CSE 344

JANUARY 31ST – SEMI-STRUCTURED DATA

ADMINISTRATIVE MINUTIAE

- **HW3 due Friday**
- **OQ due Wednesday**
- **HW4 out Wednesday**
- **Exam next Friday**
  - 3:30 - 5:00

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)

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

WHAT IS THE PROBLEM?

Single server DBMS are too small for Web data

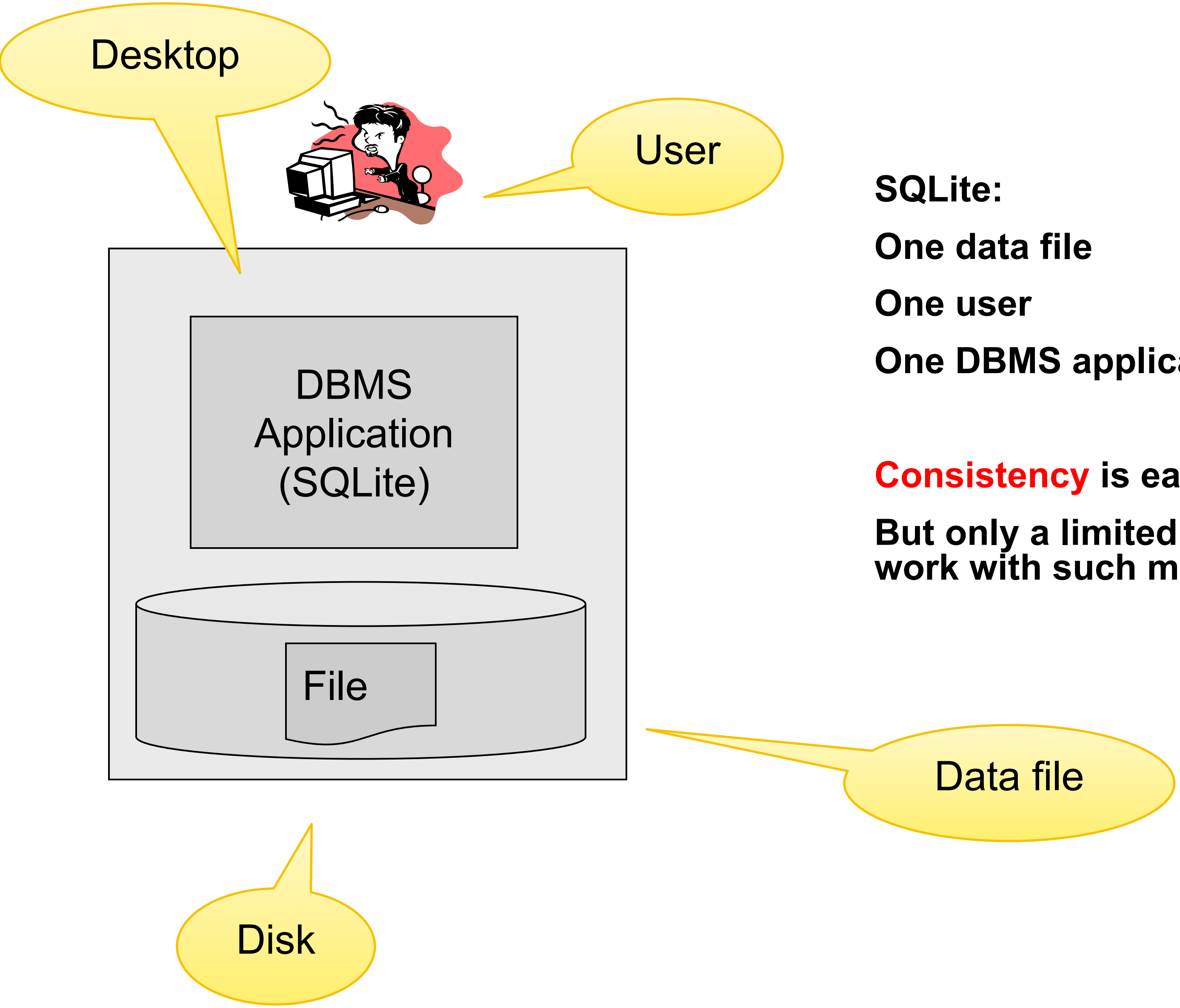
Solution: scale out to multiple servers

This is hard for the *entire* functionality of DMBS

NoSQL: reduce functionality for easier scale up

- Simpler data model
- Very restricted updates

RDBMS REVIEW: SERVERLESS



SQLite:

One data file

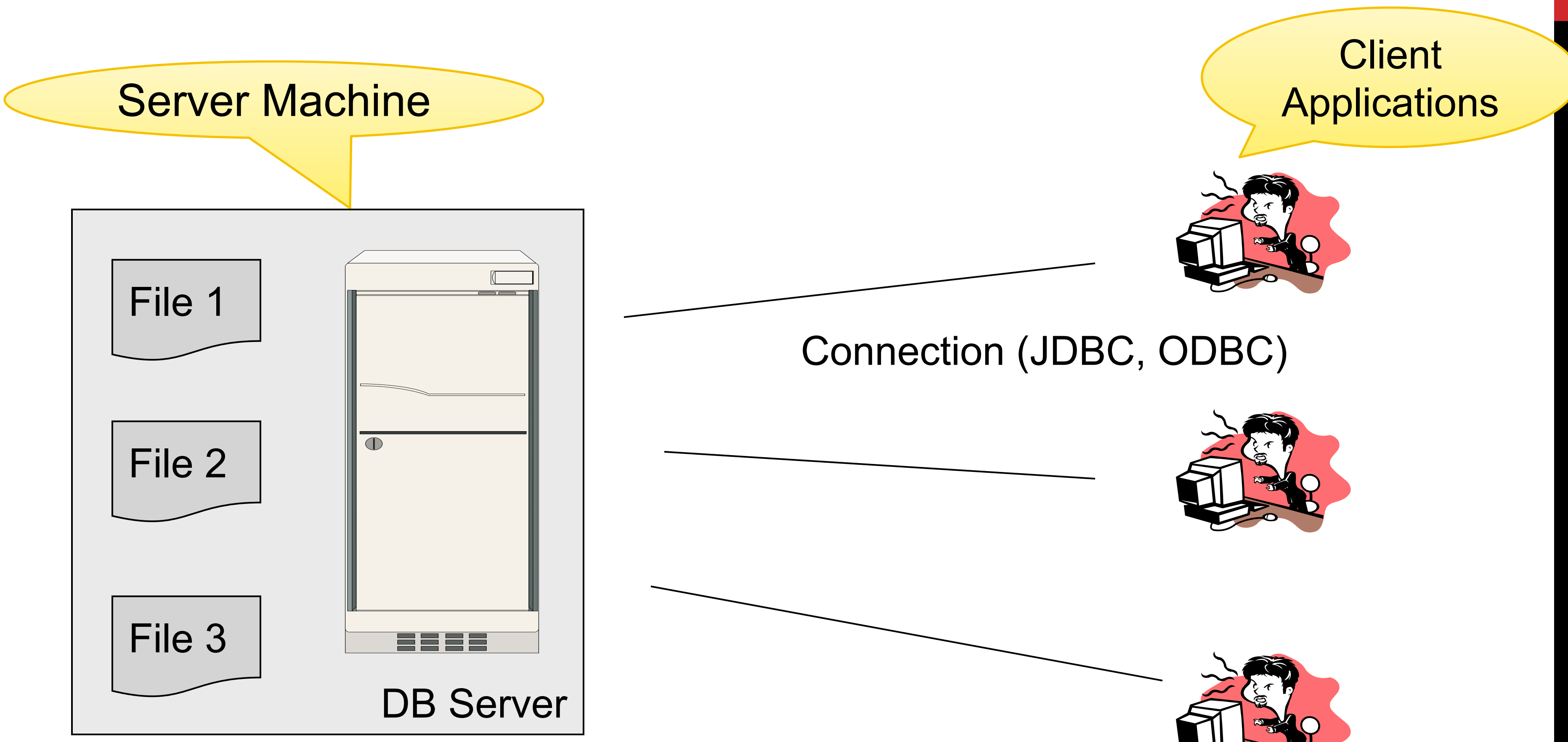
One user

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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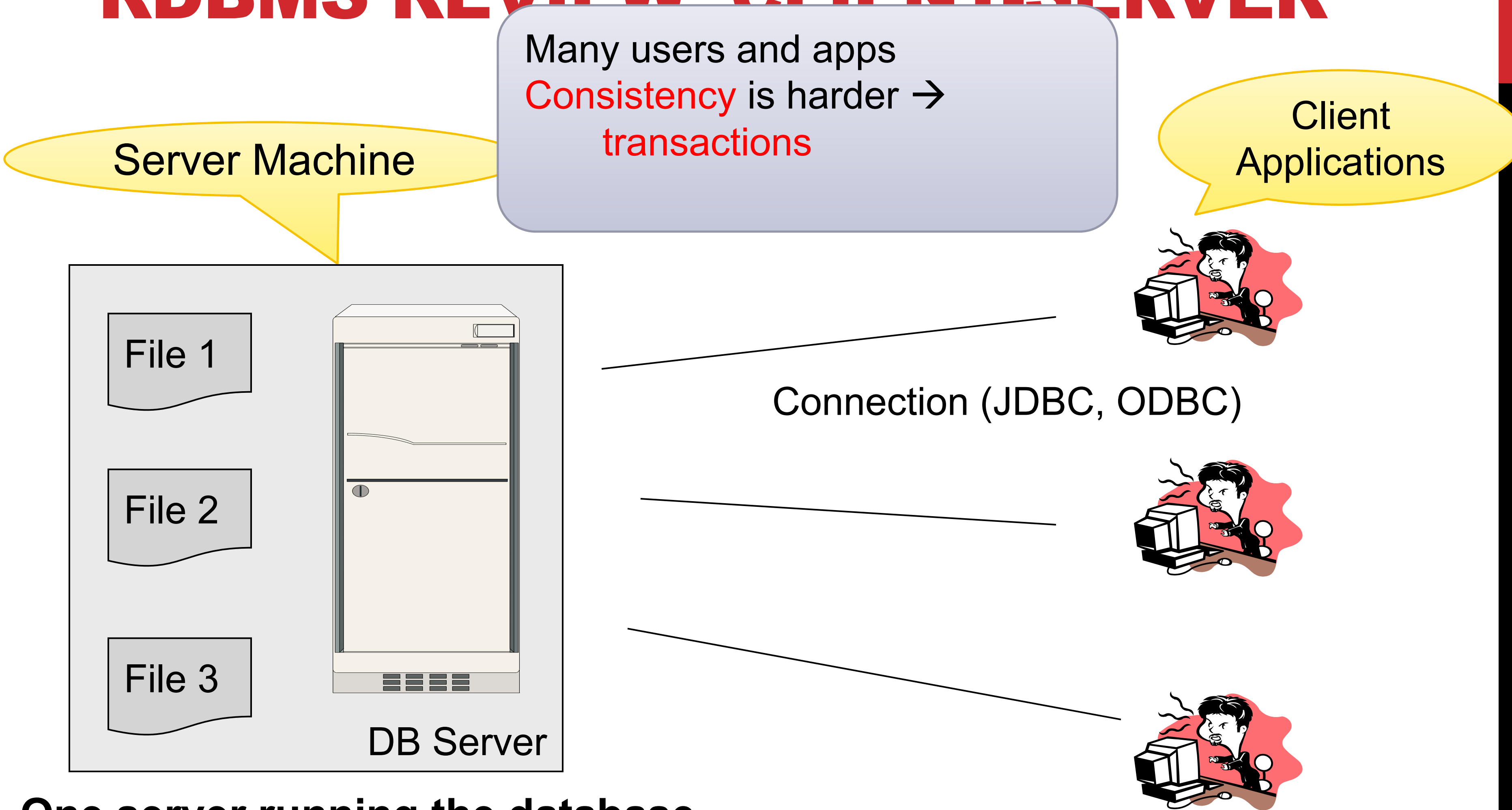

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CLIENT-SERVER

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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Many *clients* run apps and connect to DBMS

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

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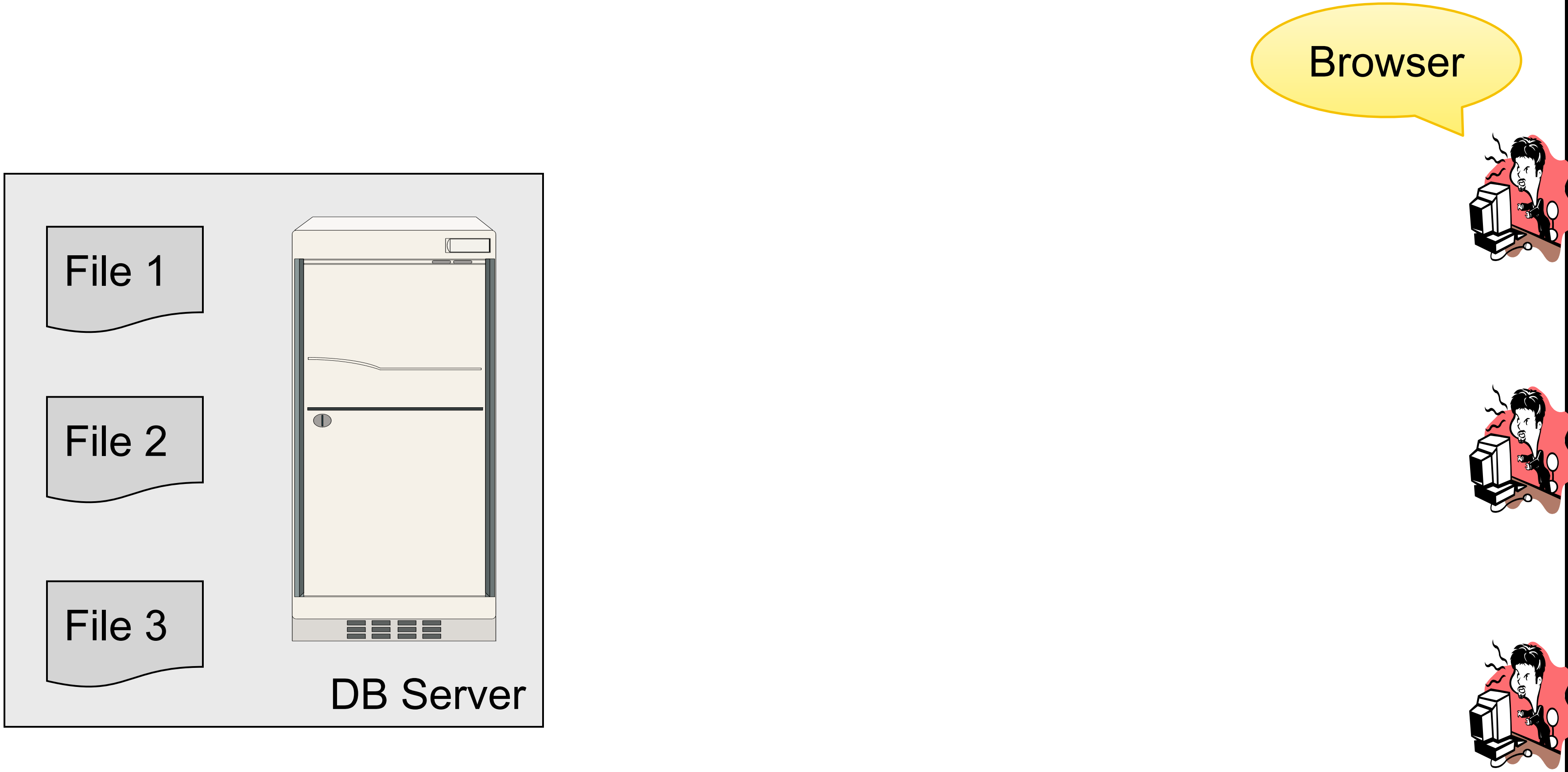
Clients "talk" to server using JDBC/ODBC protocol

WEB APPS: 3 TIER



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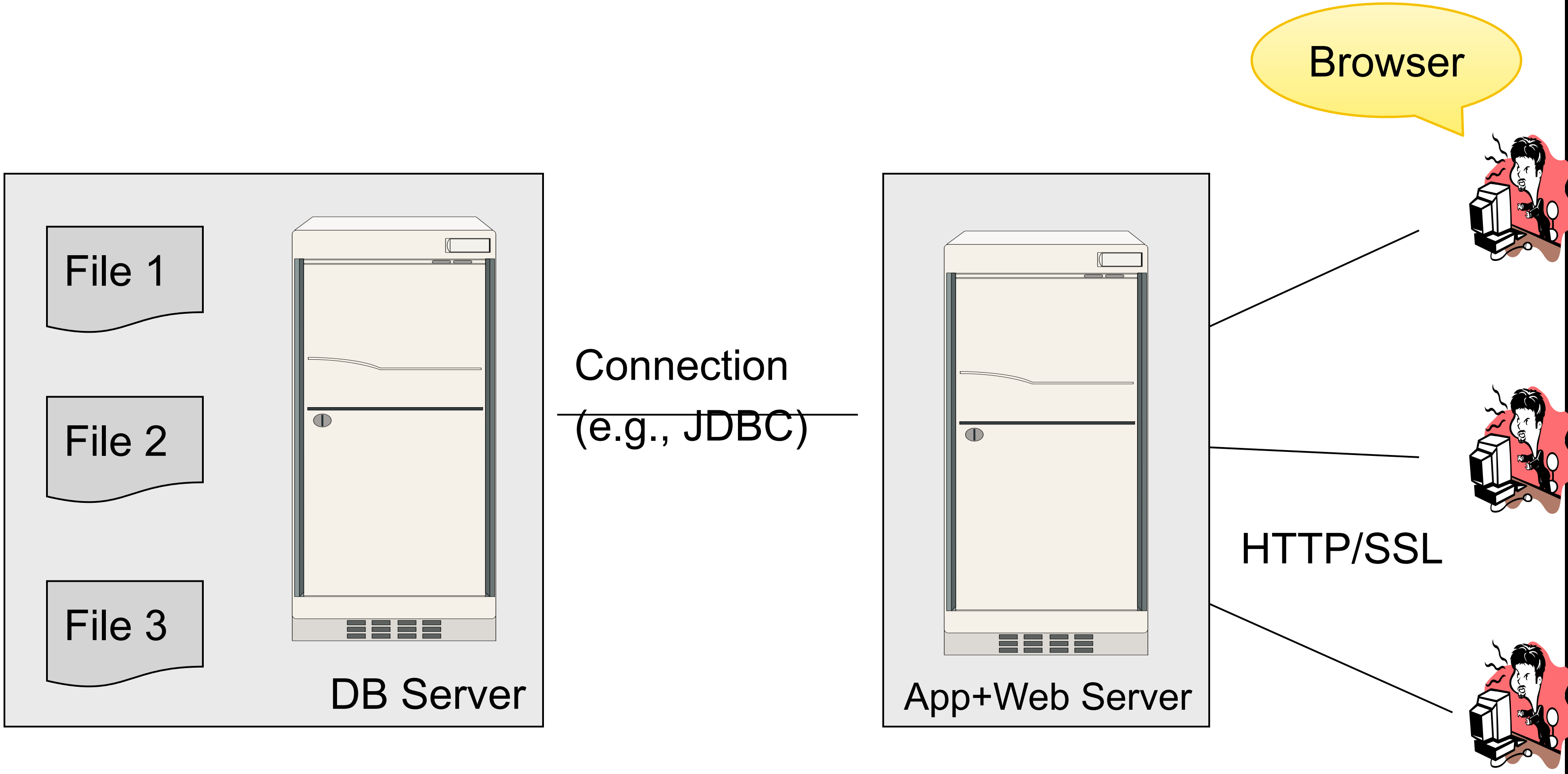

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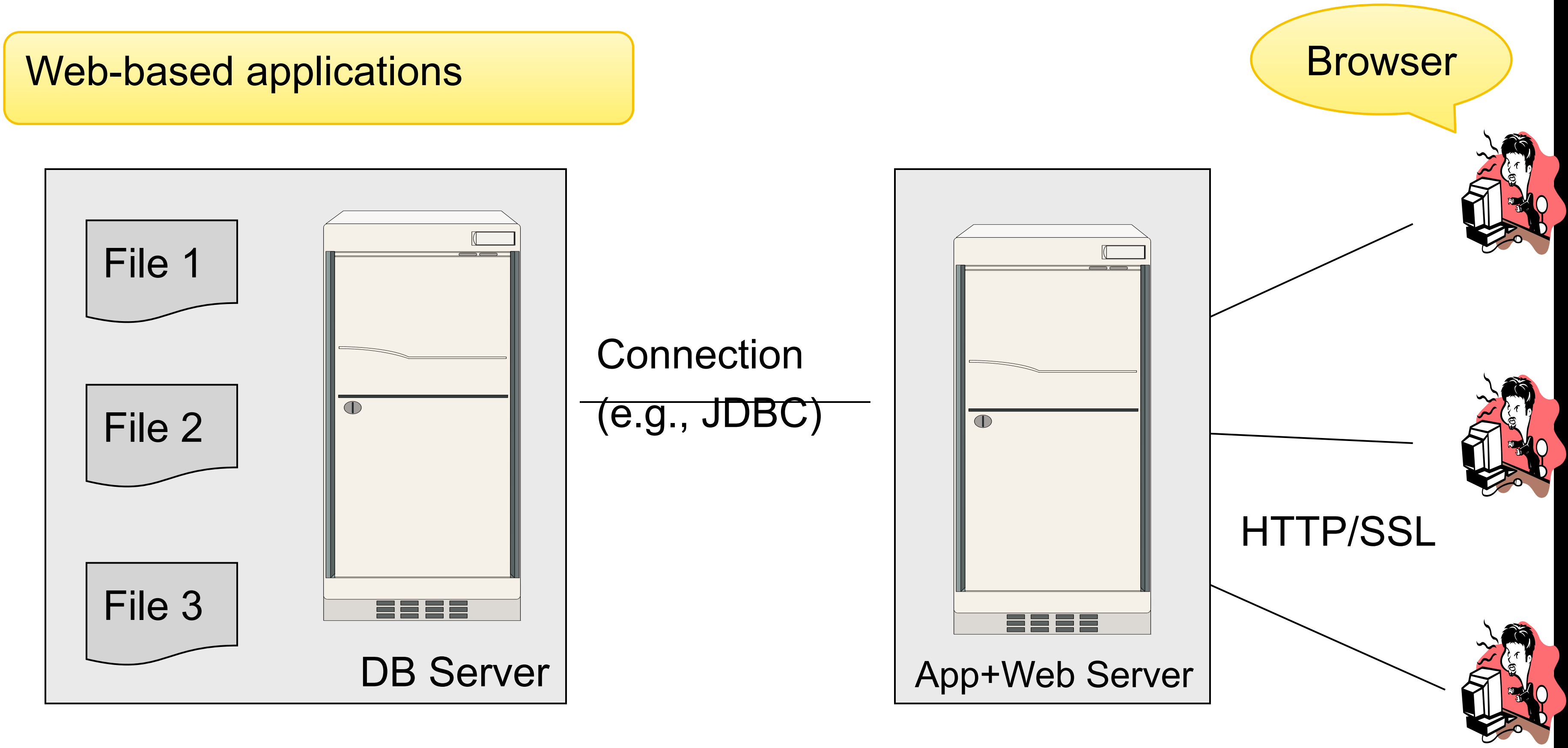
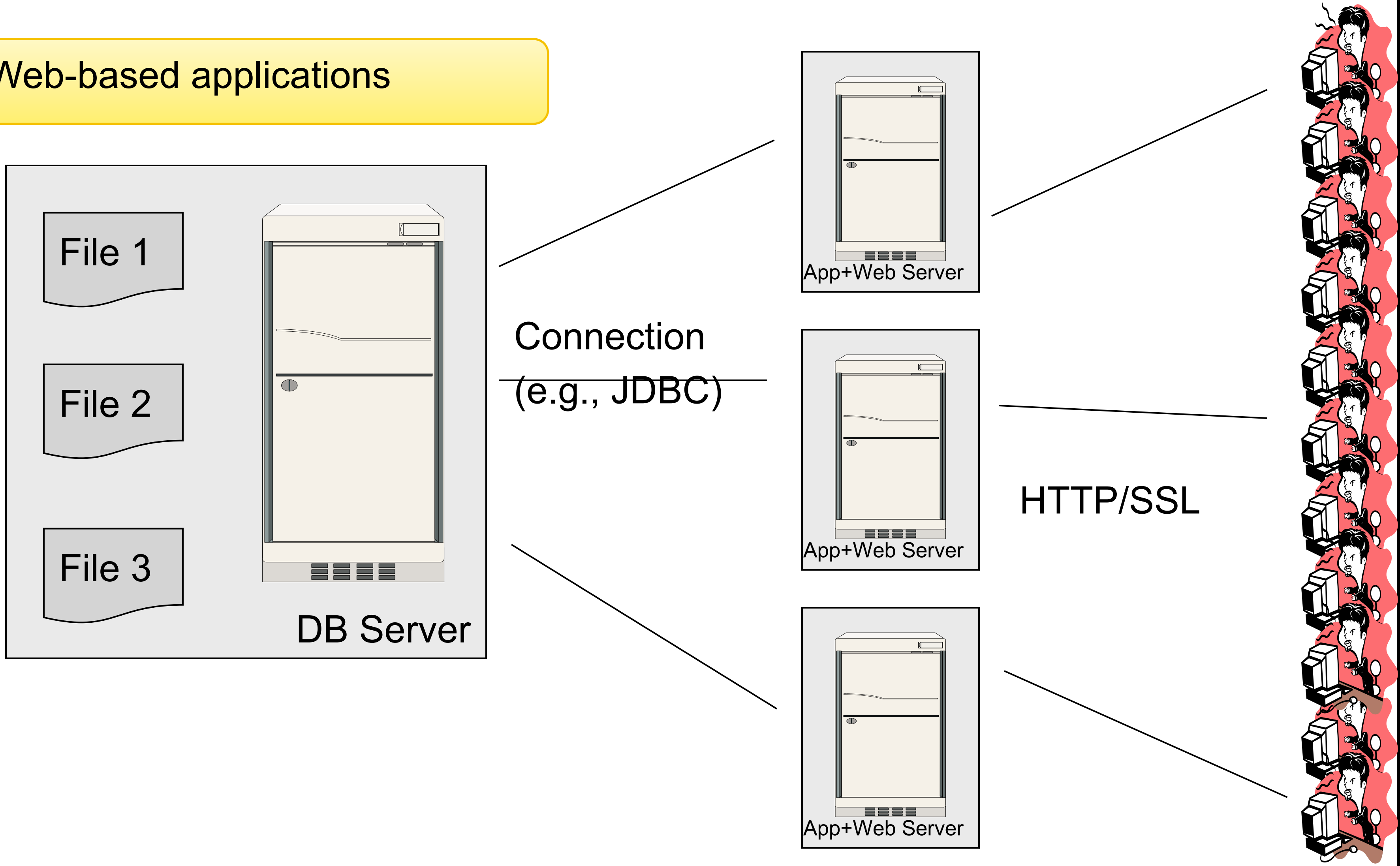


WEB APPS: 3 TIER

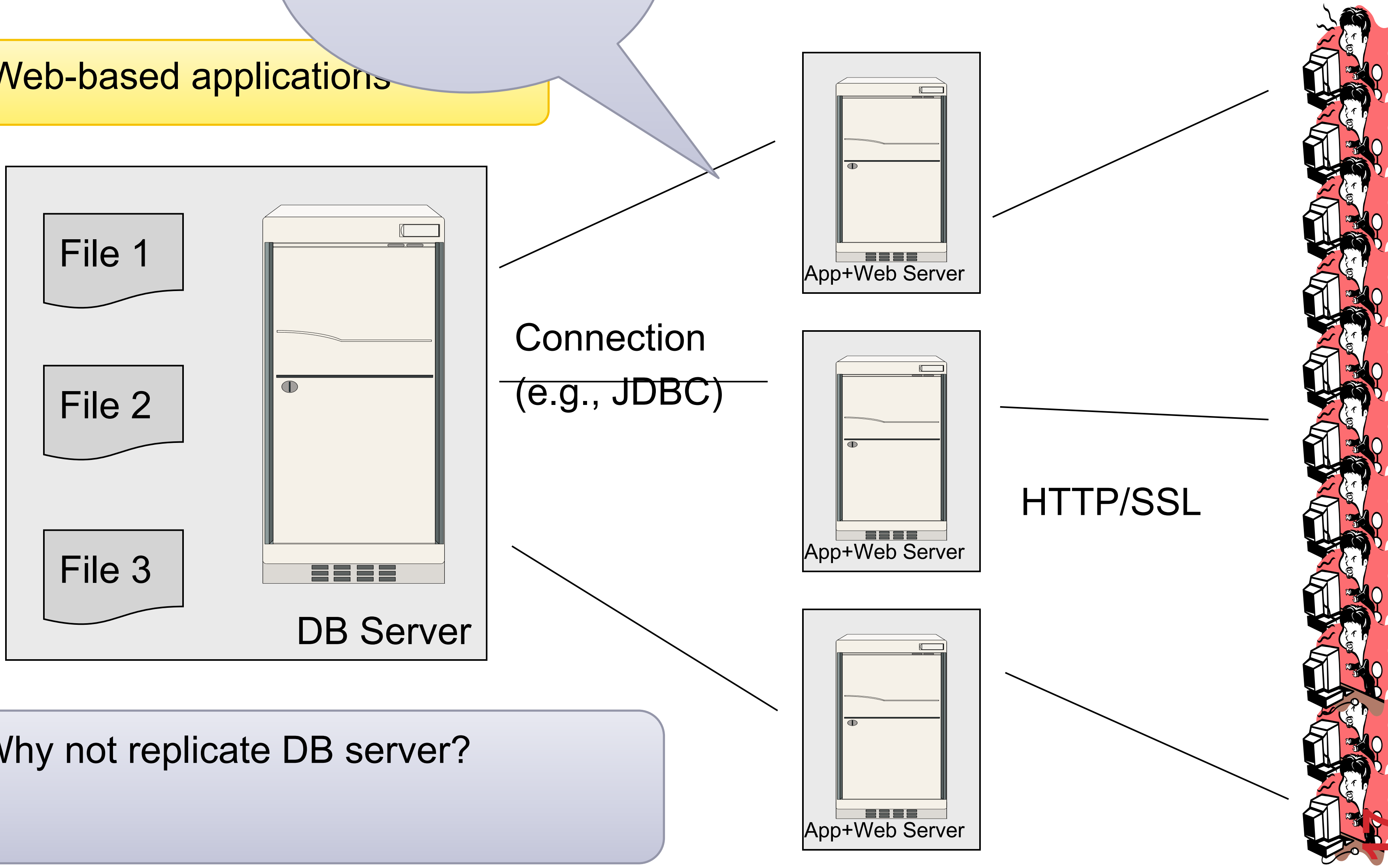
Web-based applications



WEB A… ER

Replicate
App server
for scaleup

Web-based applications



Why not replicate DB server?

WEB A… ER

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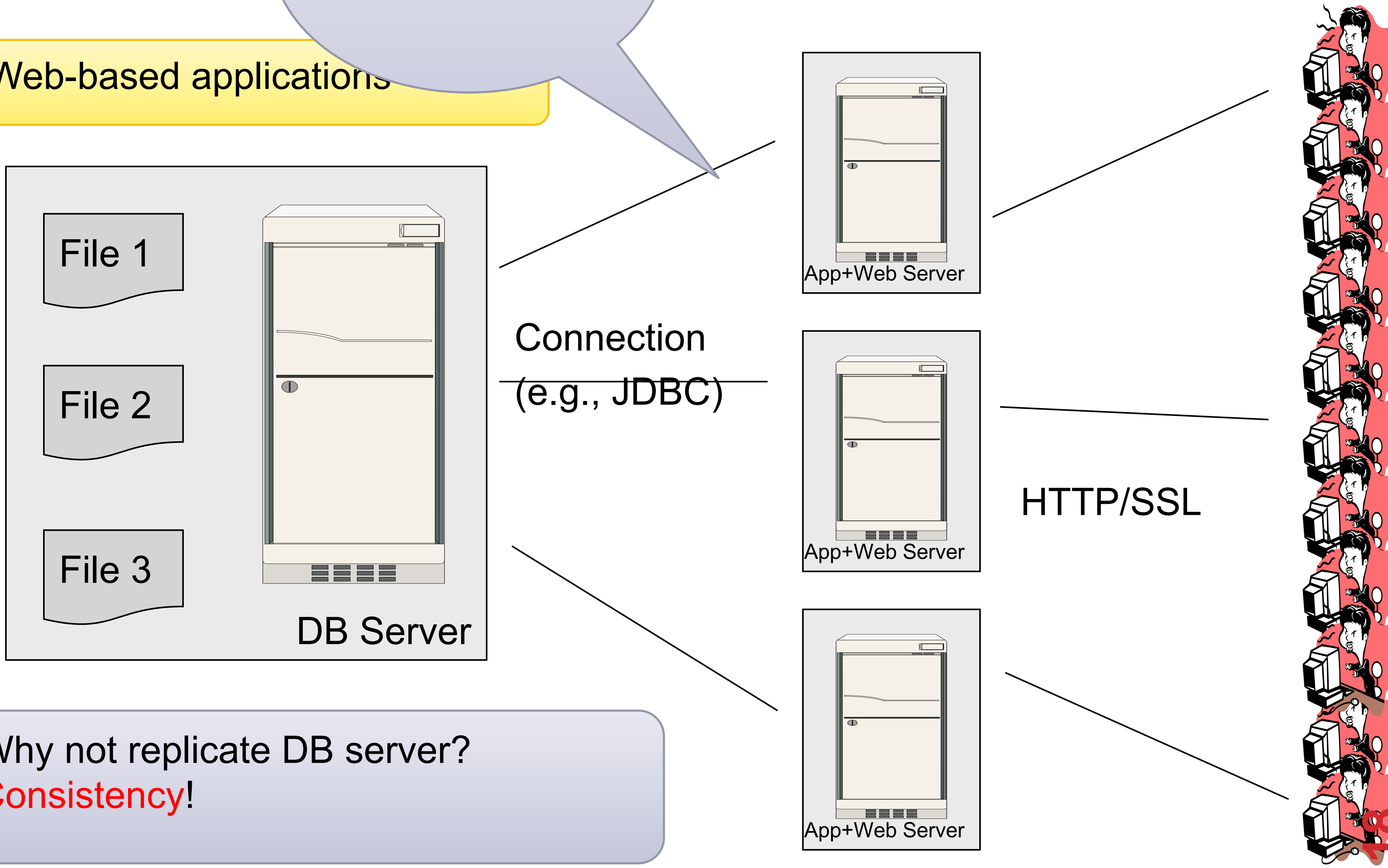


Why not replicate DB server?
Consistency!

REPLICATING THE DATABASE

Two basic approaches:

- Scale up through partitioning
- Scale up through replication

Consistency is much harder to enforce

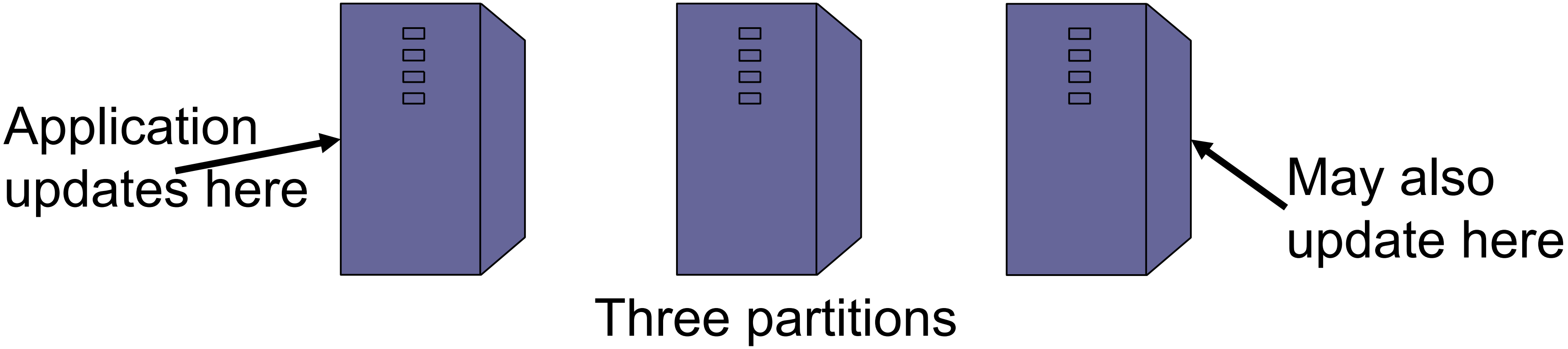
SCALE THROUGH PARTITIONING

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!



SCALE THROUGH REPLICATION

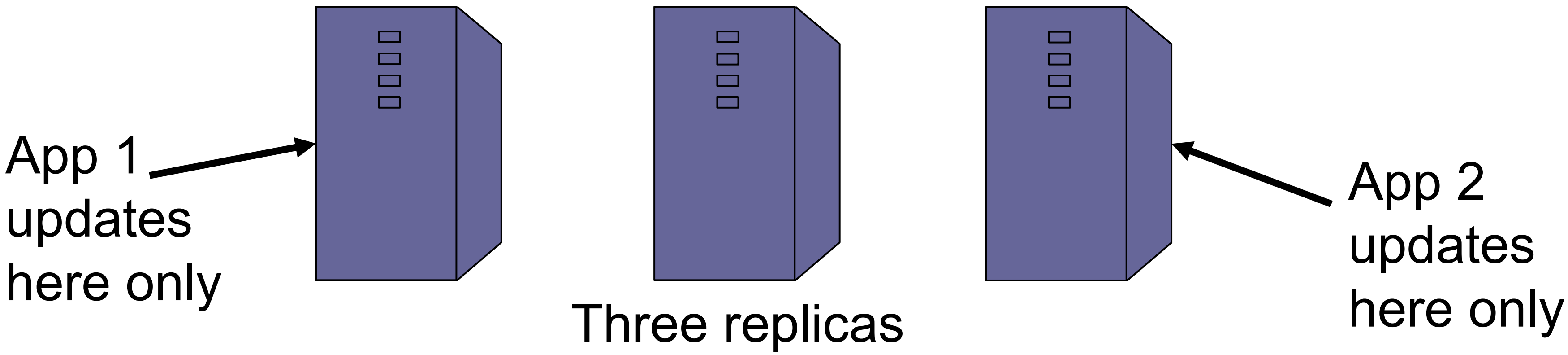
Create multiple copies of each database partition

Spread queries across these replicas

Can increase throughput and lower latency

Can also improve fault-tolerance

Easy for reads but writes become expensive!



RELATIONAL MODEL → NOSQL

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

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)

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- Operations on value not supported

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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)

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Distribution / Partitioning – w/ hash function

- No replication: key k is stored at server h(k)
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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?

How does query processing work?

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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, ...)
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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?

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

Partitioning:

- Use a hash function h, and store every (key,value) pair on server h(key)
- In class: discuss get(key), and put(key,value)

Replication:

- Store each key on (say) three servers
- On update, propagate change to the other servers; *eventual consistency*
- Issue: when an app reads one replica, it may be stale

Usually: combine partitioning+replication

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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]

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

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EXTENSIBLE RECORD STORES

Based on Google's BigTable

Data model is rows and columns

Scalability by splitting rows and columns over nodes

- Rows partitioned through sharding on primary key
- Columns of a table are distributed over multiple nodes by using "column groups"

HBase is an open source implementation of BigTable

WHERE WE ARE

So far we have studied the *__relational data model__*

- Data is stored in tables(=relations)
- Queries are expressions in SQL, relational algebra, or Datalog

Today: Semistructured data model

- Popular formats today: XML, JSon, protobuf

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)
- Does not require predefined schema ("self describing”)
- Text representation: good for exchange, bad for performance
- 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

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

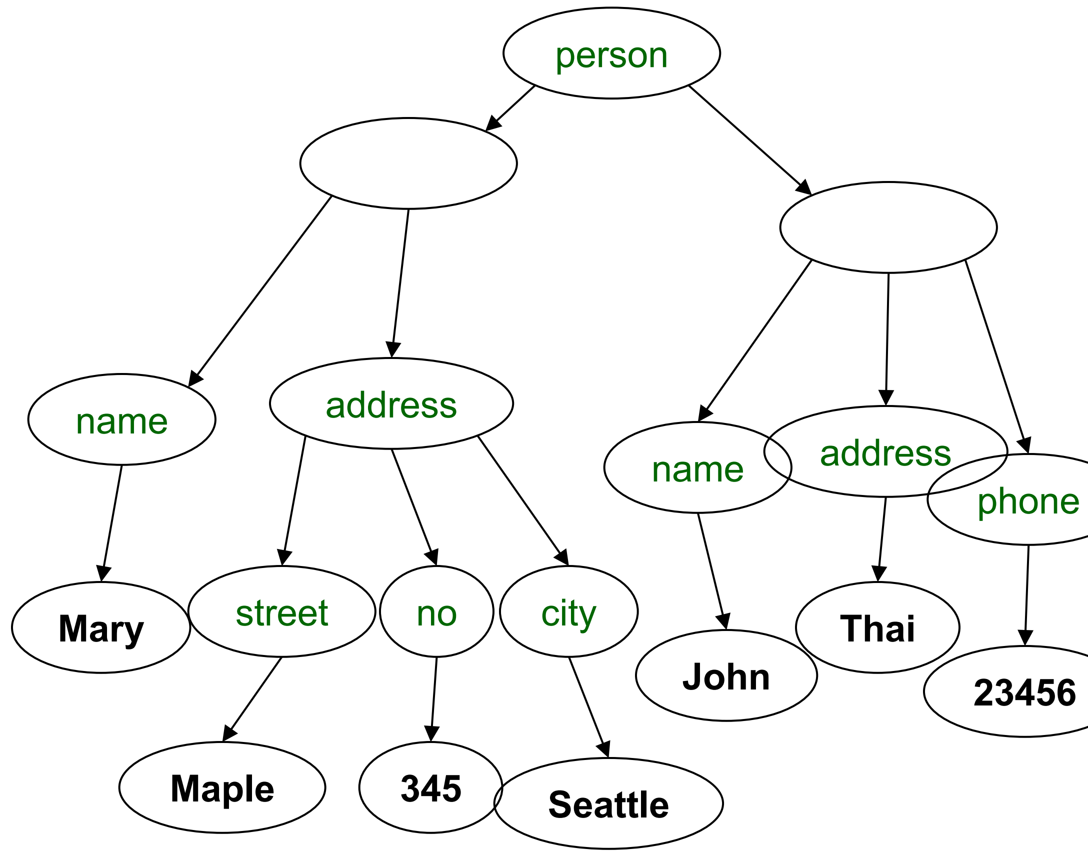
String = double-quoted

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

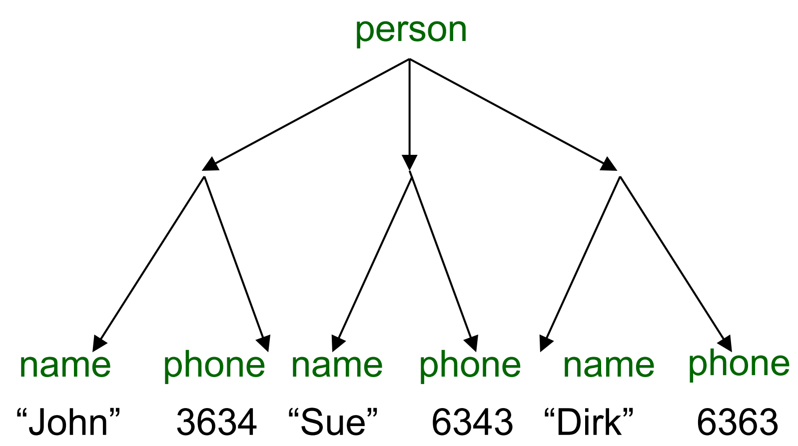
Consequence: JSon is much more flexible

JSon = semistructured data

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 J

May inline foreign keys

Person

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"}
               ]
     }
    ]
}
```

JSON=SEMI-STRUCTURED DATA (1/3)

Missing attributes:

```
{"person":
   [{"name":"John", "phone":1234},
    {"name":"Joe"}]
}
```

no phone !

Could represent in a table with nulls

name	phone
John	1234
Joe	-

JSON=SEMI-STRUCTURED DATA (2/3)

Repeated attributes

```
{“person”:
    [{“name”:”John”, “phone”:1234},
     {“name”:”Mary”, “phone”:[1234,5678]}]
}
```

Two phones !

Impossible in one table:

name	phone	
Mary	2345	3456

???

JSON=SEMI-STRUCTURED DATA (3/3)

Attributes with different types in different objects

```
{"person":
    [{"name":"Sue", "phone":3456},
     {"name":{"first":"John","last":"Smith"},"phone":2345}
    ]
}
```

Structured name !

Nested collections

Heterogeneous collections