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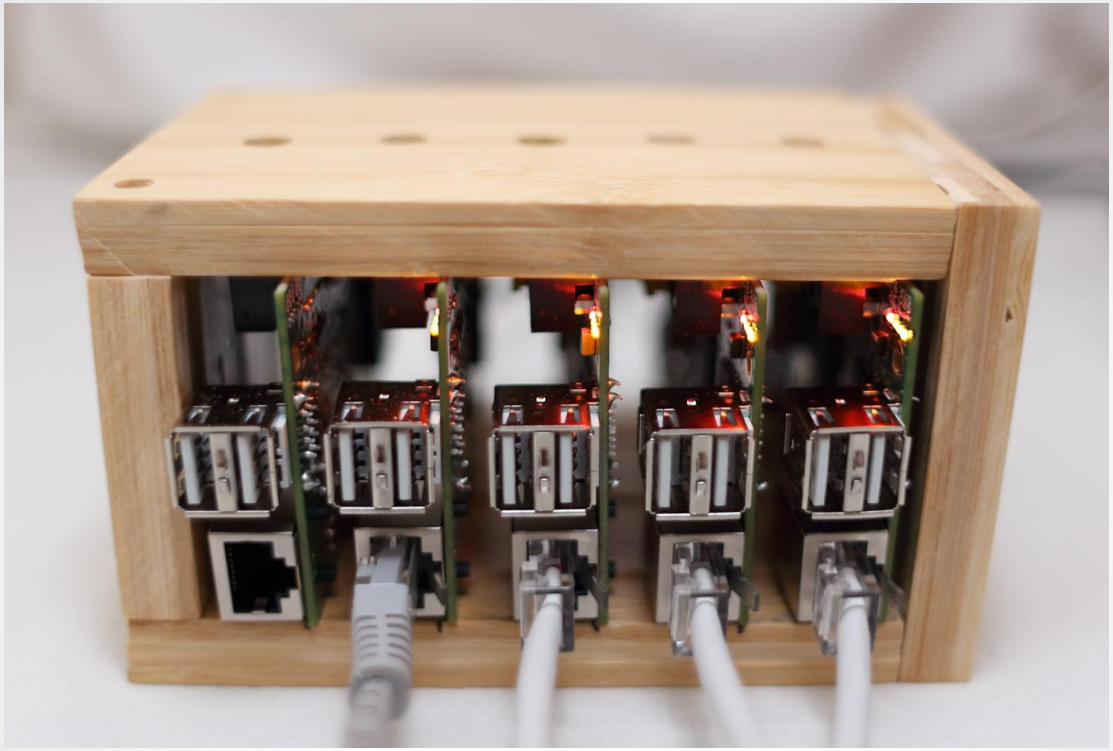
RIAK

The most powerful open-source, distributed database you'll ever put into production

Raspberry PI Cluster running Riak



- 4 nodes running Riak, fully operational
- Energy efficient: max 3.5 watts per node
- Based on the **ARM** architecture
- Very cheap
- Not a production grade cluster :-)

The Agenda

1. Riak: basic facts, main features
2. Objects and buckets
3. A demo: a classic distributed shopping cart
4. Data distribution
5. CAP theorem
6. Concurrency control: vector clocks, siblings
7. Tunable consistency
8. Operations on Riak with REST
9. Secondary Indexes (2i)
10. MapReduce in Riak
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14. Convergent Replicated Data Types
15. Wrap-up
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Riak: Basic Facts

- A distributed key-value NoSQL database
- Based on Amazon Dynamo
- Fault tolerant
- No single point of failure
- Peer-to-peer architecture
- Easily scalable
- Highly available
- Eventually consistent (tunable consistency)
- Written in Erlang with elements in C and JavaScript

Riak: main features

- Data distribution and replication
- Interfaces: REST-ful API, Protocol Buffers
- Client libraries: Java, Python, Perl, Erlang, Ruby, PHP, .NET
- MapReduce
- Riak Search (full text search)
- Secondary Indexes

Objects in Riak

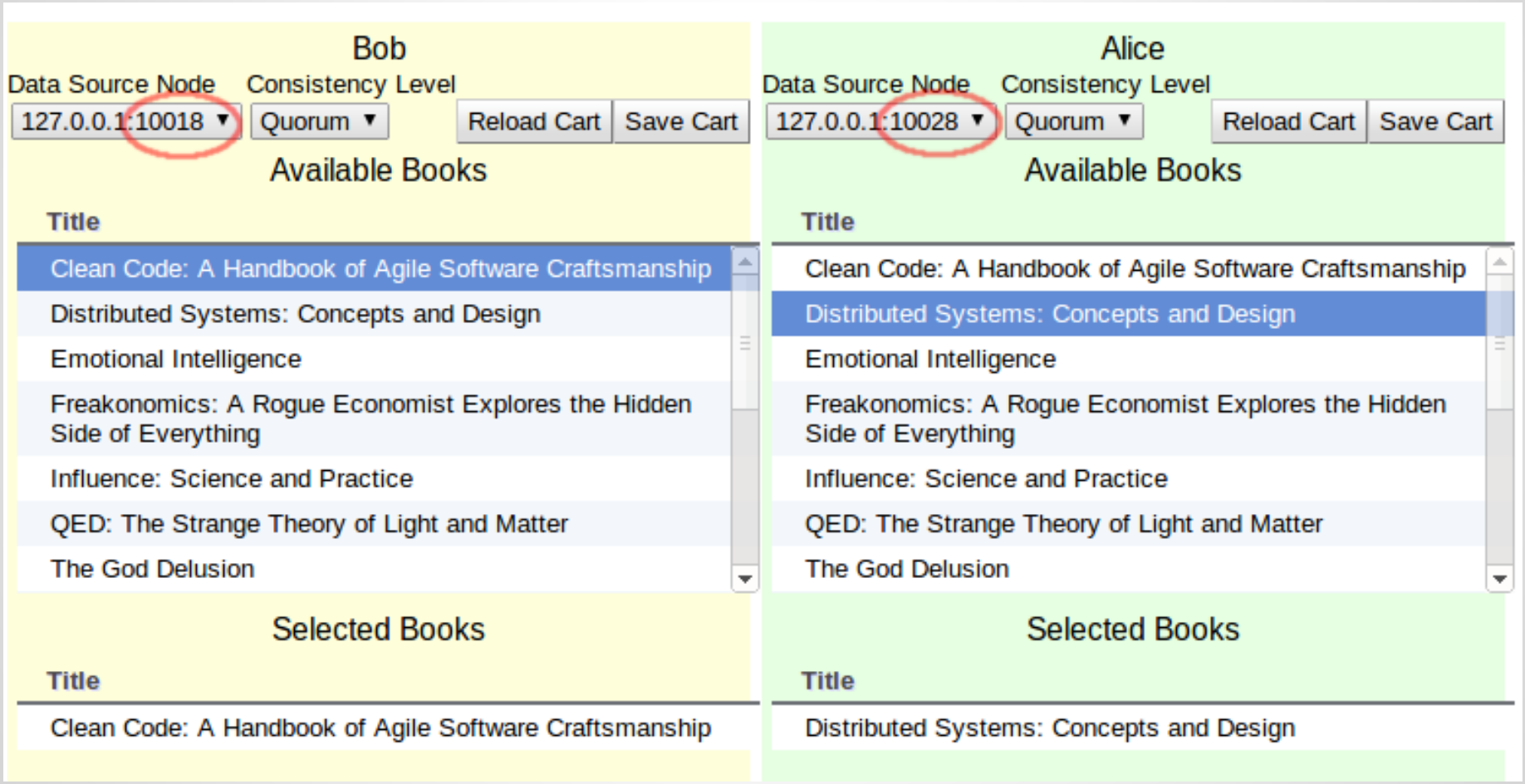
Riak stores values as opaque **binary objects**.

The most convenient way of storing objects: **JSON**-encoded objects, e.g. we have a "book" object:

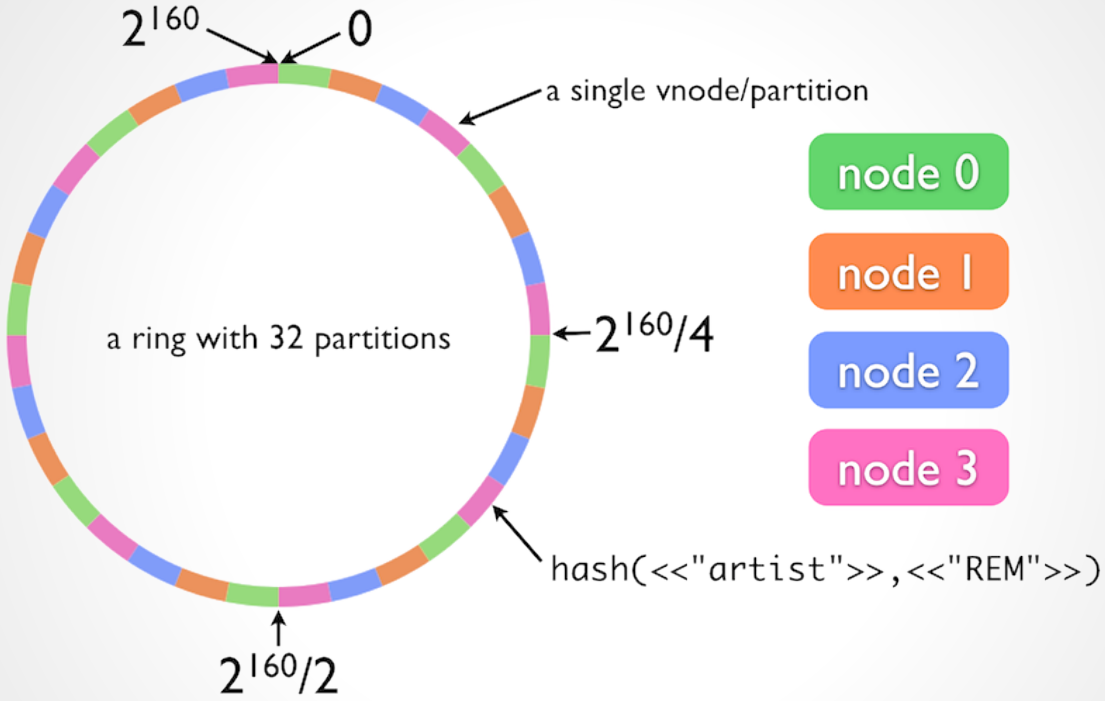
```
{
    "title": "The Prince",
    "author": "Niccolo Machiavelli"
}
```

Objects are grouped into **buckets**. Objects in a bucket share replication level, consistency parameters, storage backend. Objects in a bucket do not have to be related to themselves in any other way.

Demo: Distributed Shopping Cart

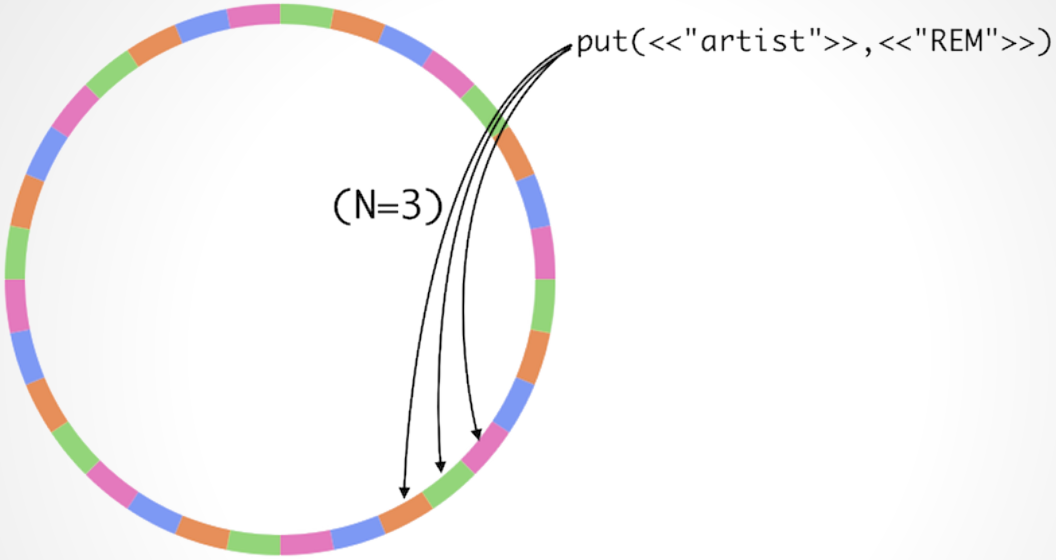


Riak: Data Distribution



Key space is divided into partitions (vnodes) and forms a "ring".
Partitions are distributed over Riak nodes.
There are 32 partitions and 4 nodes in the example above

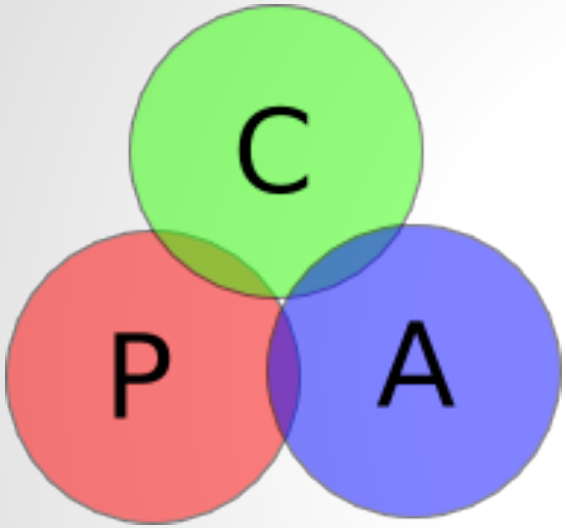
Riak: Data Replication



Each object is replicated to N vnodes (by default N = 3).

When a given node is unavailable then an object is saved to next available node (a fallback node). This is called a "hinted hand-off".

CAP Theorem



Consistency

Availability

Partition Tolerance

- We have to give up **one** of the properties: C, A or P
- Father of the CAP Theorem: Dr. Eric Brewer, Basho board member

CAP in Riak

- Availability and Partition Tolerance guaranteed
- Eventually consistent
- Tunable consistency
- Strong consistency can be easily achieved:

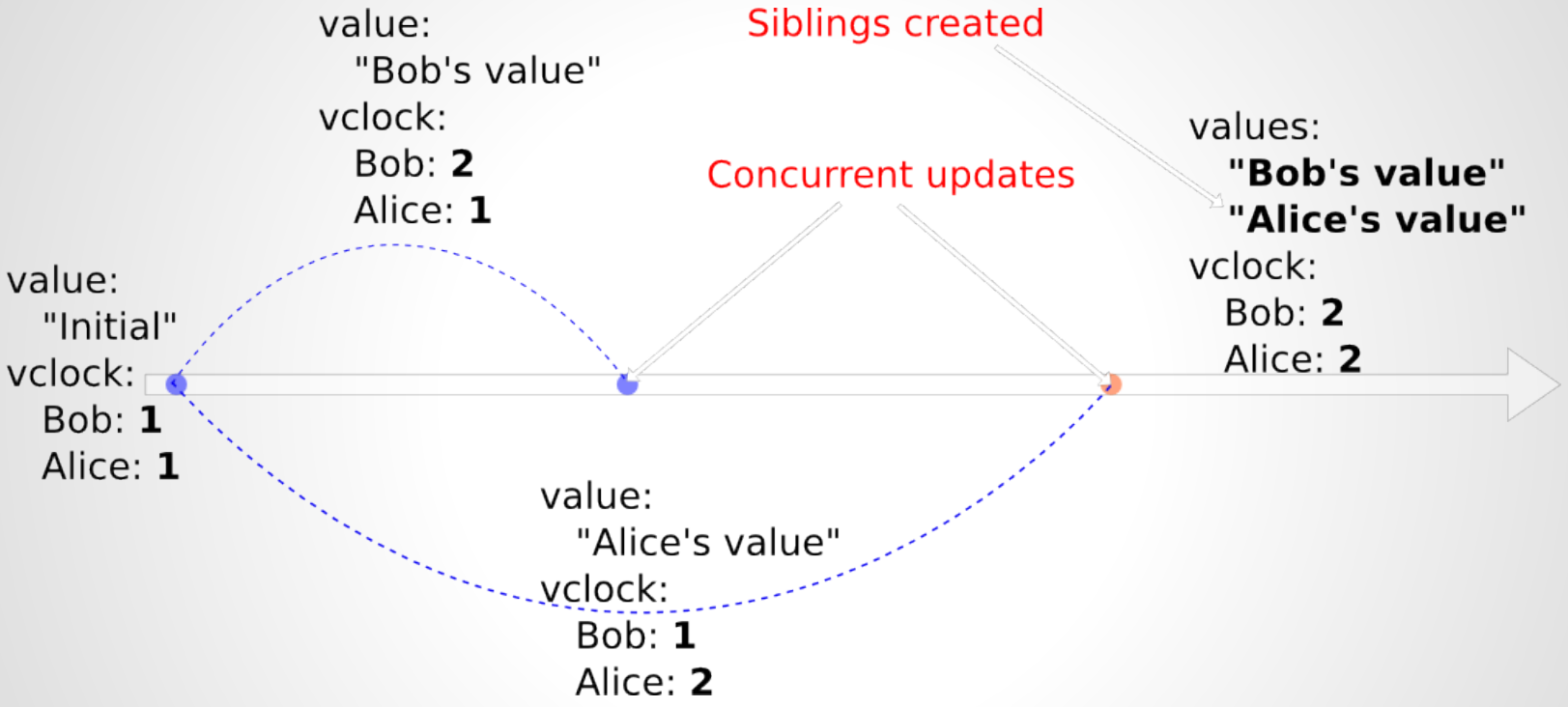
R + W > N

N - number of replicas

R - how many replicas are used for reading

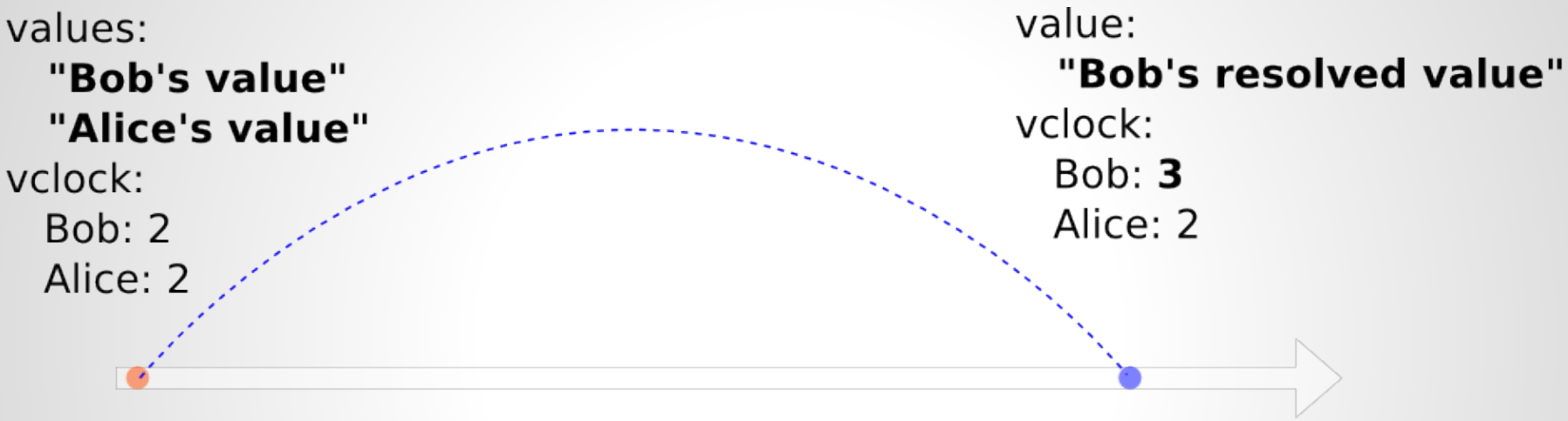
W - how many replicas are used for writing

Vector Clocks in Riak



- **Concurrent operations**: when we cannot order them sequentially
- In Riak: Bob = node1, Alice = node2

Sibling Resolution



- Siblings are detected **while reading**
- Best general strategy to resolve siblings: **merge**
- Dedicated data types optimal for merging: **C**onvergent **R**eplicated **D**ata **T**ypes

More on Siblings

If we want to control **concurrent operations** with siblings then we have to set **allow_mult = true** at the bucket level (it is turned off by default).

Siblings are created when:

- an update on an object is done in parallel
- a stale vector clock is used during an update
- a network partition occurs, object is updated in separate partitions and network partitions reconnect
- when we use a cluster-to-cluster replication

Riak: CAP Controls

CAP controls = query parameters

- **r** - (read quorum) how many replicas need to agree when retrieving the object
- **pr** - (primary read quorum) how many replicas to commit to **primary** nodes before returning a successful response
- **w** - (write quorum) how many replicas to write to before returning a successful response
- **dw** - (durable write quorum) how many replicas to commit to durable storage before returning a successful response
- **pw** - (primary write quorum) how many replicas to commit to **primary** nodes before returning a successful response
- **rw** - how many replicas need to agree for both operations (get and put) involved in deleting an object

Riak: Tunable Consistency

Possible values of CAP controls:

- **all** - All replicas must reply
- **one** - One replica myst reply
- **quorum** - A majority of the replicas must reply (half plus one)
- **default** - uses per-bucket consistency property
- an **arbitrary** integer value - not recommended since "all", "one", "quorum", "default" are enough

By default query parameters (r, w, ...) are set at the **bucket level** to **quorum** which is a very reasonable value.

Querying with REST

Creating/updating an object with PUT:

curl -v -XPUT -H "Content-Type: **application/json**" -d '{"title": "The Prince","author": "Niccolo Machiavelli"}' http://localhost:10018/riak/**book**/**book1**

book: the bucket

book1: the key

Querying an object with GET:

curl -v -XGET http://localhost:10018/riak/**book**/**book1**

Deleting an object with DELETE:

curl -v -XDELETE http://localhost:10018/riak/**book**/**book1**

Creating an object and generating they key with POST:

curl -v -XPOST -H "Content-Type: application/json" -d '{"title": "The Prince","author": "Niccolo Machiavelli"}' http://localhost:10018/riak/**book**

Querying Buckets With REST

Listing buckets:

curl -v http://localhost:10018/buckets?buckets=true

Listing keys in a bucket:

curl -v http://localhost:10018/buckets/**book**/keys?keys=true

Querying bucket properties:

curl -v http://localhost:10018/riak/**book**

Updating bucket properties:

curl -v -XPUT -H "Content-Type: application/json" -d '{"props":{"**allow_mult**": true}}' http://localhost:10018/riak/**book**

Property "allow_mult" is set true above.

Secondary Indexes (2i)

- Objects are tagged with values stored as metadata
- Two types of secondary attributes: integers and strings
- Querying by exact match or range on **one** index
- Query results can be used as input to a MapReduce query

Storing tags:

```
curl -v -XPUT -H "x-riak-index-email_bin: sidorykp@gmail.com" \
 -H "x-riak-index-age_int: 39" \
 -H "Content-Type: application/json" \
 -d '{"firstName": "Pawel","lastName": "Sidoryk"}' http://localhost:10018/riak/user/user1
```

Querying by tag value:

```
curl -v http://localhost:10018/buckets/user/index/email_bin/sidorykp@gmail.com
```

Querying by a range of values:

```
curl -v http://localhost:10018/buckets/user/index/age_int/18/100
```

MapReduce in Riak

Map phase operates on single objects, generates a list of values. Map phase is used to filter and extract data from single objects. A variable length list of values can be produced from a single object

Reduce phase takes a list of values from the Map phase and **aggregates** them. Reduce can count values, group values, sort values.

MapReduce: Counting Objects

```
curl -XPOST http://localhost:10018/mapred \
-H 'Content-Type: application/json' \
-d @- \
<<EOF
{
"inputs":"book",
"query":[{
        "map":{
                "language":"javascript",
                "source":"function(riakObject) {
                        return [1];
                }"
        }},{
        "reduce":{
                "language":"javascript",
                "source":"function(values, arg){
                        return [values.reduce(function(acc, item){ return acc + item; }, 0)];
                }"
        }
}]
}
EOF
```

MapReduce: Map inputs

- Can be all objects in a bucket: "inputs":"book"
- Can be objects in a bucket filtered by a key:

```
"inputs": {
    "bucket":"book",
    "key_filters":[["string_to_int"],["greater_than", 5]]
}
```

- Can be a bucket filtered by index

```
"inputs": {
    "bucket":"user",
    "index":"age_int",
    "start":"18",
    "end":"100"
}
```

- Can be a full text search result

MapReduce: continued

We can have just Map without Reduce

Map and Reduce phases can be chained, e.g.:

map -> reduce1 -> reduce2

filter input (map)-> group by (reduce) -> order by (reduce)

Erlang and JavaScript functions can be used for Map and Reduce.

Extracting a member variable in Map is easy:

```
"source":"function(riakObject) {
    var m = Riak.mapValuesJson(riakObject)[0];
    return [m.firstName];
}"
```

Riak Search

- Distributed, full-text search engine
- Objects are indexed in a precommit hook
- Text extraction based on a mime type
- Can feed data into MapReduce
- Query syntax the same as in Lucene, most of Lucene operators are supported

Examples:

bin/**search-cmd** search book "author:Robert"

curl http://localhost:10018/**solr**/book/select?q=author:Robert

Riak Search: Weaknesses

- Uses timestamps, rather than vector clocks
- Does not use quorum values when writing (indexing) data and reading (querying) data
- Has no read-repair mechanism. If Search index data is lost, the entire data set must be re-indexed

Riak developers are working on a next-generation full text search engine: Yokozuna.

Java Client: Objects (POJOS)

```
public class Book {
    @RiakKey
    private String id;
    @RiakVClock
    private byte[] vclockBytes;
    private String title;
    @RiakIndex(name = "created_by_user_id_bin")
    private String createdByUser;
}
```

@RiakKey: Riak ID of an object

@RiakVClock: a serialized Riak VClock (we do not touch it)

@RiakIndex: member variable "createdByUser" stores **index values**. The index name is "created_by_user_id_bin"

Java Client: Buckets

Creating a bucket (with "allow_mult = true"):

```
Bucket bucket = riakClient.createBucket("book").allowSiblings(true).execute();
```

Fetching a bucket:

```
Bucket bucket = riakClient.fetchBucket("book").execute();
```

Listing keys in a bucket:

```
for (String key: bucket.keys()) {...}
```

Java Client: Objects

Storing a POJO:

```
Book book = new Book(id);
bucket.store(book).execute();
```

Fetching a POJO by a key:

```
bucket.fetch(id, Book.class).execute();
```

Specifying CAP controls:

```
bucket.fetch(id, Book.class).r(Quora.QUORUM).execute();
```

Fetching with the use of a Conflict Resolver:

```
BookConflictResolver cr = new BookConflictResolver();
bucket.fetch(id, Book.class).withResolver(cr).execute();
```

Java Client: Conflict Resolver

- The task of a Conflict Resolver is to **merge** siblings into one object
- Conflict Resolvers work on a client
- A Conflict Resolver must be defined for each class for which siblings may be produced
- A Conflict Resolver is active during reading objects
- Using dedicated data types (CRDT-s) is recommended for the merge to make sense

Conflict Resolver: Shopping Cart

```
public ShoppingCart resolve(Collection<ShoppingCart> siblings) {
        ShoppingCart shoppingCartM = null;
        for (ShoppingCart shoppingCart: siblings) {
            if (shoppingCartM == null) {
                shoppingCartM = shoppingCart;
            } else {
                Set<BookUidPair> addSet = shoppingCartM.getAddSet();
                Set<BookUidPair> addSetToMerge = shoppingCart.getAddSet();
                addSet.addAll(addSetToMerge);

                Set<BookUidPair> removeSet = shoppingCartM.getRemoveSet();
                Set<BookUidPair> removeSetToMerge = shoppingCart.getRemoveSet();
                removeSet.addAll(removeSetToMerge);
            }
        }
        return shoppingCartM;
}
```

Java Client: Indexes

Returning object **keys** with exact match on index "email_bin":

```
List<String> userKeys = bucket.fetchIndex(BinIndex.named("email_bin")).
withValue("sidorykp@gmail.com").execute();
```

Range query on index "age_int", index is used as an input filter to MapReduce, MapReduce must be used to return whole objects instead of just their keys:

```
IndexQuery indexQuery = new IntRangeQuery(IntIndex.named("age_int"),
"person", 18, 100);
MapReduceResult result = riakClient.mapReduce(indexQuery).addMapPhase
(mapFunction).execute();
```

Java Client: MapReduce

Example: returning all objects in a bucket "book":

```
Function map = new JSSourceFunction(
        "function(riakObject) {" +
                "var m = Riak.mapValuesJson(riakObject)[0];" +
                "return [m];" +
        "}");

MapReduceResult result = riakClient.mapReduce("book").addMapPhase(map).
execute();
```

Convergent Replicated Data Types

Eventually consistent replicas easily **converge** when we use data types for which we define a **merge** function that is:

- commutative
- associative
- idempotent

Such data types are called **C**onvergent **R**eplicated **D**ata **T**ypes (**CRDT**-s).

The simplest example: grow-only set (a set that supports "add" and does not support "remove"). The "merge" function is implemented by union of sets.

Important CRDT-s:

- vector clock
- distributed counter
- observed-remove set (OR-Set), good for a distributed shopping cart
- multi-value register
- Treedoc, good for cooperative document editing

CRDT example: OR-Set

Consists of 2 sets: "**add set**" and "**remove set**". "Add set" and "remove set" contain pairs {elem, uid} where "elem" is the actual element being stored in the OR-Set and "uid" is a unique identifier allocated during an "add" operation.

We remove an "elem" from an OR-Set by adding all {elem, uid1}, {elem, uid2} etc. pairs found in the "add set" to the "remove set".

Merging OR-Sets is easy: we make a union of "add sets" to get a merged "add set" and we make a union of "remove sets" to get a merged "remove set".

- adding "book1":
  - add set: [{"book1", **uid1**}], remove set: []
- removing "book1:"
  - add set [{"book1", uid1}], remove set: [{"book1", uid1}]
- adding "book1" once more:
  - add set [{"book1", uid1}, {"book1", **uid2**}], remove set: [{"book1", uid1}]

CRDT-s: continued

Riak developers are working on implementation of a library of CRTD-s straight in Riak. Currently one has to implement his/her own CRDT-s on top of Riak.

Some data operations cannot be implemented by a CRDT, e.g. a non-negative counter. Some data operations require a global synchronization and they cannot be implemented in a eventually-consistent manner.

Riak: Strengths

- Efficient concurrency control with vector clocks
- High scalability
- Fault tolerance
- Tunable consistency
- Efficient query options: secondary indexes, MapReduce, Riak Search
- Many client interfaces: Java, Python, Ruby etc.
- Supports REST and Protocol Buffers

Riak: Weaknesses

- No security: you must implement your own security layer
- Secondary Indexes do not scale well beyond > 512 nodes
- Failed MapReduce jobs are not restarted (rather use Hadoop for long running MapReduce jobs)
- No high level query language
- Various weaknesses of Riak Search

Conclusions

- Don't be afraid of eventual consistency
- Consider Riak if you want a complete data solution for the Cloud or Big Data
- Scale your applications at ease

Further Reading

- basho.com
- **Eventually Consistent - Revisited**: www.allthingsdistributed.com/2008/12/eventually_consistent.html
- M. Shapiro et al. **A comprehensive study of convergent and commutative replicated data types.** Technical Report RR-7506, INRIA, 2011.
- Nuno Preguica et a. **A commutative replicated data type for cooperative editing.** Int. Conf. on Distributed Computing Systems (ICDCS), 2009.

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Questions ?