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DataStax

Hands-on Workshop

Cassandra Data Modeling & Application Development

You can't build a successful app without data modeling

Some words about data modeling

* Not a relational database!
* Denormalization
* Keys and Partitions
* Querying tables
* Data Modeling methodology
* **HANDS-ON**: explore a full data model

Build a successful app

* Apps & Drivers (Python, Java)
* **HANDS-ON**: run your first Cassandra-backed API

Resources, homework, badges

Not a relational database

Definition

Data modeling =

the act of laying out the structure of your database to fit your application's purposes

Begins with an abstract idea of your application's needs

Ends with the commands that create the physical tables and the read/write operations that they support

Data Modeling: Relational vs. Cassandra

Data -> Model -> Application	Application -> Model -> Data
Joins, indexes	Denormalization
Referential integrity	No (would not scale well anyway)
Primary key = uniqueness	Primary key = uniqueness + partitioning + access
Entity-driven	Query-driven

Normalization vs Denormalization

Normalization

"Database normalization is the process of structuring a relational database in accordance with a series of so-called normal forms in order to reduce data redundancy and improve data integrity. It was first proposed by Edgar F. Codd as part of his relational model."

PROS: Simple write, Data Integrity
CONS: Slow read, Complex Queries

Employees

userId	deptId	firstName	lastName
1	1	Edgar	Codd
2	1	Raymond	Boyce

Departments

departmentId	department
1	Engineering
2	Math

Denormalization

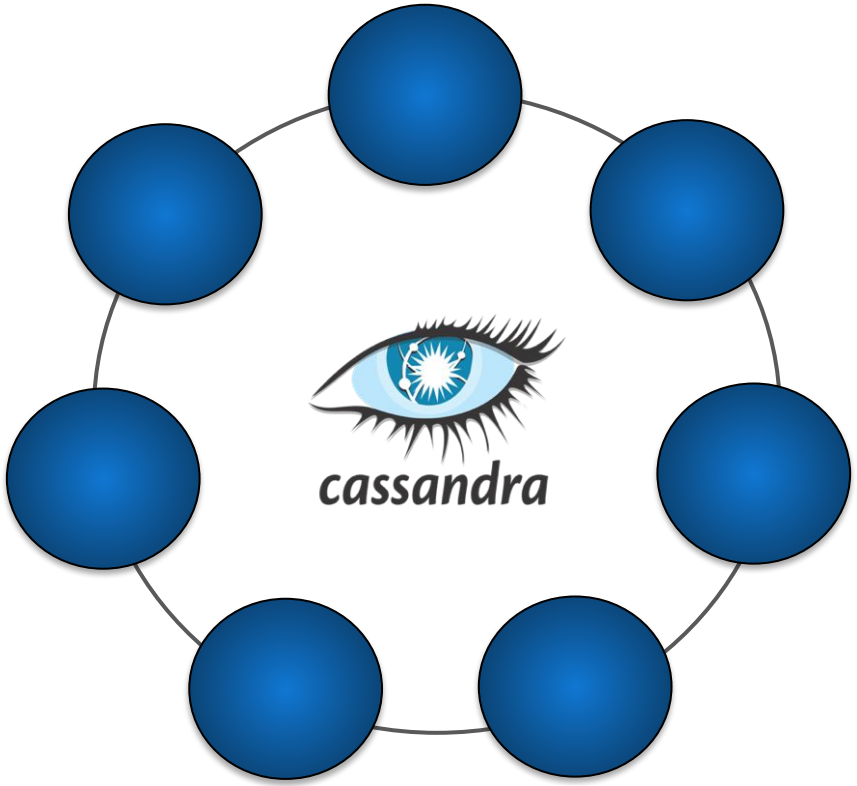
"**Denormalization** is a strategy used on a database to increase performance. In computing, denormalization is the process of trying to improve the read performance of a database, at the expense of losing some write performance, by adding redundant copies of data"

PROS: Quick Read, Simple Queries
CONS: Multiple Writes, Manual Integrity

Employees

userId	firstName	lastName	department
1	Edgar	Codd	Engineering
2	Raymond	Boyce	Engineering
3	Sage	Lahja	Math
4	Juniper	Jones	Botany

departmentId	department
1	Engineering
2	Math



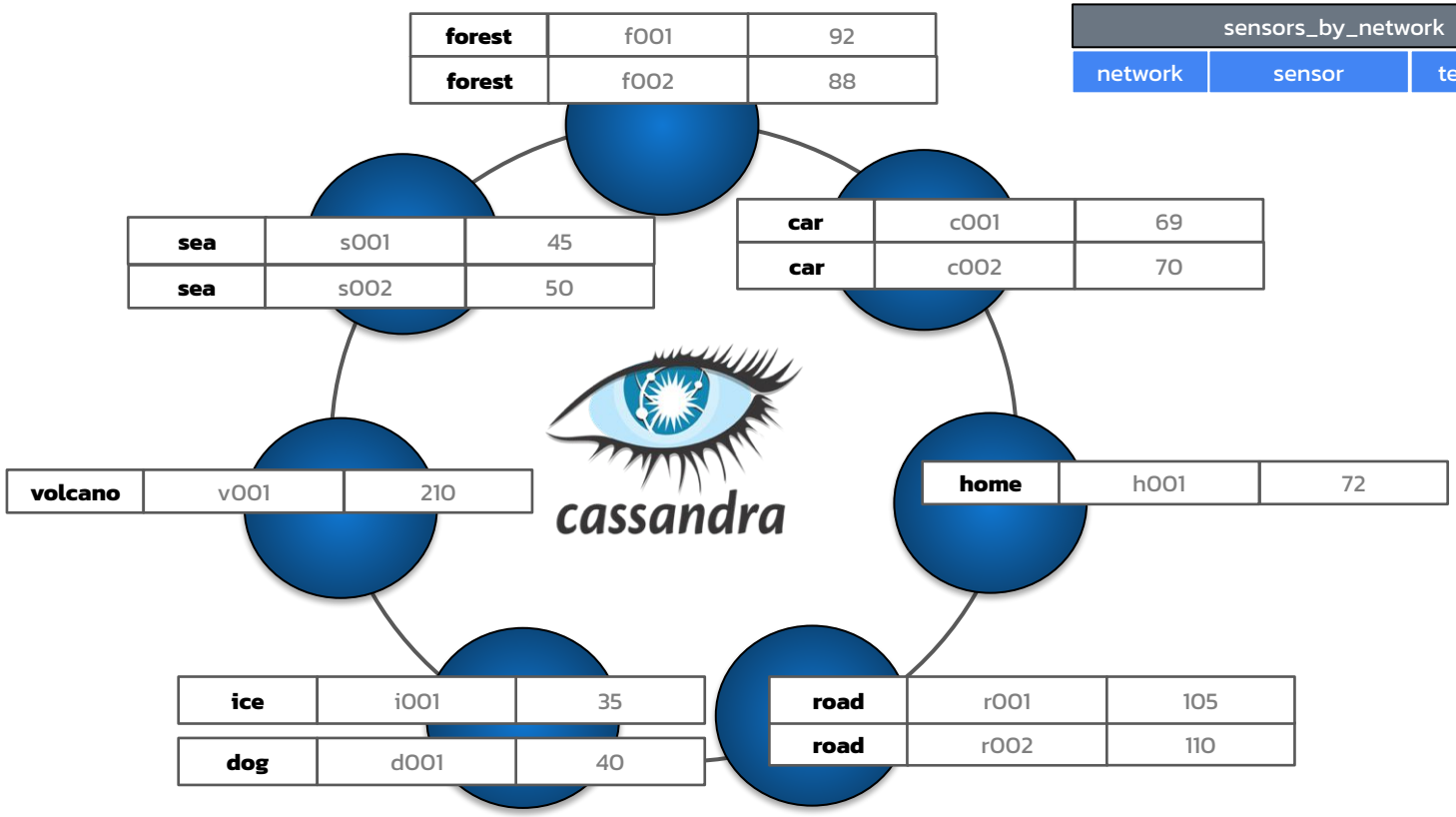
sensors_by_network		
network	sensor	temperature
forest	f001	92
forest	f002	88
volcano	v001	210
sea	s001	45
sea	s002	50
home	h001	72
car	c001	69
car	c002	70
dog	d001	40
road	r001	105
road	r002	110
ice	i001	35

Partition Key

Primary Key

Keys and Partitions

Data is Organized into **Distributed** Tables



sensors_by_network		
network	sensor	temperature

Partition Key

An identifier for a partition.
Consists of at least one column, may have more if needed.

PARTITIONS TABLE.
Defines data distribution strategy

```
CREATE TABLE sensor_data.temperatures_by_sensor (
  sensor      TEXT,
  date        DATE,
  timestamp   TIMESTAMP,
  value       FLOAT,
  PRIMARY KEY ((sensor, date), timestamp)
);
```

Partition key

Examples:

```
PRIMARY KEY ((sensor), timestamp);
```

```
PRIMARY KEY ((sensor), date, timestamp);
```

```
PRIMARY KEY ((sensor, timestamp));
```

Clustering Columns

Used to **ensure uniqueness** and **sorting order.** Optional.

Defines physical ordering on disk

```
CREATE TABLE sensor_data.temperatures_by_sensor (
  sensor      TEXT,
  date        DATE,
  timestamp   TIMESTAMP,
  value       FLOAT,
  PRIMARY KEY ((sensor, date), timestamp)
) WITH CLUSTERING ORDER BY (timestamp DESC);
```

Clustering columns

```
PRIMARY KEY ((sensor));
```
Not Unique

```
PRIMARY KEY ((sensor), timestamp);
```
Not filter on dates

```
PRIMARY KEY ((sensor), value, timestamp);
```
Not sorted

```
PRIMARY KEY ((sensor), date, timestamp);
```

Primary Key

An identifier for a row. Consists of at least one Partition Key and zero or more Clustering Columns.

UNIQUELY IDENTIFIES A ROW

```
CREATE TABLE sensor_data.temperatures_by_sensor (
  sensor     TEXT,
  date       DATE,
  timestamp  TIMESTAMP,
  value      FLOAT,
  PRIMARY KEY ((sensor, date), timestamp)
) WITH CLUSTERING ORDER BY (timestamp DESC);
```

Primary key

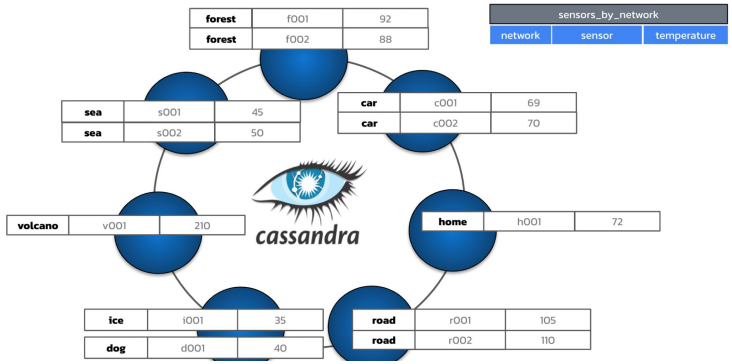
Examples:

```
PRIMARY KEY ((sensor), timestamp);
```

```
PRIMARY KEY ((sensor, date), timestamp);
```

Primary Key = Ensure Uniqueness = PK + CC

Partition Keys:
Defines data distribution over the cluster



Clustering Columns
Defines how data is physically stored (written on disk)

```
CREATE TABLE sensor_data.temperatures_by_sensor (
  sensor      TEXT,
  date        DATE,
  timestamp   TIMESTAMP,
  value       FLOAT,
  PRIMARY KEY ((sensor, date), timestamp)
) WITH CLUSTERING ORDER BY (timestamp DESC);
```

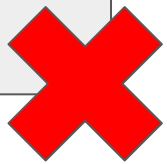
Corollary: Schema Immutability

Important:

Once created, the data model cannot be changed! You will need new tables and migration. Stay lazy, design it right in advance!

```
ALTER TABLE temperatures_by_sensor
ADD season TEXT;
```

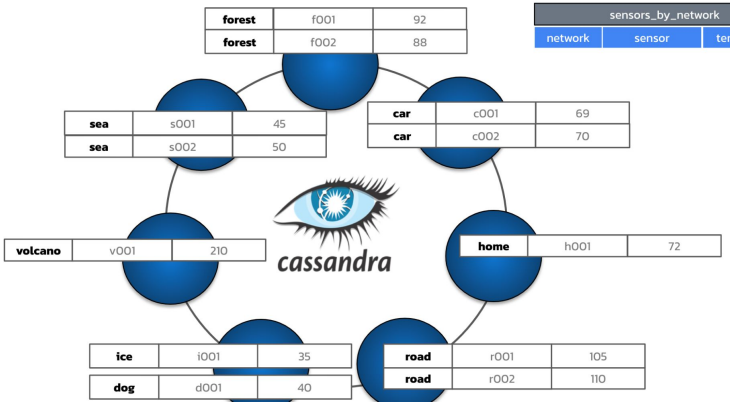
```
ALTER TABLE temperatures_by_sensor
DROP PRIMARY KEY
ADD PRIMARY KEY (sensor, timestamp)
```



Keys and Partitions (Recap)

Primary Key, Partition Key, Clustering Columns, Oh My!

```
CREATE TABLE sensor_data.temperatures_by_sensor (
  sensor      TEXT,
  date        DATE,
  timestamp   TIMESTAMP,
  value       FLOAT,
  PRIMARY KEY (  (  sensor ,  date  ) ,      timestamp     )
) WITH CLUSTERING ORDER BY (timestamp DESC);
```



sensors_by_network		
network	sensor	temperature

Partition Key
DEFINES DATA DISTRIB.

Clustering column(s)
ENSURE UNIQUENESS

Primary key
UNIQUELY IDENTIFIES A ROW

Querying Tables

"Rule Zero" of Querying

"I want to read ALL rows of my table"

Sorry, **not today**.
If you really need to,
⇒ OLAP workload: use Apache Spark & co.

but in a typical OLTP app,
you actually **don't need** to run such a query!

Reading all rows ("*full-table scan*") is a performance capital sin, since it involves a lot of nodes in the cluster!

Table Structure ⇒ Valid Queries

```
PRIMARY KEY ((sensor, date), timestamp);
```

```
SELECT * FROM temperatures_by_sensor ...

    WHERE sensor = ?;

    WHERE sensor > ?;

    WHERE sensor = ? AND date > ?;

    WHERE sensor = ? AND date = ?;

    WHERE sensor = ? AND date = ? AND timestamp > ?;
```

Rules of a Good Partition 1/4

```
CREATE TABLE sensor_data.temperatures_by_sensor (
  sensor     TEXT,
  date       DATE,
  timestamp  TIMESTAMP,
  value      FLOAT,
  PRIMARY KEY ((sensor, date), timestamp)
) WITH CLUSTERING ORDER BY (timestamp DESC);
```

Rules of a Good Partition 2/4

- **Store together what you retrieve together**
- Avoid big partitions
- Avoid hot partitions

Q: Show temperature evolution over time for sensor X On Sept 20th 2022

```
PRIMARY KEY ((sensor, timestamp));
```

```
PRIMARY KEY ((sensor), timestamp);
```

Rules of a Good Partition 3/4

- Store together what you retrieve together
- **Avoid big partitions**
- Avoid hot partitions

BUCKETING

```
PRIMARY KEY ((sensor), timestamp);
```

```
PRIMARY KEY ((sensor, month), timestamp);
```

- Up to 2 billion cells per partition
- Up to ~100k values in a partition
- Up to ~100MB in a Partition

Rules of a Good Partition 4/4

- Store together what you retrieve together
- Avoid big partitions
- **Avoid hot partitions**

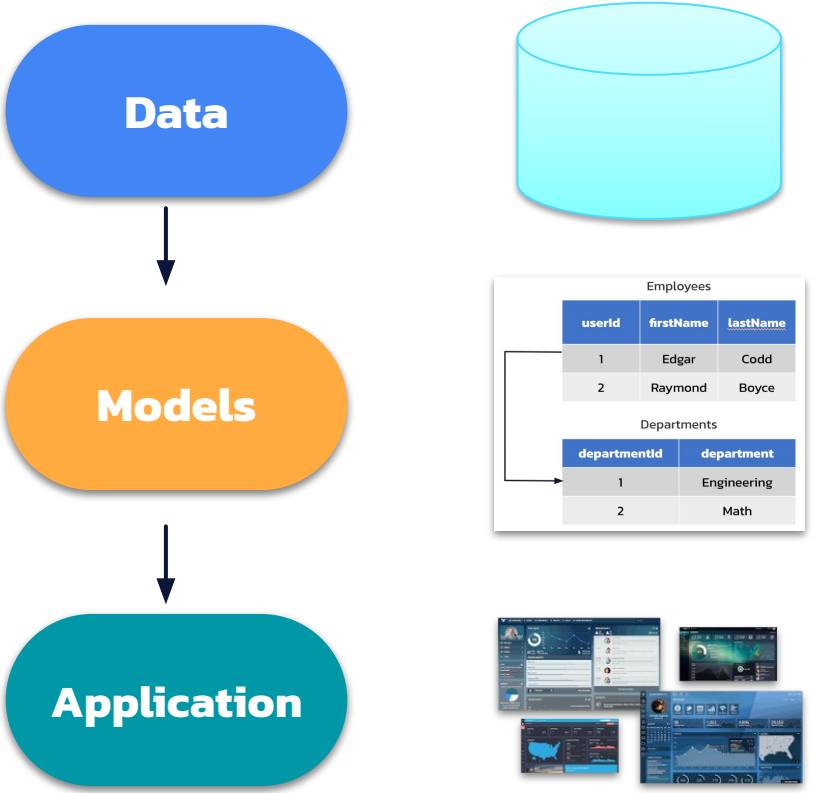
```
PRIMARY KEY ((date), sensor, timestamp);
```

```
PRIMARY KEY ((date, sensor), timestamp);
```

Data Modeling Methodology

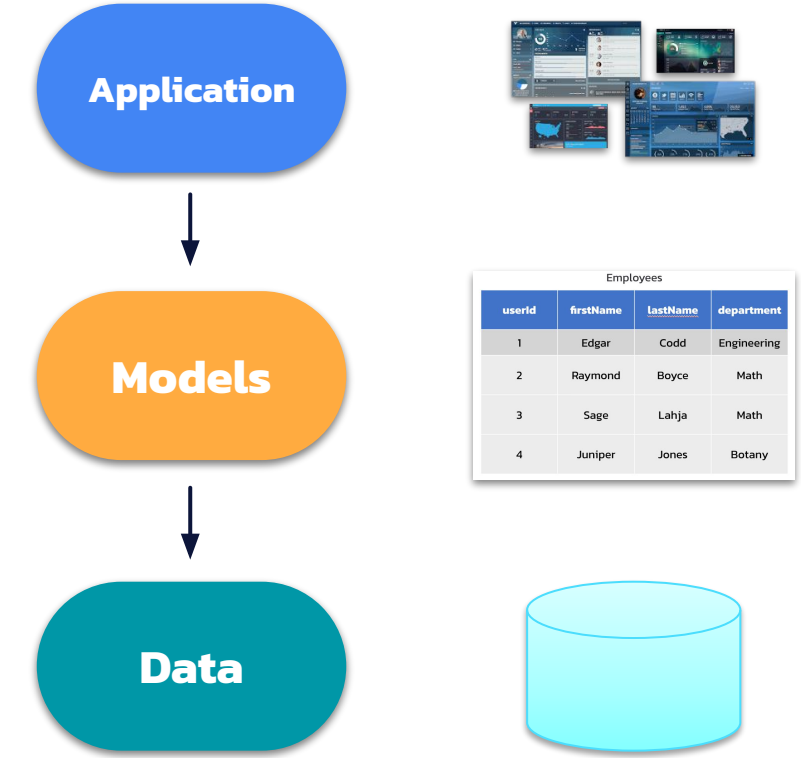
Relational Data Modeling

1. Analyze raw data
2. Identify entities, their properties and relations
3. Design tables, using **normalization** and foreign keys.
4. Use JOIN when doing queries to join normalized data from multiple tables



NoSQL Data Modeling

1. Analyze user behaviour (customer first!)
2. Identify workflows, their dependencies and needs
3. Define Queries to fulfill these workflows
4. Knowing the queries, design tables, using **denormalization**.
5. Use BATCH when inserting or updating denormalized data of multiple tables



What is Data Modeling?

- Collection and analysis of data requirements
- Identification of participating entities and relationships
- Identification of data access patterns
- A particular way of organizing and structuring data
- Design and specification of a database schema
- Schema optimization and data indexing techniques

Data Quality: completeness consistency accuracy
Data Access: queryability efficiency scalability

Cassandra Data Modeling Principles

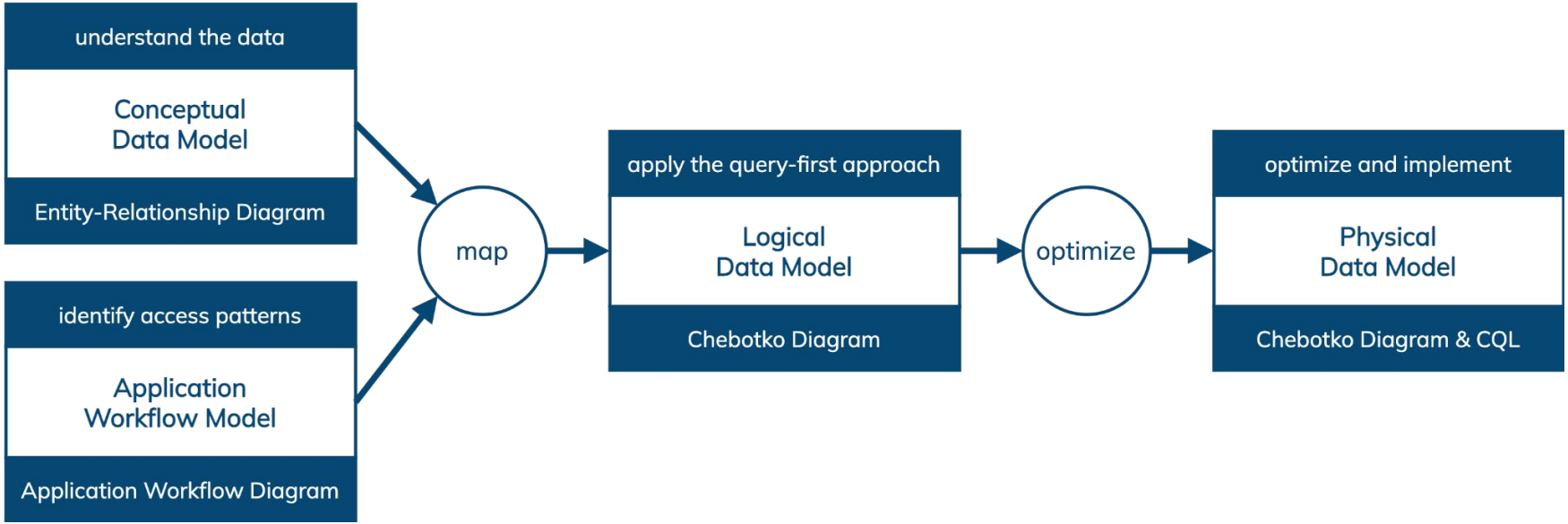
Modeling principle 1: “Know your data”
- Key and cardinality constraints are fundamental to schema design

Modeling principle 2: “Know your queries”
- Queries drive schema design

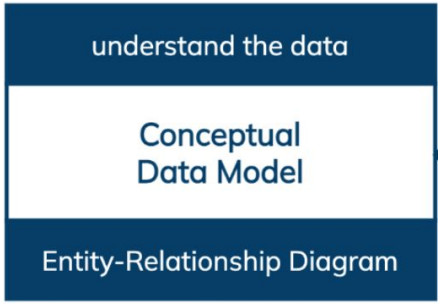
Modeling principle 3: “Nest data”
- Data nesting is the main data modeling technique

Modeling principle 4: “Duplicate data”
- Better to duplicate than to join

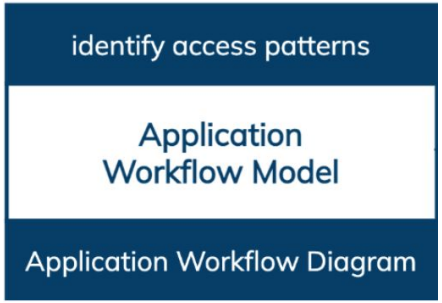
Modeling Workflow



Data Modeling Methodology: Step I

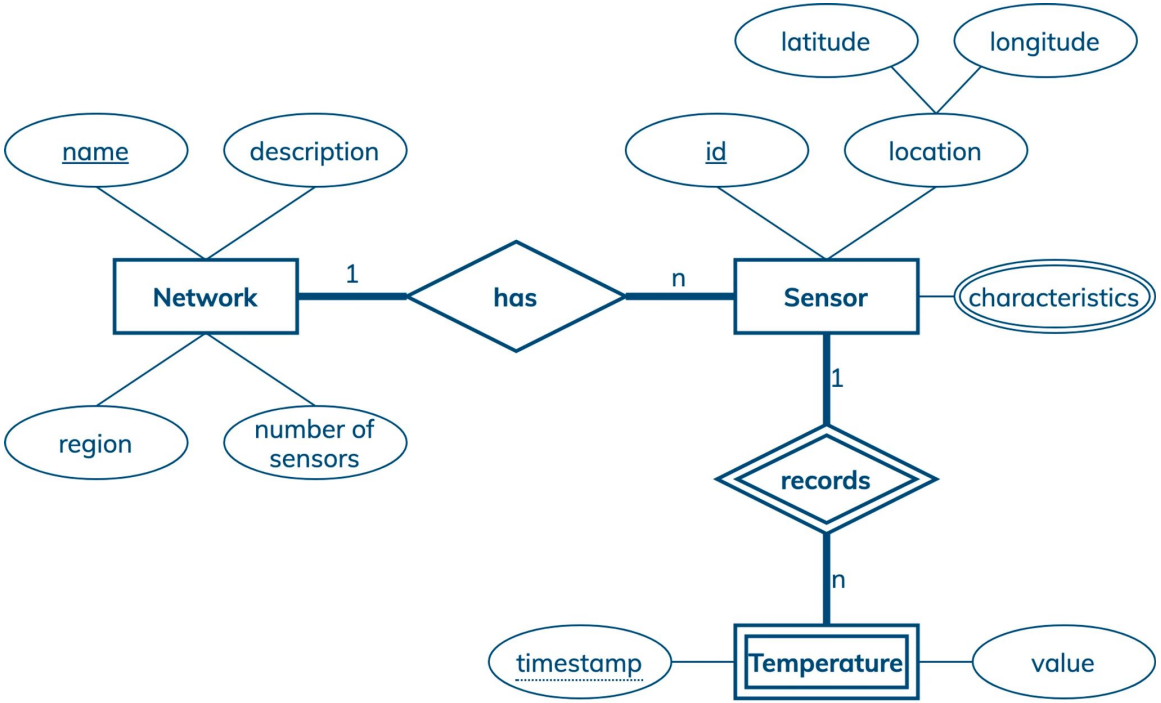


Analyze the Domain

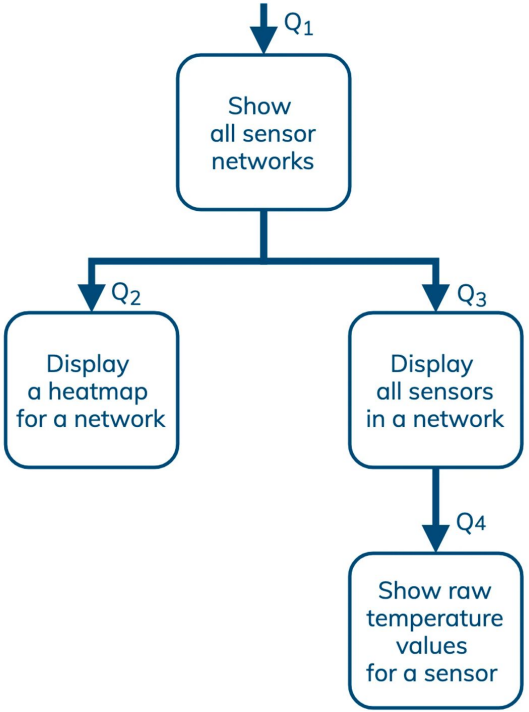


Analyze Customer Workflows

Entity-Relationship Diagram



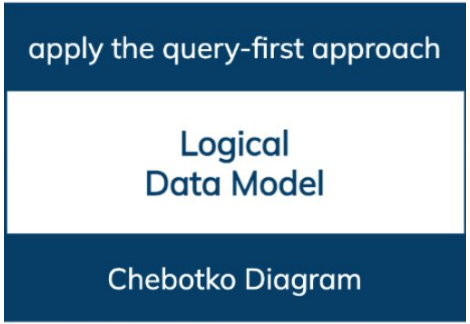
Application Workflow Diagram



Data access patterns

Q_1: Find information about all networks; order by name (asc)
Q_2: Find hourly average temperatures for every sensor in a specified network for a given date range; order by date (desc) and hour (desc)
Q_3: Find information about all sensors in a specified network
Q_4: Find raw measurements for a particular sensor on a specified date; order by timestamp (desc)

Data Modeling Methodology: Step II



Design queries and build tables based on the queries

Mapping Rules

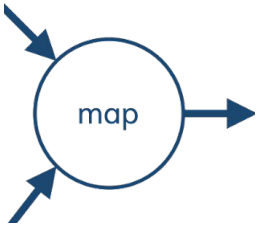
Mapping rule 1: “Entities and relationships”
- Entity and relationship types map to tables

Mapping rule 2: “Equality search attributes”
- Equality search attributes map to the beginning columns of a primary key

Mapping rule 3: “Inequality search attributes”
- Inequality search attributes map to clustering columns

Mapping rule 4: “Ordering attributes”
- Ordering attributes map to clustering columns

Mapping rule 5: “Key attributes”
- Key attributes map to primary key columns

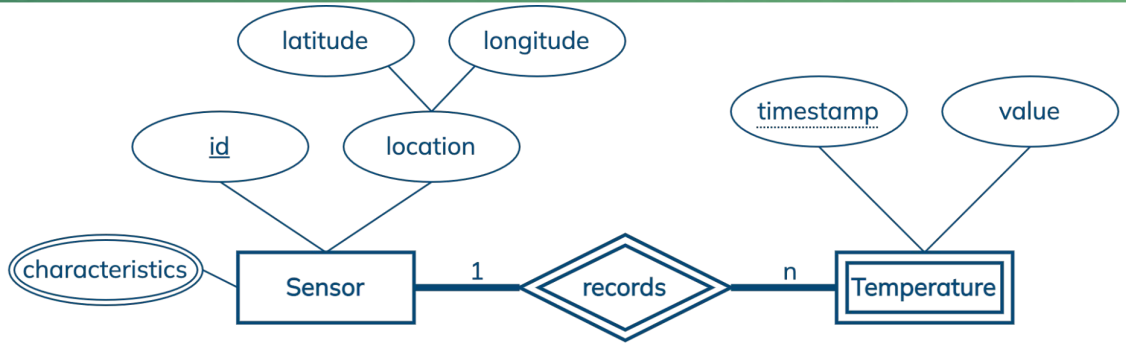


Based on a conceptual data model

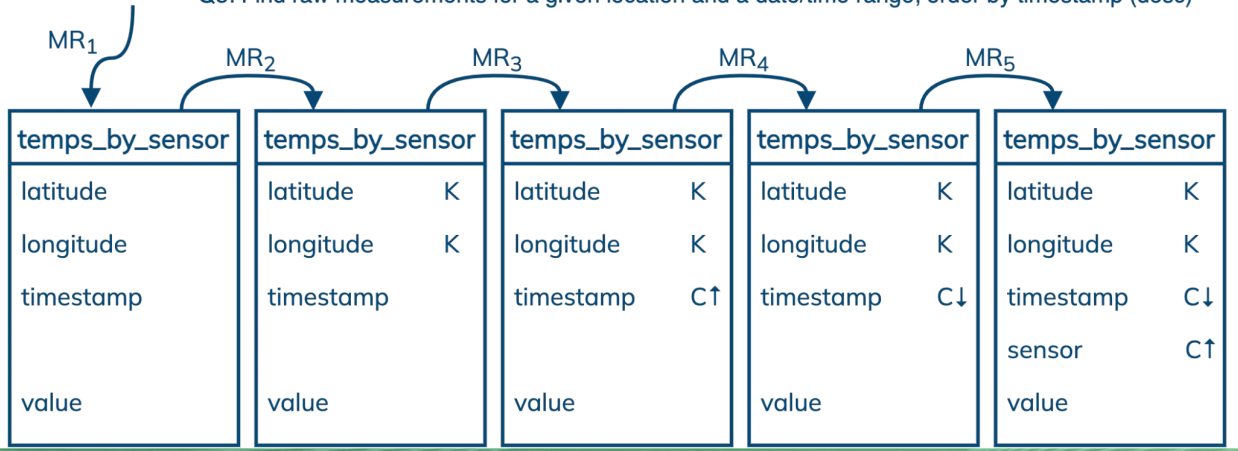
Based on a query

Based on a conceptual data model

Mapping Rules: Example



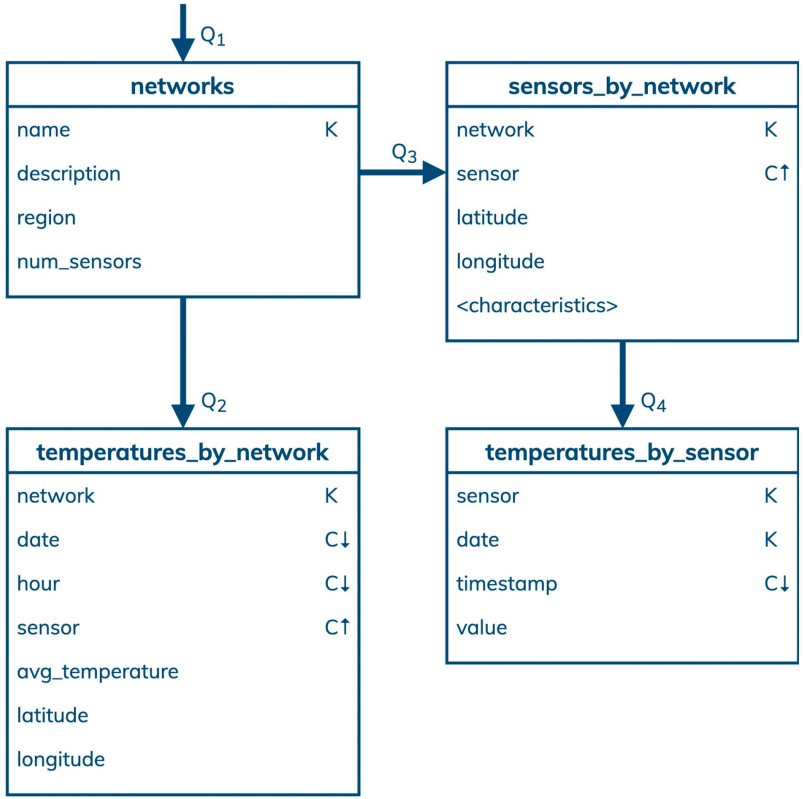
Q5: Find raw measurements for a given location and a date/time range; order by timestamp (desc)



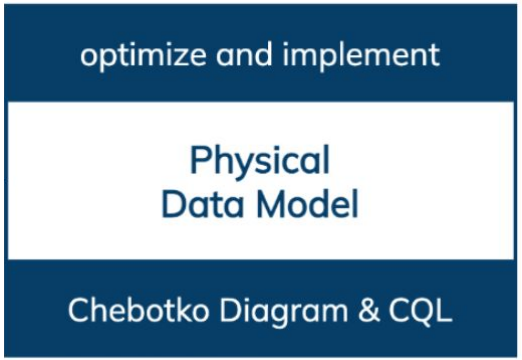
Chebotko Diagram

Data access patterns

Q_1: Find information about all networks; order by name (asc)
Q_2: Find hourly average temperatures for every sensor in a specified network for a given date range; order by date (desc) and hour (desc)
Q_3: Find information about all sensors in a specified network
Q_4: Find raw measurements for a particular sensor on a specified date; order by timestamp (desc)



Data Modeling Methodology: Step III



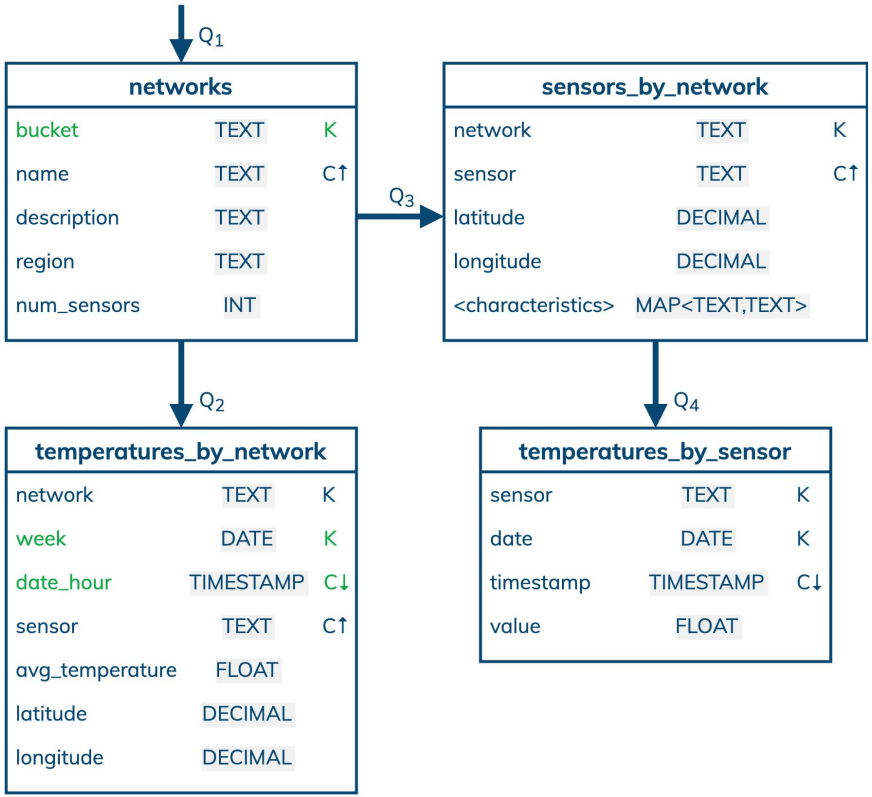
Optimize and Create

Optimization Techniques

- Partition size limits and splitting large partitions
- Data duplication and batches
- Indexes and materialized views*
- Concurrent data access and lightweight transactions*
- Dealing with tombstones*

* Explained in details at our free DS220 course at academy.datastax.com

Physical Data Model: Chebotko Diagram



Cassandra Query Language (CQL)

Q1

```
CREATE TABLE networks (
  bucket TEXT,
  name TEXT,
  description TEXT,
  region TEXT,
  num_sensors INT,
  PRIMARY KEY ((bucket),name)
);
```

Q2

```
CREATE TABLE temperatures_by_network (
  network TEXT,
  week DATE,
  date_hour TIMESTAMP,
  sensor TEXT,
  avg_temperature FLOAT,
  latitude DECIMAL,
  longitude DECIMAL,
  PRIMARY KEY ((network,week),date_hour,sensor)
) WITH CLUSTERING ORDER BY (date_hour DESC, sensor ASC);
```

Q3

```
CREATE TABLE sensors_by_network (
  network TEXT,
  sensor TEXT,
  latitude DECIMAL,
  longitude DECIMAL,
  characteristics MAP<TEXT,TEXT>,
  PRIMARY KEY ((network),sensor)
);
```

Q4

```
CREATE TABLE temperatures_by_sensor (
  sensor TEXT,
  date DATE,
  timestamp TIMESTAMP,
  value FLOAT,
  PRIMARY KEY ((sensor,date),timestamp)
) WITH CLUSTERING ORDER BY (timestamp DESC);
```

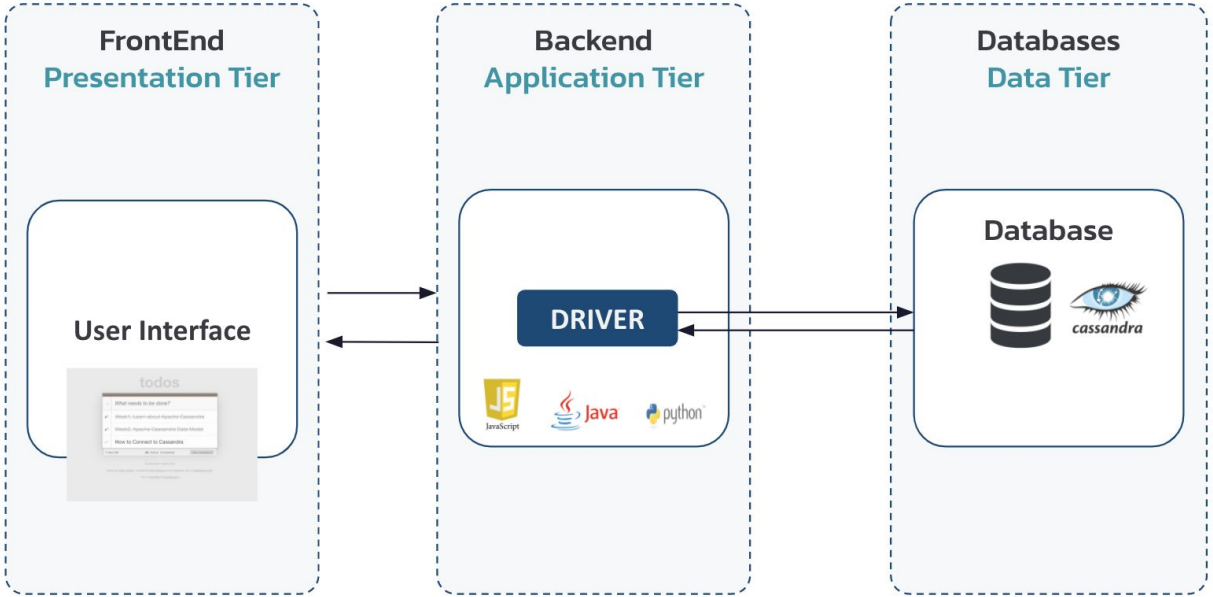
Lab 1

Explore a data model

Start here: `dtsx.io/cday-ws2`

Apps & Drivers

Application Development with Apache Cassandra™



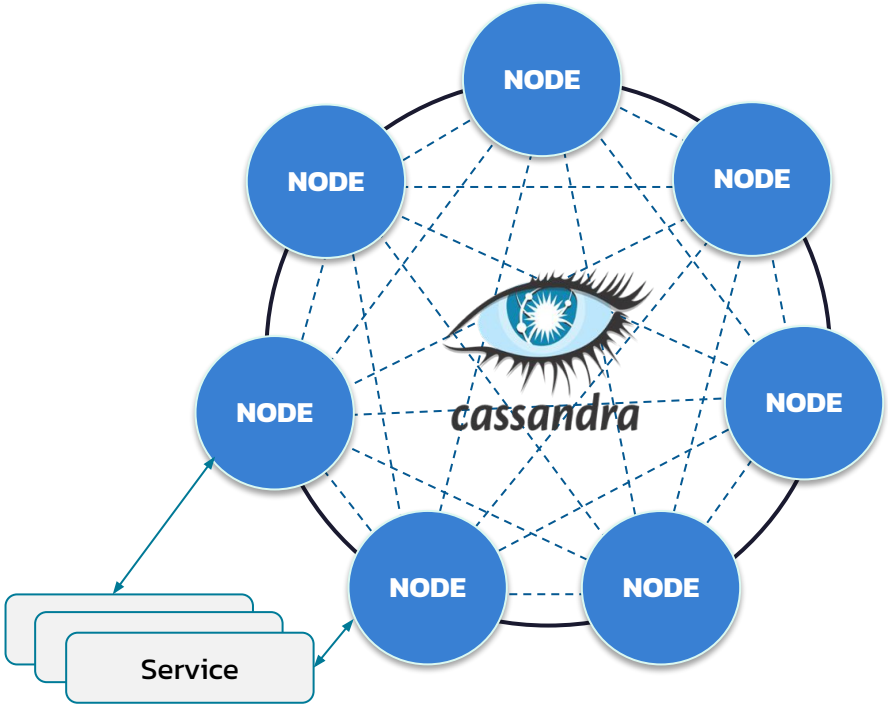
Cassandra ❤ Microservices

Loose Coupling: Data resiliency

- Data Replicated on multiple Nodes
- Load Balancing at driver side
- Health Check at driver side
- Hinted HandOff

Shared nothing: Data isolation

- Per Keyspace (with replications)
- Per Tables (1 query = 1 table)
- Per profile (RBAC)



Drivers






Connectivity

- ★ Token & Datacenter Aware
- ★ Load Balancing Policies
- ★ Retry Policies
- ★ Reconnection Policies
- ★ Connection Pooling
- ★ Health Checks
- ★ Authentication | Authorization
- ★ SSL

Query

- ★ CQL Support
- ★ Schema Management
- ★ Sync/Async/Reactive API
- ★ Query Builder
- ★ Compression
- ★ Paging

Parsing Results

- ★ Lazy Load
- ★ Object Mapper
- ★ Spring Support
- ★ Paging

Installing the Drivers

Maven

```
<dependency>
    <groupId>com.datastax.oss</groupId>
    <artifactId>java-driver-core</artifactId>
    <version>4.13.1</version>
</dependency>
```

Java

```
npm install cassandra-driver
```

4.6.3

npm

```
{
  "dependencies": {
      "cassandra-driver": "^4.6.3"
  }
}
```

JavaScript

python Package Index

```
pip install cassandra-driver==3.25.0
```

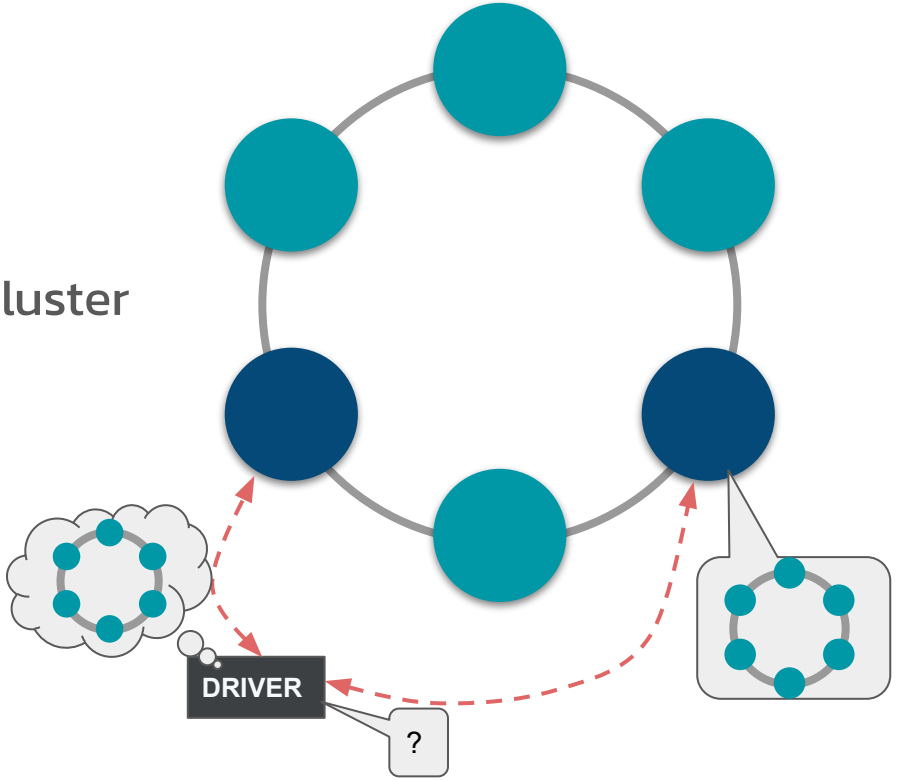
python

nuget v3.15.0

```
Install-Package CassandraCSharpDriver -Version 3.15.0
```

Contact Points (Cassandra)

- One contact point *would be enough*
  … unless that node is down
- ~3 nodes per DC for resilience
- From there, drivers discover whole cluster
- Local Datacenter



Create "Session" Client (with contact points)

```java
CqlSession cqlSession = CqlSession.builder()
 .addContactPoint(new InetSocketAddress("127.0.0.1", 9042))
 .withKeyspace("sensor_data")
 .withLocalDatacenter("dc1")
 .withAuthCredentials("U","P")
 .build();
```


```node
const client = new cassandra.Client({
  contactPoints: ['127.0.0.1'],
  localDataCenter: 'dc1',
  keyspace: 'sensor_data',
  credentials: { username: 'U', password: 'P' }
});
await client.connect();
```


```python
auth_provider = PlainTextAuthProvider(
   username='U', password='P')
cluster = Cluster(['127.0.0.1'],
  auth_provider=auth_provider, protocol_version=5)
session = cluster.connect('sensor_data')
```


```dotnet
Cluster cluster = Cluster.Builder()
.AddContactPoint("127.0.0.1")
.WithCredentials("U", "P")
.Build();
session = cluster.Connect("sensor_data");
```

Create "Session" Client (with Astra DB)

```java
CqlSession cqlSession = CqlSession.builder()
 .withCloudSecureConnectBundle(Paths.get("secure.zip"))
 .withAuthCredentials("U","P")
 .withKeyspace("sensor_data")
 .build();
```


```node
const client = new cassandra.Client({
  cloud: { secureConnectBundle: 'secure.zip' },
  credentials: { username: 'u', password: 'p' },
  keyspace: 'sensor_data'
});
await client.connect();
```


```python
auth_provider = PlainTextAuthProvider(
   username='U', password='P')
cluster = Cluster(
   cloud ={'secure_connect_bundle': 'secure.zip'},
   auth_provider=auth_provider, protocol_version=4)
session= cluster.connect('sensor_data')
```


```csharp
var cluster = Cluster.Builder()
 .WithCloudSecureConnectionBundle("secure.zip")
 .WithCredentials("u", "p")
 .Build();
var session = cluster.Connect("sensor_data");
```

There Should Only Be One Session !

- Stateful object handling communications with each node
- Should be unique in the Application (*Singleton*)
- Should be closed at application shutdown (*shutdown hook*) in order to free opened TCP sockets (*stateful*)

```
Java:       cqlSession.close();
Python:     session.shutdown();
Node:       client.shutdown();
CSharp:     IDisposable
```

Executing CQL Queries

```
session.execute(
    "SELECT * FROM sensors_by_network WHERE network = %s;",
    (network,)
)
```

```
cqlSession.execute(
    "SELECT * FROM sensors_by_network WHERE network = '" + network + "'"
);
```

Prepare Your Statements

```
q3_statement = session.prepare(
    "SELECT * FROM sensors_by_network WHERE network = ?;"
)
rows = session.execute(q3_statement, (network,) )
```

Prepare Your Statements

```
PreparedStatement q3Prepared = session.prepare(
    "SELECT * FROM sensors_by_network WHERE network = ?");
BoundStatement q3Bound = q3Prepared.bind(network);
ResultSet rs = session.execute(q3Bound);
```

Advantages of Prepared Statements

- Parse once, run many times.
- Saves network trips for result set metadata.
- Client-side type validation.
- Statements binding on partition keys compute their own cluster routing.

Pick Your Language (For Today)

today: +Spring Boot

today: +FastAPI

Lab 2

Create DB and run API

Start here: `dtsx.io/cday-ws2`

Conclusion & Next Steps

Homework (see AppDev Github Repo!)

A couple of "theory" questions, plus ...

Coding exercise: *Enrich the API with a* ***new***

GET endpoint *for Q1 ("get all networks")*

Get help about Cassandra

(*):

stackoverflow.com/questions/tagged/cassandra


DBA Stack Exchange(*):

dba.stackexchange.com/questions/tagged/cassandra


Discord:

dtsx.io/discord

(*) for best results, follow the "cassandra" tag

This is just the beginning of your journey

Enjoy the rest of today
Do the homework ⇒ get a badge
We have more workshops & hands-on labs!
Get Cassandra Certified (Academy & Exam voucher)

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Thank You