Couchbase

Architecture and Administration Basics

Architecture

1 | Buckets and Documents

What is Couchbase Server?

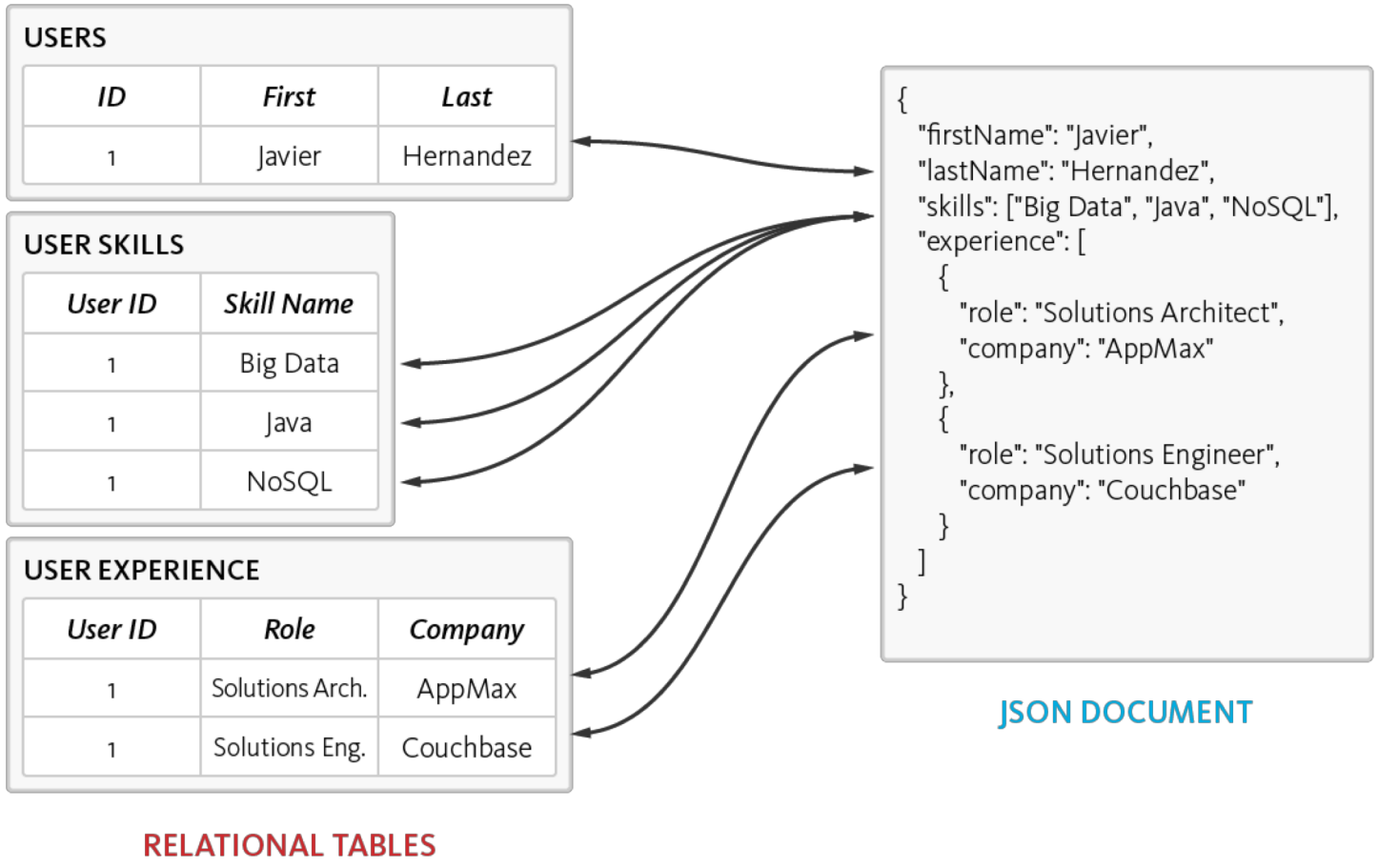
- Couchbase Server
  - Core database has key/value based orientation
  - Has various indexing and querying capabalities
  - Is geared for JSON
  - Runs on a networked cluster of nodes
  - Has caching and persistence layers
- Couchbase Server is best suited for fast-changing data items of relatively small size

Couchbase as Key-Value Store vs. Document Store

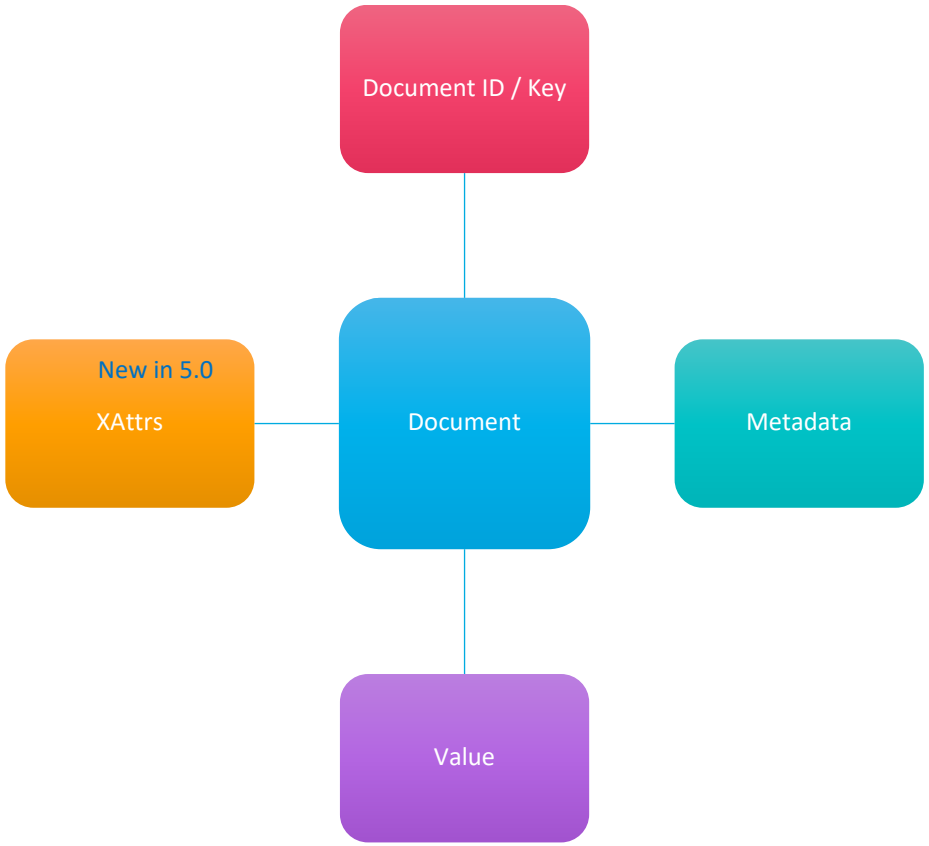
- Couchbase is capable of storing multiple data types.
  - Simple data types such as string, number, datetime, and boolean
  - Arbitrary binary data
  - For most of the simple data types, Couchbase offers a scalable, distributed data store that provides both key-based access as well as minimal operations on the values
- Document databases encapsulate stored data into “documents” that they can operate on
  - A document is simply an object that contains data in some specific format.
  - For example, a JSON document holds data encoded in the JSON format

The Power of JSON

- A lightweight format to store structured data
- Both human readable and easy to process
- Denormalized single document, as opposed to normalizing data across multiple tables
- Dynamic schema makes it easy to add new values when needed



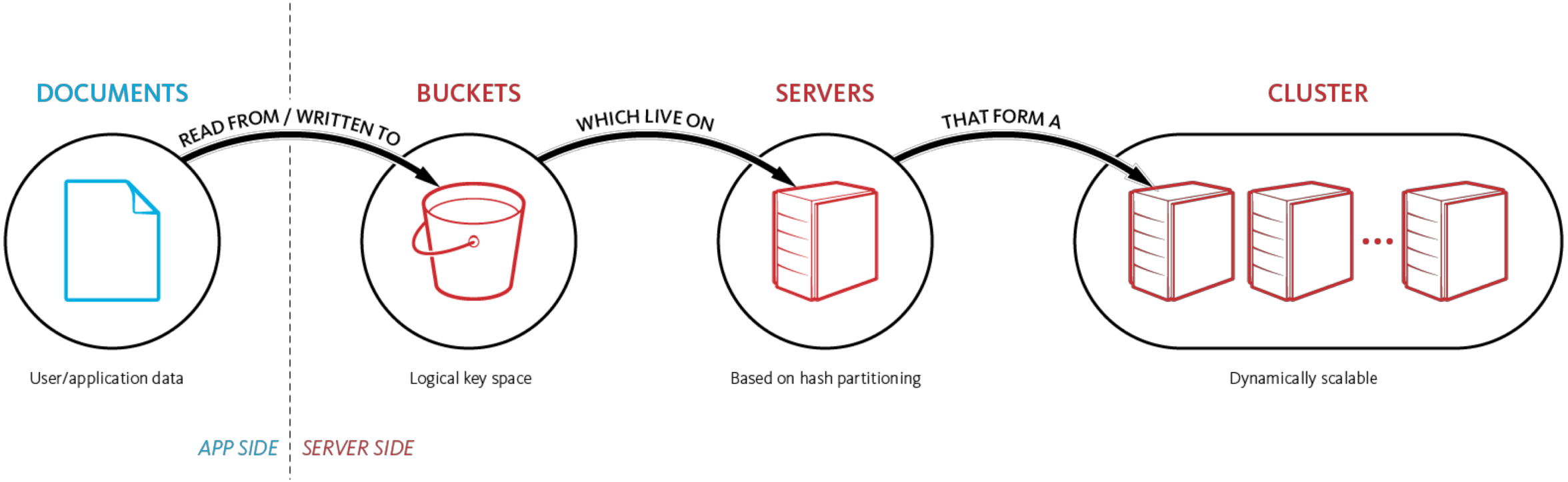
Document Structure



- **Document ID / Key (Max 250 bytes):**
  - Must be unique / Lookup is extremely fast
  - Similar to primary keys in relational databases
  - Documents are partitioned based on the document ID
- **Value (Max 20 MB)**
  - JSON
  - Binary - integers, strings, booleans
  - Common binary values include serialized objects, compressed XML, compressed text, encrypted values
- **Metadata (Fixed 56 bytes)**
  - CAS Value (unique identifier for concurrency)
  - TTL
  - Flags (optional client library metadata)
  - Revision ID # New in 5.0
- **XAttr (Max 20 MB)**
  - Non-enumerable e**X**tended **Attr**ibutes

Buckets

- The Couchbase server stores the data as key value pairs – Data lives in a “Bucket” as key/value pairs.
  - Create a named bucket on the cluster (logical structure)
  - Data managed for you as vBuckets
  - Data is spread around the cluster automatically

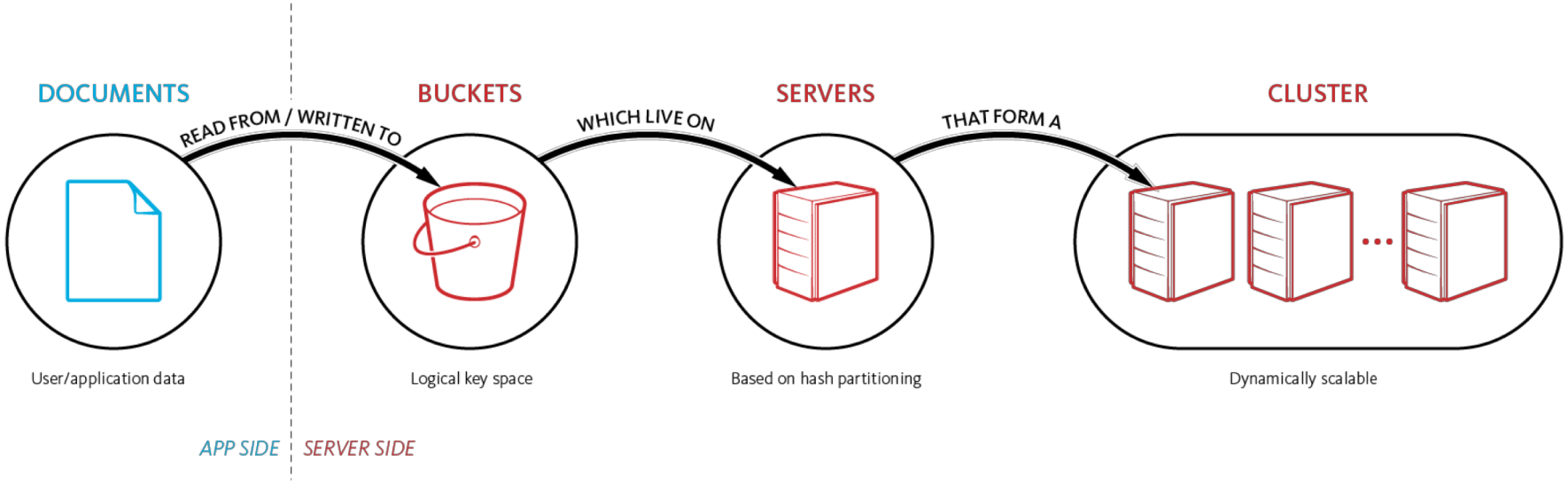


Map RDBMS to Couchbase

RDBMS	Couchbase
Database	Bucket
Table	Documents with common shapes
Row	JSON document
Fixed Schema	Flexible Schema

Buckets - When to use more than one ?

- When you need to treat or access the data differently
  - Different High Availability requirements (1,2 or 3 replicas)
  - Different performance / residency needs (how much data to cache)
  - Security / Multi-tenancy
  - Segregating Binary and JSON data – especially with view usage



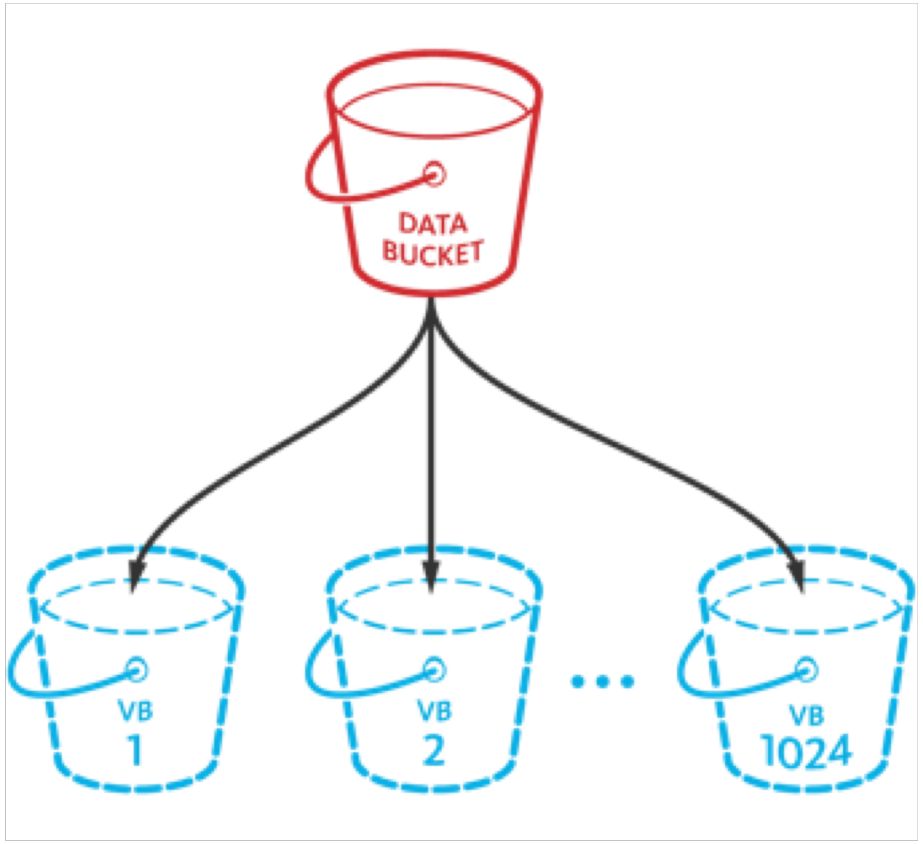
Bucket Types

	Memcached	Couchbase	Ephemeral New in 5.0
Persistence	X		X
Replication	X		
Rebalance	X		
XDCR	X		
N1QL	X		
Indexing	X		*
Max Object Size	1MB	20MB	20MB

* MOI, FTS only

2 | Data Sharding

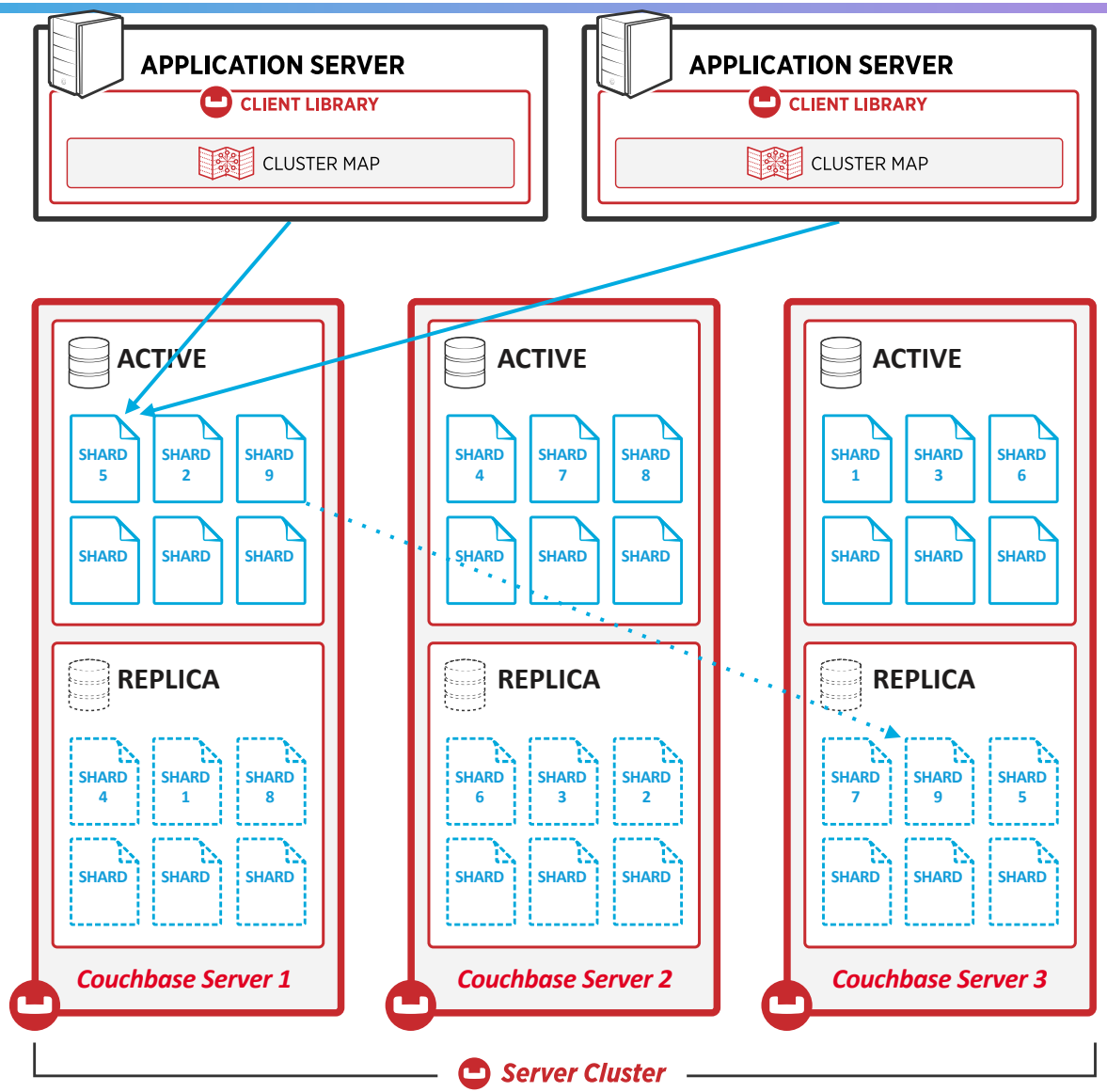
Auto sharding – Bucket and vBuckets



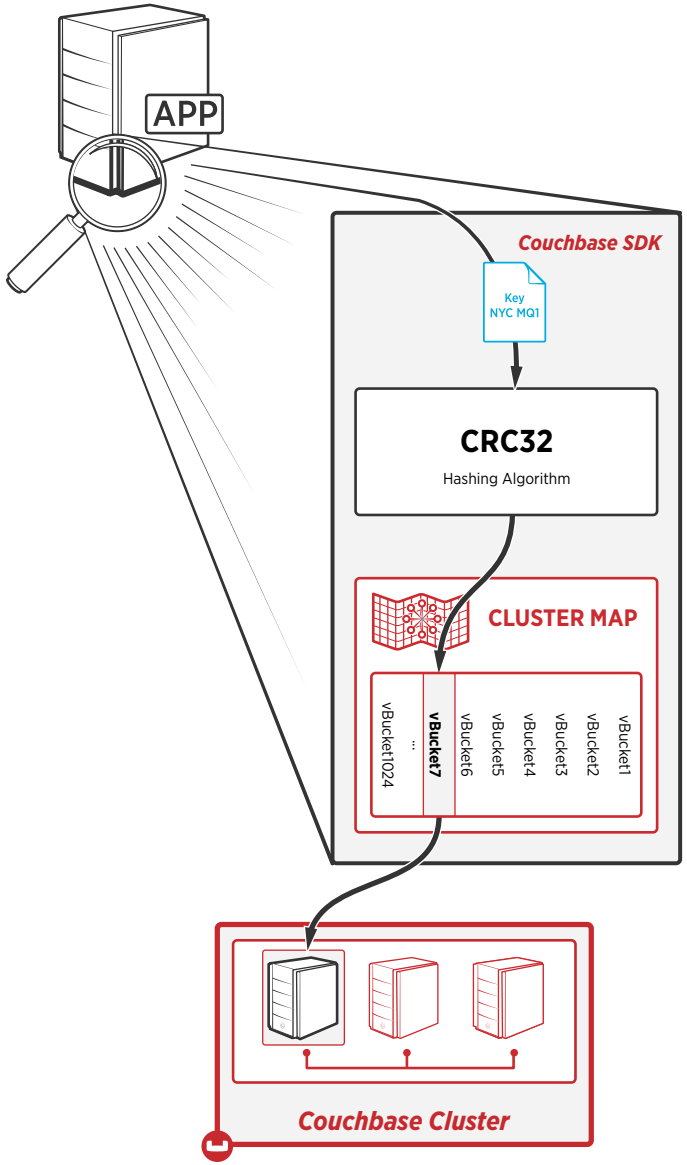
Virtual buckets

- Bucket
  - A bucket is a logical, unique key space
  - Multiple buckets can exist within a single cluster of nodes
- vBuckets
  - Each bucket has active and replica data sets (1, 2 or 3 **extra** copies)
  - Each data set has 1024 Virtual Buckets (vBuckets)
  - Each vBucket contains 1/1024th portion of the data set
  - vBuckets do not have a fixed physical server location
  - Mapping between the vBuckets and physical servers is called the cluster map
  - Document IDs (keys) always get hashed to the same vBucket (consistent hashing)
  - Couchbase SDK's lookup the vBucket -> server mapping

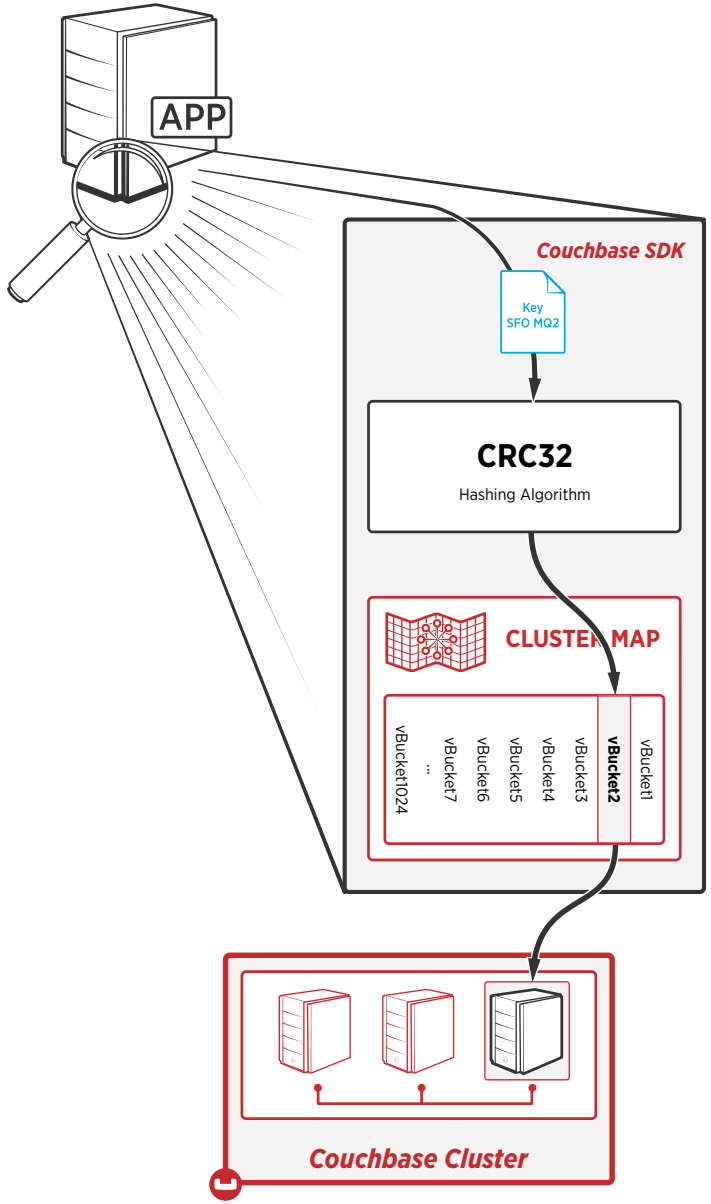
Sharding Architecture



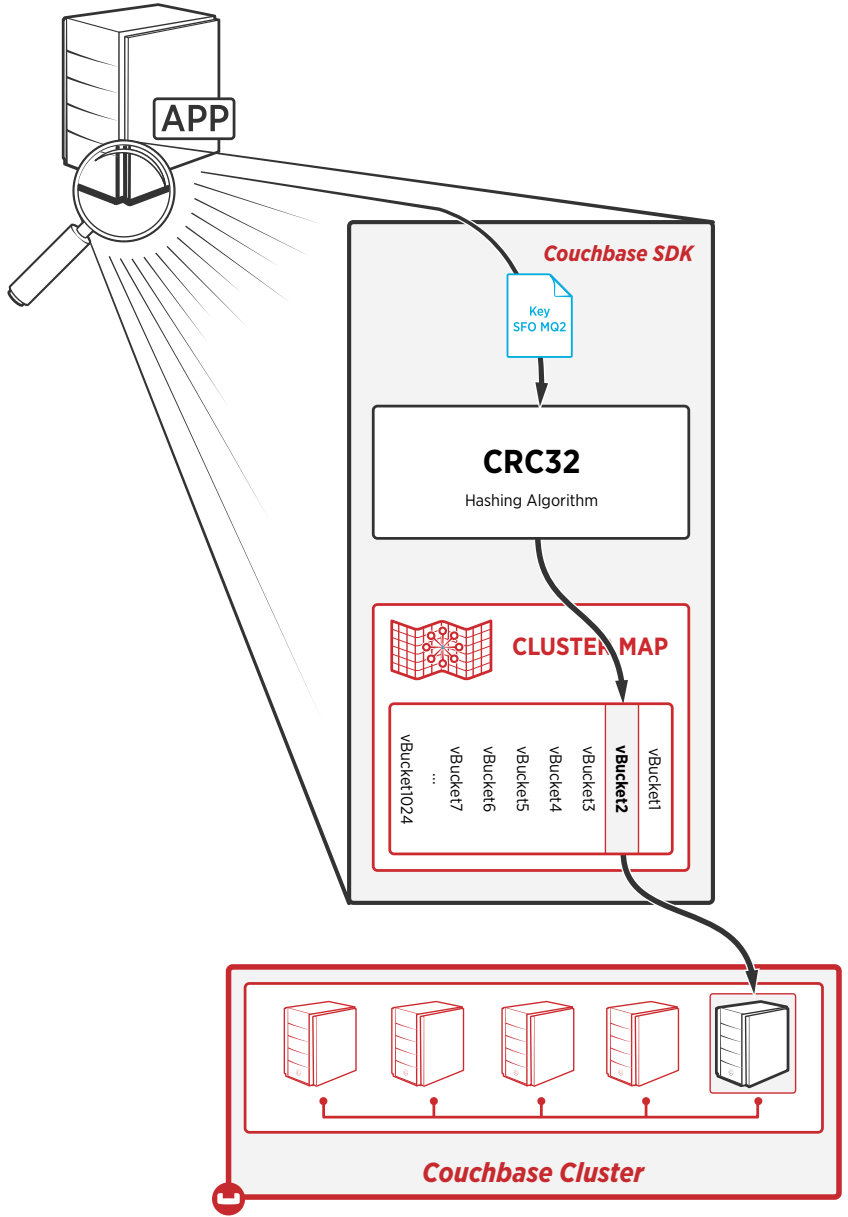
Cluster Map


APP
Couchbase SDK
Key
NYC MQ1
CRC32
Hashing Algorithm
CLUSTER MAP
vBucket1
vBucket2
vBucket3
vBucket4
vBucket5
vBucket6
vBucket7
...
vBucket1024
Couchbase Cluster

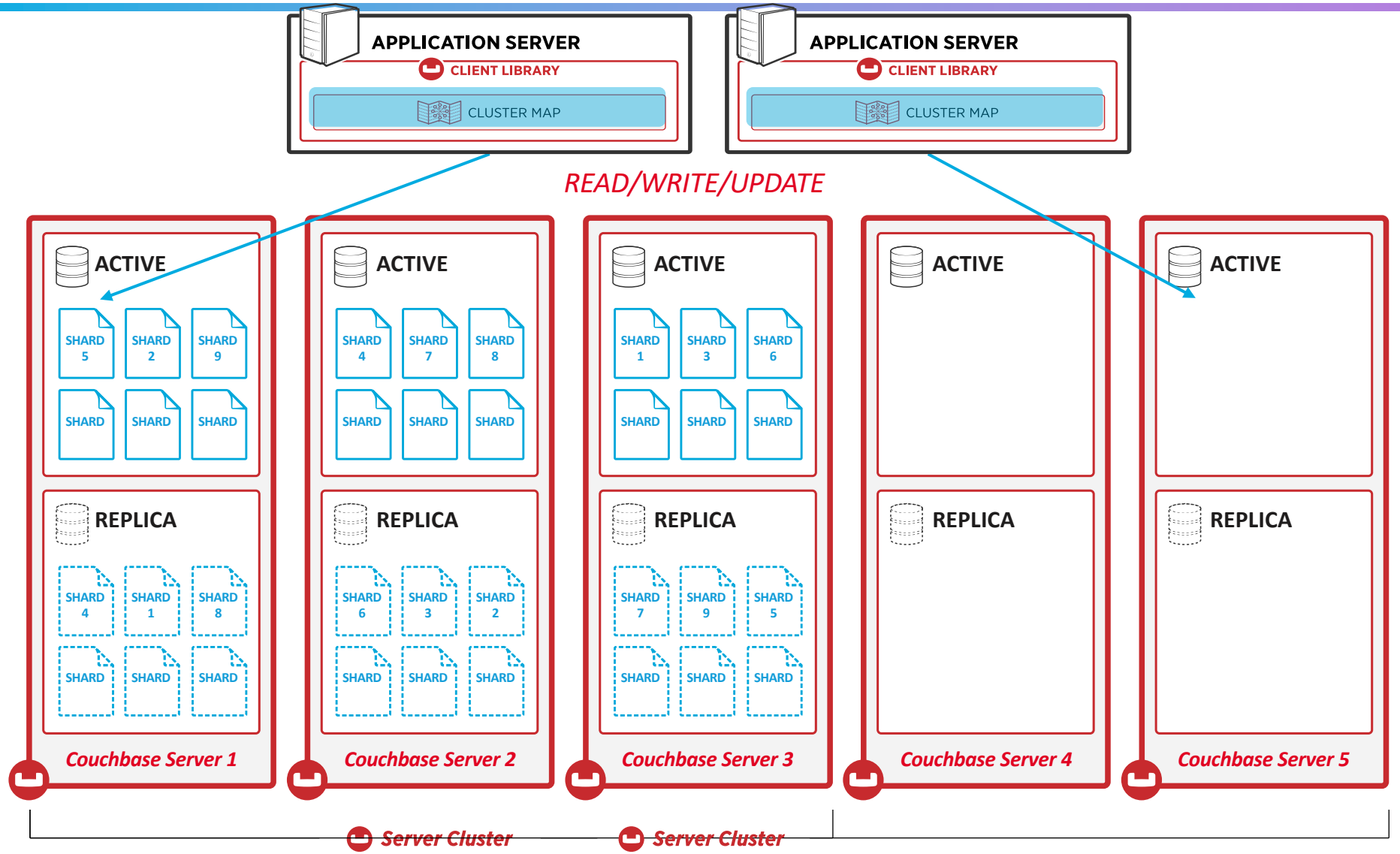
Cluster Map


APP
Couchbase SDK
Key
SFO MQ2
CRC32
Hashing Algorithm
CLUSTER MAP
vBucket1
vBucket2
vBucket3
vBucket4
vBucket5
vBucket6
vBucket7
...
vBucket1024
Couchbase Cluster

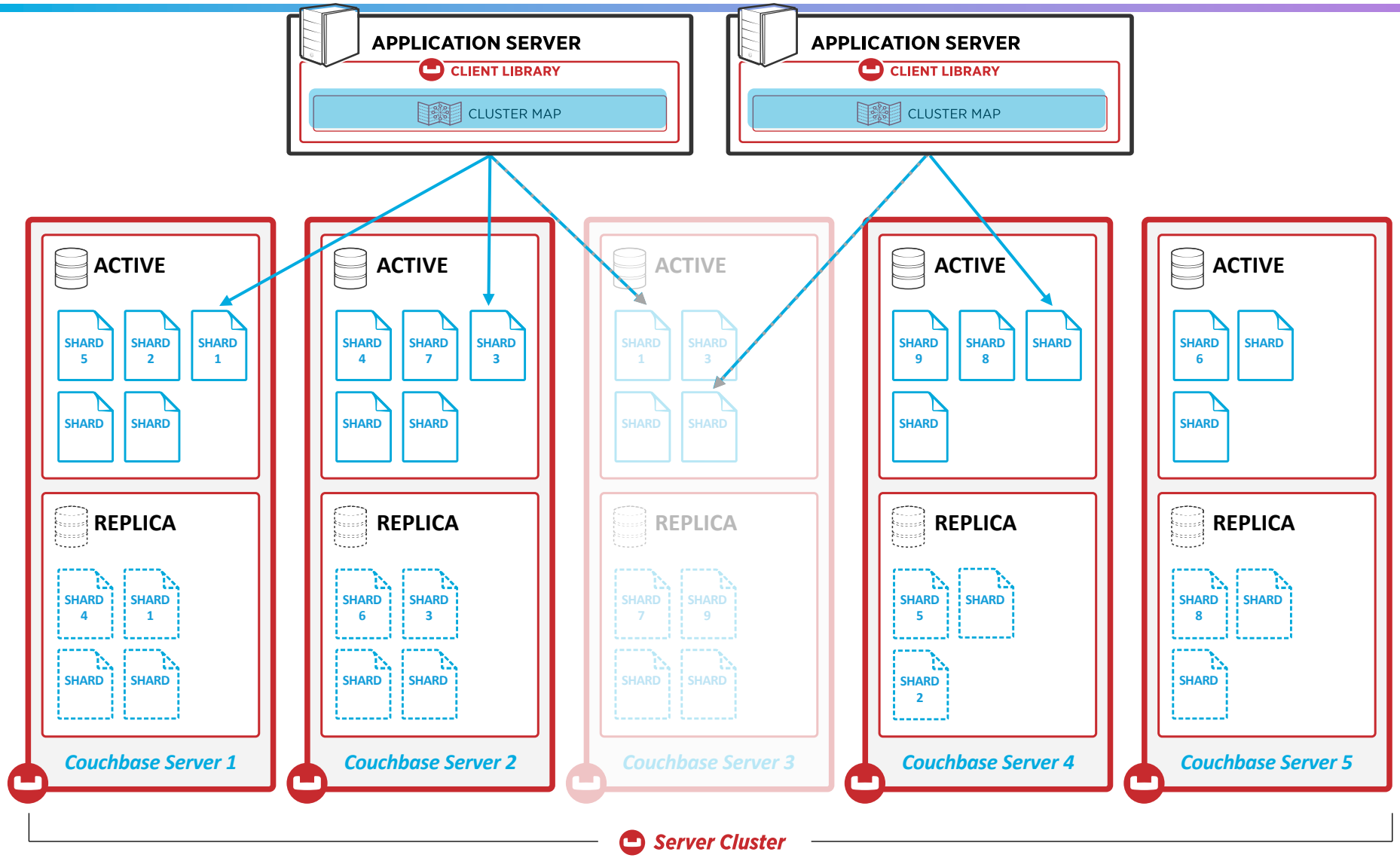
Cluster Map – Addition of 2 Nodes



Adding Nodes to Cluster

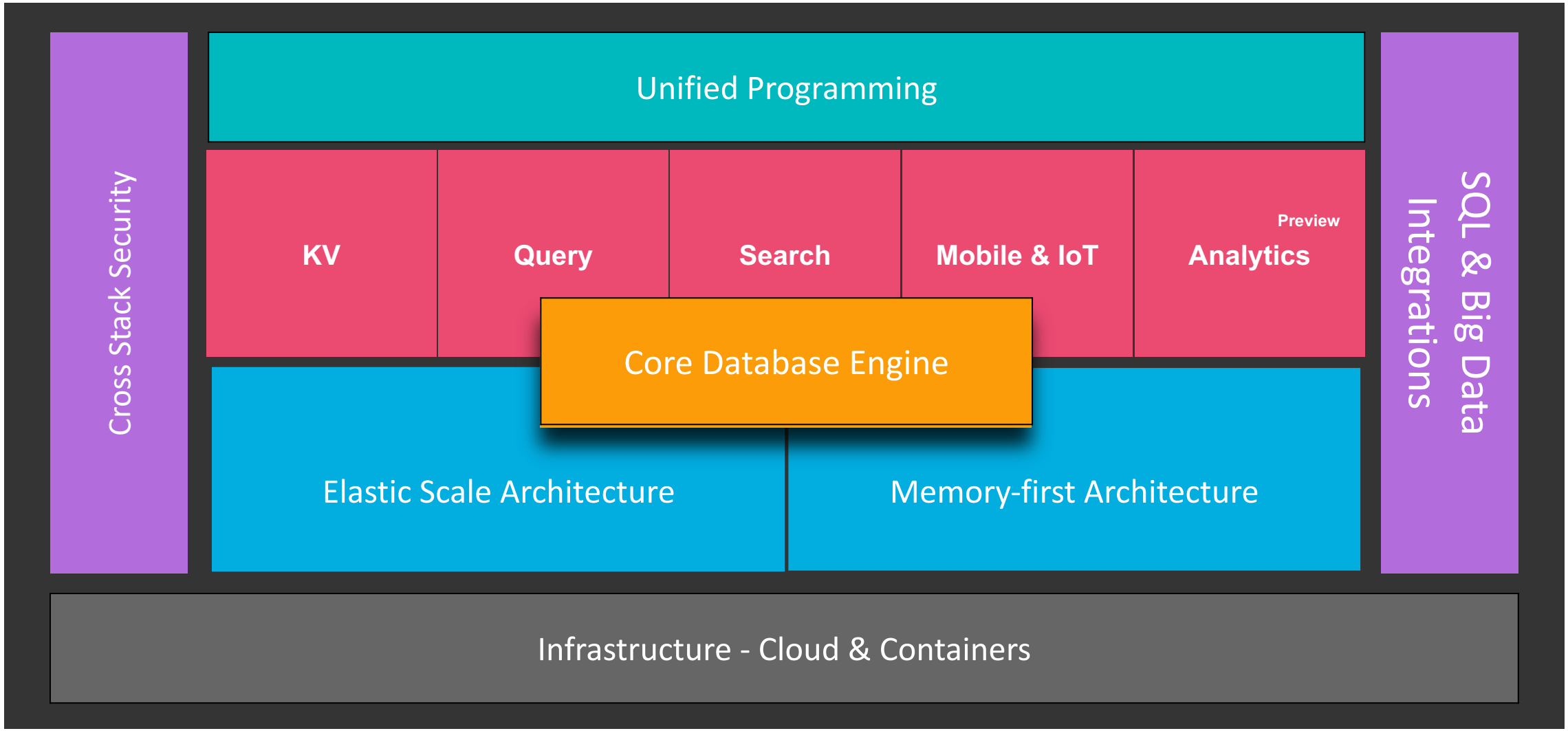


Node Failover



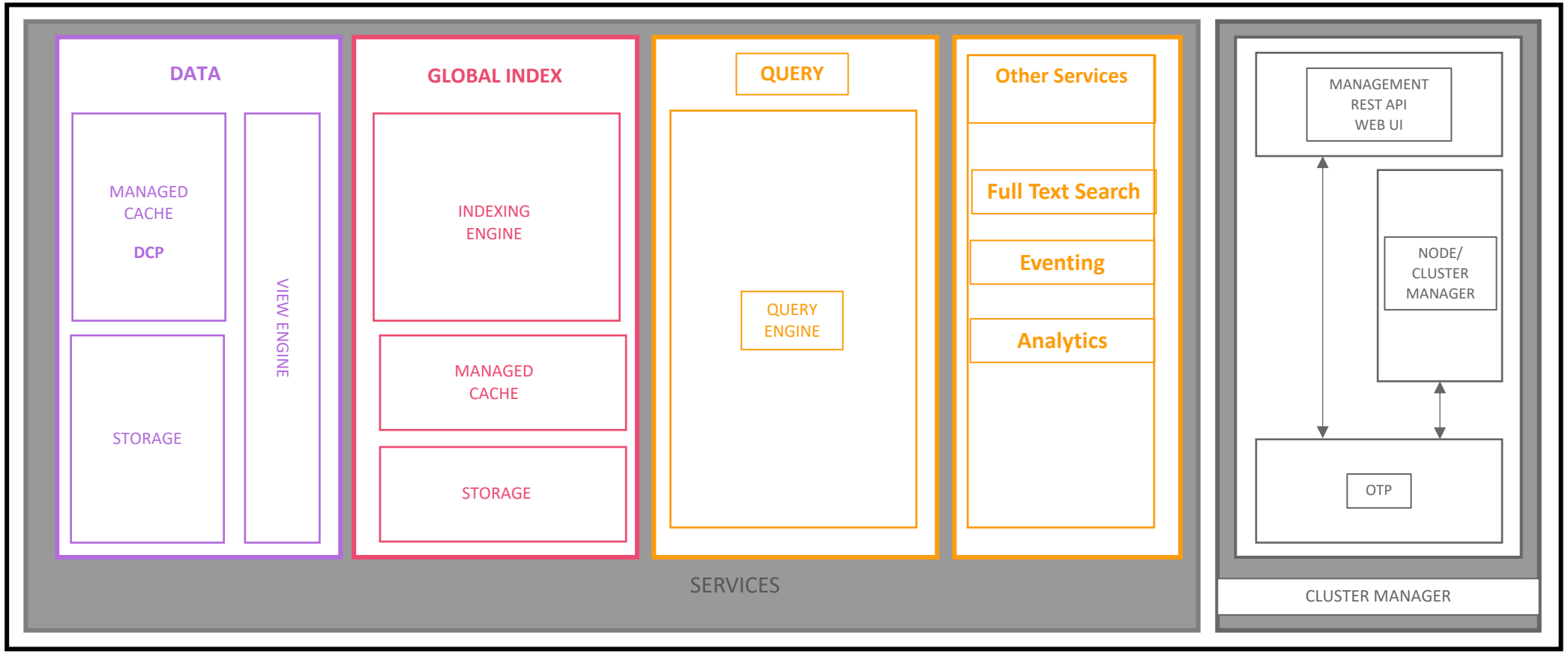
2 | Services

Couchbase Data Platform



Couchbase Node Architecture, Services

- Every Couchbase node can be configured to provide an arbitrary set of services
- Every node provides REST API, Web UI, participates in cluster management

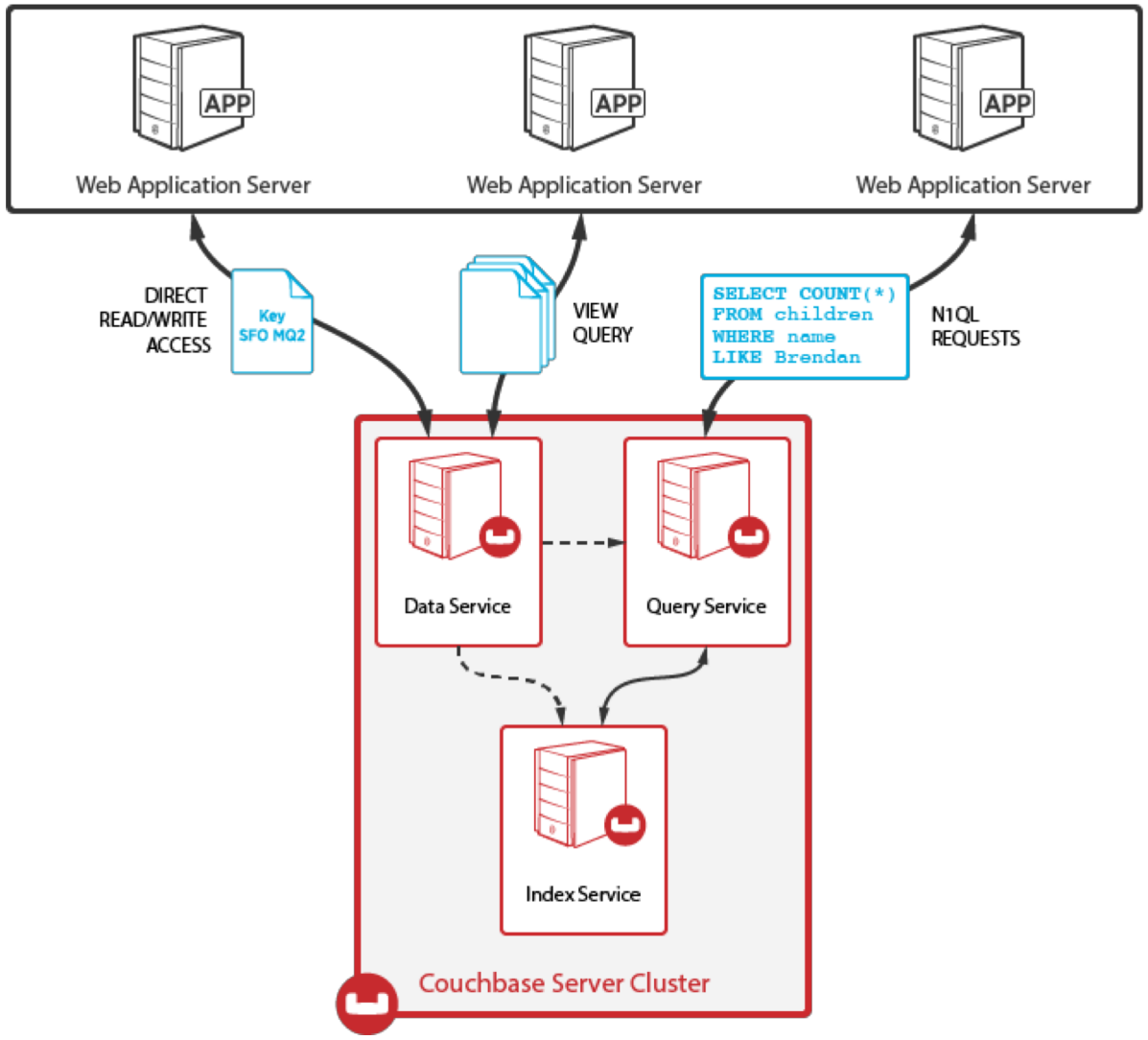


COUCHBASE SERVER NODE

Couchbase Services

- Data Service:
  - Stores the data and provides key-value access to it
  - Supplies data to all other services
  - Takes care of persistence and replication
  - Indexing by map-reduce views (becoming obsolete)
- Services, providing different data access methods:
  - **Query Service:** Access data over N1QL queries
  - **Index Service:** Index data by various keys, used by query service
  - **FTS Service:** Enable searching documents by keywords
  - **Analytics Service:** Run analytics queries
  - **Eventing Service:** Trigger actions on changes to data
- Cluster Manager, Web UI, REST API

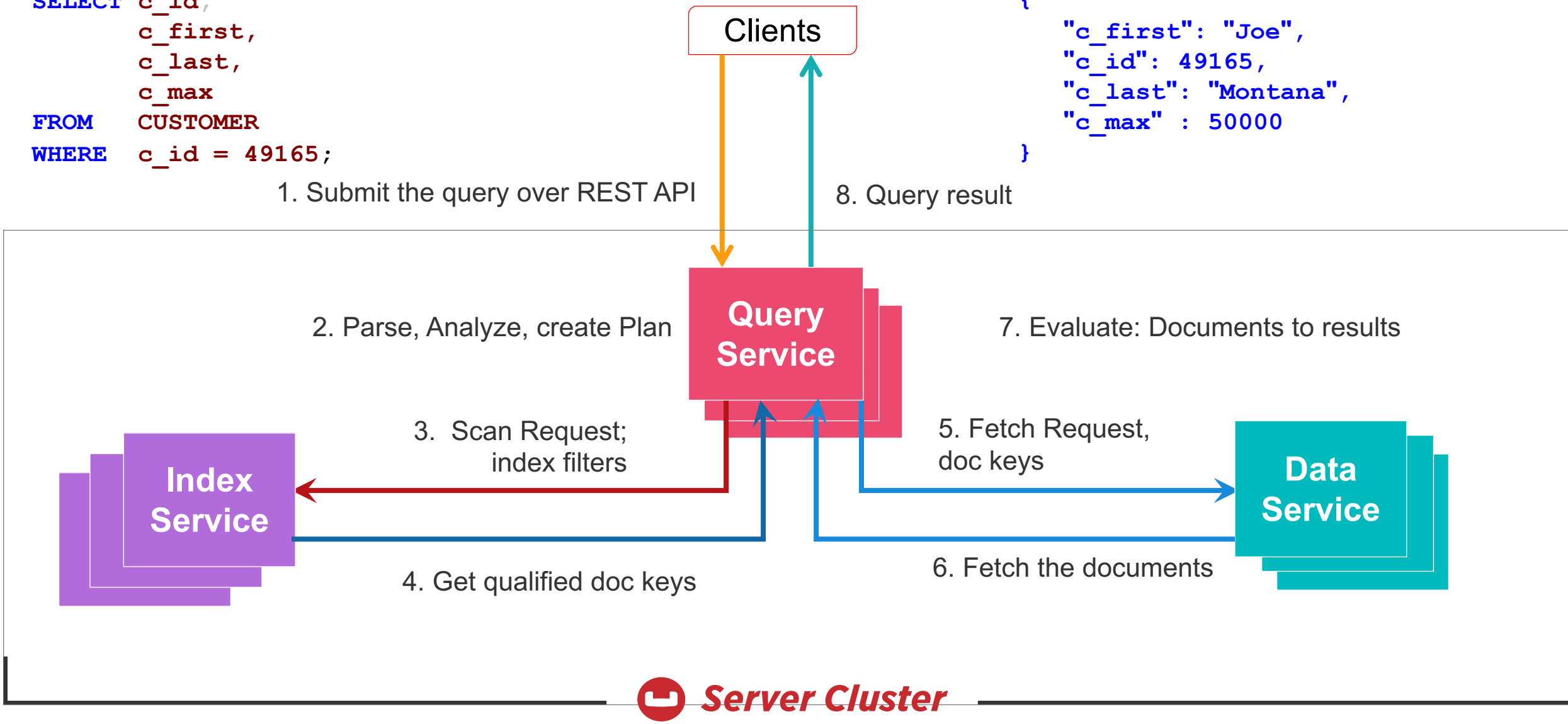
Application to Database Interaction



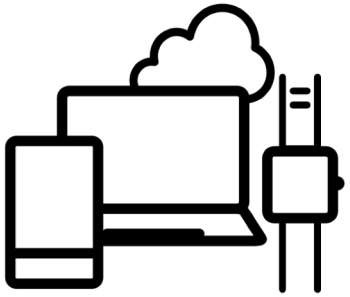
Example: Interaction of Services for Execution of N1QL Queries

```
SELECT c_id,
       c_first,
       c_last,
       c_max
FROM   CUSTOMER
WHERE  c_id = 49165;
```

```
{
   "c_first": "Joe",
   "c_id": 49165,
   "c_last": "Montana",
   "c_max" : 50000
}
```

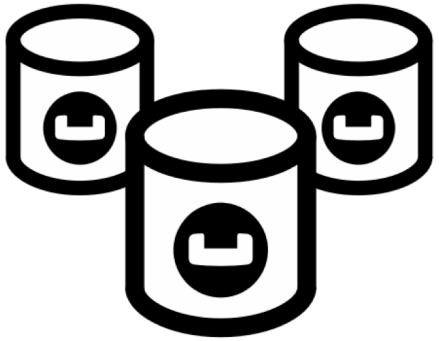


Database Change Protocol



Anything
From
Anywhere

Data Service

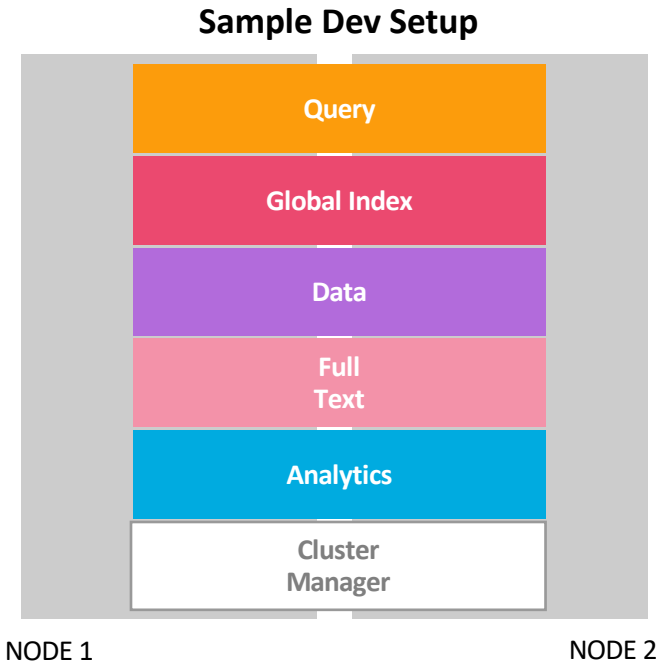


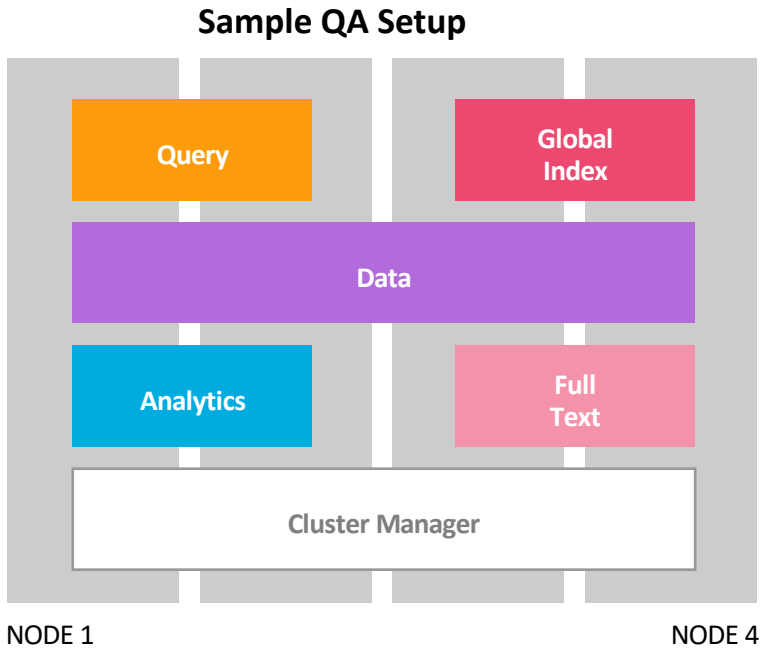
DCP

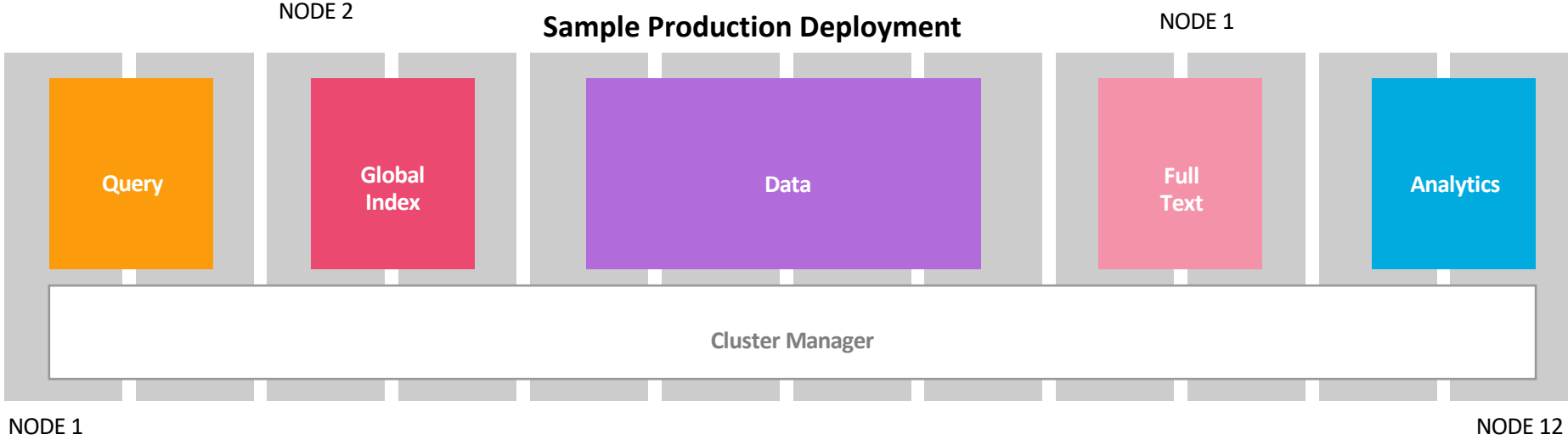
- Data Replicas
- XDCR
- GSI
- Views
- FTS
- Connectors
- Eventing

- High Performance / In-Memory
- De-Duplication
- Ordered, predictable and consistent
- Restartable

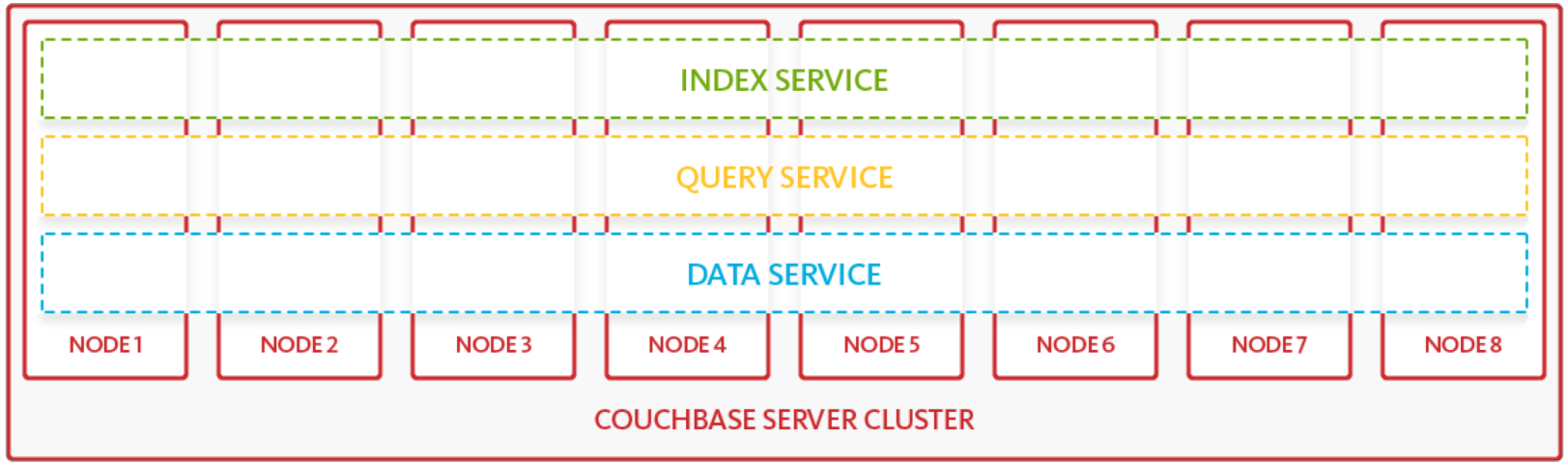
Elastic Scaling Architecture







Homogeneus Scaling



- Components processing core data operations (inserts, updates, deletes), index maintenance or executing queries compete and interfere with each other
- It is impossible to fine-tune each component because each of them has different demands on hardware resources
- While the core data operations can benefit greatly from scale-out with smaller commodity nodes, many low latency queries do not always benefit from wider fan-out

Multi-Dimensional Scaling

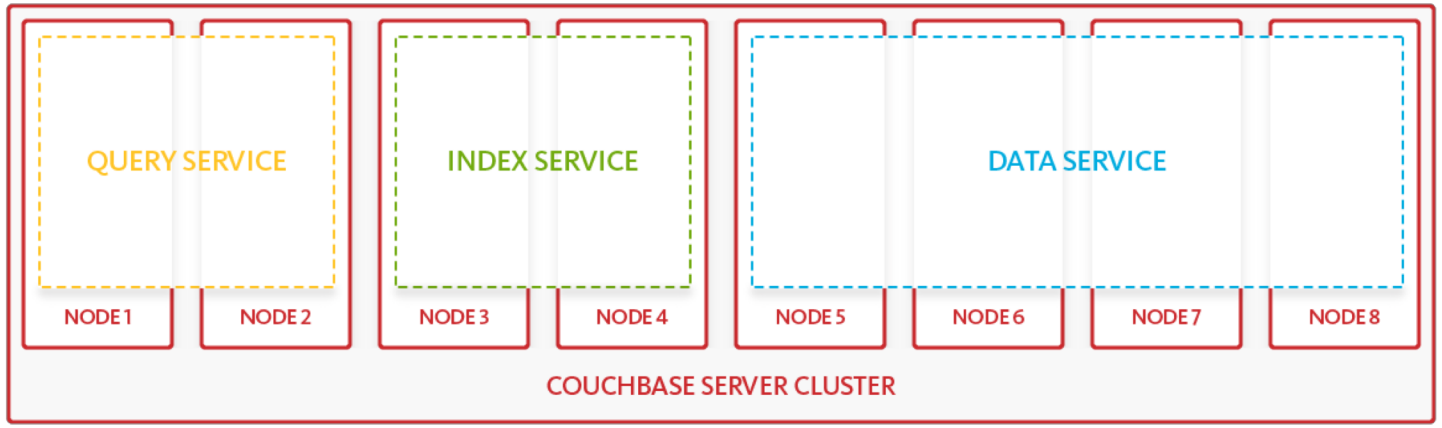
Independent Scalability for Best Computational Capacity — *per Service.*

Heavier Indexing?

Scale up or out
Index Service Nodes.

More RAM for Query Processing?

Scale up or out
Query Service Nodes.



Multi-Dimensional Scaling

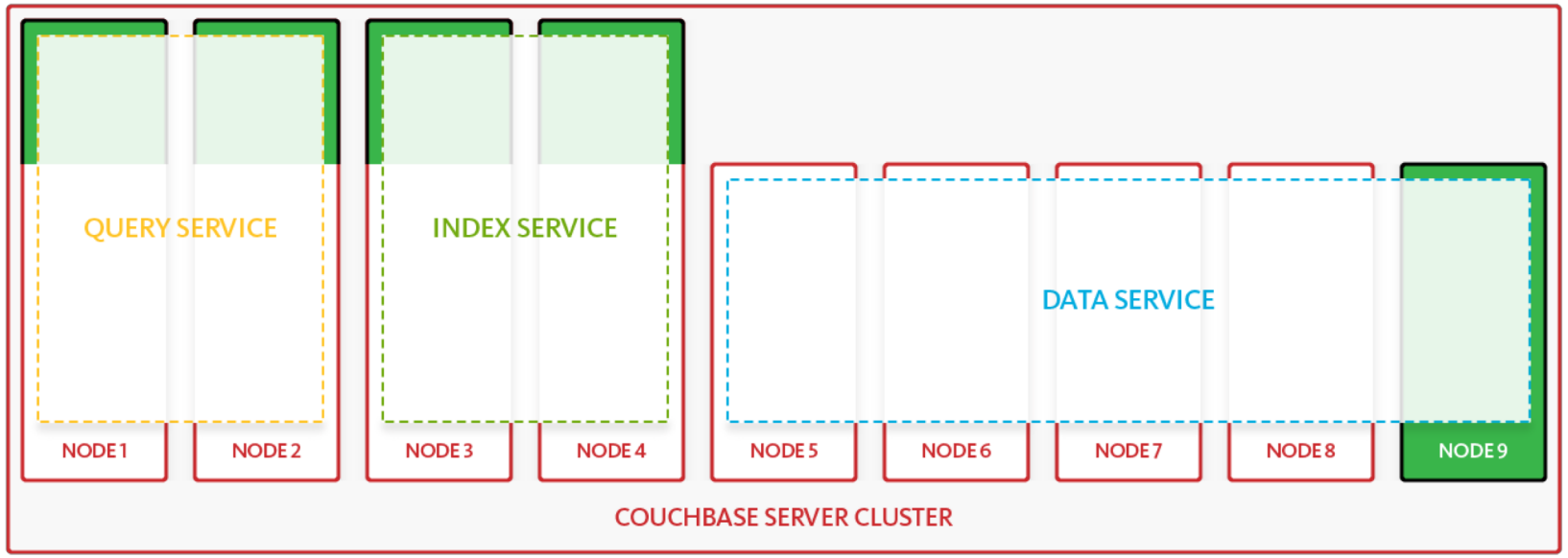
Independent Scalability for Best Computational Capacity — *per Service.*

Heavier Indexing?

Scale up or out
Index Service Nodes.

More RAM for Query Processing?

Scale up or out
Query Service Nodes.

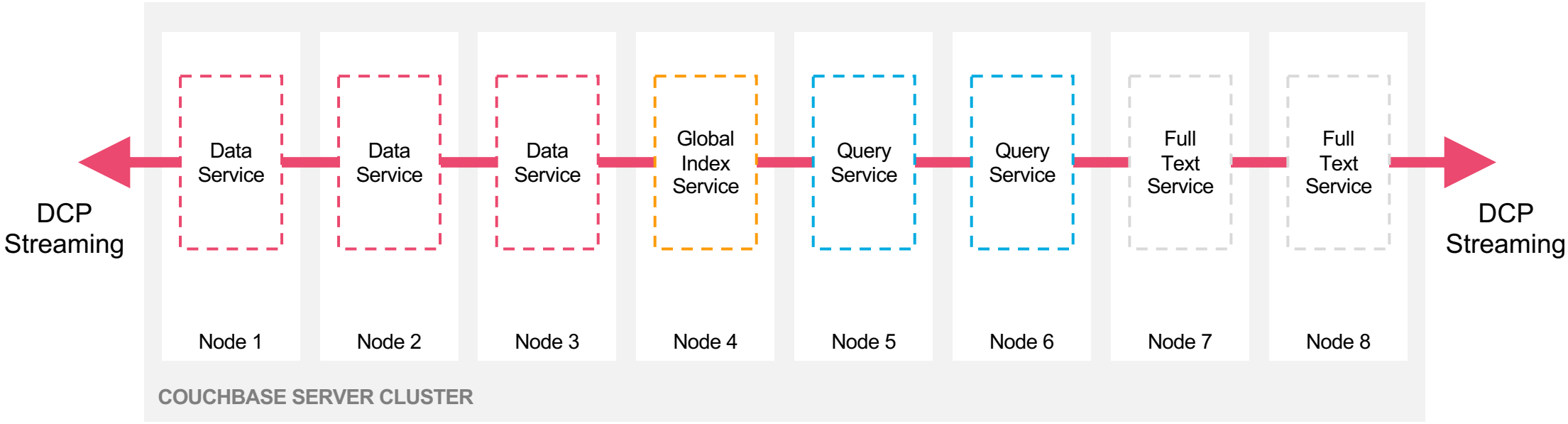


The same applies for other services

2 | Database Operations

#1 Principle: Memory-first architecture

Data movement free from disk bottlenecks



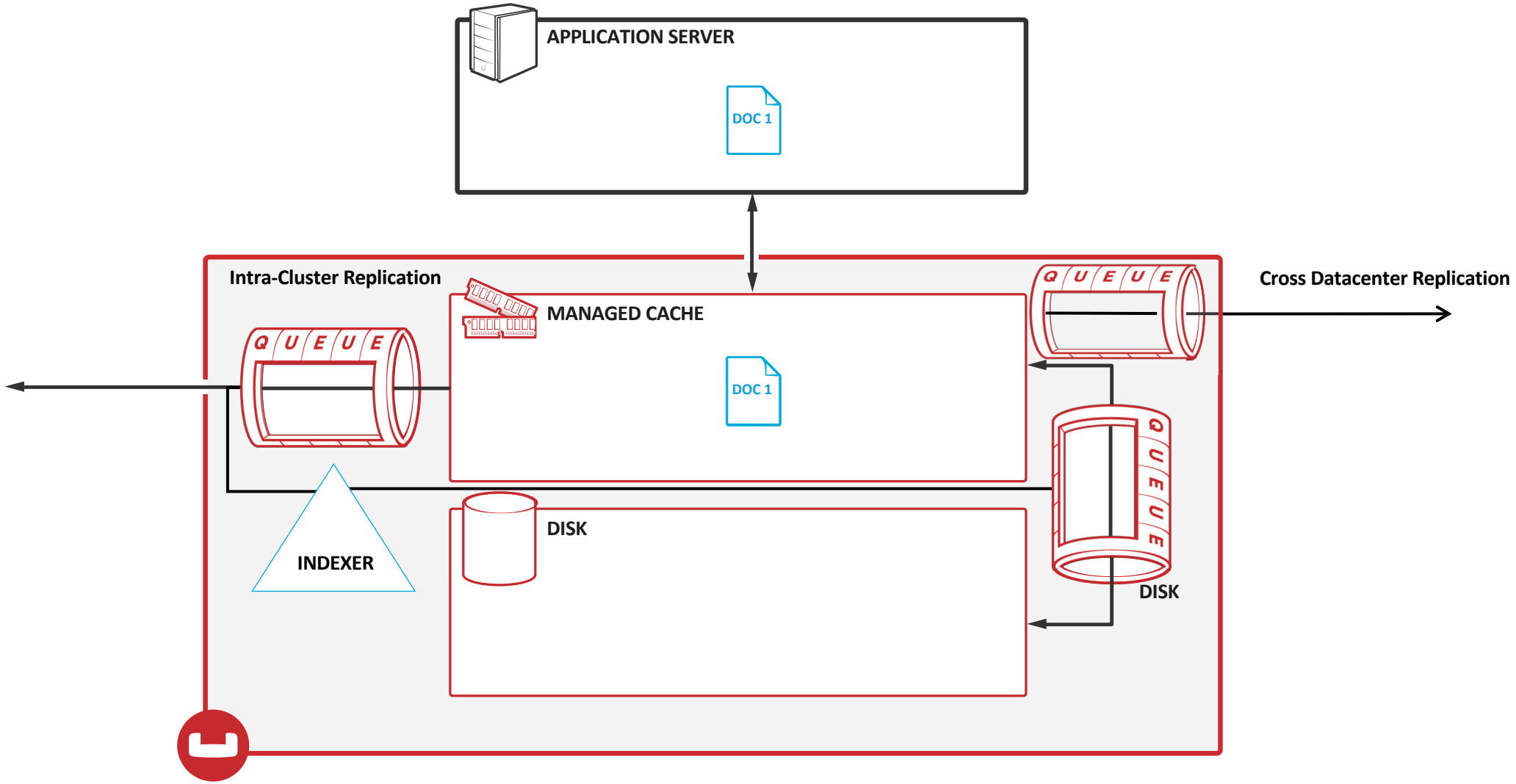
- In-memory streaming of updates to all components
- In-memory cache
- Memory-only data buckets
- Memory-only indexes

In-memory streaming of updates to all components
In-memory (cached) access to data and indexes
Memory-only indexes

#2 Principle: Asynchronous approach to everything

- Persistence
- Intra-cluster Replication
- Inter-cluster Replication
- Global secondary Indexing updates
- Full-Text Search update
- Analytics service updates

Asynchronous Approach to Everything



Usage of RAM

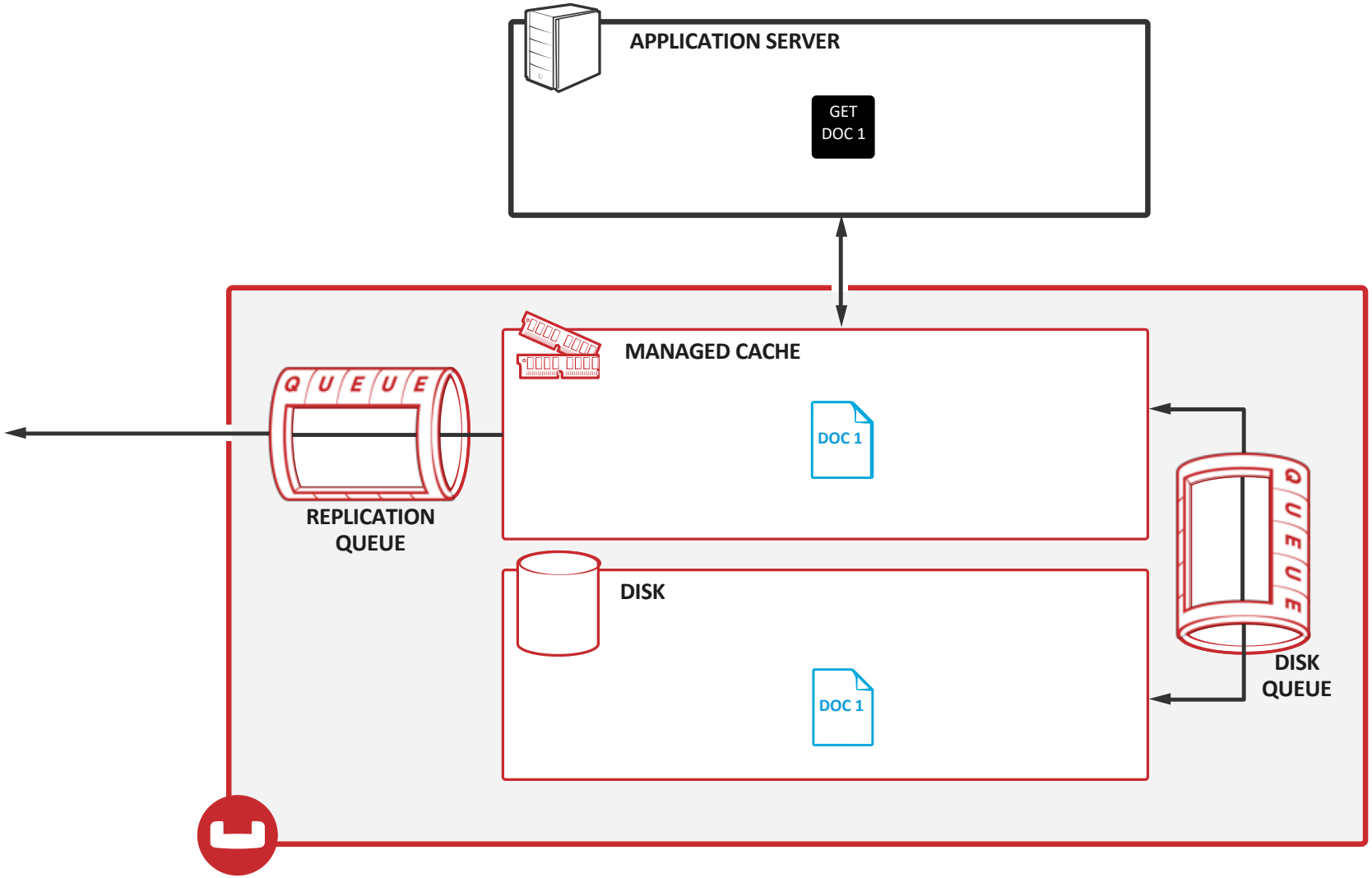
- RAM is used as much as possible
  - Cached documents
  - Metadata and key information
  - Internal process data structures
- All document IDs and metadata are stored in RAM at all times
  - Also persisted to disk
- All data is transferred in and out through RAM
  - Client Libraries accesses go through RAM layer
- Data is persisted immediately to disk
  - Queued if necessary
  - Checkpoints used for de-duplication and synchronization off-node
- Replication is RAM-to-RAM

Cache Management

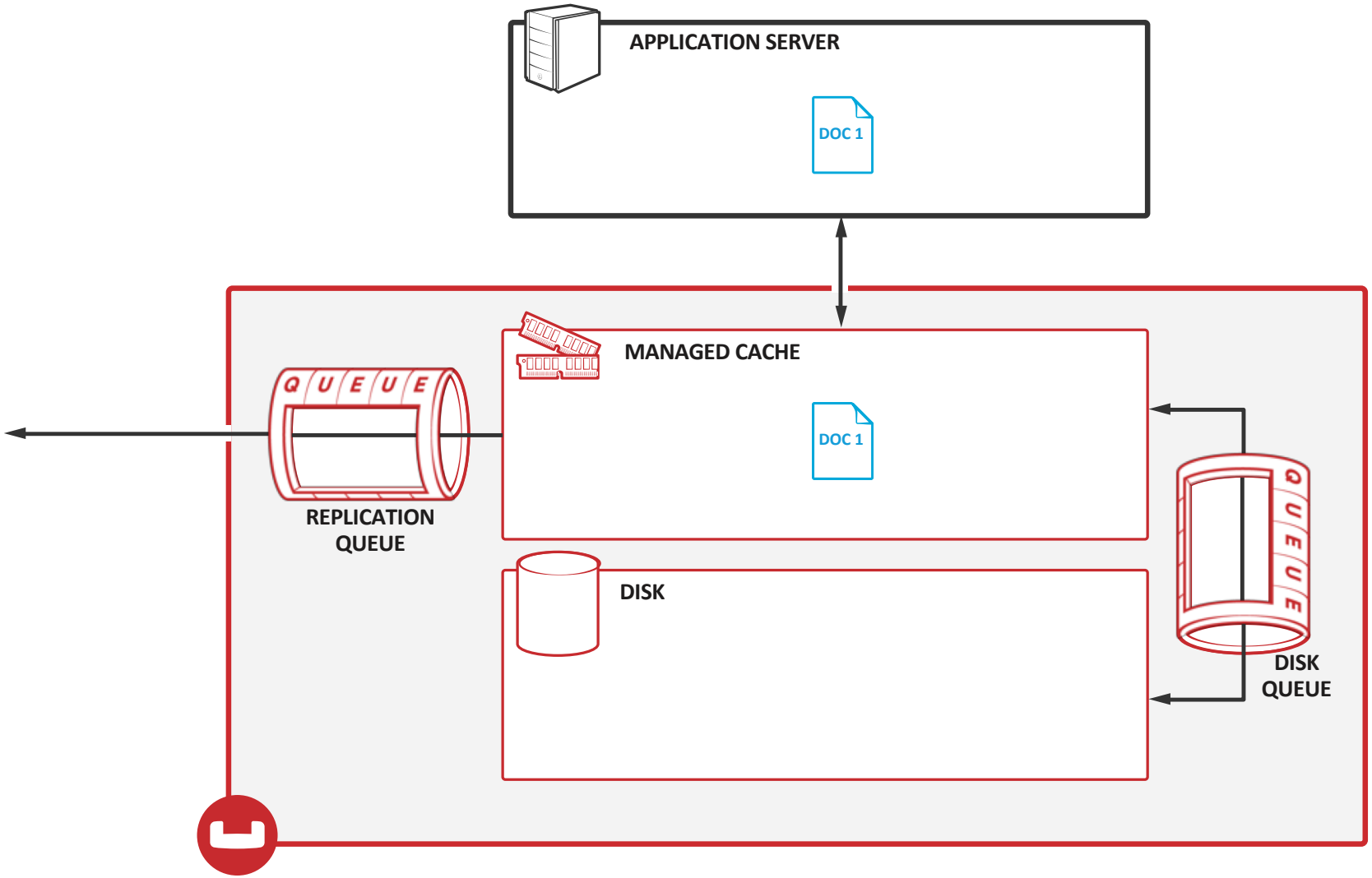
- As RAM fills up, data will be ejected to disk:
  - Only data already persisted can be ejected
  - Ejection happens in background, not related to traffic
  - Only the “values” can be ejected; metadata remains in RAM at all times

- NRU (Not Recently Used) Algorithm used for ejection
  - Client reads or writes update an item NRU attribute
  - Daily process scrapes and resets frequently used items
  - Resulting list of items is used to determine items to be ejected when needed

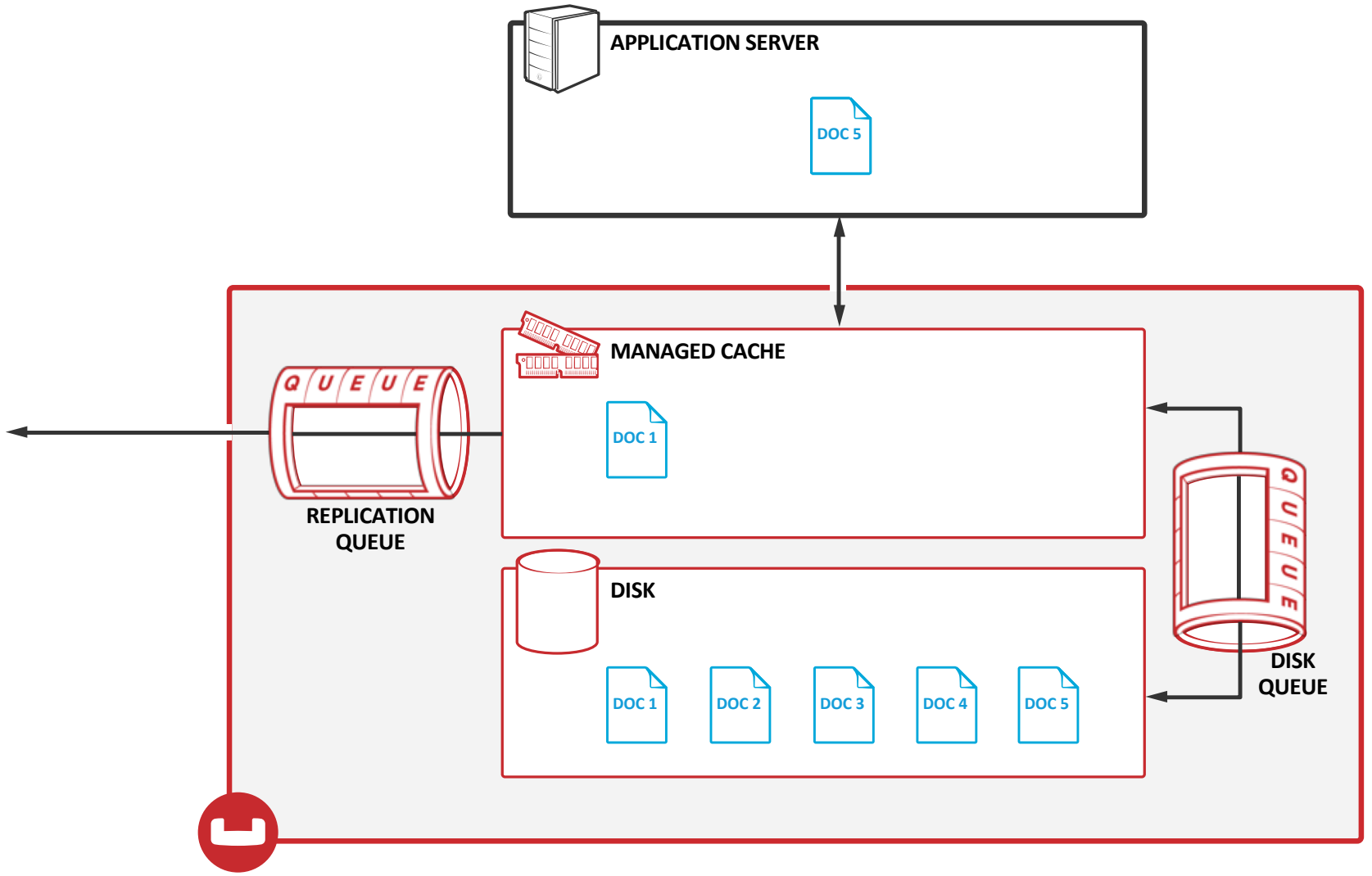
Couchbase Read Operation



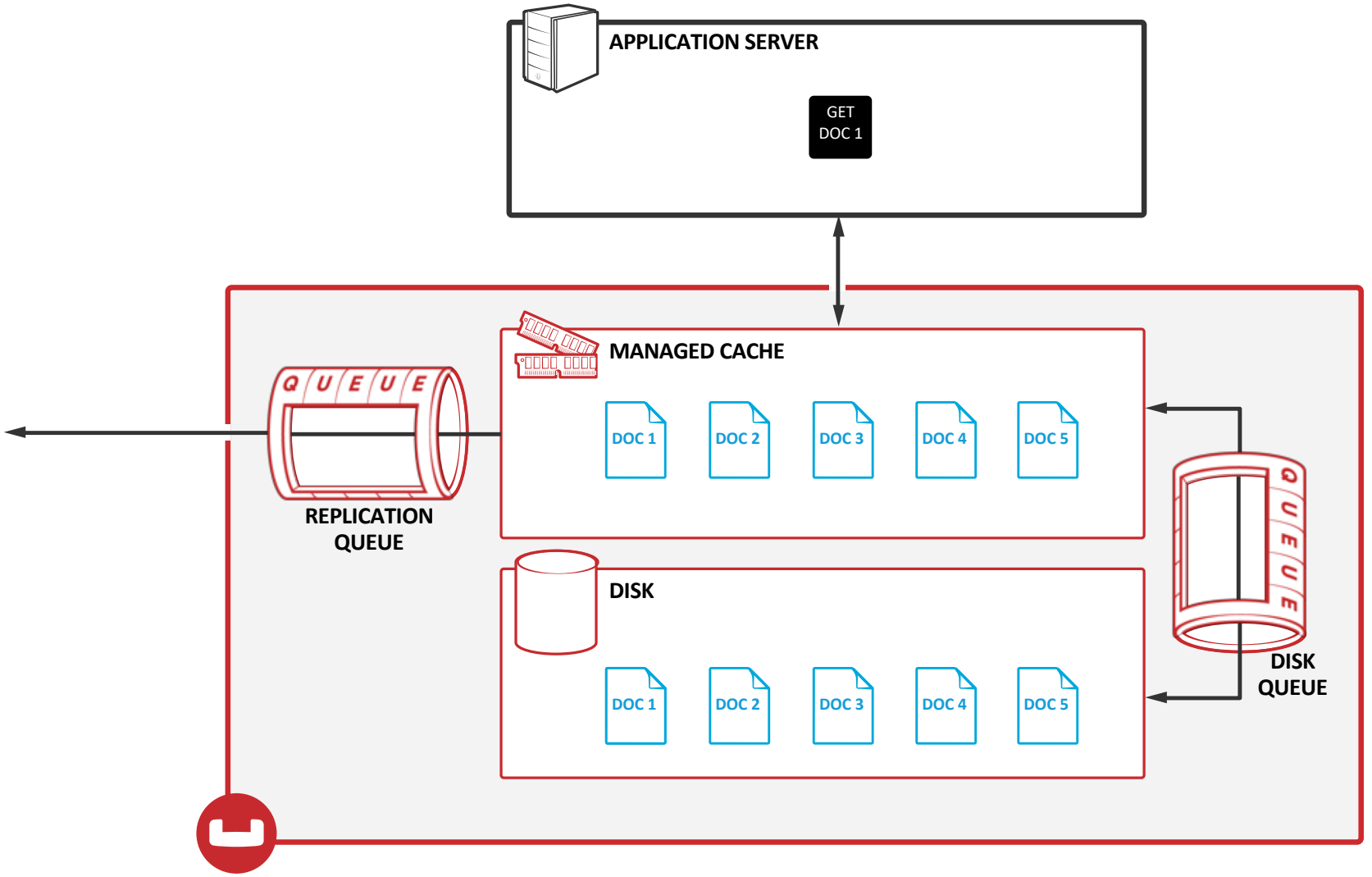
Write Operation



Cache Ejection

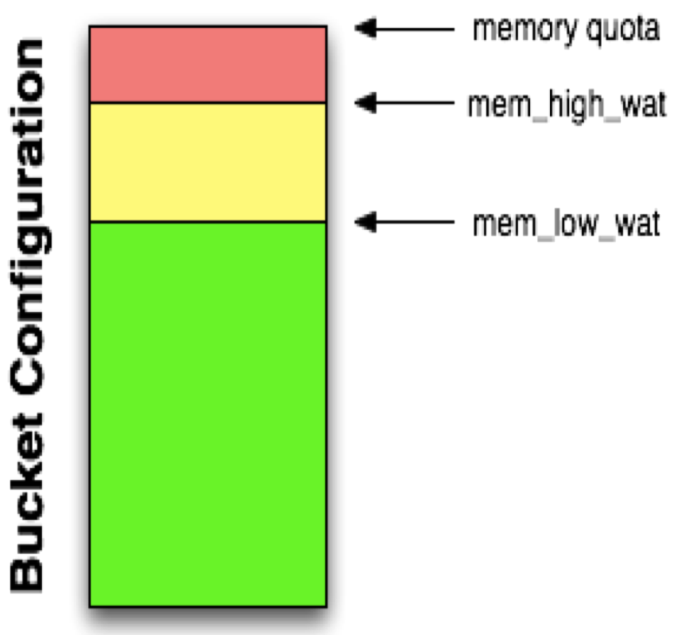


Cache Miss


APPLICATION SERVER
GET
DOC 1
MANAGED CACHE
DOC 1
DOC 2
DOC 3
DOC 4
DOC 5
QUEUE
REPLICATION
QUEUE
DISK
DOC 1
DOC 2
DOC 3
DOC 4
DOC 5
QUEUE
DISK
QUEUE

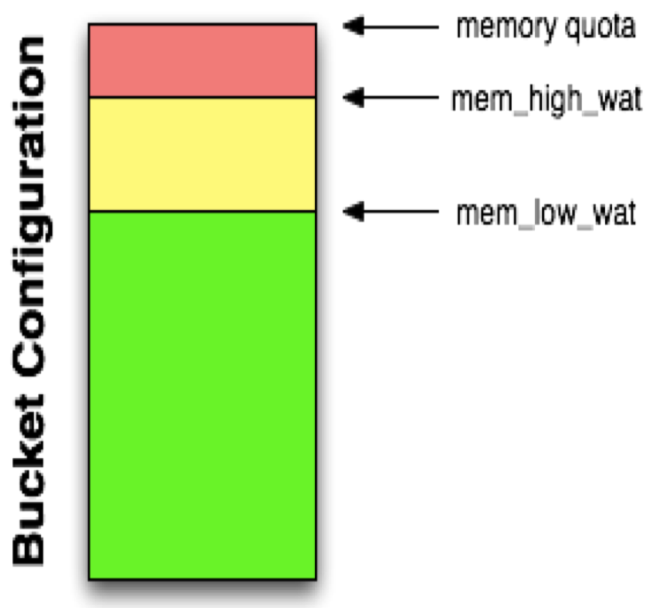
Cache Management

- User defined quota is max memory usage
- High and Low watermarks are automatically set (%85 and %75 by default):
  - Watermarks can be raised/lowered manually if needed (not recommended)



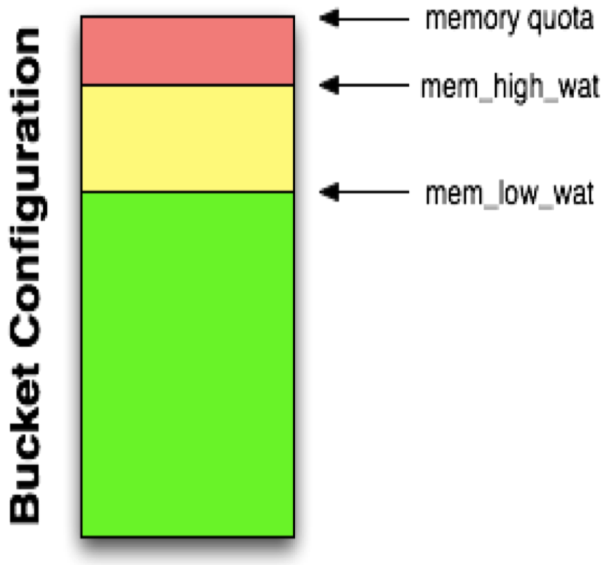
Cache Management

- When memory usage passes:
  - Low watermark:
    - Nothing
  - High watermark: NRU used first, random afterwards
    - Ejection continues as needed until low watermark reached
  - Overhead is built-in to leave space for:
    - unexpected spikes
    - rebalancing
- Best practice is to keep “working set” (some percentage of overall dataset) below high watermark for best performance



Out-of-Memory Errors

- If memory usage reaches 90% of quota, clients are told to temporarily back off (“temp_oom”)
  - Typically caused by too many/spike in writes
- If memory cannot be reclaimed, clients are told system is full (“oom”)
  - Typically caused by RAM being filled with metadata



Working Set Management

- The high water mark and low water mark values can be tuned for performance
  - 85% high water mark default
  - 75% low water mark default
  - Configured as percentage or absolute RAM usage
- Balance of replica to active ejection after NRU can be set
  - 60/40 replica to active by default
- Expiry pager interval can be changed
  - 60 minutes by default

Storage on Disk

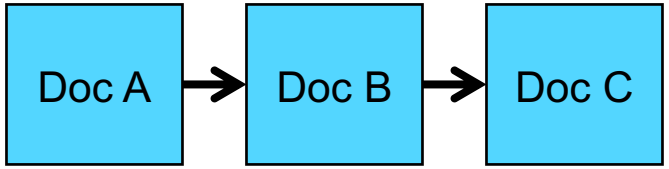
- *ALL* files are append-only b-trees (as of CB6.0):
- All modifications (writes/updates/deletes/index changes) go to end of file
- New b-tree header written to end of file after batch of changes
- Each vbucket (per-bucket) is separate file

Compaction

- On-disk size increases compared to actual stored data (append-only)
- Compaction defragments data and index information
- Operates on a live bucket (no downtime)
- Both automatic and manual compaction available
- Compaction operates on a single server basis
  - Nodes operate independently
  - Compaction is per-vbucket, whole data set can be compacted incrementally

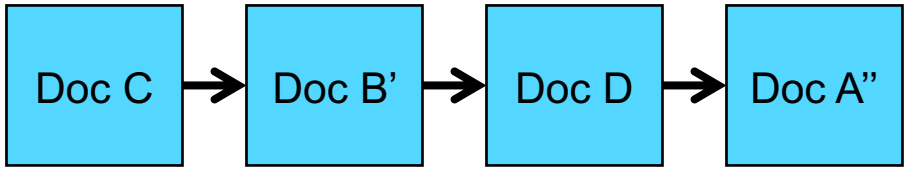
Compaction

Initial file layout:



Update some data:

After compaction:

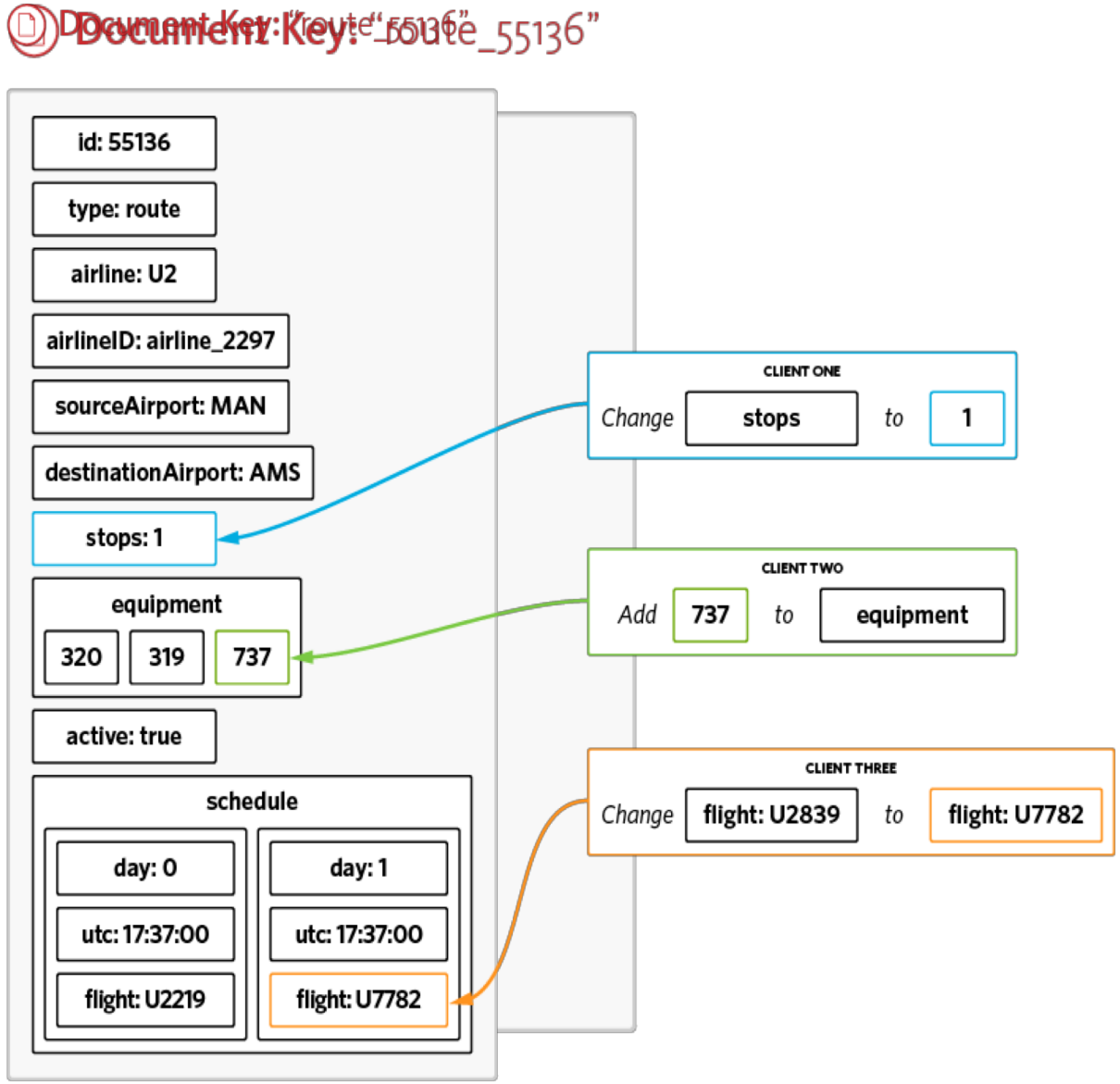


Compaction

- Compaction creates a new file
  - Available disk space is checked (need twice current data size)
- Existing data is written to new file
  - Existing file is used until compaction has completed
  - Data file extension is numeric; new version has uses next increment (i.e. current data in 1.couch.12 is compacted to 1.couch.13)
- Once compaction is complete, old file disabled, new file enabled, old file deleted
- Compaction is both disk and CPU intensive
  - Configuration available to control time of day of automatic compaction

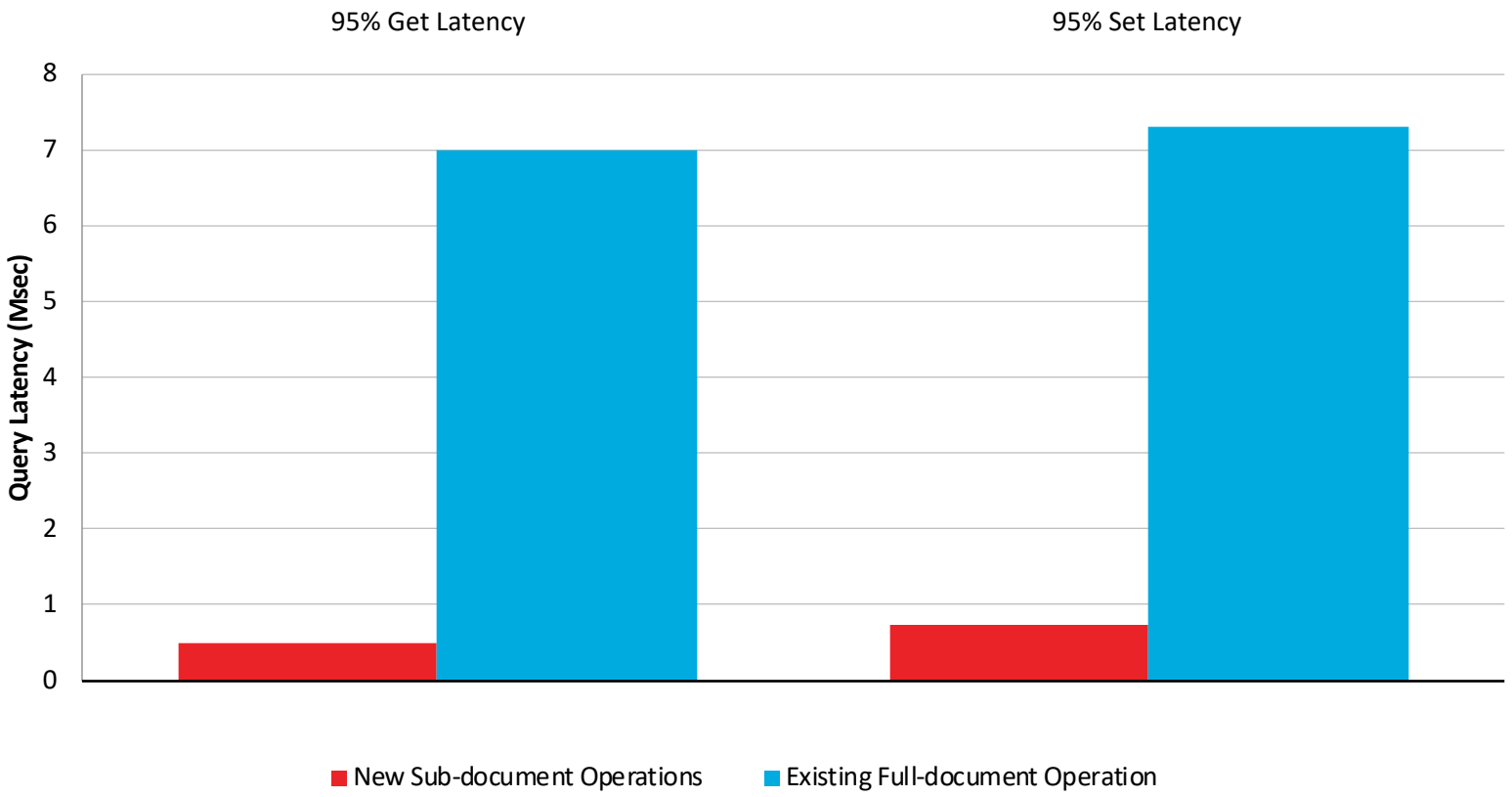
Efficient Sub-Document Operations

- **Document Mutations:**
  - Atomic Operate on individual fields
  - Identical syntax behavior to regular bucket methods (upsert, insert, get, replace)
  - Support for JSON fragments.
  - Support for Arrays with uniqueness guarantees and ordinal placement (front/back)



Faster Key Based Operations!

10-14X Faster Document Read & Update Operation



95% Get & Set Latency Measured (Msecs) on single INT field update with sub-document vs full-document call

Thank you

Couchbase