The Genealogy of Troy

Client-side Cassandra in Java with Hector & Astyanax

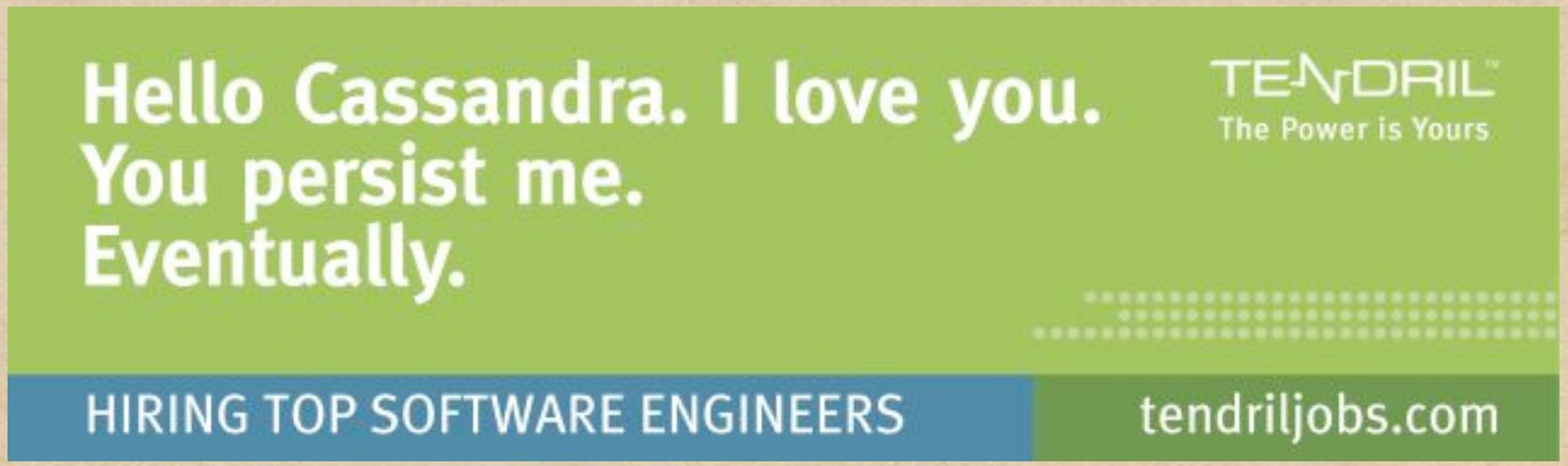
Joe McTee

About Me

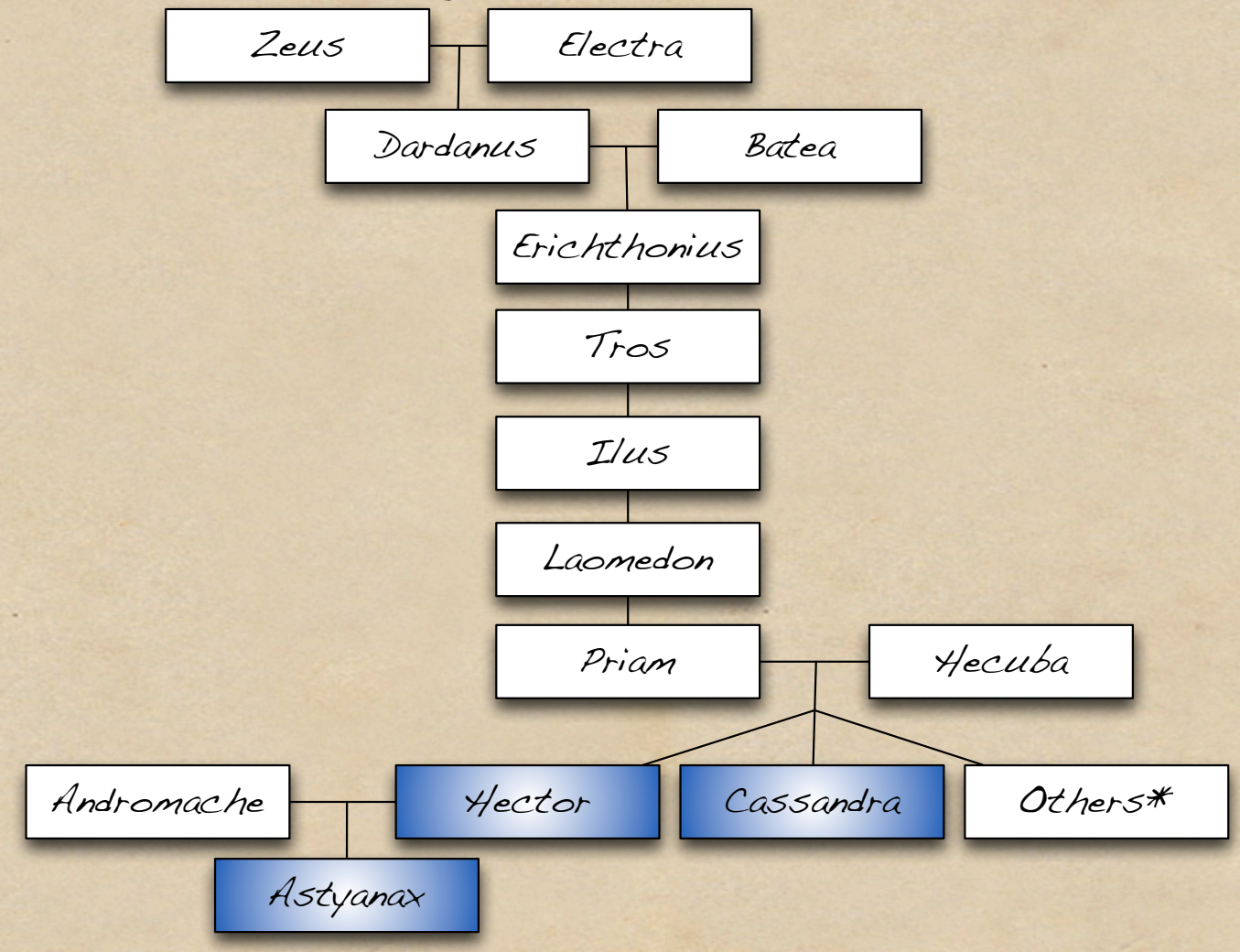
- Principal Engineer at Tendril Networks
- Experience with embedded programming, server-side Java (haven't done much web development)
- JEKLsoft is my sandbox for experiment and play
- Contact me at
  - mcjoe@jeklsoft.com / jmctee@tendrilinc.com
  - @jmctee on twitter
  - https://github.com/jmctee for teh codez

About Tendril

- We develop products that bring consumers, utilities, and consumer product manufacturers together in a partnership to save energy while maintaining quality of life
- And we're hiring!



The Family Tree



* Suggestions for aspiring library writers... Paris, Helenus, Ilione, Deiphobus, Troilus, Polites, Creusa, Laodice, Polyxena, Polydorus

The "Contrived" Problem

- We want to collect atmospheric readings in multiple cities
- In each city, we deploy a large number of sensors
- Sensors transmit a reading every 15 minutes via a web service call
  - Web service back-end stores the data
- Data will be queried by sensor and range of reading times
- Each sensor "reading" is a combination of multiple measurements
- The types for each reading form the contrivance...
  - Strings are boring and don't expose design issues
  - Chosen types probably not optimal for readings

A Reading

- ID of sensor that took reading (UUID)
- Time of reading (DateTime)
- Air Temperature in Celsius (BigDecimal)
- Wind Speed in kph (Integer)
- Wind Direction as compass abbreviation (String)
- Relative Humidity as percent (BigInteger)
- Bad Air Quality Detected flag (Boolean)

Where are we going to store the data?

Cassandra!

Why Cassandra?

- Optimized for fast writes
  - We need that because we have "lots" of sensors
- Highly scalable
  - Add a node, scale increases
- Tunable to provide high availability and/or high consistency
  - Independent write & read consistency levels
  - There are tradeoffs here, but key is we control it

Cassandra in 1 Slide

- Node - A Cassandra instance responsible for storing a pre-defined range of information (row keys)
- Cluster - group of Cassandra nodes organized in a ring, such that all possible row key ranges are covered by one "or more" nodes
- Keyspace - A grouping of column (or super column) families
- Column Family - An ordered collection of Rows that contain columns
- Super Column Family - An ordered collection of Rows that contain super columns
- Row - Key to access a given set of orderable (by name, not value!) columns or super columns
- Column - A name/value pair
  - +meta data: timestamp and time-to-live (TTL)
- Super Column - A name/column pair

OK, maybe not...

- Columns are multi-dimensional maps
  - [keyspace] [column family] [row] [column]
- And super columns add one more dimension
  - [keyspace] [column family] [row] [super column] [column]
- All columns (or super columns) for a given row key are stored on the same node
- Name/Value store
  - Not an RDMS
  - No joins, denormalization is your friend.

```
Cluster:
     Keyspace:
          Column Family:
               Row:
                    Column: name/value/timestamp/ttl
                    ...
                    Column: name/value/timestamp/ttl
               ...
               Row:
                    Column: name/value/timestamp/ttl
                    ...
                    Column: name/value/timestamp/ttl
          Super Column Family:
               Row:
                    Super Column:
                         Column: name/value/timestamp/ttl
                         ...
                         Column: name/value/timestamp/ttl
                    ...
                    Super Column:
                         Column: name/value/timestamp/ttl
                         ...
                         Column: name/value/timestamp/ttl
               ...
               Row:
                    Super Column:
                         Column: name/value/timestamp/ttl
                         ...
                         Column: name/value/timestamp/ttl
                    ...
                    Super Column:
                         Column: name/value/timestamp/ttl
                         ...
                         Column: name/value/timestamp/ttl
```

Compact JSONish Schema

- This notation is derived from WTF-is-a-SuperColumn (see references)
  - Ditch the timestamp & TTL from Column
  - Pull the Columns' and SuperColumns' name component out so that it looks like a key/value pair.

Example JSONish

```
Info: {
    Contacts: {
        People: {
            McTee_Joe: {
                street: "Tendril Plaza",
                city: "Boulder",
                zip: "80301",
                phone: "555.555.5555"
            }
            Someone_Else: {
                phone: "555.555.1234"
            }
        }
    }
}
```

Download the code

- Public project, please fork/contribute/provide feedback!
- Pre-download requirements
  - Git
  - Maven 3
- In directory where you want project
  - git clone git@github.com:jmctee/Cassandra-Client-Tutorial.git
  - Project readme file has link to slides

Run with Maven

- Does not require Cassandra to be installed on machine
  - Uses Embedded Cassandra
- Note: POM specifies forked tests. This is required!
  - <forkMode>pertest</forkMode>
- mvn clean test
  - "Tests run: 70, Failures: 0, Errors: 0, Skipped: 0"
  - Ready to experiment

Installing Cassandra

- Download tarball from http://cassandra.apache.org/download/
  - e.g., apache-cassandra-1.0.8-bin.tar.gz
  - I like to put these in /opt, then
  - sudo ln -s /opt/apache-cassandra-1.0.8 /opt/cassandra
  - Add /opt/cassandra/bin to your path
  - Upgrading Cassandra is simply a new sym-link
    - ...and editing config described in next step

Configuring Cassandra

- This is for development use, not a production configuration!
- Assume $HOME is absolute path below, e.g., /Users/joemctee
  - Relative paths, e.g., ~, or env vars, e.g. $HOME don't work in config files
- Make some directories
  - $HOME/cassandra/
  - $HOME/cassandra/data
  - $HOME/cassandra/commitlog
  - $HOME/cassandra/saved_caches
  - $HOME/cassandra/log
- Edit /opt/cassandra/conf/cassandra.yaml
  - Globally replace /var/lib with $HOME
- Edit /opt/cassandra/conf/log4j-server.properties
  - Globally replace /var/log/cassandra with $HOME/cassandra/log

Starting Cassandra

- If /opt/cassandra/bin is in your path, from a terminal
  - cassandra -f
    - -f option keeps process in foreground, easier to kill that way
  - ctrl-c to stop
    - Without -f option, need to find and kill process

Using the CLI

- If /opt/cassandra/bin is in your path, from a terminal
  - cassandra-cli
- help; for help
- exit; to quit
- Example session (super column):

```
connect localhost/9160;
drop keyspace Climate;
create keyspace Climate;
use Climate;
create column family BoulderSensors with column_type = 'Super';
list BoulderSensors;
```

- Example session (super column):

```
connect localhost/9160;
drop keyspace Climate;
create keyspace Climate;
use Climate;
create column family BoulderSensors;
list BoulderSensors;
```

Embedded Cassandra

- com.jeklsoft.cassandraclient.EmbeddedCassandra
  - wraps org.apache.cassandra.service.EmbeddedCassandraService
  - No dependencies on Hector or Astyanax
  - Great tool for unit testing after things are working
  - No CLI, so not as great for debugging
  - Uses builder pattern for easy construction
    - Set and forget
  - Uses port 9161, so can run embedded and stand-alone instances simultaneously
    - Note: These are separate instances, not data sharing

Starting Embedded Cassandra

```
public class TestEmbeddedCassandra {

    private static final String embeddedCassandraHostname = "localhost";
    private static final Integer embeddedCassandraPort = 9161;
    private static final String embeddedCassandraKeySpaceName = "TestKeyspaceName";
    private static final String columnFamilyName = "TestColumnName";
    private static final String configurationPath = "target/cassandra";

    @Test
    public void sunnyDayTest() throws Exception {
        List<String> cassandraCommands = new ArrayList<String>();
        cassandraCommands.add("create keyspace " + embeddedCassandraKeySpaceName + ";");
        cassandraCommands.add("use " + embeddedCassandraKeySpaceName + ";");
        cassandraCommands.add("create column family " + columnFamilyName");

        URL cassandraYamlUrl = TestEmbeddedCassandra.class.getClassLoader()
                                                  .getResource("cassandra.yaml");
        File cassandraYamlFile = new File(cassandraYamlUrl.toURI());

        EmbeddedCassandra embeddedCassandra = EmbeddedCassandra.builder()
                .withCleanDataStore()
                .withStartupCommands(cassandraCommands)
                .withHostname(embeddedCassandraHostname)
                .withHostport(embeddedCassandraPort)
                .withCassandaConfigurationDirectoryPath(configurationPath)
                .withCassandaYamlFile(cassandraYamlFile)
                .build();

        assertNotNull(embeddedCassandra);
    }
}
```

Last building block, Serializers

- Everything is stored as a byte array in Cassandra
  - Serializers convert objects to / from ByteBuffer
  - public ByteBuffer toByteBuffer(T obj);
  - public T fromByteBuffer(ByteBuffer byteBuffer);
  - Hector and Astyanax provide serializers for most basic types
  - We need to provide serializers for non-standard types: DateTime, BigDecimal, Reading

Let's Model a Reading

Keyspace & Column Family

- Keyspace: Climate
- Column Family: BoulderSensors
  - One Column Family per City

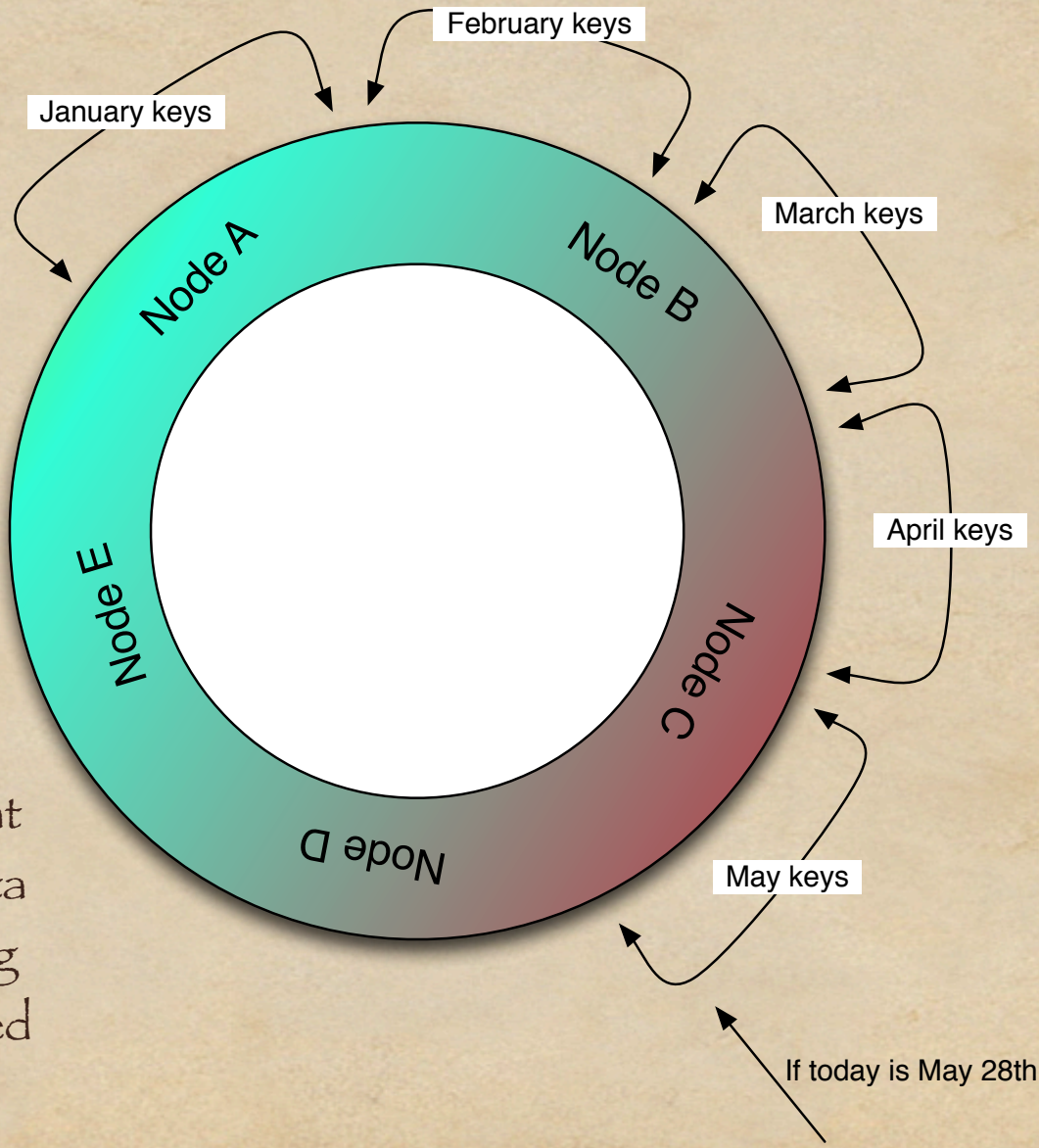
Selection of Row Key

- Need to query by Sensor ID and TimeStamp range
  - So two possible row key candidates

If We Choose TimeStamp

- We need to query on sequential ranges of TimeStamps
  - This implies we must use Order-Preserving Partitioning (OP) for the cluster
  - Cassandra requires OP for range queries of row keys (performance optimization)
  - No such requirement for range queries of column names (because all columns are co-located on one node)
- Column key would be Sensor ID

Hot Spots!

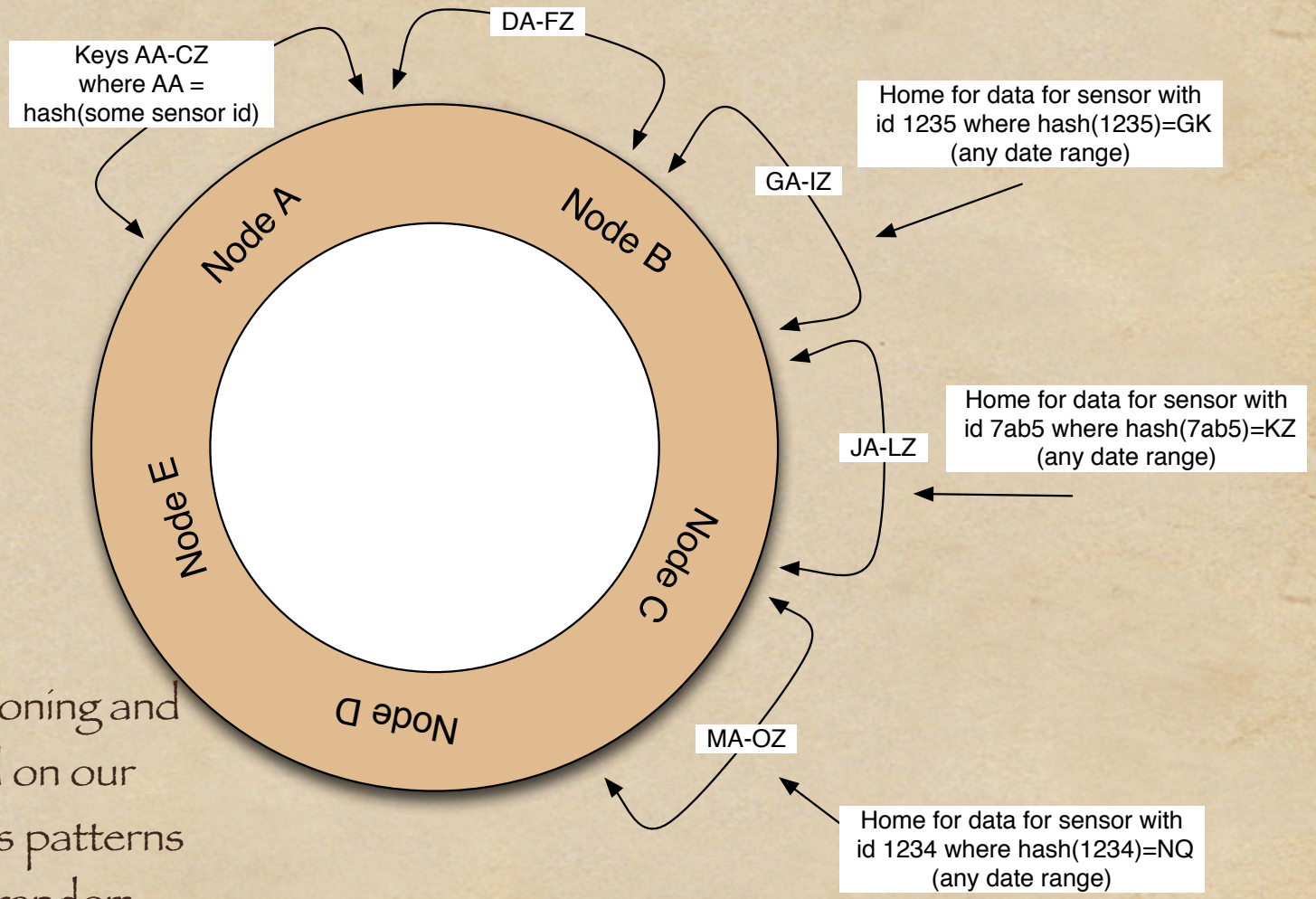


Theoretical partitioning and heat map based on writing sensor data for a ring using order-preserving partitioning with timestamp-based row keys.

If We Choose Sensor ID

- Don't need to query for ranges of IDs
- Can use Random Partitioner (RP)
  - Nodes are assigned ranges of hash values
  - Row keys are hashed and stored based on value
  - For large number of row keys distribution is random
- Column key would be TimeStamp

Writes are evenly distributed

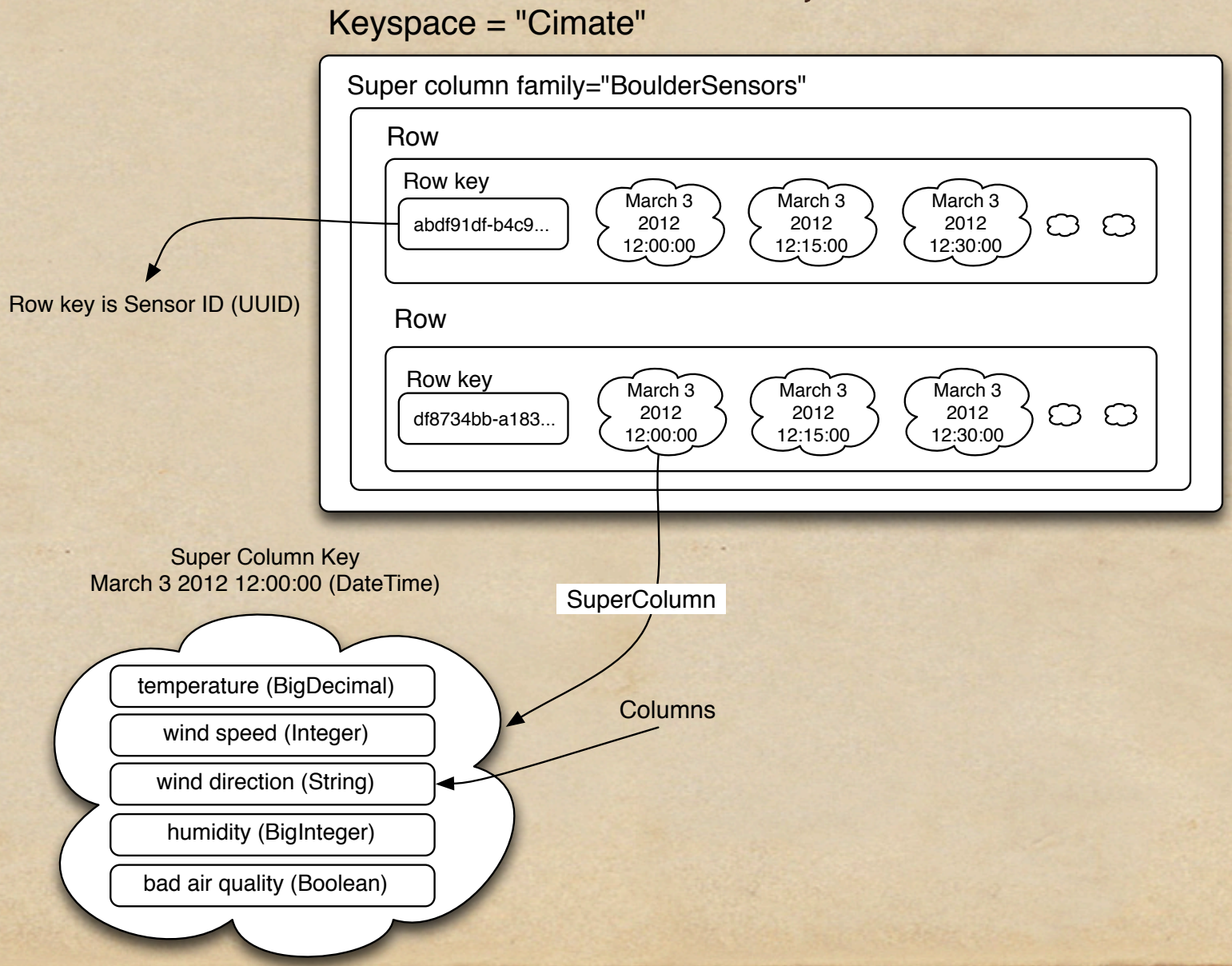


Theoretical partitioning and heat map based on our sensor data access patterns for a ring using random partitioning with hashed row keys based on Sensor IDs

So Row Key is Sensor ID

- Note: if we needed to query ranges of sensors, would have to handle in application code
  - Essentially, multiple queries with the application doing the join
  - Possibly solve with Cassandra composite key
  - A good candidate for Map-Reduce?
  - YAGNI

Looks like a Job for Super Columns!



Using JSONish Notation

```
SensorNet: {
    Climate: {
        BoulderSensors: {
            March 3 2012 12:00:00: {
                Temperature: 23.0
                WindSpeed: 16
                WindDirection: "W"
                Humidity: 17
                BadAirQualityDetected: false
            }
        }
    }
}
```

Hector with Super Columns

Snapshot from the CLI

```
[default@Climate] list BoulderSensors;
Using default limit of 100
-------------------
RowKey: 00000000000000000000000000000c8
=> (super_column=00000135fe7bcebd,
     (column=4261644169725175616c697479446574656356 3746564, value=00, timestamp=1331414421255004, ttl=31536000)
     (column=48756d6964697479, value=11, timestamp=1331414421255003, ttl=31536000)
     (column=54656d7065726174757265, value=31392e35, timestamp=1331414421255000, ttl=31536000)
     (column=57696e64446972656374696f6e, value=455345, timestamp=1331414421255002, ttl=31536000)
     (column=57696e645370656564, value=00000018, timestamp=1331414421255001, ttl=31536000))

...

=> (super_column=00000135fef7675d,
     (column=4261644169725175616c697479446574656356 3746564, value=00, timestamp=1331414421257039, ttl=31536000)
     (column=48756d6964697479, value=11, timestamp=1331414421257038, ttl=31536000)
     (column=54656d7065726174757265, value=31382e36, timestamp=1331414421257035, ttl=31536000)
     (column=57696e64446972656374696f6e, value=455345, timestamp=1331414421257037, ttl=31536000)
     (column=57696e645370656564, value=00000018, timestamp=1331414421257036, ttl=31536000))
-------------------
RowKey: 00000000000000000000000000000064
=> (super_column=00000135fe7bcebd,
     (column=4261644169725175616c697479446574656356 3746564, value=00, timestamp=1331414421246003, ttl=31536000)
     (column=48756d6964697479, value=11, timestamp=1331414421246002, ttl=31536000)
     (column=54656d7065726174757265, value=32332e30, timestamp=1331414421240000, ttl=31536000)
     (column=57696e64446972656374696f6e, value=57, timestamp=1331414421246001, ttl=31536000)
     (column=57696e645370656564, value=00000010, timestamp=1331414421246000, ttl=31536000))

...

=> (super_column=00000135fef7675d,
     (column=4261644169725175616c697479446574656356 3746564, value=00, timestamp=1331414421257033, ttl=31536000)
     (column=48756d6964697479, value=11, timestamp=1331414421257032, ttl=31536000)
     (column=54656d7065726174757265, value=32332e39, timestamp=1331414421257029, ttl=31536000)
     (column=57696e64446972656374696f6e, value=57, timestamp=1331414421257031, ttl=31536000)
     (column=57696e645370656564, value=00000010, timestamp=1331414421257030, ttl=31536000))

2 Rows Returned.
Elapsed time: 86 msec(s).
[default@Climate]
```

Super Column Issues

- Every sub-column has overhead
  - Choice of string for key adds some overhead
    - We control that, could change
  - Every sub-column has Cassandra timestamp and TTL
    - We don't control that, stuck with it
- Remember, queries are at the row level
  - We must pull in the entire super column for each request we want
- So super column queries can be expensive

Enter Protocol Buffers

- Developed by Google
- Provide efficient way to serialize/deserialize objects
- Fall back to standard Cassandra column and store an entire reading as a serialized protocol buffer
- ProtoBuf uses ByteString, not ByteBuffer
  - Google type
- Both approaches are valid, we have to handle the impedance mismatch

Protocol Buffer Intro

- Developed and open-sourced by Google
  - http://code.google.com/apis/protocolbuffers/
- ProtoBuf definition created in .proto file using a DSL
- Then translated to Java file using ProtoBuf complier
  - protoc --java_out=../src/main/java/ reading_buffer.proto
- Provides a builder interface to create and use the object

Example .proto file

```
package com.jeklsoft.cassandraclient;

option java_package = "com.jeklsoft.cassandraclient";
option java_outer_classname = "ReadingBuffer";

message Reading {
  optional bytes temperature = 1; // BigDecimal
  optional int32 wind_speed = 2; // Integer
  optional string wind_direction = 3; // String
  optional bytes humidity = 4; // BigInteger
  optional bool bad_air_quality_detected = 5; // Boolean
}
```

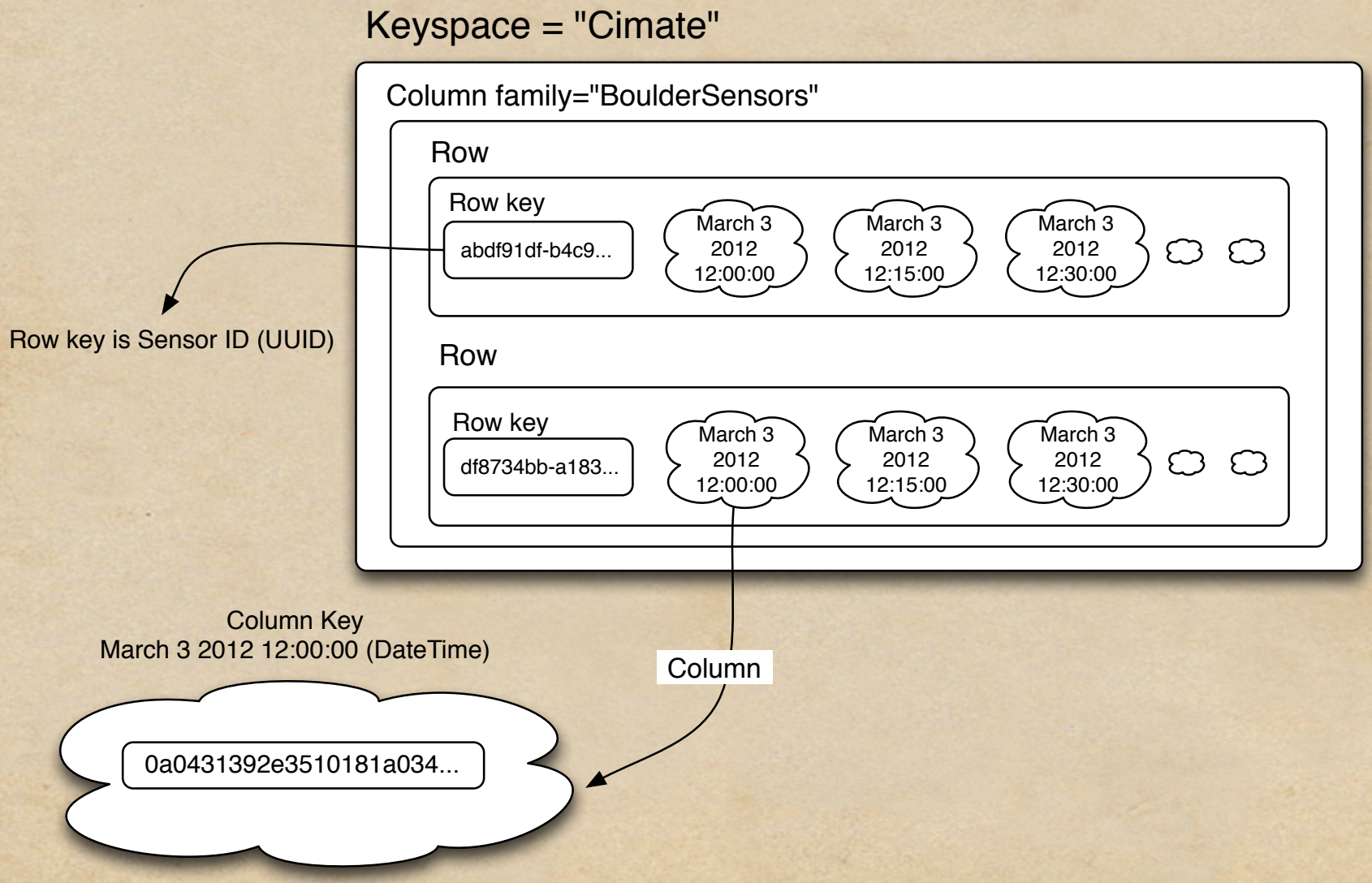
Using a ProtoBuf

```
private static ReadingBuffer.Reading getBufferedReading(Reading reading) {
    return ReadingBuffer.Reading.newBuilder()
            .setTemperature(getByteString(BigDecimalSerializer.get(),
                                          reading.getTemperature()))
            .setWindSpeed(reading.getWindSpeed())
            .setWindDirection(reading.getDirection())
            .setHumidity(getByteString(BigIntegerSerializer.get(),
                                       reading.getHumidity()))
            .setBadAirQualityDetected(reading.getBadAirQualityDetected())
            .build();
}

private static Reading getReading(ReadingBuffer.Reading bufferedReading) {
    return new Reading((BigDecimal) getObject(BigDecimalSerializer.get(),
                                      bufferedReading.getTemperature()),
            bufferedReading.getWindSpeed(),
            bufferedReading.getWindDirection(),
            (BigInteger) getObject(BigIntegerSerializer.get(),
                                   bufferedReading.getHumidity()),
            bufferedReading.getBadAirQualityDetected());
}
```

Now we're ready to model using a column

Schema using Column



Using JSONish Notation

```
SensorNet: {
    Climate: {
        BoulderSensors: {
            00000000000000000000000000000c8
                March 3 2012 12:00:00: 0a0431392e3510181a03455345220...
        }
    }
}
```

Hector with Protocol Buffers

Snapshot from the CLI

```
[default@Climate] list BoulderSensors;
Using default limit of 100
-------------------
RowKey: 00000000000000000000000000000c8
=> (column=00000135fe7fdb04, value=0a0431392e3510181a034553452201112800, timestamp=1331414686561000, ttl=31536000)
=> (column=00000135fe8d96a4, value=0a0431392e3410181a034553452201112800, timestamp=1331414686561002, ttl=31536000)
=> (column=00000135fe9b5244, value=0a0431392e3310181a034553452201112800, timestamp=1331414686561004, ttl=31536000)
=> (column=00000135fea90de4, value=0a0431392e3210181a034553452201112800, timestamp=1331414686561006, ttl=31536000)
=> (column=00000135feb6c984, value=0a0431392e3110181a034553452201112800, timestamp=1331414686562000, ttl=31536000)
=> (column=00000135fec48524, value=0a0431392e3010181a034553452201112800, timestamp=1331414686562002, ttl=31536000)
=> (column=00000135fed240c4, value=0a0431382e3910181a034553452201112800, timestamp=1331414686562004, ttl=31536000)
=> (column=00000135fedffc64, value=0a0431382e3810181a034553452201112800, timestamp=1331414686562006, ttl=31536000)
=> (column=00000135feedb804, value=0a0431382e3710181a034553452201112800, timestamp=1331414686562008, ttl=31536000)
=> (column=00000135fefb73a4, value=0a0431382e3610181a034553452201112800, timestamp=1331414686562010, ttl=31536000)
-------------------
RowKey: 00000000000000000000000000000064
=> (column=00000135fe7fdb04, value=0a0432332e3010101a01572201112800, timestamp=1331414686529000, ttl=31536000)
=> (column=00000135fe8d96a4, value=0a0432332e3110101a01572201112800, timestamp=1331414686561001, ttl=31536000)
=> (column=00000135fe9b5244, value=0a0432332e3210101a01572201112800, timestamp=1331414686561003, ttl=31536000)
=> (column=00000135fea90de4, value=0a0432332e3310101a01572201112800, timestamp=1331414686561005, ttl=31536000)
=> (column=00000135feb6c984, value=0a0432332e3410101a01572201112800, timestamp=1331414686561007, ttl=31536000)
=> (column=00000135fec48524, value=0a0432332e3510101a01572201112800, timestamp=1331414686562001, ttl=31536000)
=> (column=00000135fed240c4, value=0a0432332e3610101a01572201112800, timestamp=1331414686562003, ttl=31536000)
=> (column=00000135fedffc64, value=0a0432332e3710101a01572201112800, timestamp=1331414686562005, ttl=31536000)
=> (column=00000135feedb804, value=0a0432332e3810101a01572201112800, timestamp=1331414686562007, ttl=31536000)
=> (column=00000135fefb73a4, value=0a0432332e3910101a01572201112800, timestamp=1331414686562009, ttl=31536000)

2 Rows Returned.
Elapsed time: 15 msec(s).
[default@Climate]
```

The Benefits of Column

- At the expense of an extra application-level serialization on write, deserialization on read
  - Storage space on nodes is reduced
  - Network traffic between nodes is reduced
  - Benefits scale as a multiple of Replication Factor!
- This is the way to go
- Note: Future implementations of SuperColumn may be optimized, but this is on the horizon

Astyanax with Protocol Buffers

Hector vs Astyanax

- No clear winner, both libraries work very well
- Hector
  - The incumbent
  - Great support from DataStax via the Google Group (they also have commercial support)
  - Will be playing catch-up on some Astyanax features, namely async support
- Astyanax
  - NetFlix has a great rep for quality code
  - Support channel, via github wiki, seems good
  - Learned from Hector, kept the best, modified the rest
  - Asynchronous model probably better approach

References

- This project, https://github.com/jmctee/Cassandra-Client-Tutorial
- Tim Berglund, "Radical NoSQL Scalability with Cassandra"
  - Catch him at NFJS or UberConf for everything I didn't talk about
- Berglund and McCullough, Mastering Cassandra for Architects
  - http://shop.oreilly.com/product/0636920024811.do
- Apache Cassandra, http://cassandra.apache.org
- DataStax - Commercial Cassandra support, http://www.datastax.com/
- Hector, https://github.com/hector-client/hector
- Hector mailing list, http://groups.google.com/group/hector-users
- Astyanax, https://github.com/Netflix/astyanax/wiki/Getting-Started

References, cont.

- WTF Is A Super Column, http://arin.me/blog/wtf-is-a-supercolumn-cassandra-data-model
- Hewitt, Cassandra: The Definitive Guide
  - http://shop.oreilly.com/product/0636920010852.do
- Capriolo, Cassandra: High Performance Cookbook
  - http://www.packtpub.com/cassandra-apache-high-performance-cookbook/book

- Also, thanks to Ben Hoyt at Tendril for advice and technical contributions to this preso!

Thank You!

Did I mention Tendril is hiring?

FLASH PULP