Introduction to Database Systems
CSE 414

Lecture 11: NoSQL

Announcements

- HW 3 due Friday
  - Upload data with DataGrip editor – see message board
  - Azure timeout for question 5:
    - Try DataGrip or SQLite
- HW 2 Grades and Feedback out
  - Check feedback, some tag errors
- HW 4 posted today, due week from Tuesday

Class Overview

- Unit 1: Intro
- Unit 2: Relational Data Models and Query Languages
- Unit 3: Non-relational data
  - NoSQL
  - Json
  - SQL++
- Unit 4: RDMBS internals and query optimization
- Unit 5: Parallel query processing
- Unit 6: DBMS usability, conceptual design
- Unit 7: Transactions
- Unit 8: Advanced topics (time permitting)

Two Classes of Database Applications

- OLTP (Online Transaction Processing)
  - Queries are simple lookups: 0 or 1 join
    E.g., find customer by ID and their orders
  - Many updates. E.g., insert order, update payment
  - Consistency is critical: transactions (more later)

can we maintain a valid state if two identical queries come simultaneously?

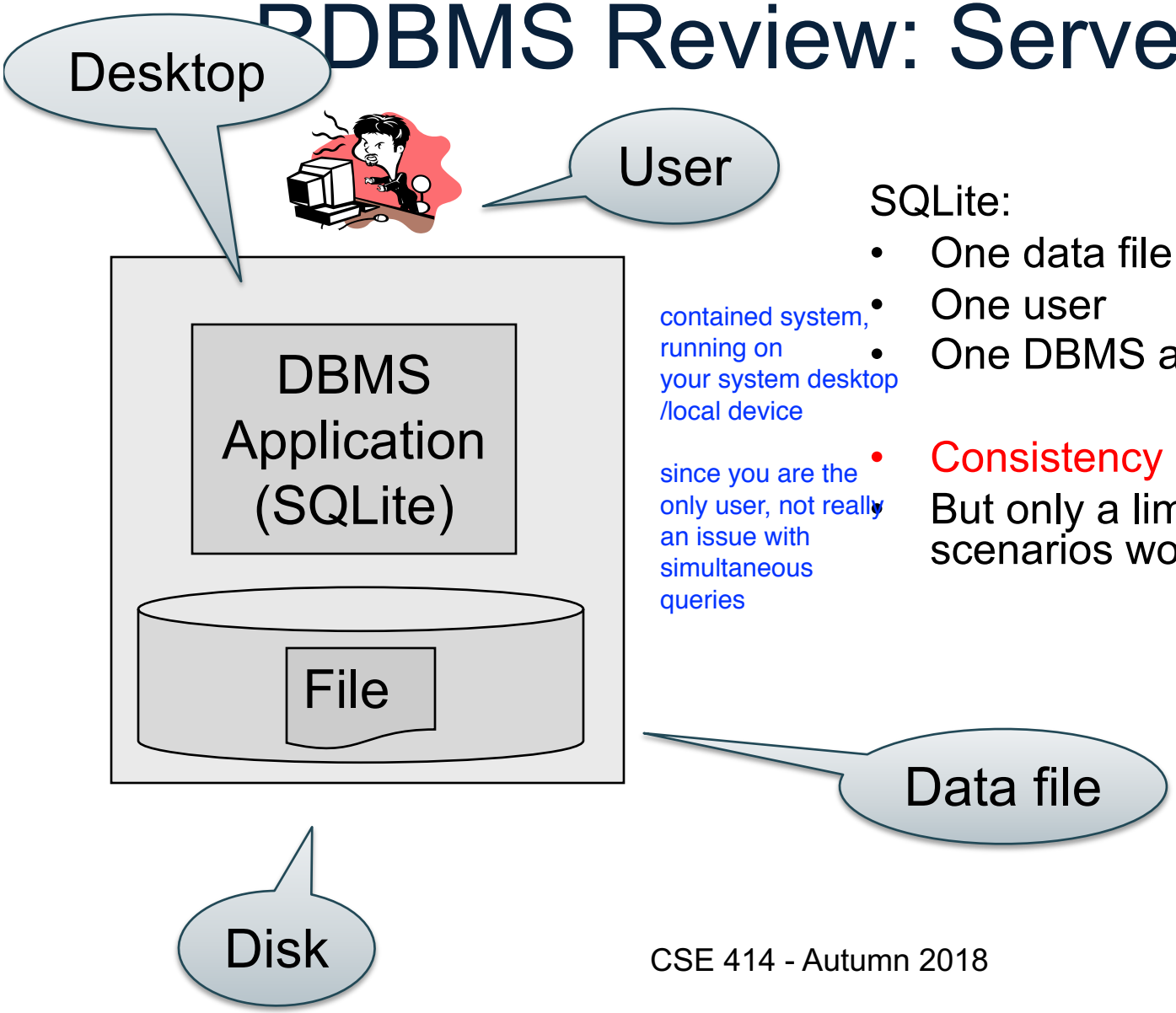
- OLAP (Online Analytical Processing)
  - aka “Decision Support”
  - Queries have many joins, and group-by’s
    E.g., sum revenues by store, product, clerk, date
  - No updates

NoSQL Motivation

- Originally motivated by Web 2.0 applications
  - E.g. Facebook, Amazon, Instagram, etc
  - Web startups need to scaleup from 10 to 100000 users very quickly

- Needed: very large scale OLTP workloads
- Give up on consistency
- Give up OLAP

RDBMS Review: Serverless



contained system, running on your system desktop /local device

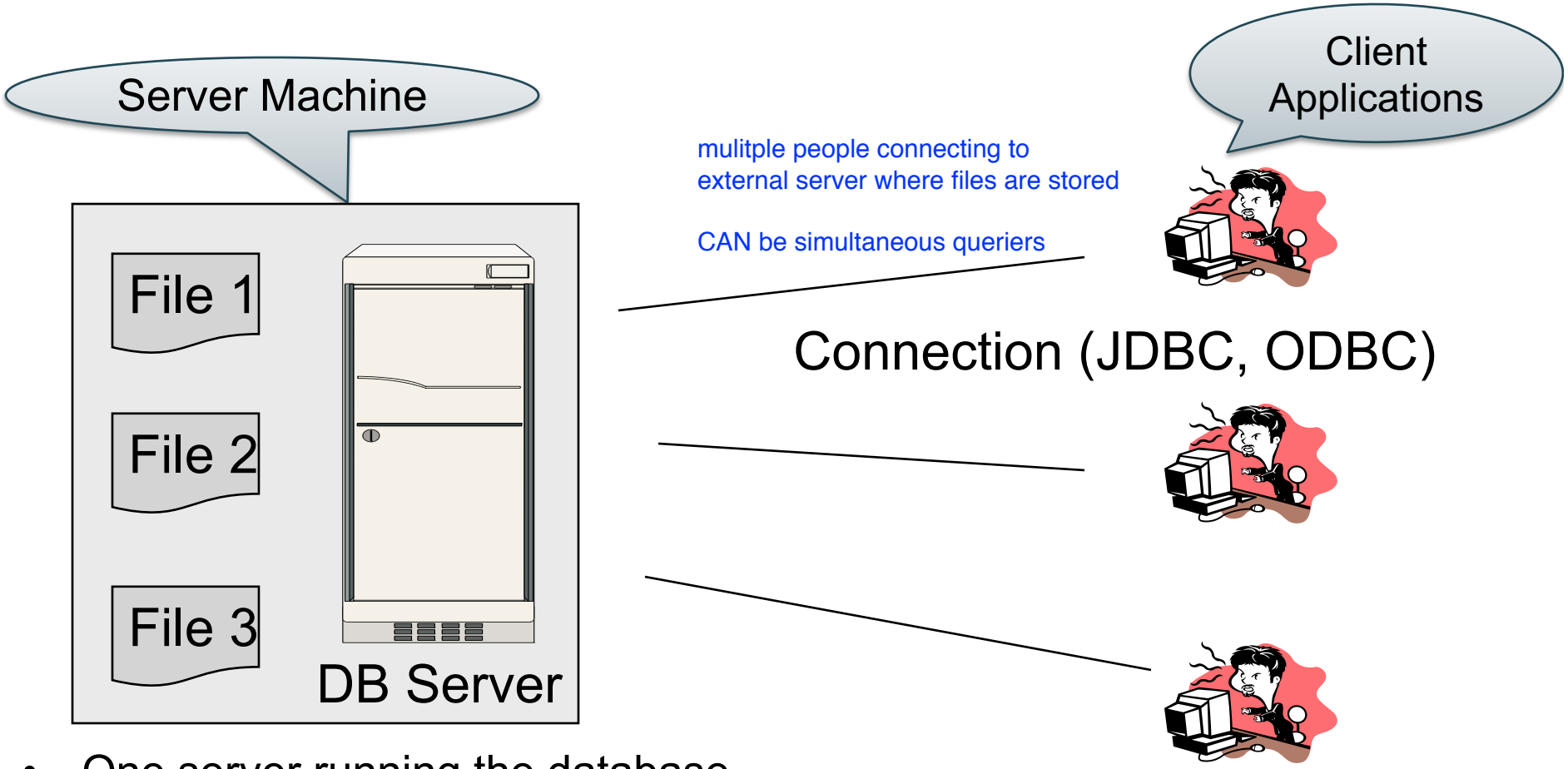
since you are the only user, not really an issue with simultaneous queries

SQLite:

- One data file
- One user
- One DBMS application

- Consistency is easy
- But only a limited number of scenarios work with such model

RDBMS Review: Client-Server



- One server running the database
- Many clients, connecting via the ODBC or JDBC (Java Database Connectivity) protocol

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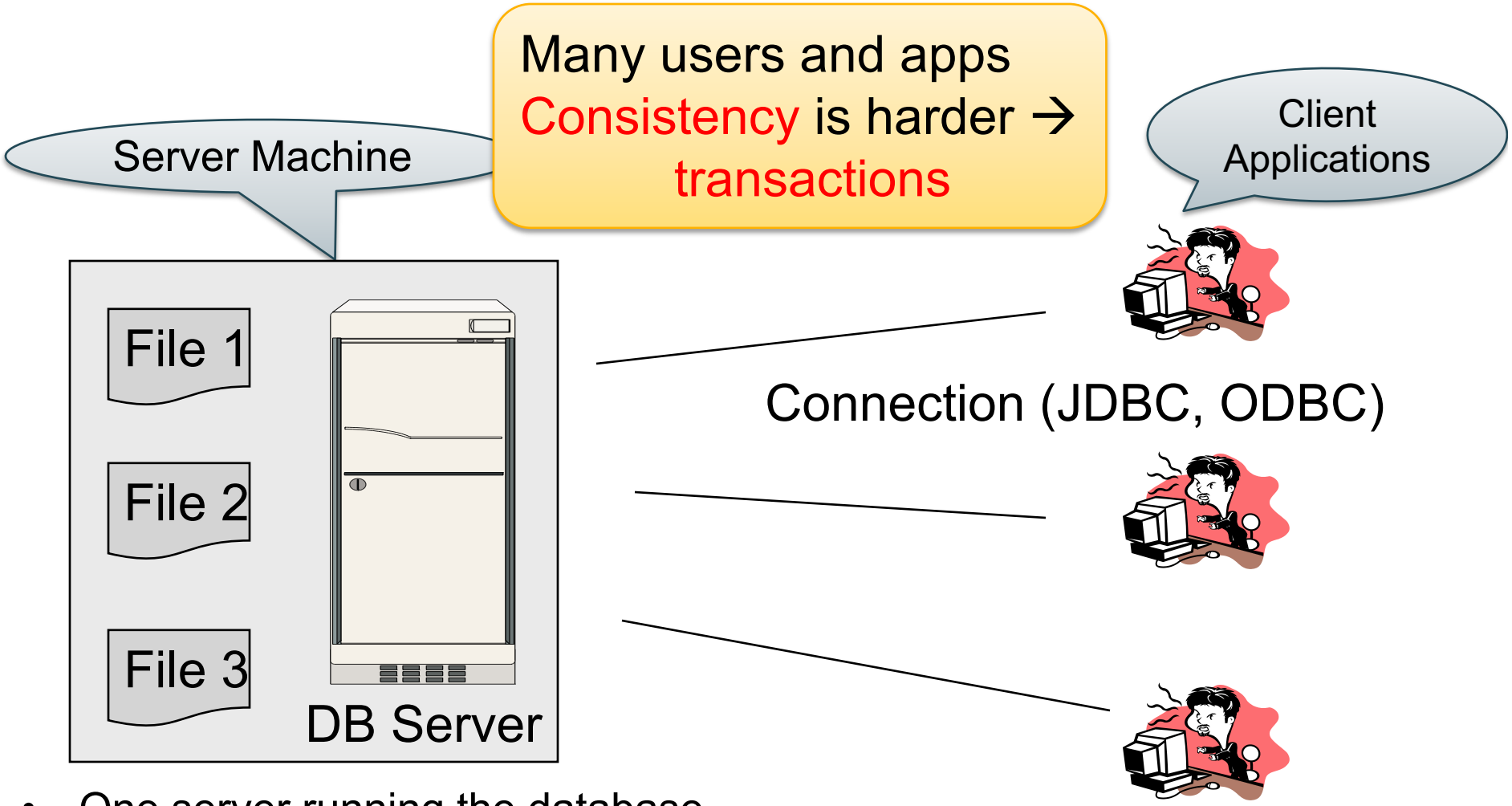

- One server running the database
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DB server has to do a lot of work, holding on to connections to each client

Client-Server

- One *server* that runs the DBMS (or RDBMS):
  - Your own desktop, or
  - Some beefy system, or
  - A cloud service (SQL Azure)

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  - Microsoft's Management Studio (for SQL Server), or
  - psql (for postgres)
  - Some Java program (HW8) or some C++ program

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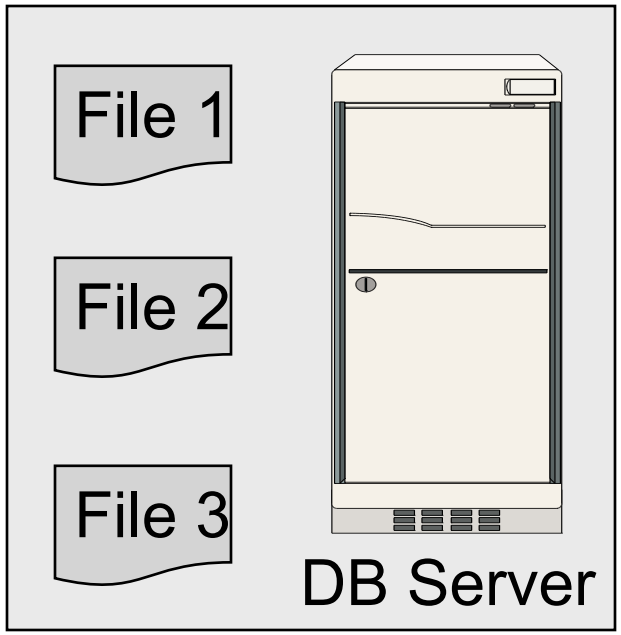
- Clients "talk" to server using JDBC/ODBC protocol

Web Apps: 3 Tier



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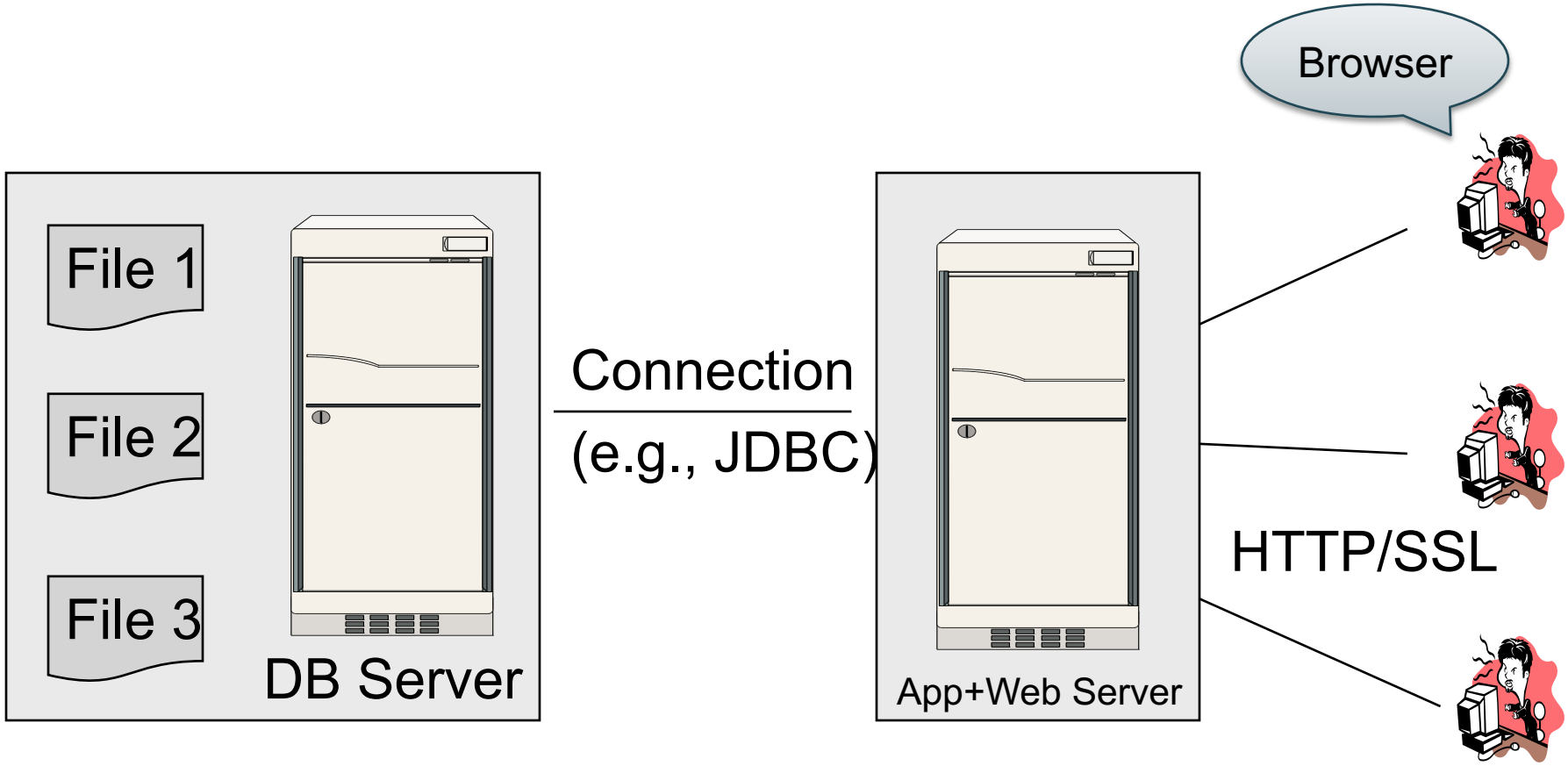

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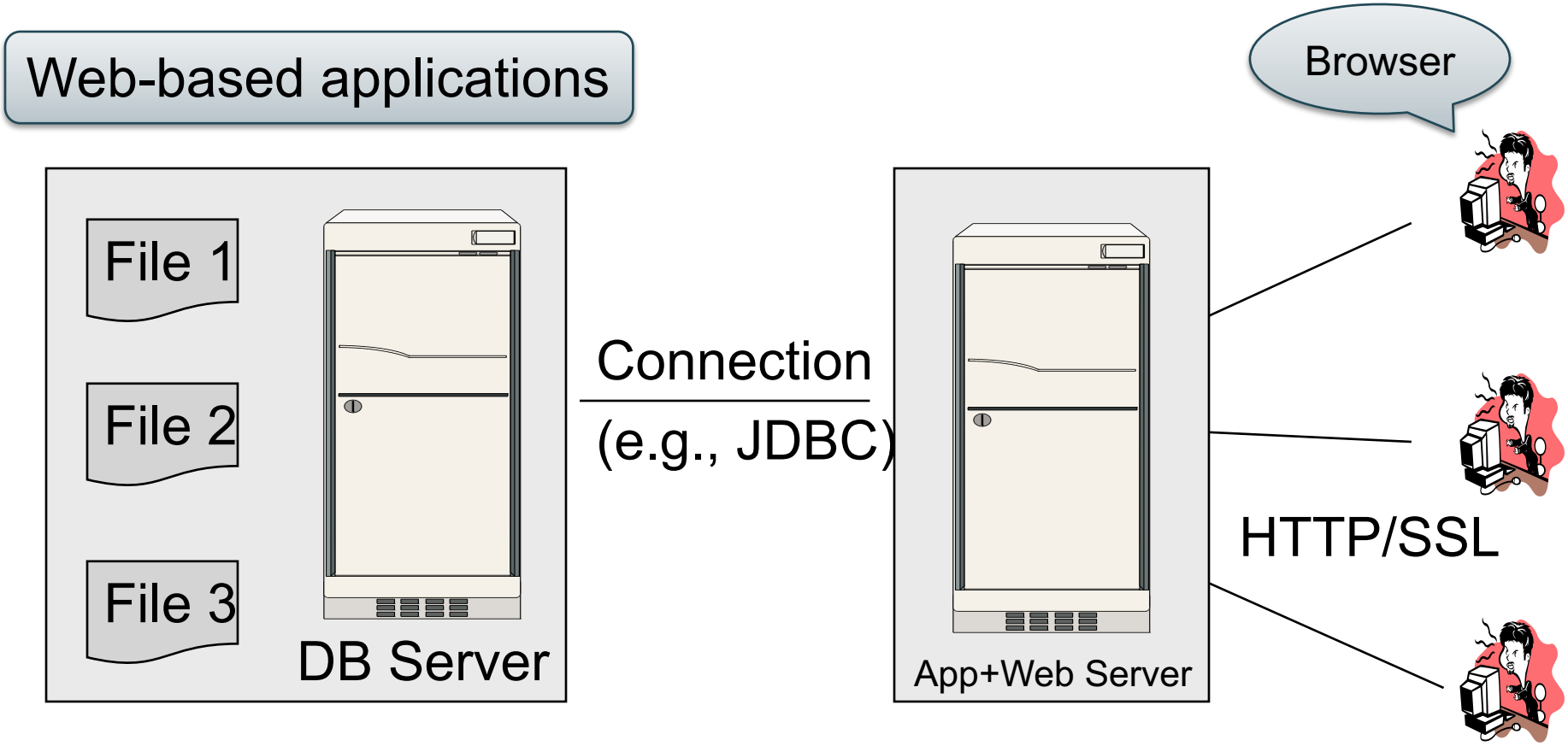

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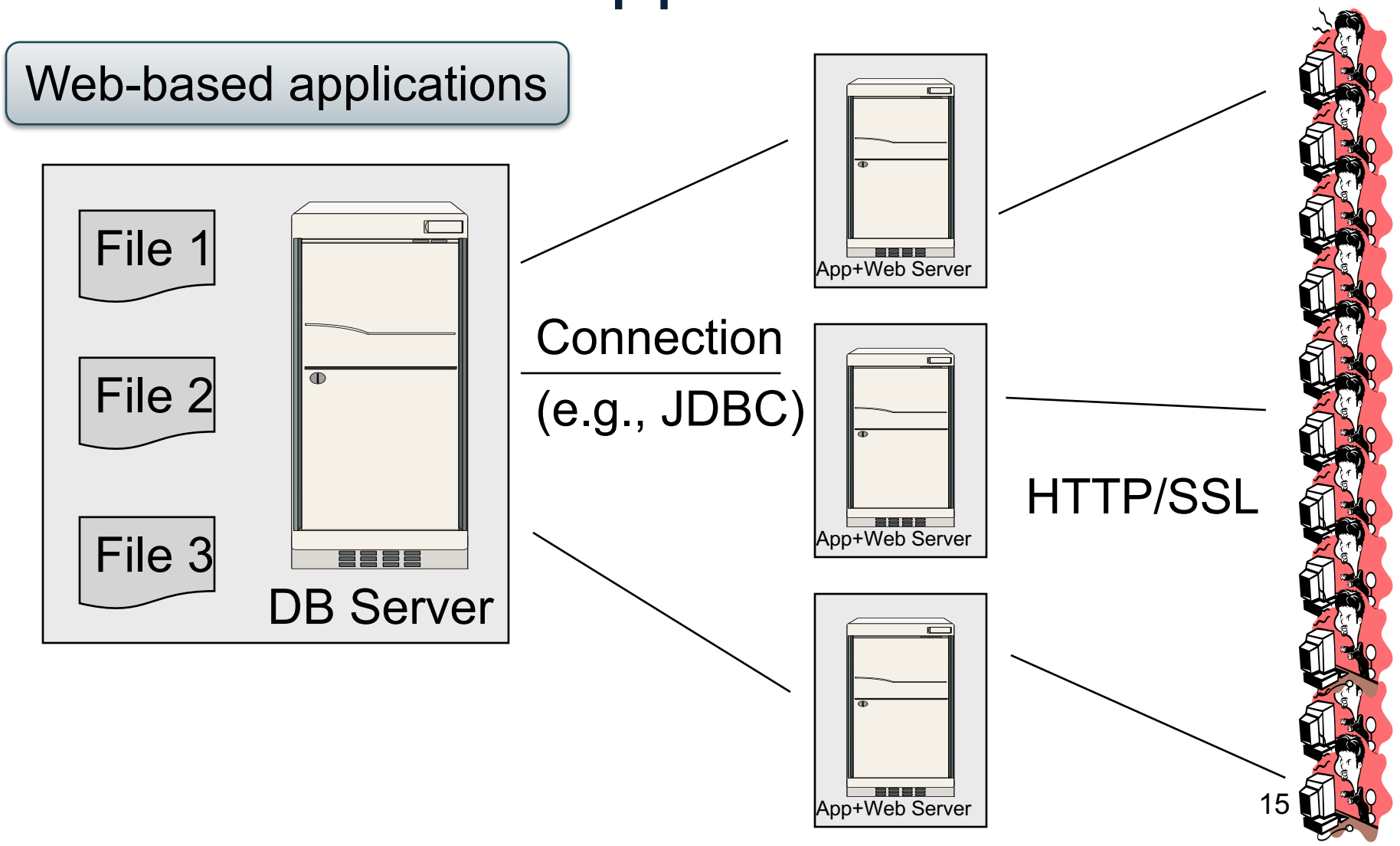
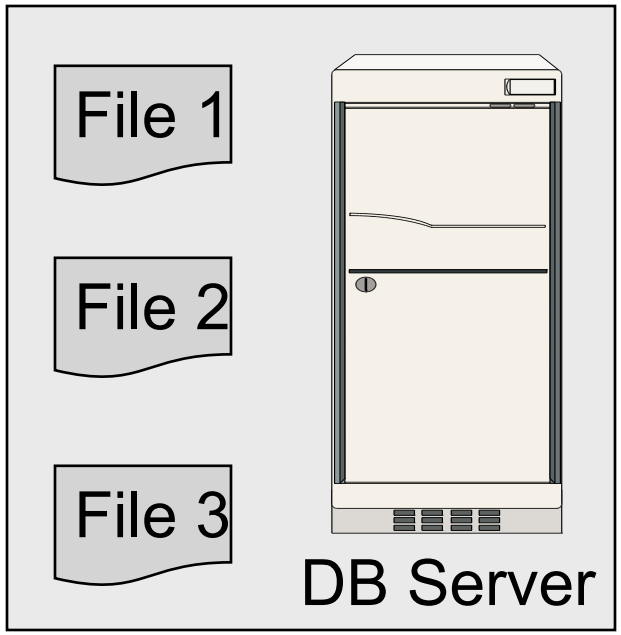


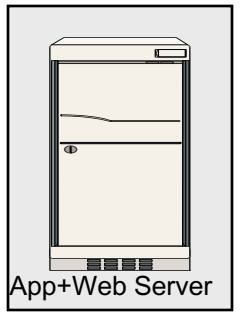
...os: 3 Tier

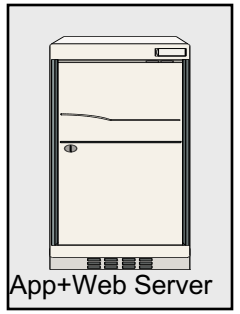
Replicate App server for scaleup

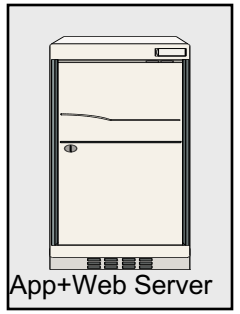
Web-based applications



Connection (e.g., JDBC)







HTTP/SSL

Why not replicate DB server?

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Replicate App server for scaleup

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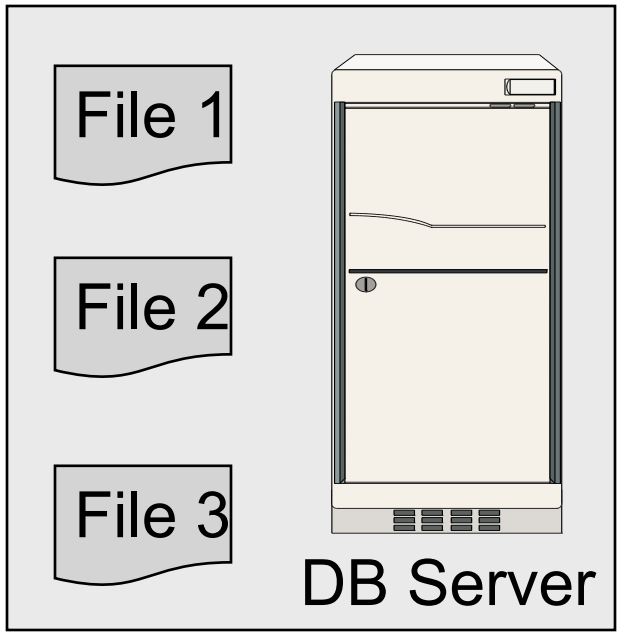

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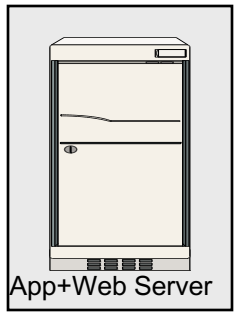
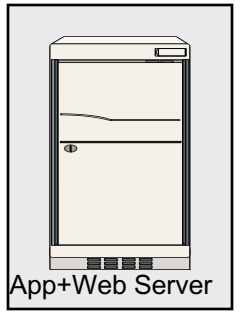
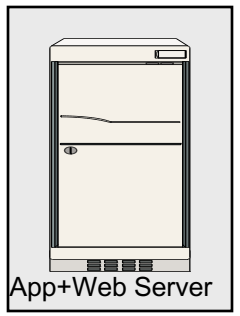






HTTP/SSL

Why not replicate DB server?
Consistency!

hard to keep files identical across both devices

Replicating the Database

INCREASE scale of the database (how many users it can handle)

- Two basic approaches:
  - Scale up through partitioning — divide up data across multiple machines
  - Scale up through replication — multiple identical copies of database

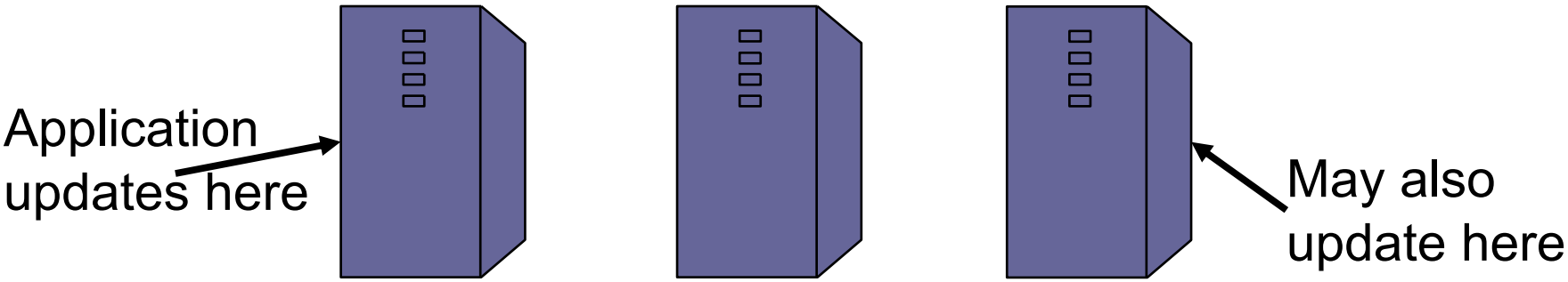
- Consistency is much harder to enforce

Scale Through Partitioning

- Partition the database across many machines in a cluster
  - Database now fits in main memory
  - Queries spread across these machines
- Can increase throughput
- Easy for writes but reads become expensive!

store individual attributes on each server? Lowers space requirement per tuple, can store whole database on a single machine

might have to read from every machine!

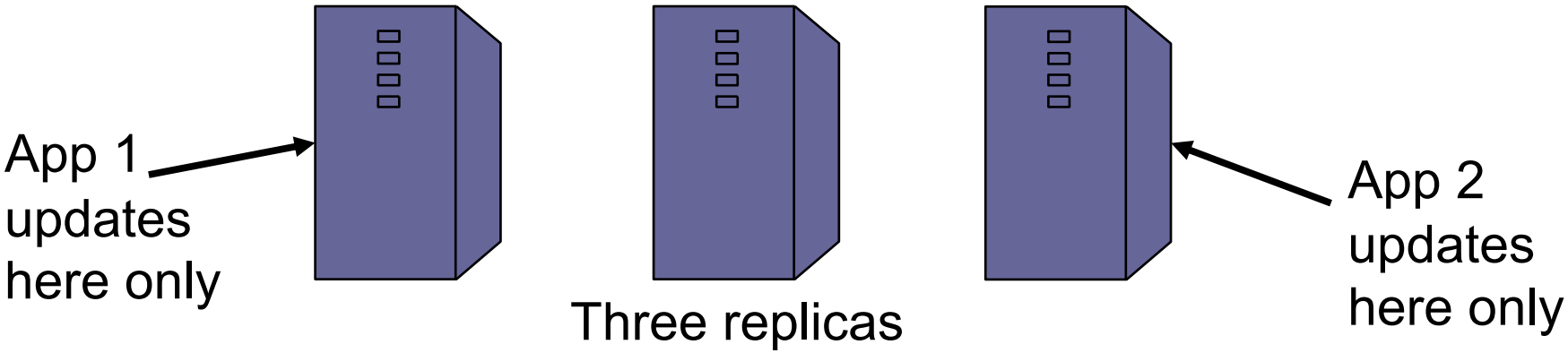


Three partitions

Scale Through Replication

- Create multiple copies of each database partition
- Spread queries across these replicas
- Can increase throughput and lower latency
- Can also improve fault-tolerance
- Easy for reads but writes become expensive!

as that piece of data is stored on separate machines; might have to talk to all machines



Relational Model → NoSQL

thats why a new data model was needed

- Relational DB: difficult to replicate/partition
- Given `Supplier(sno,…),Part(pno,…),Supply(sno,pno)`
  - Partition: we may be forced to join across servers
  - Replication: local copy has inconsistent versions
  - Consistency is hard in both cases (why?)

- NoSQL: simplified data model
  - Given up on functionality
  - Application must now handle joins and consistency

can only extract full tuples of data

Data Models

Taxonomy based on data models:

- Key-value stores — similar to hash tables
  - e.g., Project Voldemort, Memcached
- Document stores — key value basically where value is a document
  - e.g., SimpleDB, CouchDB, MongoDB

Key-Value Stores Features

- **Data model**: (key,value) pairs
  - Key = string/integer, unique for the entire data
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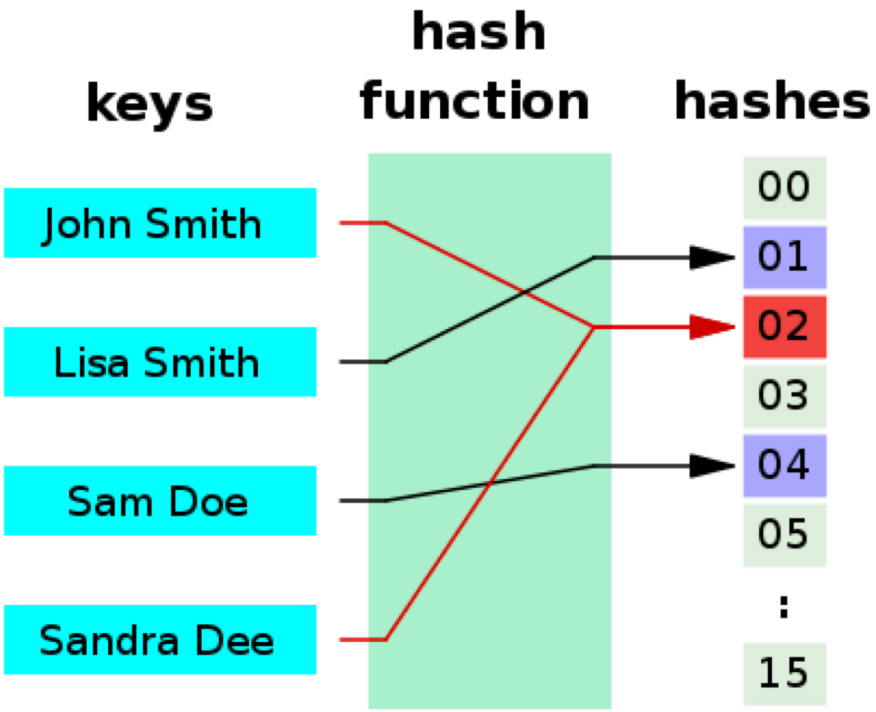
- **Distribution / Partitioning**

Now as these keys uniquely identify each data set, it is much easier to distribute

doesnt have to be a schema, or in First Normal Form

Aside: Hash Functions

- A function that maps any data to a "hash value" (e.g., an integer)



Aside: Hash Functions

- Example: data and hash value are integers
- Simple hash function:
  - `h(key) = key % 42;`
  - `h(10) = 10`
  - `h(2) = 2`
  - `h(50) = 8`

Text

- What does this have to do with data distribution?

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- **Operations**
  - `get(key)`, `put(key,value)`
  - Operations on value not supported
- **Distribution / Partitioning** – w/ hash function
  - No replication: key k is stored at server h(k)
  - 3-way replication: key k stored at h1(k),h2(k),h3(k)

USE HASH FUNCTIONS to decide what server to put on

How does get(k) work? How does put(k,v) work?

apply hash, and the output tells us what server data is on. Look there.

Flights(fid, date, carrier, flight_num, origin, dest, ...)
Carriers(cid, name)

Example

- How would you represent the Flights data as key, value pairs?

How does query processing work?

Flights(fid, date, carrier, flight_num, origin, dest, ...)
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Example

- How would you represent the Flights data as key, value pairs?

- Option 1: key=fid, value=entire flight record

How does query processing work?

Flights(fid, date, carrier, flight_num, origin, dest, ...)
Carriers(cid, name)

Example

- How would you represent the Flights data as key, value pairs?
- Option 1: key=fid, value=entire flight record
- Option 2: key=date, value=all flights that day

How does query processing work?

Flights(fid, date, carrier, flight_num, origin, dest, ...)
Carriers(cid, name)

Example

- How would you represent the Flights data as key, value pairs?

  have a bunch of choices to decide how you organize the data; carefully choosing key value pair can make certain operations much faster.

- Option 1: key=fid, value=entire flight record

- Option 2: key=date, value=all flights that day

- Option 3: key=(origin,dest), value=all flights between

How does query processing work?

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Motivation

- In Key, Value stores, the Value is often a very complex object
  - Key = '2010/7/1', Value = [all flights that date]

Document Store: Force Value to have a specific format

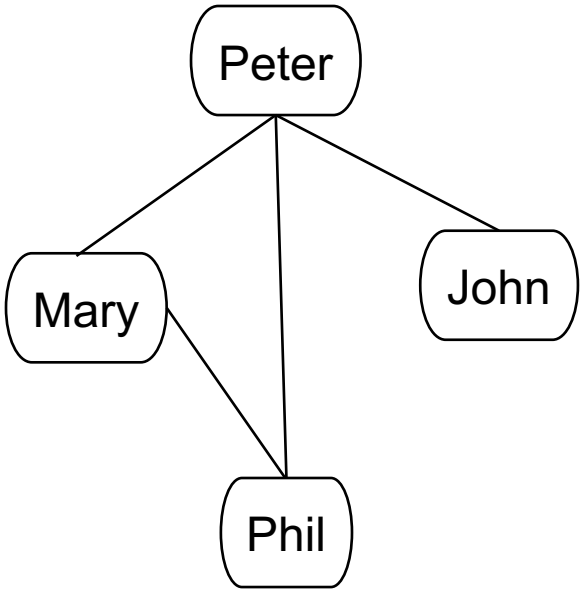
- Better: allow DBMS to understand the *value*
  - Represent *value* as a JSON (or XML...) document
  - [all flights on that date] = a JSON file
  - May search for all flights on a given date

Document Stores Features

- **Data model**: (key,document) pairs
  - Key = string/integer, unique for the entire data
  - Document = JSon, or XML
- **Operations**
  - Get/put document by key
  - Query language over JSon
- **Distribution / Partitioning**
  - Entire documents, as for key/value pairs

We will discuss JSon

Example: storing FB friends



As a graph

OR

Add new attributes?

Storing lists?

Person1	Person2	is_friend
Peter	John	1
John	Mary	0
Mary	Phil	1
Phil	Peter	1
…	…	…

As a relation

We will learn the tradeoffs of different data models later this quarter

JSON

JSON - Overview

- JavaScript Object Notation = lightweight text-based open standard designed for human-readable data interchange. Interfaces in C, C++, Java, Python, Perl, etc.

- The filename extension is .json.

We will emphasize JSon as semi-structured data

JSon Syntax

```
{  "book": [
     {"id":"01",
       "language": "Java”,
       "author": ”H. Javeson”,
        “year”: 2015
     },
     {"id":"07",
       "language": "C++",
       "edition": "second"
       "author": ”E. Sepp”,
       “price”: 22.25
     }
   ]
}
```

JSon vs Relational

- Relational data model
  - Rigid flat structure (tables)
  - Schema must be fixed in advanced
  - Binary representation: good for performance, bad for exchange
  - Query language based on Relational Calculus

- Semistructured data model / JSon
  - Flexible, nested structure (trees) do NOT have a fixed schema
  - Does not require predefined schema ("self describing")
  - Text representation: good for exchange, bad for performance human readable
  - Most common use: Language API; query languages emerging

JSon Terminology

- Data is represented in name/value pairs.
- Curly braces hold objects
  - Each object is a list of name/value pairs separated by , (comma)
  - Each pair is a name is followed by ':'(colon) followed by the value
- Square brackets hold arrays and values are separated by ,(comma).

JSon Data Structures

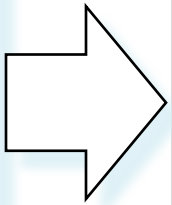
where value can be a complex object (i.e. can store another table within a value)

- Collections of name-value pairs:
  - {“name1”: value1, “name2”: value2, …}
  - The “name” is also called a “key”
- Ordered lists of values:
  - [obj1, obj2, obj3, ...]

Avoid Using Duplicate Keys

The standard allows them, but many implementations don't

```
{"id":"07",      DONT DO THIS
   "title": "Databases",
   "author": "Garcia-Molina",
   "author": "Ullman",
   "author": "Widom"
}
```



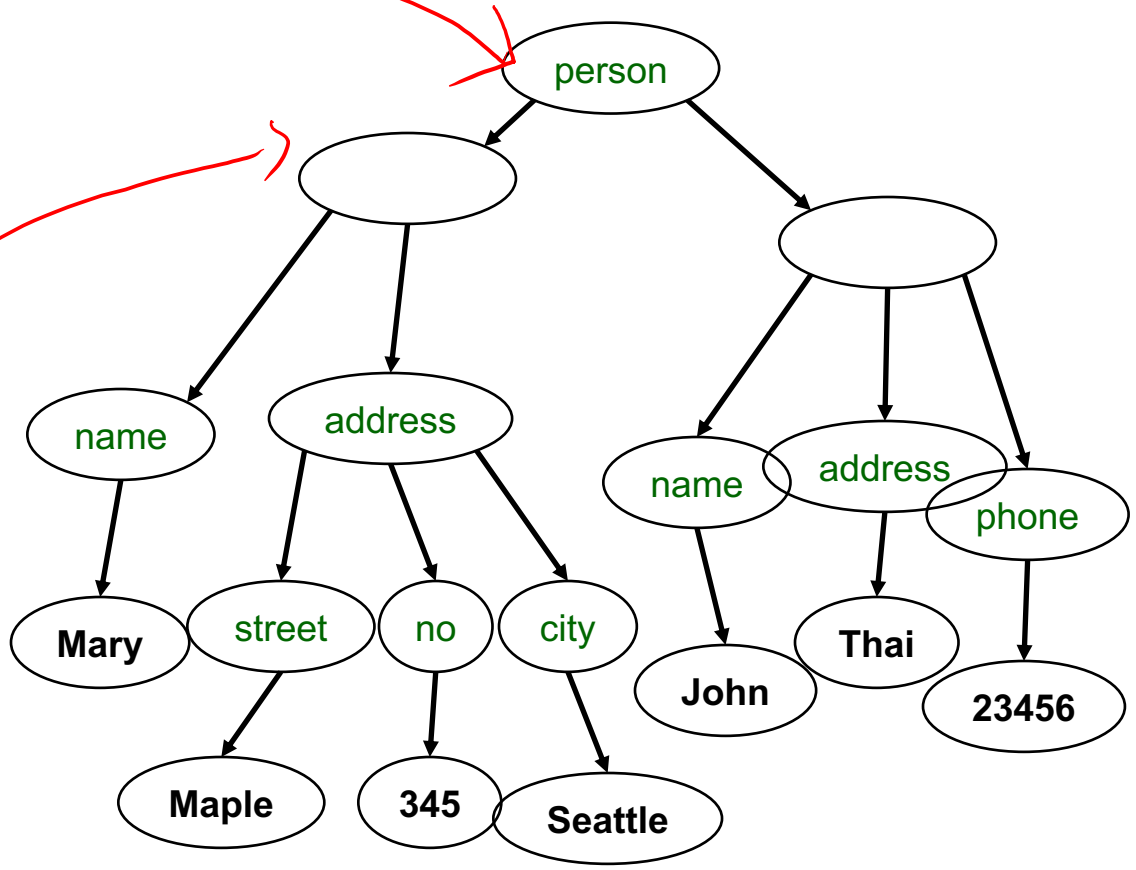
```
{"id":"07",
   "title": "Databases",
   "author": ["Garcia-Molina",
              "Ullman",
              "Widom"]
}
```

JSon Datatypes

- Number
- String = double-quoted
- Boolean = true or false
- nullempty

JSon Semantics: a Tree !

```
{"person":
  [ {"name": "Mary",
     "address":
       {"street":"Maple",
        "no":345,
        "city": "Seattle"}},
    {"name": "John",
     "address": "Thailand",
     "phone":2345678}}
    ]
}
```

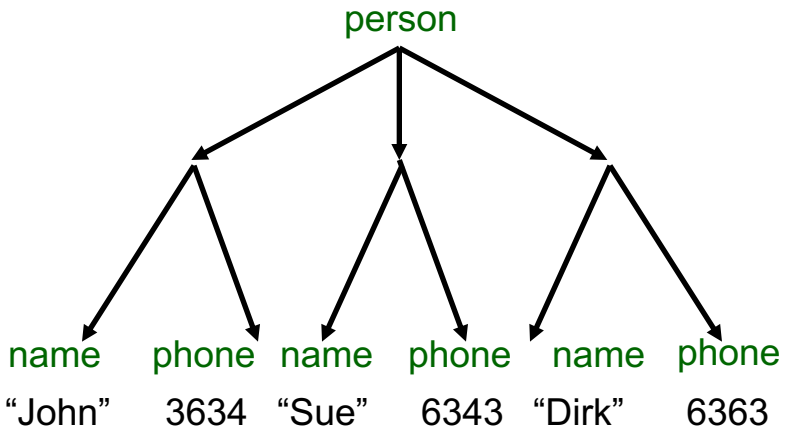


JSon Data

- JSon is self-describing NO SET SCHEMA; keys of JSON tells us what our attributes are
- Schema elements become part of the data
  - Relational schema: person(name,phone)
  - In Json "person", "name", "phone" are part of the data, and are repeated many times
- Consequence: JSon is much more flexible
- JSon = semistructured data

i.e. attributes can vary across tuples

Mapping Relational Data to JSon



Person

name	phone
John	3634
Sue	6343
Dirk	6363

```
{“person”:
     [{“name”: “John”, “phone”:3634},
      {“name”: “Sue”,  ”phone”:6343},
      {“name”: “Dirk”,  ”phone”:6383}
     ]
}
```

Mapping Relational Data to JSon

May inline foreign keys

Person

CAN STORE SUB-tables -> dont need joins

name	phone
John	3634
Sue	6343

Orders

personName	date	product
John	2002	Gizmo
John	2004	Gadget
Sue	2002	Gadget

```
{"Person":
    [{"name": "John",
      "phone":3646,
      "Orders":[{"date":2002,
                 "product":"Gizmo"},
                {"date":2004,
                 "product":"Gadget"}
                ]
     },
     {"name": "Sue",
      "phone":6343,
      "Orders":[{"date":2002,
                 "product":"Gadget"}
                ]
     }
    ]
}
```