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Big Data Storage and Database Services – common systems & integration problems

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Common data models and data storage/database systems

Common data models

- File
- Relational data model
- Key-Value data model
- Document-oriented model
- Column family model
- Graph model
- Vectorization model

Special file formats in big data

- **For analytical big data, remember the patterns about data**
  - write once, read many
  - analytics queries often access data based on "columns" (e.g., sum of all "trip payments")
- **File formats**
  - compression, columnar representation for column-based queries/accesses, encryption
  - suitable with big data analytics (e.g., Spark, Hadoop)
- **Examples**
  - Apache ORC (https://orc.apache.org/)
  - Apache Parquet (https://parquet.apache.org/)
- **They are the file formats under many big data systems**

Blob data

Big files:

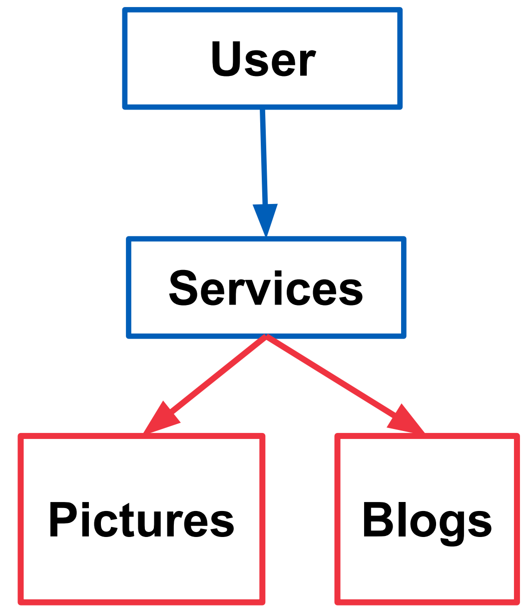
- Pictures, documents, big log files, images, video, backup data

Storage

- File systems or blob storage

Implementations

- File systems: NFS, GPFS, Lustre (http://lustre.org/), Hadoop File systems
- Storage: Amazon S3, Azure Blob storage, OpenStack Swift, Minio
- Simple API for direct access



Example - Amazon S3

Store blob files and their metadata

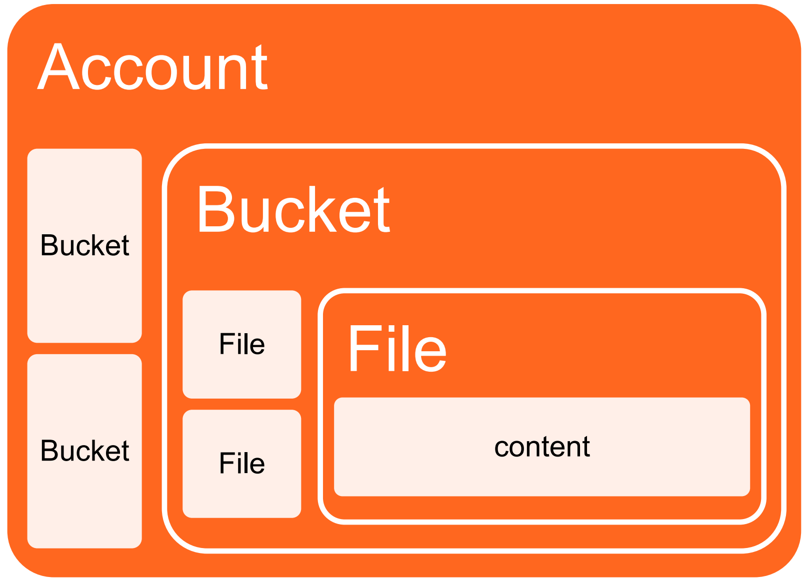
- Max 5TB per file
- A file is identified by a key

Structure

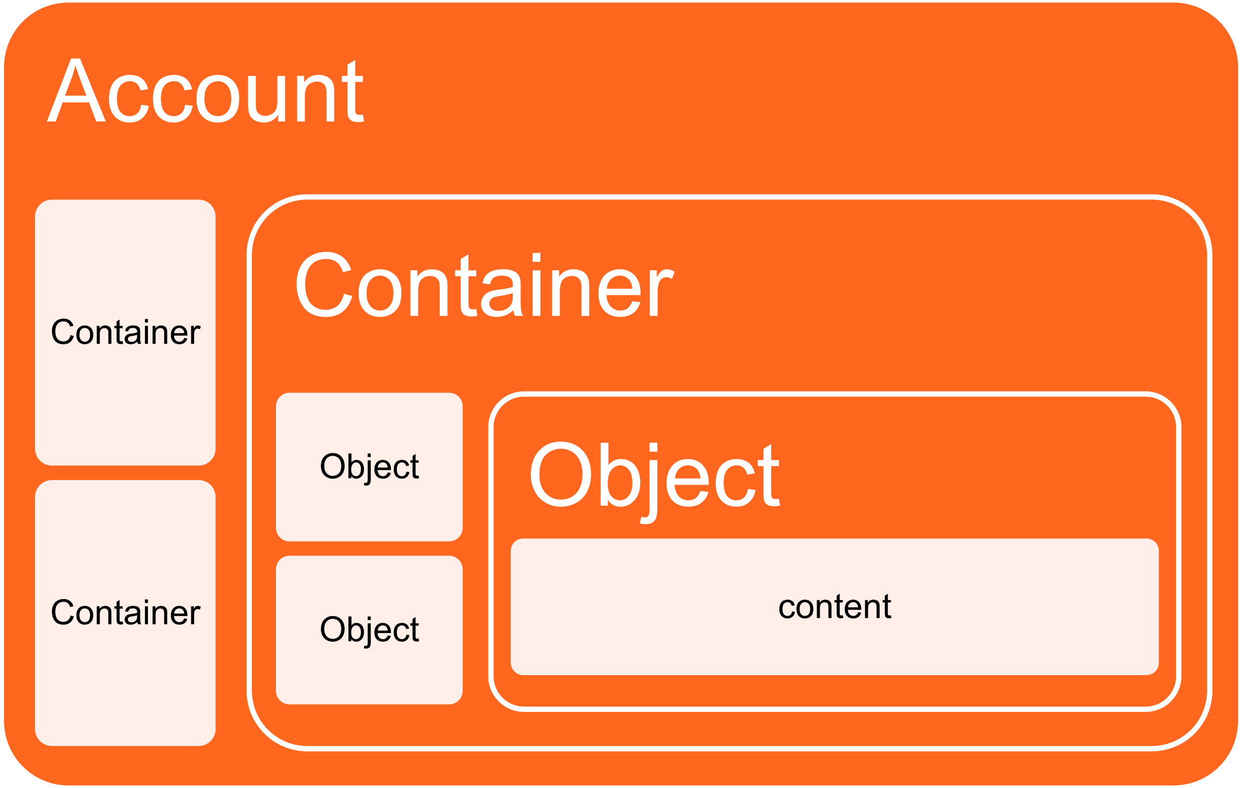
- File = Object
- Object: name and metadata
- Objects are organized into Buckets

Simple APIs

- REST



OpenStack Swift



http://docs.openstack.org/developer/swift/

Minio

- **Check https://min.io/**
- **For different deployment models: Kubernetes, VMs, edge-cloud**
- **S3 compatibility**

Relational Model

- **Well-known, long history**
- **Tables with rows and columns**
  - Strict schema requirements
- **Powerful querying & strong consistency support**
  - E.g.: Oracle Database, MySQL Server, PostgreSQL, MariaDB

Example: Alarm in BigQuery

stationparameters

Schema | Details | Preview

Field name	Type	Mode
reading_time	TIMESTAMP	NULLABLE
value	FLOAT	NULLABLE
station_id	INTEGER	NULLABLE
parameter_id		

stationdescription

Schema | Details | Preview

Field name	Type	Mode
station_id	INTEGER	NULLABLE
code	STRING	NULLABLE
name	STRING	NULLABLE
address	STRING	NULLABLE
description	STRING	NULLABLE
latitude	STRING	NULLABLE
longitude	STRING	NULLABLE

stationalarms

Schema | Details | Preview

Field name	Type	Mode
station_id	INTEGER	NULLABLE
alarm_id	INTEGER	NULLABLE
parameter_id	INTEGER	NULLABLE
start_time	TIMESTAMP	NULLABLE
end_time	TIMESTAMP	NULLABLE
value	FLOAT	NULLABLE
threshold	INTEGER	NULLABLE

Relational Databases for big data scenarios

- **Relational database at very large-scale**
  - Amazon Aurora, CockroachDB, Microsoft Azure SQL Data Warehouse
- **We said ACID is hard with big data**
  - relational big database must address replication, distribution, and scalability issues
- **Examples of Amazon Aurora (reading list)**
  - based on MySQL/InnoDB but change the architecture, separate storage from engine, support cloud scale and replication, etc.

Key-Value Model

- **Tuple = (key, value)**
  - Values can be base on different structures
- **Scalable and performance**
- **Primary use case: caching (pages, sessions, frequently access data, distributed lock)**
  - Simple, very efficient but limited querying capabilities
- **Implementation:**
  - Memcached, Riak, Redis, Apache Accumulo

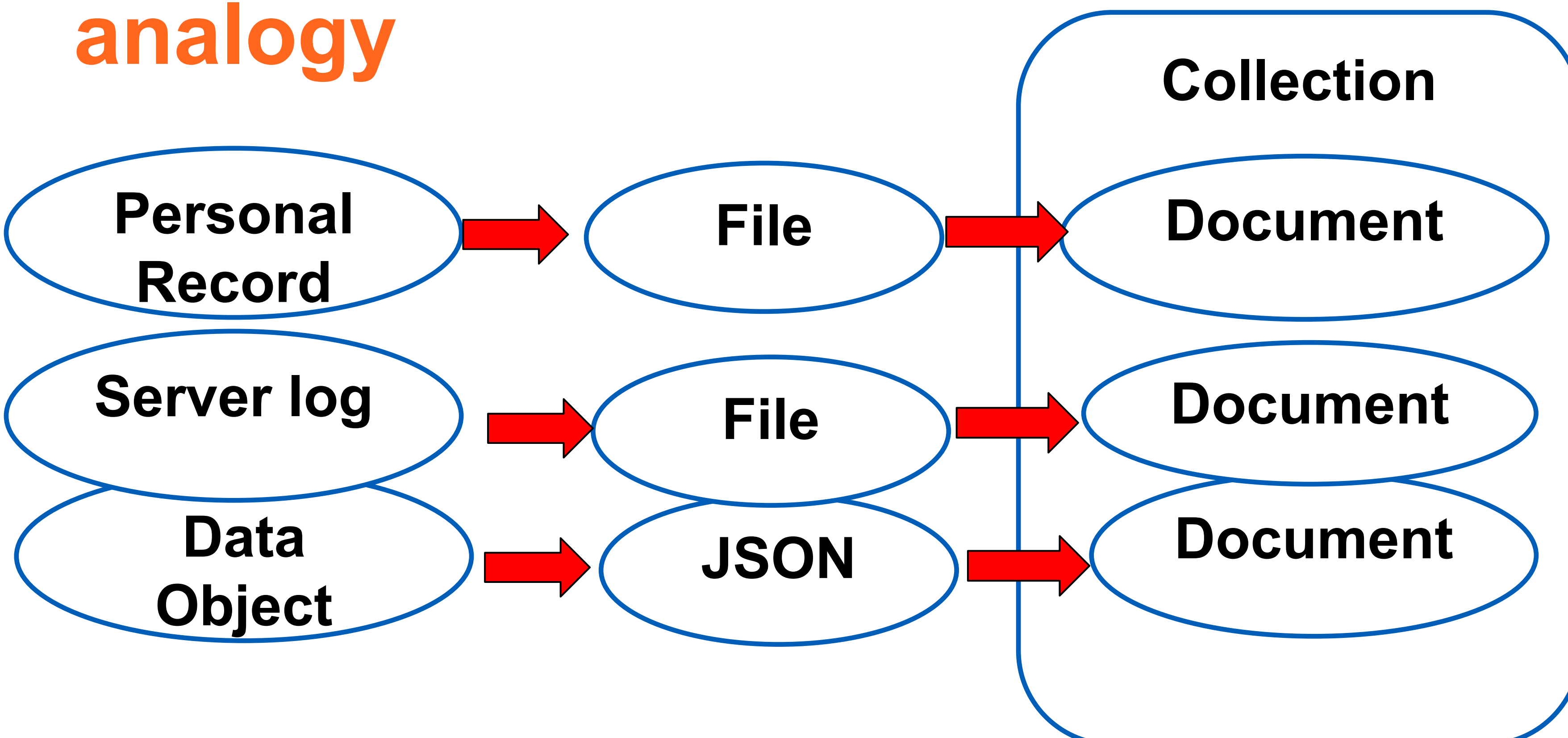
Example: Redis

- **http://redis.io/**
- **In-memory cache service**
  - *Store (key,value) tuples in memory but persistent back to database*
- Simple APIs
  - Well support with many programming languages
  - Widely used in big data ecosystems
- **Learning**
  - *https://app.redislabs.com/#/login provides a free account*

Example: Redis

http://redis.io/topics/benchmarks

Document-oriented model – simple analogy



Document-oriented Model

- **Documents**
  - flexible schema (schemaless) with flexible content
  - data fields can be complex for sub documents
  - use collections, each collection is a set of documents
- **Primary use cases**
  - large amounts of semi-structured data
  - collection of data with different structures

Examples: MongoDB.Atlas

https://www.mongodb.com/atlas/database

Graph-oriented model

- **Data is represented as a graph**
  - nodes or vertices represent objects
  - an edge describes a relationship between nodes
  - properties associated with nodes and edge provide other information
- **Use cases**
  - when searching data is mainly based on relations (social networks, asset relationship, knowledge graph)

Working with graph databases

- **Graph databases**
  - Azure CosmosDB, ArgangoDB, Titan, TypeDB, Neo4J, OrientDB
- **Query languages:**
  - Gremlin, SPARQL, Cypher
- **Graph computing frameworks (analysis)**
  - Apache TinkerPop, Apache Spark GraphX

Example

https://github.com/vaticle/typedb

Column-family data model

Motivation: scalable, distributed storage for multi-dimensional sparse sorted map data

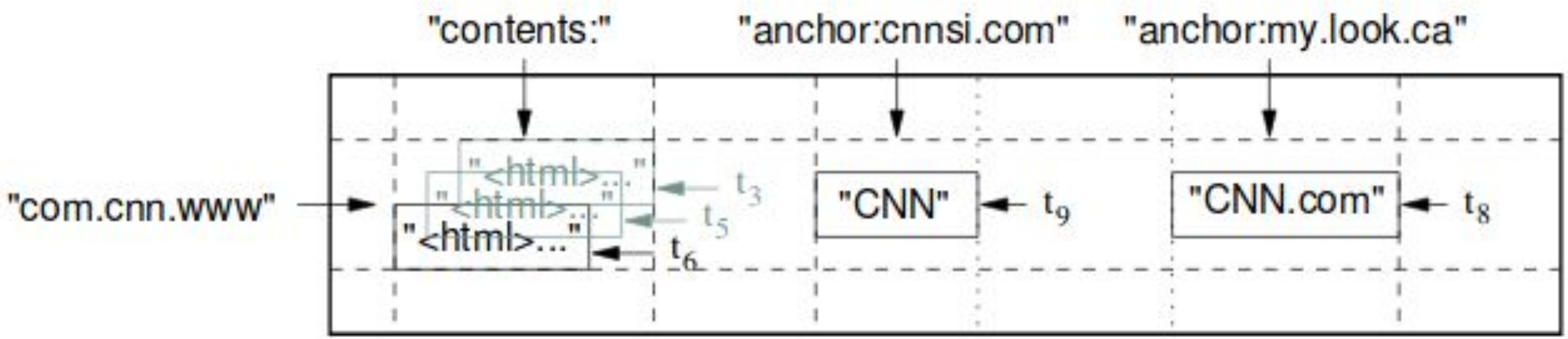
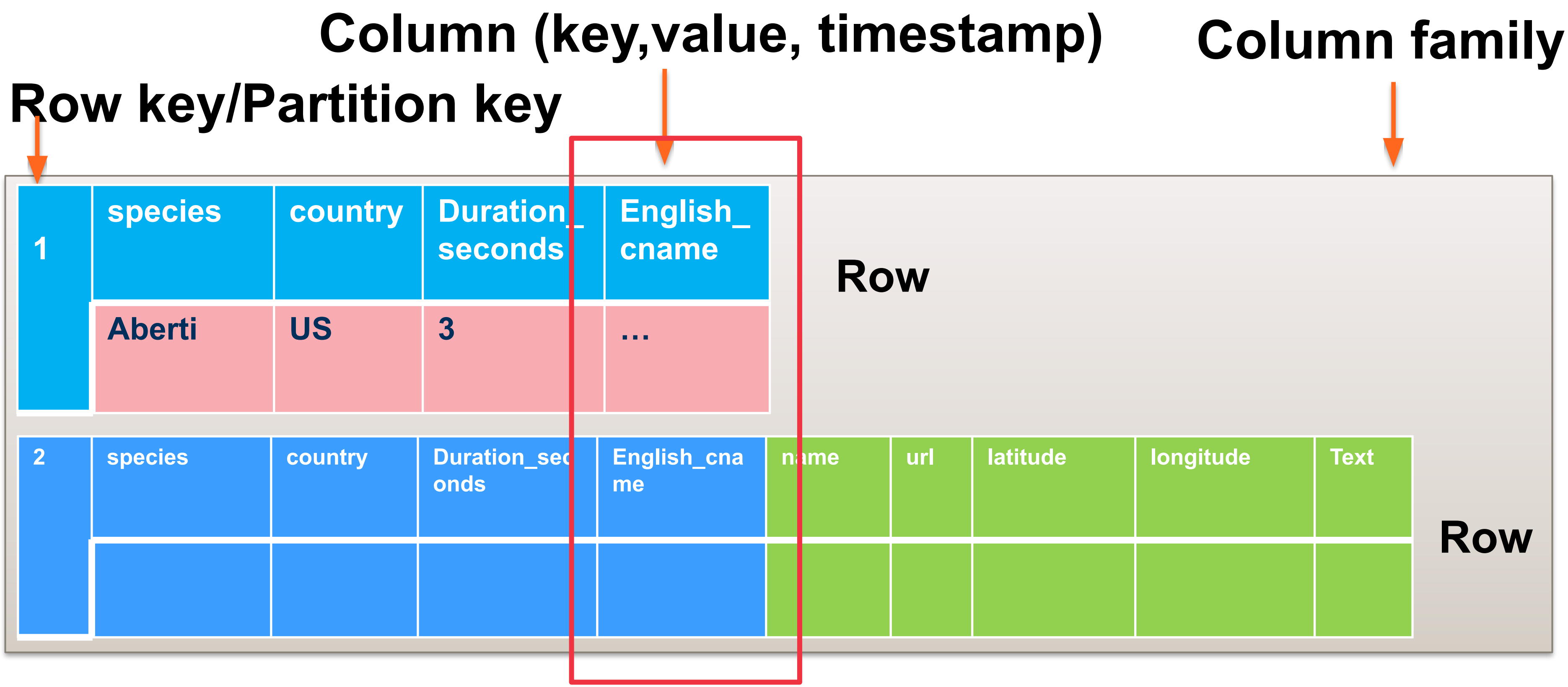


Figure source: Fay Chang, Jeffrey Dean, Sanjay Ghemawat, Wilson C. Hsieh, Deborah A. Wallach, Mike Burrows, Tushar Chandra, Andrew Fikes, and Robert E. Gruber. 2006. Bigtable: a distributed storage system for structured data. In Proceedings of the 7th symposium on Operating systems design and implementation (OSDI '06). USENIX Association, Berkeley, CA, USA, 205-218.

Column-family data model

- **Data Model**
  - Table consists of rows
  - Row consists of a key and one or more columns
  - Columns (column name, value, timestamp)
  - Columns are grouped into column families
  - Columns can be different in rows
    - flexible, wide columns → save spaces

Example of a data model in Cassandra



Examples

Examples of rows

Column (name, value, timestamp)

```
 english_cname          | writetime(english_cname)
------------------------+-------------------------
 Black-tailed Gnatcatcher |        1569966171073228

(1 rows)
```

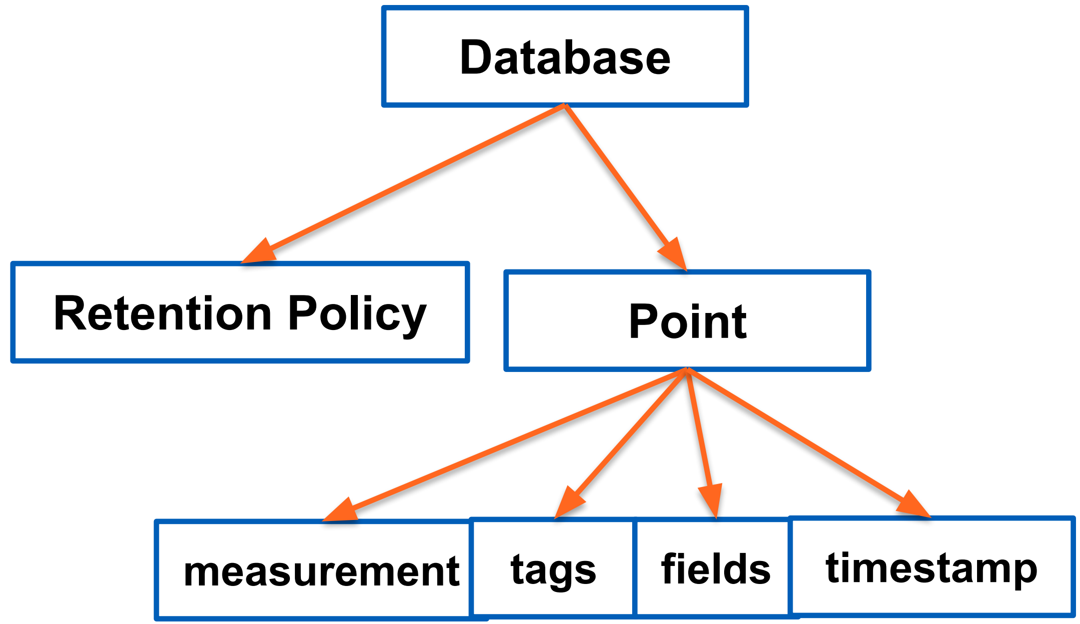
```
cassandra@cqlsh> select * from tutorial12345.bird2;

@ Row 1
-----------------+-------------------------
 species         | melanura
 country         | Mexico
 duration_seconds | 29
 english_cname   | Black-tailed Gnatcatcher
 file_id         | 71907
 latitude        | 32.156
 longitude       | -115.793

@ Row 2
-----------------+-------------------------
 species         | melanura
 country         | United States
 duration_seconds | 29
 english_cname   | Black-tailed Gnatcatcher
 file_id         | 358907
 latitude        | 33.7329
 longitude       | -115.8023
```

Time Series Database

- **So many types of data in big data are time series**
  - IoT measurements, session data, log, etc.
- **Of course you can also use other databases**
  - e.g., Cassandra, ElasticSearch, BigTable
- **Time Series Databases specially designed for time series data**
  - *examples: Riak TS (Time Series), InfluxDB, Apache Druid*

Example: InfluxDB

- https://www.influxdata.com/
- High-level query, SQL-alike Language
- Retention policy for data storage, sharding and replication



An example of InfluxDB

```
> show measurements
name: measurements
name
----
stationalarm
stationaparameter
> select * from stationalarm;
name: stationalarm
time            alarm_id   datapoint_id      station_id   value   valueThreshold
----            --------   ------------      ----------   -----   --------------
1487444343000000    308          121         1161115016   240     240
```

In-memory databases

- **Databases use machine memory for storage**
  - Persist data on disks
  - Require very powerful machines
- **In principle it is not just about data models but also data management, data processing, software and hardware optimization, e.g.,**
  - SAP HANA, VoltDB: in memory relational databases
- **Why are in-memory databases important?**

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Interfaces between a data storage/databases system and its external analysis systems

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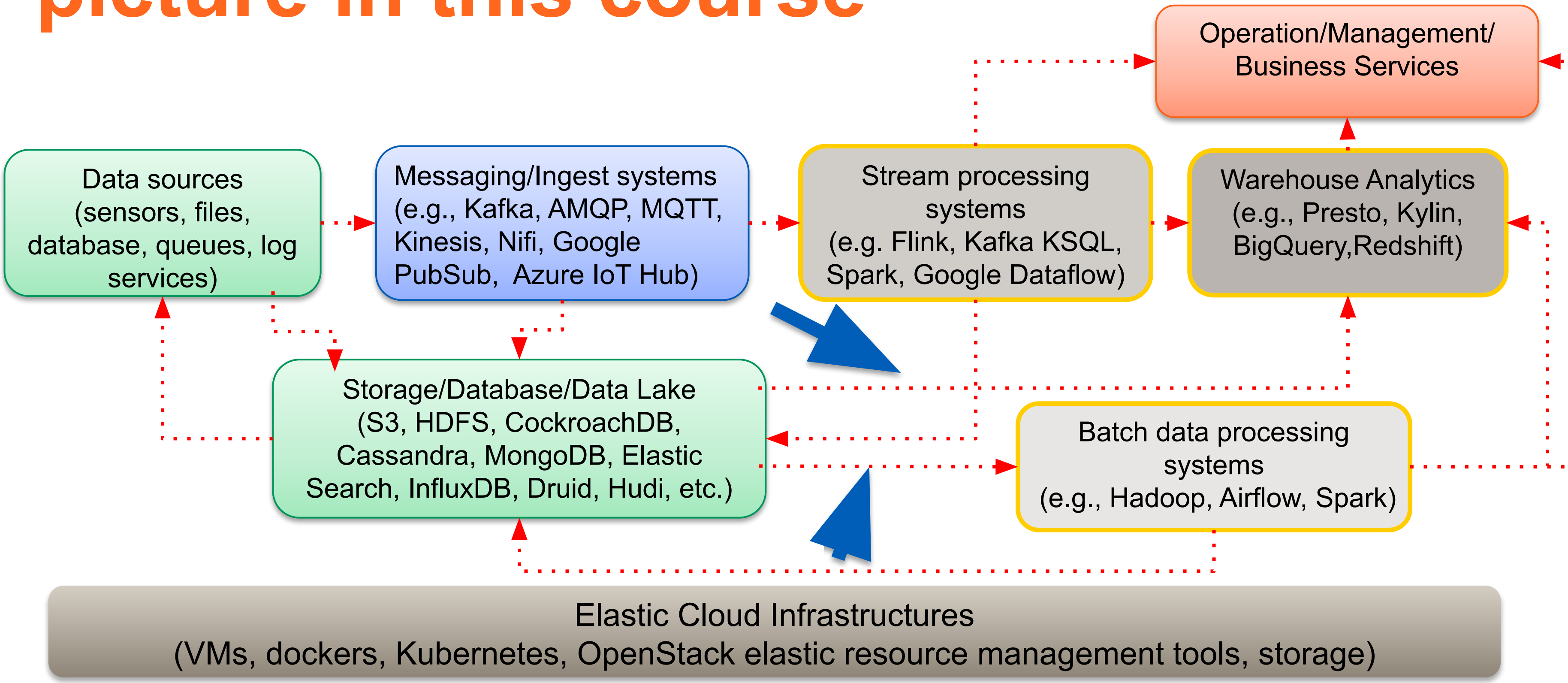
In many cases: the data in data storage/database service must be made available for large-scale analysis:

large-scale analytics and data are managed by different systems

an important consideration in big data platforms design!

Big data at large-scale: the big picture in this course



Making data available to the analytics

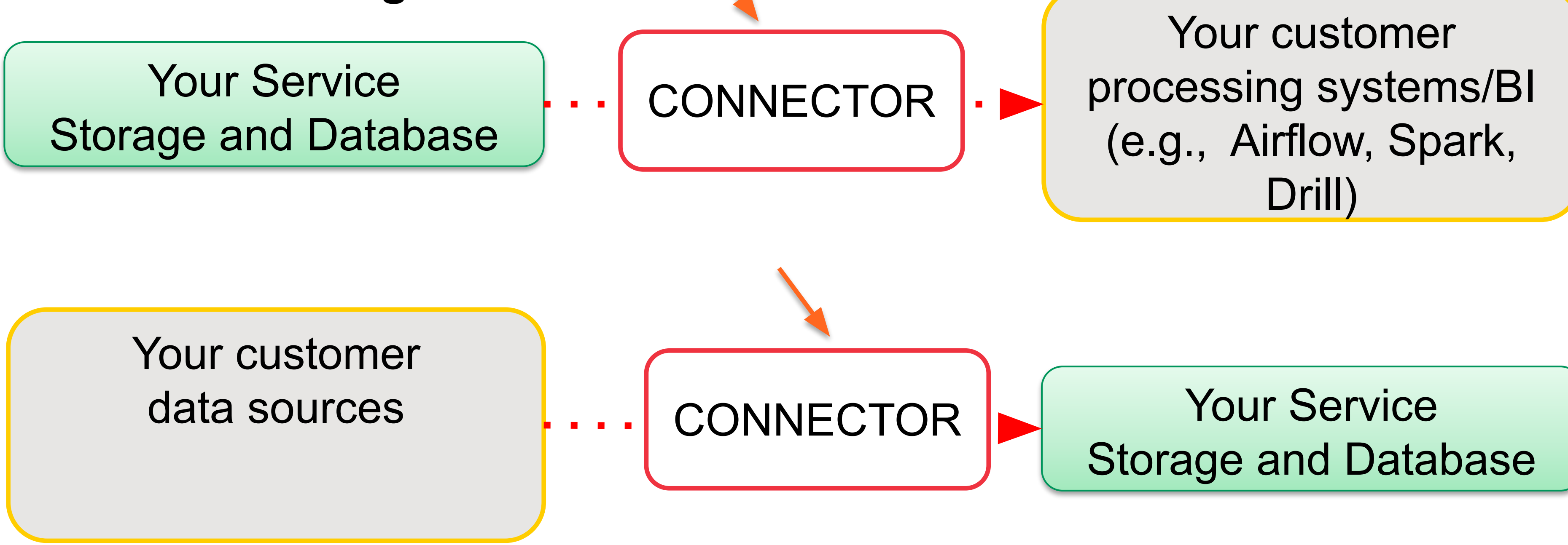
- **Data layer must map/provide data to processing layer**
  - maximize the analytics possibilities
- **Key issues**
  - avoid data movement as much as possible
  - avoid contention between the data management and the data analytics system
- **Techniques**
  - “mount”, specific connectors/drivers, copy-process-remove activities

Mount/"Fuse"

- **Mapping a remote storage as a local file system**
  - Blobfuse (Microsoft Azure), gcsfuse (Google Storage)
  - the network performance is important

Connectors

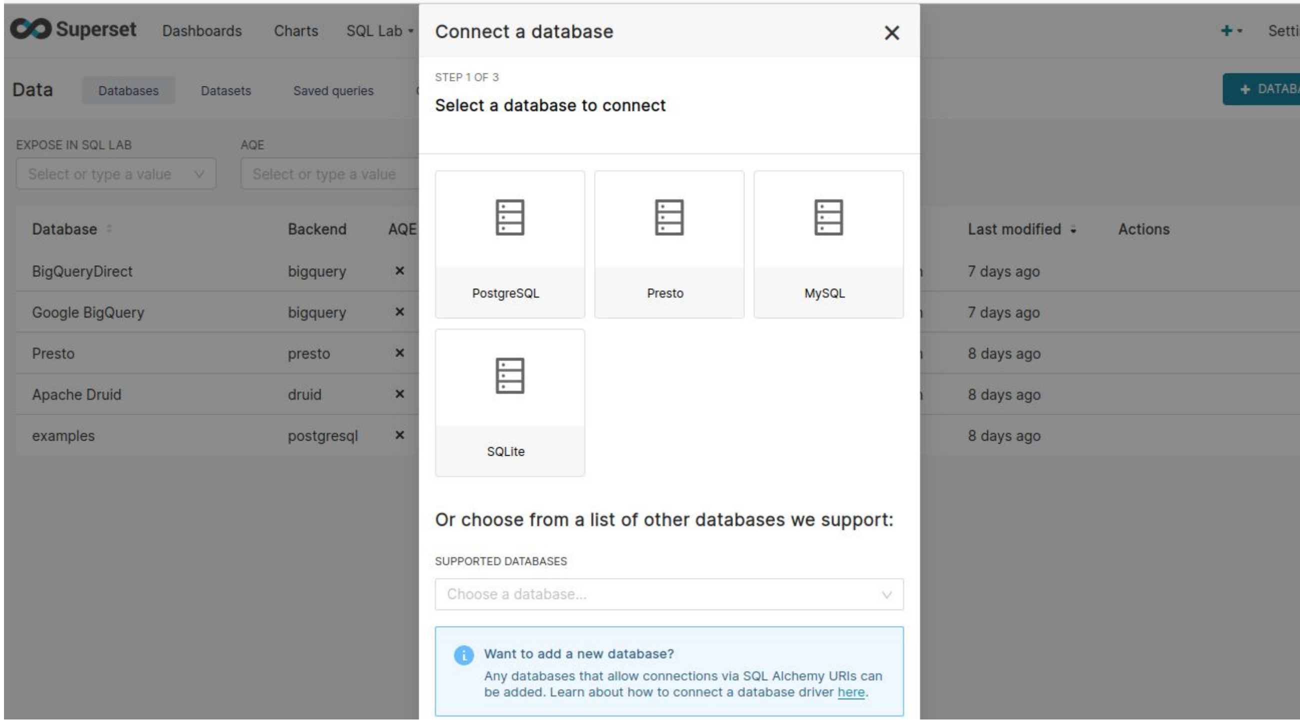
ODBC or other specific protocol connectors to enable data access and ingestion!



Example: Superset connectors

https://superset.apache.org/

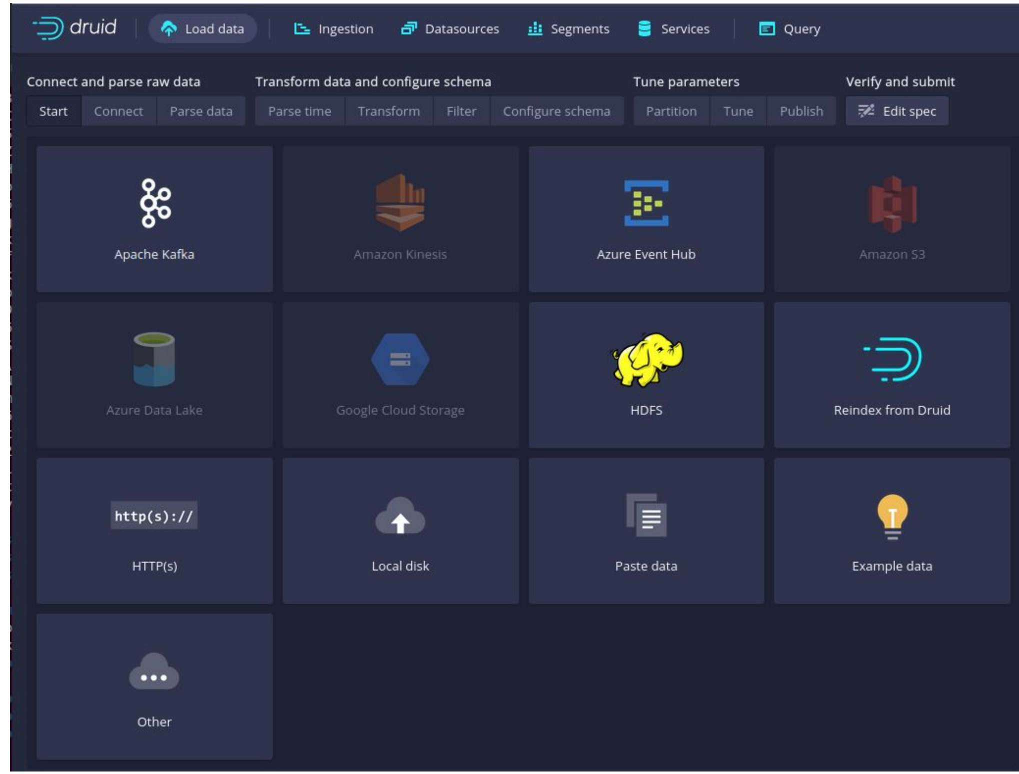
Connectors to different types of databases/datasets to retrieve and analyze data



Example: Druid

https://druid.apache.org/

Different types of connectors (e.g., Kafka, Files, S3, etc.) to allow data ingestion into the database



Analytics and Cloud Storage

- **Various connectors for making data in cloud storages available for analytics**
- **Apache Hadoop/Spark (data analysis) can work with Amazon S3, OpenStack Swift, Google Cloud Storage**
- **Examples:**
  - https://github.com/GoogleCloudDataproc/hadoop-connectors
  - https://spark.apache.org/docs/latest/cloud-integration.html

“Copy and Process”

Client libraries are used to move data from storages and databases to processing places

Examples:

```
import pandas as pd
from sklearn.tree import DecisionTreeClassifier
from cassandra.cluster import Cluster

cluster = Cluster(contact_points=hosts, port=9042,auth_provider=auth_provider)
session = cluster.connect(“tutorial12345”)
sql_query = "SELECT * FROM tutorial12345.bird1234;“
df = pd.DataFrame()
rows= session.execute(sql_query)
df = rows._current_rows
print(df)
```

Thanks!

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