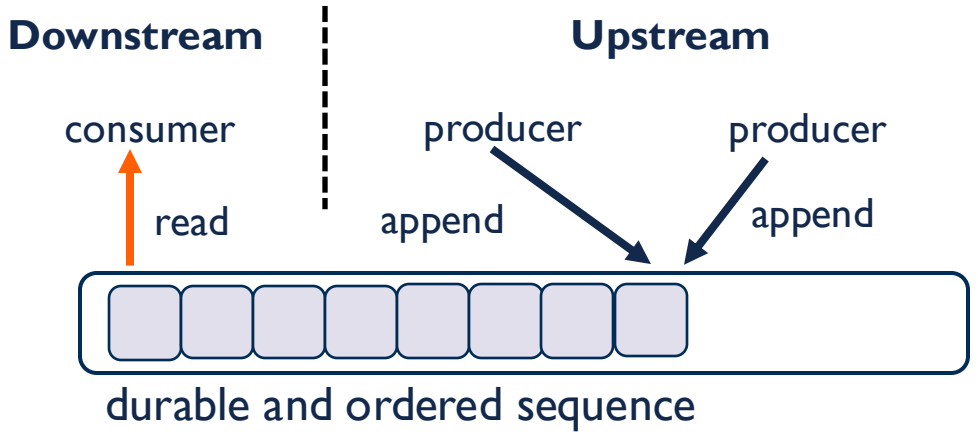

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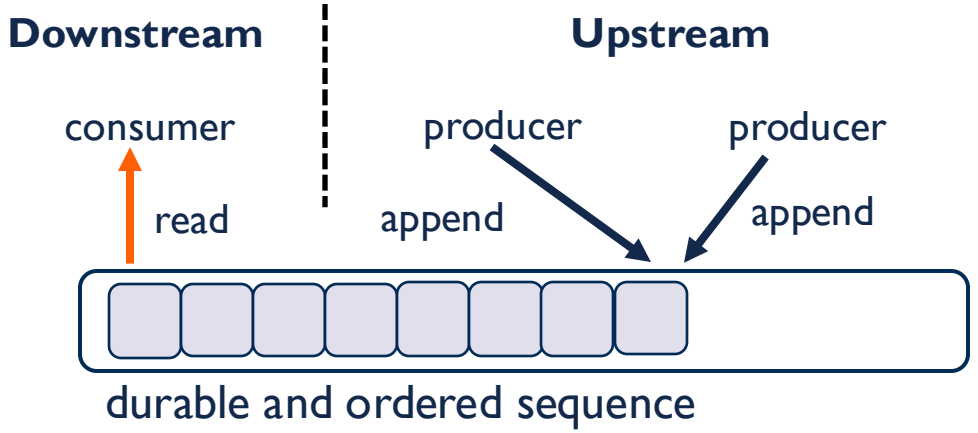

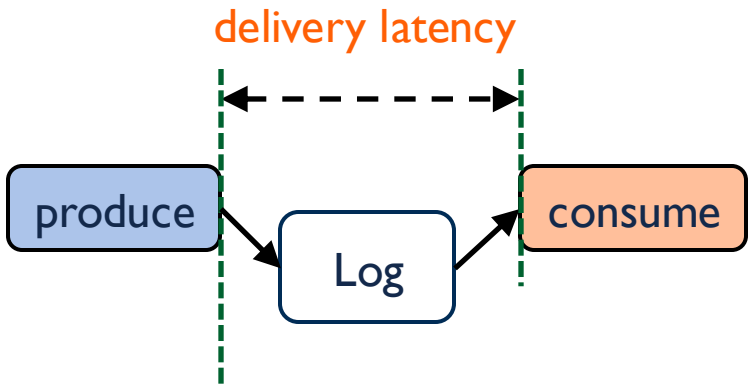

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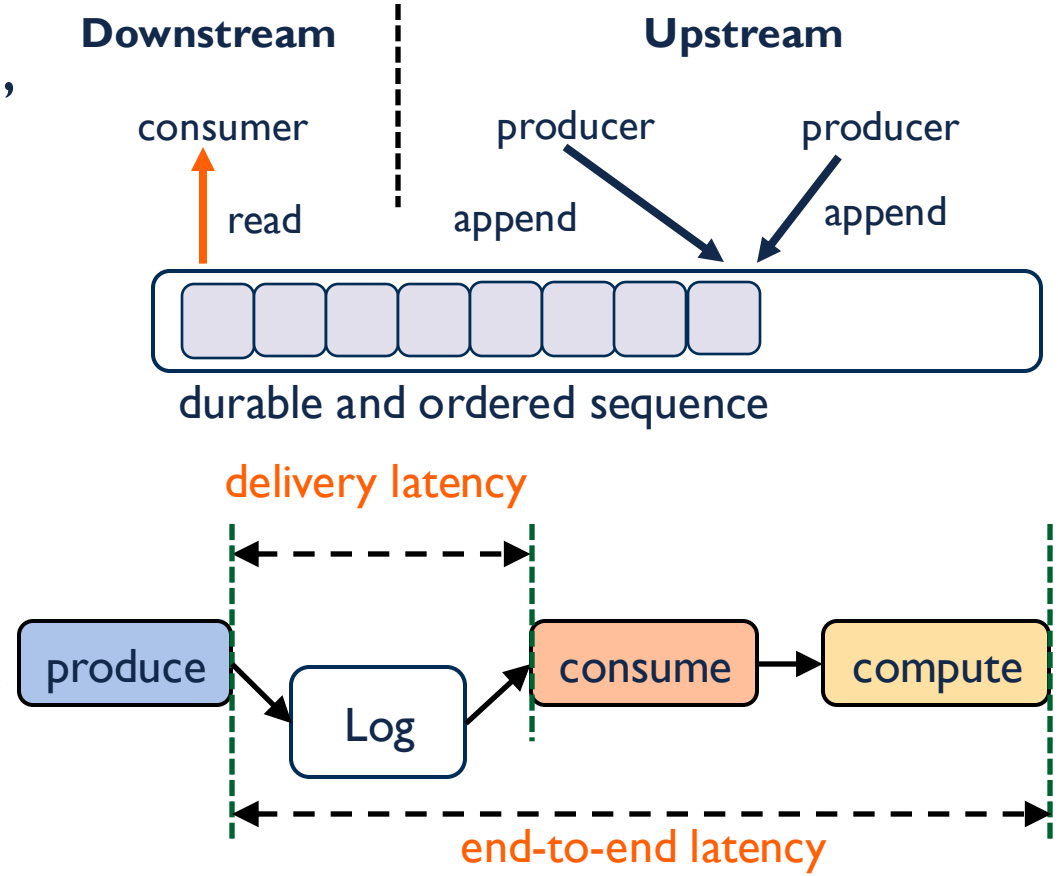

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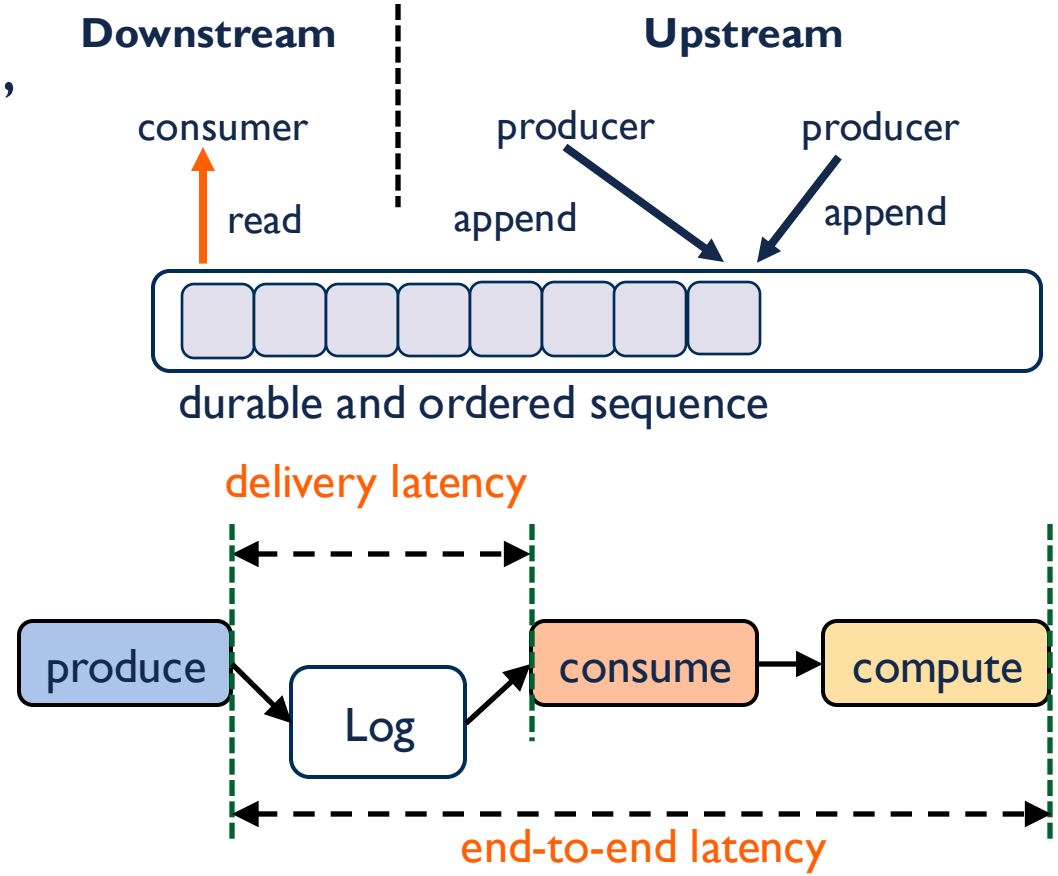
Cause: expensive ordering before record delivery



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Allow speculative consumption of records by predicting order

Overlap ordering and application compute

Confirm the order after compute

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Fix-Ante Ordering

Predetermine the global order for easy prediction

Make system adhere to that order

High speculation success!

Contributions

- *SpecLog* – A new speculative shared log abstraction, uses fix-ante ordering to enable near perfect speculation

- *Belfast* – Implementation of *SpecLog* abstraction and fix-ante ordering
  - Addresses practical challenges that arise in implementing fix-ante ordering
  - Enables low e2e latency while retaining benefits and guarantees of today's shared logs

- E2E latency benefits in end applications like fraud detection, intrusion detection and high-frequency trading

Outline

- Introduction
- Motivation
- SpecLog Abstraction and Interface
- Belfast – An Implementation of SpecLog
- Evaluation

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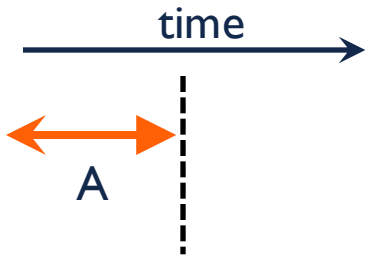

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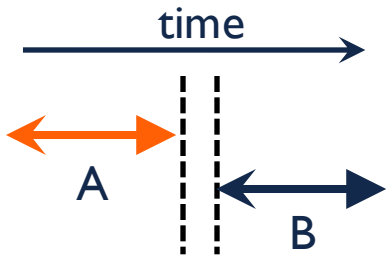

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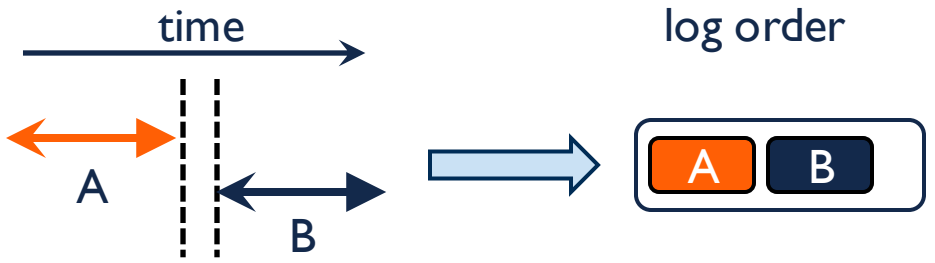

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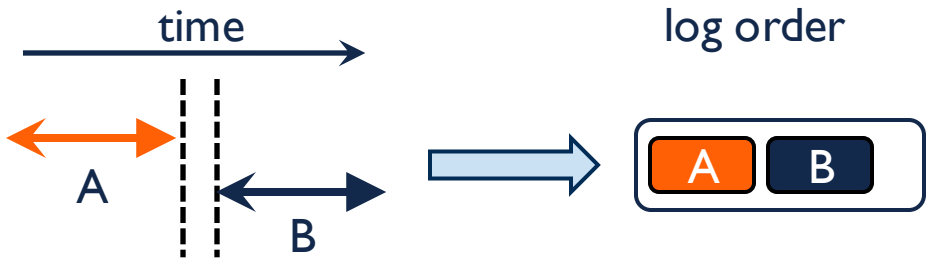
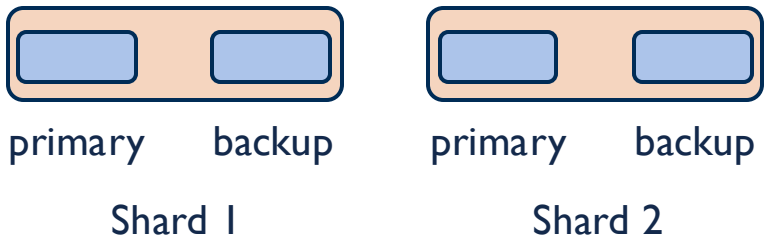


Store records over multiple *storage shards*



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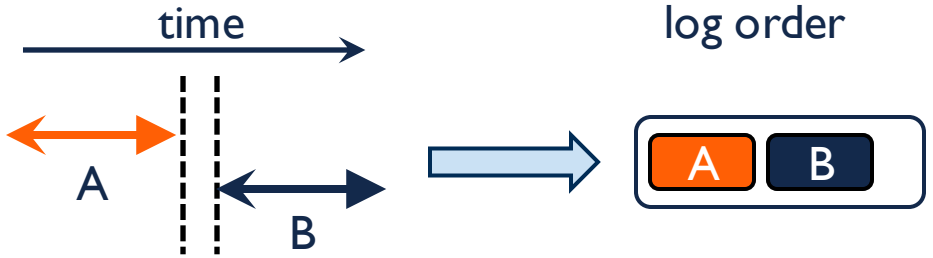

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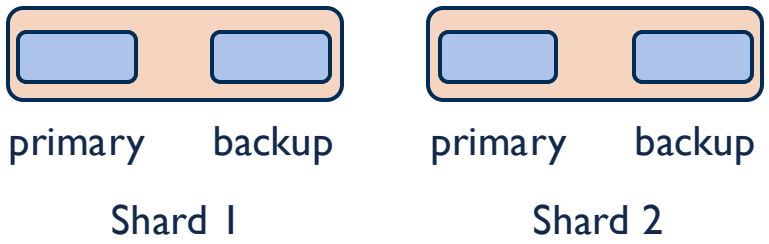

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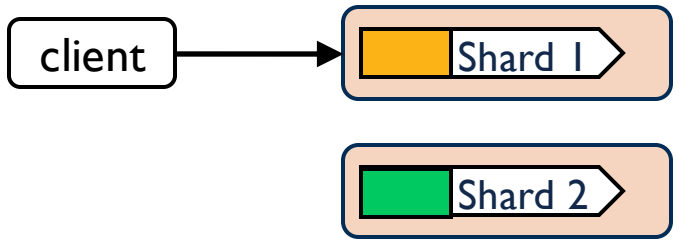

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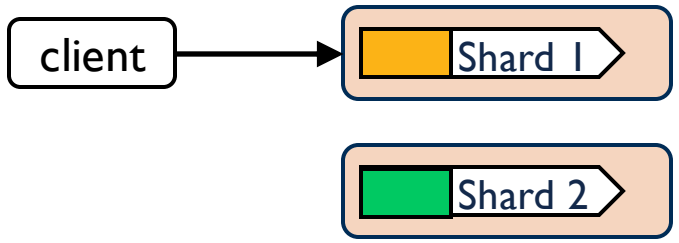

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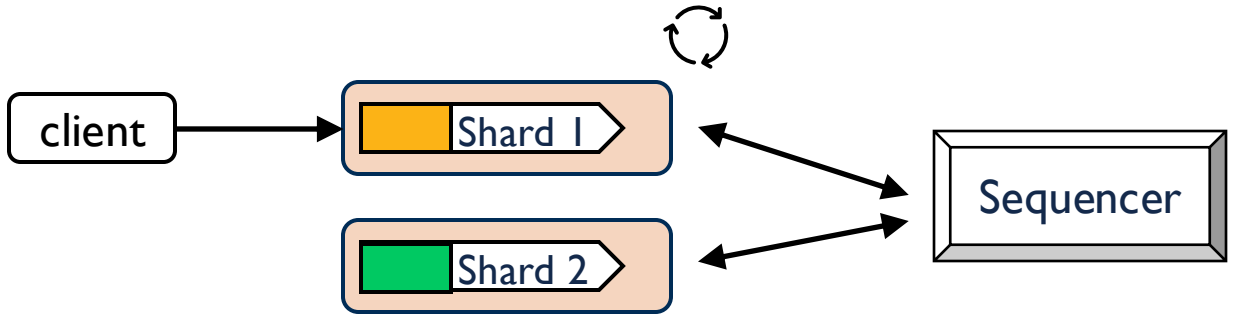

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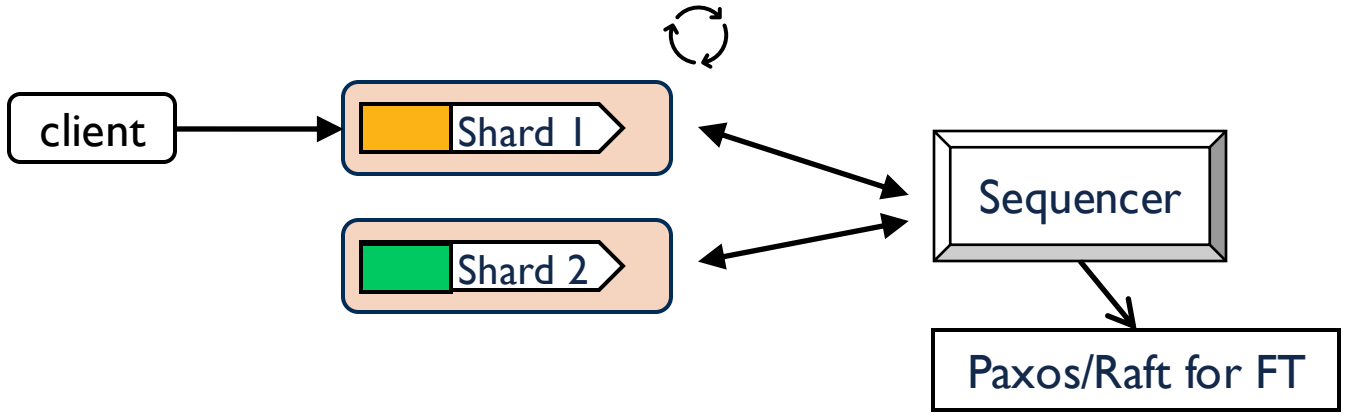

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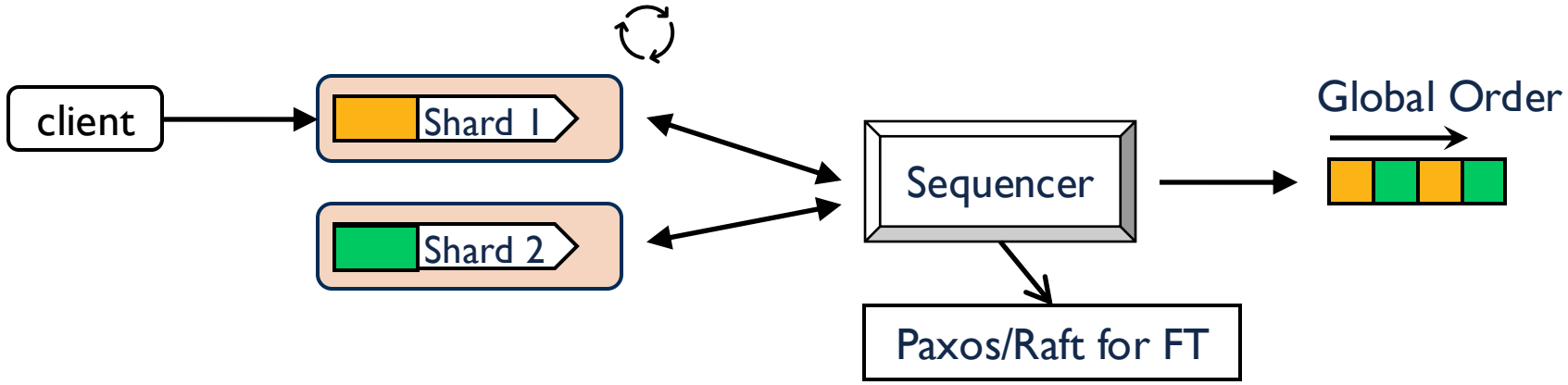

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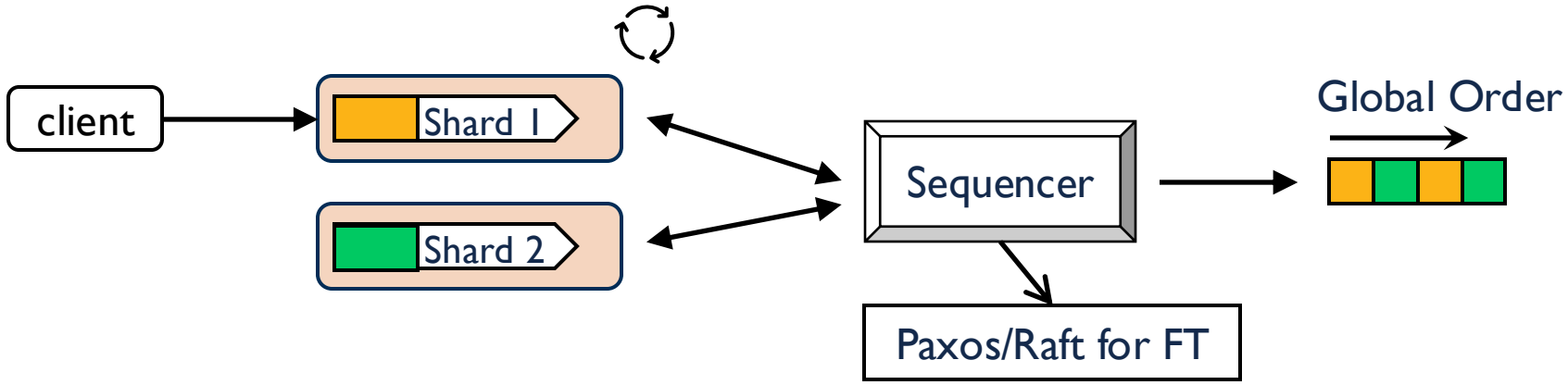

Flexible Data Placement **Seamlessly Reconfigurable** **Scalablity**

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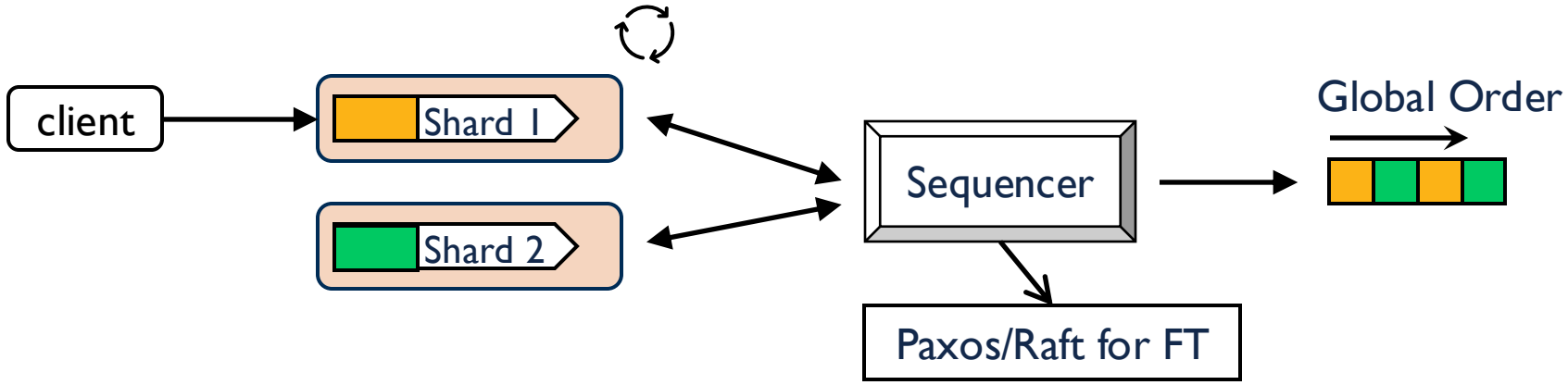

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Similar designs adopted by Boki [SOSP'21], FlexLog [HPDC'23]

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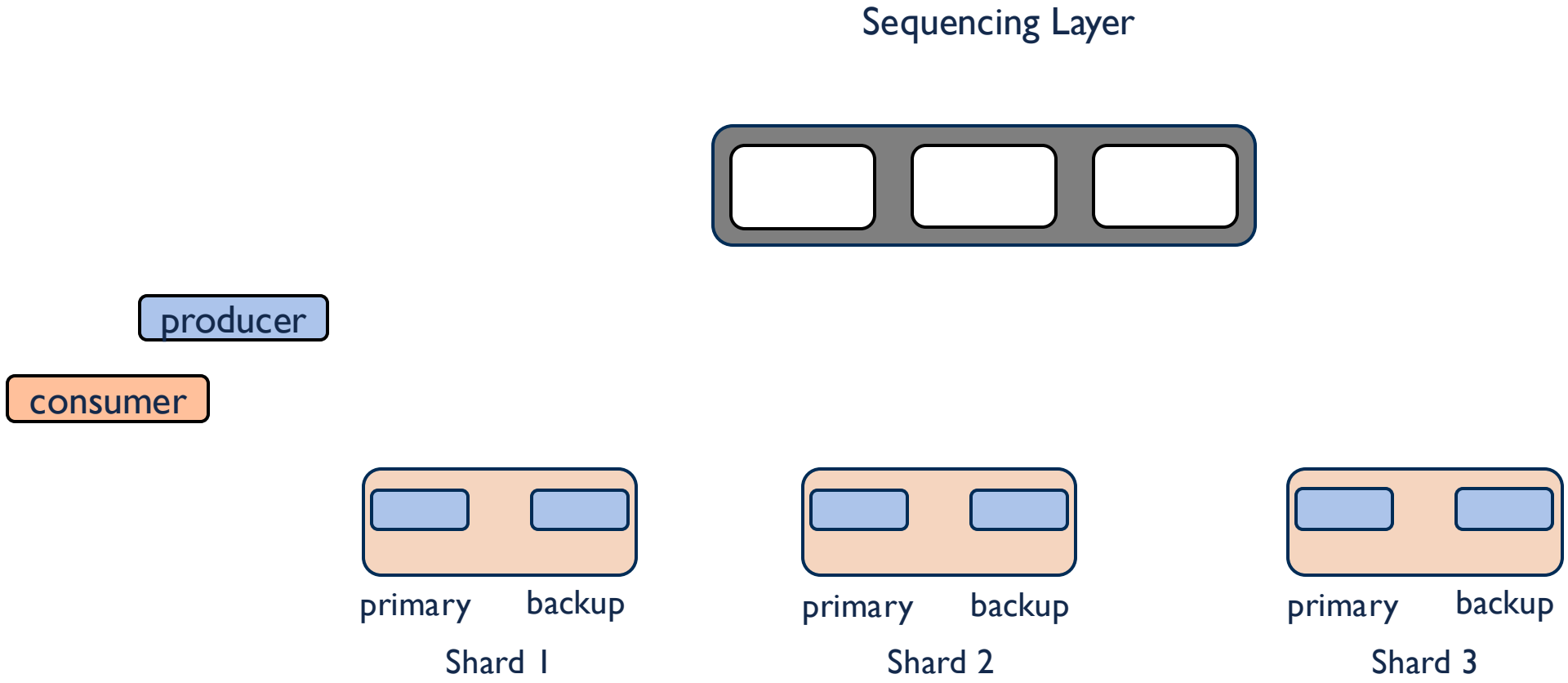

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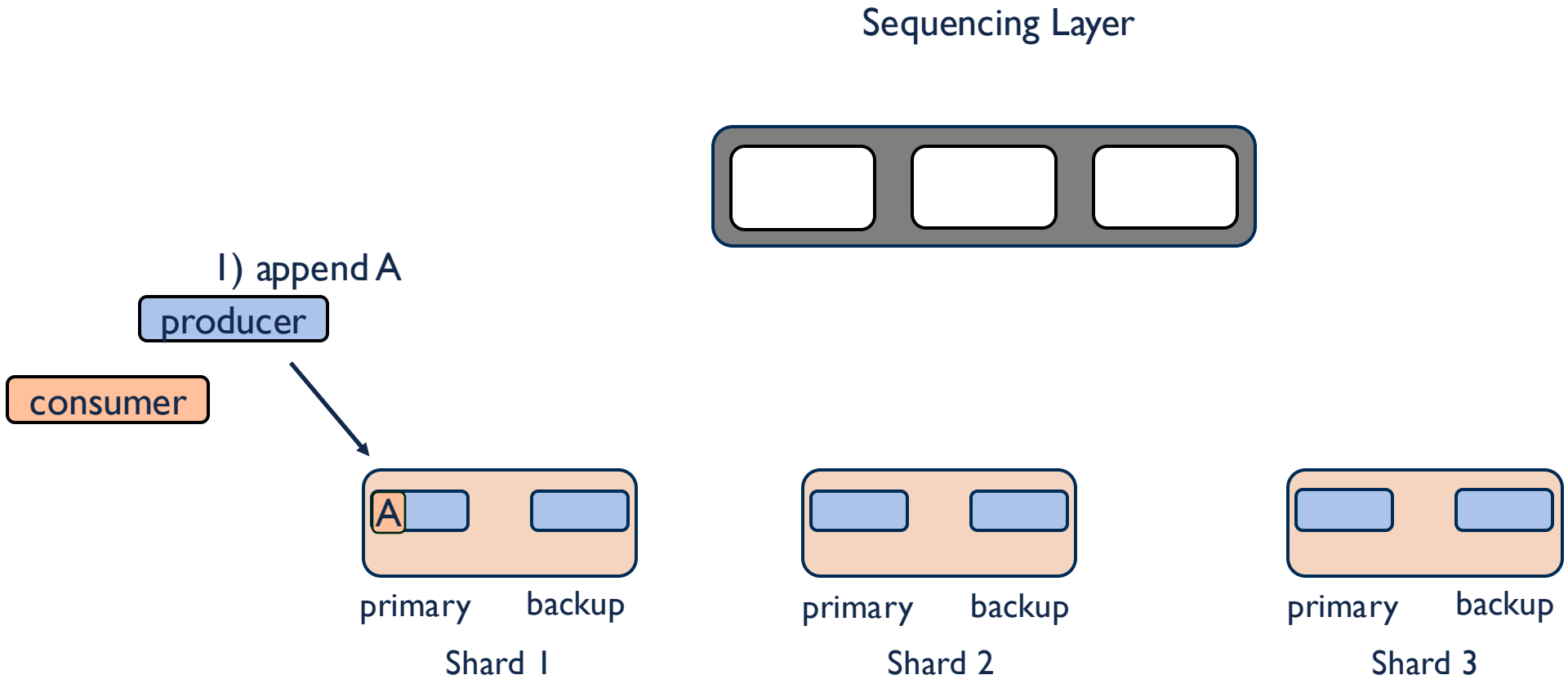

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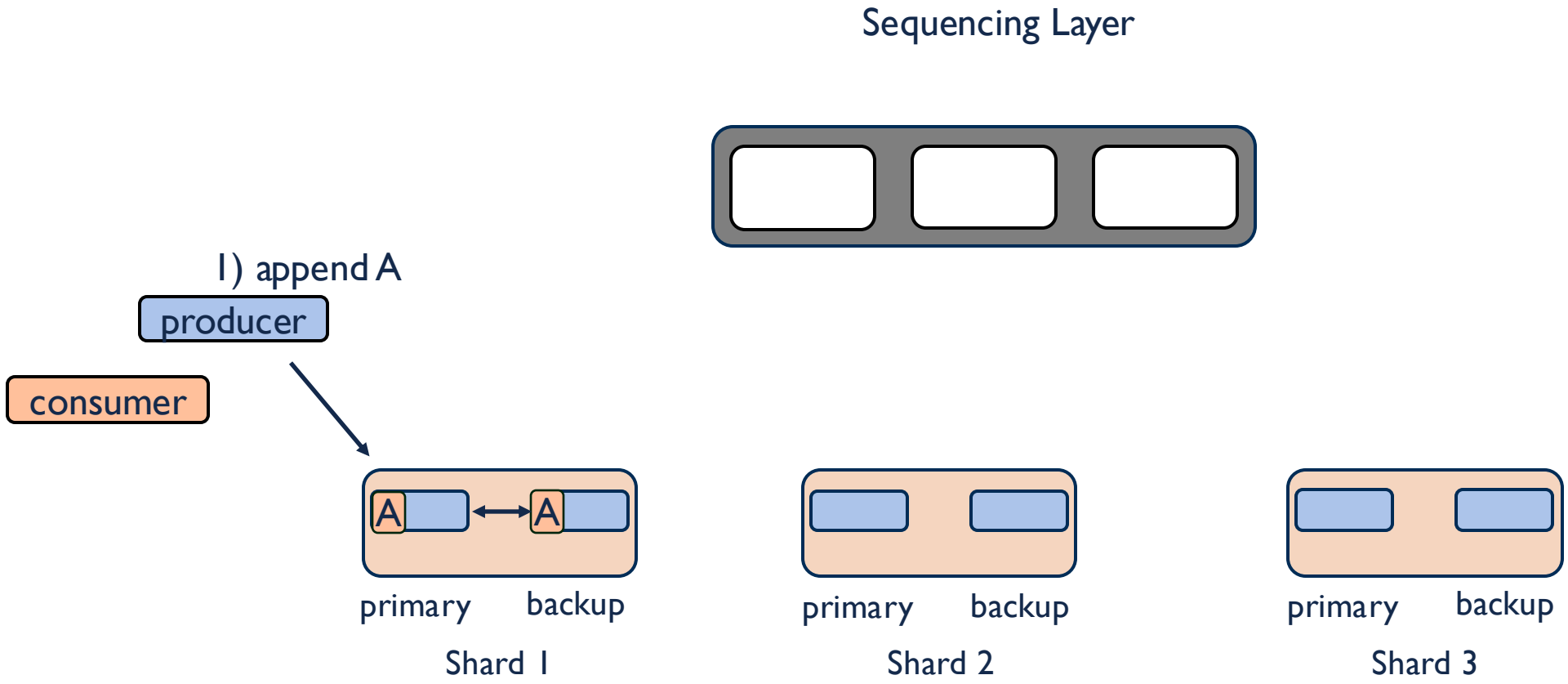

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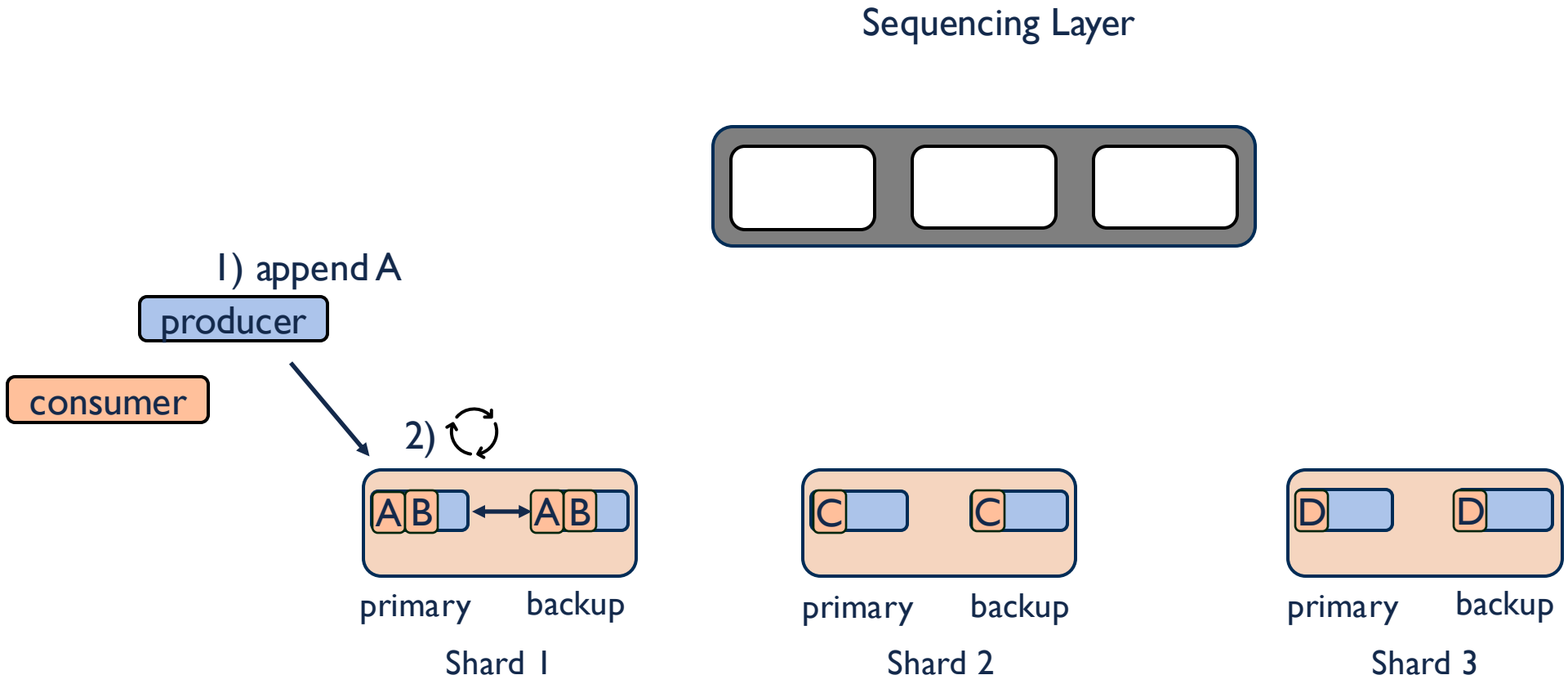

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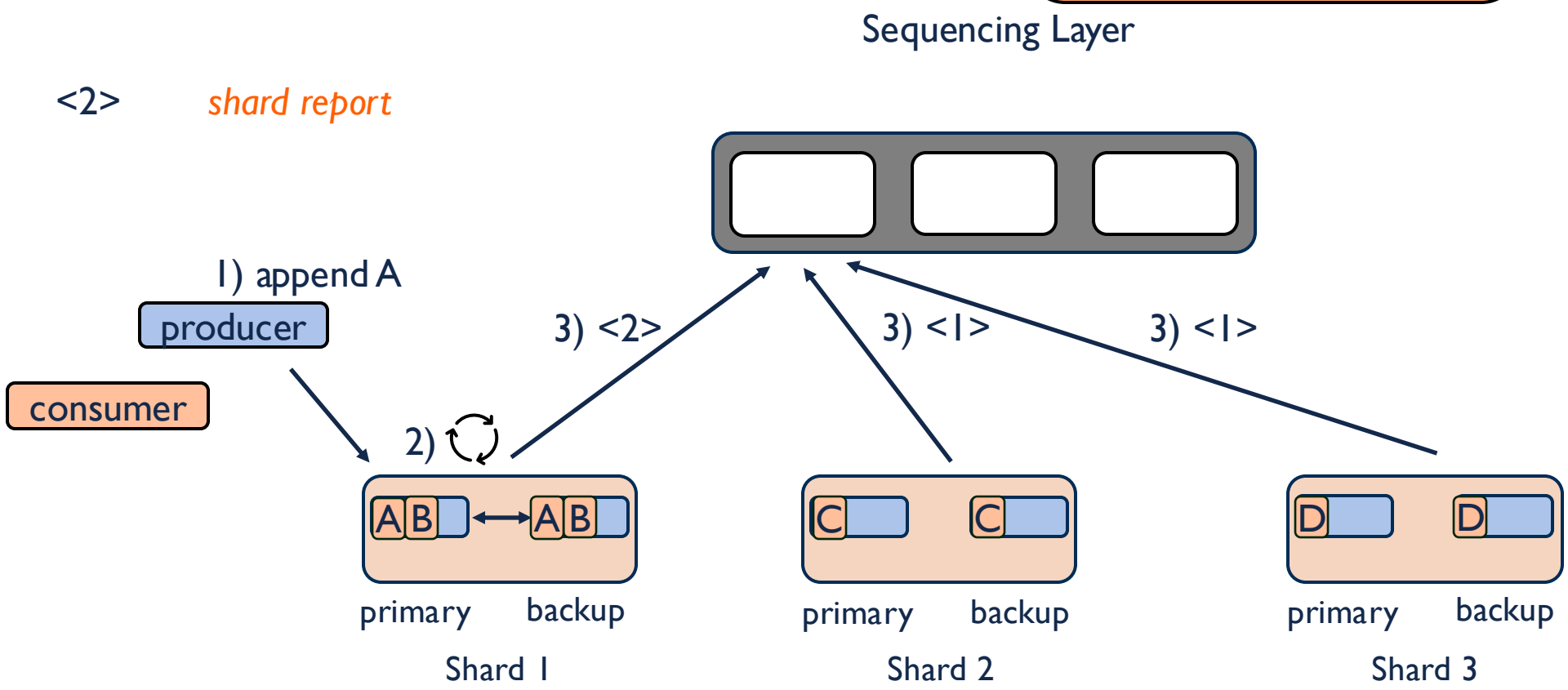

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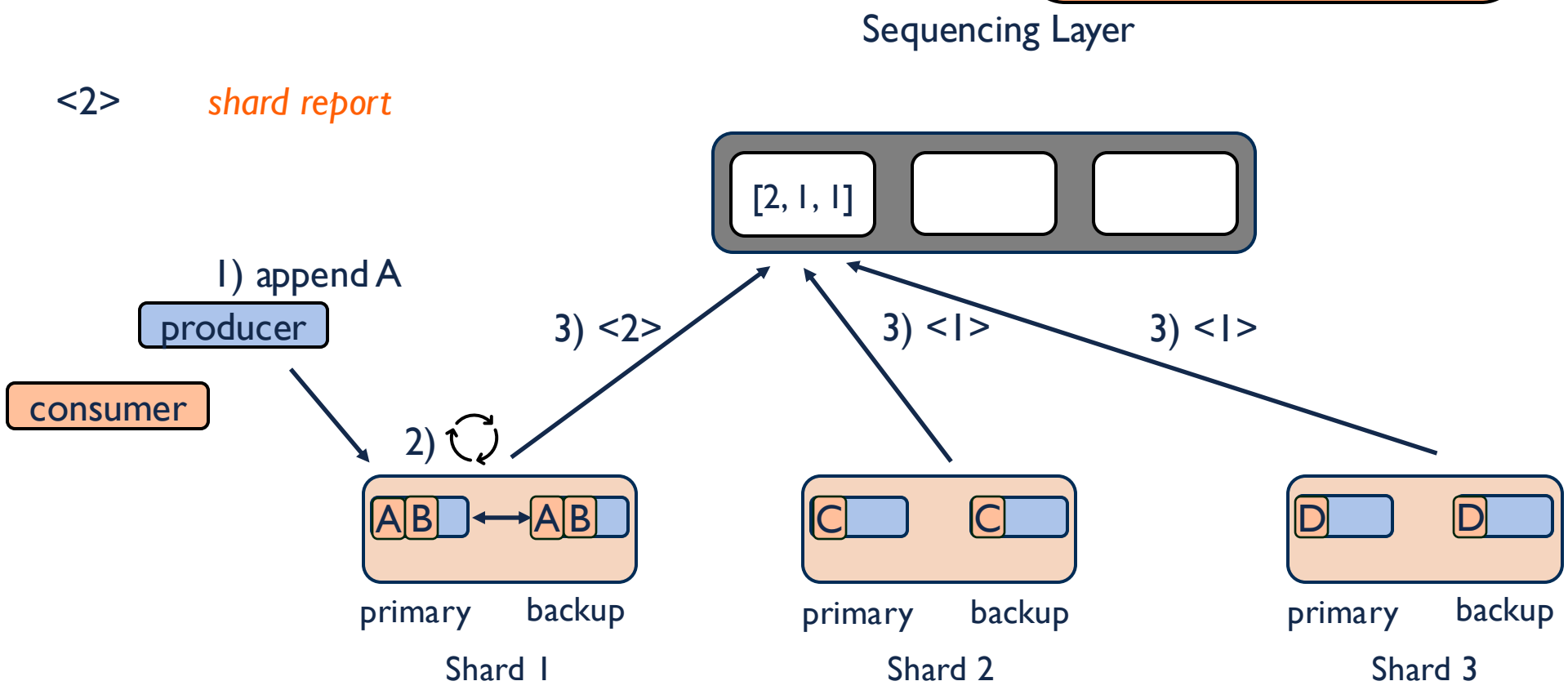

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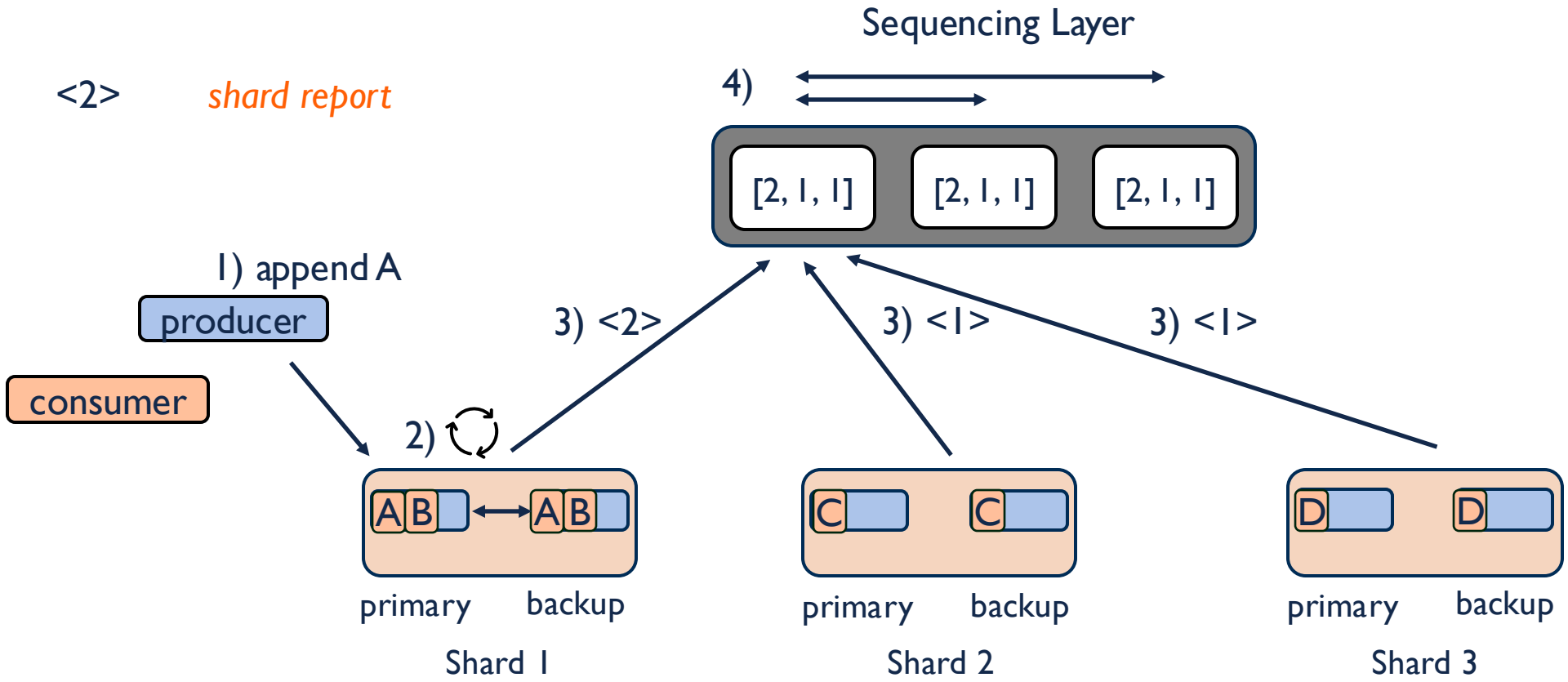

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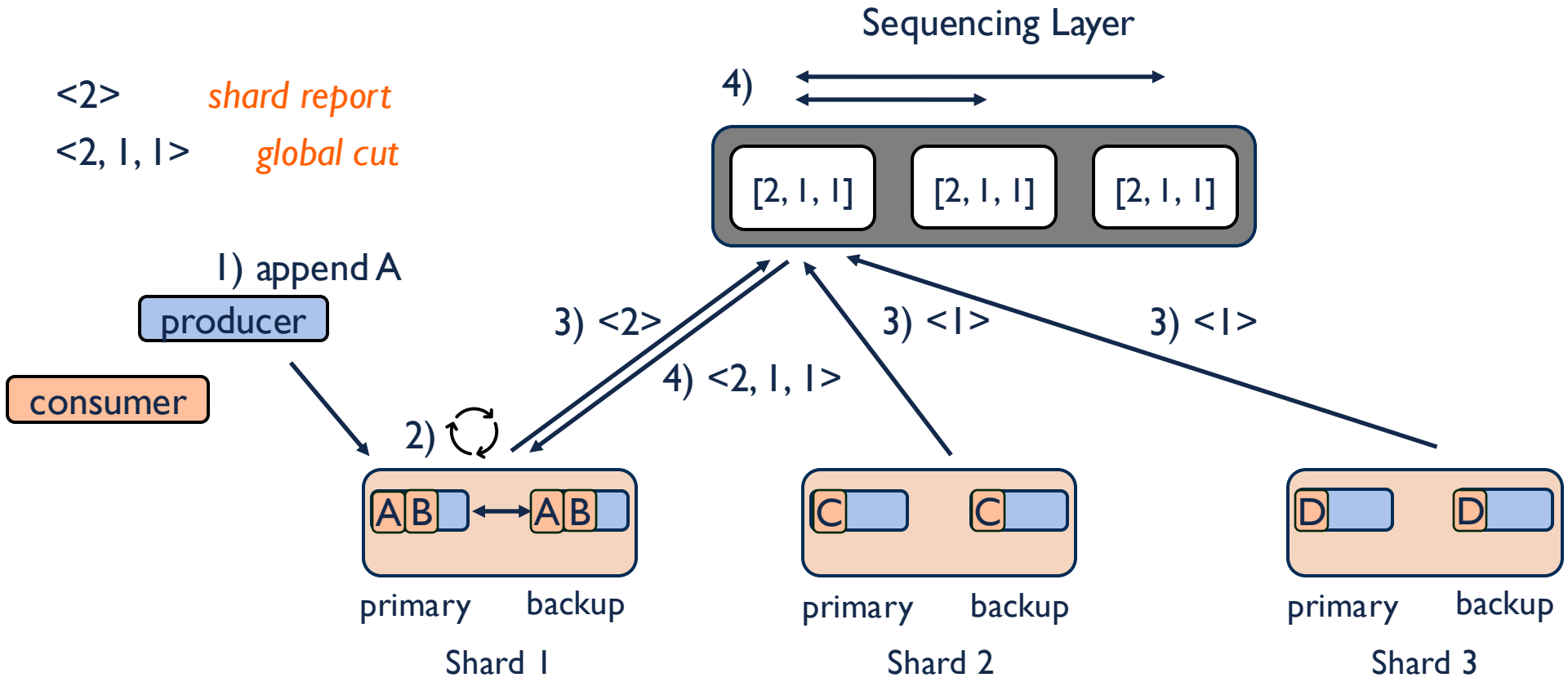

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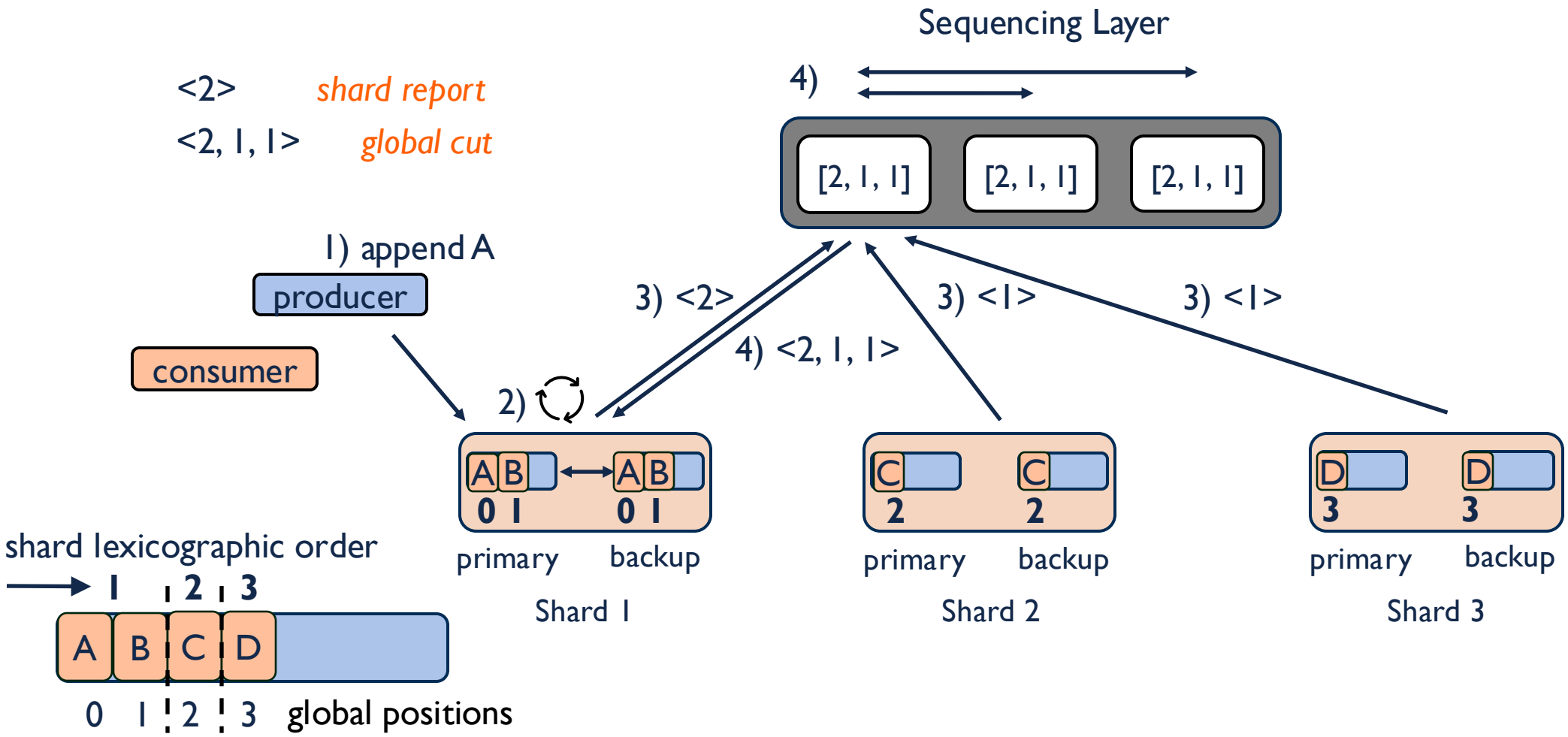

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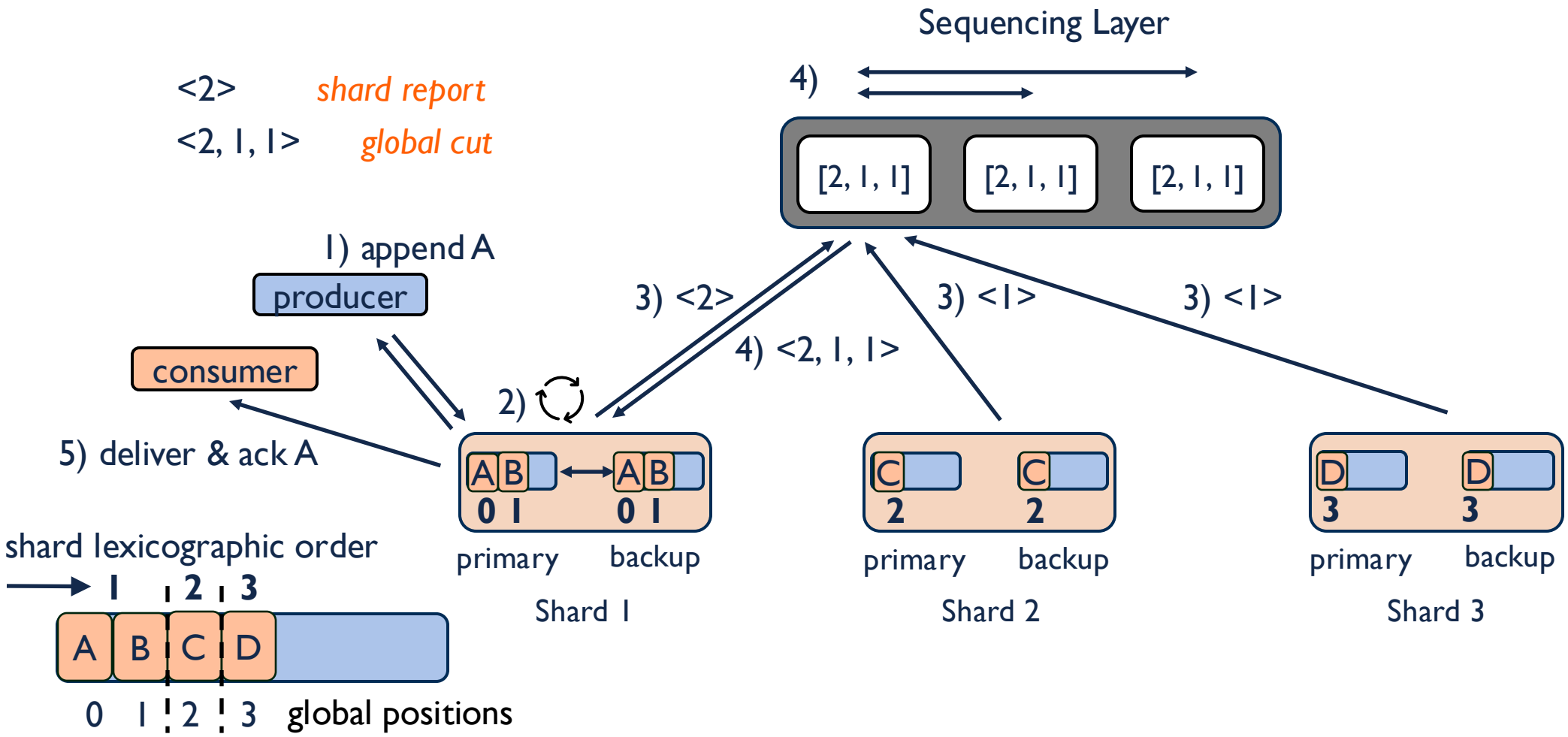

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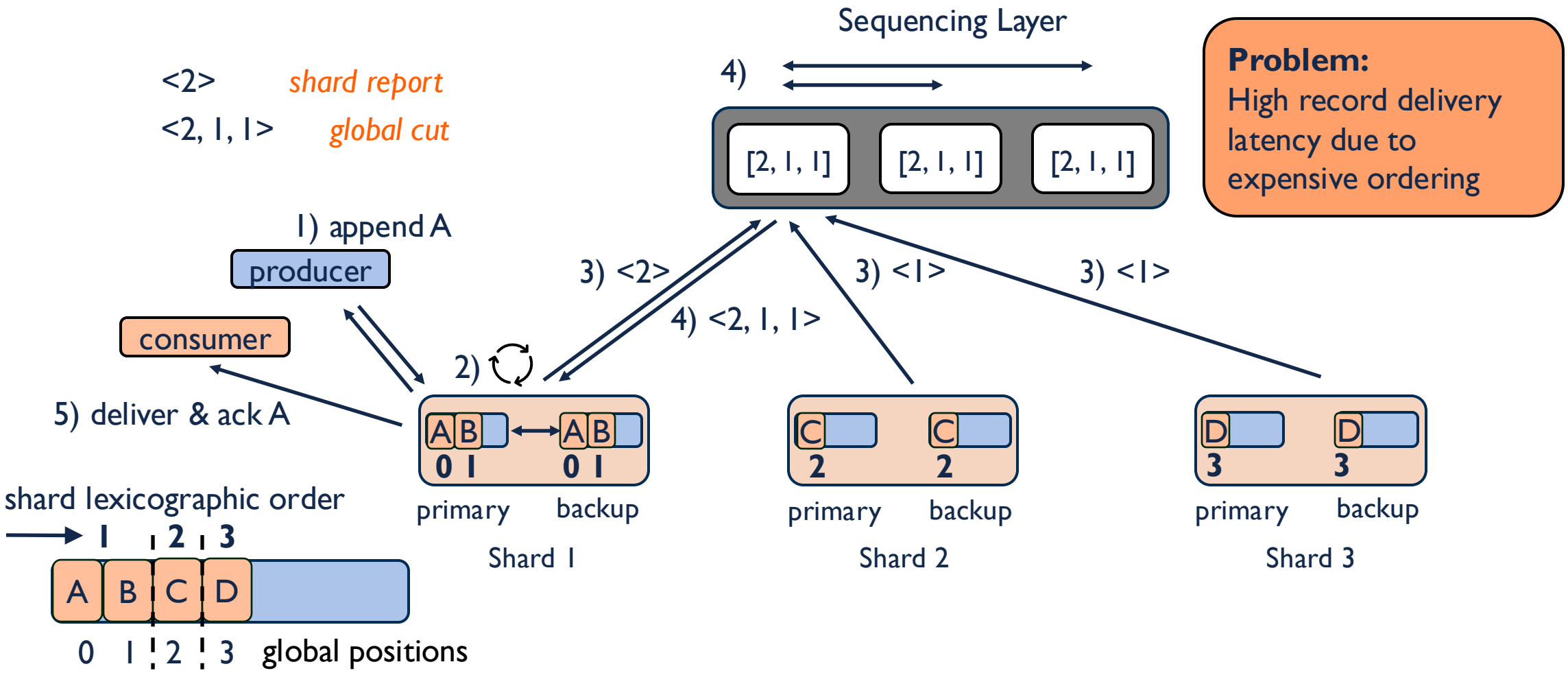
Problem:
High record delivery latency due to expensive ordering



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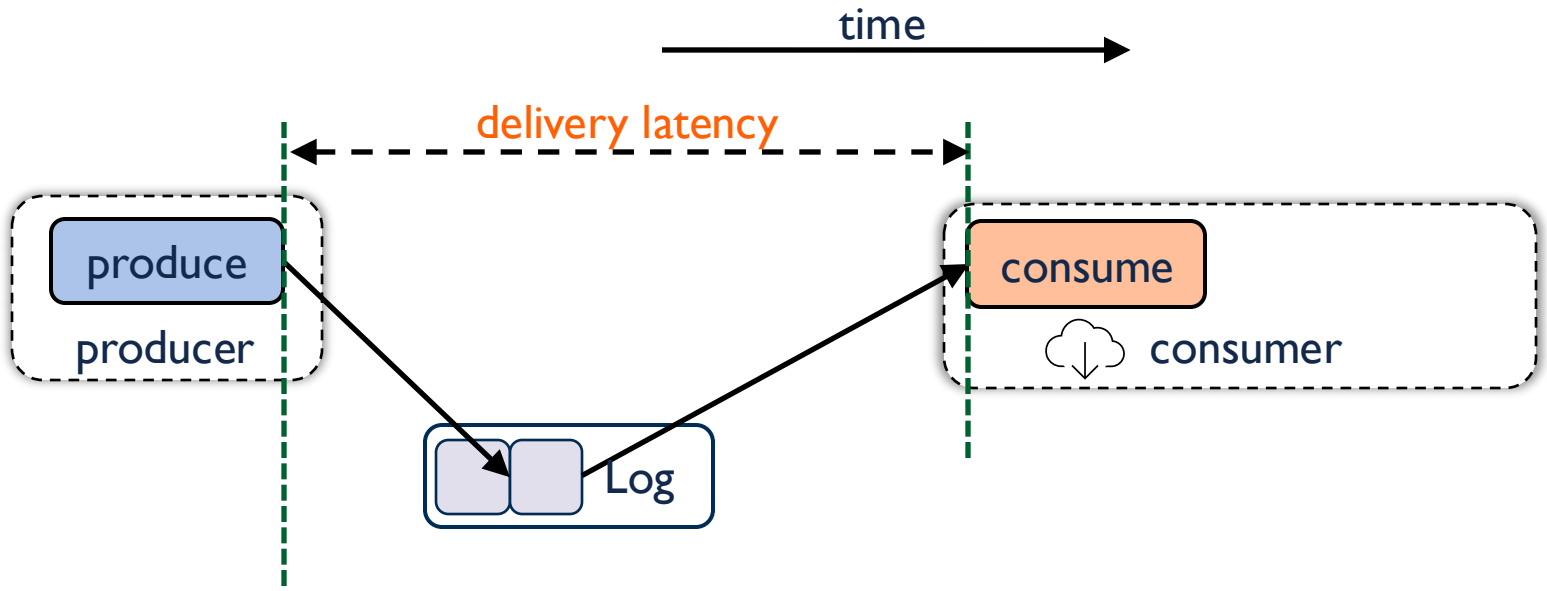

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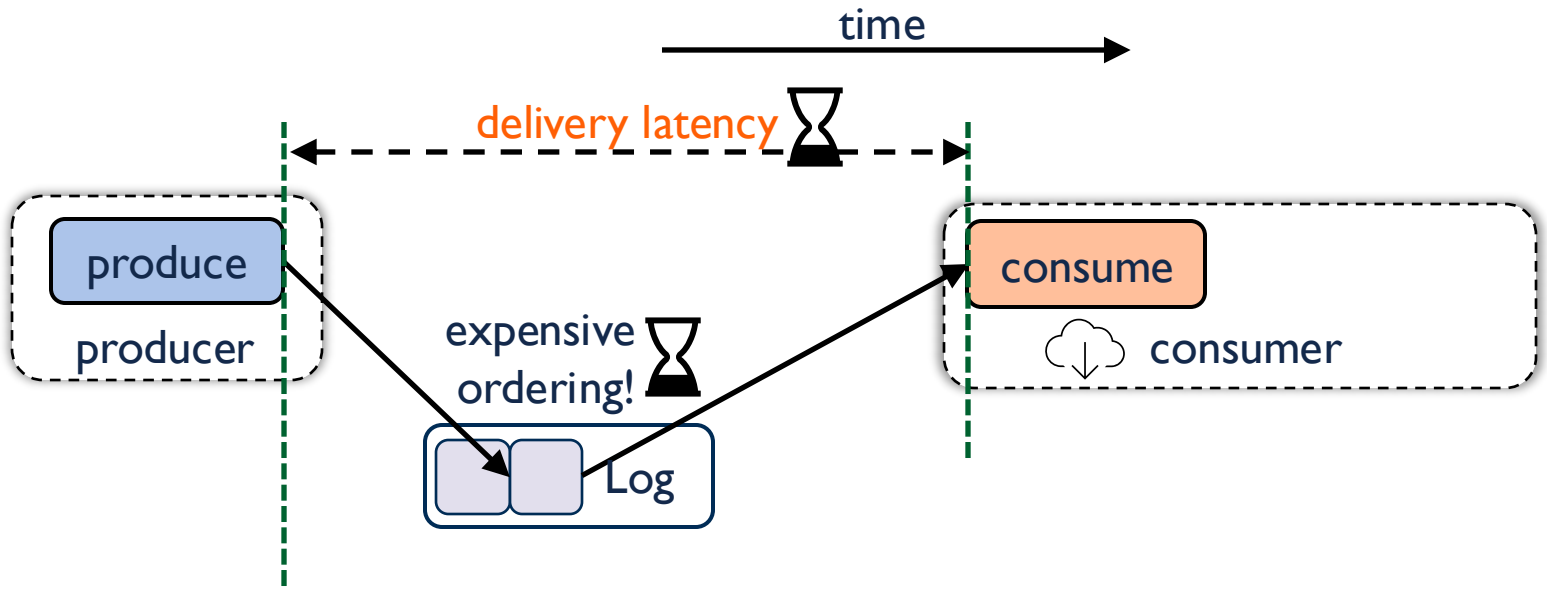

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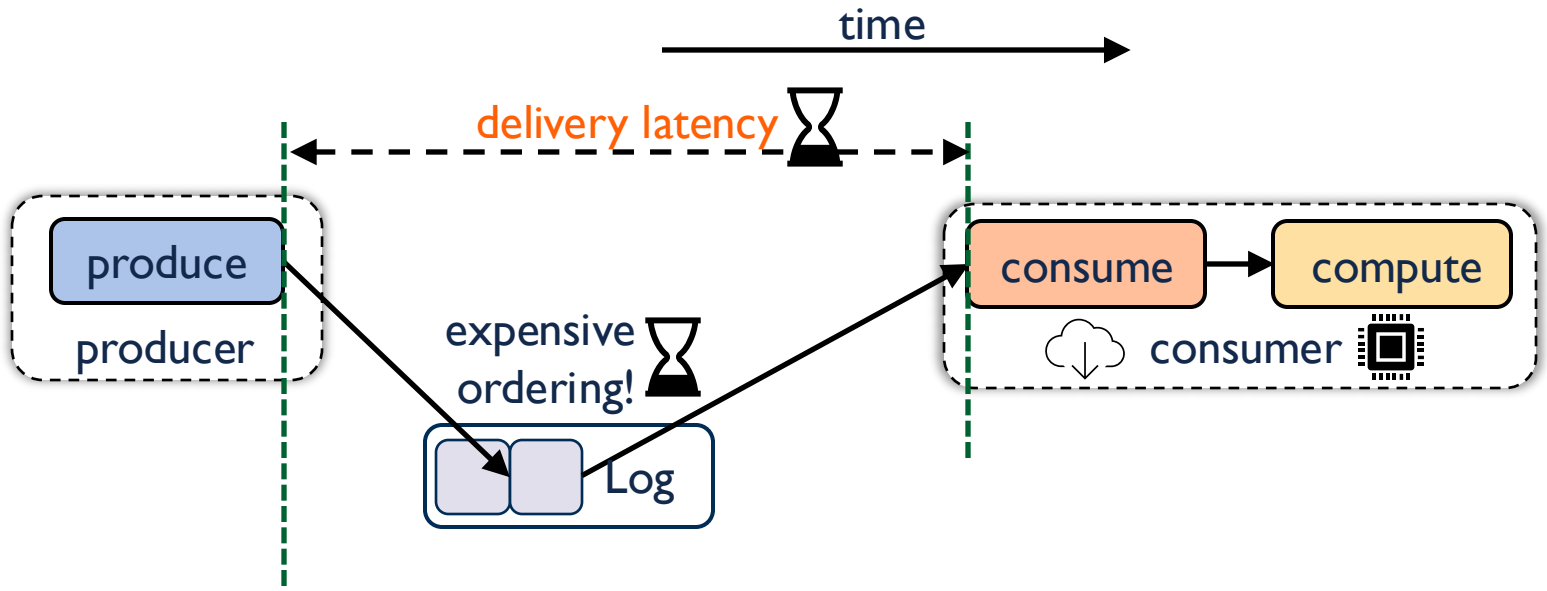

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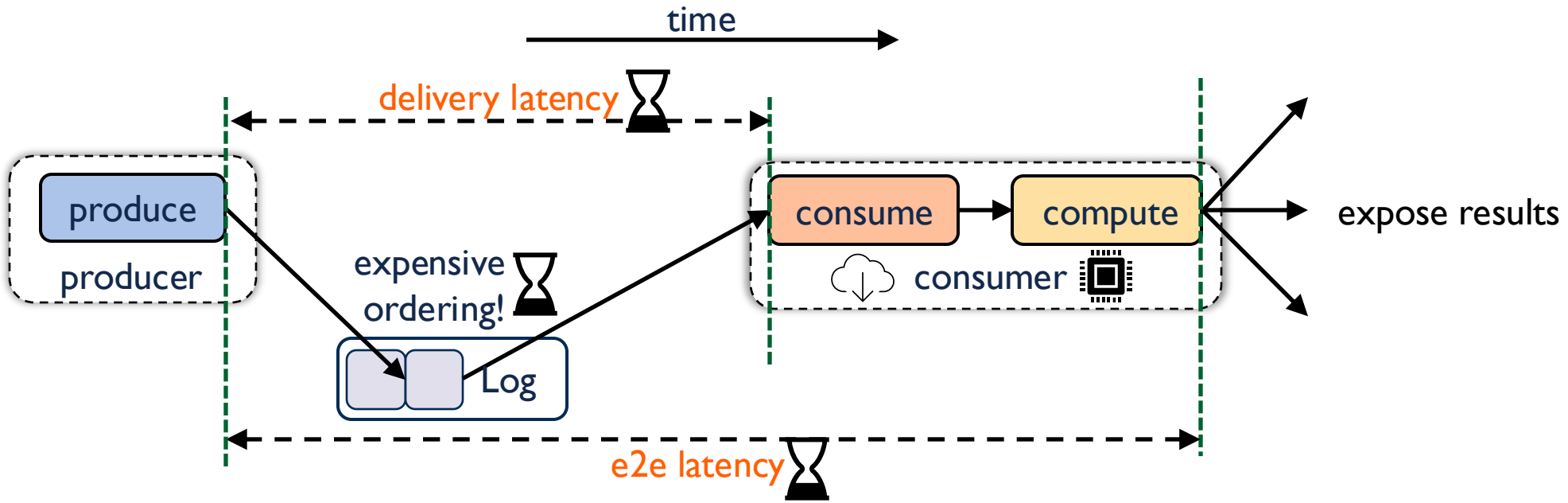

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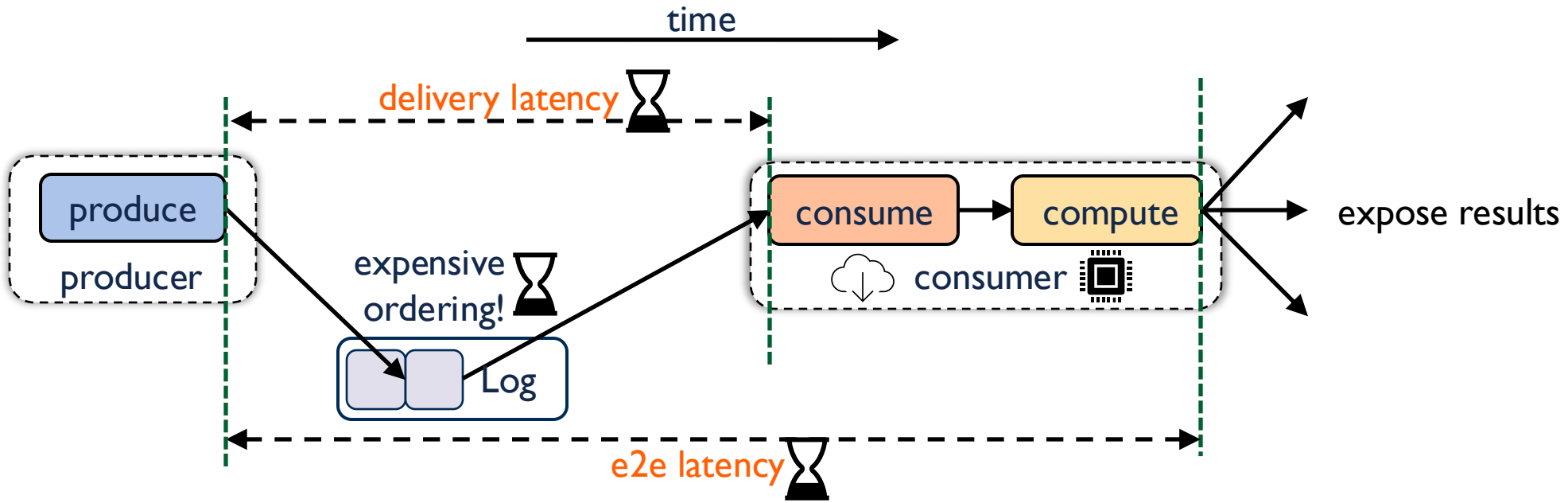

Fraud detection: consume txn → match w/ history (compute) → flag txn

Latency Demands of Real-Time Applications

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2023 streaming report by RedPanda

~35% practitioners primarily care about delivery latency of their streaming system

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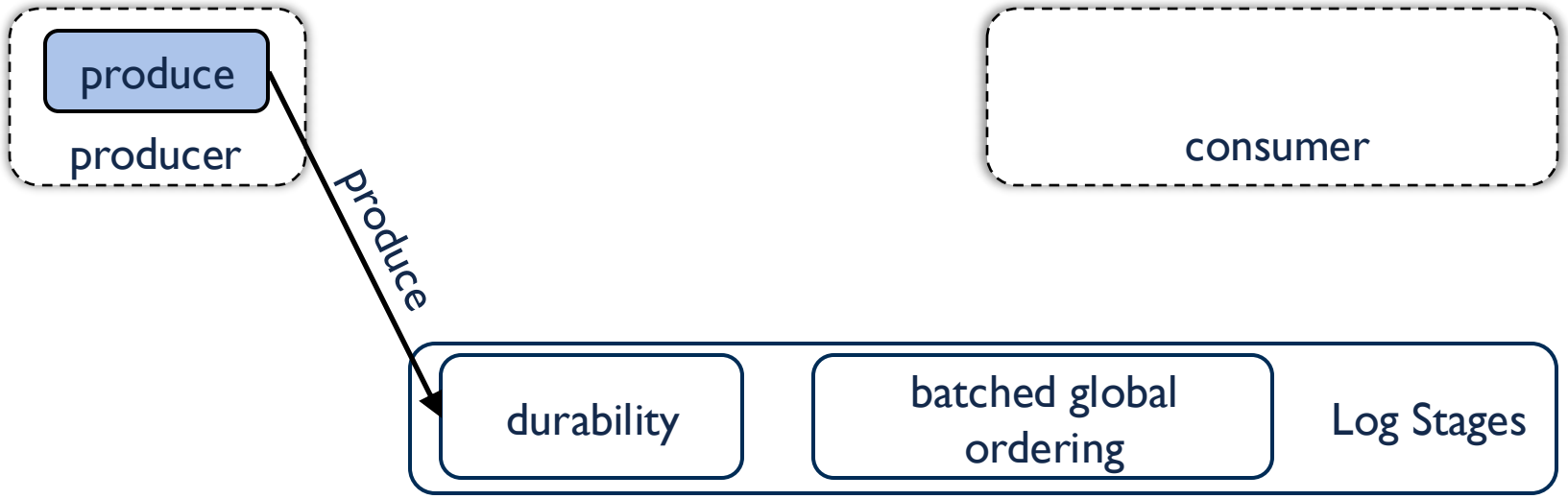

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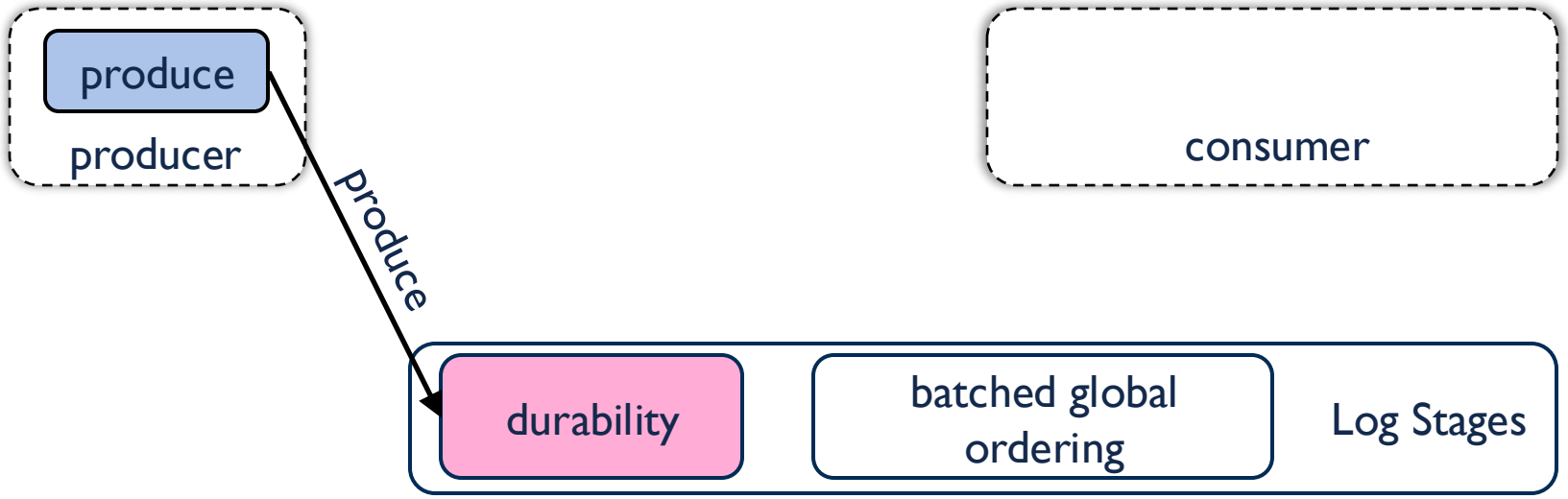

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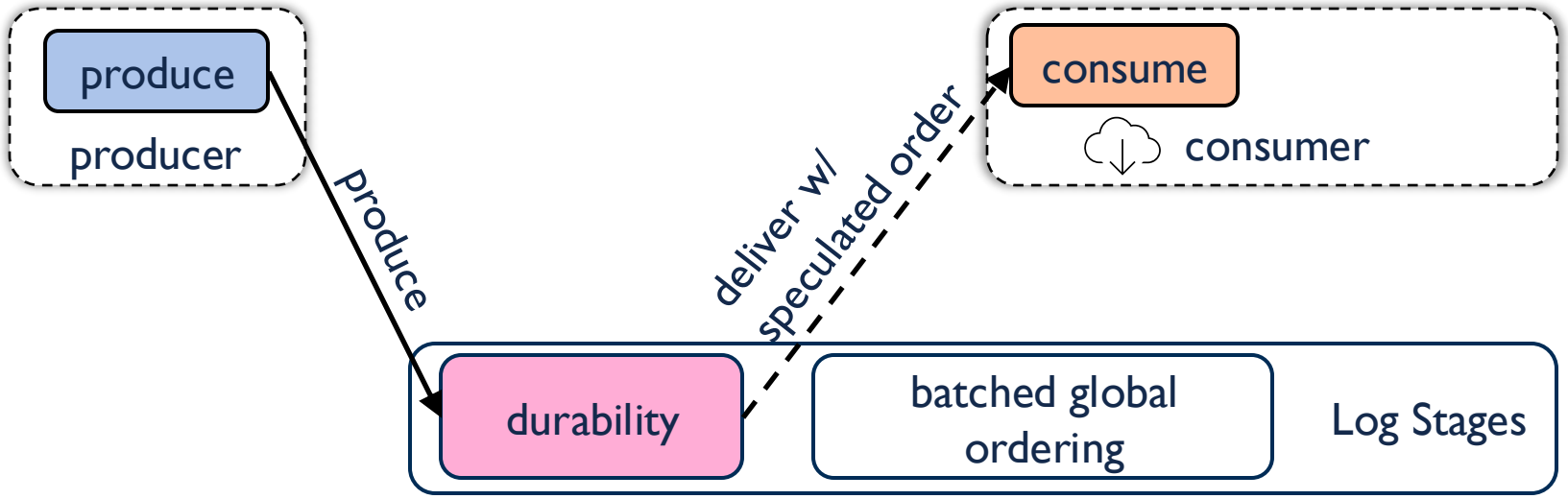

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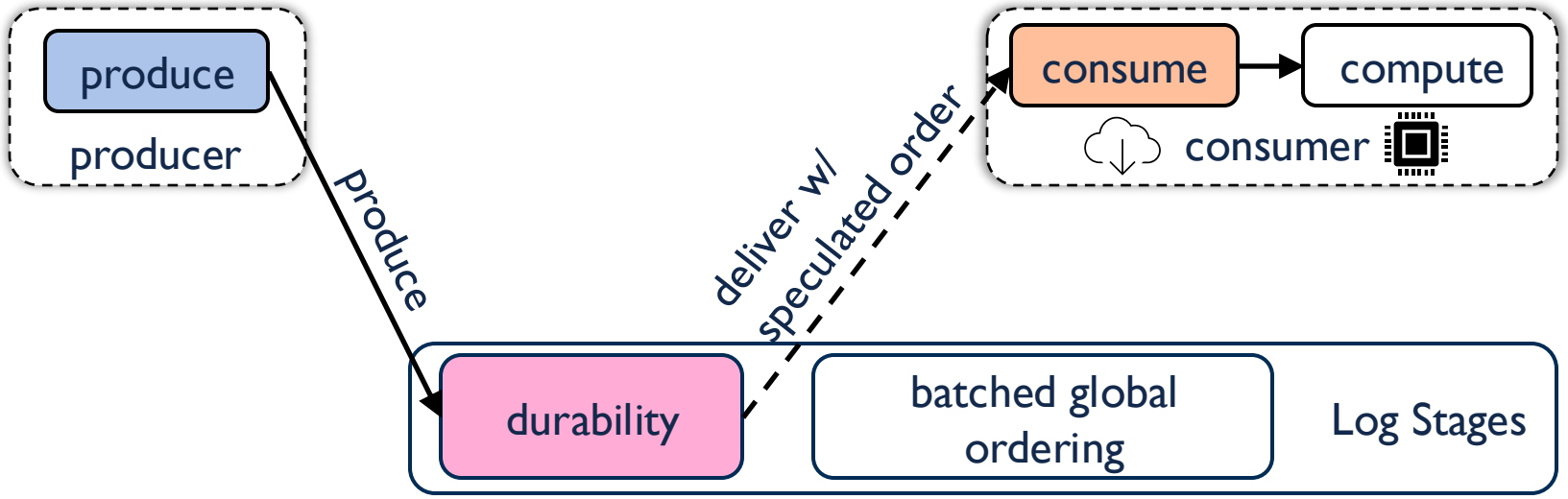

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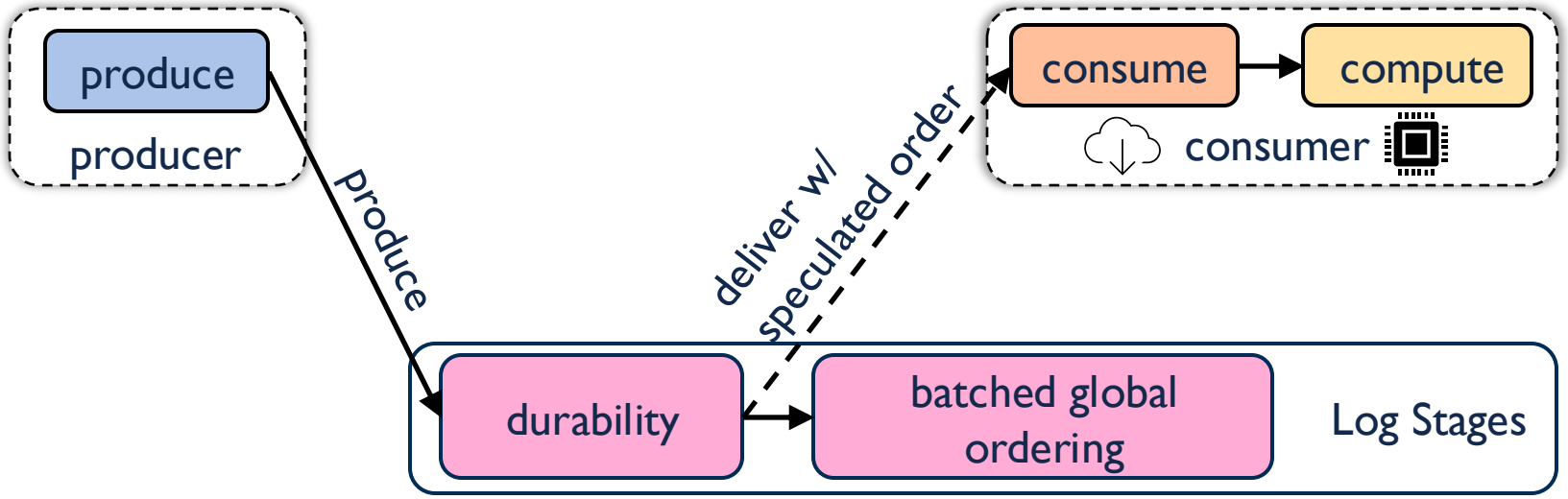

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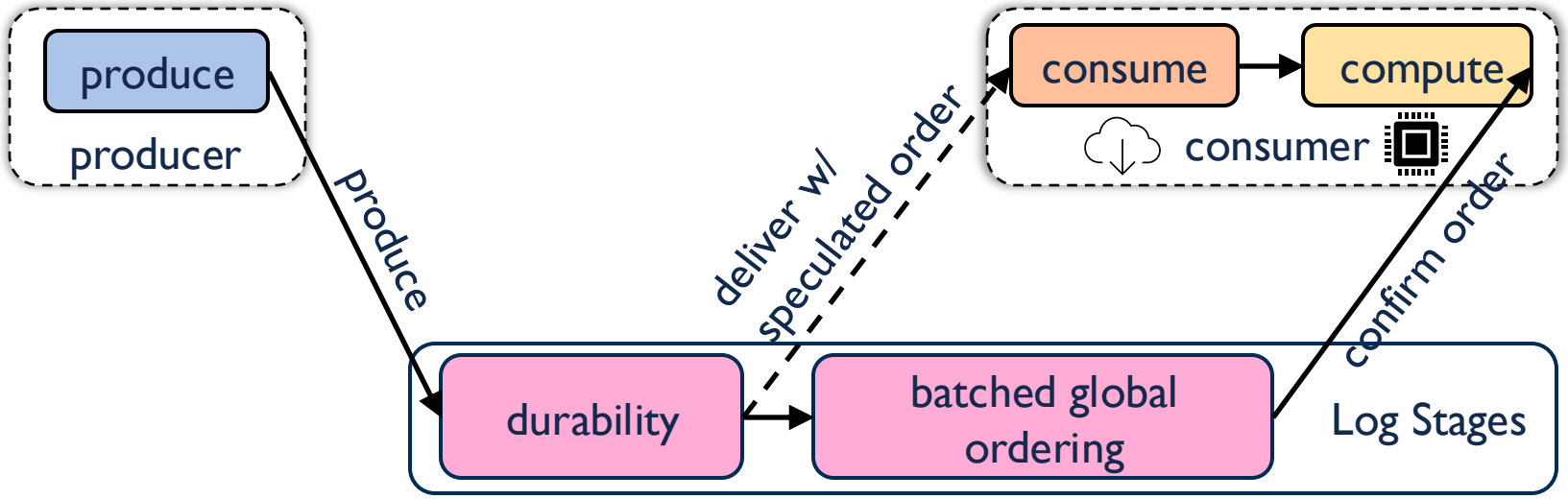

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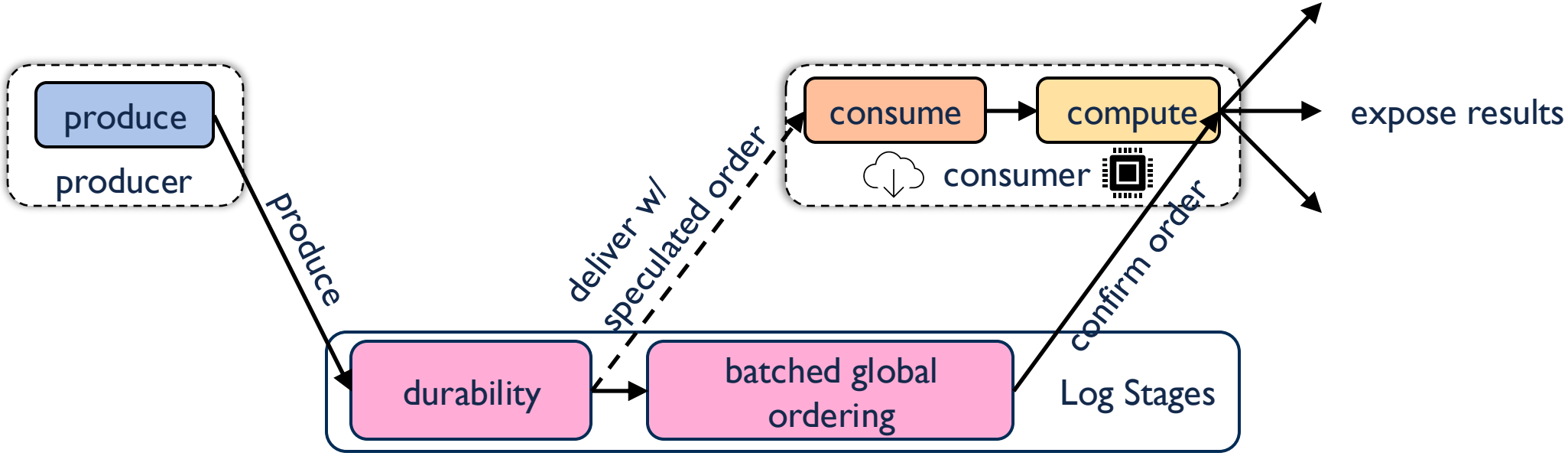

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SpecLog – Abstraction and Interface

Abstraction

Interface

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Abstraction

SpecLog appends return after global ordering

Interface

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SpecLog – Abstraction and Interface

Abstraction

SpecLog appends return after global ordering

SpecLog allows speculative consumption of records

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SpecLog appends return after global ordering

SpecLog allows speculative consumption of records

SpecLog confirms or fails speculation

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SpecLog – Abstraction and Interface

Impact to Apps

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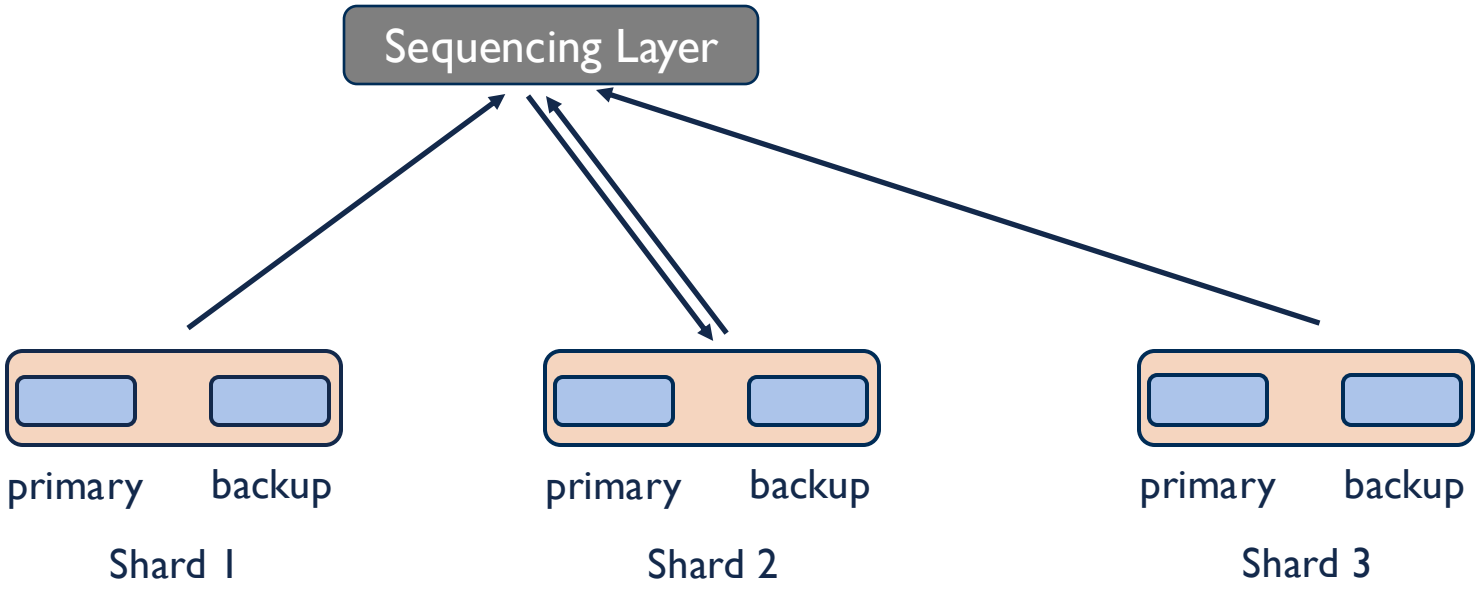
Hard to predict position in global order



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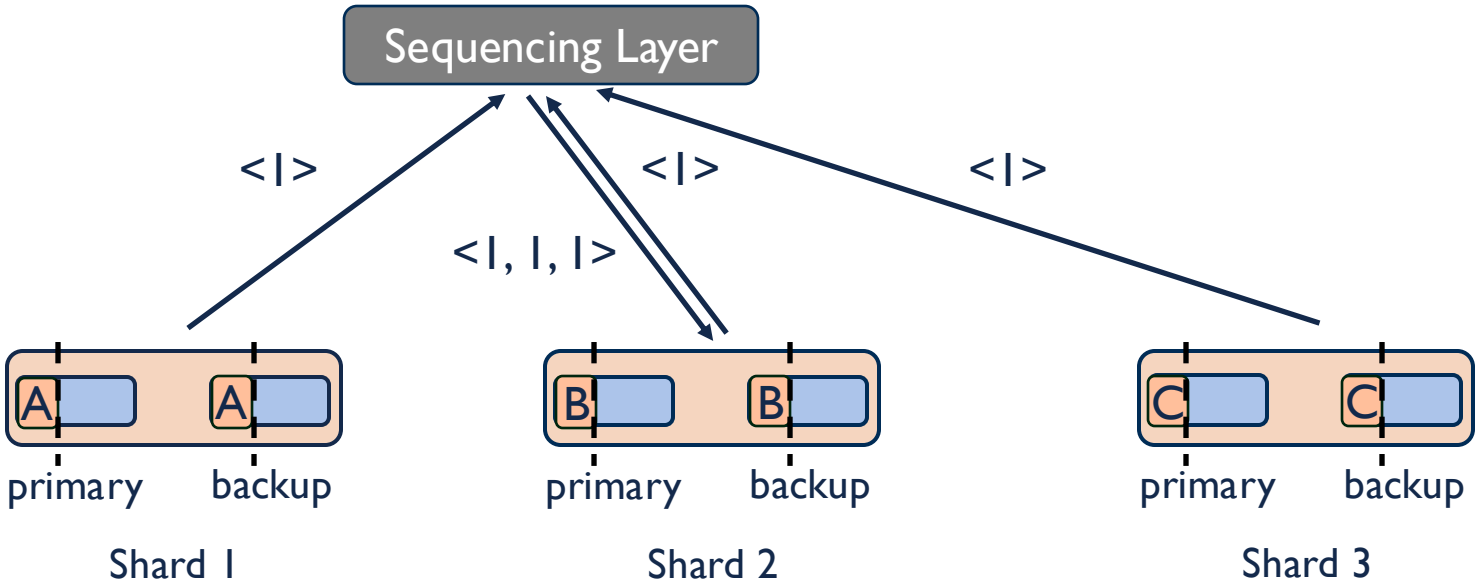

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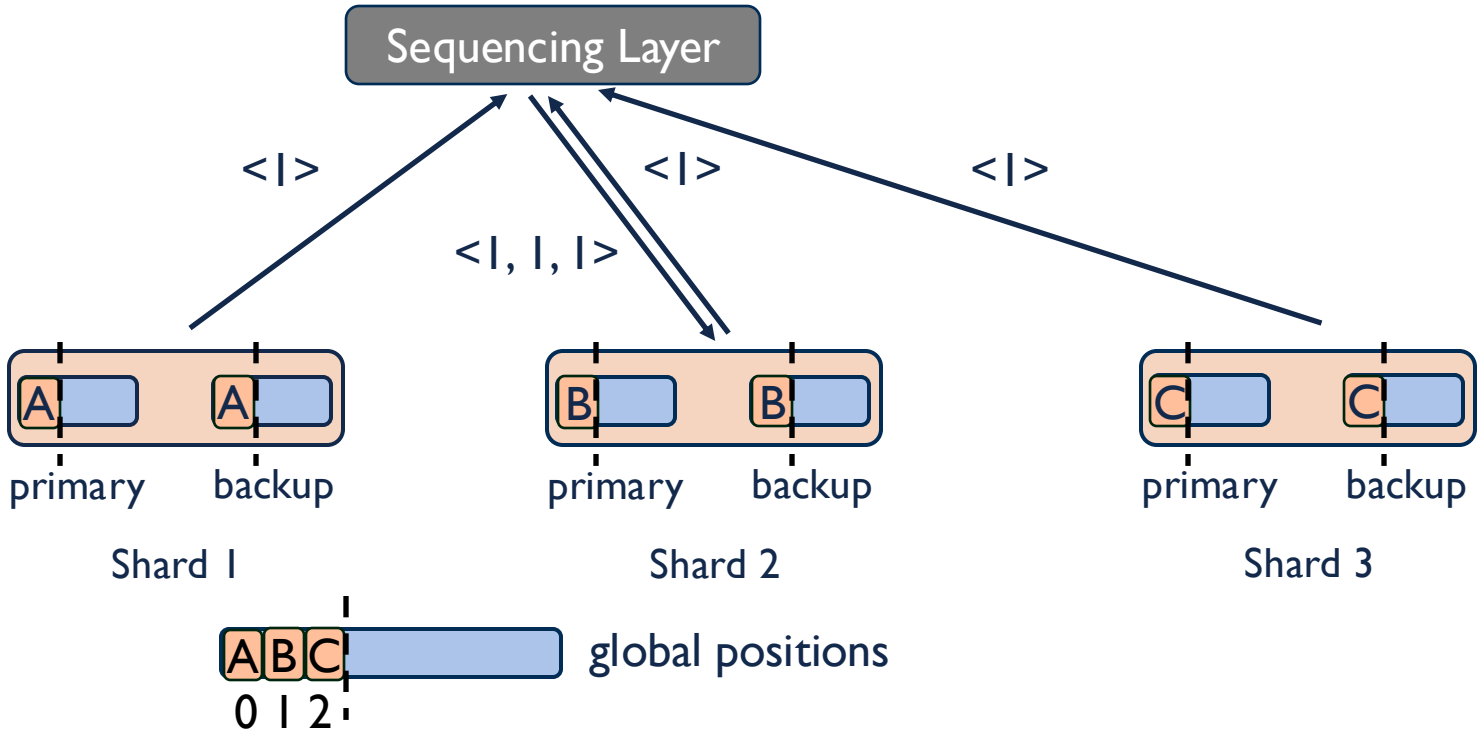

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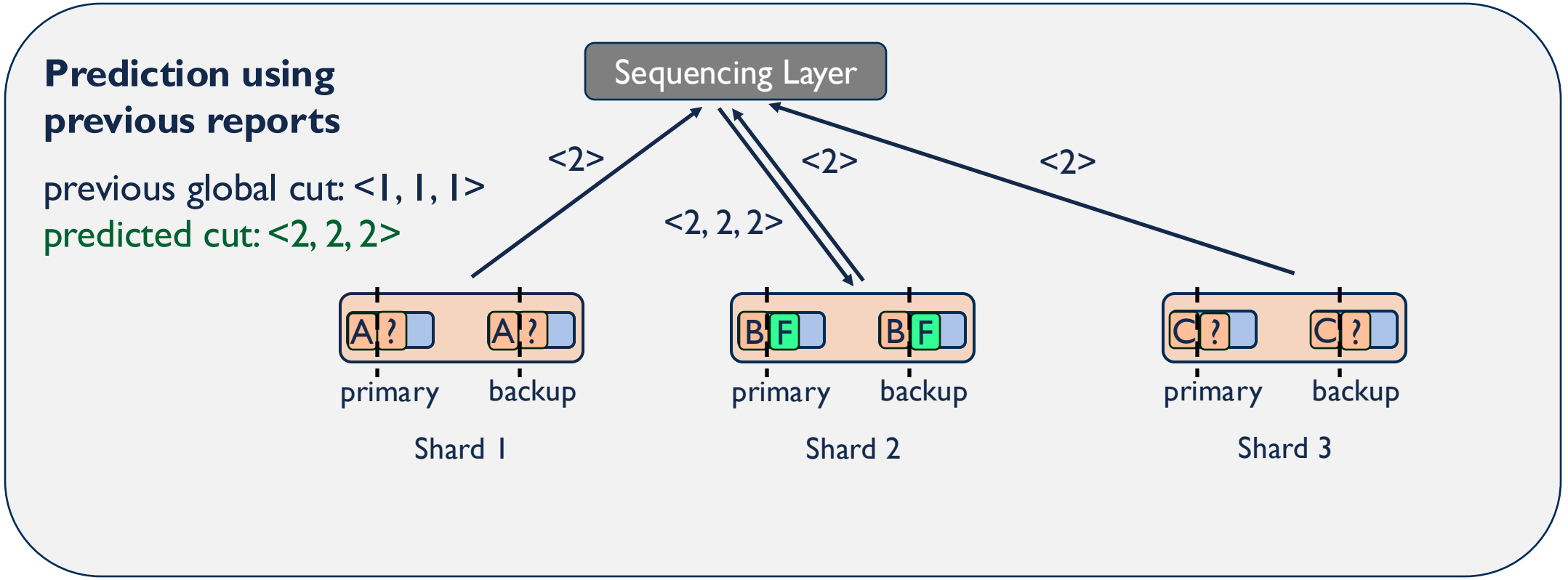

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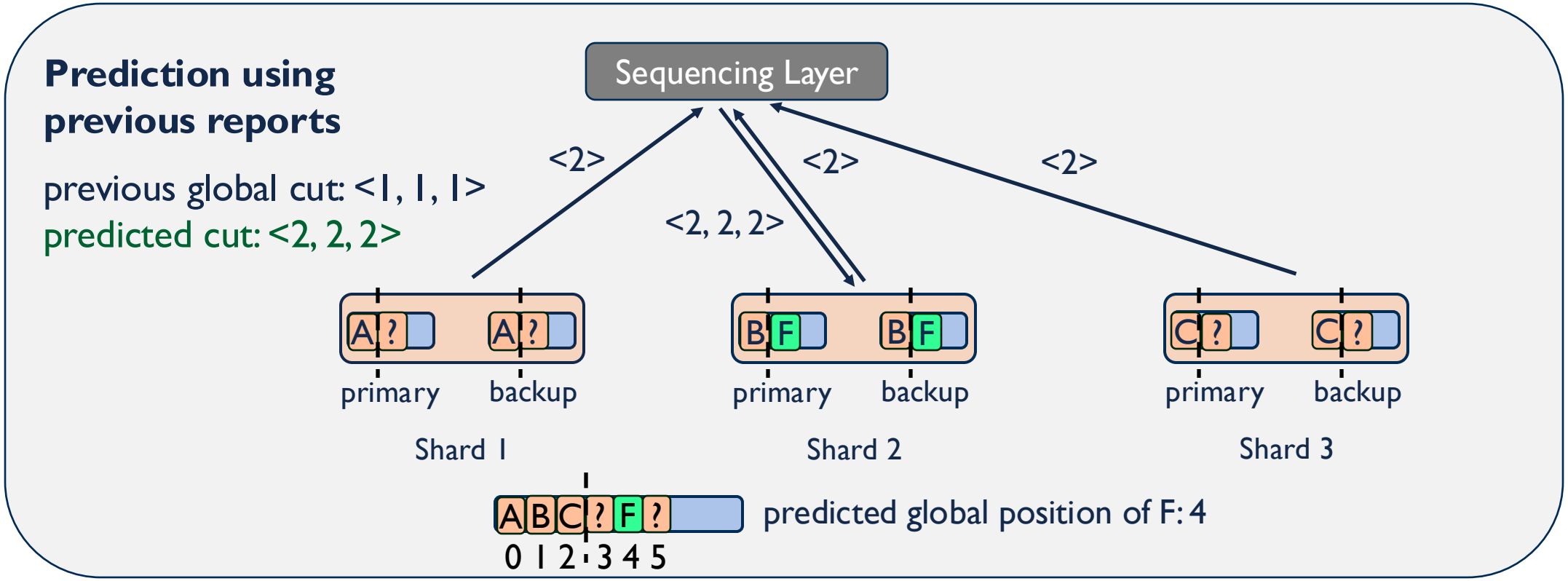

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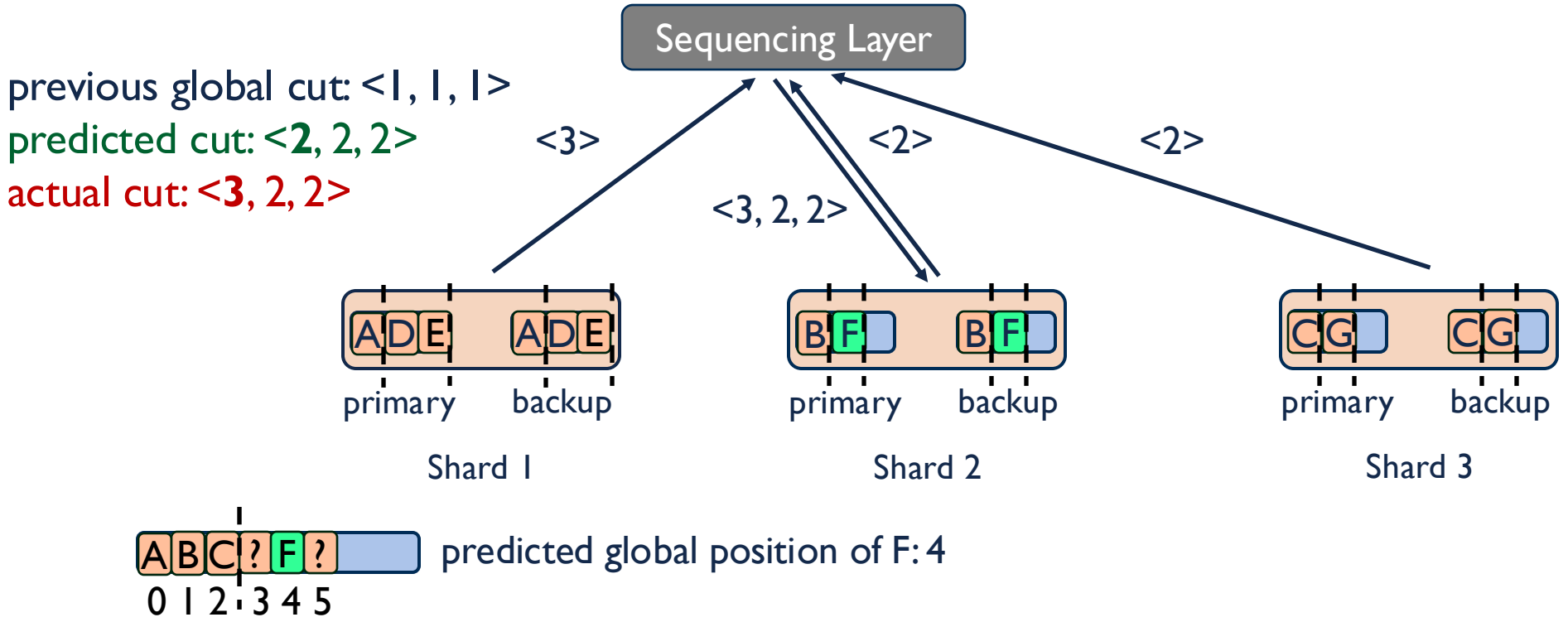

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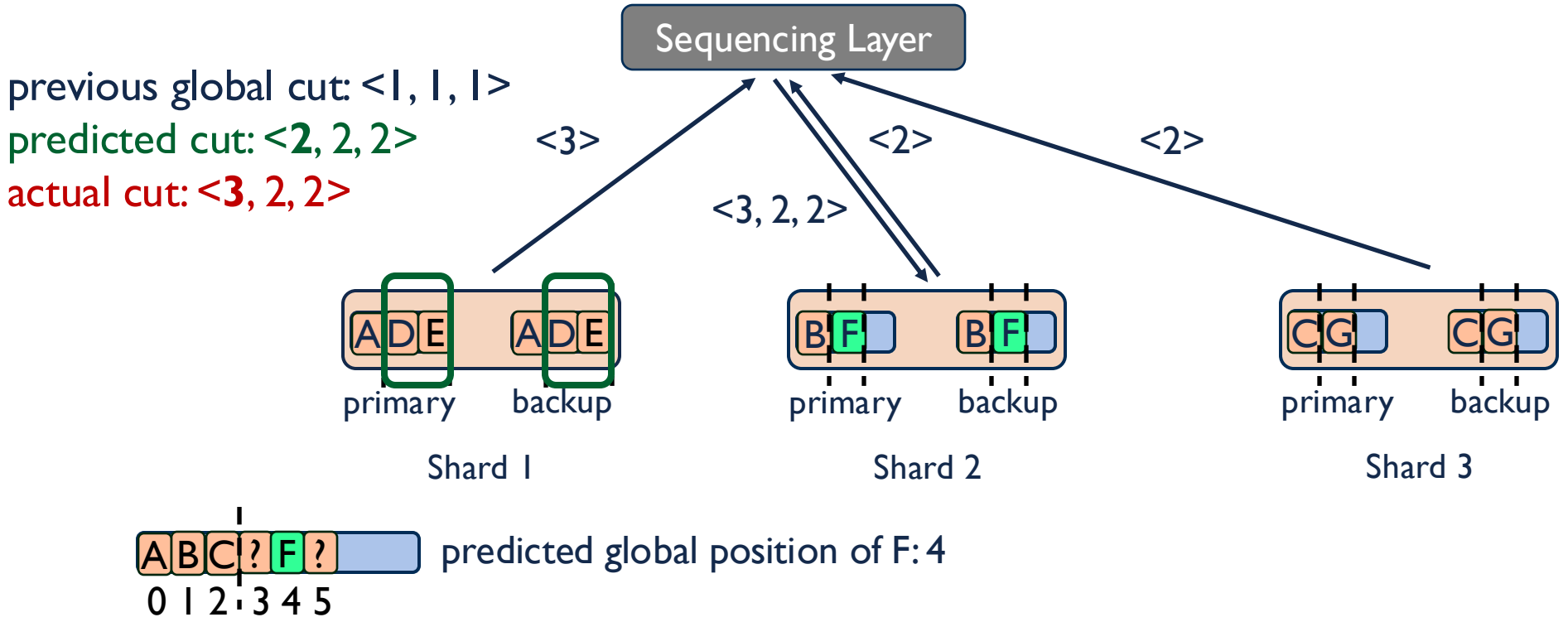

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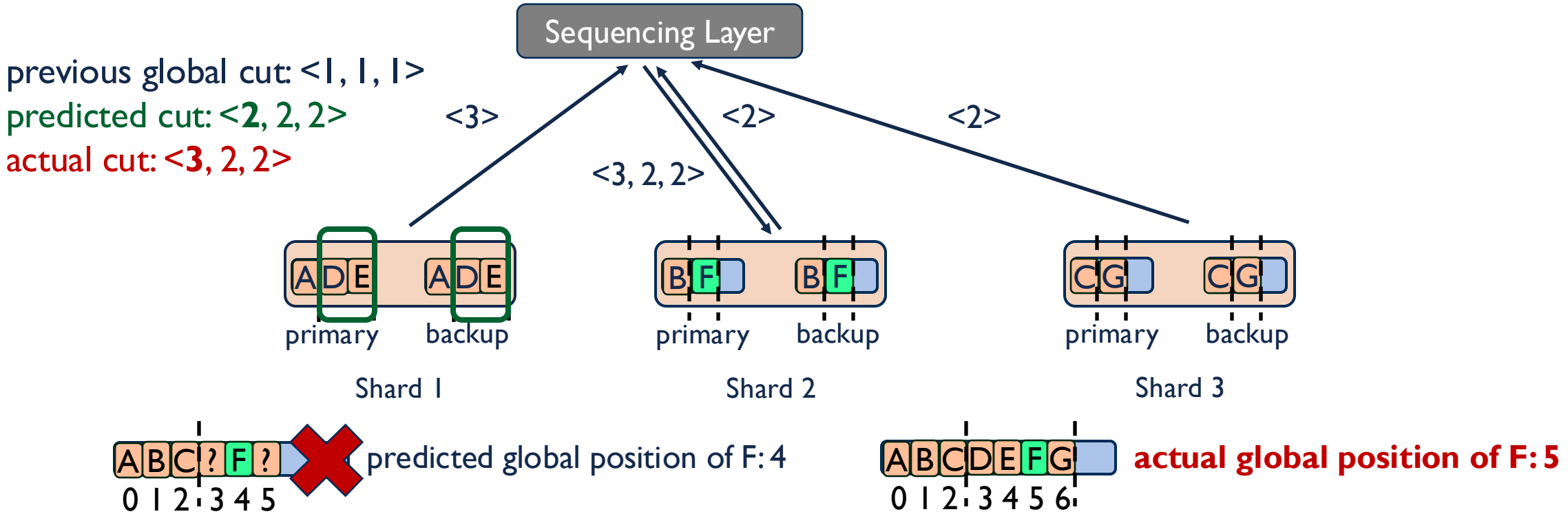

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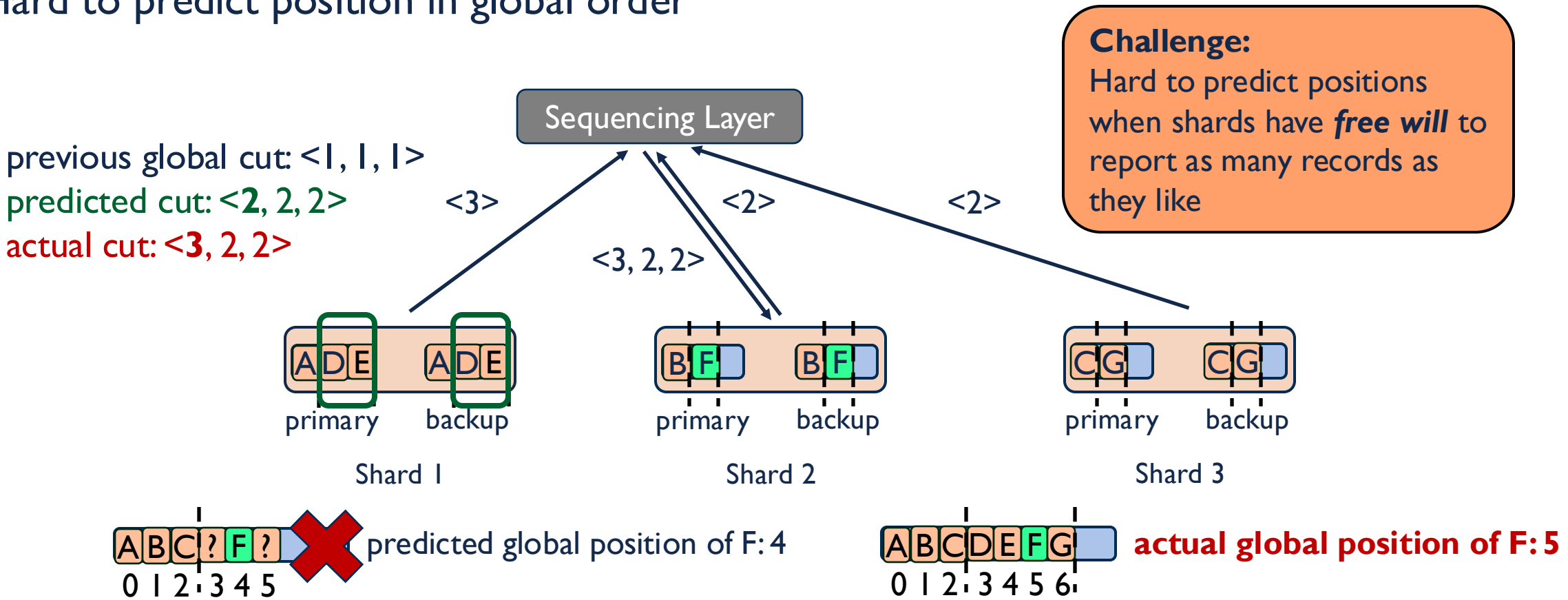

Challenge:
Hard to predict positions when shards have ***free will*** to report as many records as they like

Idea – Fix-Ante Ordering

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predetermined cuts – fix beforehand global cuts system is expected to produce

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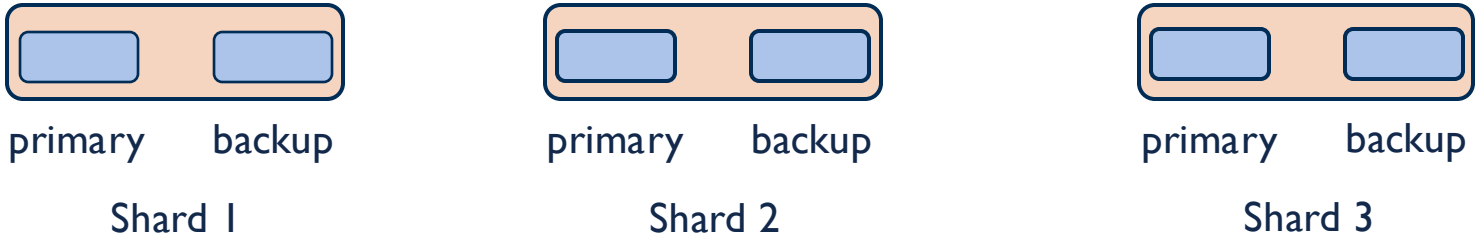

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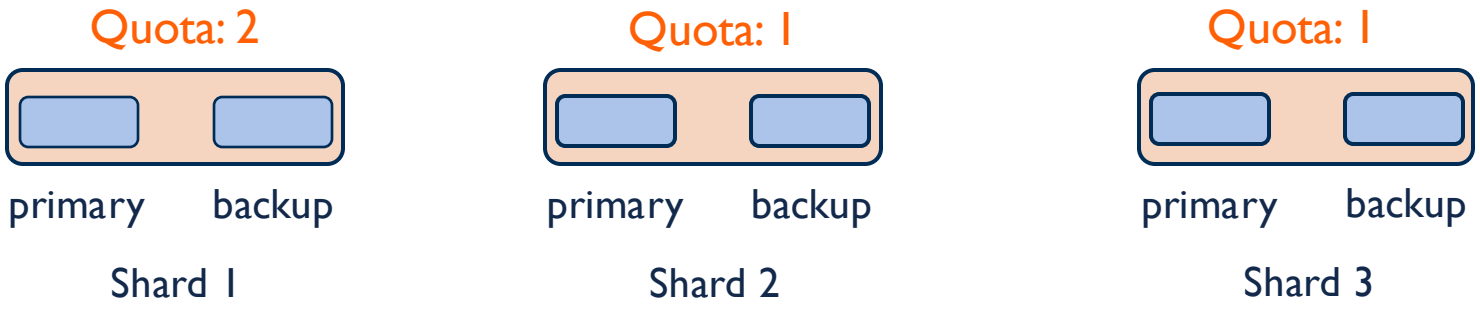

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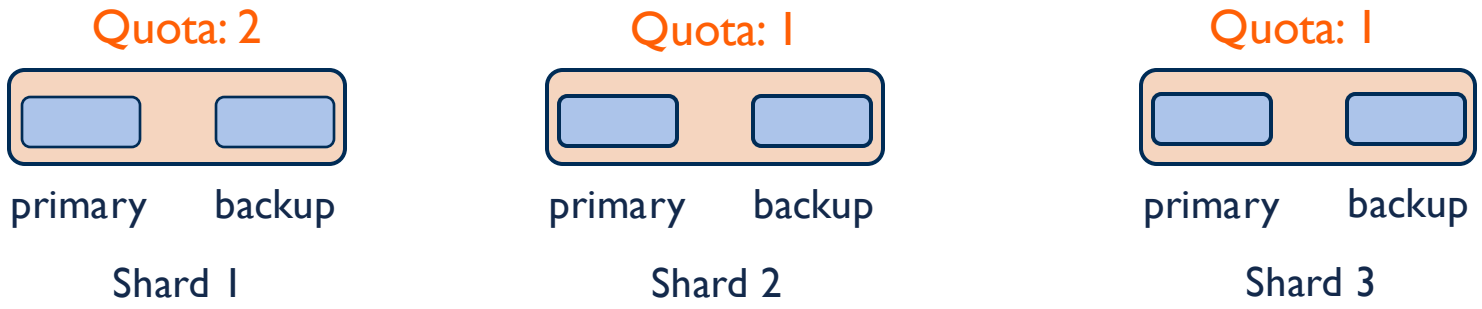

Predetermined cuts - <2, 1, 1> <4, 2, 2> <6, 3, 3> … <2n, n, n>

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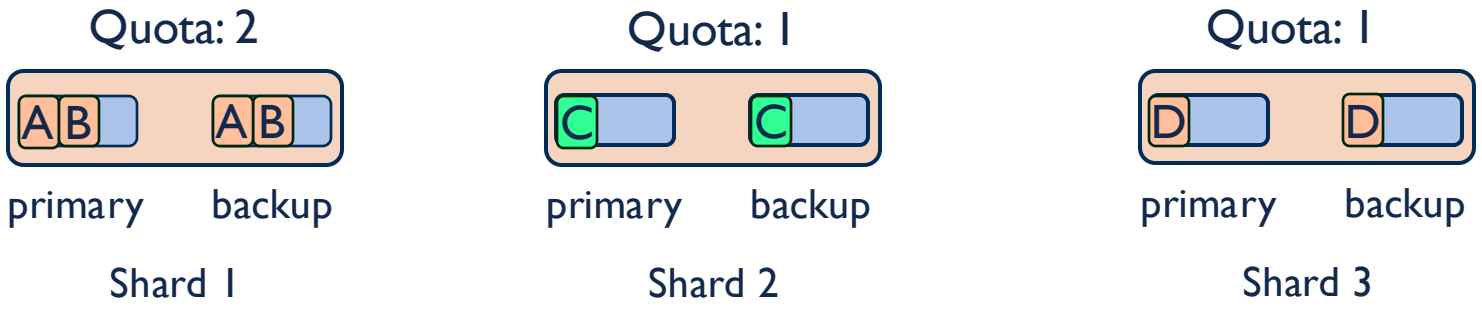
Each shard knows the sequence of global cuts the system will produce

Any shard can predict positions of its records easily!



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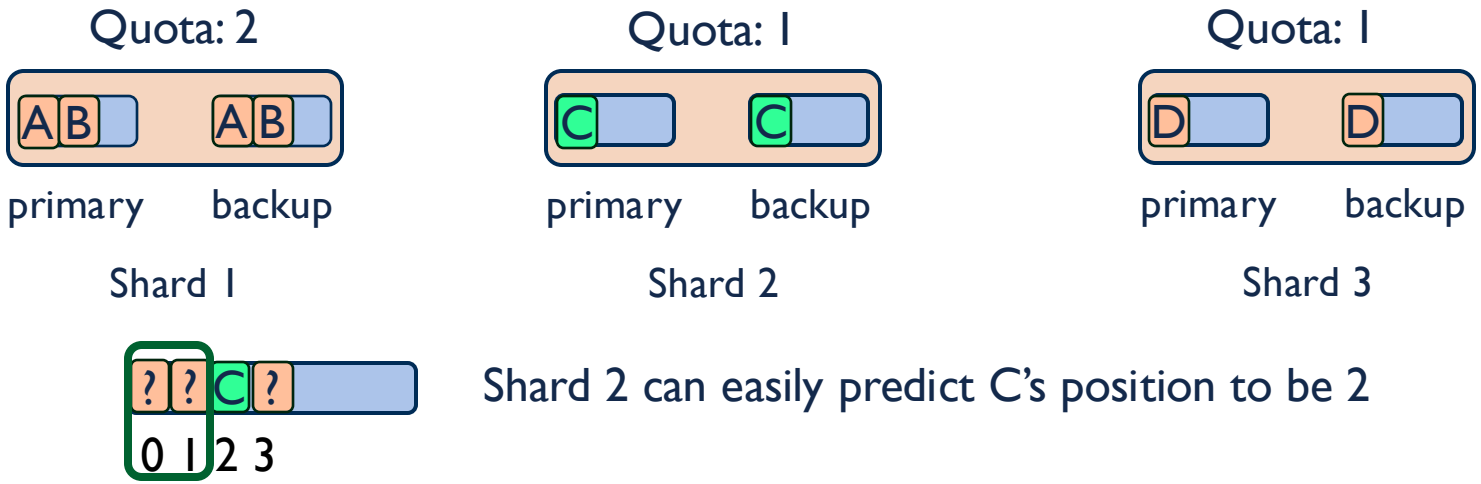

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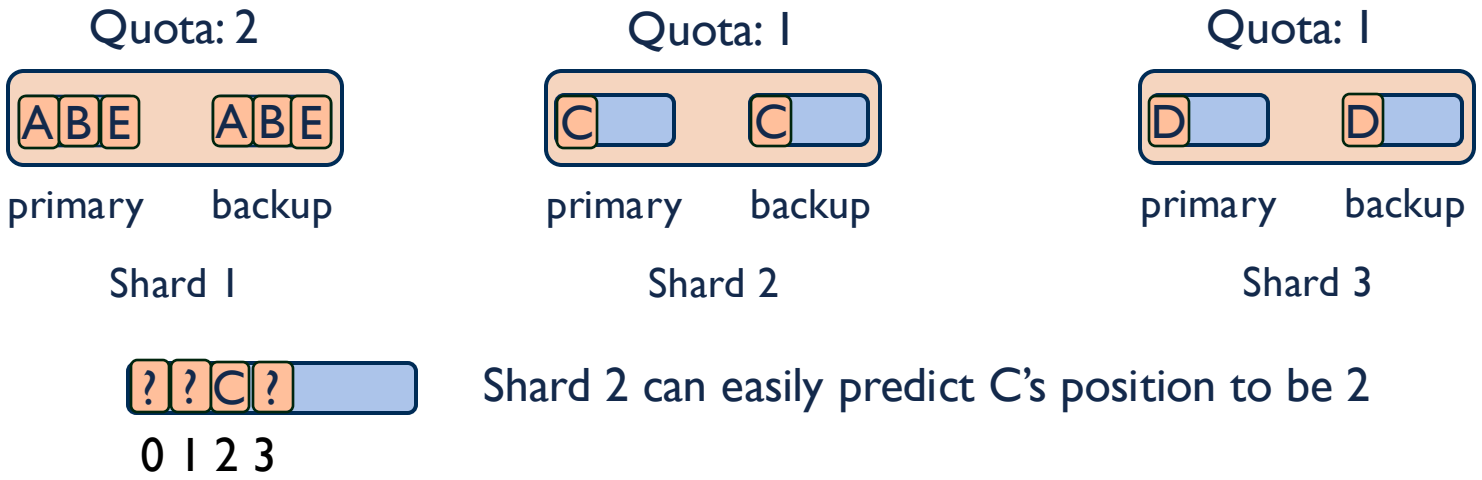

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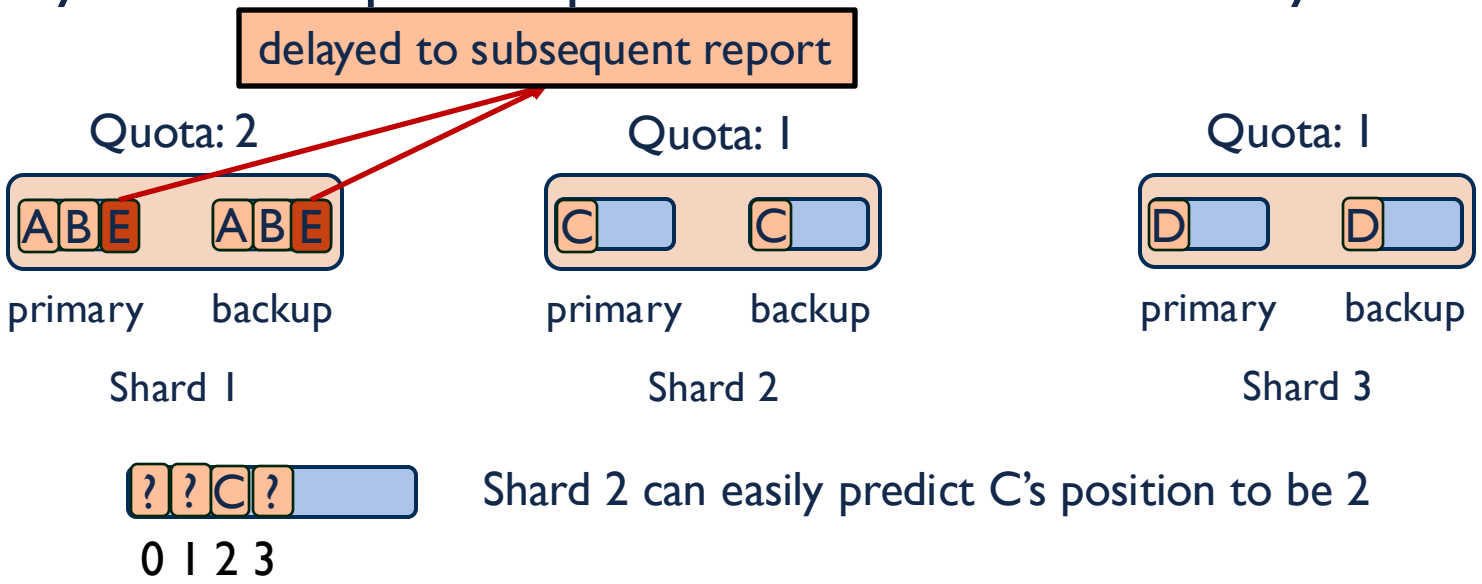

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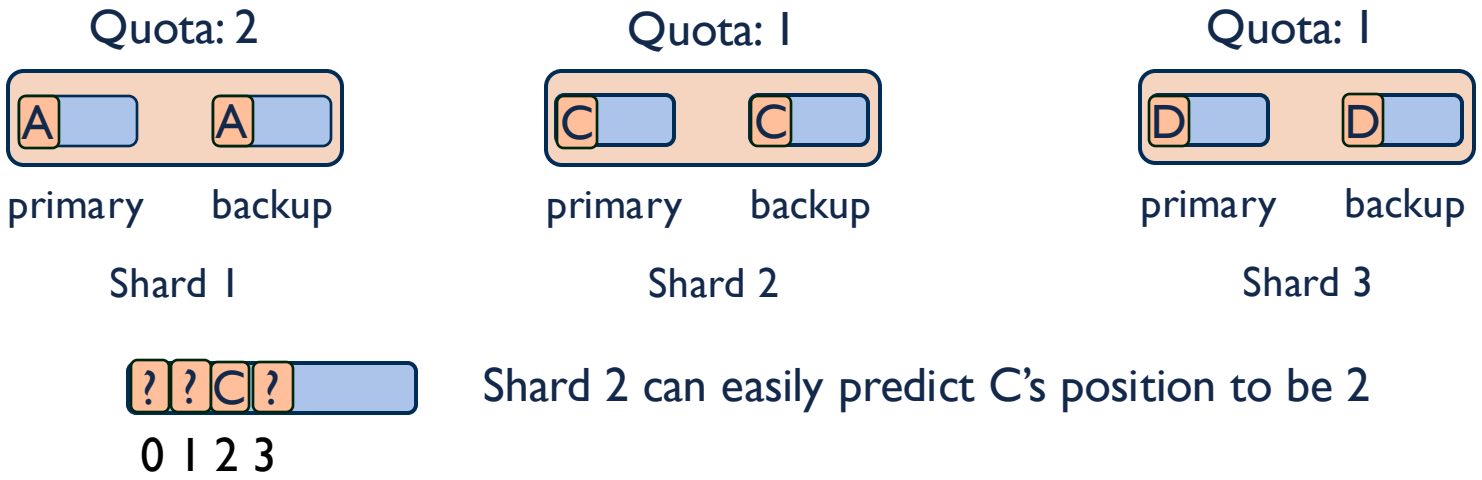

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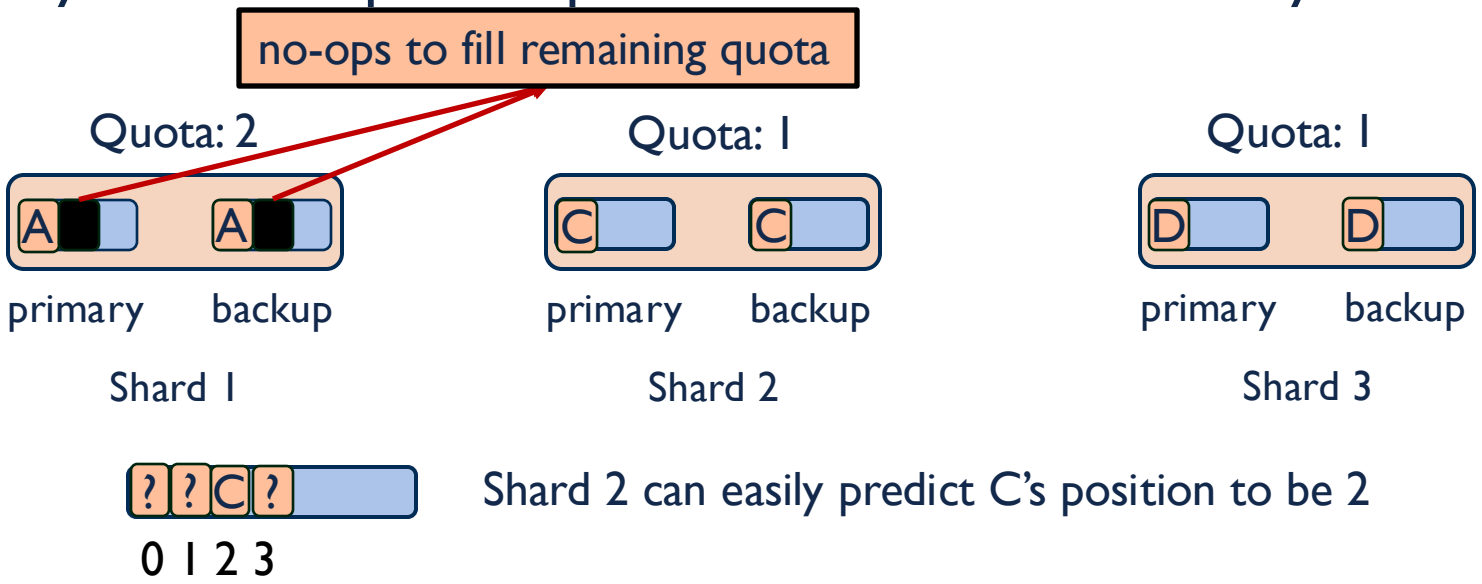

What if a shard has more records to report?
Solution:
Delay to subsequent reports

What if a shard does not have enough records?
Solution:
Pad quota with no-ops

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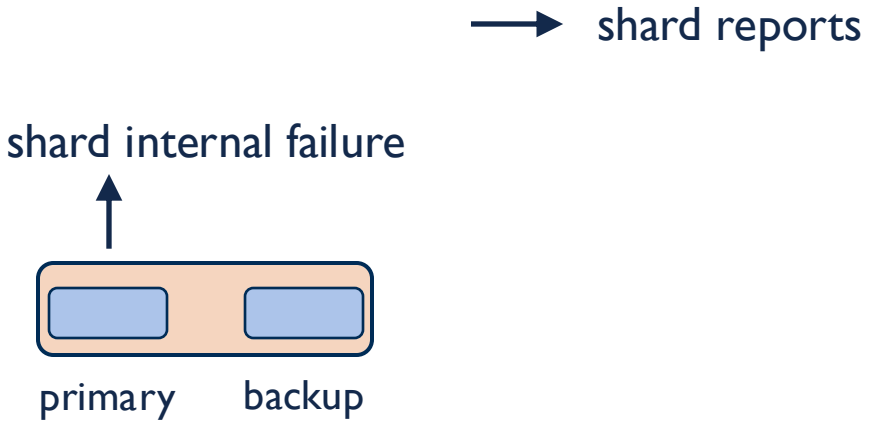

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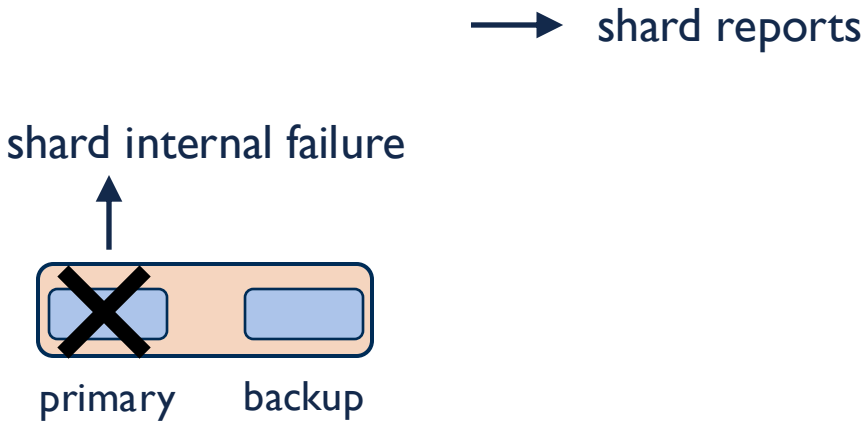

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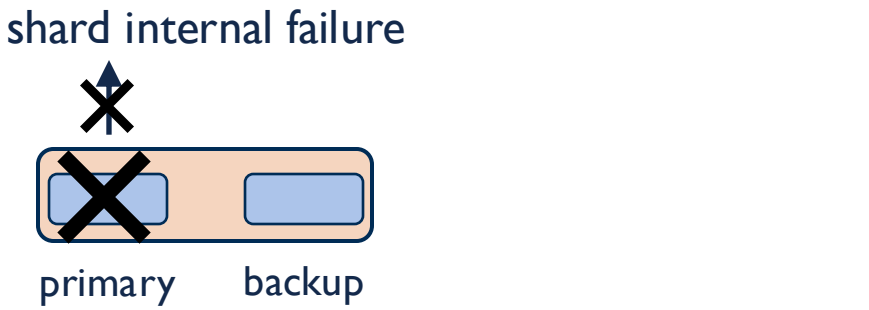

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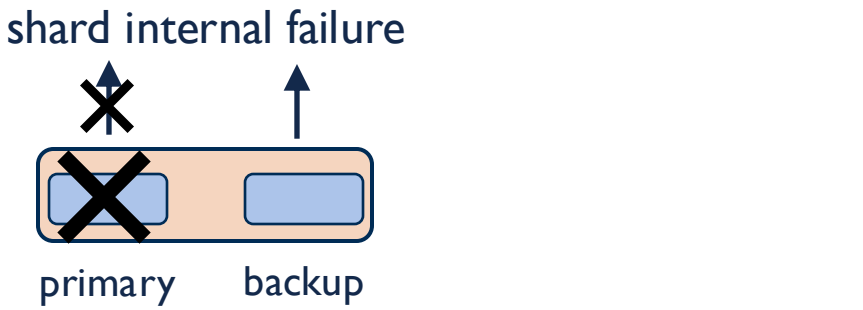

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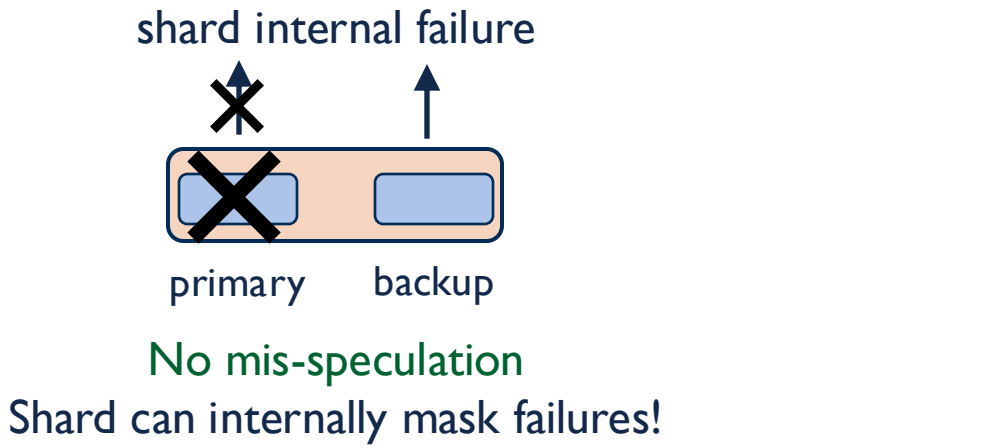

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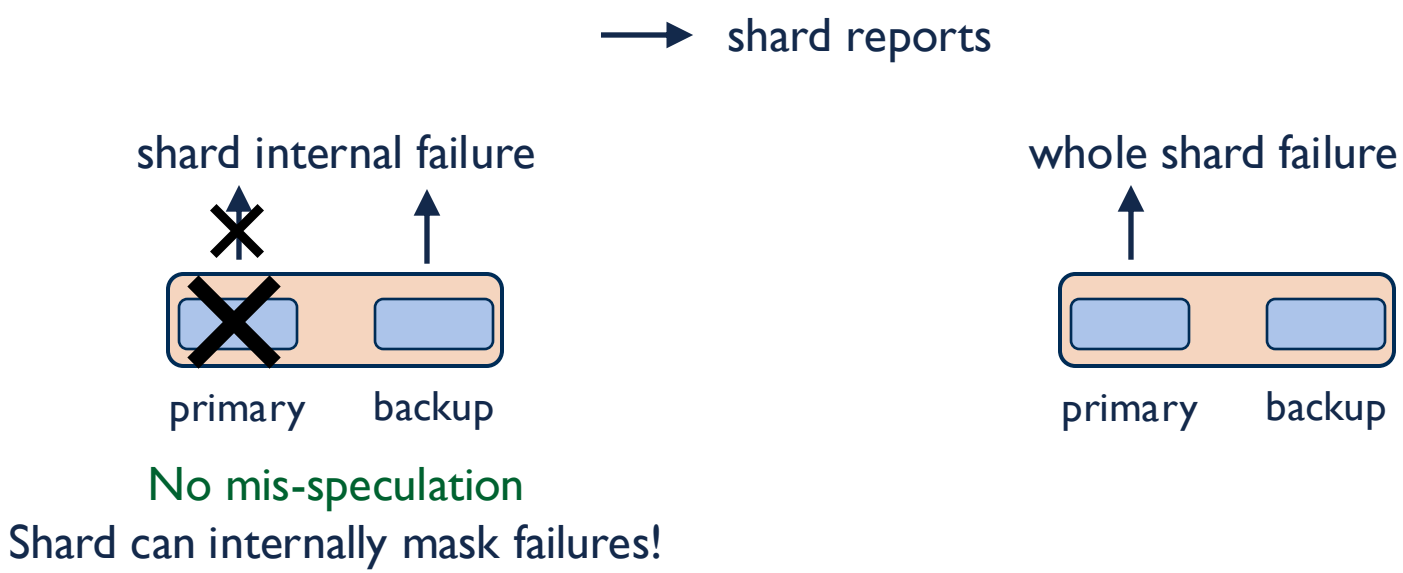

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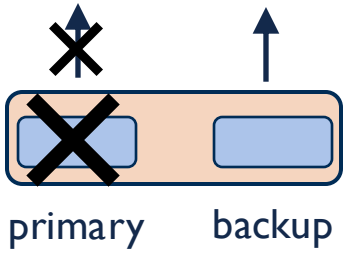
→ shard reports

Rare!

shard internal failure



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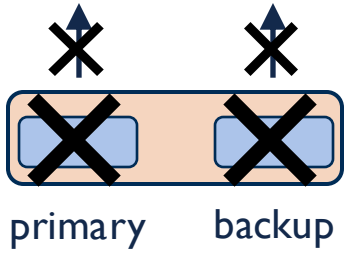
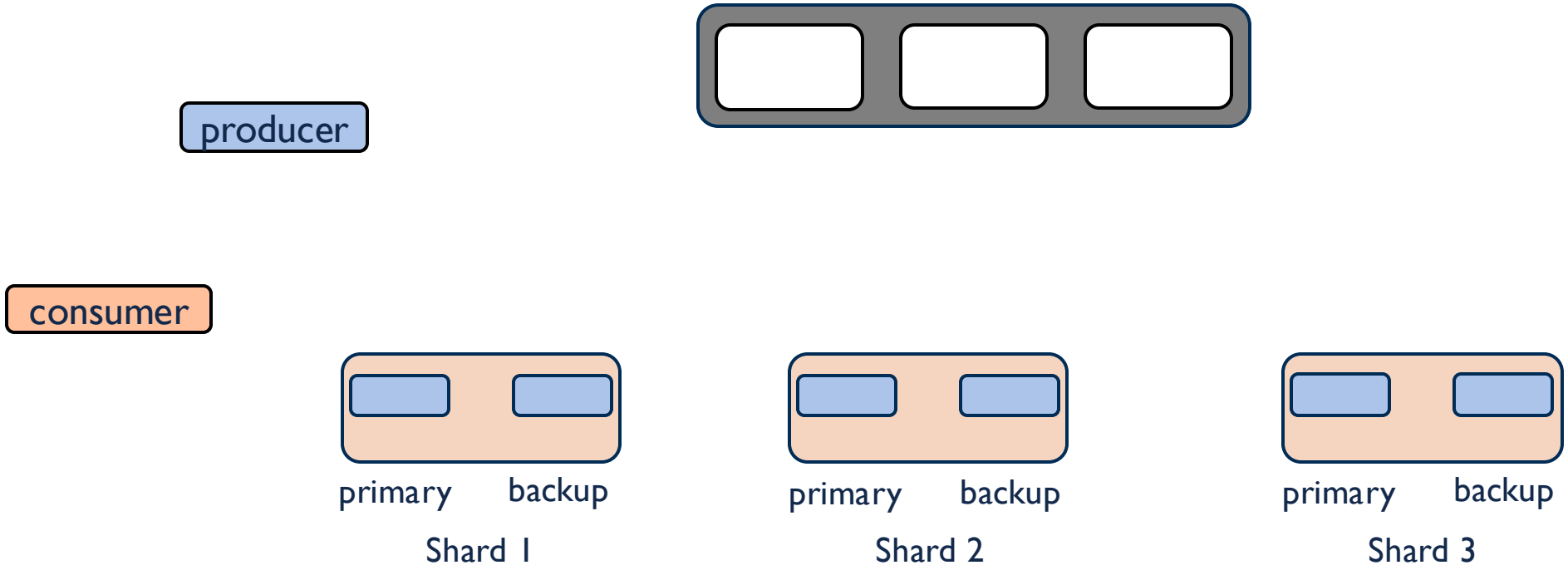
whole shard failure



Mis-speculations occur

Shard cannot meet quota

Real-Time App atop SpecLog



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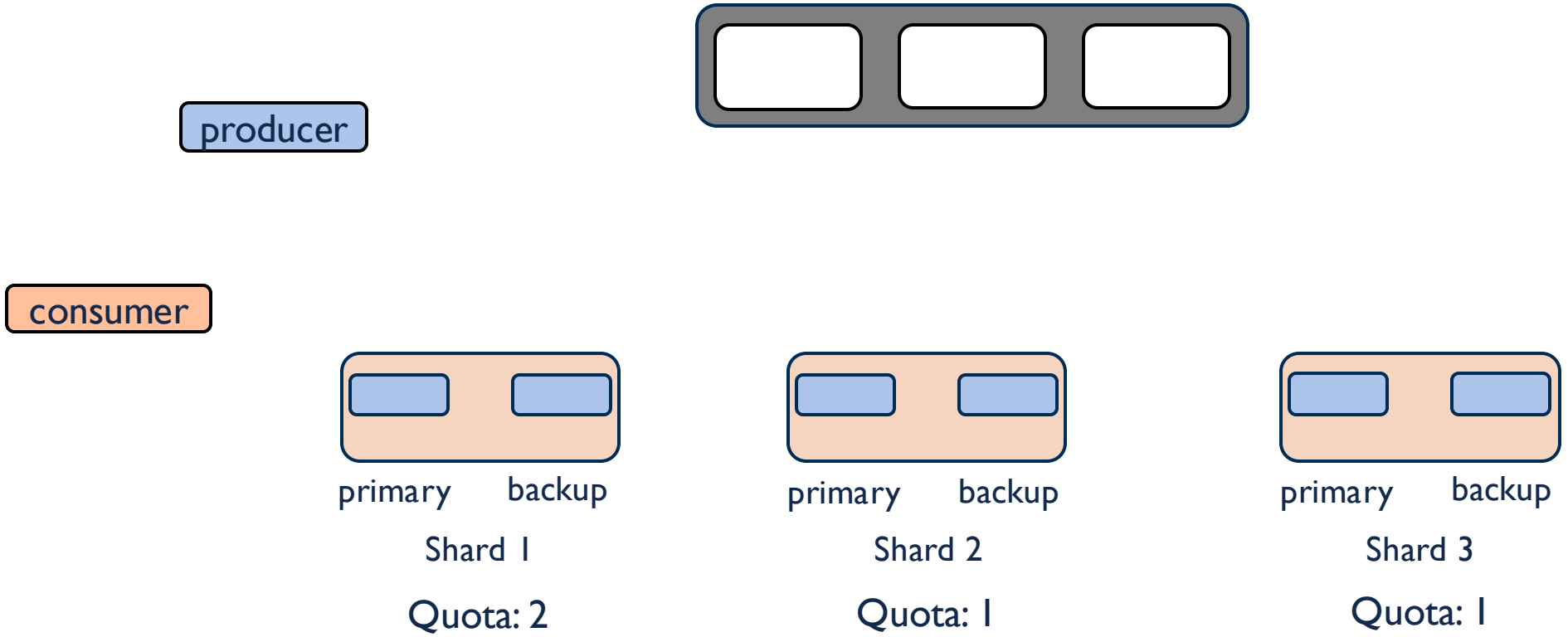

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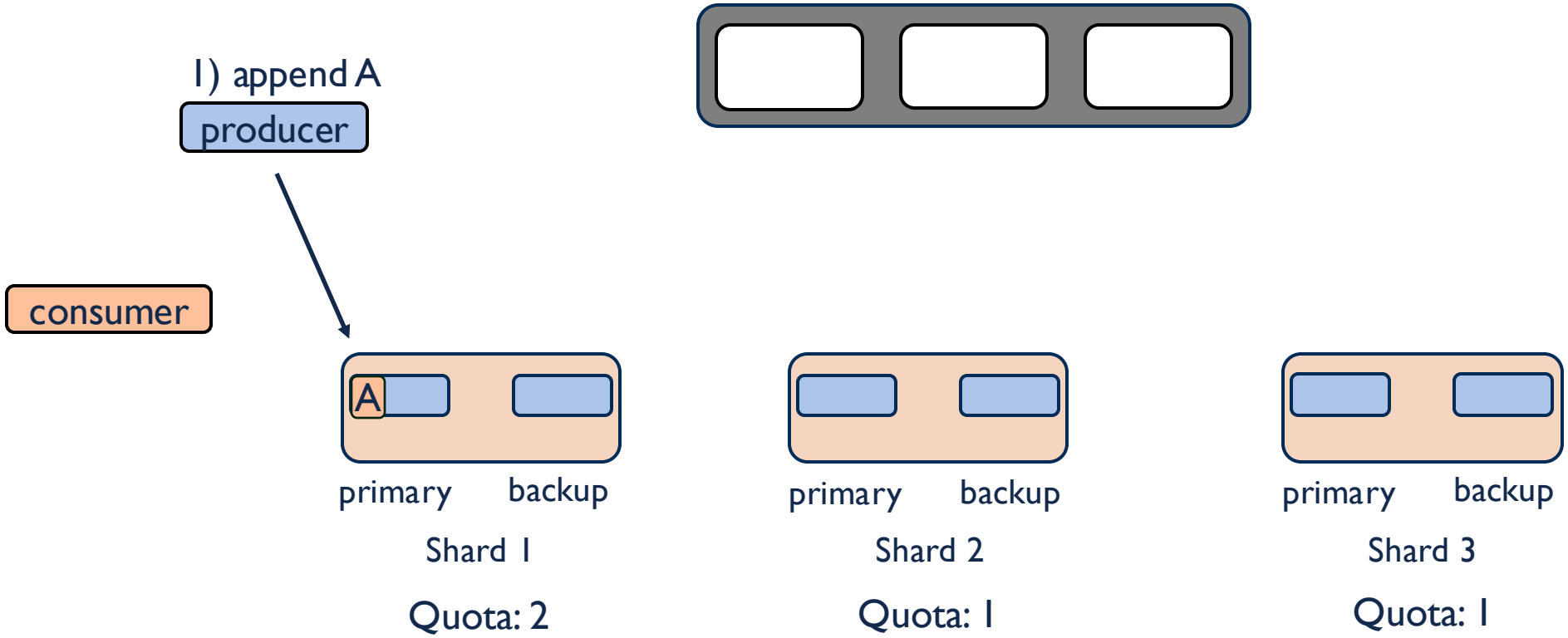

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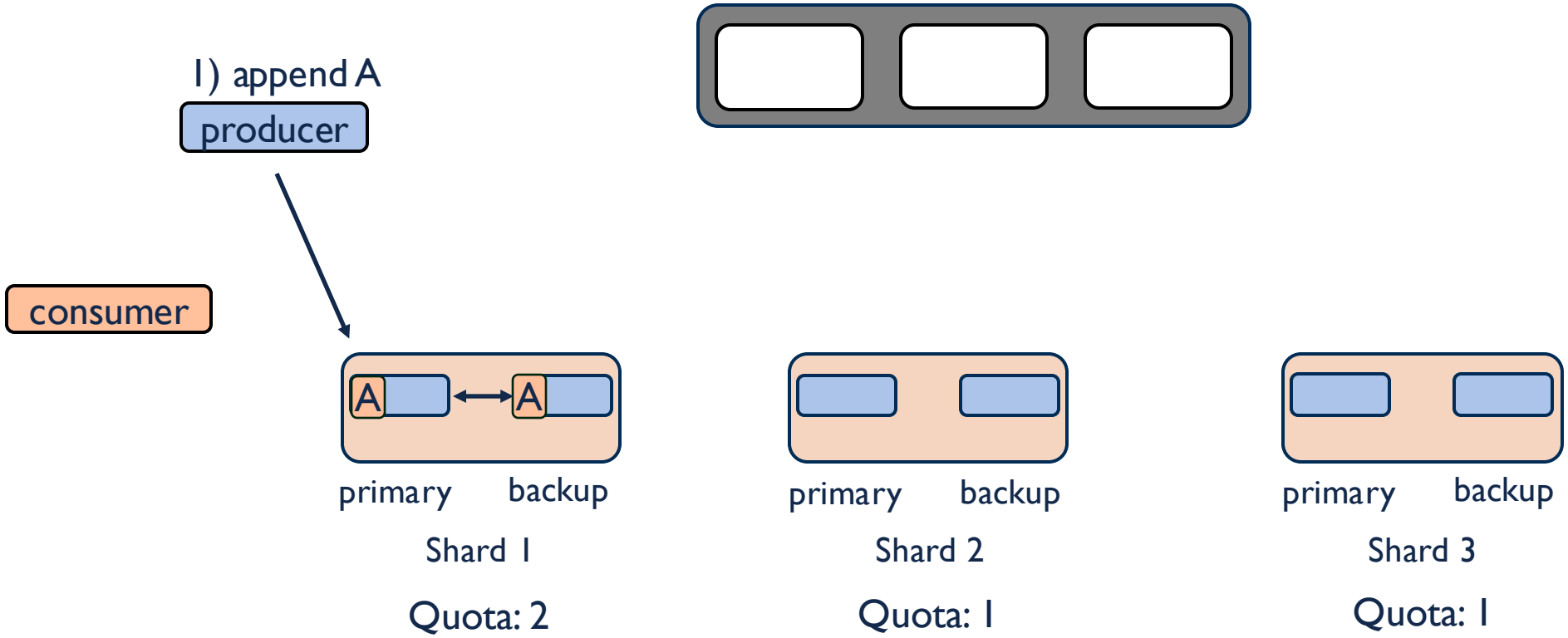

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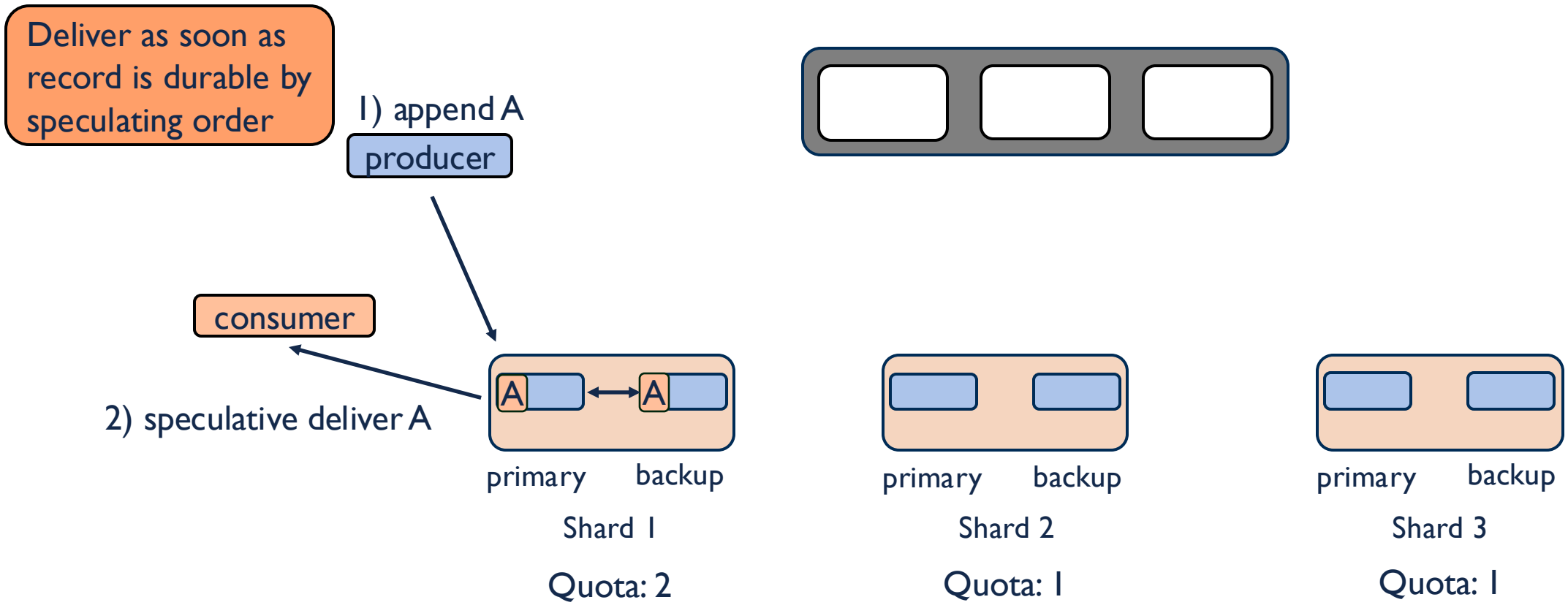

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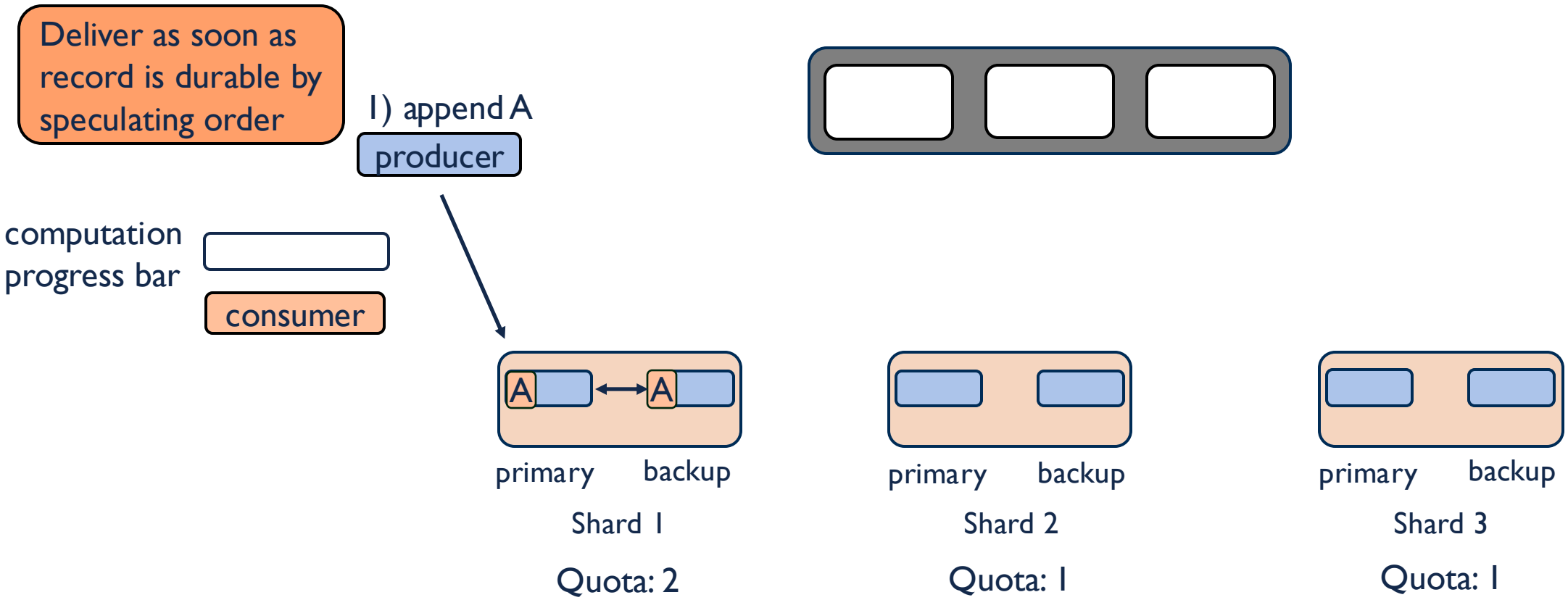

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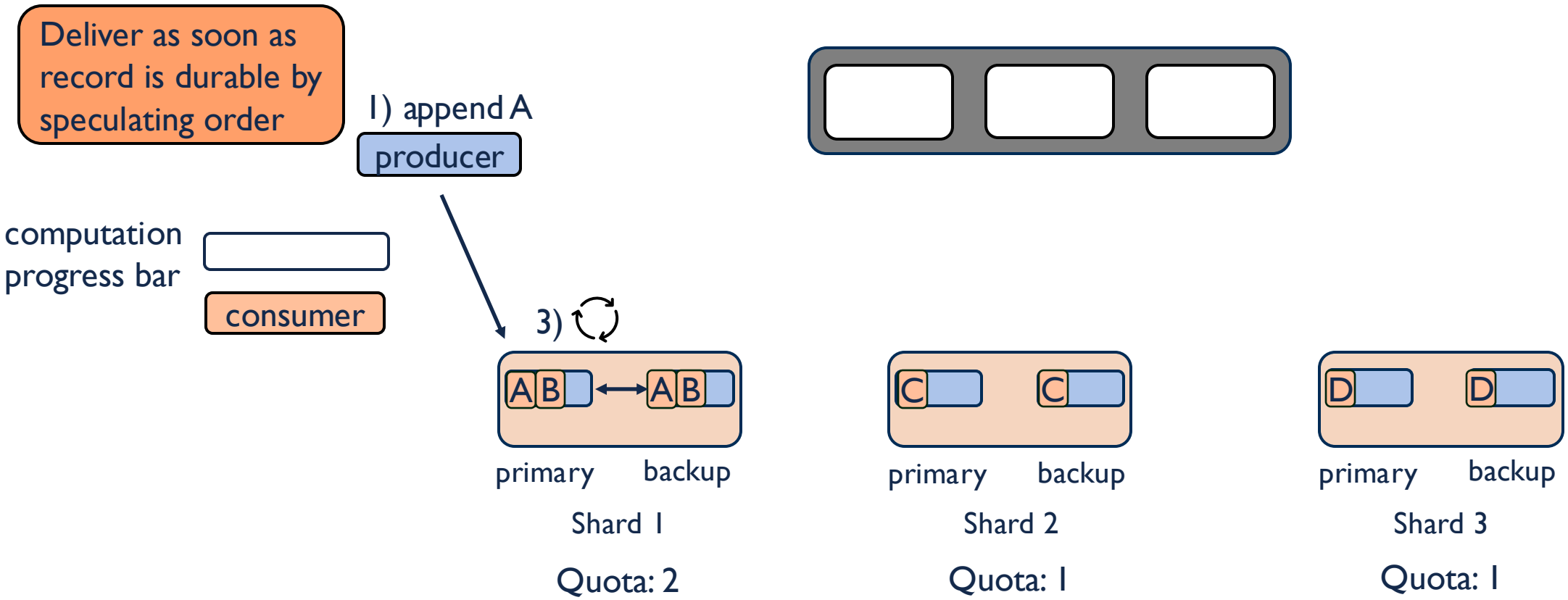

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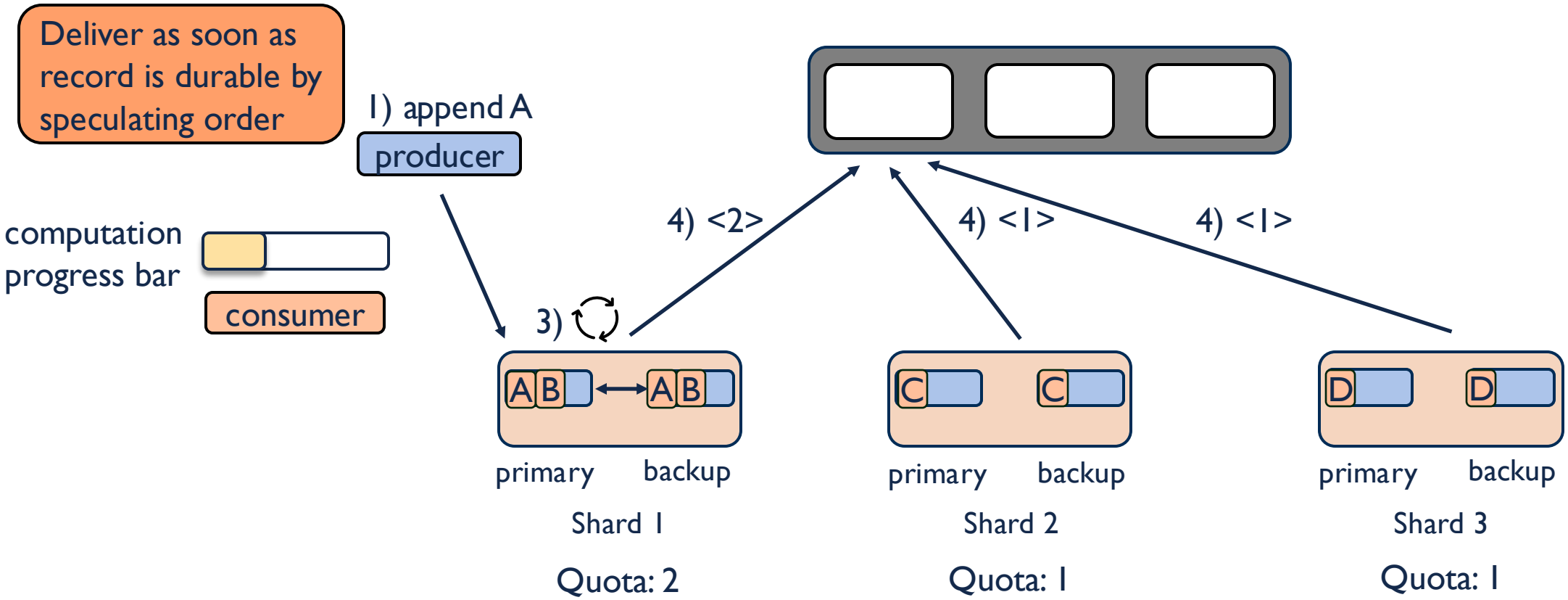

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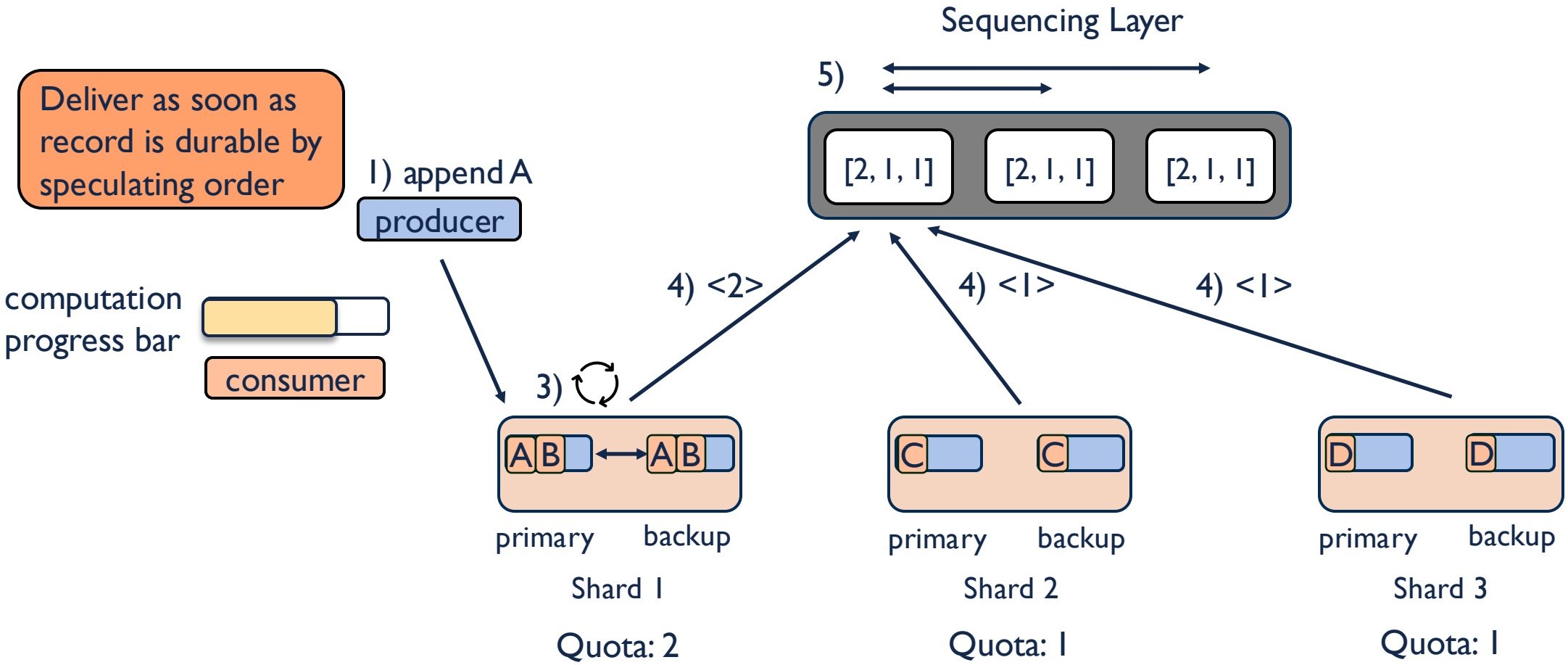

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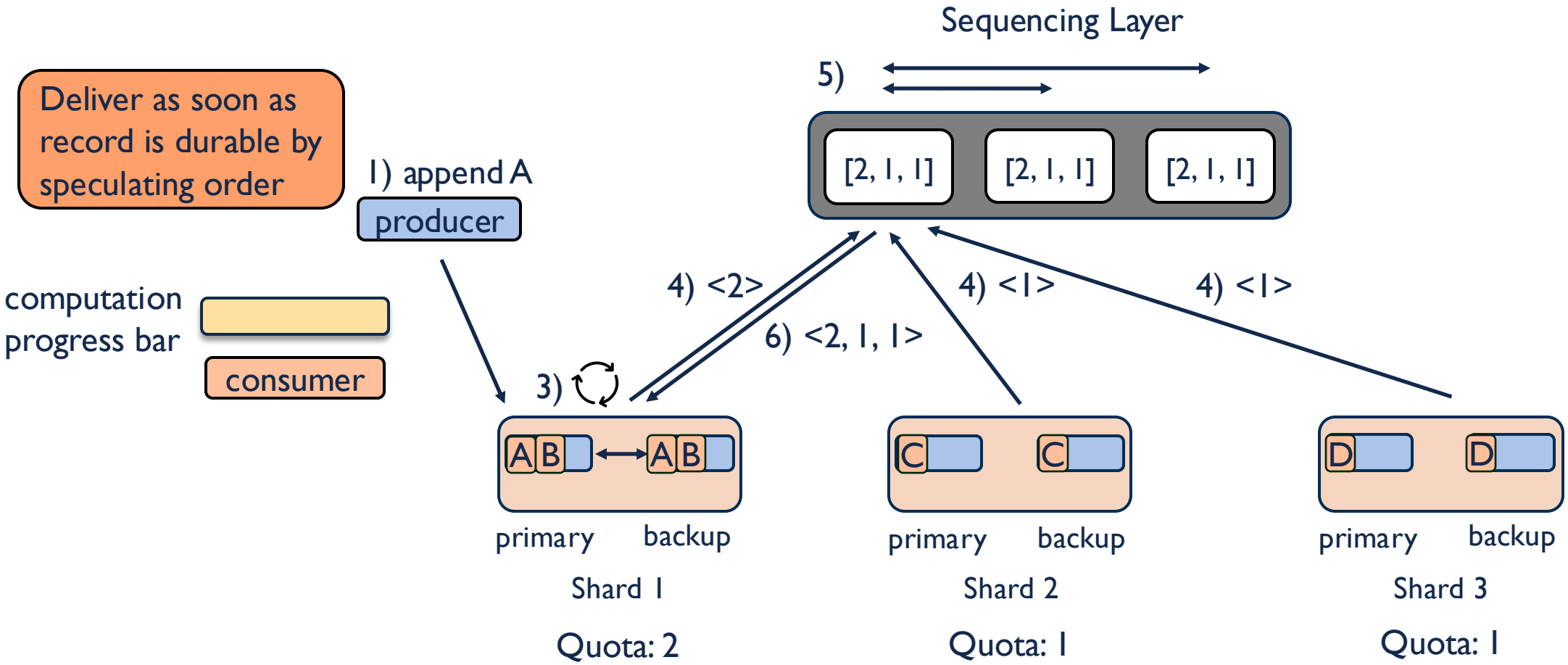

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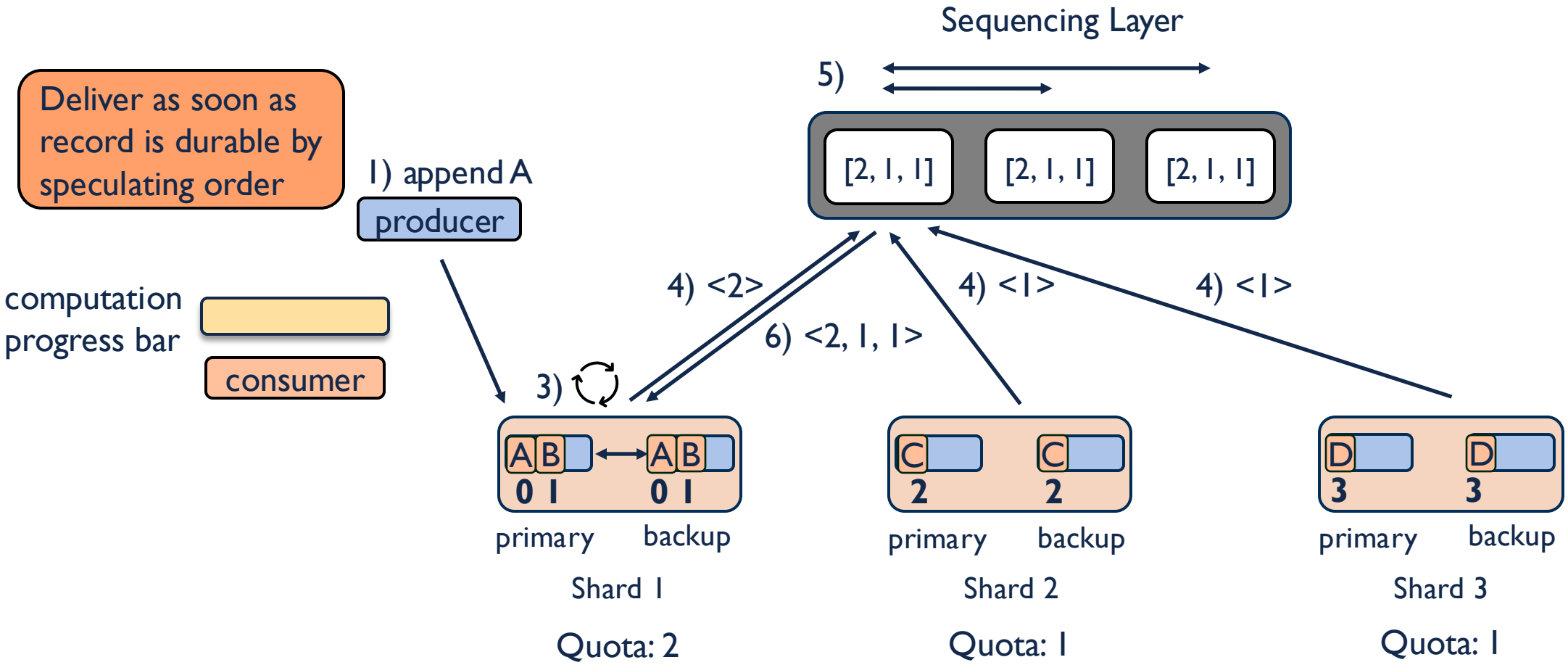

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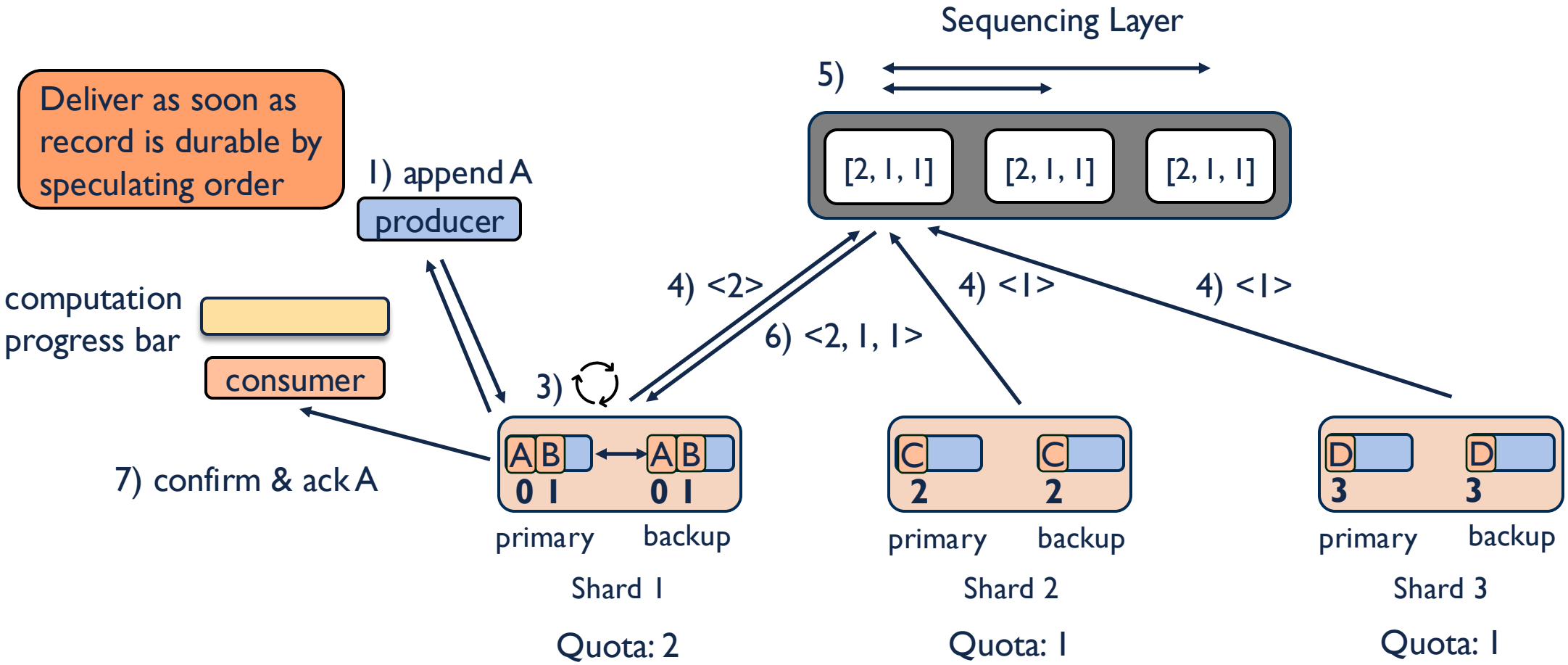

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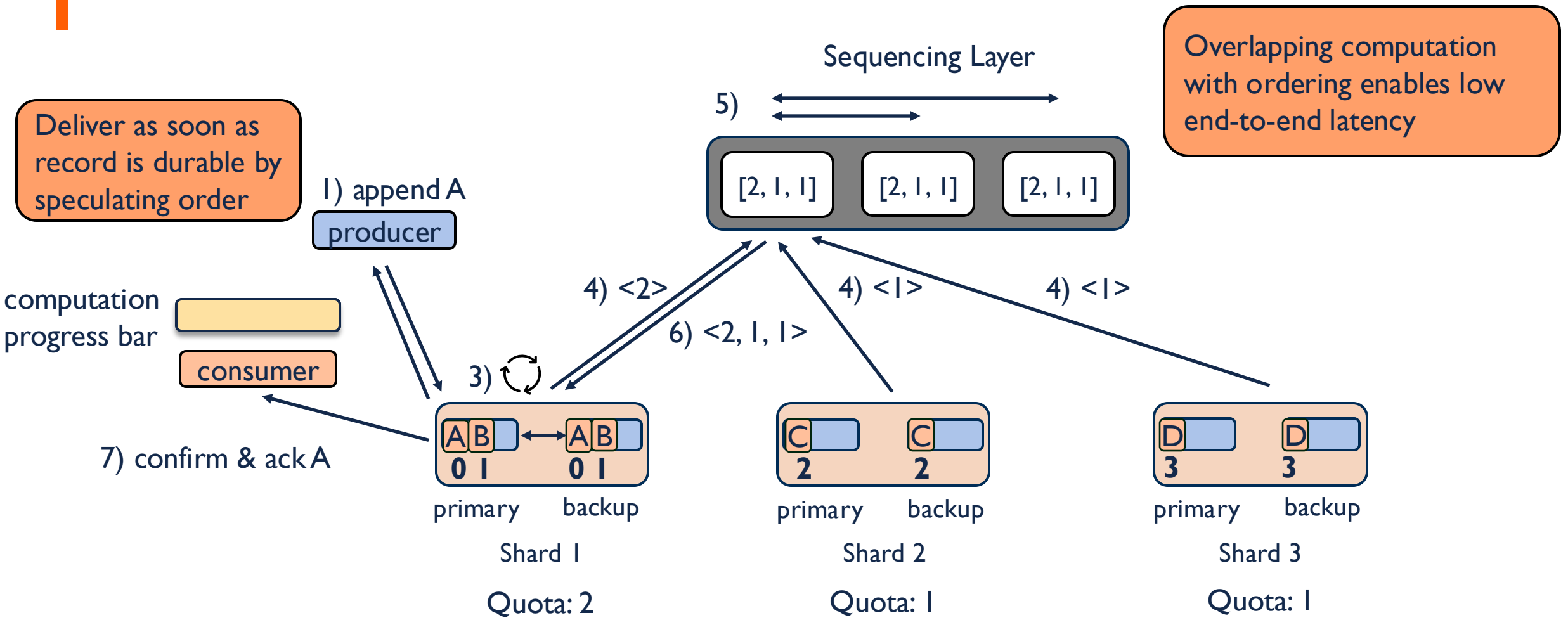

Outline

- Introduction
- Motivation
- SpecLog Abstraction and Interface
- Belfast Design and Implementation
- Evaluation

Implementing the SpecLog Abstraction

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- Mis-speculations and failure handling – view-change protocol

Evaluation

- What are the end-to-end latency benefits of Belfast?
- Does Belfast benefit end applications?

End-to-End Latency Benefits

Workload: 4KB records, downstream computation of 1.5ms per batch of consumed records

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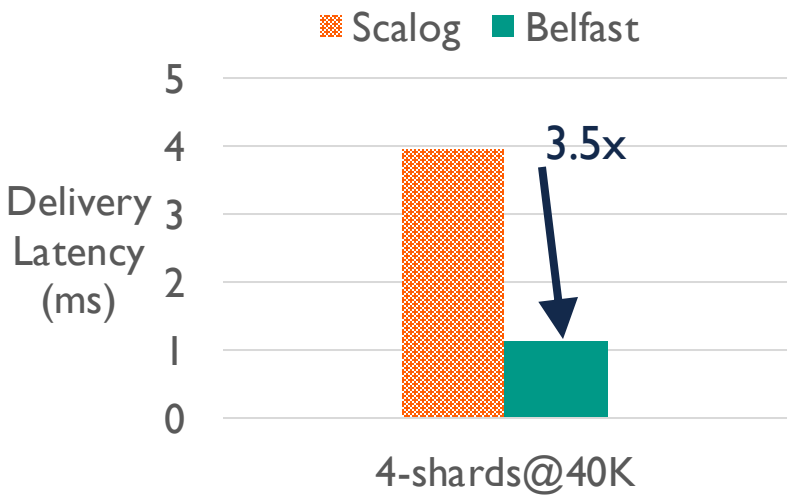
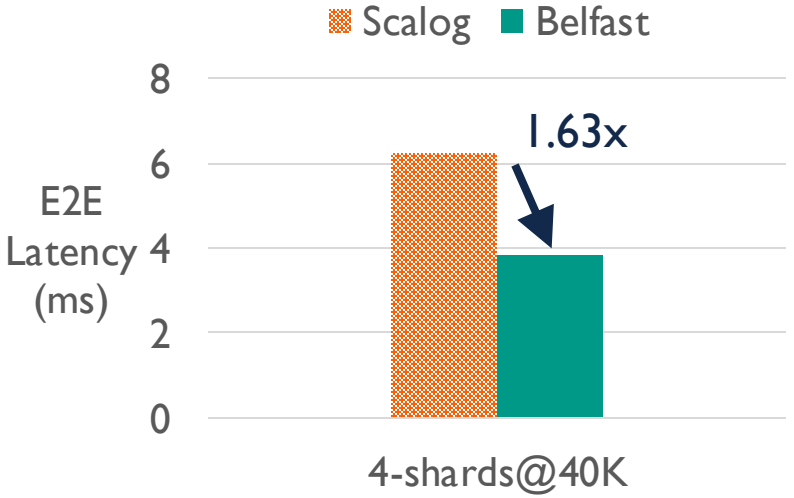


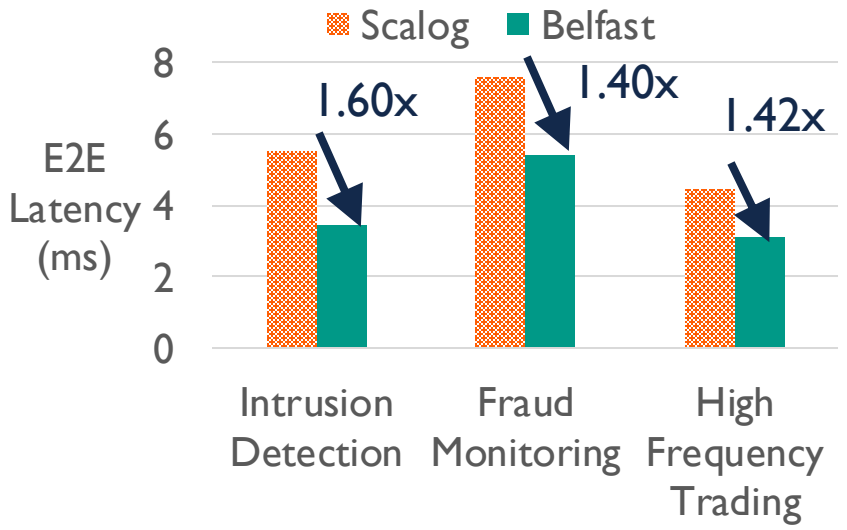
Delivers records 3.5x earlier



Enables 1.6x lower end-to-end latencies

Benefits in Applications

Build 3 applications – intrusion detection, fraud monitoring and high-frequency trading



Benefits in e2e latency for real-world applications

More details and experiments in the paper

Many more experiments in the paper

- App evaluation under failure scenarios and mis-speculations
- Evaluation under bursts, rate changes
- End-to-end latency at scale

The paper covers many more discussions about Belfast

Summary

- Today's shared logs suffer high delivery latencies due to expensive ordering
- SpecLog, a new abstraction, allows speculative delivery by predicting global order
- SpecLog uses Fix-Ante ordering, enables high speculation success
- Belfast, an implementation of SpecLog, enables low e2e latencies for end applications

Available on GitHub:
https://github.com/dassl-uiuc/speclog-artifact