DS-2002: Data Systems

An Overview of NoSQL Databases

Prof. Jon Tupitza – Fall 2022

NoSQL Databases

Understanding the Principles Behind NoSQL Databases

University of Virginia

An Explosion of Data… “BIG Data”

A Rapid, Exponential Proliferation of New Devices: The Internet of Things (IoT)

olume (Size)

- Explosion in social media, mobile apps, digital sensors, RFID, GPS, and more have caused exponential data growth.

elocity (Speed)

- Sources like social networking and sensor signals create data at a tremendous rate; making it a challenge to capture, store, and analyze that data in a timely or economical manner.

ariety (Structure)

- Traditionally BI has sourced structured data, but now insight must be extracted from unstructured or poly-schematic data like large text blobs, digital media, sensor data, etc.

eracity (Quality)

- The anonymity of the WWW, incredible sources like social networking and duplicate systems bring into question the authenticity of the information being generated and collected.

Architectural Models: How They're Used

"Big Data" technologies aren't necessarily intended to replace existing database technologies; rather they play a critical role in extending the capabilities of a data management ecosystem.

Standalone Data Analysis and Visualization	Experiment with data sources to discover if they provide useful information. Handle data that can't be processed using existing systems.
Data Transfer, Cleansing or ETL	Extract and transform data before loading it into existing databases. Categorize, normalize, and extract summary results to remove duplication and redundancy.
Data Warehouse or Data Storage	Create robust data repositories that are reasonably inexpensive to maintain. Especially useful for storing and managing huge data volumes.
Integrate with Existing EDW and BI Systems	Integrate Big Data at different levels; EDW, OLAP, Excel PowerPivot. Also, APS enables querying Hadoop to integrate Big Data with existing dimension & fact data.

NoSQL Databases

- NoSQL databases are defined by a collection of characteristics that they share rather than having a formal definition:

  Non-relational

  Scale-out

  Schema-less

- They were all born out of this desire to address new needs of the internet world.

Key–value databases	Column family databases
Document databases	Graph databases

NoSQL: Not Only SQL

Key-value stores

- The simplest NoSQL database; based on “dictionaries” or “maps”.
- Items are stored in associative arrays; pairing a name (or "key"), with a value.
- **Riak, FoundationDB, and Redis**

Column stores

- Combines a key, value and timestamp for each item.
- Optimized for large datasets by storing columns of data together, rather than in rows.
- **Cassandra, BigTable and HBase**

Document databases

- Pairs keys with complex data structures (documents) using XML, JSON or BSON.
- Documents may contain key-value pairs, key-array pairs, and nested documents.
- **MongoDB, MarkLogic, and Apache CouchDB**

Graph stores

- Stores interrelated networks of data such as social connections, or network topologies.
- Optimized for interconnected data elements with an undetermined number of relations.
- **AllegroGraph, Neo4J and HyperGraphDB**.

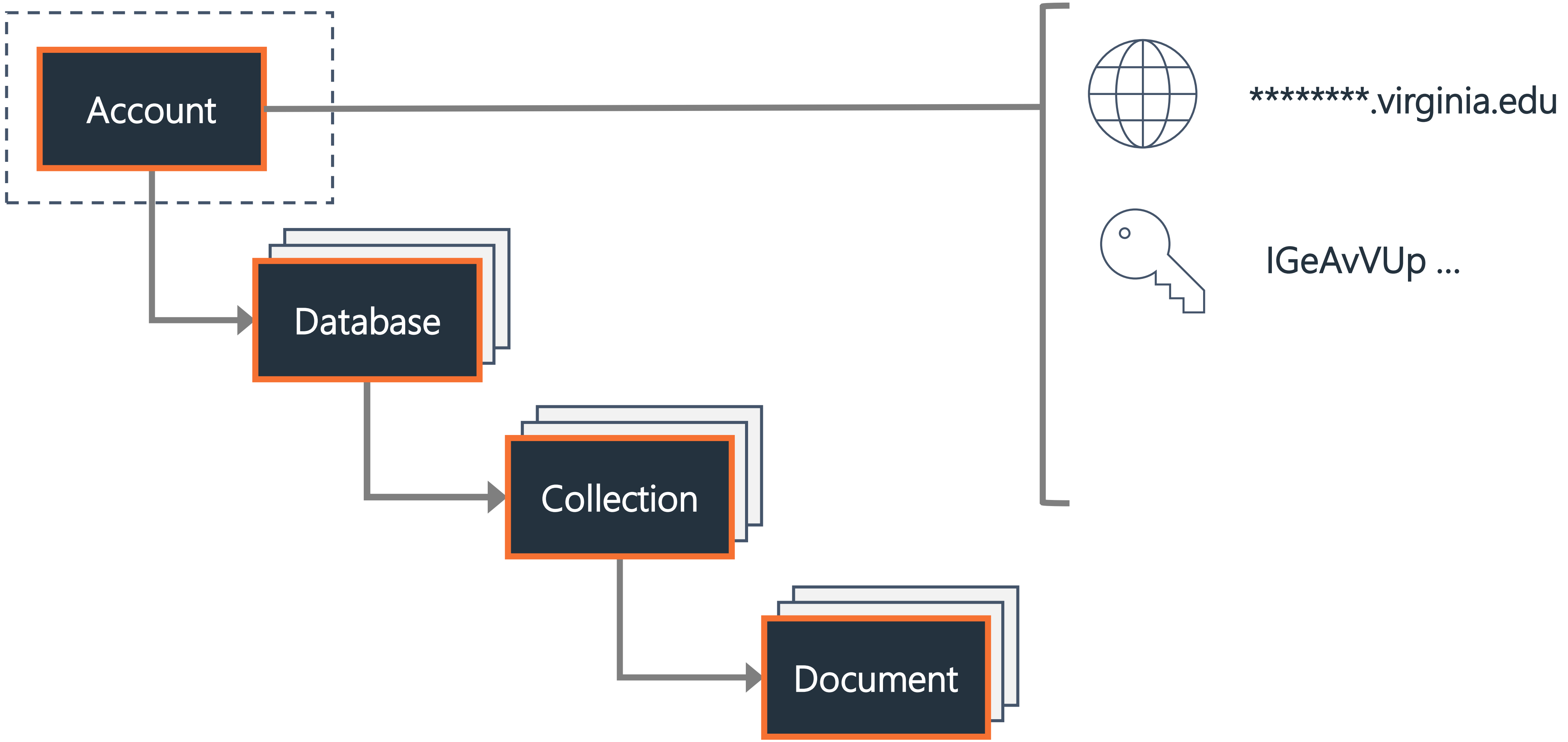
Relational versus NoSQL Databases

Relational Databases	NoSQL Databases
• Good for **structured data** and high-performance workloads • Provides transactional consistency • **Predefined Schema Architecture** enforces integrity of data structure • Products are Proven and Mature with a Variety of Available Tools • **Limited Scalability** [Vertically]: Not well suited to distribution	• Good for **non-relational** data • Provides eventual consistency • **Schema-less Architecture** allows for frequent structural changes and easy addition of varied data • **Poly-schematic:** Supports multiple document types • **Easily Scalable** [Horizontally]: Runs well on distributed systems

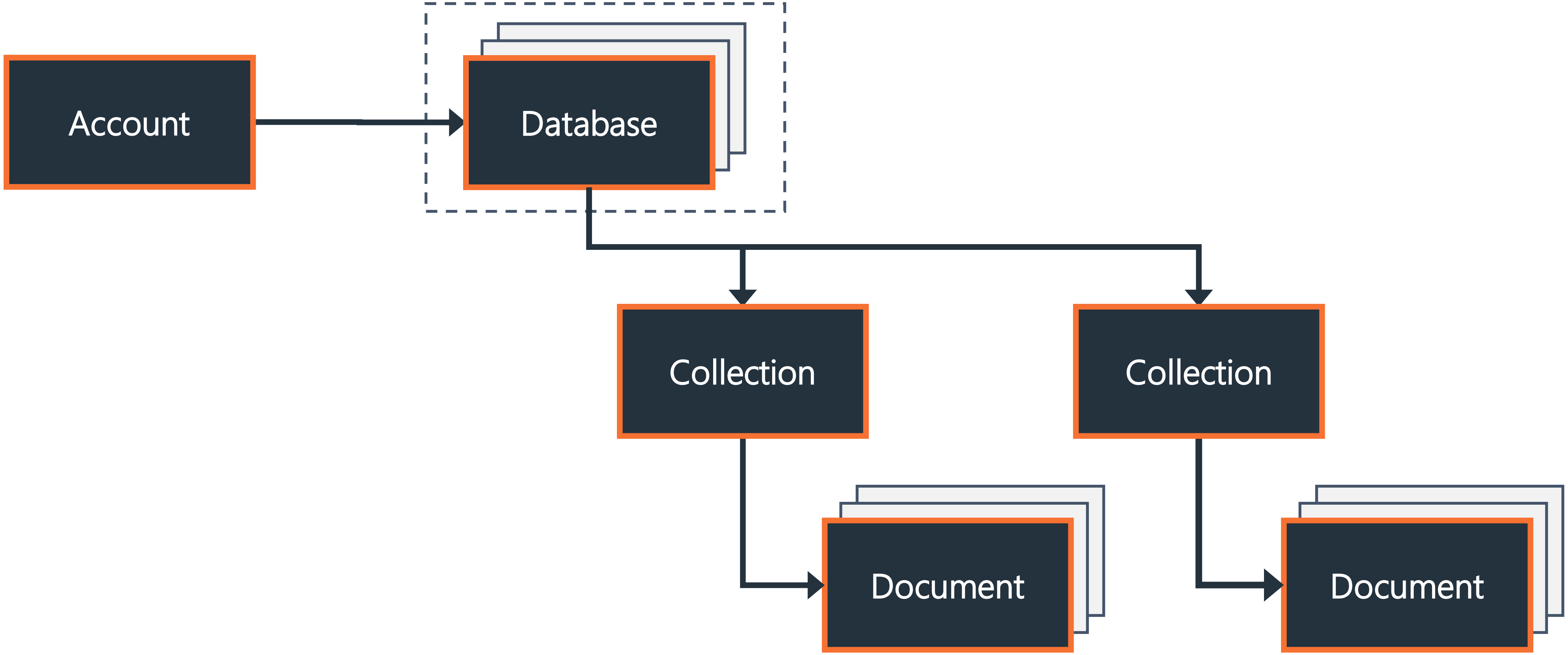
SQL versus NoSQL Databases

	SQL Databases	NoSQL Databases
Types	One: Relational Database	Many: Key-value, document, column, and graph databases
Data Storage	Records are stored as rows in tables that represent entities. Entity relationships are modeled by joining tables.	Records may be stored as "documents" using XML or JSON. Entity relationships are modeled by nesting them hierarchically.
Schemas	Static: Structure & data types are fixed at design time. Adding new elements requires schema design changes.	Dynamic: New elements can be added at runtime. Poly-schematic: Dissimilar data can be stored together as necessary.
Scaling	Vertically: A single server must be made increasingly powerful to cope with increasing demand.	Horizontally: New commodity servers and storage are added to an array. Data is automatically distributed across all servers.
Transactions	Full transactional consistency (ACID)	Single element (document) only.
Manipulation	Using platform-specific languages (SQL)	Using OSS API's, low-level lang., JavaScript
Consistency	Supports strong consistency	Per-product: Most are eventually consistent.

Resource Model: Account URI and Credentials



Resource Model: Database & Collection Resources



Document Collections versus Tables

JSON Documents
(Nested Hierarchies)

```
{
  "FirstName" : "Bob",
  "LastName" : "Smith",
  "BirthDate" : "03/11/1985",
  "PhoneNumbers" :
   [ { "Home" : "571-555-1212" },
     { "Cell" : "703-525-1234" } ],
  "Interests: [ "golf", "movies" ]
}
```

versus

RDBMS Tables
(Inter-tabular Relational Integrity)

Contacts

ContactID	123
FirstName	Bob
LastName	Smith
BirthDate	03/11/1985

Interests

InterestID	3
ContactID	123
Interest	Golf

PhoneNumbers

PhoneID	1
ContactID	123
Location	Home
Number	571-555-1212

Interacting with Data: Relational vs Document

Relational Databases
(SQL: Sequential Query Language)

SELECT * FROM *[Table]* WHERE…

INSERT INTO *[Table]* (Col1, Col1)

UPDATE *[Table]* *SET [Col1]* = *'value'*

DELETE FROM *[Table]* *WHERE…*

Filtering: the WHERE clause

- WHERE LastName = 'Smith'
  AND InterestID IN (1,2)

Projection: the SELECT clause

- SELECT FirstName, LastName… FROM

versus

Document Collections
(Documents: JSON Expressions)

db.*collection*.find({ *criteria* }, { *projection* })

db.*collection*.insert({ *field* : *'value'* })

db.*collection*.update({ *criteria* }, { *action* })

db.*collection*.remove({ *criteria* })

Filtering: More JSON Documents

- { "LastName" : "Smith",
  "Interests" : {"Golf", "Movies"} }

Projection: More JSON Documents

- { "FirstName" : 1, "BirthDate" : 0,
  "PhoneNumbers.Home" : 1 }

The JSON Language

Understanding How JSON is Used to Store and Retrieve Data

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JSON in NoSQL: How JSON Sparked NoSQL

Features of JSON

- Data Structure of the Web
- **Simple** Data Format
- Has Displaced More Complex Data Formats Such As XML and *ML
- **Developer Friendly:** Supported in Nearly Every Programming Language
- **Agility** of JSON Records
- **Extensible:** Lack of a Predefined Schema Makes Upgrades Easy

```
"firstName": "John",
"lastName": "Smith",
"age": 25,
"address": {
     "streetAddress": "21 2nd S
     "city": "New York",
     "state": "NY",
     "postalCode": 10021
},
"phoneNumbers": [
     {
          "type": "home",
```

Document = BSON Document

- BSON simply stands for “Binary JSON”
- Based in Open JSON document format
- Extended to add some optional non-JSON-native data types.
- MongoDB stores data in BSON format both internally, and over the network


```json
{
  "InvoiceID": "IN1241287",
  "TotalItems": 9,
  "TotalValue": 52.15,
  "Customer": {
    "CSID": 112423532,
    "FullName": "Fred Flaire"
  },
  "Lines": [
    {
      "ProductCode": 63137,
      "Description": "Formal Work Pants (M)",
      "Quantity": 1,
      "Price": 42.43,
      "Size": 32,
      "Color": "Black"
    },
    {
      "ProductCode": 63137,
      "Description": "KitKat Jumbo",
      "Quantity": 8,
      "Price": 2.34,
      "Pack": 6,
      "Units": "Bars"
    }
  ]
}
```

Document = BSON Document

- Open JSON standard document format
- Language-independent data format
- Made up of attribute–value pairs
- Supports recursive embedding
- Supports embedded arrays
- Flexible schema

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}
```

Items = JSON Document

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}
```

MongoDB API CRUD Operations - Insert

Inserting New Documents (Rows) Into a Collection (Table)

```
db.users.insertOne(
   {
      name: "sue",
      age: 26,
      status: "pending"
   }
)
```

collection

field: value

field: value

field: value

document

MongoDB API CRUD Operations - Read

Retrieving Documents (Rows) From a Collection (Table)

`db.users.find(`	collection
`{ age: { $gt: 18 } },`	query criteria
`{ name: 1, address: 1 }`	projection
`).limit(5)`	cursor modifier

MongoDB API Features – Creating Databases

Creating New Databases in MongoDB

```
db.users.find(
    { age: { $gt: 18 } },
    { name: 1, address: 1 }
).limit(5)
```

collection
query criteria
projection
cursor modifier

MongoDB API Features – Creating Collections

Creating New Collections in a MongoDB Database

```
db.runCommand({
        customAction: "CreateCollection",
        collection: "testCollection",
        offerThroughput: 400
});

db.runCommand({
        customAction: "UpdateCollection",
        collection: "testCollection",
        offerThroughput: 1200 });
```

MongoDB API Features – Indexing

Single Field Indexes:	• db.coll.createIndex({name:1})
Compound indexes:	• db.coll.createIndex({name:1,age:1})
Geospatial Indexes:	• db.coll.createIndex({ location : "2dsphere" })
Wildcard Indexes:	• db.coll.createIndex({ "$**" : 1 })

Q & A

A Survey of Data Management Systems