Database Systems
CSE 414

Lecture 15: NoSQL & JSON
(mostly not in textbook…
only Ch 11.1)

Announcements

- Homework 4 due tomorrow night
- [No Web Quiz 5]

- Midterm grading *hopefully* finished tonight
  - post online today / tomorrow
  - hand back in section

- Today's lecture:
  - NoSQL & (if time) JSON
  - The book covers XML instead (11.1-11.3, 12.1)

NoSQL

NoSQL Motivation

- Originally motivated by Web 2.0 applications
- Goal is to scale simple OLTP-style workloads to millions or billions of users
  - Ex: Facebook has 1.2B *daily* active users
    - use often correlated in time within in each region
    - > 10M req/sec if 25% of users arrive within one hour
    - SQL Server would crumble under that workload
- Users are doing both updates and reads

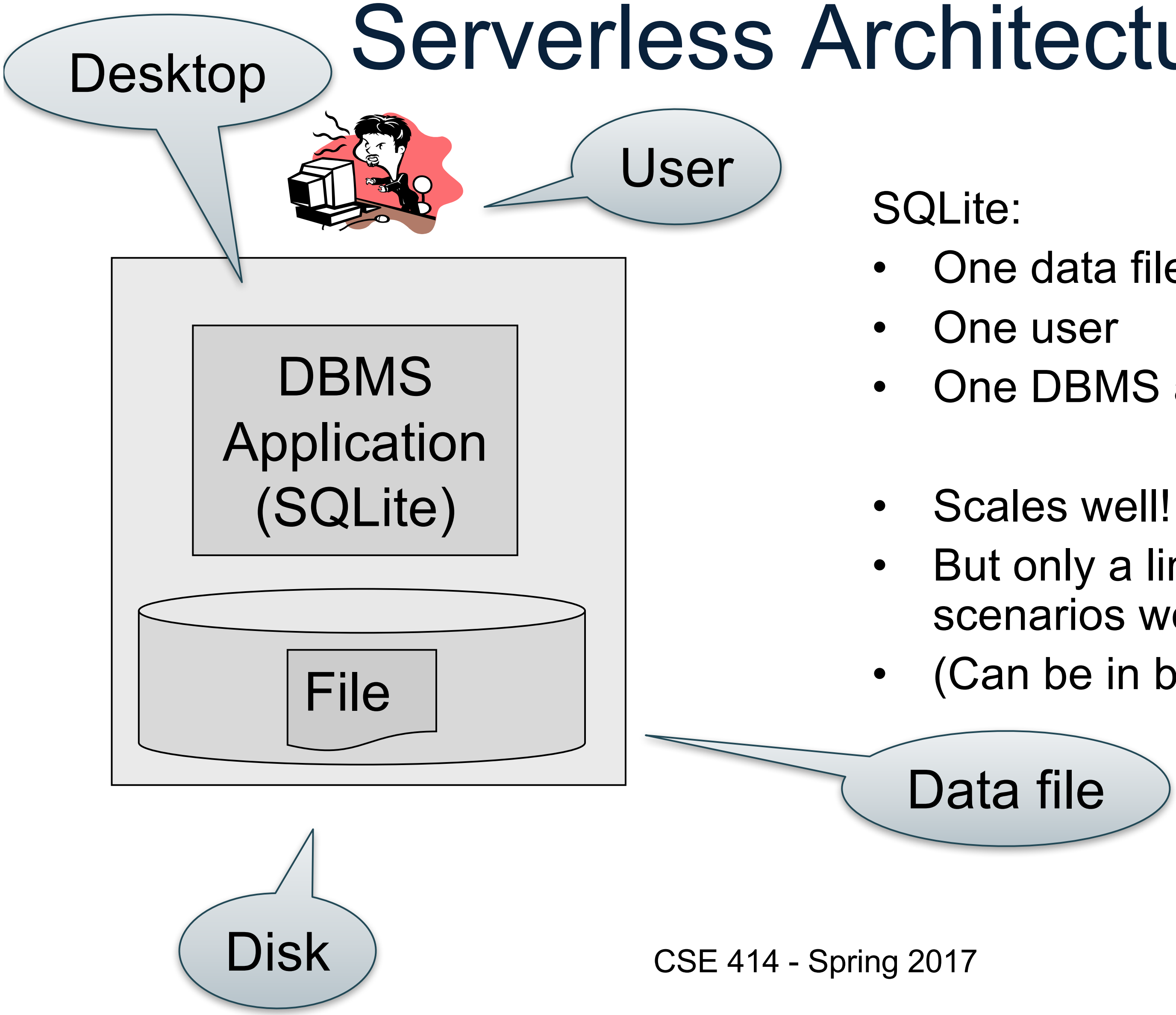
What is the Problem?

- Single server DBMS are too small for Web data
- **Solution**: scale out to multiple servers

- This is hard for the *entire* functionality of DMBS
  - as we will see next…

- NoSQL: reduce functionality for easier scaling
  - Simpler data model
  - Fewer guarantees

Serverless Architecture

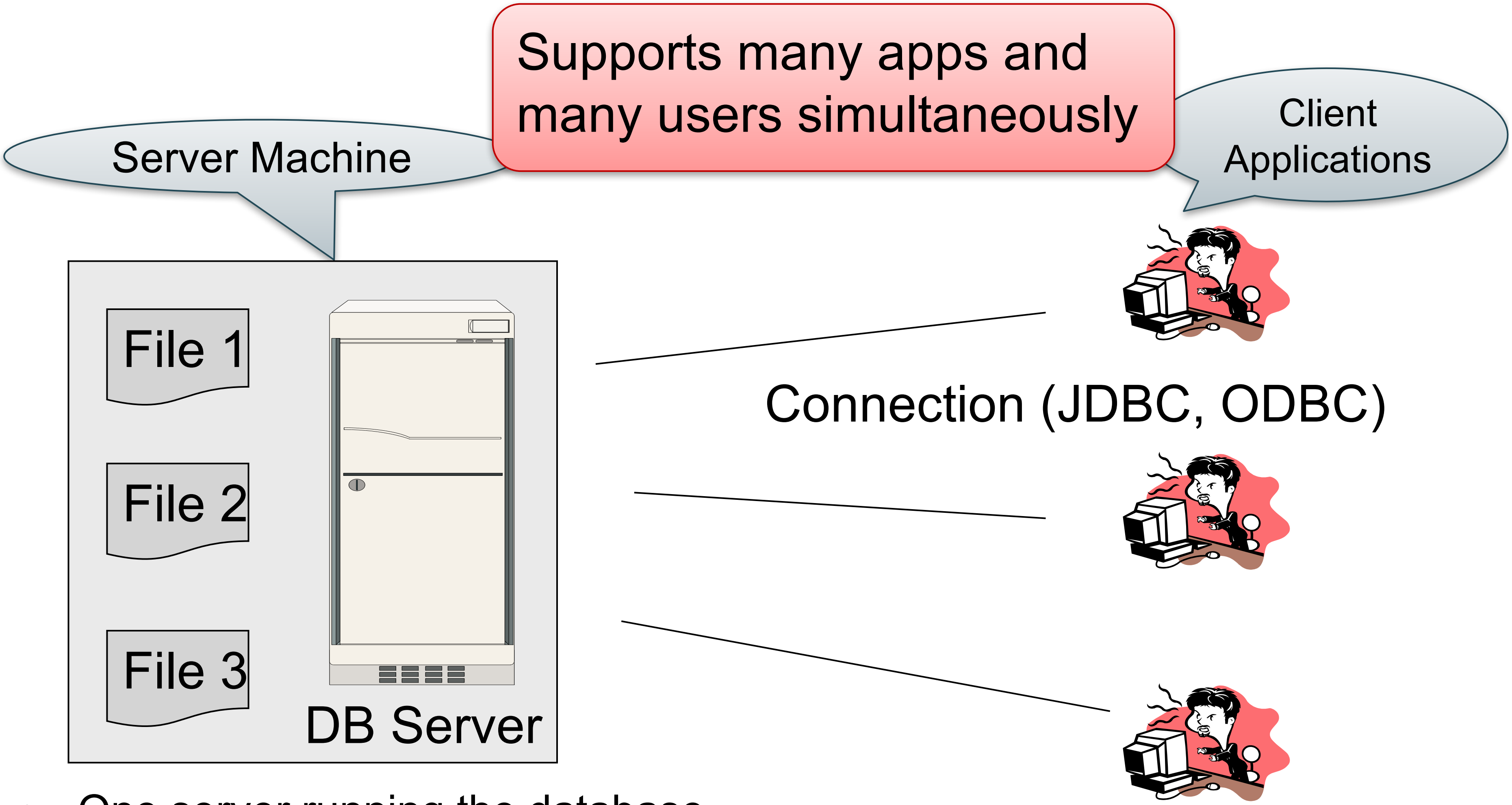


SQLite:

- One data file
- One user
- One DBMS application

- Scales well!
- But only a limited number of scenarios work with such model
- (Can be in browser / phone!)

Client-Server Architecture



Supports many apps and many users simultaneously

Server Machine

Client Applications

File 1

File 2

File 3

DB Server

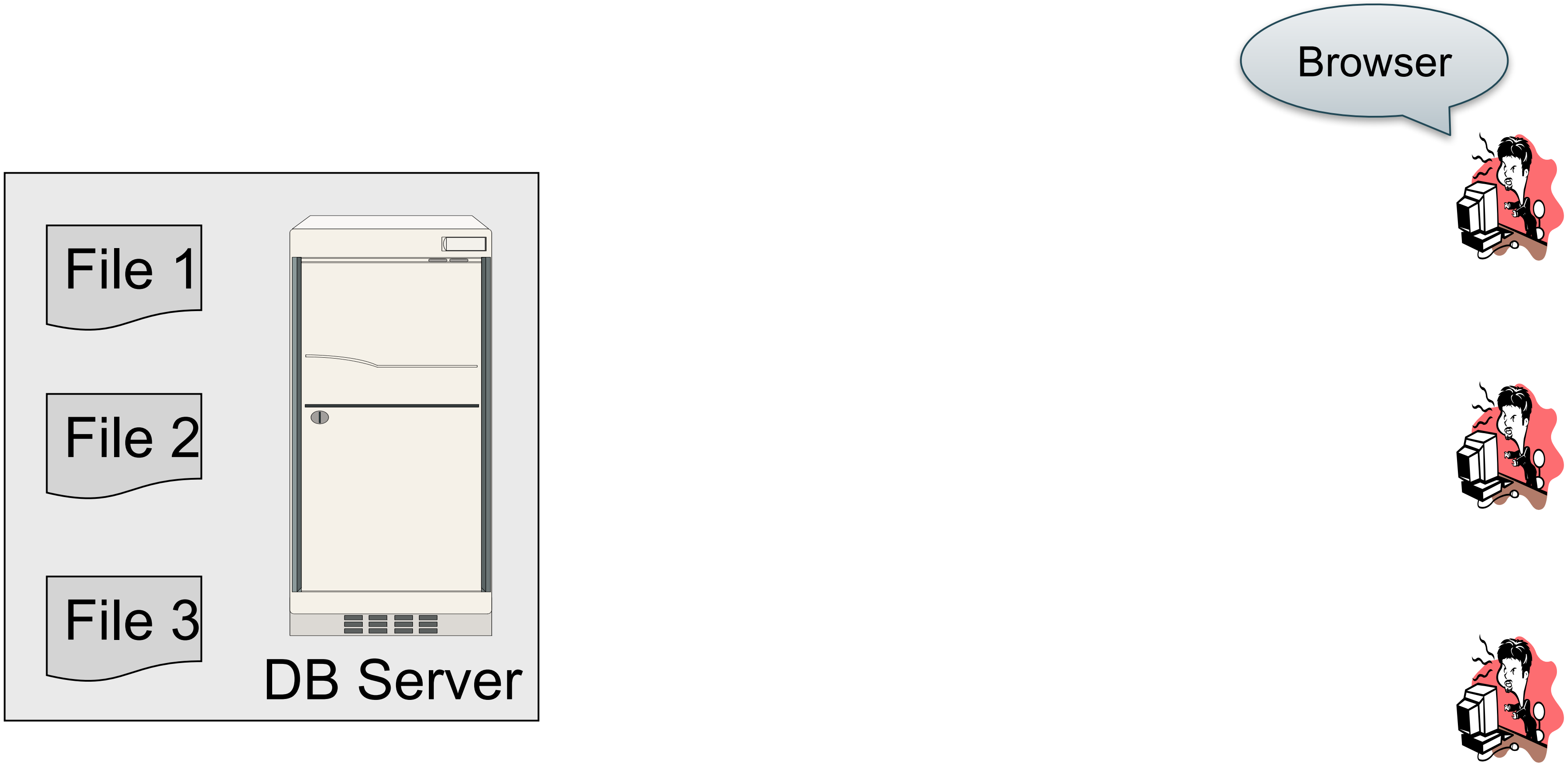
Connection (JDBC, ODBC)

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

Client-Server

- One *server* that runs the DBMS (or RDBMS):
  - Your own desktop, or
  - Some beefy system, or
  - A cloud service (SQL Azure)
- Many *clients* run apps and connect to DBMS
  - Microsoft's Management Studio (for SQL Server), or
  - psql (for postgres)
  - Some Java program (HW7) or some C++ program
- Clients "talk" to server using JDBC/ODBC protocol

3-Tiered Architecture



File 1

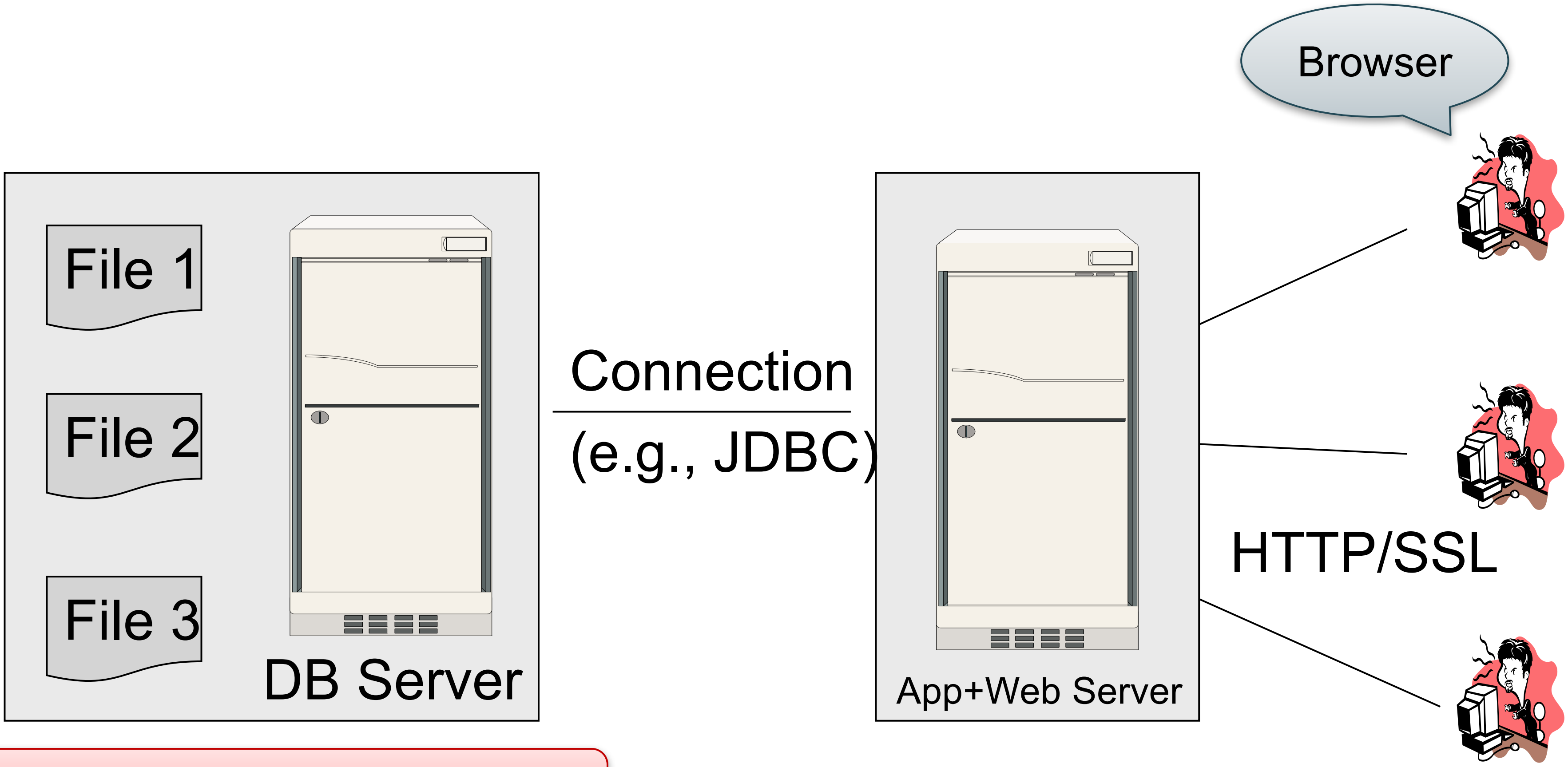
File 2

File 3

DB Server

Browser

3-Tiered Architecture



Browser

File 1

File 2

File 3

DB Server

Connection

(e.g., JDBC)

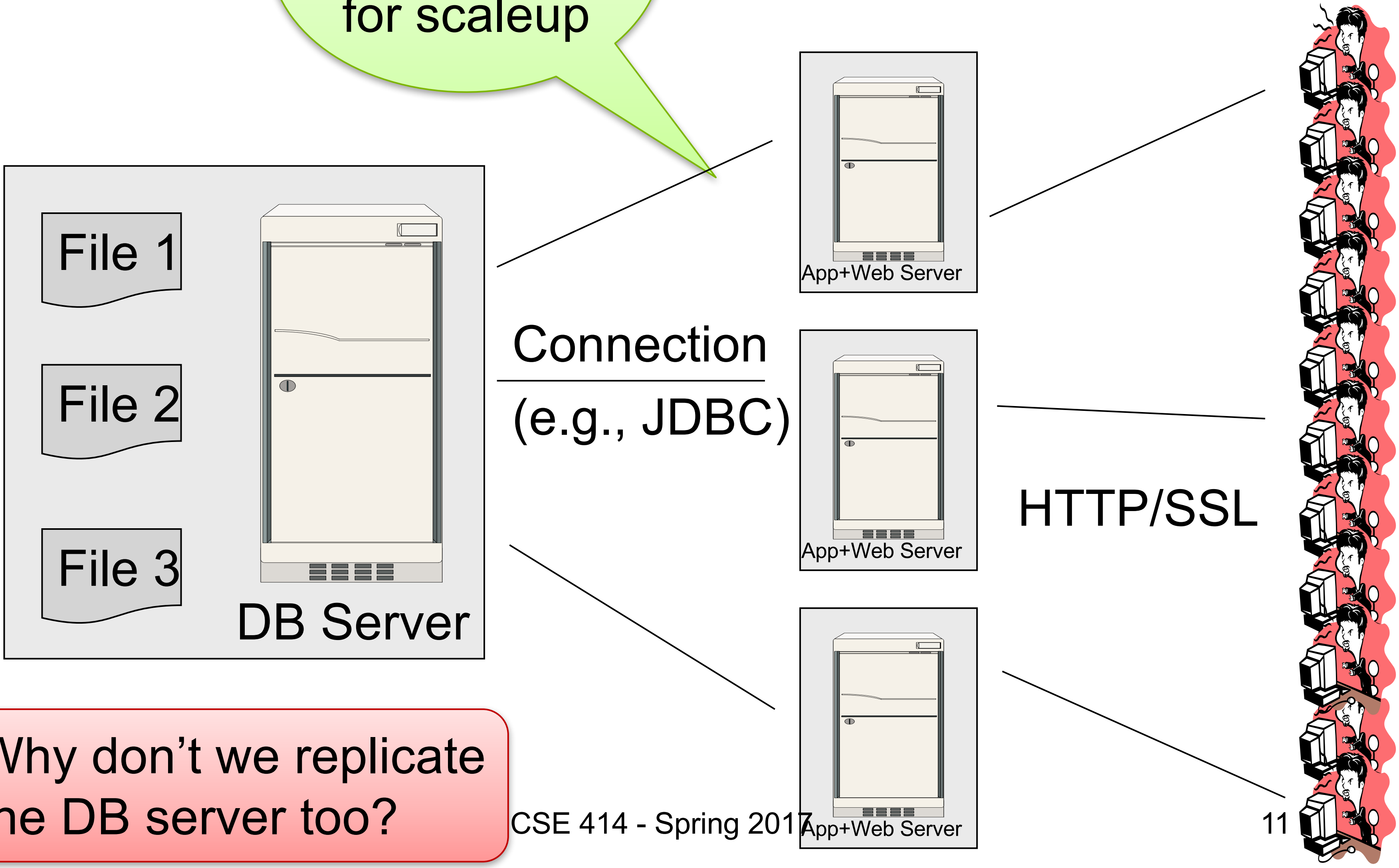
App+Web Server

HTTP/SSL

Web-based applications

rchitecture

Replicate
App server
for scaleup



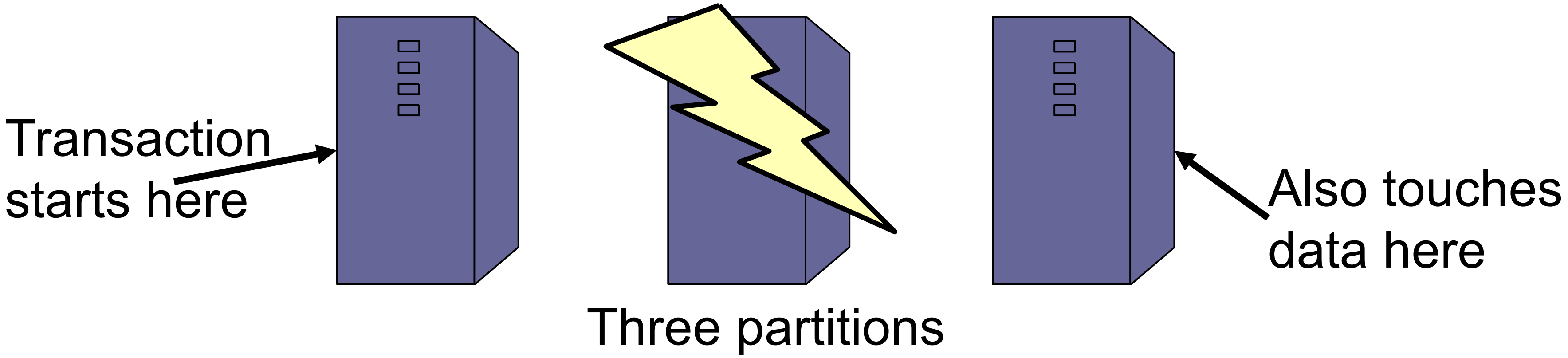
Why don't we replicate
the DB server too?

Replicating the Database

- Much harder, because the state must be unique, in other words the database must act as a whole
  - Current DB instance must be *consistent* always
    - Ex: foreign keys must exist
    - as a result, some updates must occur simultaneously
- Two basic approaches:
  - Scale up through partitioning
  - Scale up through replication

Scale Through Partitioning

- Partition the database across many machines in a cluster
  - Database could fit in main memory
  - Queries spread across these machines
- Can increase throughput
- Easy for (simple) writes but reads become harder



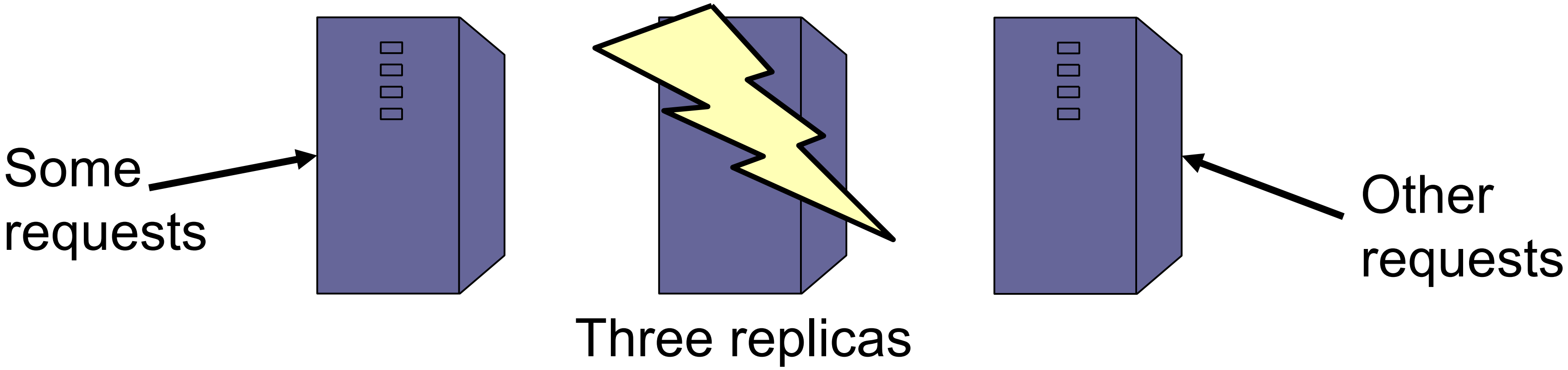
Transaction starts here

Also touches data here

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 harder



NoSQL Data Models

Taxonomy based on data models:

- ☞ Key-value stores
  - e.g., Project Voldemort, Memcached
- Document stores
  - e.g., SimpleDB, CouchDB, MongoDB
- Extensible Record Stores
  - e.g., HBase, Cassandra, PNUTS

Key-Value Stores Features

- **Data model**: (key,value) pairs
  - – Key = string/integer, unique for the entire data
  - – Value = can be anything (very complex object)
- **Operations**
  - – Get(key), Put(key,value)
  - – Operations on value not supported
- **Distribution / Partitioning**
  - – No replication: key k is stored at server h(k)
  - – 3-way replication: key k stored at h1(k),h2(k),h3(k)

How does get(k) work? How does put(k,v) 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
- Option 3: key=(origin,dest), value=all flights between

How does query processing work?

Key-Value Stores Internals

- Data remains in main memory
  - one implementation: distributed hash table
- Most systems also offer a persistence option
- Others use replication to provide fault-tolerance
  - Asynchronous or synchronous replication
  - Tunable consistency: read/write one replica or majority
- Some offer transactions others do not
  - multi-version concurrency control or locking

Data Models

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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
  - Limited, non-standard query language on JSON
- **Distribution / Partitioning**
  - Entire documents, as for key/value pairs

We will discuss JSon today or tomorrow

Data Models

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Extensible Record Stores

- Based on Google's BigTable
  - HBase is an open source implementation of BigTable
- Data model is rows and columns
  - can add both new rows and new columns
- Scalability by splitting rows and columns over nodes
  - Rows partitioned through hashing on primary key
  - Columns of a table are distributed over multiple nodes by using "column groups"

NoSQL Summary

- Simpler data model with weaker guarantees
- But they scale as far as we need them to

- Meanwhile…
  SQL systems continue to improve

Recent SQL Progress

- Modern systems need to store data across the globe
  - individual data centers go offline
  - need servers close to users to be efficient
- Speed of light is a fundamental limit
  - 200+ms latency (across US) is visible to users
- Systems must weaken guarantees
- Google's Spanner (supports SQL):
  - write data over the whole globe (a bit slowly)
  - reads occur slightly in the *past*

Prediction

- My guess: SQL will win again
- Pieces are out there already
  - Spanner: multi-node transactions
  - AsterixDB: multi-node query optimization
- For now, NoSQL still offers key benefits

JSon and Semistructured Data

Where We Are

- So far we have studied the *relational data model*
  - Data is stored in tables (relations)
  - Queries are expressions in the SQL / datalog / relational algebra

- Today: Semistructured data model
  - Popular formats today: XML, JSon, protobuf

JSON – Personal History

- 10 years ago…
  - JavaScript interpreters were very slow
  - native browser function parsed JSON 100x faster
- XML was also an option, but
  - IE had a memory leak in its XML parser
- JSON used in Gmail etc. for this reason
- Spread organically to server-side systems

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 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)
  - Does not require predefined schema ("self describing”)
  - Text representation: good for exchange, bad for performance
  - Most common use: Language API; query languages emerging

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 Terminology

- 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).
- Data made up of objects, lists, and atomic values (integers, floats, strings, booleans).

JSon Data Structures

- 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",
   ”title": ”Databases”,
   "author": ”Garcia-Molina”,
   "author": ”Ullman”,
   "author": ”Widom”
}
```

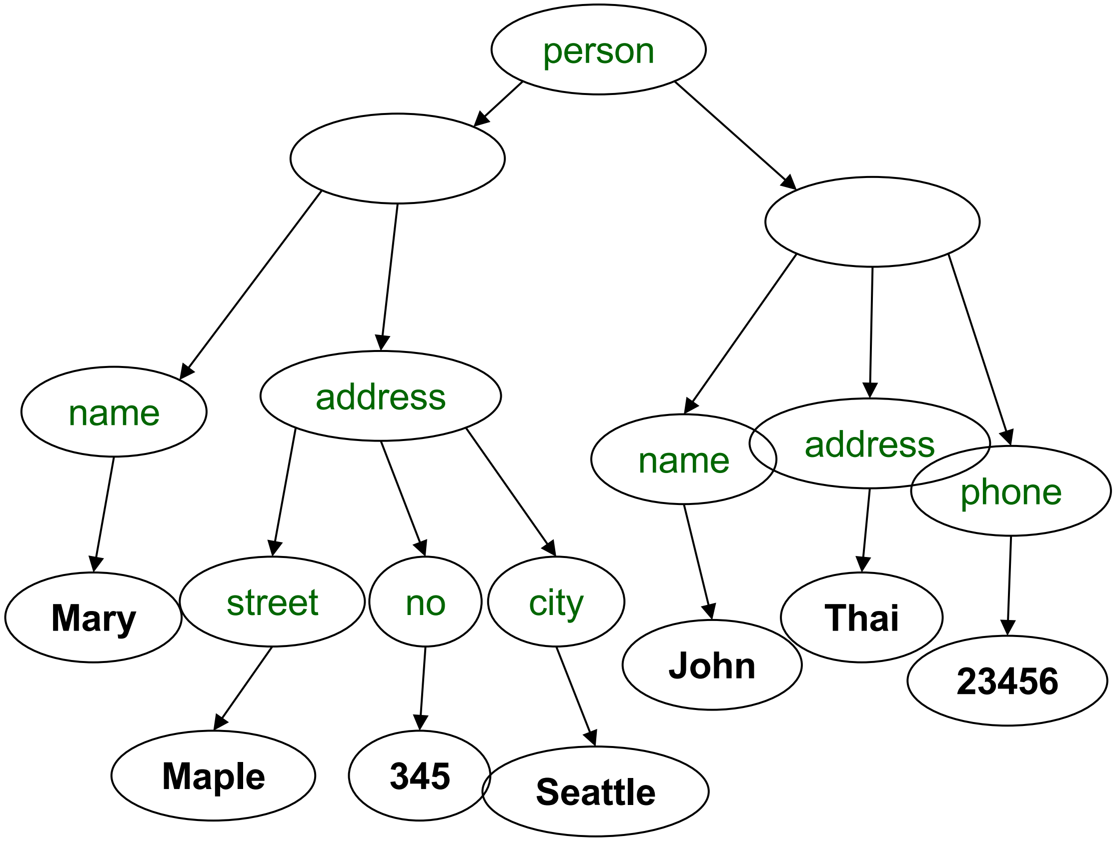
```
{"id":"07",
   ”title": ”Databases”,
   "author": [”Garcia-Molina”,
               ”Ullman”,
               ”Widom”]
}
```

JSon Datatypes

- Number
- String = double-quoted
- Boolean = true or false
- null / empty

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
- 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
  - also uses more space (but can be compressed)
- JSon is an example of semistructured data