SQL, NoSQL, NewSQL? What's a developer to do?

Chris Richardson

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Overall presentation goal

The joy and pain of building Java applications that use NoSQL and NewSQL

About Chris

Aberdeen
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Glasgow
Londonderry / Derry
Belfast
United Kingdom
Hartlepool
Isle of Man
Leeds
Preston
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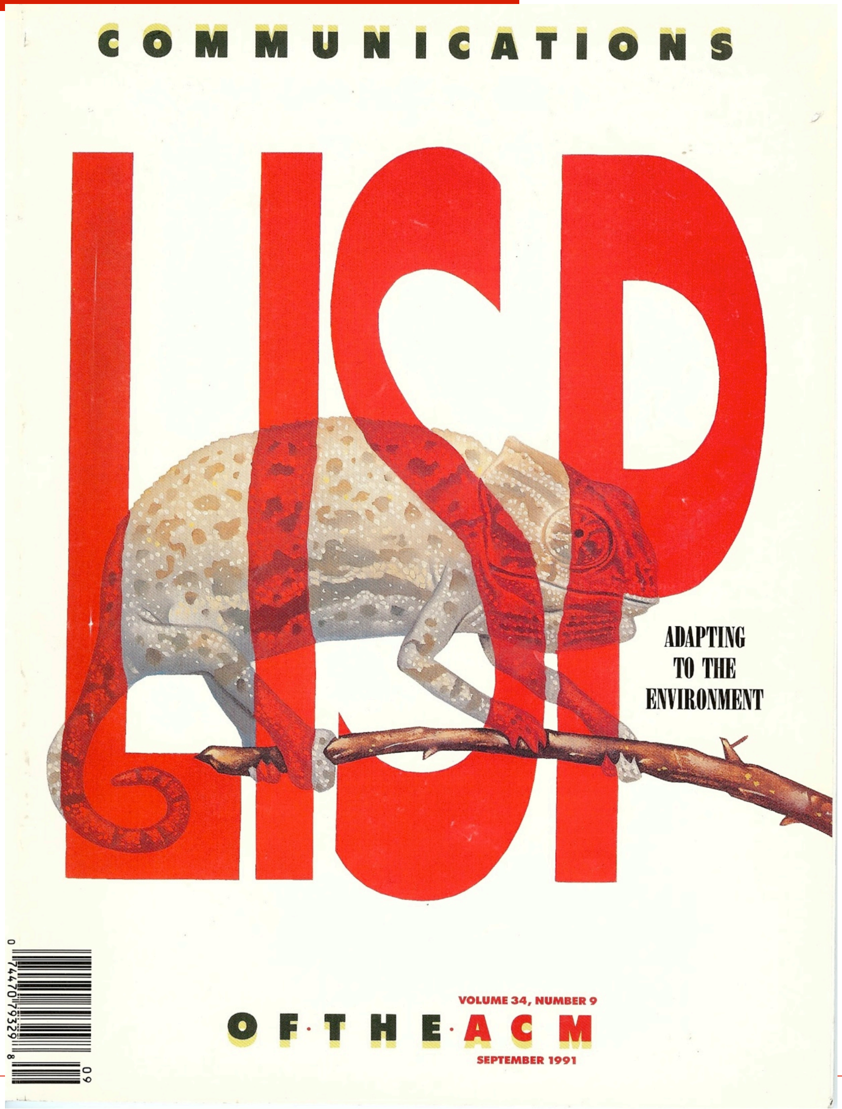
(About Chris)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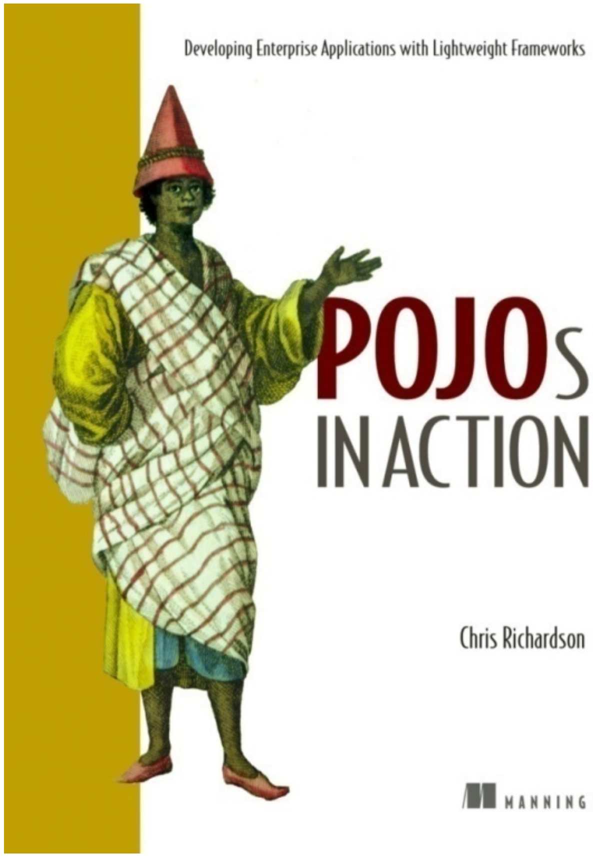
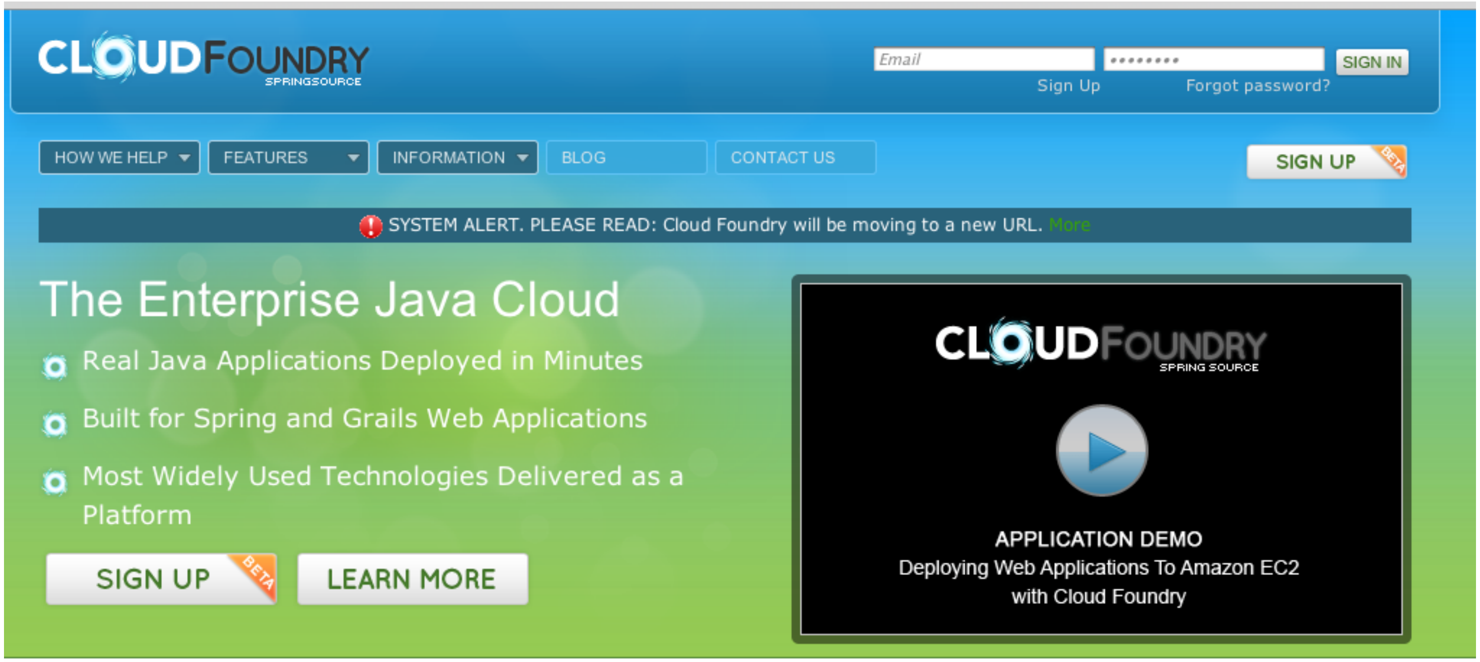
SEPTEMBER 1991

About Chris()



Developing Enterprise Applications with Lightweight Frameworks
POJOs
IN ACTION
Chris Richardson
MANNING

About Chris



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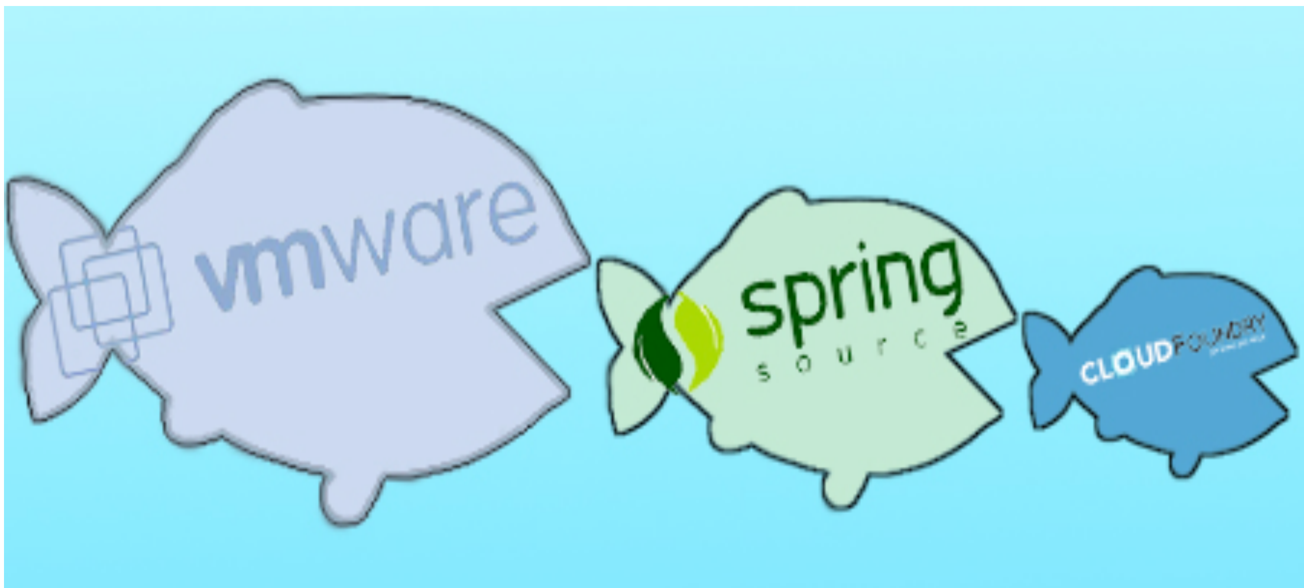


http://www.theregister.co.uk/2009/08/19/springsource_cloud_foundry/

About Chris

Developer Advocate for

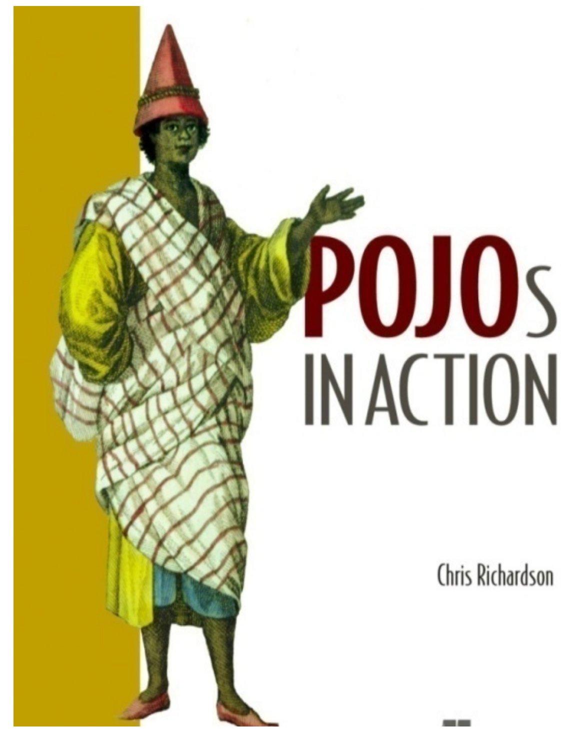
Signup at CloudFoundry.com using promo code JFokus

Agenda

- **Why NoSQL? NewSQL?**
- Persisting entities
- Implementing queries

Food to Go

- Take-out food delivery service
- "Launched" in 2006
- Used a relational database (naturally)



Success → Growth challenges

- Increasing traffic
- Increasing data volume
- Distribute across a few data centers
- Increasing domain model complexity

Limitations of relational databases

- Scaling
- Distribution
- Updating schema
- O/R impedance mismatch
- Handling semi-structured data

Solution: Spend Money

http://upload.wikimedia.org/wikipedia/commons/e/e5/Rising_Sun_Yacht.JPG

- Buy SSD and RAM
- Buy Oracle
- Buy high-end servers
- …

OR

- Hire more DevOps
- Use application-level sharding
- Build your own middleware
- …

http://www.trekbikes.com/us/en/bikes/road/race_performance/madone_5_series/madone_5_2/#

Solution: Use NoSQL

Benefits

- Higher performance
- Higher scalability
- Richer data-model
- Schema-less

Drawbacks

- Limited transactions
- Relaxed consistency
- Unconstrained data

MongoDB

- Document-oriented database
  - JSON-style documents: Lists, Maps, primitives
  - Schema-less
- Transaction = update of a single document
- Rich query language for dynamic queries
- Tunable writes: speed ⇔ reliability
- Highly scalable and available
- Use cases
  - High volume writes
  - Complex data
  - Semi-structured data

Apache Cassandra

- Column-oriented database/Extensible row store
  - Think Row ~= java.util.SortedMap
- Transaction = update of a row
- Fast writes = append to a log
- Tunable reads/writes: consistency ⇔ latency/ availability
- Extremely scalable
  - Transparent and dynamic clustering
  - Rack and datacenter aware data replication
- CQL = “SQL”-like DDL and DML
- Use cases
  - Big data
  - Multiple Data Center distributed database
  - (Write intensive) Logging
  - High-availability (writes)

Other NoSQL databases

Type	Examples
Extensible columns/Column-oriented	Hbase SimpleDB DynamoDB
Graph	Neo4j
Key-value	Redis Membase
Document	CouchDb

Sorry if I left out your favorite

http://nosql-database.org/ lists 122+ NoSQL databases

Solution: Use **New**SQL

- Relational databases with SQL and ACID transactions

AND

- New and improved architecture
- Radically better scalability and performance

- NewSQL vendors: ScaleDB, NimbusDB, ..., VoltDB

Stonebraker’s motivations

“…Current databases are designed for 1970s hardware …”

Stonebraker: http://www.slideshare.net/VoltDB/sql-myths-webinar

Significant overhead in “…logging, latching, locking, B-tree, and buffer management operations…”

SIGMOD 08: Though the looking glass: http://dl.acm.org/citation.cfm?id=1376713

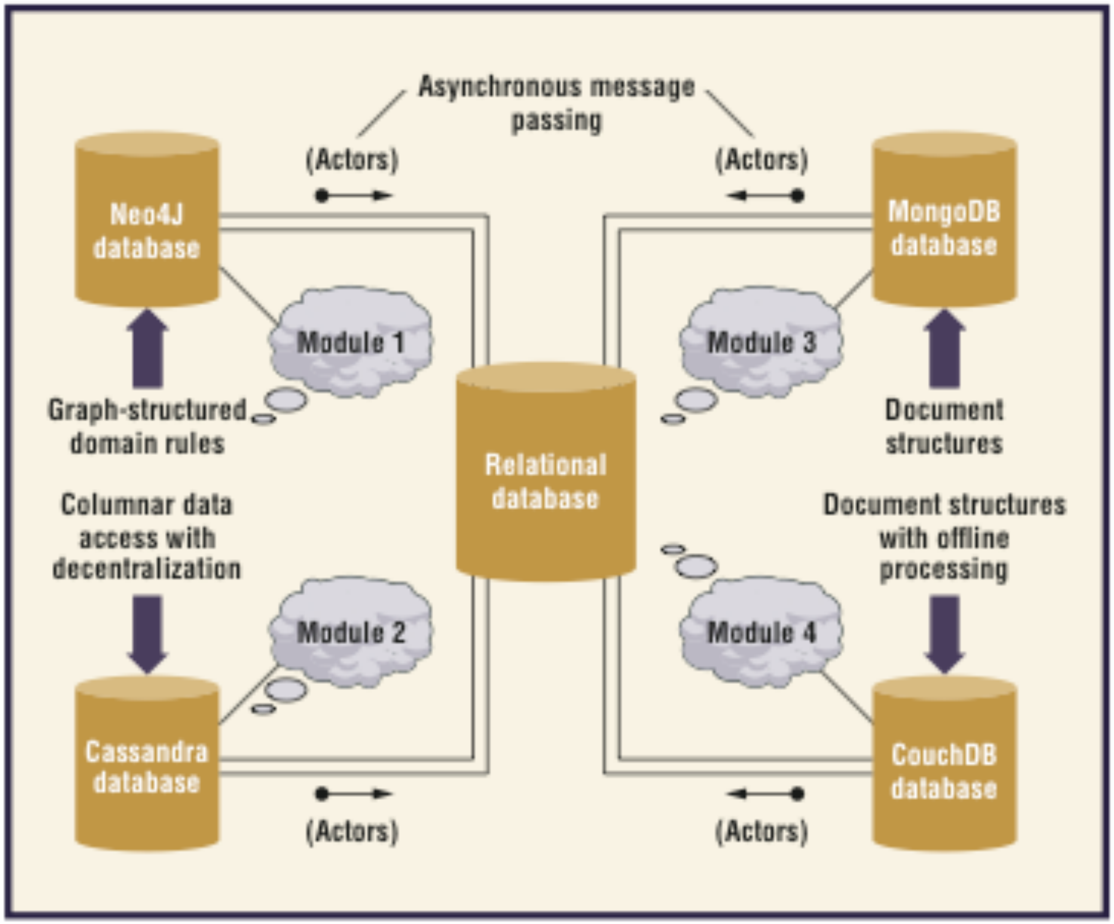
About VoltDB

- Open-source
- In-memory relational database
- Durability thru replication; snapshots and logging
- Transparent partitioning
- Fast and scalable

…VoltDB is very scalable; it should scale to 120 partitions, 39 servers, and 1.6 million complex transactions per second at over 300 CPU cores…

http://www.mysqlperformanceblog.com/2011/02/28/is-voltdb-really-as-scalable-as-they-claim/

The future is polyglot persistence

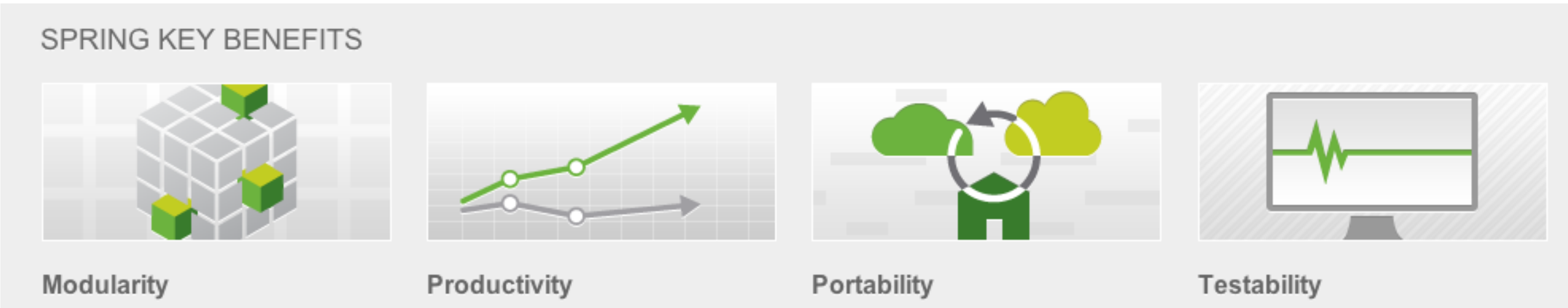


IEEE Software Sept/October 2010 - Debasish Ghosh / Twitter @debasishg

e.g. Netflix

- RDBMS
- SimpleDB
- Cassandra
- Hadoop/Hbase

Spring Data is here to help



For

NoSQL databases

http://www.springsource.org/spring-data

Agenda

- Why NoSQL? NewSQL?
- **Persisting entities**
- Implementing queries

Food to Go – Place Order use case

1. Customer enters delivery address and delivery time
2. System displays available restaurants
3. Customer picks restaurant
4. System displays menu
5. Customer selects menu items
6. Customer places order

Food to Go – Domain model (partial)

```
class Restaurant {
  long id;
  String name;
  Set<String> serviceArea;
  Set<TimeRange> openingHours;
  List<MenuItem> menuItems;
}
```

```
class TimeRange {
  long id;
  int dayOfWeek;
  int openingTime;
  int closingTime;
}
```

```
class MenuItem {
  String name;
  double price;
}
```

Database schema

ID	Name	...
1	Ajanta	
2	Montclair Eggshop	

RESTAURANT table

Restaurant_id	zipcode
1	94707
1	94619
2	94611
2	94619

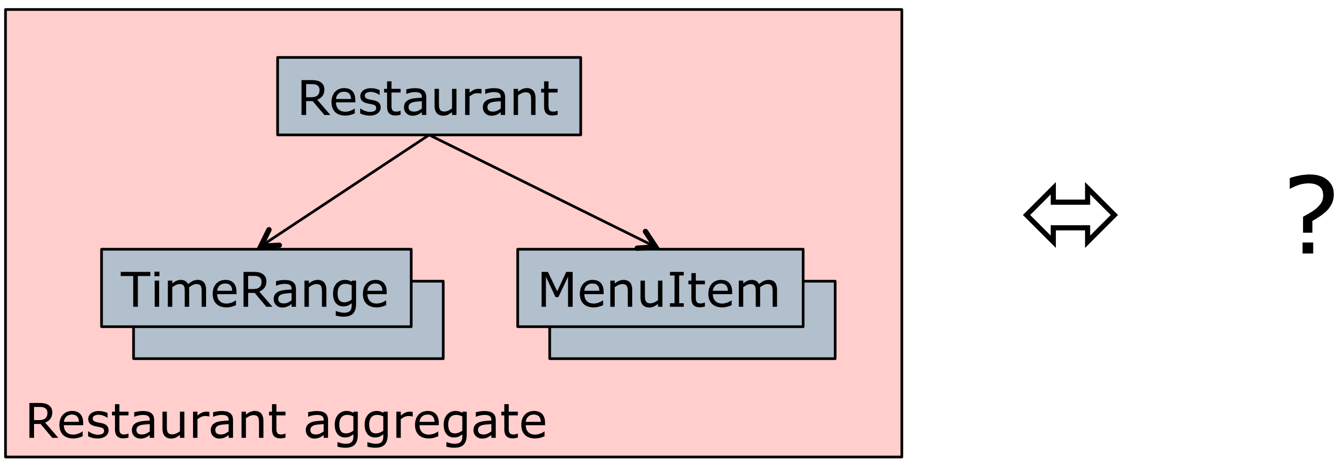
RESTAURANT_ZIPCODE table

RESTAURANT_TIME_RANGE table

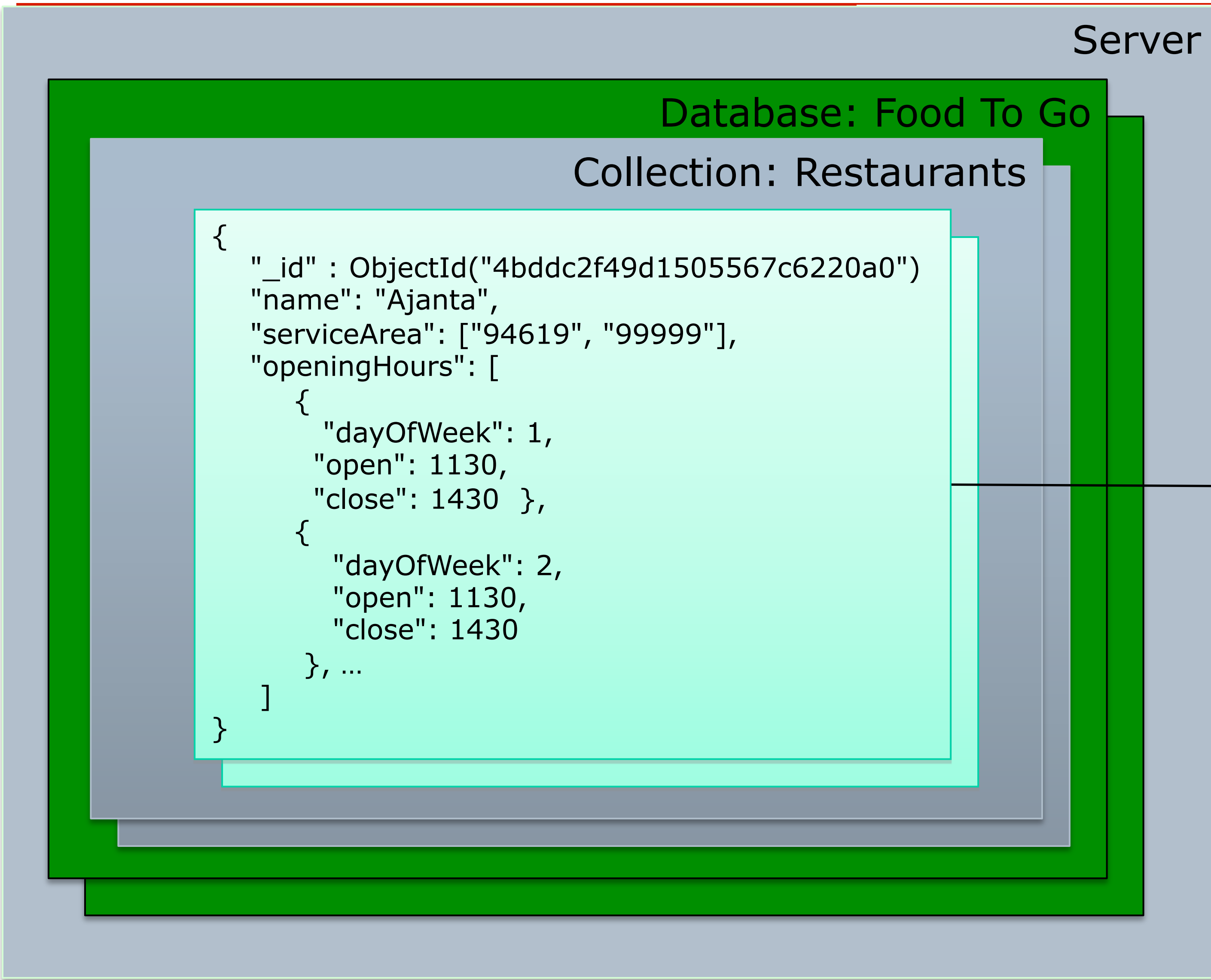
Restaurant_id	dayOfWeek	openTime	closeTime
1	Monday	1130	1430
1	Monday	1730	2130
2	Tuesday	1130	...

How to implement the repository?

```
public interface AvailableRestaurantRepository {

  void add(Restaurant restaurant);
  Restaurant findDetailsById(int id);
  …
}
```



MongoDB: persisting restaurants is easy



BSON = binary JSON

Sequence of bytes on disk ➔ fast i/o

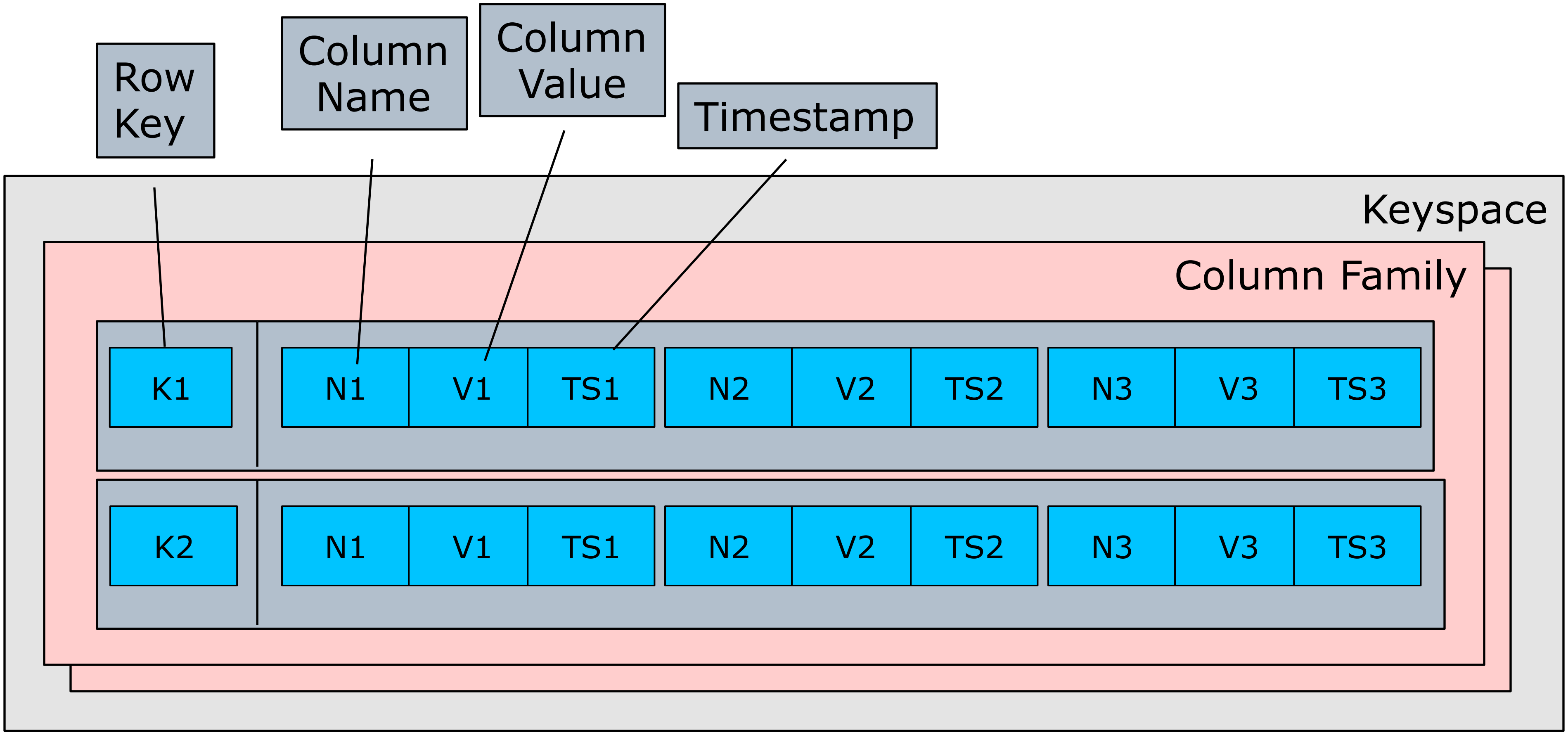
Spring Data for Mongo code

```
@Repository
public class AvailableRestaurantRepositoryMongoDbImpl
          implements AvailableRestaurantRepository {

  public static String AVAILABLE_RESTAURANTS_COLLECTION = "availableRestaurants";

  @Autowired
  private MongoTemplate mongoTemplate;

  @Override
  public void add(Restaurant restaurant) {
    mongoTemplate.insert(restaurant, AVAILABLE_RESTAURANTS_COLLECTION);
  }

 @Override
  public Restaurant findDetailsById(int id) {
      return mongoTemplate.findOne(new Query(where("_id").is(id)),
                                   Restaurant.class,
                                   AVAILABLE_RESTAURANTS_COLLECTION);
  }
}
```

Spring Configuration

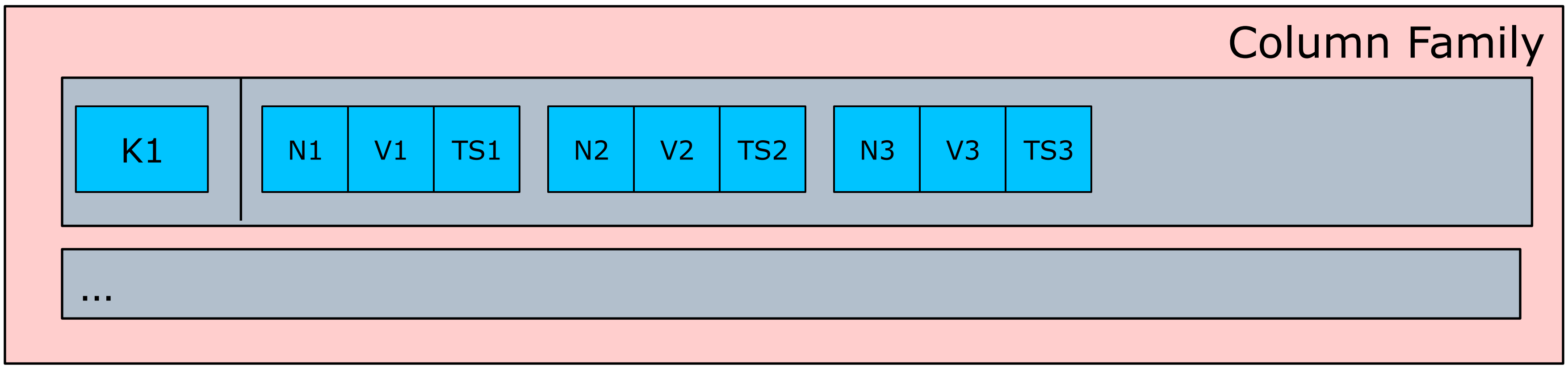
```
@Configuration
public class MongoConfig extends AbstractDatabaseConfig {

  @Value("#{mongoDbProperties.databaseName}")
  private String mongoDbDatabase;

 @Bean
  public Mongo mongo() throws UnknownHostException, MongoException {
    return new Mongo(databaseHostName);
  }

 @Bean
 public MongoTemplate mongoTemplate(Mongo mongo) throws Exception {
    MongoTemplate mongoTemplate = new MongoTemplate(mongo, mongoDbDatabase);
    mongoTemplate.setWriteConcern(WriteConcern.SAFE);
    mongoTemplate.setWriteResultChecking(WriteResultChecking.EXCEPTION);
    return mongoTemplate;
  }
}
```

Cassandra data model



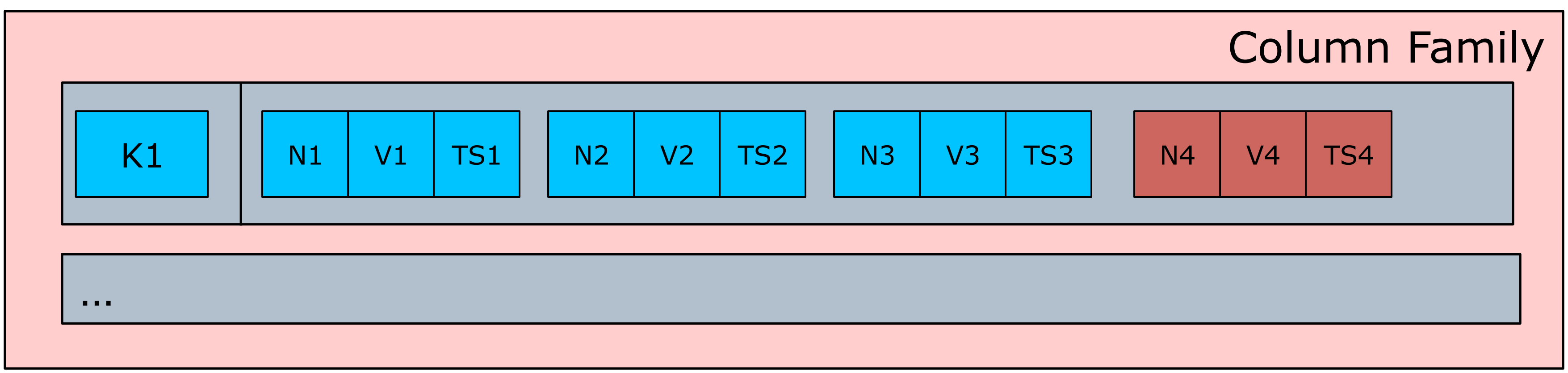
Column name/value: number, string, Boolean, timestamp, and **composite**

Cassandra– inserting/updating data

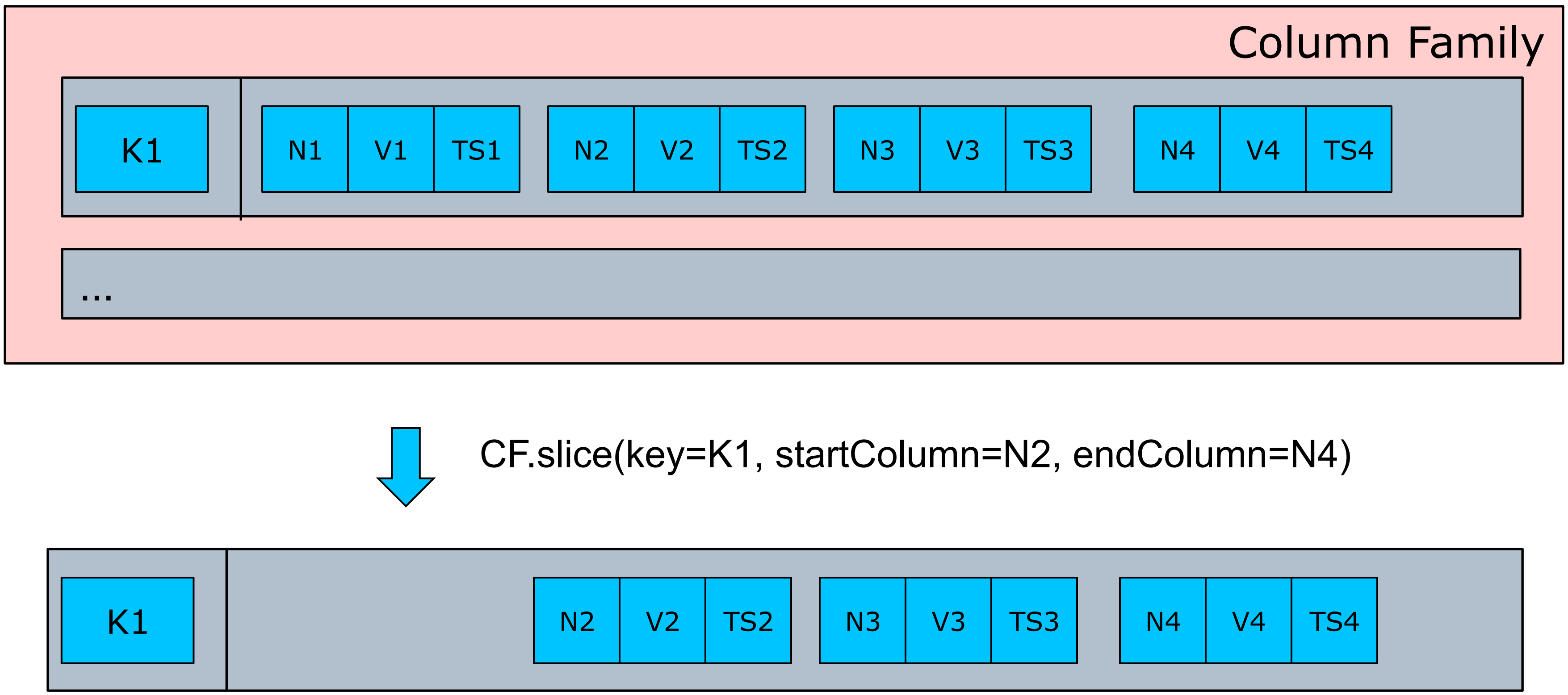


Idempotent= transaction

CF.insert(key=K1, (N4, V4, TS4), …)

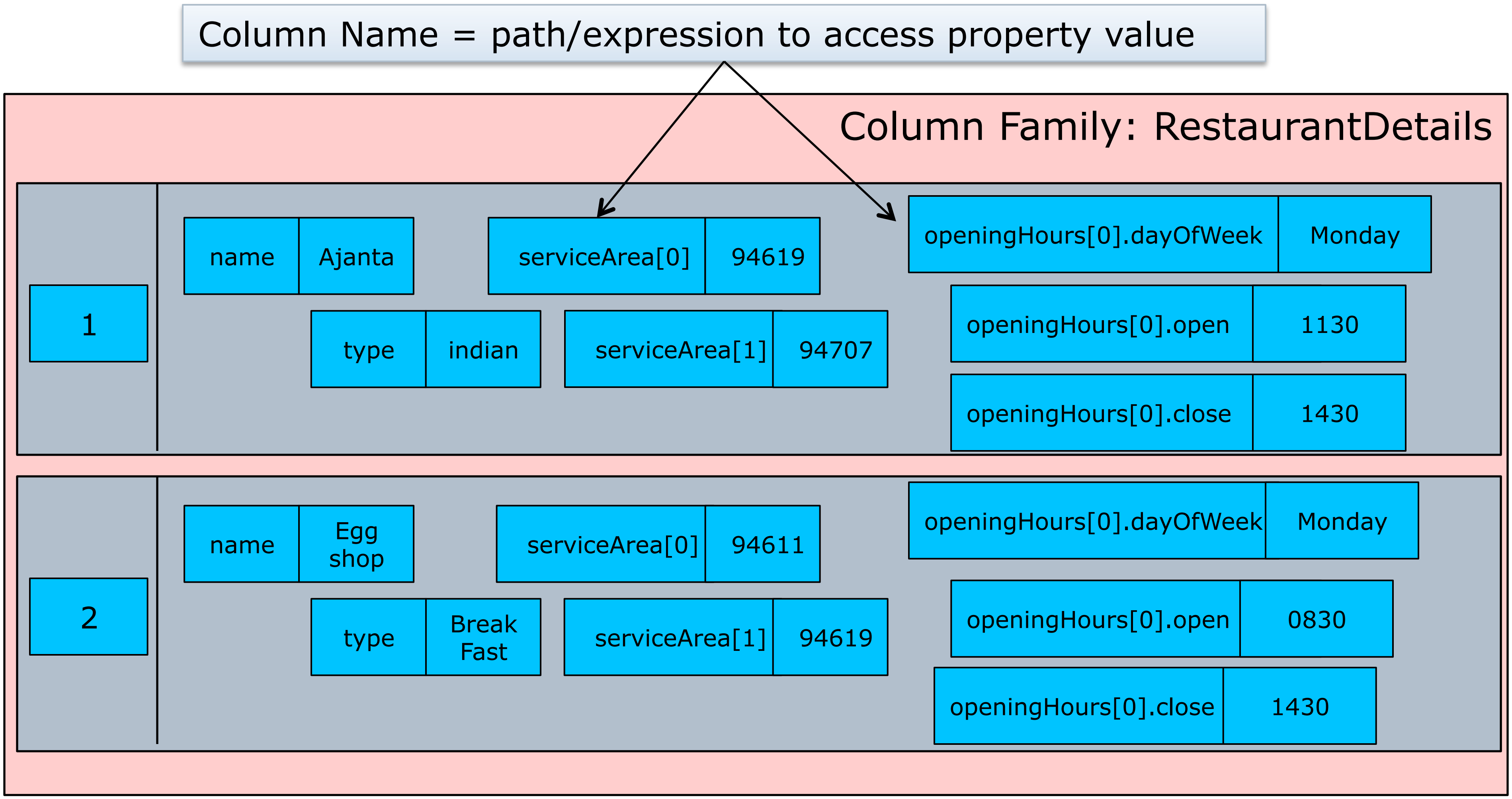


Cassandra– retrieving data

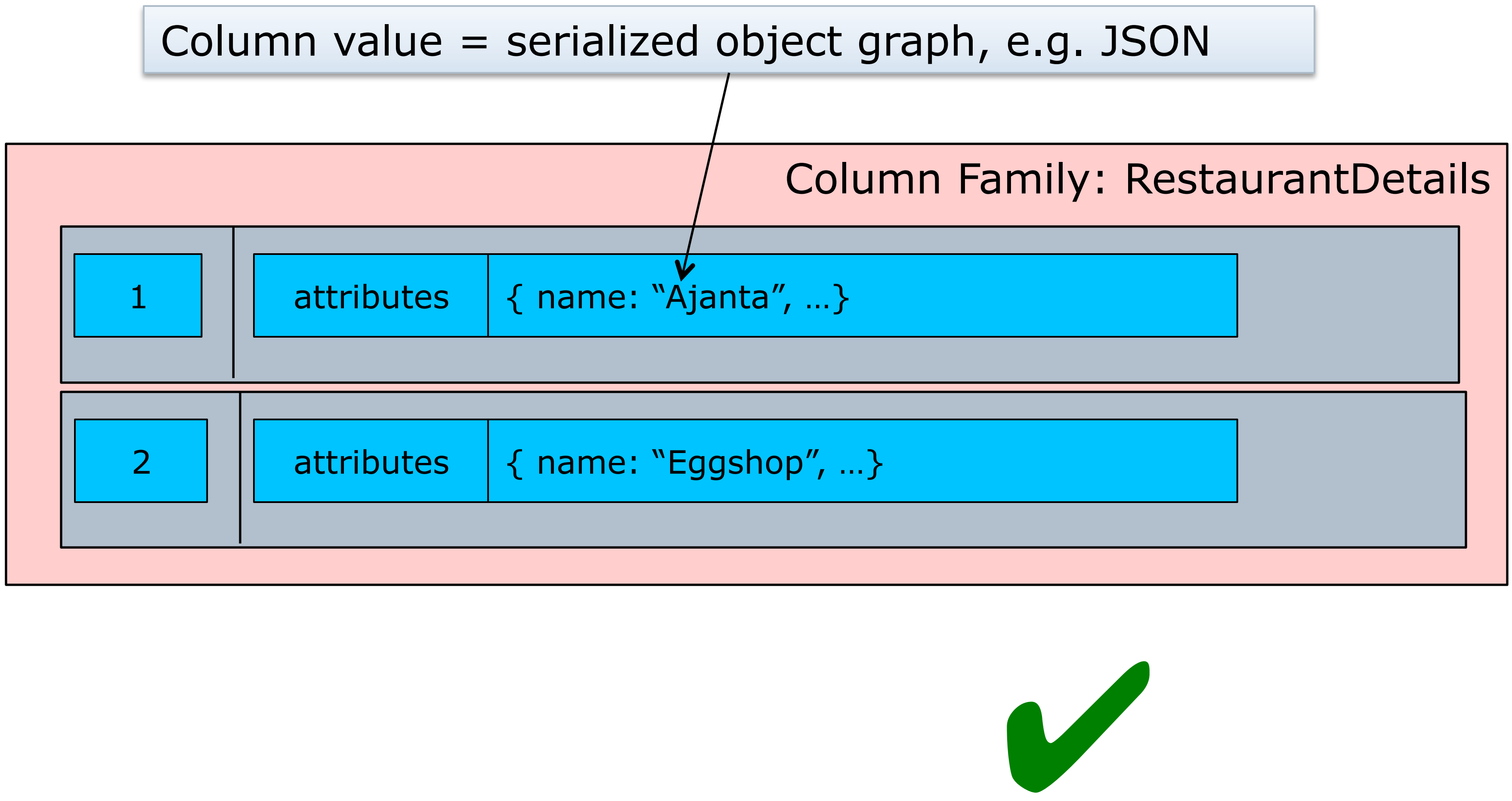


Cassandra has secondary indexes but they aren’t helpful for these use cases

Option #1: Use a column per attribute



Option #2: Use a single column



Cassandra code

```
public class AvailableRestaurantRepositoryCassandraKeyImpl
          implements AvailableRestaurantRepository {

@Autowired
private final CassandraTemplate cassandraTemplate;

public void add(Restaurant restaurant) {
  cassandraTemplate.insertEntity(keyspace,
                                 RESTAURANT_DETAILS_CF,
                                 restaurant);
}

public Restaurant findDetailsById(int id) {
    String key = Integer.toString(id);
    return cassandraTemplate.findEntity(Restaurant.class,
          keyspace, key, RESTAURANT_DETAILS_CF);
   …
}
```

…

Home grown wrapper class

Hector brought back to Troy. From a Roman sarcophagus of ca. 180–200 AD.

http://en.wikipedia.org/wiki/Hector

Using VoltDB

- Use the original schema
- Standard SQL statements

BUT YOU MUST

- Write stored procedures and invoke them using proprietary interface
- Partition your data

About VoltDB stored procedures

- Key part of VoltDB
- Replication = executing stored procedure on replica
- Logging = log stored procedure invocation
- Stored procedure invocation = transaction

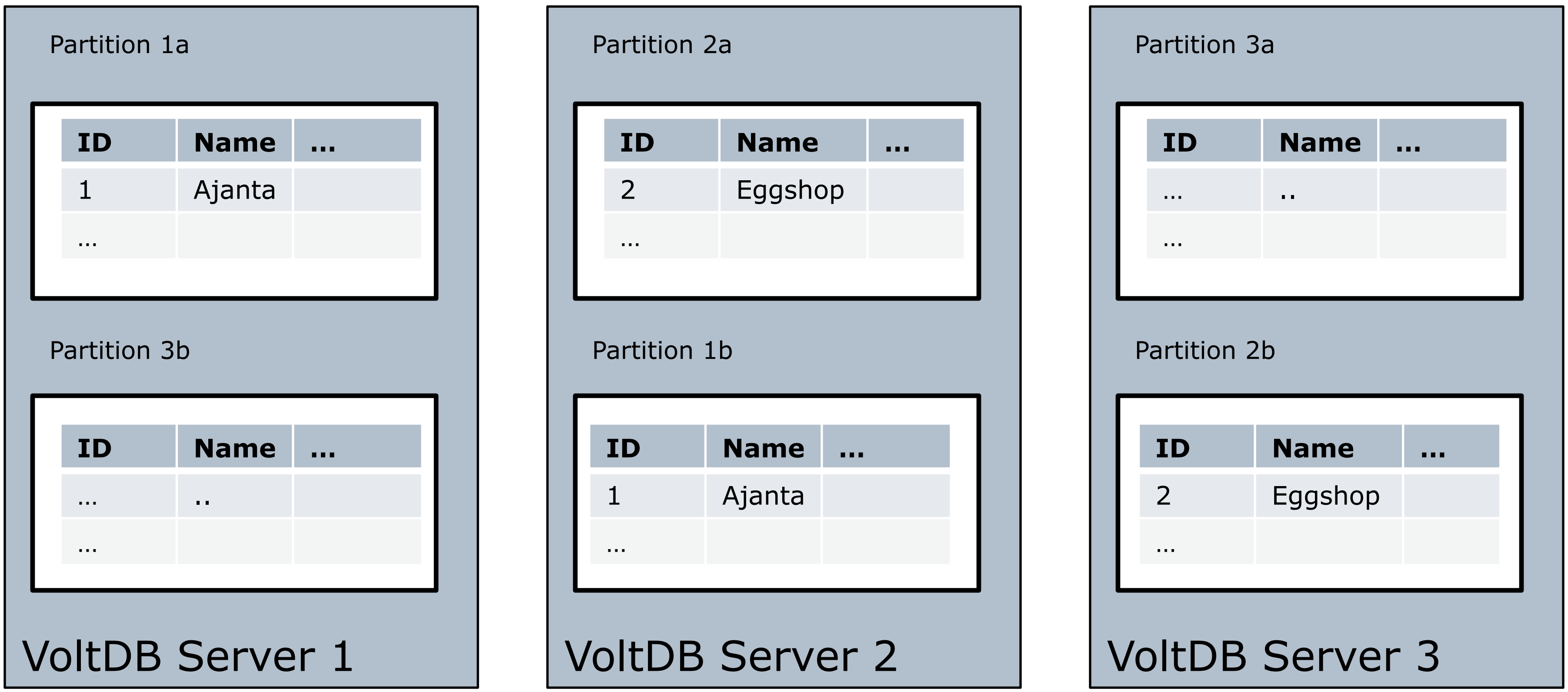
About partitioning

Partition column

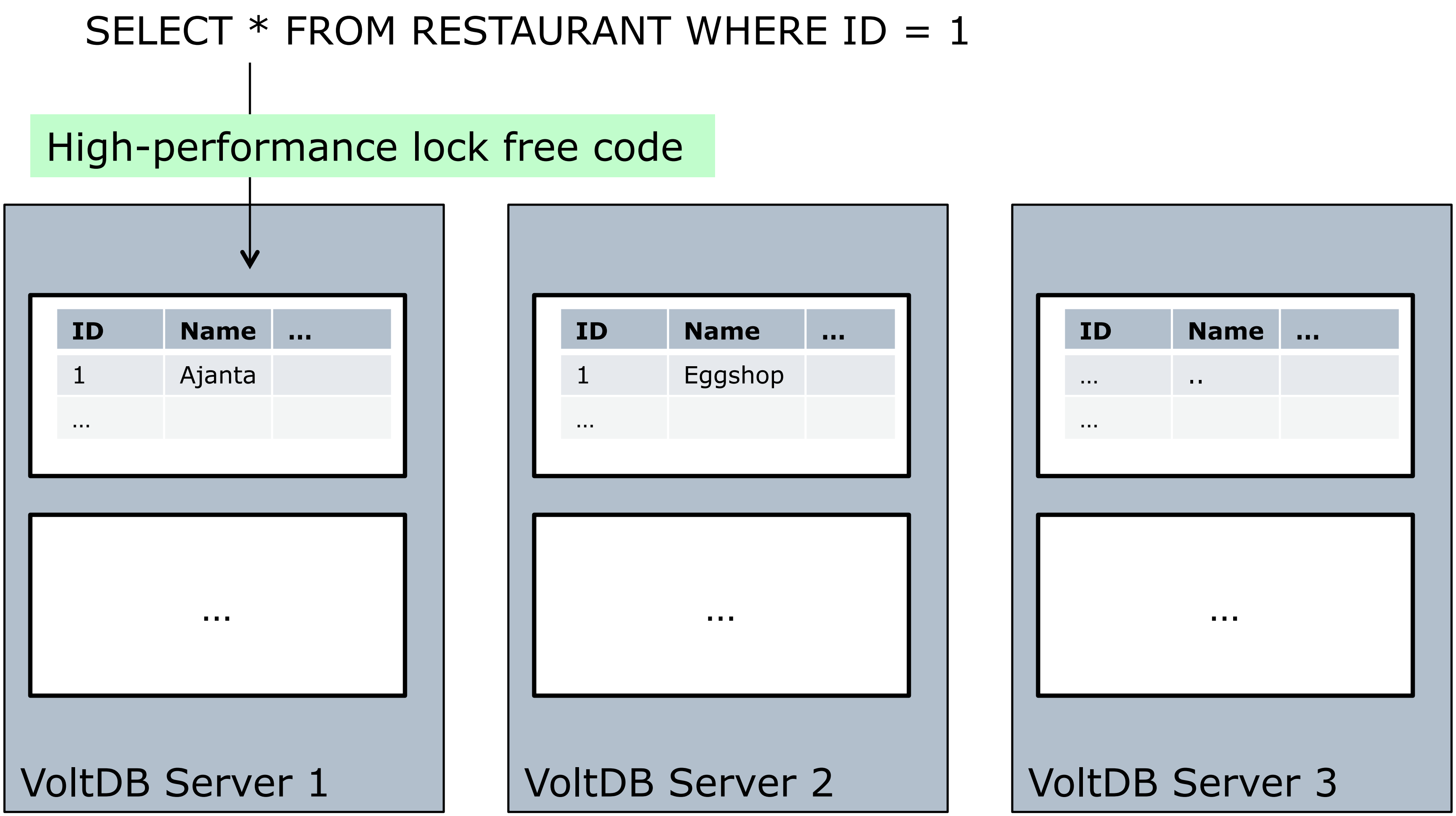
RESTAURANT table

ID	Name	...
1	Ajanta	
2	Eggshop	
...		

Example cluster

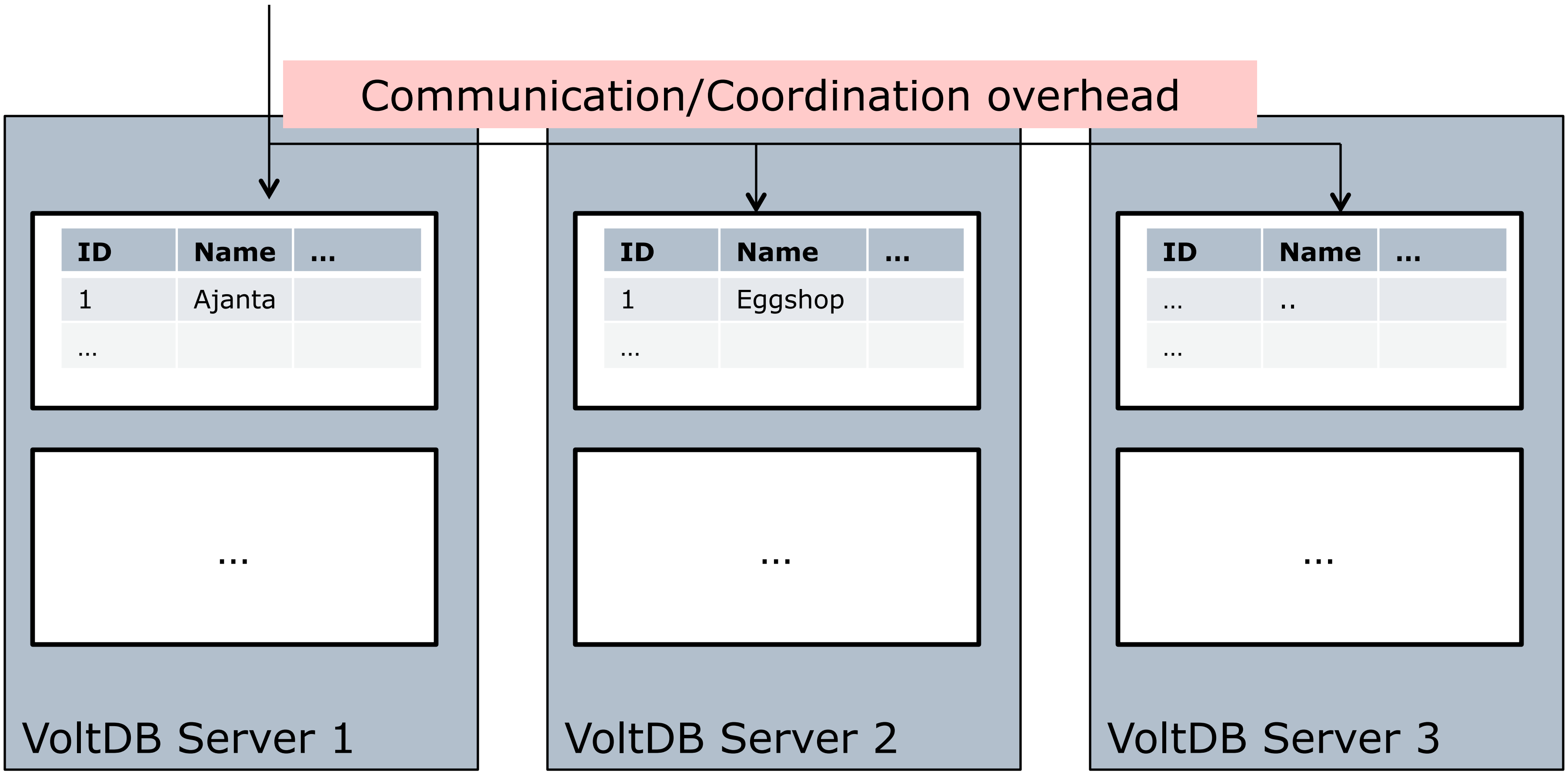


Single partition procedure: FAST



Multi-partition procedure: SLOWER

SELECT * FROM RESTAURANT WHERE NAME = ‘Ajanta’



Chosen partitioning scheme

```
<partitions>
    <partition table="restaurant" column="id"/>
    <partition table="service_area" column="restaurant_id"/>
    <partition table="menu_item" column="restaurant_id"/>
    <partition table="time_range" column="restaurant_id"/>
    <partition table="available_time_range" column="restaurant_id"/>
</partitions>
```

Performance is excellent: much faster than MySQL

Stored procedure – AddRestaurant

```
@ProcInfo( singlePartition = true, partitionInfo = "Restaurant.id: 0”)

public class AddRestaurant extends VoltProcedure {

  public final SQLStmt insertRestaurant =
              new SQLStmt("INSERT INTO Restaurant VALUES (?,?);");
  public final SQLStmt insertServiceArea =
              new SQLStmt("INSERT INTO service_area VALUES (?,?);");
  public final SQLStmt insertOpeningTimes =
              new SQLStmt("INSERT INTO time_range VALUES (?,?,?,?);");
  public final SQLStmt insertMenuItem =
              new SQLStmt("INSERT INTO menu_item VALUES (?,?,?);");

 public long run(int id, String name, String[] serviceArea, long[] daysOfWeek, long[] openingTimes,
                                            long[] closingTimes, String[] names, double[] prices) {

   voltQueueSQL(insertRestaurant, id, name);

   for (String zipCode : serviceArea)
      voltQueueSQL(insertServiceArea, id, zipCode);

   for (int i = 0; i < daysOfWeek.length ; i++)
      voltQueueSQL(insertOpeningTimes, id, daysOfWeek[i], openingTimes[i], closingTimes[i]);

   for (int i = 0; i < names.length ; i++)
      voltQueueSQL(insertMenuItem, id, names[i], prices[i]);

   voltExecuteSQL(true);

   return 0;
  }
}
```

VoltDb repository – add()

```
@Repository
public class AvailableRestaurantRepositoryVoltdbImpl
          implements AvailableRestaurantRepository {

  @Autowired
  private VoltDbTemplate voltDbTemplate;

  @Override
  public void add(Restaurant restaurant) {
    invokeRestaurantProcedure("AddRestaurant", restaurant);
  }

  private void invokeRestaurantProcedure(String procedureName, Restaurant restaurant) {
    Object[] serviceArea = restaurant.getServiceArea().toArray();
    long[][] openingHours = toArray(restaurant.getOpeningHours());
    Object[][] menuItems = toArray(restaurant.getMenuItems());

    voltDbTemplate.update(procedureName, restaurant.getId(), restaurant.getName(),
                          serviceArea, openingHours[0], openingHours[1],
                          openingHours[2], menuItems[0], menuItems[1]);
}
```

Flatten Restaurant

VoltDbTemplate wrapper class

```
public class VoltDbTemplate {

    private Client client;          VoltDB client API

    public VoltDbTemplate(Client client) {
      this.client = client;
    }

    public void update(String procedureName, Object... params) {
      try {
        ClientResponse x =
                  client.callProcedure(procedureName, params);
        …
    } catch (Exception e) {
        throw new RuntimeException(e);
      }
    }
```

VoltDb server configuration

```xml
<?xml version="1.0"?>
<project>
   <info>
      <name>Food To Go</name>
      ...
   </info>
   <database>
      <schemas>
         <schema path='schema.sql' />
      </schemas>

      <partitions>
            <partition table="restaurant" column="id"/>
            ...
      </partitions>

      <procedures>
         <procedure class='net.chrisrichardson.foodToGo.newsql.voltdb.procs.AddRestaurant' />
         ...
      </procedures>
   </database>
</project>
```

```xml
<deployment>
   <cluster hostcount="1"
         sitesperhost="5" kfactor="0" />
</deployment>
```

```
voltcompiler target/classes \
   src/main/resources/sql/voltdb-project.xml foodtogo.jar
```

```
bin/voltdb leader localhost catalog foodtogo.jar deployment deployment.xml
```

Agenda

- Why NoSQL? NewSQL?
- Persisting entities
- **Implementing queries**

Finding available restaurants

Available restaurants =

Serve the zip code of the delivery address

AND

Are open at the delivery time

```
public interface AvailableRestaurantRepository {

  List<AvailableRestaurant>
          findAvailableRestaurants(Address deliveryAddress,
                                   Date deliveryTime);  …
}
```

Finding available restaurants on Monday, 6.15pm for 94619 zip

```
select r.*
from restaurant r
 inner join restaurant_time_range tr
   on r.id =tr.restaurant_id
 inner join restaurant_zipcode sa
   on r.id = sa.restaurant_id
Where '94619' = sa.zip_code
and tr.day_of_week='monday'
and tr.openingtime <= 1815
and 1815 <= tr.closingtime
```

Straightforward three-way join

MongoDB = easy to query

```
{
  serviceArea:"94619",
  openingHours: {
    $elemMatch : {
          "dayOfWeek" : "Monday",
          "open": {$lte: 1815},
          "close": {$gte: 1815}
     }
  }
}
```

```
DBCursor cursor = collection.find(qbeObject);
while (cursor.hasNext()) {
    DBObject o = cursor.next();
    …
 }
```

```
db.availableRestaurants.ensureIndex({serviceArea: 1})
```

Find a restaurant that serves the 94619 zip code and is open at 6.15pm on a Monday

MongoTemplate-based code

```
@Repository
public class AvailableRestaurantRepositoryMongoDbImpl
                                   implements AvailableRestaurantRepository {

@Autowired private final MongoTemplate mongoTemplate;

@Override
public List<AvailableRestaurant> findAvailableRestaurants(Address deliveryAddress,
                                                          Date deliveryTime) {
  int timeOfDay = DateTimeUtil.timeOfDay(deliveryTime);
  int dayOfWeek = DateTimeUtil.dayOfWeek(deliveryTime);

  Query query = new Query(where("serviceArea").is(deliveryAddress.getZip())
          .and("openingHours").elemMatch(where("dayOfWeek").is(dayOfWeek)
                  .and("openingTime").lte(timeOfDay)
                  .and("closingTime").gte(timeOfDay)));

  return mongoTemplate.find(AVAILABLE_RESTAURANTS_COLLECTION, query,
                            AvailableRestaurant.class);
}
```

```
mongoTemplate.ensureIndex("availableRestaurants",
    new Index().on("serviceArea", Order.ASCENDING));
```

BUT how to do this with Cassandra??!

- How can Cassandra support a query that has
  - A 3-way join
  - Multiple =
  - > and <

?

➔ **We need to implement an index**

Queries instead of data model drives NoSQL database design

Simplification #1: Denormalization

Restaurant_id	Day_of_week	Open_time	Close_time	Zip_code
1	Monday	1130	1430	94707
1	Monday	1130	1430	94619
1	Monday	1730	2130	94707
1	Monday	1730	2130	94619
2	Monday	0700	1430	94619
…				

```
SELECT restaurant_id
 FROM time_range_zip_code
 WHERE day_of_week = 'Monday'
     AND zip_code = 94619
     AND 1815 < close_time
     AND open_time < 1815
```

Simpler query:

- No joins
- Two = and two <

Simplification #2: Application filtering

```
SELECT restaurant_id, open_time
 FROM time_range_zip_code
 WHERE day_of_week = ‘Monday’
    AND zip_code = 94619
    AND 1815 < close_time
    AND open_time < 1815
```

Even simpler query

- No joins
- Two = and one <

Simplification #3: Eliminate multiple ='s with concatenation

Restaurant_id	Zip_dow	Open_time	Close_time
1	94707:Monday	1130	1430
1	94619:Monday	1130	1430
1	94707:Monday	1730	2130
1	94619:Monday	1730	2130
2	94619:Monday	0700	1430
…			

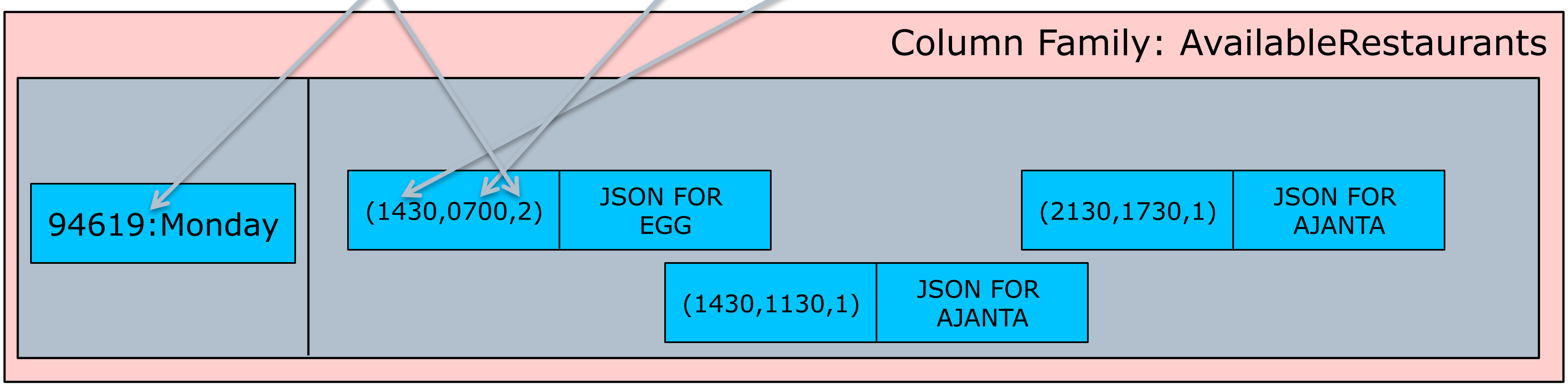
```
SELECT restaurant_id, open_time
 FROM time_range_zip_code
 WHERE zip_code_day_of_week = '94619:Monday'
   AND 1815 < close_time
```

key

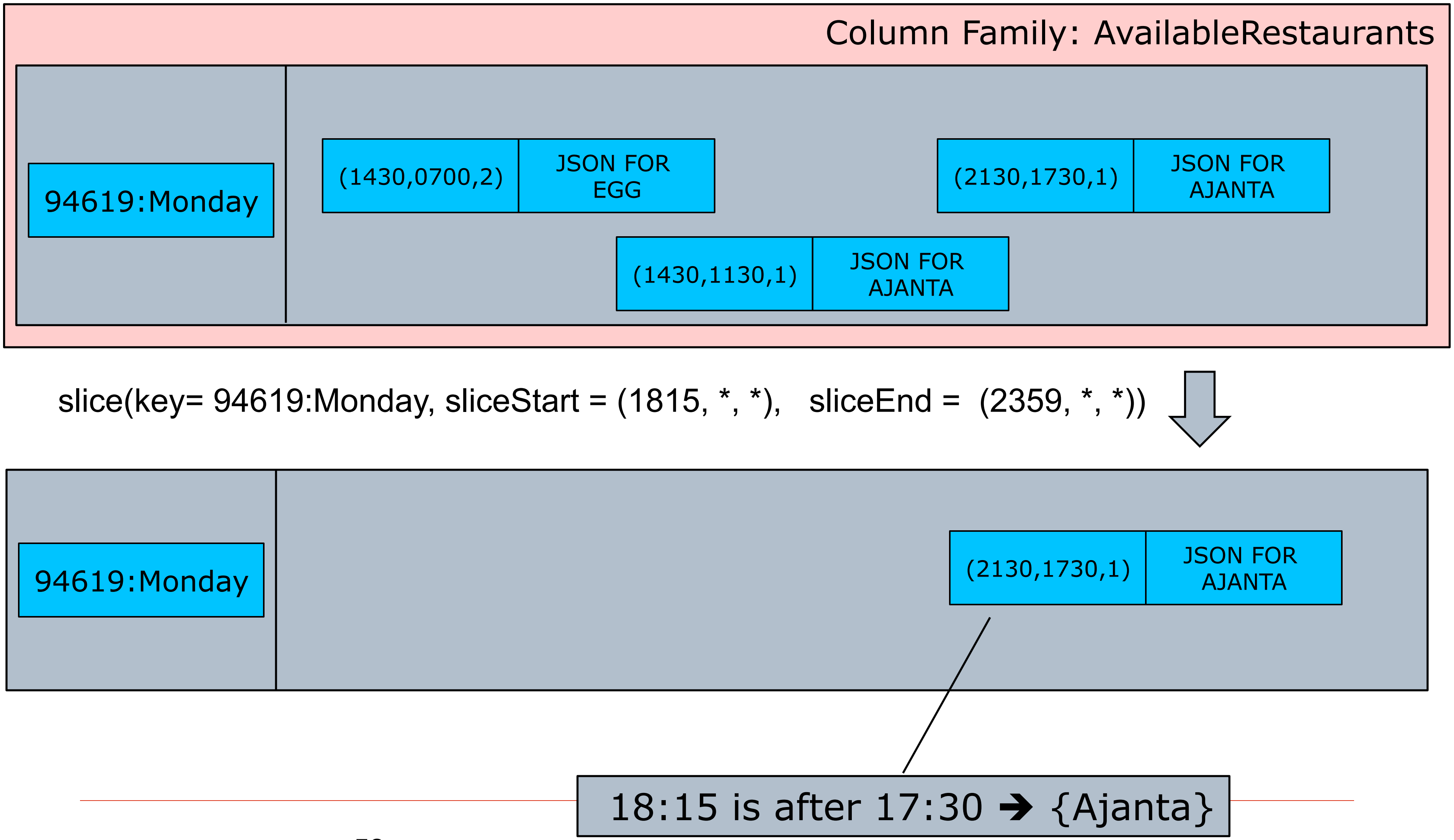
range

Column family with composite column names as an index

Restaurant_id	Zip_dow	Open_time	Close_time
1	94707:Monday	1130	1430
1	94619:Monday	1130	1430
1	94707:Monday	1730	2130
1	94619:Monday	1730	2130
2	94619:Monday	0700	1430
…			



Querying with a slice



Needs a few pages of code

```
private void insertAvailability(Restaurant restaurant) {

    for (String zipCode : (Set<String>) restaurant.getServiceArea()) {
```

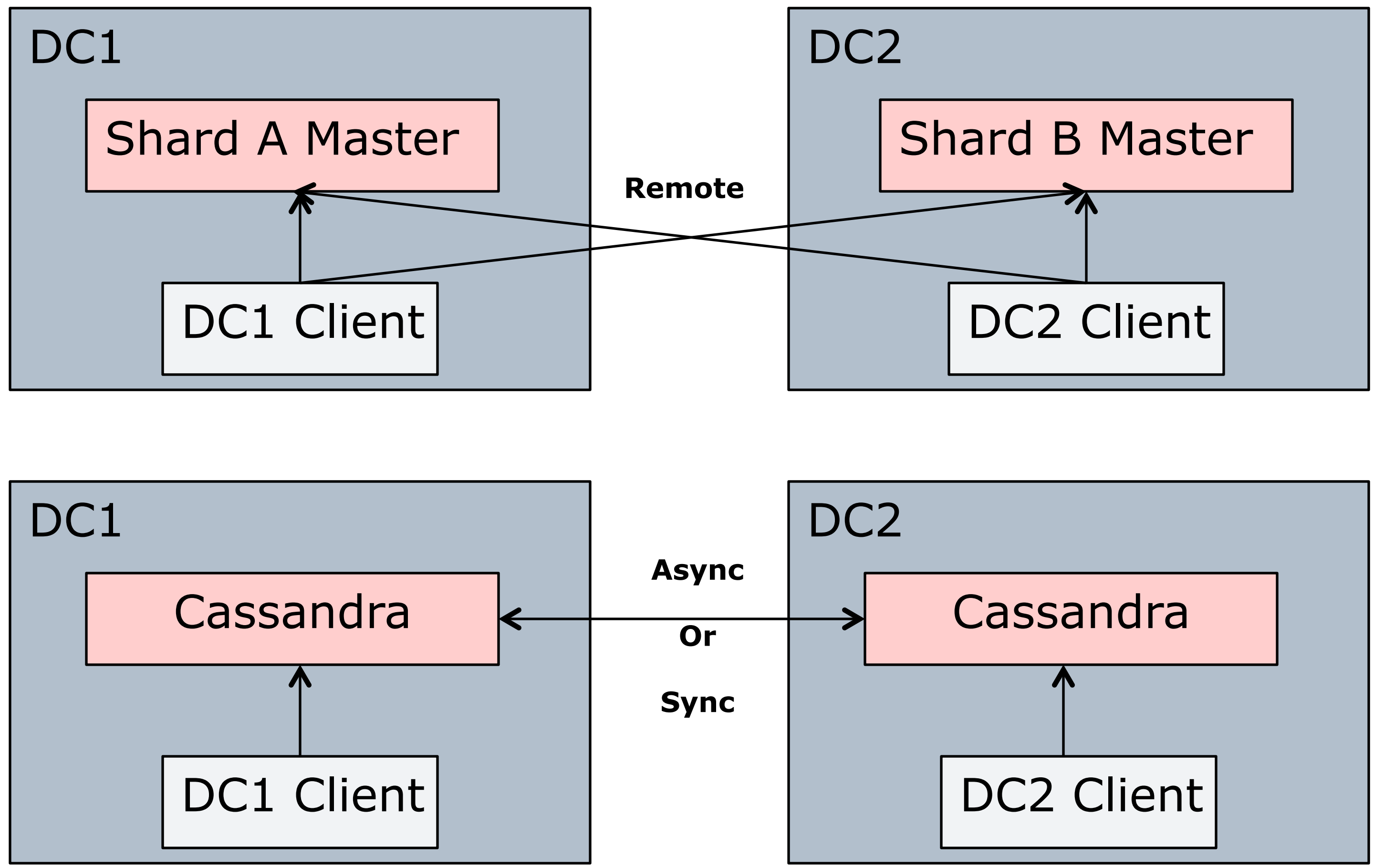
```
@Override
  public List<AvailableRestaurant> findAvailableRestaurants(Address deliveryAddress, Date deliveryTime) {
    int dayOfWeek = DateTimeUtil.dayOfWeek(deliveryTime);
    int timeOfDay = DateTimeUtil.timeOfDay(deliveryTime);
    String zipCode = deliveryAddress.getZip();
    String key = formatKey(zipCode, format2(dayOfWeek));

    HSlicePredicate<Composite> predicate = new HSlicePredicate<Composite>(new CompositeSerializer());
    Composite start = new Composite();
    Composite finish = new Composite();
    start.addComponent(0, format4(timeOfDay), ComponentEquality.GREATER_THAN_EQUAL);
    finish.addComponent(0, format4(2359), ComponentEquality.GREATER_THAN_EQUAL);
    predicate.setRange(start, finish, false, 100);

    final List<AvailableRestaurantIndexEntry> closingAfter = new ArrayList<AvailableRestaurantIndexEntry>();

    ColumnFamilyRowMapper<String, Composite, Object> mapper = new ColumnFamilyRowMapper<String, Composite, Object>() {

      @Override
      public Object mapRow(ColumnFamilyResult<String, Composite> results) {
        for (Composite columnName : results.getColumnNames()) {
          String openTime = columnName.get(1, new StringSerializer());
          String restaurantId = columnName.get(2, new StringSerializer());
          closingAfter.add(new AvailableRestaurantIndexEntry(openTime, restaurantId, results.getString(columnName)));
        }
        return null;
      }
    };

    compositeCloseTemplate.queryColumns(key, predicate, mapper);

    List<AvailableRestaurant> result = new LinkedList<AvailableRestaurant>();

    for (AvailableRestaurantIndexEntry trIdAndAvailableRestaurant : closingAfter) {
      if (trIdAndAvailableRestaurant.isOpenBefore(timeOfDay))
        result.add(trIdAndAvailableRestaurant.getAvailableRestaurant());
    }

    return result;
  }
```

What did I just do to query the data?

Mongo vs. Cassandra

MongoDB

Cassandra



VoltDB - attempt #1

```
@ProcInfo( singlePartition = false)
public class FindAvailableRestaurants extends VoltProcedure { ... }
```

```
ERROR 10:12:03,251   [main] COMPILER: Failed to plan for statement type(findAvailableRestaurants_with_join) select r.* from restaurant r,time_range tr, service_area sa   Where ? = sa.zip_code    and r.id =tr.restaurant_id    and r.id = sa.restaurant_id  and tr.day_of_week=? and tr.open_time <= ?  and ? <= tr.close_time Error: "Unable to plan for statement. Likely statement is joining two partitioned tables in a multi-partition statement. This is not supported at this time."
ERROR 10:12:03,251   [main] COMPILER: Catalog compilation failed.
```

Bummer!

VoltDB - attempt #2

```
@ProcInfo( singlePartition = true, partitionInfo = "Restaurant.id: 0”)
public class AddRestaurant extends VoltProcedure {

  public final SQLStmt insertAvailable=
              new SQLStmt("INSERT INTO available_time_range VALUES (?,?,?, ?, ?, ?);");

  public long run(....) {
              ...
   for (int i = 0; i < daysOfWeek.length ; i++) {
     voltQueueSQL(insertOpeningTimes, id, daysOfWeek[i], openingTimes[i], closingTimes[i]);
     for (String zipCode : serviceArea) {
      voltQueueSQL(insertAvailable, id, daysOfWeek[i], openingTimes[i],
                          closingTimes[i], zipCode, name);
     }
   }
              ...
   voltExecuteSQL(true);
   return 0;
  }
}
```

```
public final SQLStmt findAvailableRestaurants_denorm = new SQLStmt(
     "select restaurant_id, name from available_time_range tr " +
     "where ? = tr.zip_code " +
     "and tr.day_of_week=?  " +
     "and tr.open_time <= ? " +
     " and ? <= tr.close_time ");
```

Works but queries are only slightly faster than MySQL!

VoltDB - attempt #3

```
<partitions>
    ...
    <partition table="available_time_range" column="zip_code"/>
</partitions>
```

```
@ProcInfo( singlePartition = false, ...)
public class AddRestaurant extends VoltProcedure { ... }
```

```
@ProcInfo( singlePartition = true,
           partitionInfo = "available_time_range.zip_code: 0")
public class FindAvailableRestaurants extends VoltProcedure { ... }
```

Queries are really fast but inserts are not ☹

Partitioning scheme – optimal for some use cases but not others

Summary…

- Relational databases are great BUT there are limitations
- Each NoSQL database solves some problems BUT
  - Limited transactions: NoSQL = NoACID
  - One day needing ACID ➔ major rewrite
  - Query-driven, denormalized database design
  - …
- NewSQL databases such as VoltDB provides SQL, ACID transactions and incredible performance BUT
  - Not all operations are fast
  - Non-JDBC API

… Summary

- Very carefully pick the NewSQL/ NoSQL DB for your application
- Consider a polyglot persistence architecture
- Encapsulate your data access code so you can switch
- Startups = avoid NewSQL/NoSQL for shorter time to market?

Thank you!

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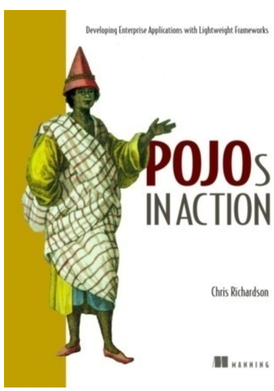

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