Replex: A Multi-Index, Highly-Available Data Store

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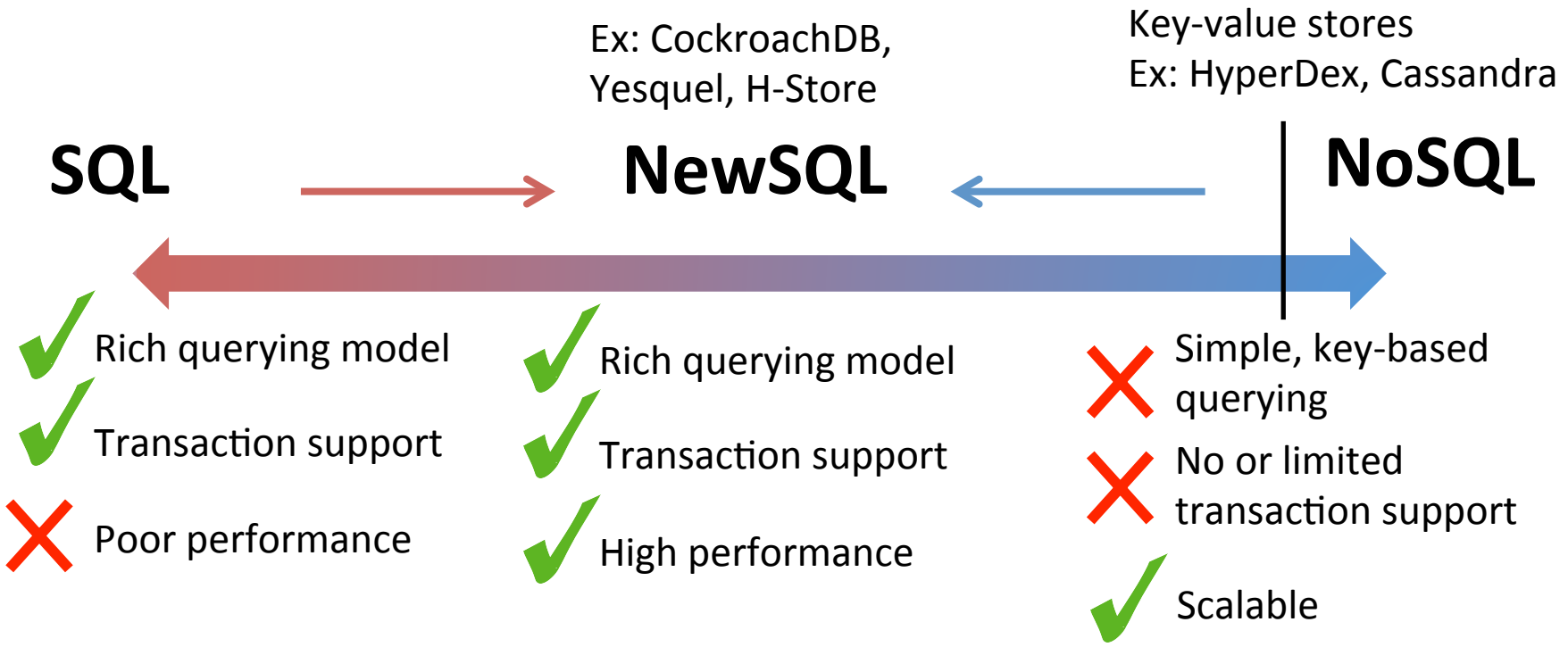
SQL vs NoSQL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Yesquel, H-Store
Key-value stores
Ex: HyperDex, Cassandra
SQL
NewSQL
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Rich querying model
Transaction support
Poor performance
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High performance
Simple, key-based querying
No or limited transaction support
Scalable

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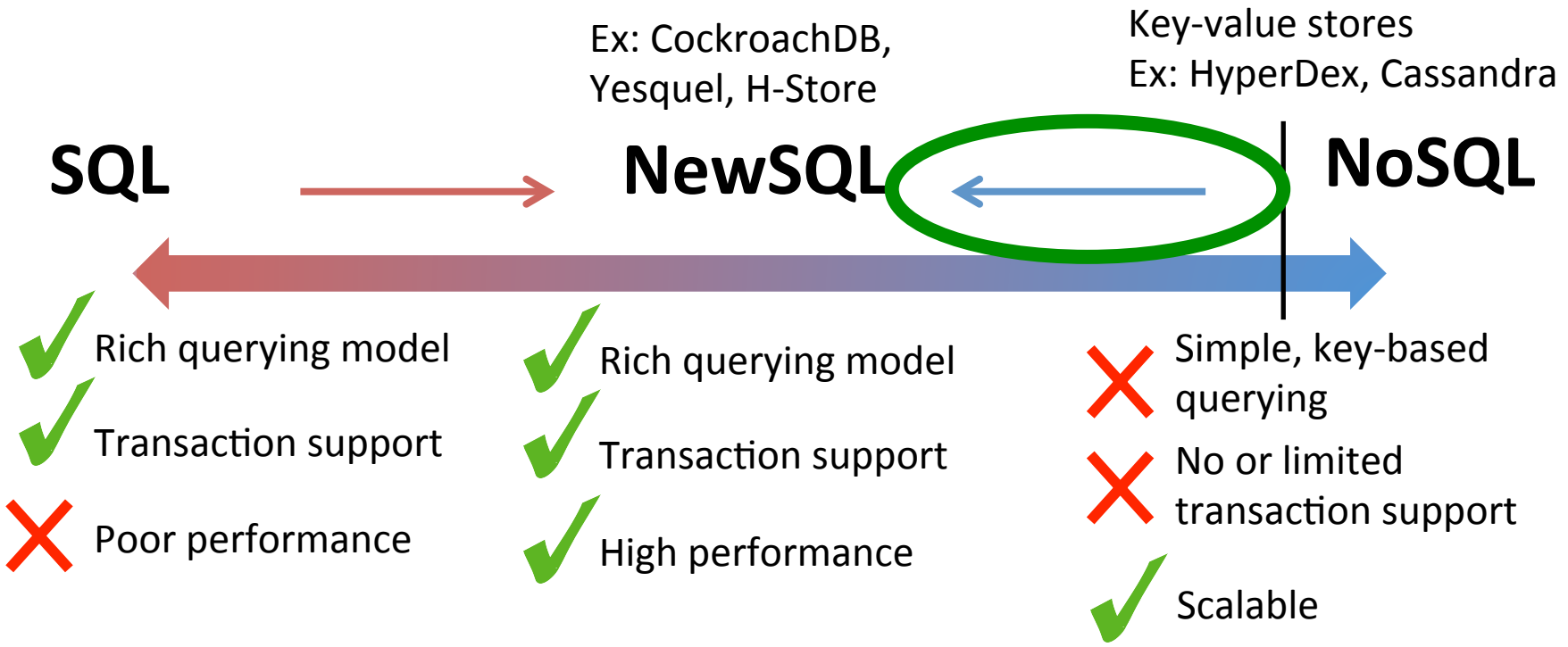
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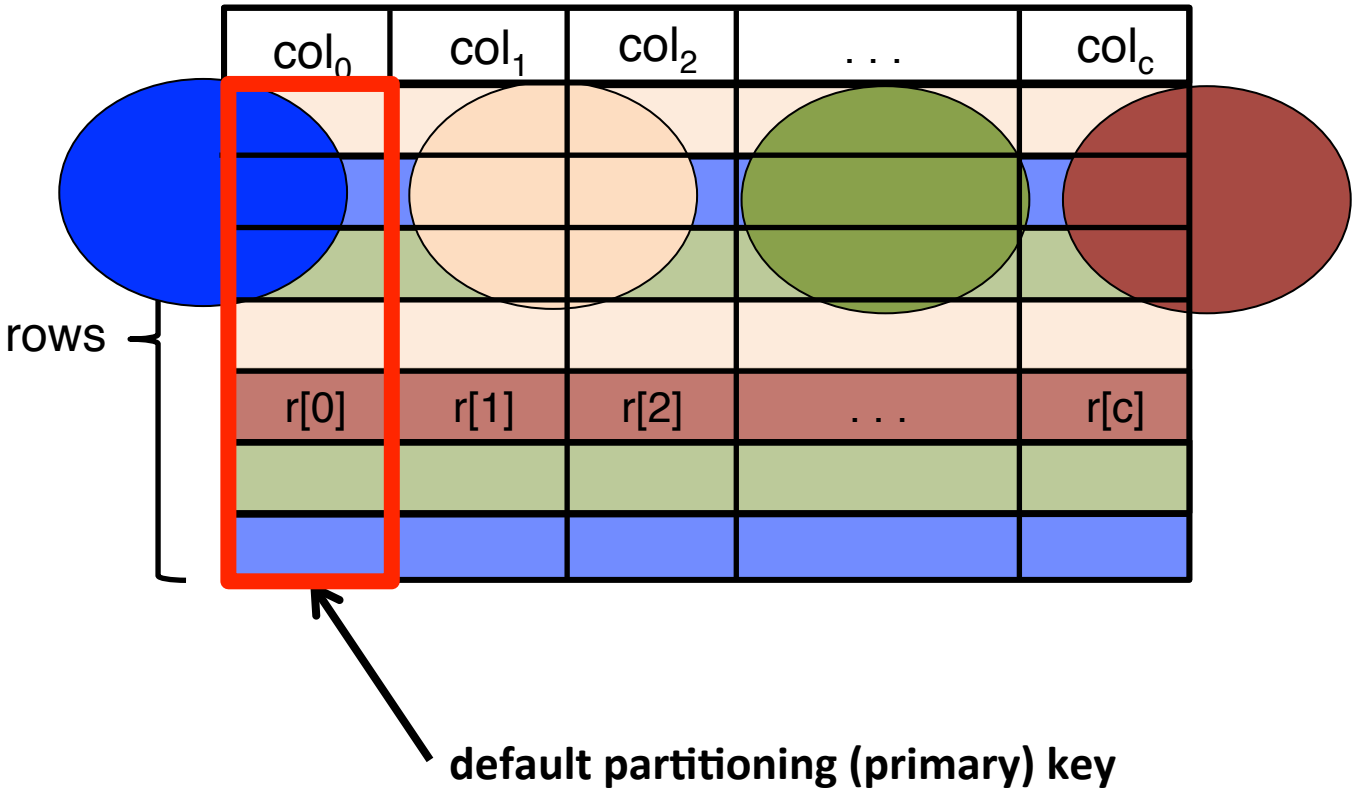
Replex enables richer queries without sacrificing shared-nothing scale-out

NoSQL Scales with Shared-Nothing Partitioning



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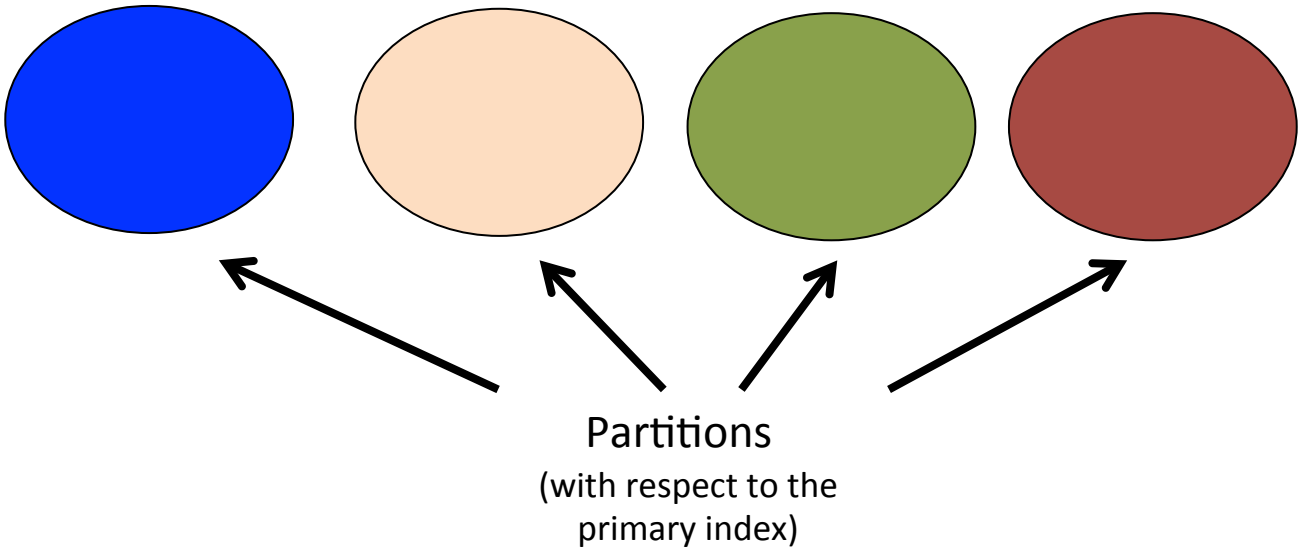


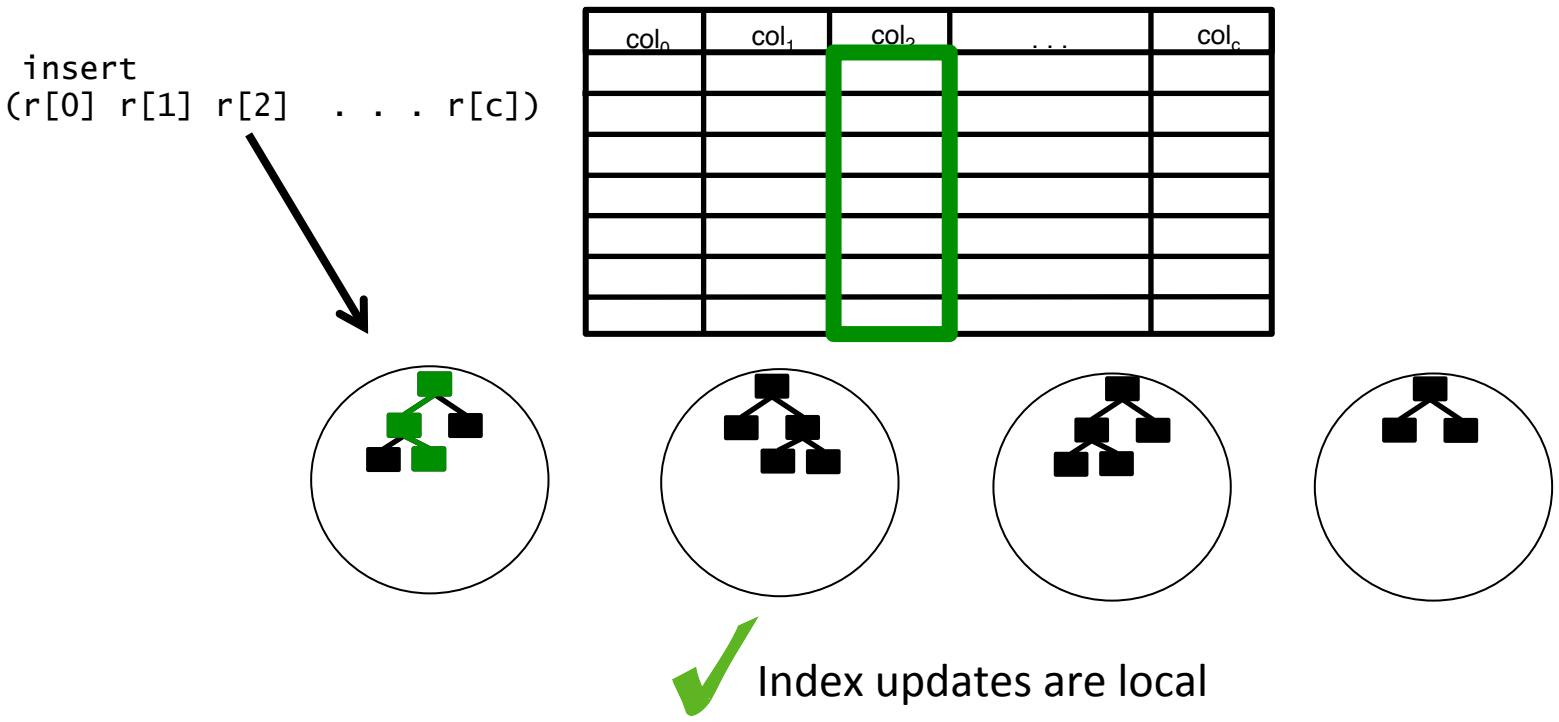
Key Observations

1. Indexing enables richer queries

(searches, joins, etc.)

Approach 1: Local Indexing

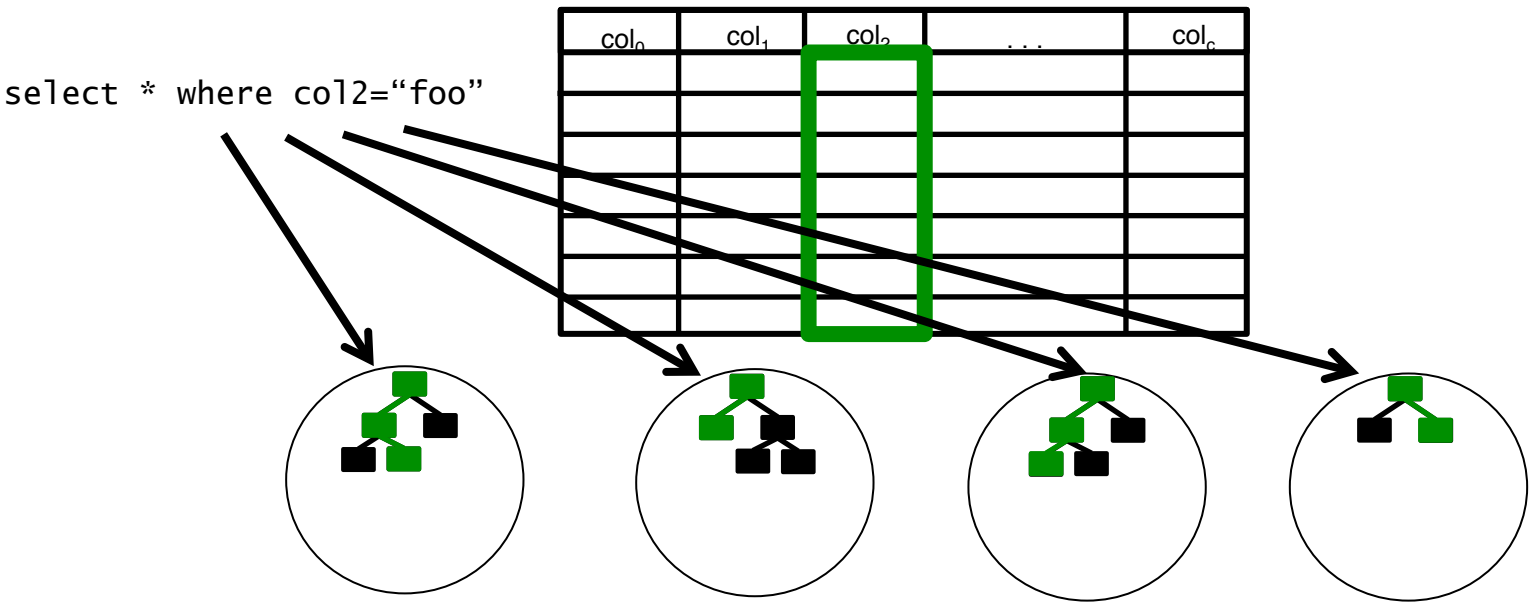
Index stored locally at each partition



✓ Index updates are local

Approach 1: Local Indexing

Each partition builds a local index



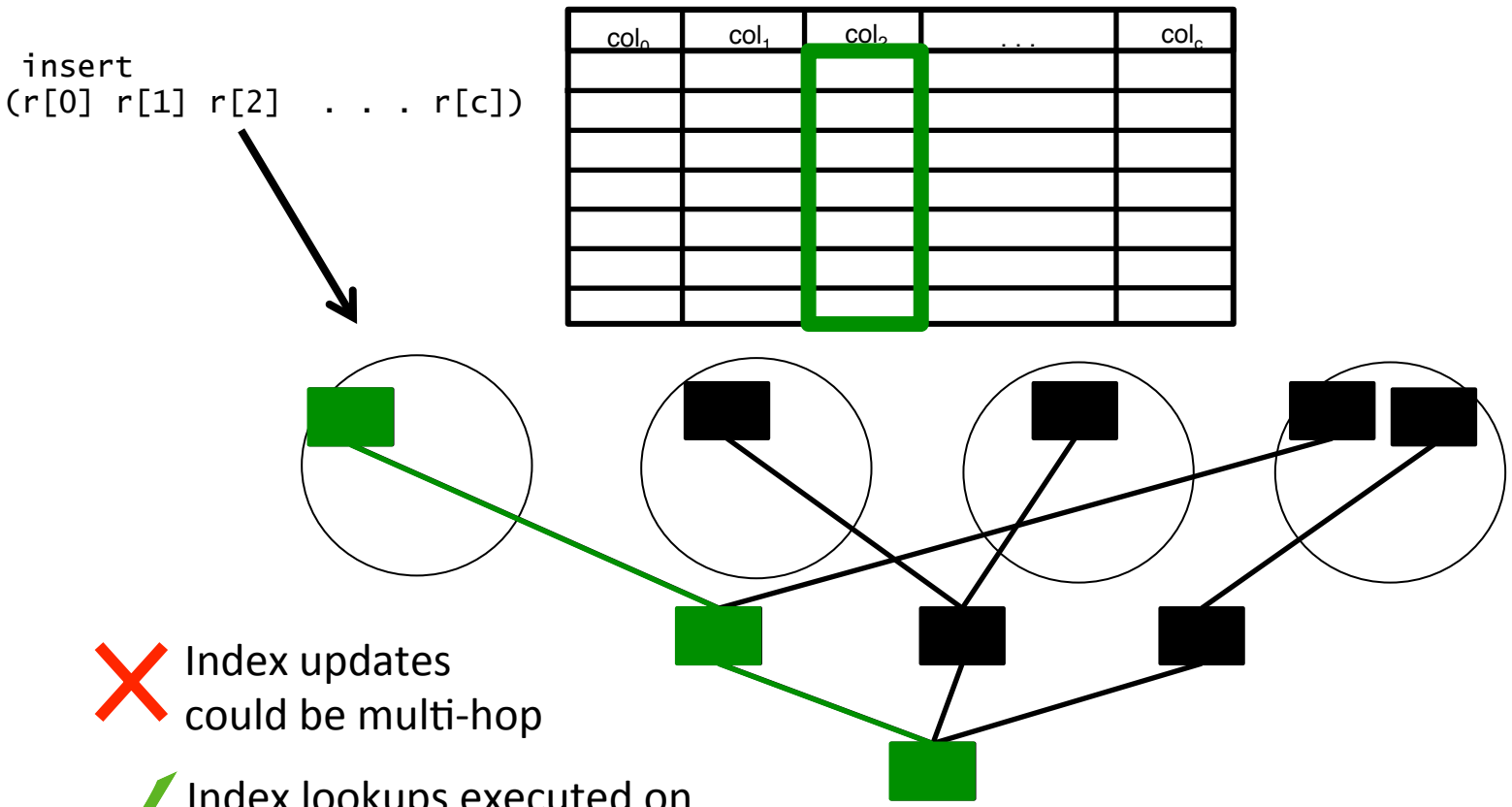
✓ Index updates are local

✗ Index lookups must be broadcast to all partitions

✗ Potential synchronization across partitions

Approach 2: Global Indexing

Distributed data structure spans all partitions



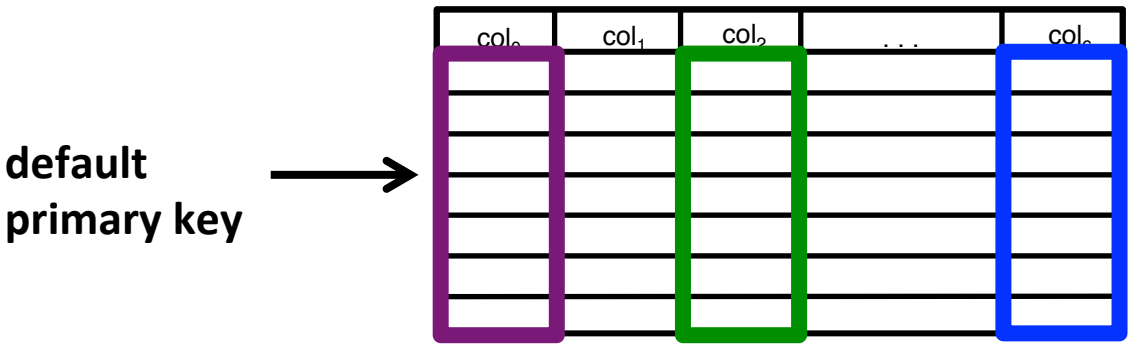
Index updates could be multi-hop

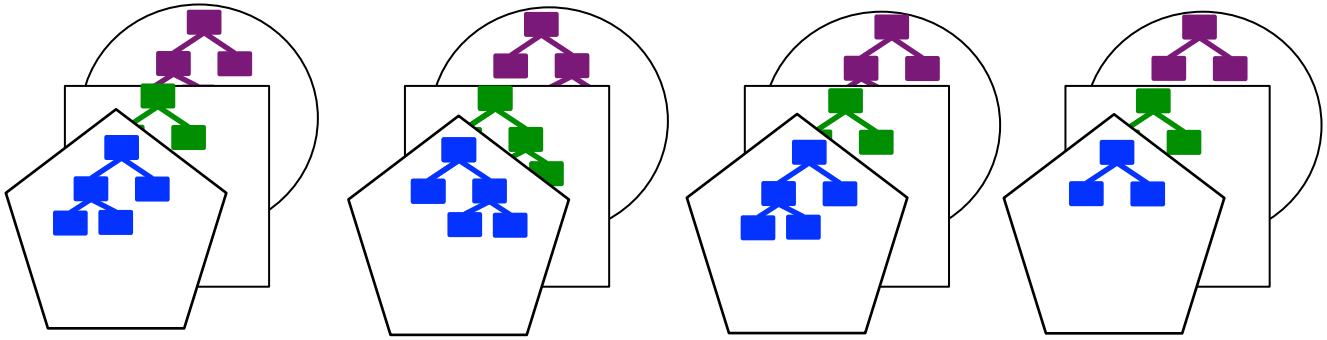
Index lookups executed on a single data structure

Key Observations

1. Indexing enables richer queries
   (searches, joins, etc.)
2. **Indexes more efficient if data is partitioned according to that index**

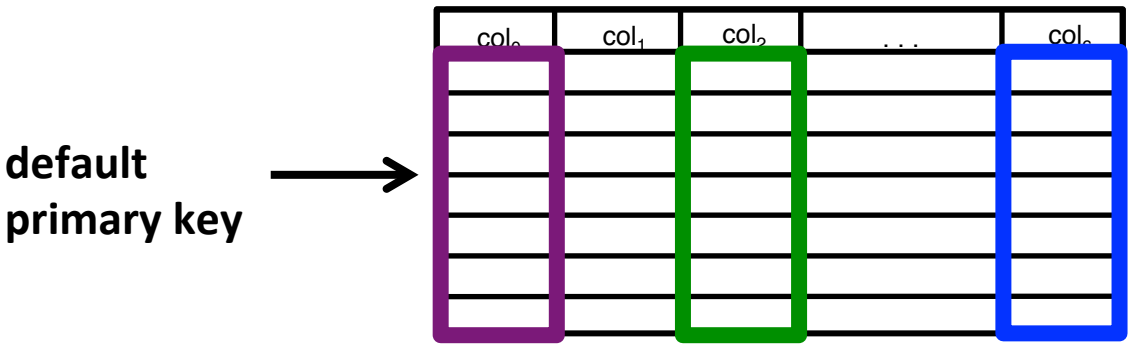
Partitioning by Index → Storage Overheads

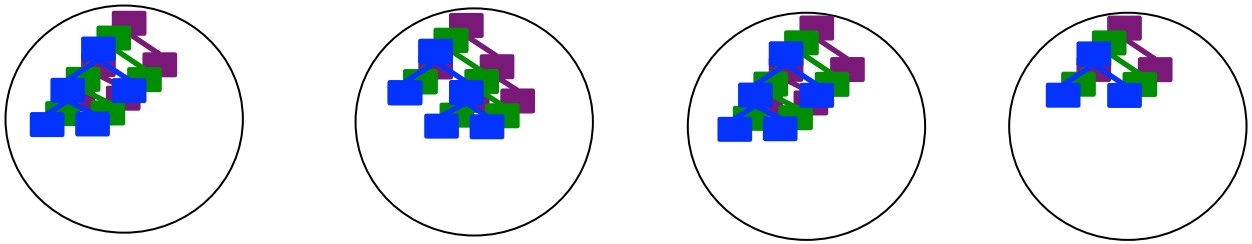




Partitioning by index → must store data again

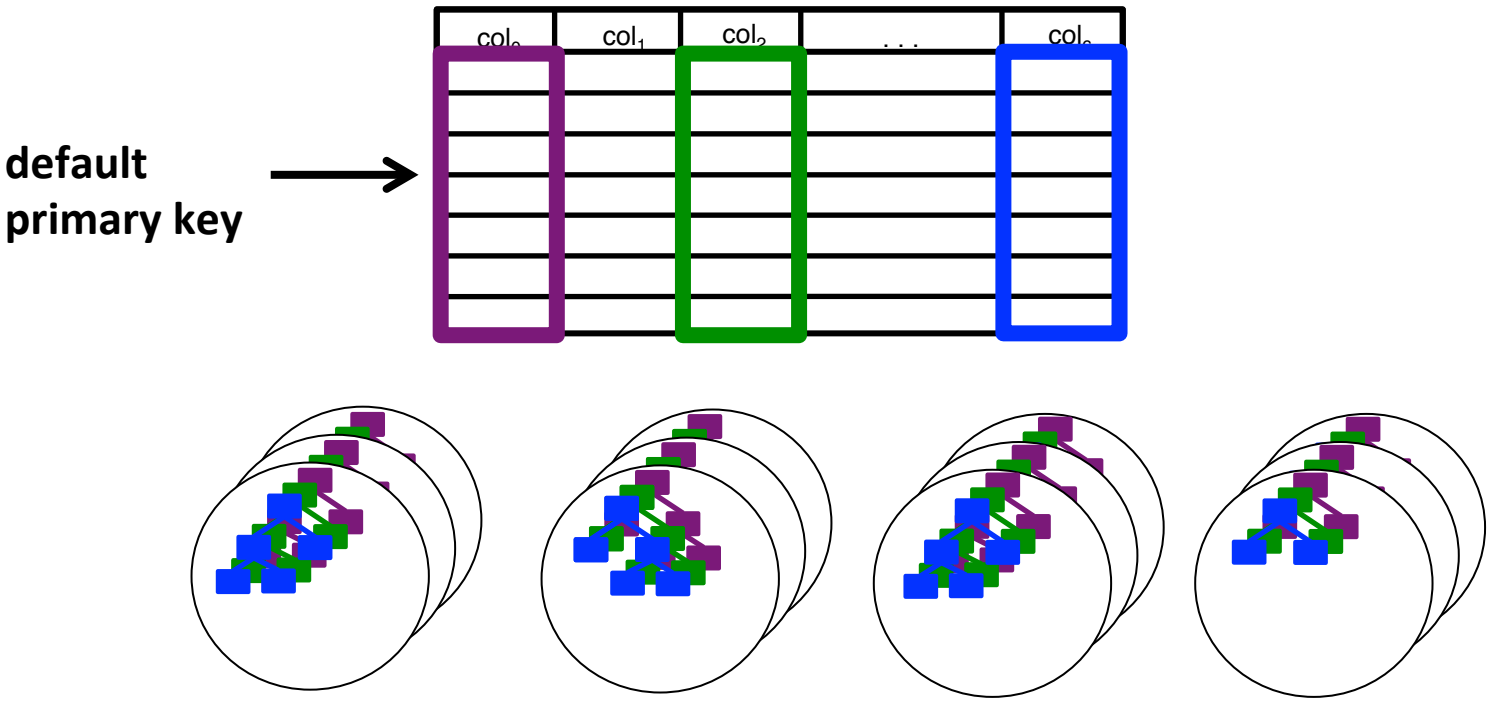
Partitioning by Index → Storage Overheads





Ideally, build all indexes over a single copy of data

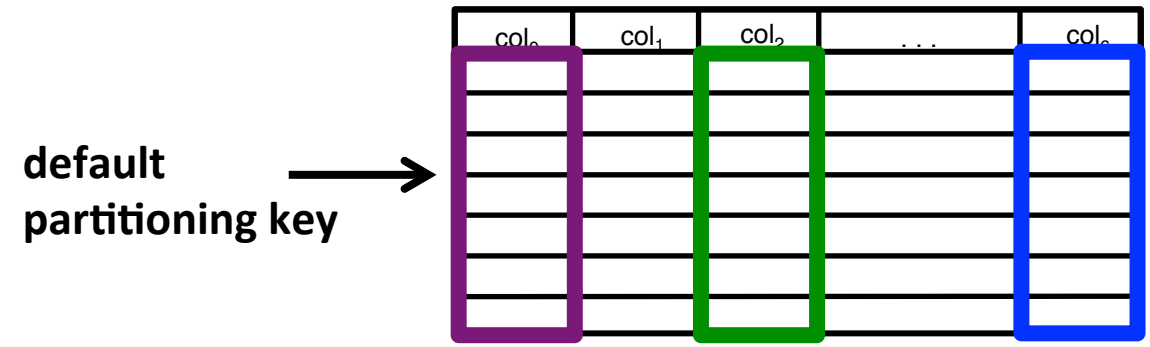
Partitioning by Index → Storage Overheads

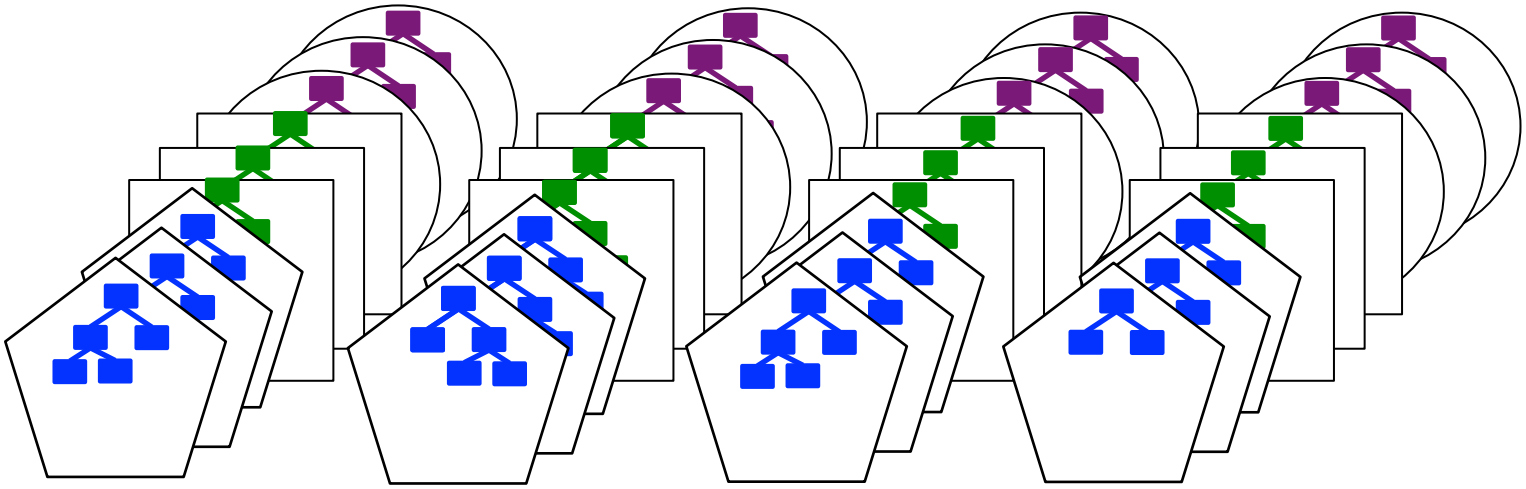


Ideally, build all indexes over a single copy of data

Then, replication also replicates indexes

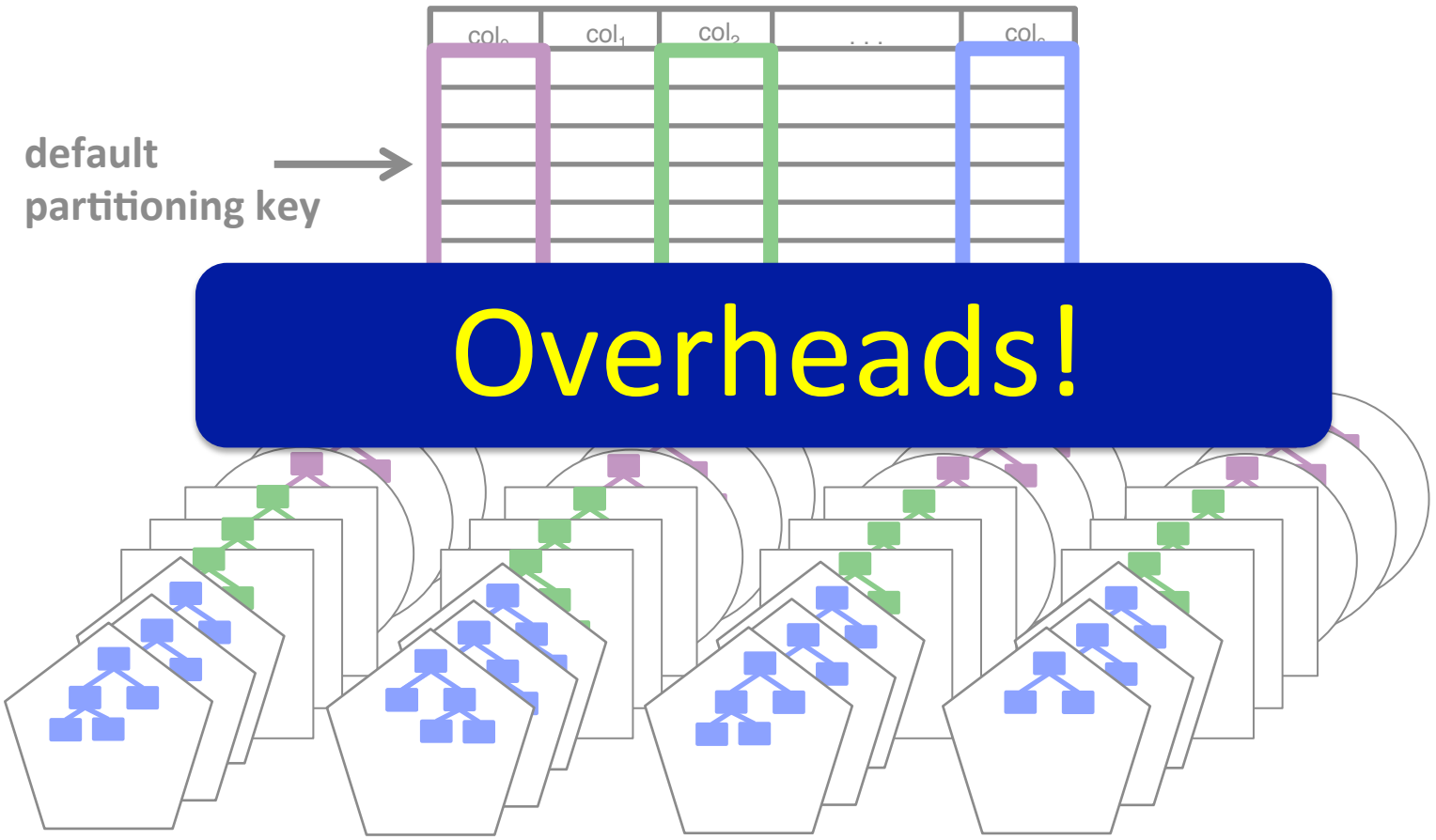
Partitioning by Index → Storage Overheads





Instead, to make indexes durable, must
3-way replicate each partitioning of data

Partitioning by Index → Storage Overheads



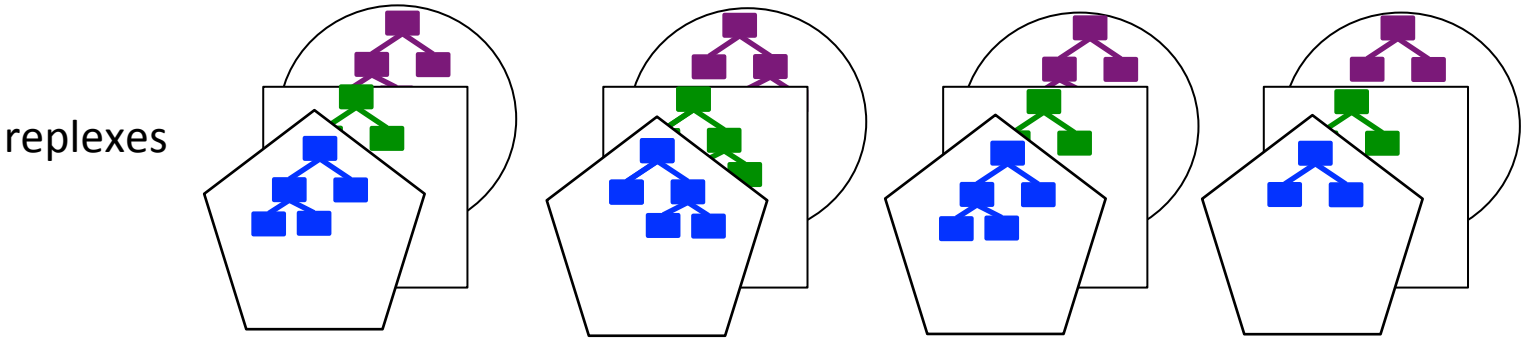
HyperDex

Replex solves the indexing problem by combining indexing and replication

Replex

New replication unit:

replex -- data replica partitioned and sorted with respect to an associated index



Serves data **repl**ication and ind**ex**ing

Replex

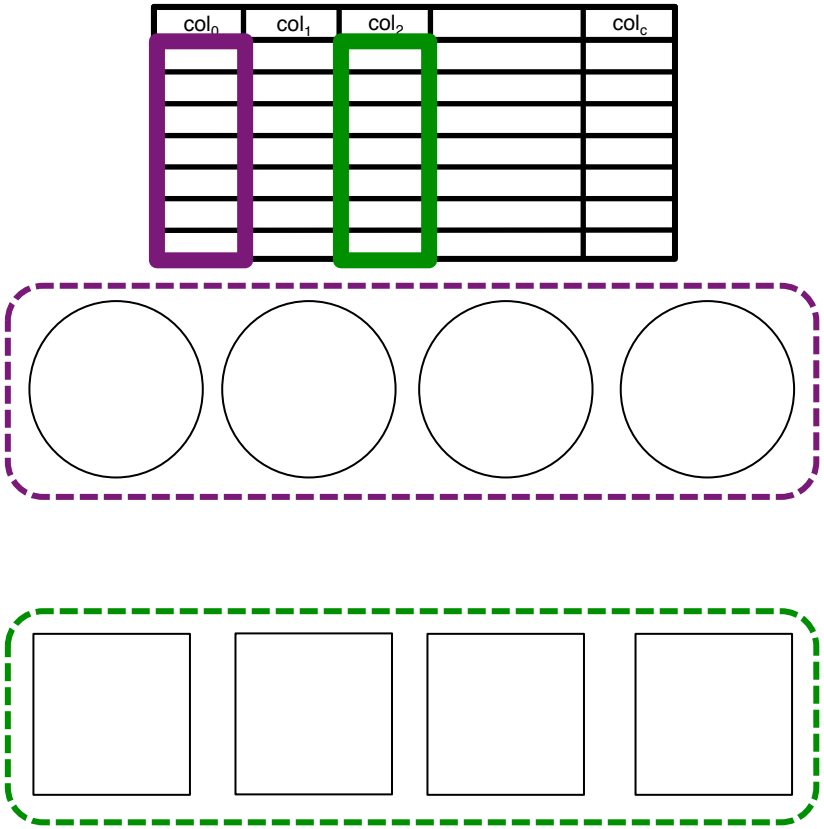
New replication unit:

Replace data replicas with replexes

Indexing comes free during replication

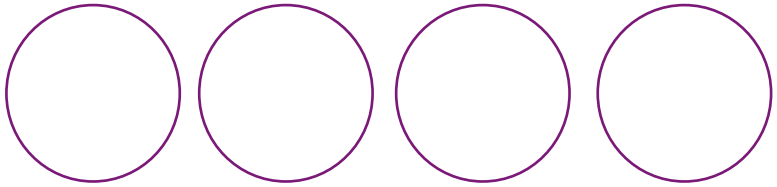
Serves data **repl**ication and ind**ex**ing

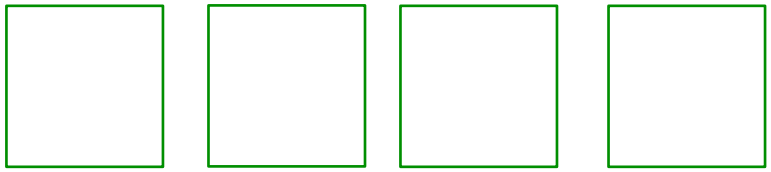
System Architecture



Inserts in Replex

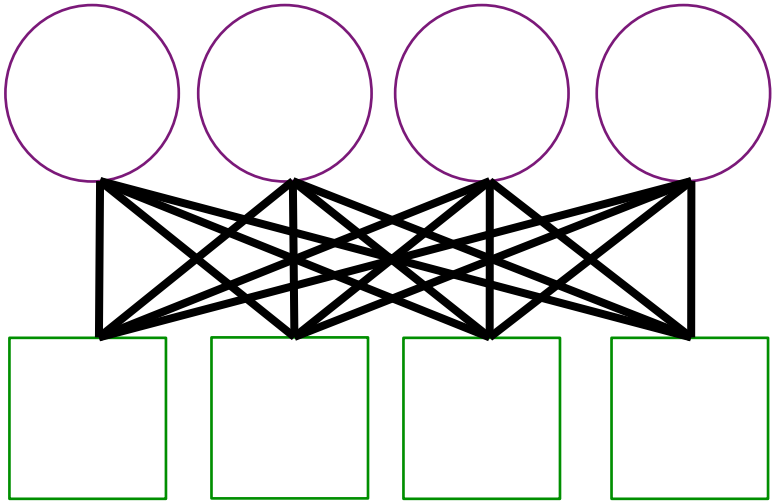
Replex uses a modified chain replication protocol





Which chain?

All pairs of partitions are potential chains



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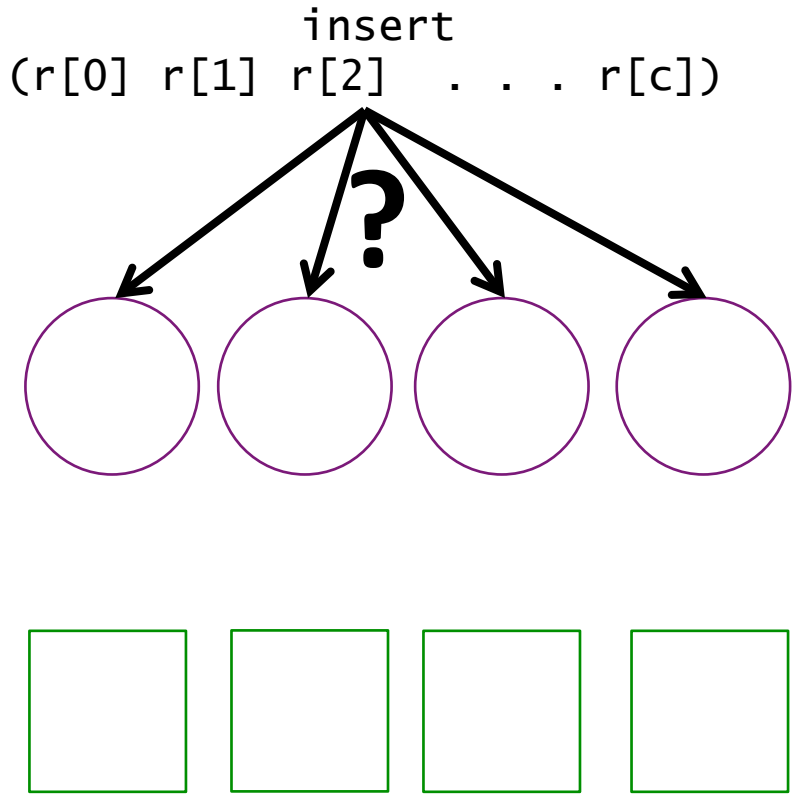
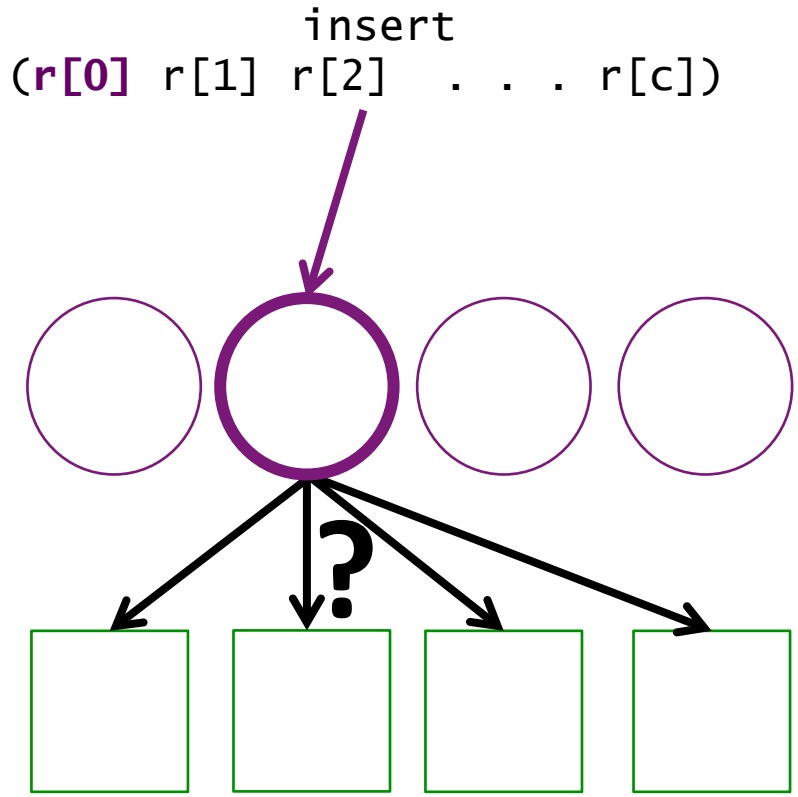
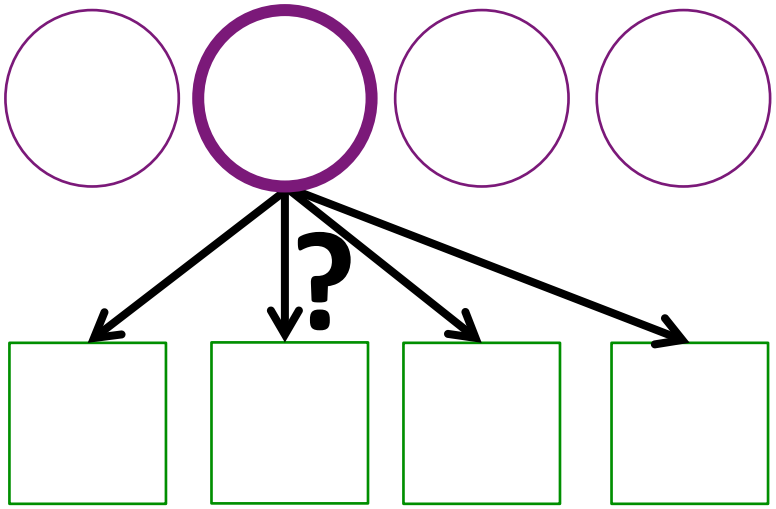


Partition Determined by a replex's Index



Partition Determined by a replex's Index

```
insert
(r[0] r[1] r[2]  . . . r[c])
```



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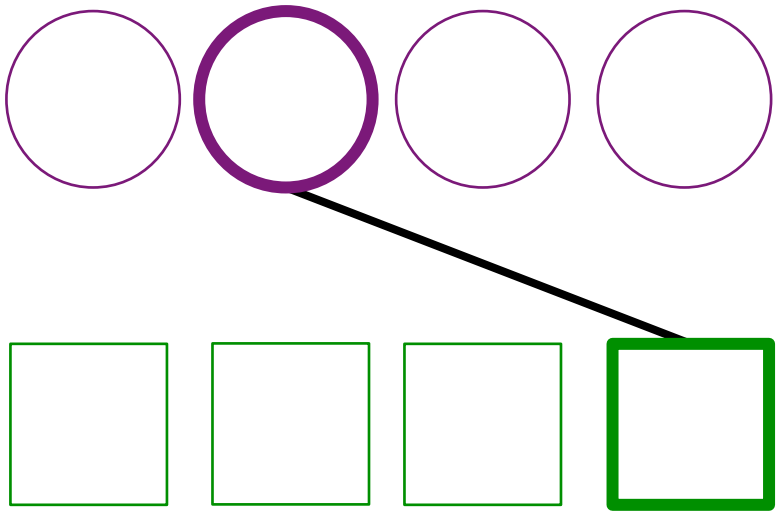
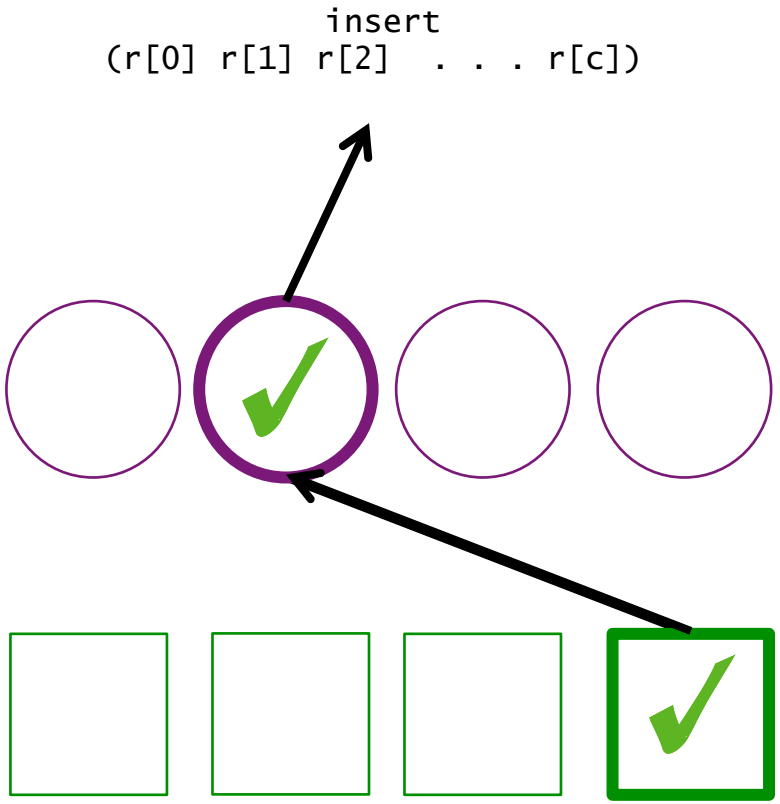


Propagating a Commit Bit



Commit bits can be aborts

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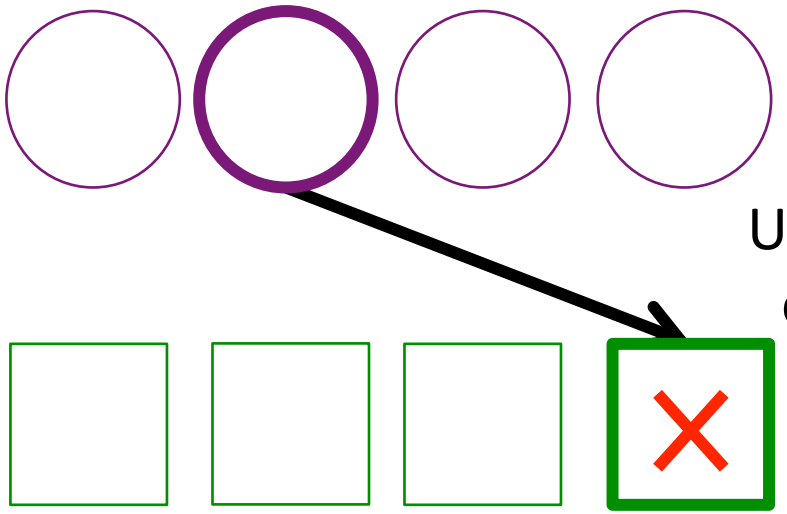
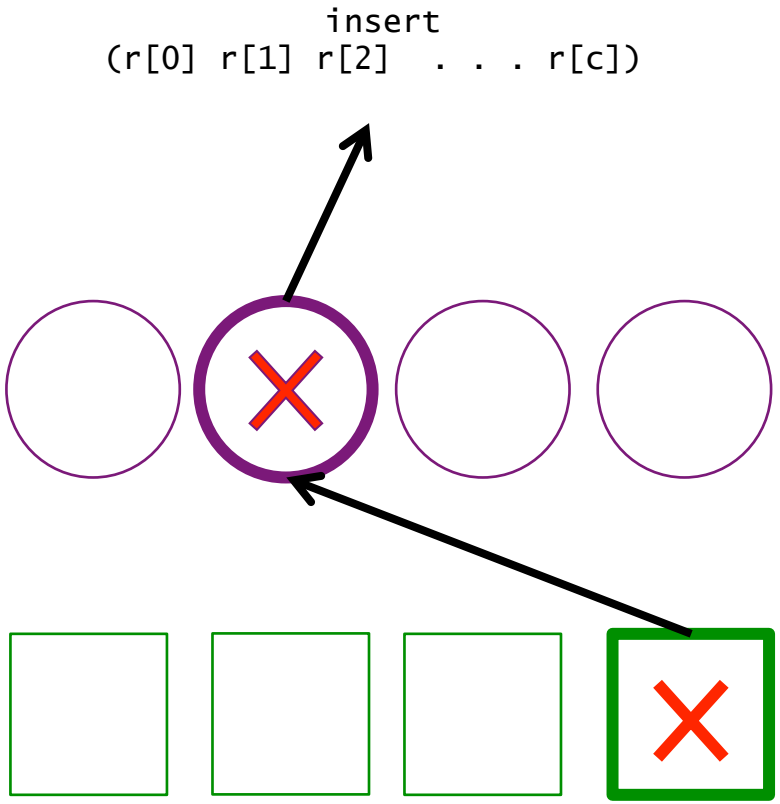
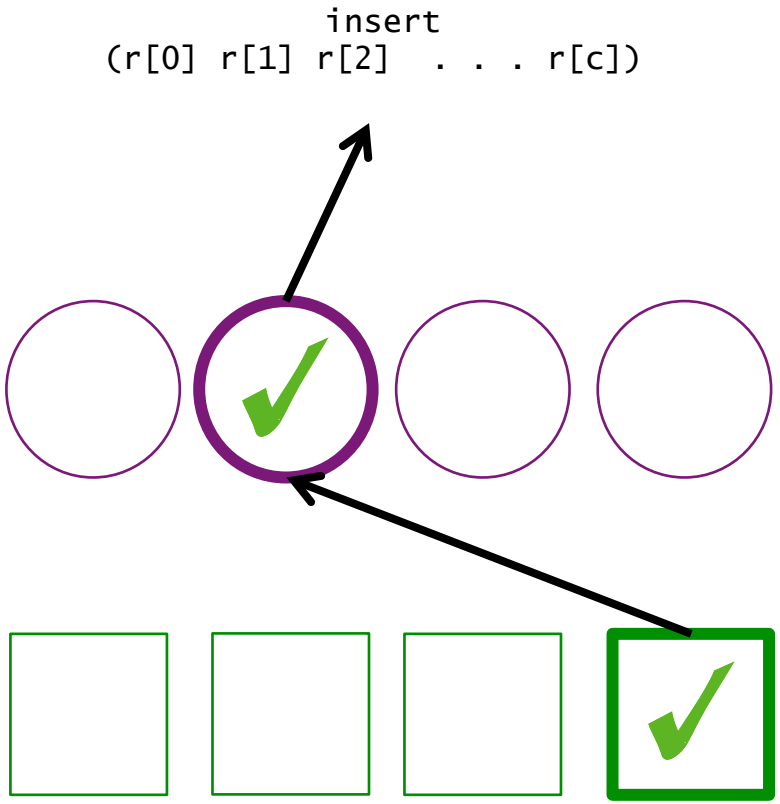


Uniqueness constraint on green replex can cause abort

Commit bits can be aborts

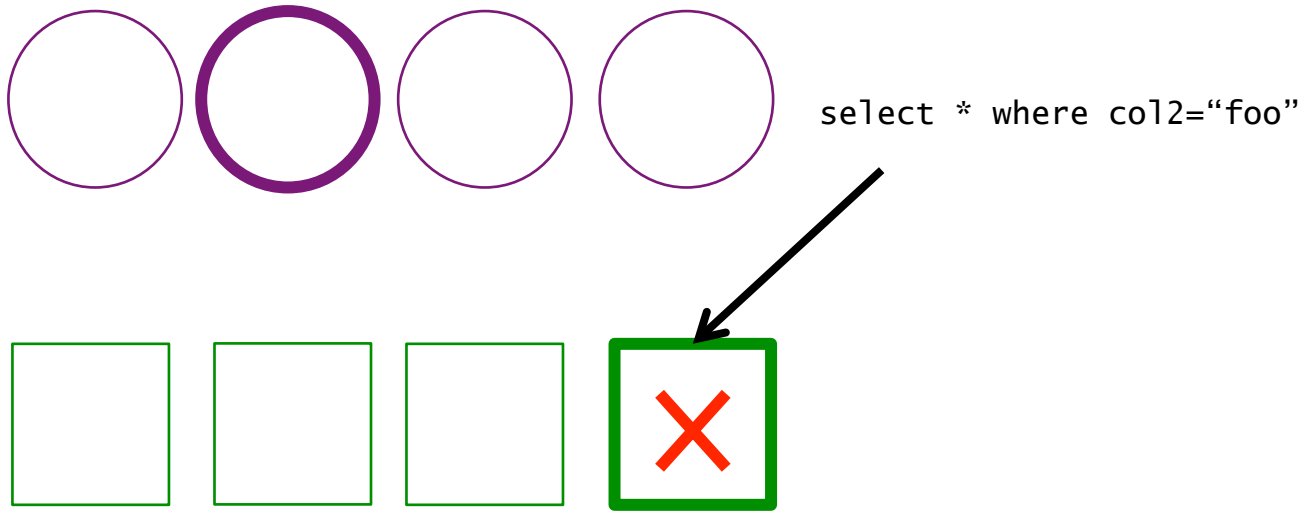


Indexing is ***Free***

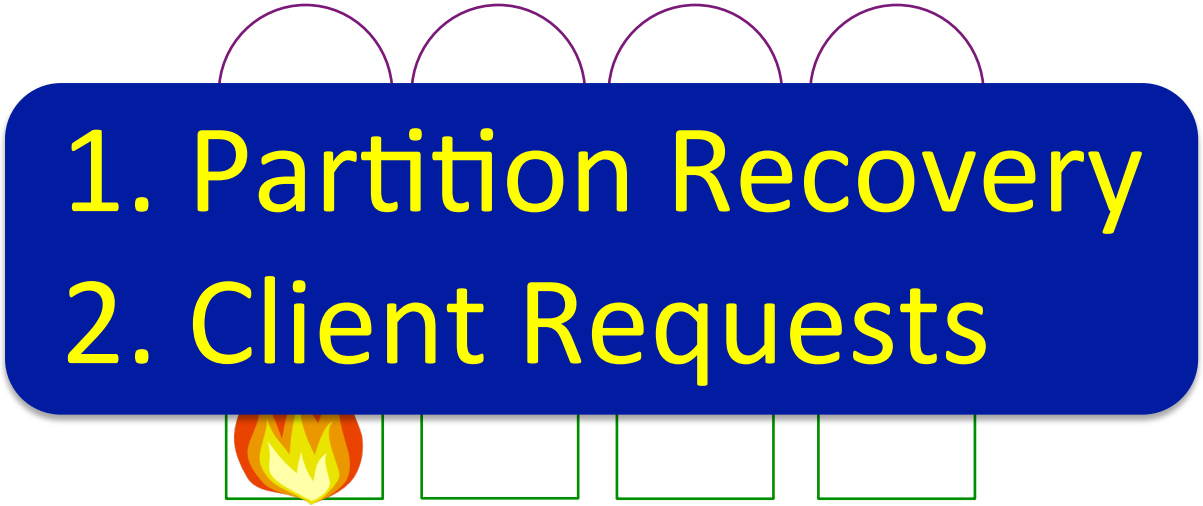


Index Reads in Replex

1. Check for a commit bit
2. Only if the bit is true, can row be returned

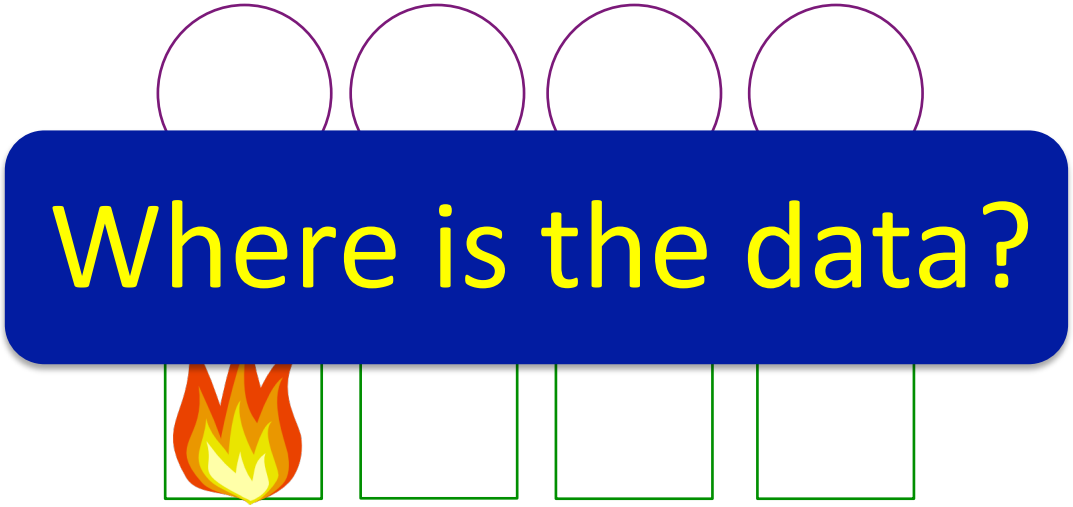


Partition Failures



Index is unavailable, **data is available**

Partition Failures



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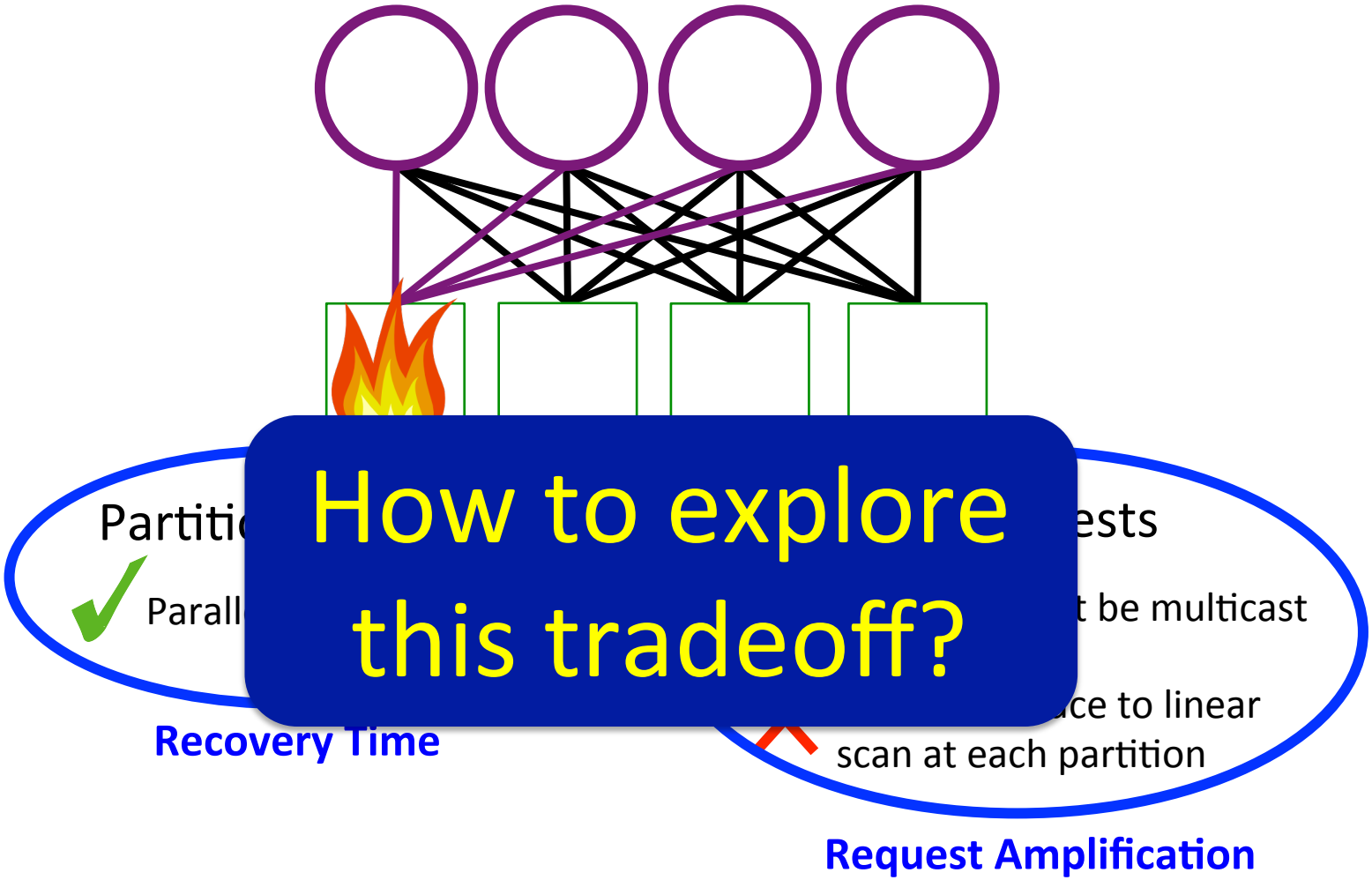
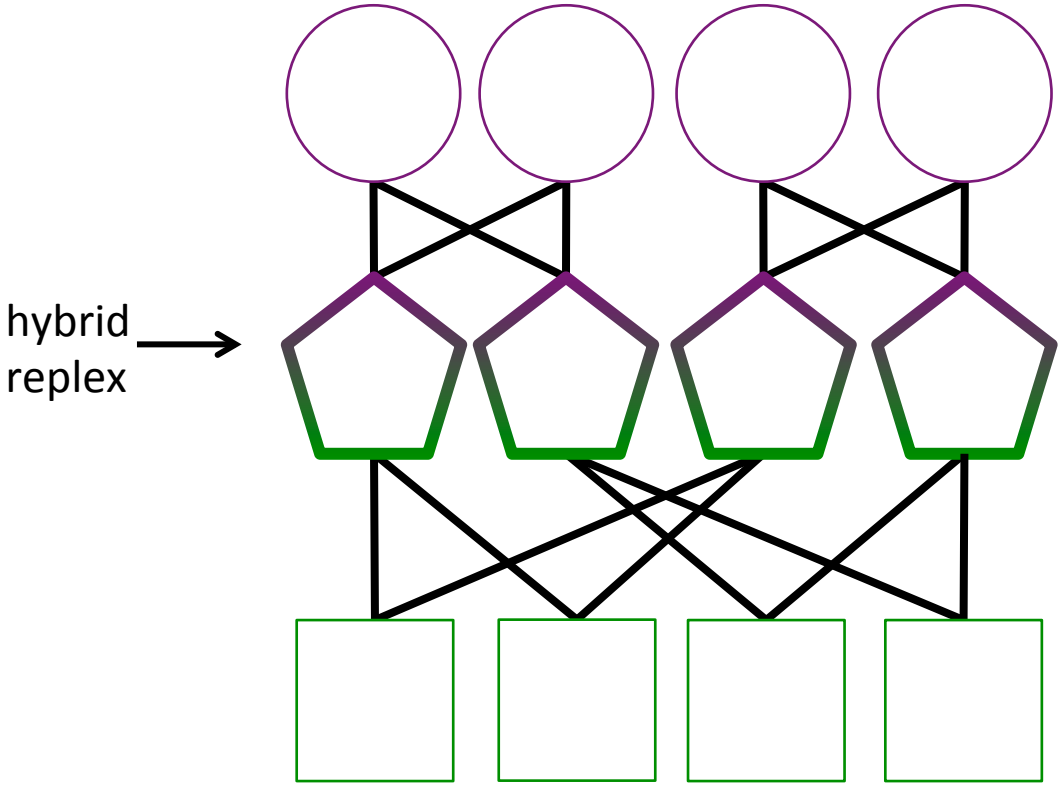
Finding Data After Failure

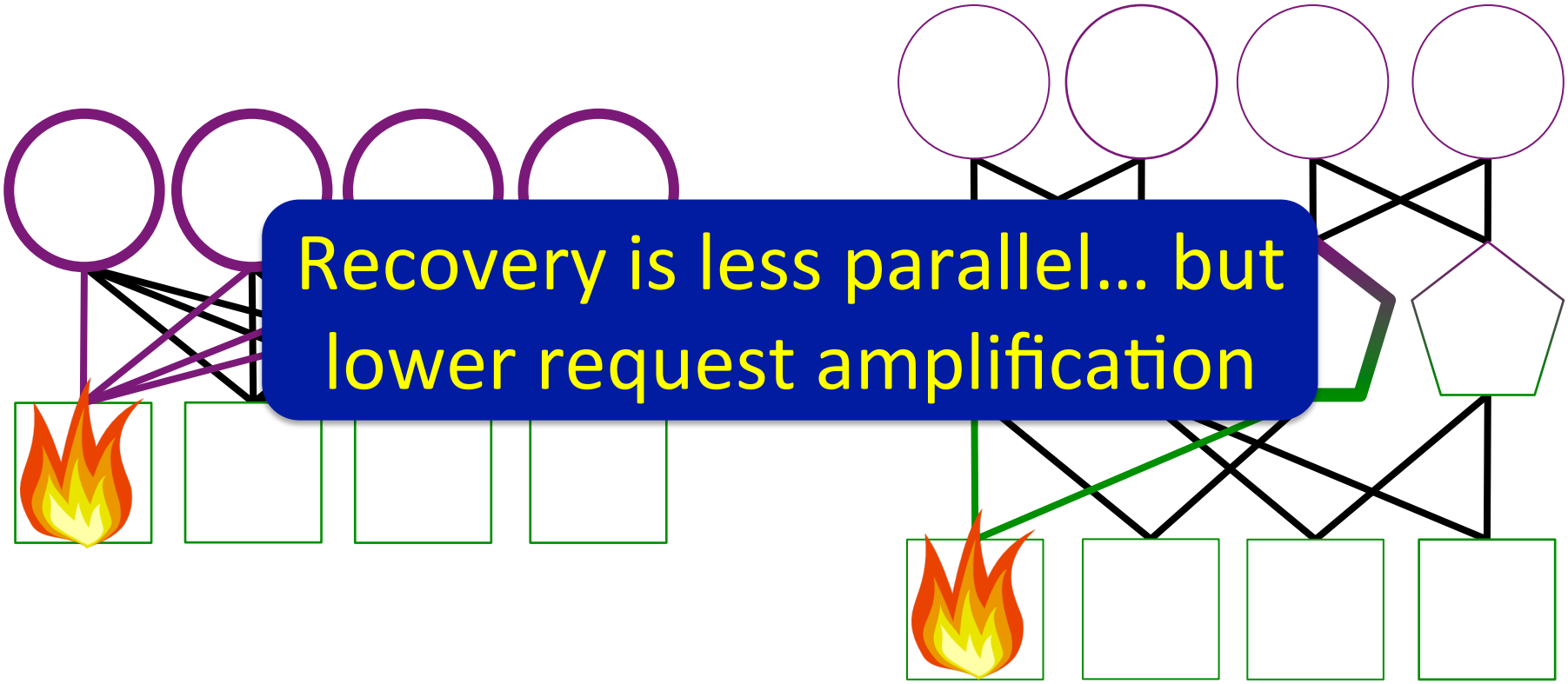


Hybrid Replex



Hybrid replexes constrain potential data chains → More targeted recovery

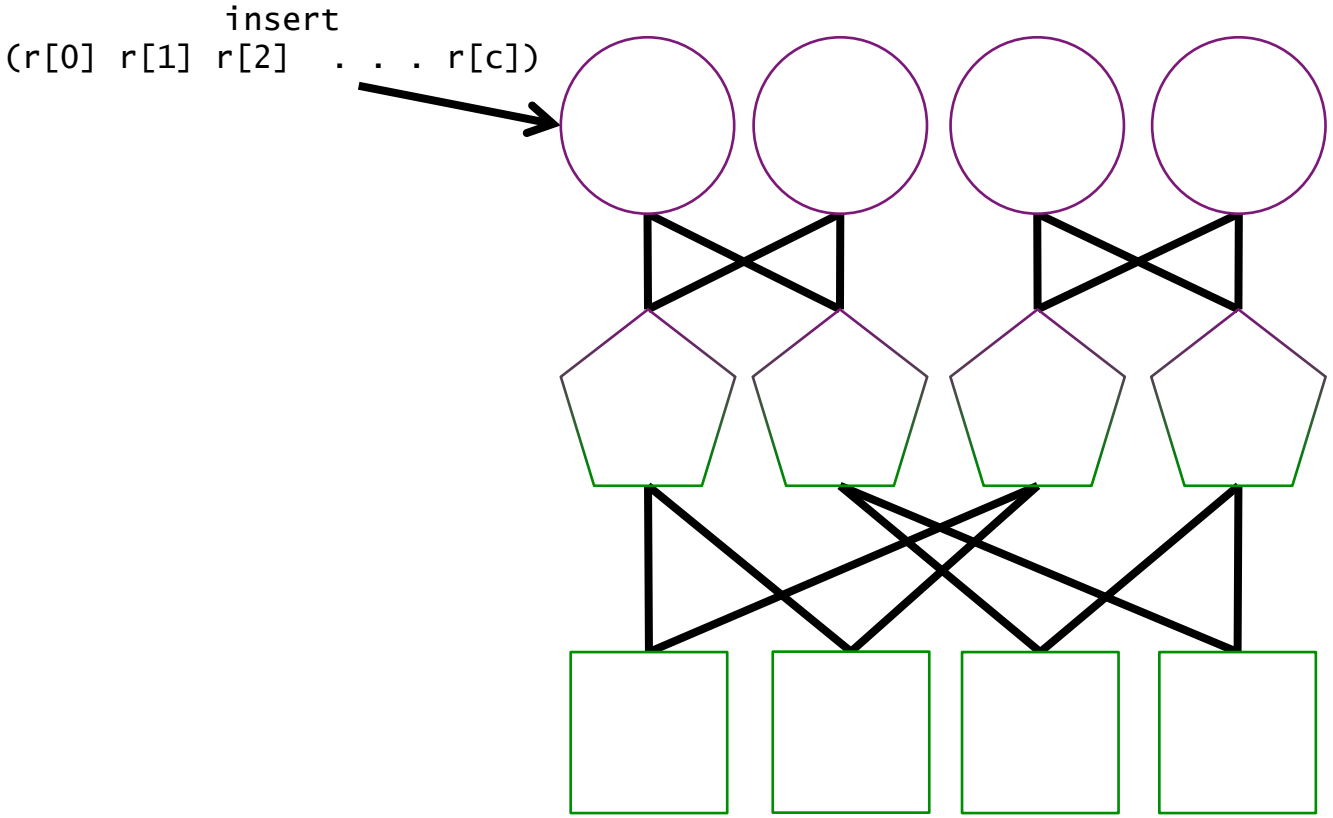
Recovery time vs Request Amplification



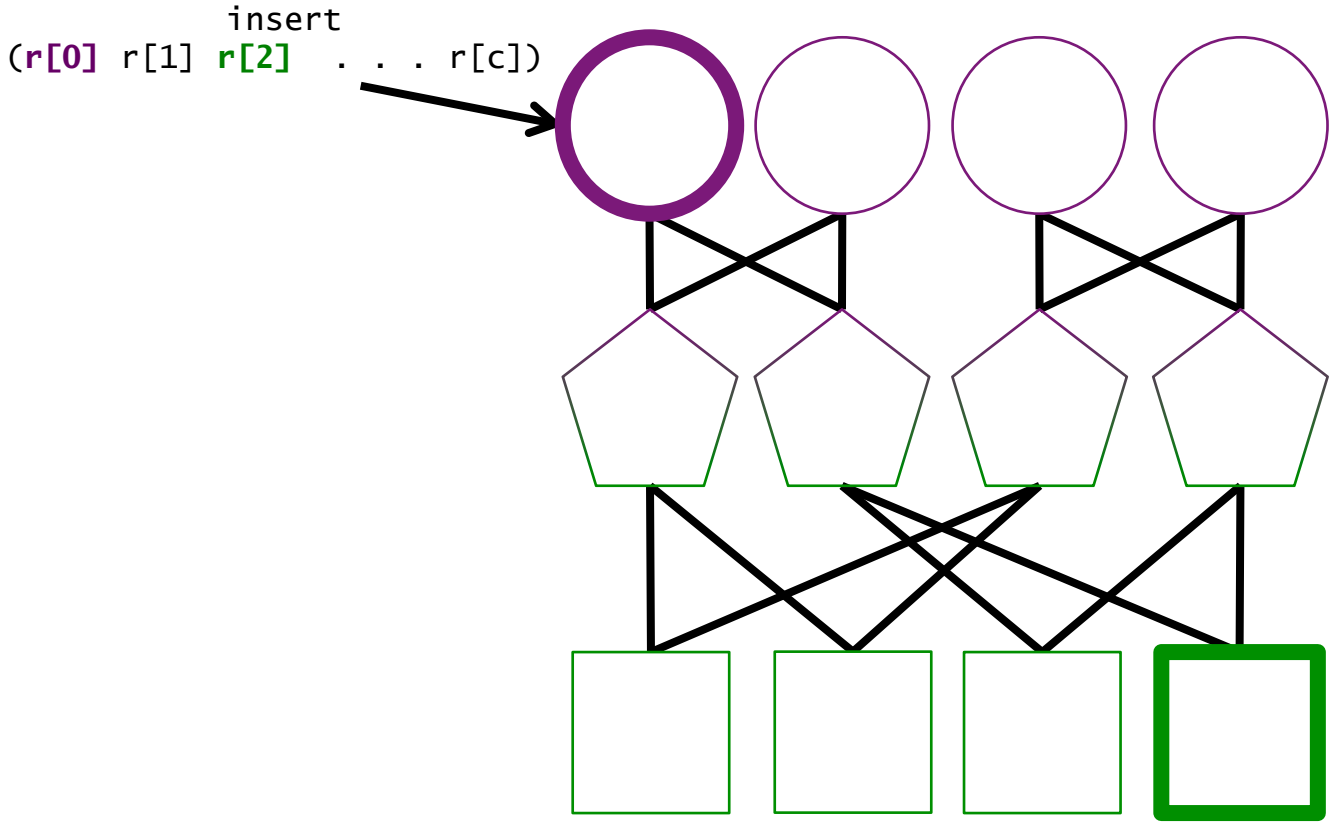
Hybrid Replex: Definition

- Shared across *r* replexes
- Not associated with an index
- Partitioning function dependent on these *r* replexes

Replication Chains with Hybrid Replex



Replication Chains with Hybrid Replex



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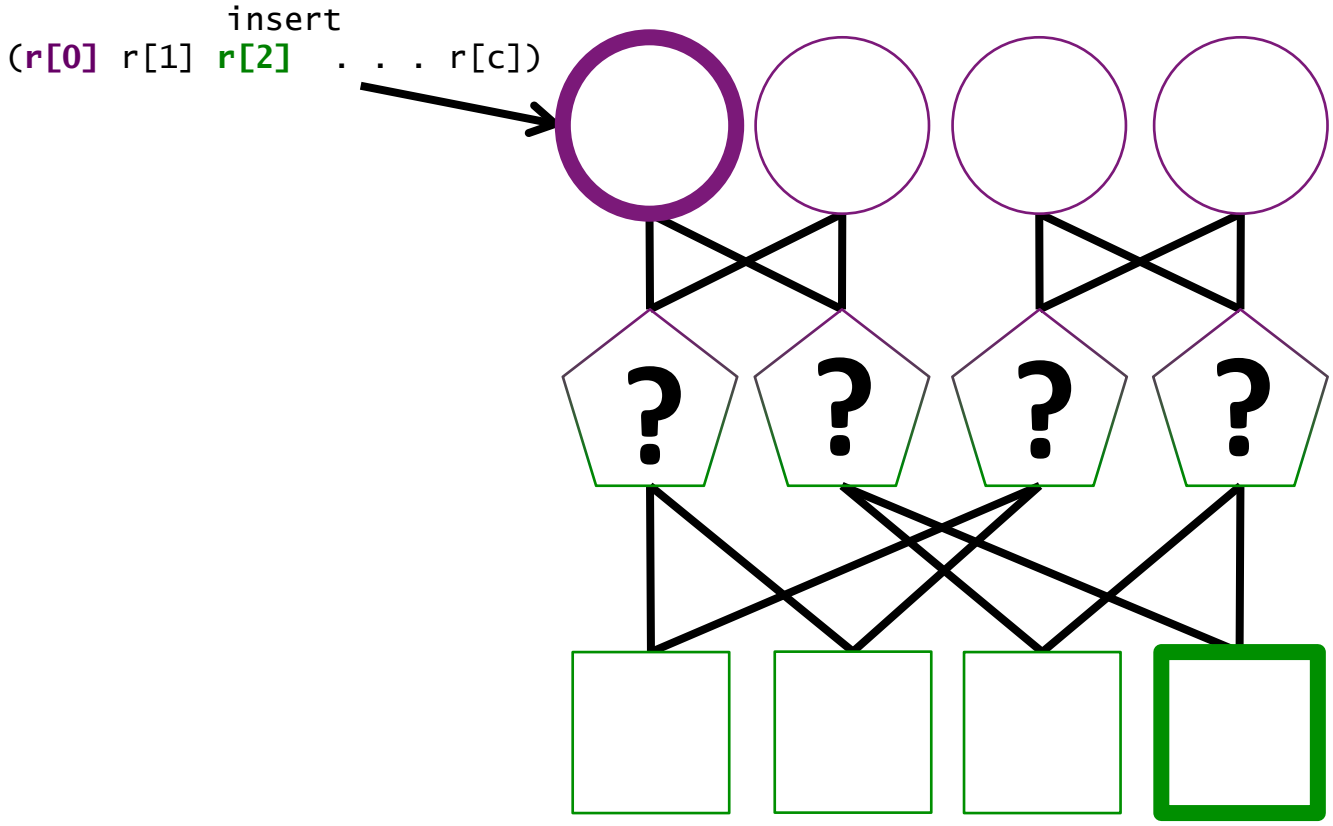
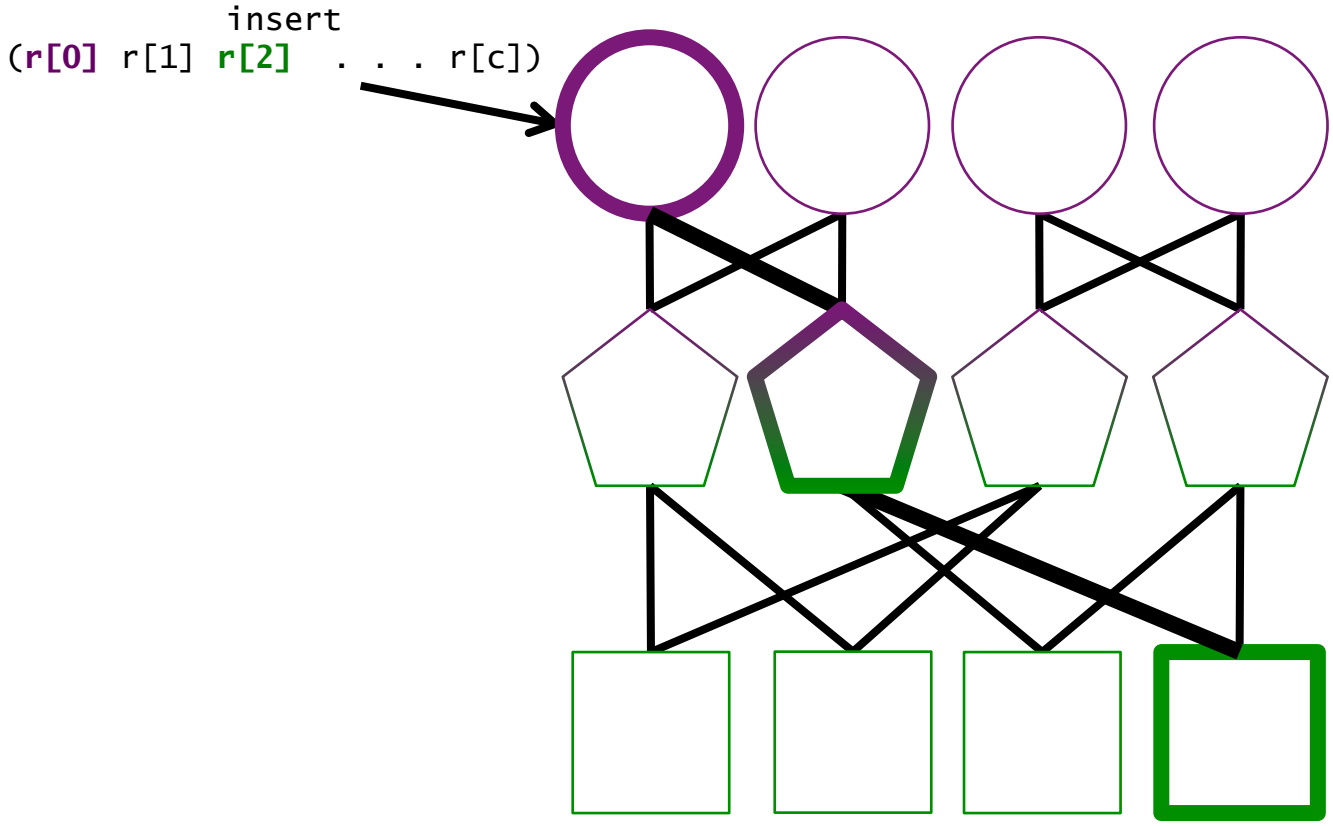


Replication Chains with Hybrid Replex



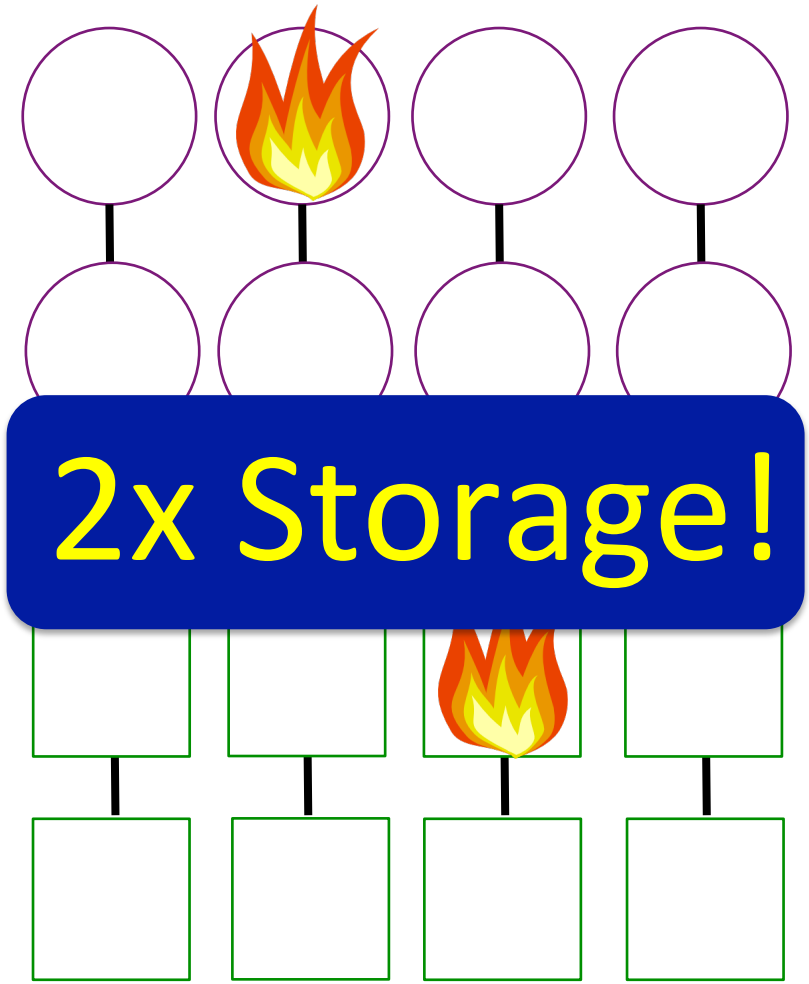
Hybrid Replex: More Properties

1. Recovery time vs request amplification tradeoff
2. Improve failure availability of multiple replexes
3. Storage vs recovery performance tradeoff
4. Graceful failure degradation

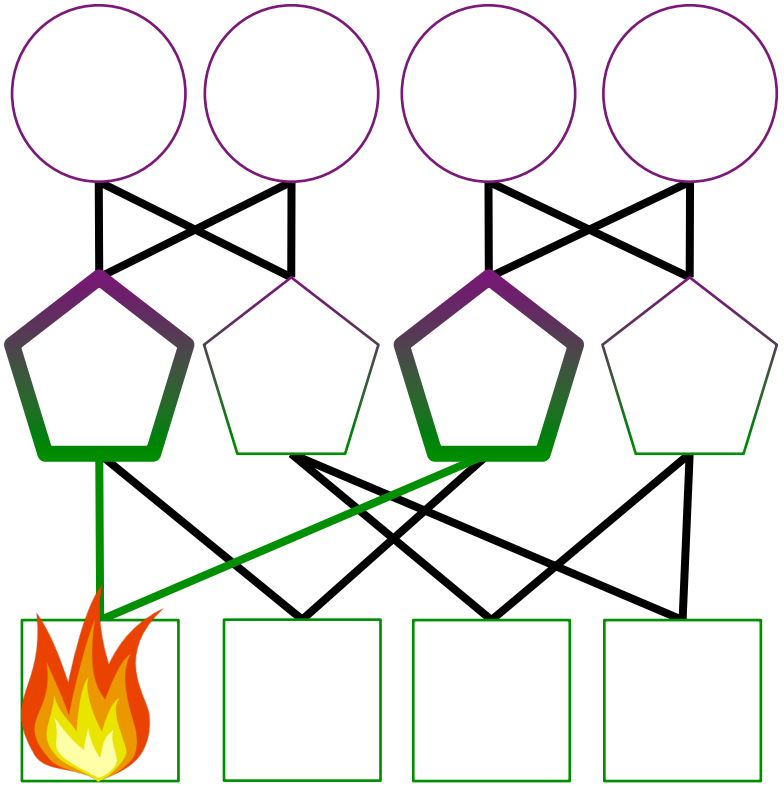
Hybrid Replex: More Properties

1. Recovery time vs request amplification tradeoff
2. **Improve failure availability of multiple replexes**
3. **Storage vs recovery performance tradeoff**
4. Graceful failure degradation

Improving Failure Availability w/o Hybrid Replexes



Improve failure availability of multiple replexes



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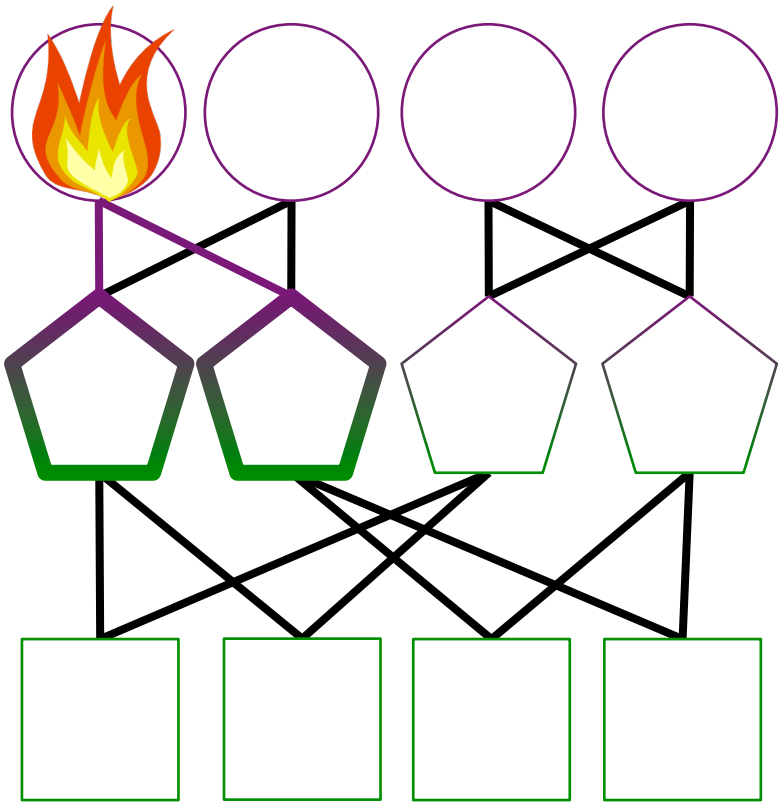


Storage vs. recovery performance

Implementation

- Built on top of HyperDex, ~700 LOC
- Implemented partition recovery and request re-routing on failure
- Implemented variety of hybrid replex configurations

Evaluation

1. What is impact of replexes on steady-state performance?

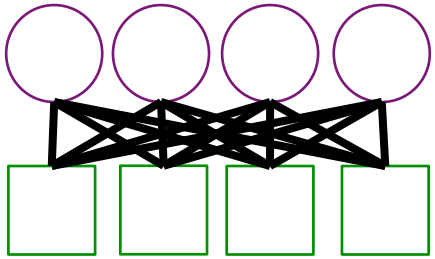
2. How do hybrid replexes affect failure performance?

Evaluation Setup

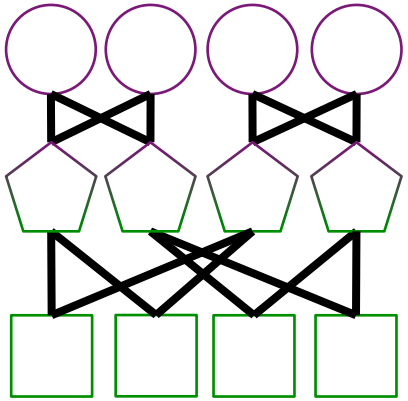
- Table with two indexes
- 12 server machines, 4 client machines
- All machines colocated in the same rack, connected via 1GB top-of-rack switch
- 8 CPU, 16GB memory per machine

Systems Under Evaluation

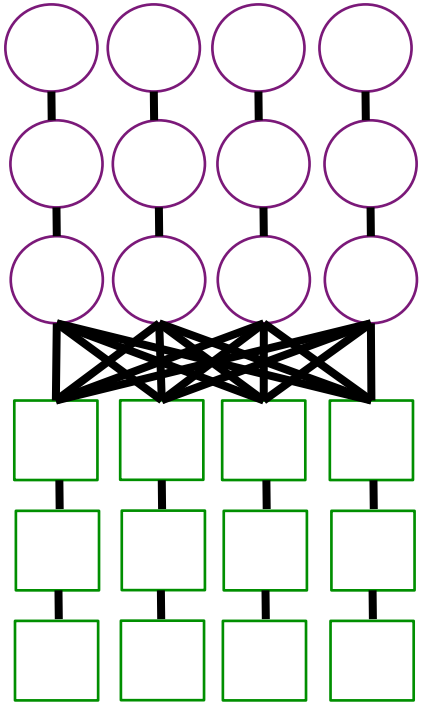
Replex-2



Replex-3

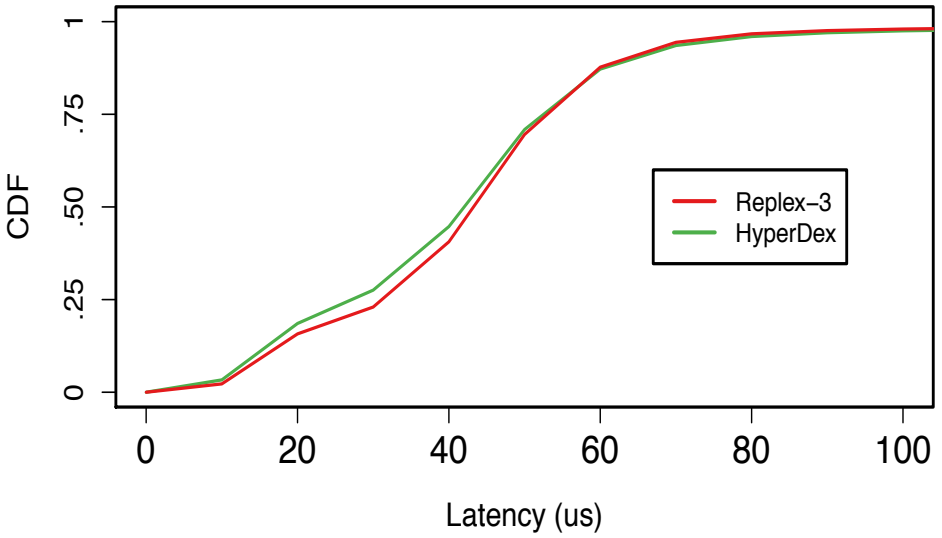


HyperDex



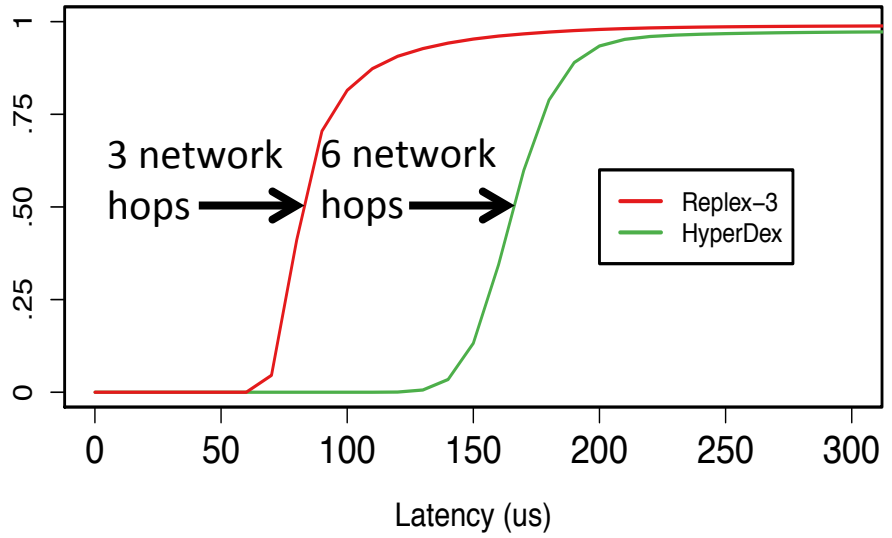
Steady State Latency

Reads



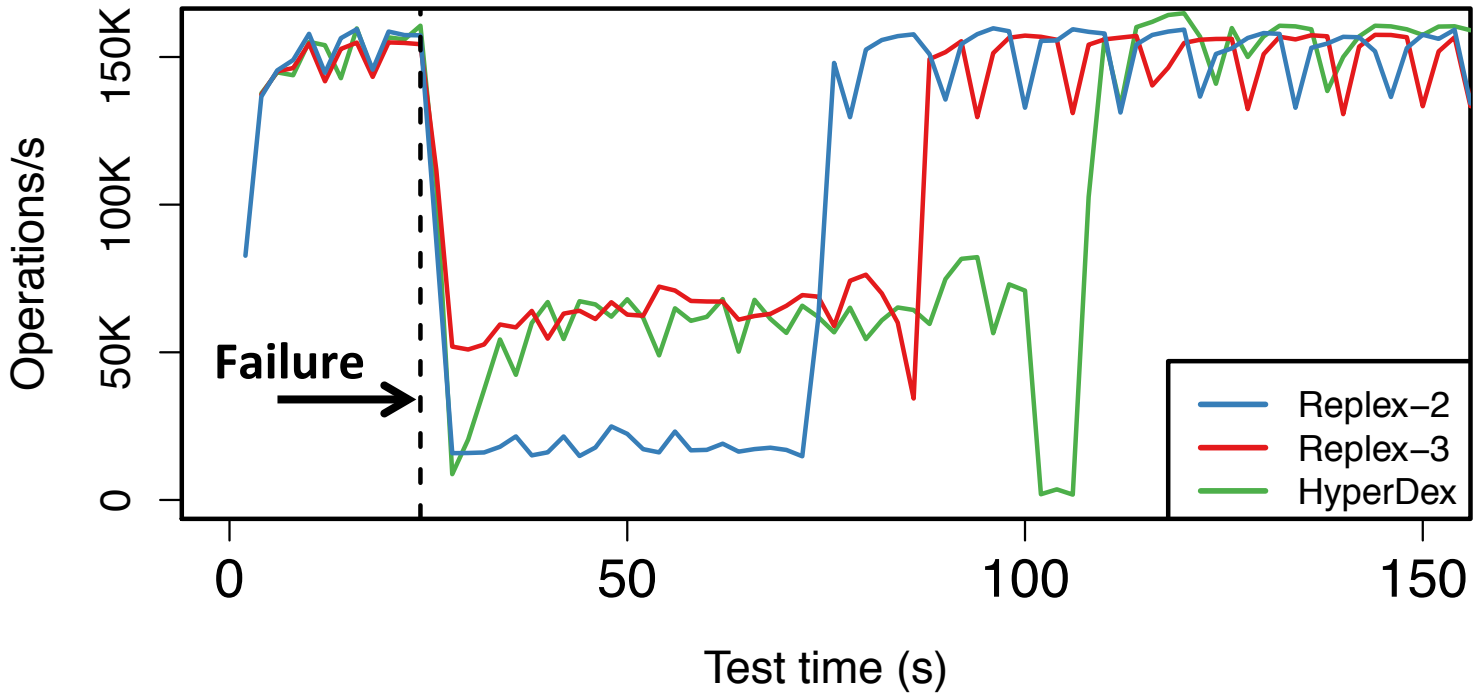
Reads against either index have similar latency, but we report reads against primary index

Inserts



Replex-2 not included because it has a lower fault tolerance threshold

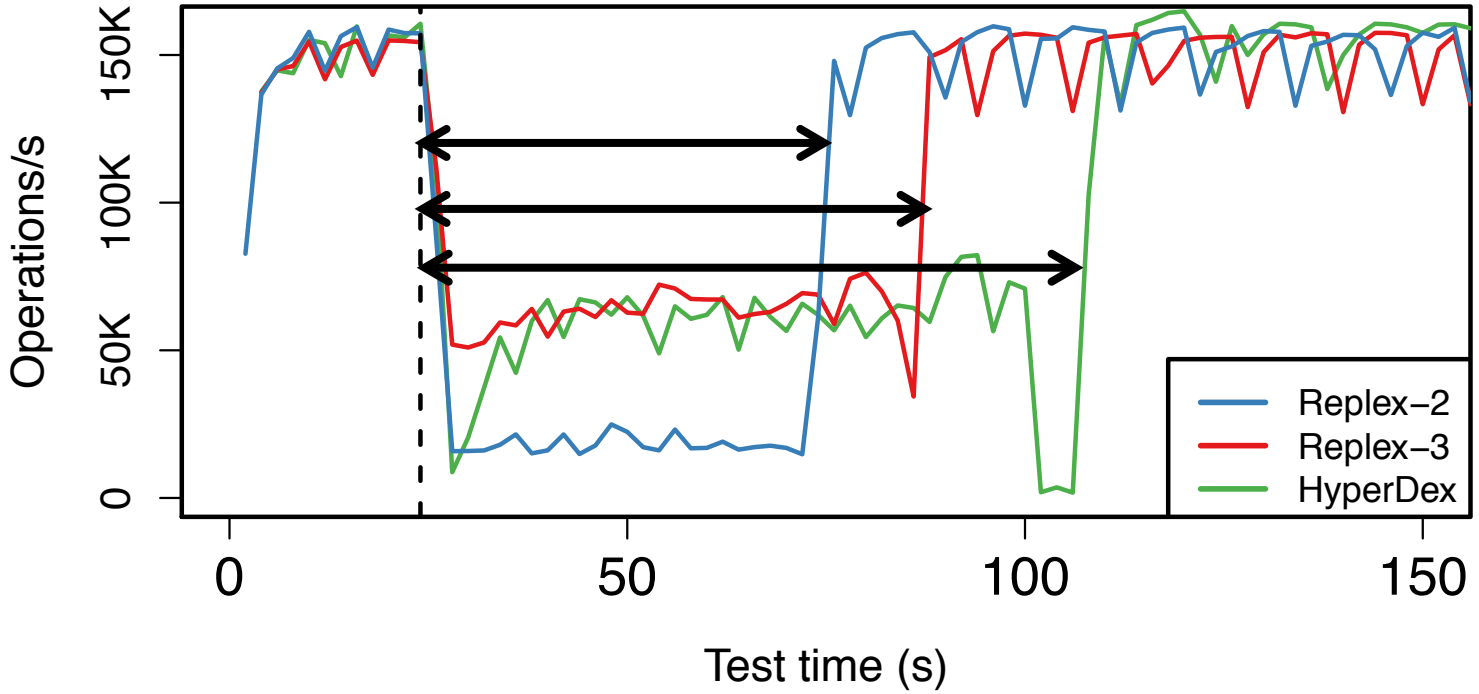
Single Failure Performance



Experiment

- Load with 10M, 100 byte rows
- Split reads 50:50 between each index

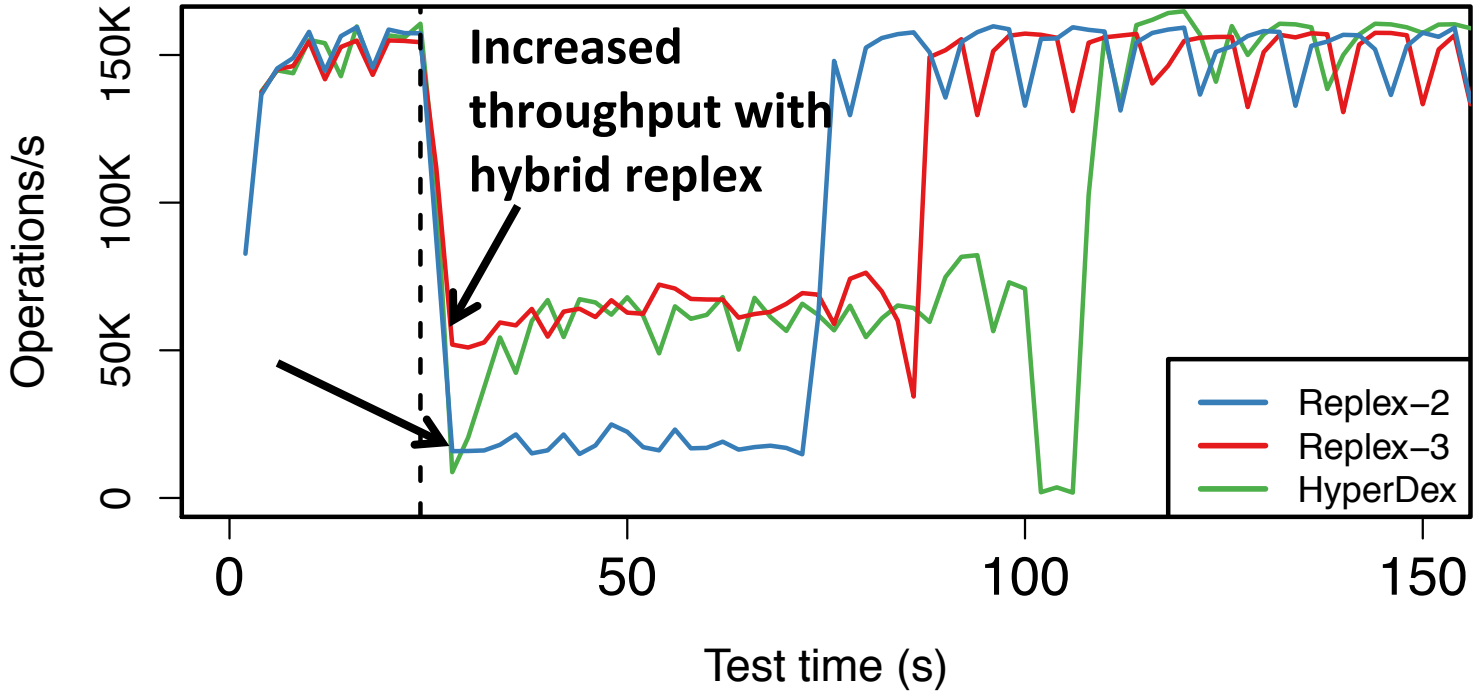
Single Failure: Recovery Time



Recovery Time

1. HyperDex recovers slowest because 2-3x more data
2. Replex-2 recovers fastest because least data, parallel recovery

Single Failure: Failure Throughput



Failure Throughput

1. Replex-2 low throughput because of high request amplification
2. Replex-3 has throughput comparable to HyperDex

Summary

1. **Rethink the replication paradigm**

2. Replacing replicas with replexes decreases index storage AND maintenance overheads

3. Hybrid replexes introduce rich tradeoff space for failure SLAs

Questions?