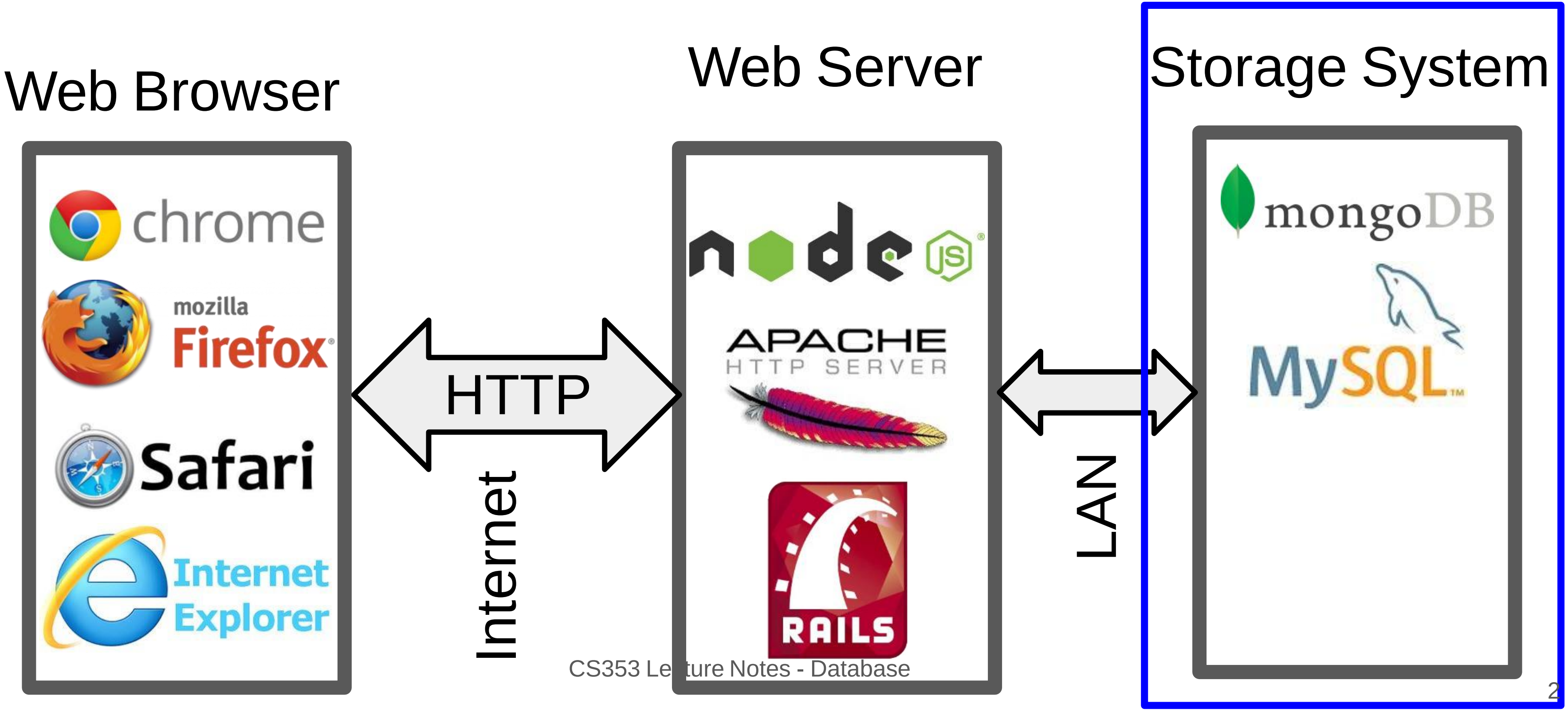
Storage Tier

Web Application Architecture



Web App Storage System Properties

- Always available - Fetch correct app data, store updates
  - Even if many request come in concurrently - Scalable
    - From all over the world
  - Even if pieces fail - Reliable / fault tolerant
- Provide a good organization of storing an application data
  - Quickly generate the model data of a view
  - Handle app evolving over time
- Good software engineering: Easy to use and reason about

Relational Database System

- Early on many different structures file system, objects, networks, etc.
  - The database community decided the answer was the **relational** model
    - Many in the community still think it is.
- Data is organized as a series of **tables** (also called **relations**)

  A table is made of up of **rows** (also called **tuples** or **records**)

  A row is made of a fixed (per table) set of typed **columns**

  - String: `VARCHAR(20)`
  - Integer: `INTEGER`
  - Floating-point: `FLOAT, DOUBLE`
  - Date/time: `DATE, TIME, DATETIME`
  - Others

Database Schema

Schema: The structure of the database

- The table names (e.g. User, and etc)
- The names and types of table columns
- Various optional additional information (constraints, etc.)

Example: User Table

Column types

```
ID         - INTEGER
first_name - VARCHAR(20)
last_name  - VARCHAR(20)
location   - VARCHAR(20)
```

ID	first_name	last_name	location
1	Ian	Malcolm	Austin, TX
2	Ellen	Ripley	Nostromo
3	Peregrin	Took	Gondor
4	Rey	Kenobi	D'Qar
5	April	Ludgate	Awnee, IN
6	John	Ousterhout	Stanford, CA

Structured Query Language (SQL)

- Standard for accessing relational data
  - Sweet theory behind it: **relational algebra**

How?

- Queries: the strength of relational databases
  - Lots of ways to extract information
  - You specify what you want
  - The database system figures out how to get it efficiently
  - Refer to data by contents, not just name

SQL Example Commands

```
CREATE TABLE Users (
    id INT AUTO_INCREMENT,
    first_name VARCHAR(20),
    last_name VARCHAR(20),
    location VARCHAR(20));

INSERT INTO Users (
   first_name,
   last_name,
   location)
   VALUES
   ('Ian',
   'Malcolm',
    'Austin, TX');
```

```
DELETE FROM Users WHERE
   last_name='Malcolm';

UPDATE Users
    SET location = 'New York, NY
    WHERE id = 2;

SELECT * FROM Users;

SELECT * from Users WHERE id = 2;
```

Keys and Indexes

Consider a model fetch: `SELECT * FROM Users WHERE id = 2`

Database could implement this by:

1. **Scan** the Users table and return all rows with id=2
2. Have built an **index** that maps id numbers to table rows. Lookup result from index.

Uses **keys** to tell database that building an index would be a good idea

Primary key: Organize data around accesses

`PRIMARY KEY(id)` on a `CREATE` table command

Secondary key: Other indexes (`UNIQUE`)

Object Relational Mapping (ORM)

- Relational model and SQL was a bad match for Web Applications
  - Object versus tables
  - Need to evolve quickly
- 2nd generation web frameworks (Rails) handled mapping objects to SQL DB
- Rail's Active Record
  - Objects map to database records
  - One class for each table in the database (called **Models** in Rails)
  - Objects of the class correspond to rows in the table
  - Attributes of an object correspond to columns from the row
- Handled all the schema creation and SQL commands behind object interface

NoSQL - MongoDB

- Using SQL databases provided reliable storage for early web applications
- Led to new databases that matched web application object model
  - Known collectively as NoSQL databases
- MongoDB - Most prominent NoSQL database
  - Data model: Stores **collections** containing **documents** (JSON objects)
  - Has expressive query language
  - Can use **indexes** for fast lookups
  - Tries to handle scalability, reliability, etc.

Schema enforcement

- JSON blobs provide super flexibility but not what is always wanted
  - Consider: `<h1>Hello {person.informalName}</h1>`
    - Good: typeof person.informalName == 'string' and length < something
    - Bad: Type is 1GB object, or undefined, or null, or …
- Would like to enforce a **schema** on the data
  - Can be implemented as **validators** on mutating operations
- Mongoose - Object Definition Language (ODL)
  - Take familiar usage from ORMs and map it onto MongoDB
  - Exports **Persistent Object** abstraction
  - Effectively masks the lower level interface to MongoDB with something that is friendlier

Using: `var mongoose = require('mongoose');`

1. Connect to the MongoDB instance

```
mongoose.connect('mongodb://localhost/CS353');
```

2. Wait for connection to complete: Mongoose exports an EventEmitter

```
mongoose.connection.on('open', function ()  {
    // Can start processing model fetch requests
});

mongoose.connection.on('error', function (err) { });
```

Can also listen for connecting, connected, disconnecting, disconnected, etc.

Mongoose: Schema define collections

Schema assign property names and their types to collections

- String, Number, Date, Buffer, Boolean
- Array - e.g. `comments: [ObjectId]`
- ObjectId - Reference to another object
- Mixed - Anything

```
var userSchema = new mongoose.Schema({
    first_name: String,
    last_name: String,
    emailAddresses: [String],
    location: String
});
```

Schema allows secondary indexes and defaults

- Simple index

```
first_name: {type: 'String', index: true}
```

- Index with unique enforcement

```
user_name: {type: 'String', index: {unique: true} }
```

- Defaults

```
date: {type: Date, default: Date.now }
```

Secondary indexes

- Performance and space trade-off
  - Faster queries: Eliminate scans - database just returns the matches from the index
  - Slower mutating operations: Add, delete, update must update indexes
  - Uses more space: Need to store indexes and indexes can get bigger than the data itself
- When to use
  - Common queries spending a lot of time scanning
  - Need to enforce uniqueness

Mongoose: Make Model from Schema

- A **Model** in Mongoose is a constructor of objects - a collection
  May or may not correspond to a model of the MVC

  ```
  var User = mongoose.model('User', userSchema);
  ```

  Exports a **persistent** object abstraction

- Create objects from Model

  ```
  User.create({ first_name: 'Ian', last_name: 'Malcolm'}, doneCallback);
  function doneCallback(err, newUser) {
     assert (!err);
     console.log('Created object with ID', newUser._id);
   }
  ```

Model used for querying collection

- Returning the entire User collection

```
User.find(function (err, users) {/*users is an array of objects*/ });
```

- Returning a single user object for `user_id`

```
User.findOne({_id: user_id}, function (err, user) { /* … */ });
```

- Updating a user object for `user_id`

```
User.findOne({_id: user_id}, function (err, user) {
    // Update user object - (Note: Object is "special")
    user.save();
});
```

Other Mongoose query operations - query builder

```
var query = User.find({});
```

- Projections

  ```
  query.select("first_name last_name").exec(doneCallback);
  ```

- Sorting

  ```
  query.sort("first_name").exec(doneCallback);
  ```

- Limits

  ```
  query.limit(50).exec(doneCallback);
  ```

```
query.sort("-location").select("first_name").exec(doneCallback);
```

Deleting objects from collection

- Deleting a single user with id `user_id`

```
User.remove({_id: user_id}, function (err) { } );
```

- Deleting all the User objects

```
User.remove({}, function (err) { } );
```