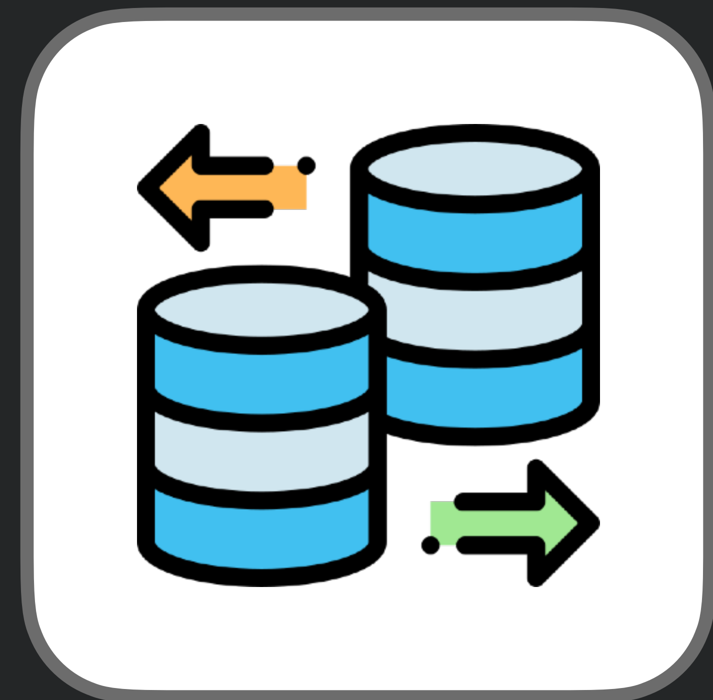
SWE 432 -Web Application Development

Fall 2022

George Mason University

Dr. Kevin Moran

Week 5: Persistence (& More Microservices)



Administrivia

- ***Quiz #3*** **-** Grades Available on Blackboard, will discuss in class today

- ***HW Assignment 2*** **-** Due October 4th Before Class
  - Make sure to sign up for GitHub Classroom if you haven't already!

Quiz 3 Review

- ***Question 1:*** What is one way in which asynchronous programming is different in JavaScript than in other languages like Java?

General Answer: Java exposes Threads that you can control, whereas while Javascript could be considered to be “multi-threaded” it is still very much an event driven language without providing explicit control over threads.

Quiz 3 Review

- ***Question 2:*** What is one way in which asynchronous programming is similar in JavaScript compared to other languages like Java?

General Answer: Both JavaScript and Java support asynchronous execution of events via event driven models

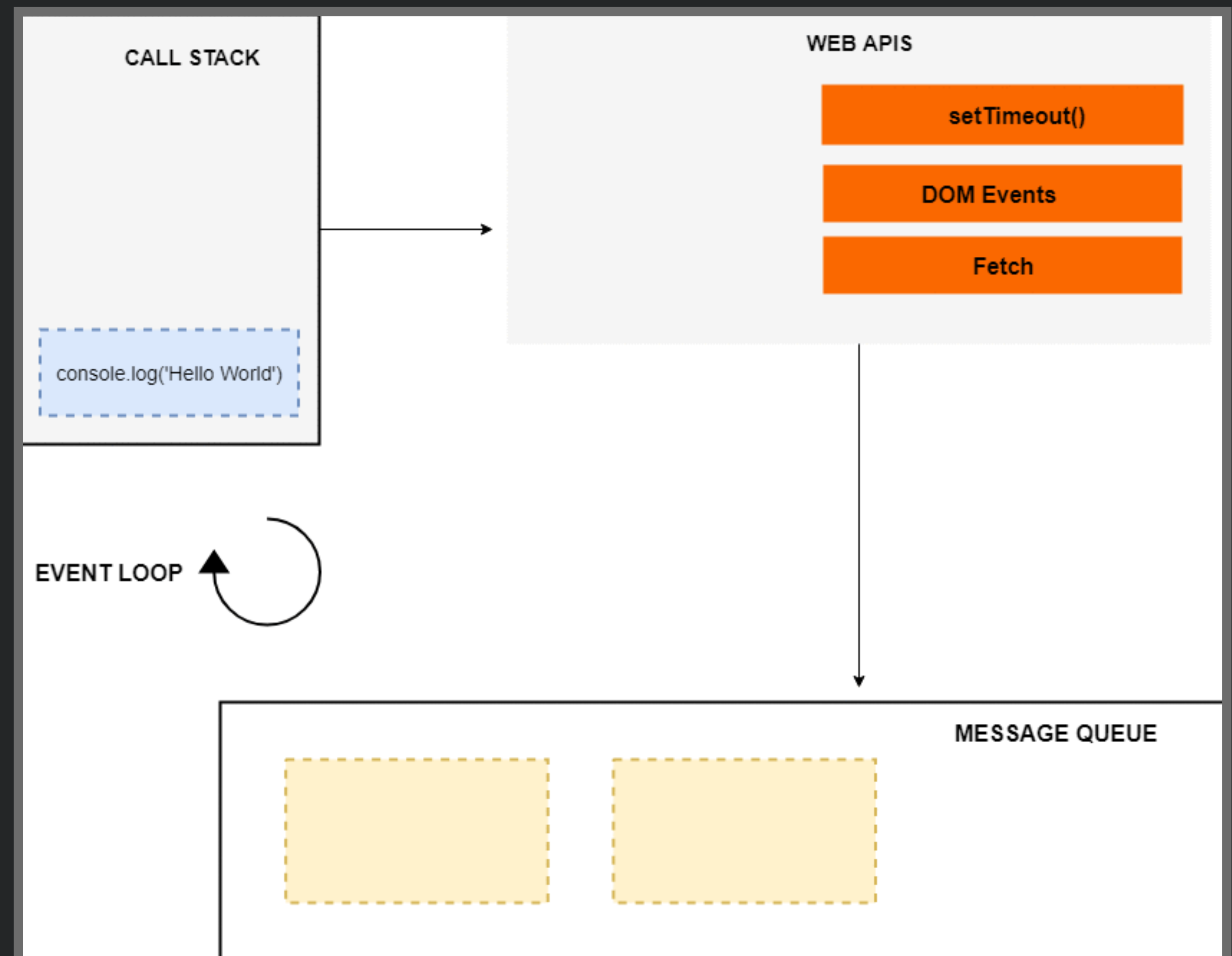
Quiz 3 Review

- *Question 3:* When should a function return a promise rather than a value?

General Answer: When the code behavior is computationally intensive (e.g large matrix multiplications) or time consuming (e.g. server requests, file reading)

A Brief Review (and Visualization) of Asynchronous JavaScript

```javascript
const networkRequest = () => {
  setTimeout(() => {
    console.log('Async Code');
  }, 2000);
};
console.log('Hello World');
networkRequest();
console.log('The End');
```



Class Overview

- ***Today - More Microservices & Persistence:*** Storing and Manipulating Data in Web Applications.
    - *In Class Activity:* Exploring a simple Microservice for city information
- ***Next Week - Even More Microservices:*** A Few More Concepts and a Demo
    - *In Class Activity:* Building on a Microservice for Jokes

More Microservices

Building a Microservice

cityinfo.org

Microservice API

GET /cities

GET /populations

API: Application Programming Interface

cityinfo.org

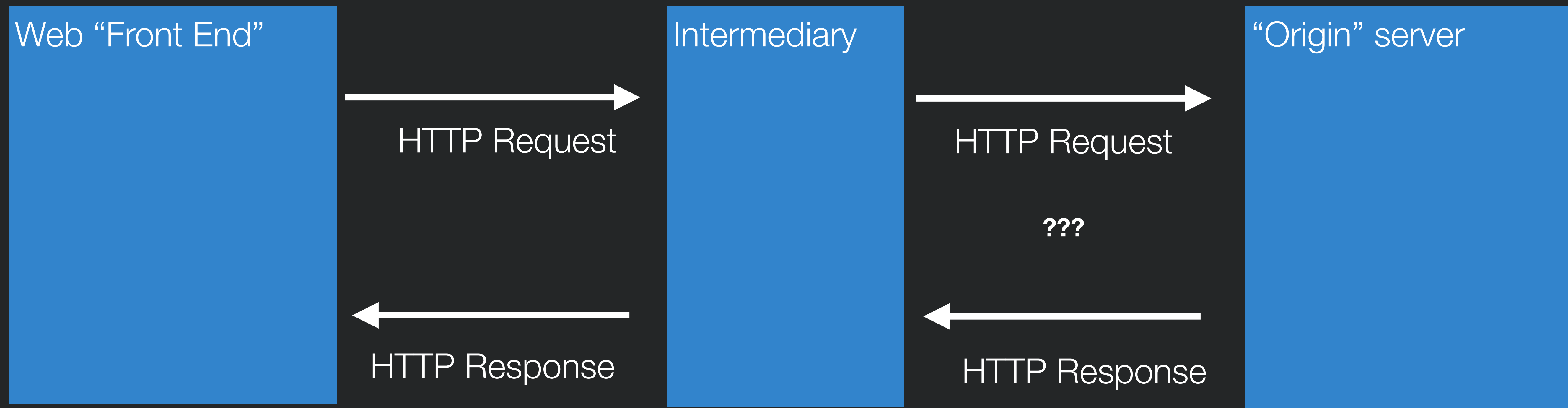
Microservice API

GET /cities

GET /populations

- Microservice offers public **interface** for interacting with backend
  - Offers abstraction that hides implementation details
  - Set of endpoints exposed on micro service
- Users of API might include
  - Frontend of your app
  - Frontend of other apps using your backend
  - Other servers using your service

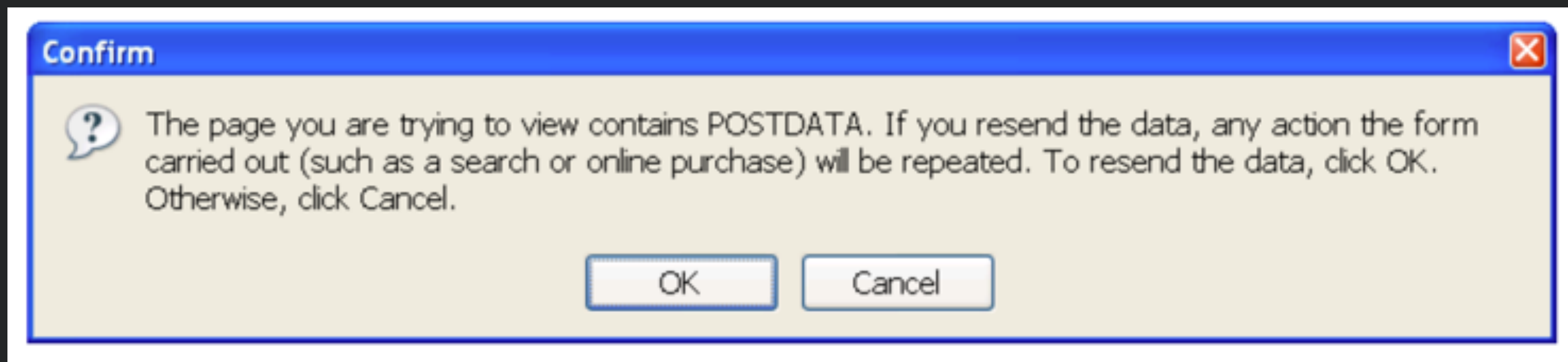
Intermediaries



- Client interacts with a resource identified by a URI
- But it never knows (or cares) whether it interacts with origin server or an unknown intermediary server
  - Might be randomly load balanced to one of many servers
  - Might be cache, so that large file can be stored locally
    - (e.g., GMU caching an OSX update)
  - Might be server checking security and rejecting requests

HTTP Actions

- GET: safe method with no side effects
  - Requests can be intercepted and replaced with cache response
- PUT, DELETE: idempotent method that can be repeated with same result
  - Requests that fail can be retried indefinitely till they succeed
- POST: creates new element
  - Retrying a failed request might create duplicate copies of new resource



Support Scaling

- Yesterday, cityinfo.org had 10 daily active users. Today, it was featured on several news sites and has 10,000 daily active users.
- Yesterday, you were running on a single server. Today, you need more than a single server.

cityinfo.org

Microservice API

GET /cities

GET /populations

Support Change

- Due to your popularity, your backend data provider just backed out of their contract and are now your competitor.
- The data you have is now in a different format.
- Also, you've decided to migrate your backend from PHP to node.js to enable better scaling.
- How do you update your backend without breaking all of your clients?

cityinfo.org

Microservice API

GET /cities

GET /populations

Support Change

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cityinfo.org

Microservice API

GET /cities.jsp

GET /populations.jsp

Versioning

- Your web service just added a great new feature!
  - You’d like to expose it in your API.
  - But… there might be old clients (e.g., websites) built using the old API.
    - These websites might be owned by someone else and might not know about the change.
  - Don’t want these clients to throw an error whenever they access an updated API.

Cool URIs don’t change

- In theory, URI could last forever, being reused as server is rearchitected, new features are added, or even whole technology stack is replaced.

- “What makes a cool URI?
  A cool URI is one which does not change.
  What sorts of URIs change?
  URIs don't change: people change them.”
  - https://www.w3.org/Provider/Style/URI.html
  - Bad:
    - https://www.w3.org/Content/id/50/URI.html (What does this path mean? What if we wanted to change it to mean something else?)
- Why might URIs change?
  - We reorganized our website to make it better.
  - We used to use a cgi script and now we use node.JS.

URI Design

- URIs represent a contract about what resources your server exposes and what can be done with them
- Leave out **anything that might change**
    - Content author names, status of content, other keys that might change
    - File name extensions: response describes content type through MIME header not extension (e.g., .jpg, .mp3, .pdf)
    - Server technology: should not reference technology (e.g., .cfm, .jsp)
- Endeavor to make all changes backwards compatible
    - Add new resources and actions rather than remove old
- If you must change URI structure, support old URI structure **and** new URI structure

Nouns vs. Verbs

- URIs should hierarchically identify **nouns** describing **resources** that exist
- Verbs describing actions that can be taken with resources should be described with an HTTP **action**

- PUT /cities/:cityID (nouns: cities, :cityID)(verb: PUT)
- GET /cities/:cityID (nouns: cities, :cityID)(verb: GET)

- Want to offer **expressive** abstraction that can be reused for many scenarios

Support Reuse

- You have your own frontend for cityinfo.org. But everyone now wants to build their own sites on top of your city analytics.
- Can they do that?

cityinfo.org

Microservice API

GET /cities

GET /populations

Support Reuse

cityinfo.org

Microservice API

/topCities GET
/topCities/:cityID/descrip PUT, GET

/city/:cityID GET, PUT, POST, DELETE
/city/:cityID/averages GET
/city/:cityID/weather GET
/city/:cityID/transitProvders GET, POST
/city/:cityID/transitProvders/:providerID GET, PUT, DELETE

What Happens When a Request has Many Parameters?

- `/topCities/:cityID/descrip` PUT
- Shouldn't this really be something more like
  - `/topCities/:cityID/descrip/:descriptionText/:submitter/:time/`

Solution 1: Query strings

PUT https://localhost:3000/topCities/Memphis/?descrip=blah&submitter=kevin

```
var express = require('express');
var app = express();

app.put('/topCities/:cityID', function(req, res){
    res.send(`descrip: ${req.query.descrip} submitter: ${req.query.submitter}`);
});

app.listen(3000);
```

- Use req.query to retrieve
- Shows up in URL string, making it possible to store full URL
  - e.g., user adds a bookmark to URL
- Sometimes works well for short params

Solution 2: JSON Request Body

- PUT /topCities/Memphis
  { "descrip": "Memphis is a city of ...",
    "submitter": "Dan", "time": 1025313 }

- Best solution for all but the simplest parameters (and often times everything)

- Use body-parser package and req.body to retrieve

```
$npm install body-parser

var express    = require('express');
var bodyParser = require('body-parser');

var app = express();

// parse application/json
app.use(bodyParser.json());

app.put('/topCities/:cityID', function(req, res){
    res.send(`descrip: ${req.body.descrip} submitter: ${req.body.submitter}`);
});

app.listen(3000);
```


https://www.npmjs.com/package/body-parser

Data Persistence

Persistence

- The user sent you some data.
- You retrieved some data from a 3rd party servcie.
- You generated some data, which you want to keep reusing.

- Where and how could you store this?

What forms of data might you have

- Key / value pairs
- JSON objects
- Tabular arrays of data
- Files

Options for backend persistence

- Where it is stored
  - On your server or another server you own
    - SQL databases, NoSQL databases
    - File system
  - Storage provider (not on a server you own)
    - NoSQL databases
    - BLOB store

Storing state in a global variable

- **Global variables**

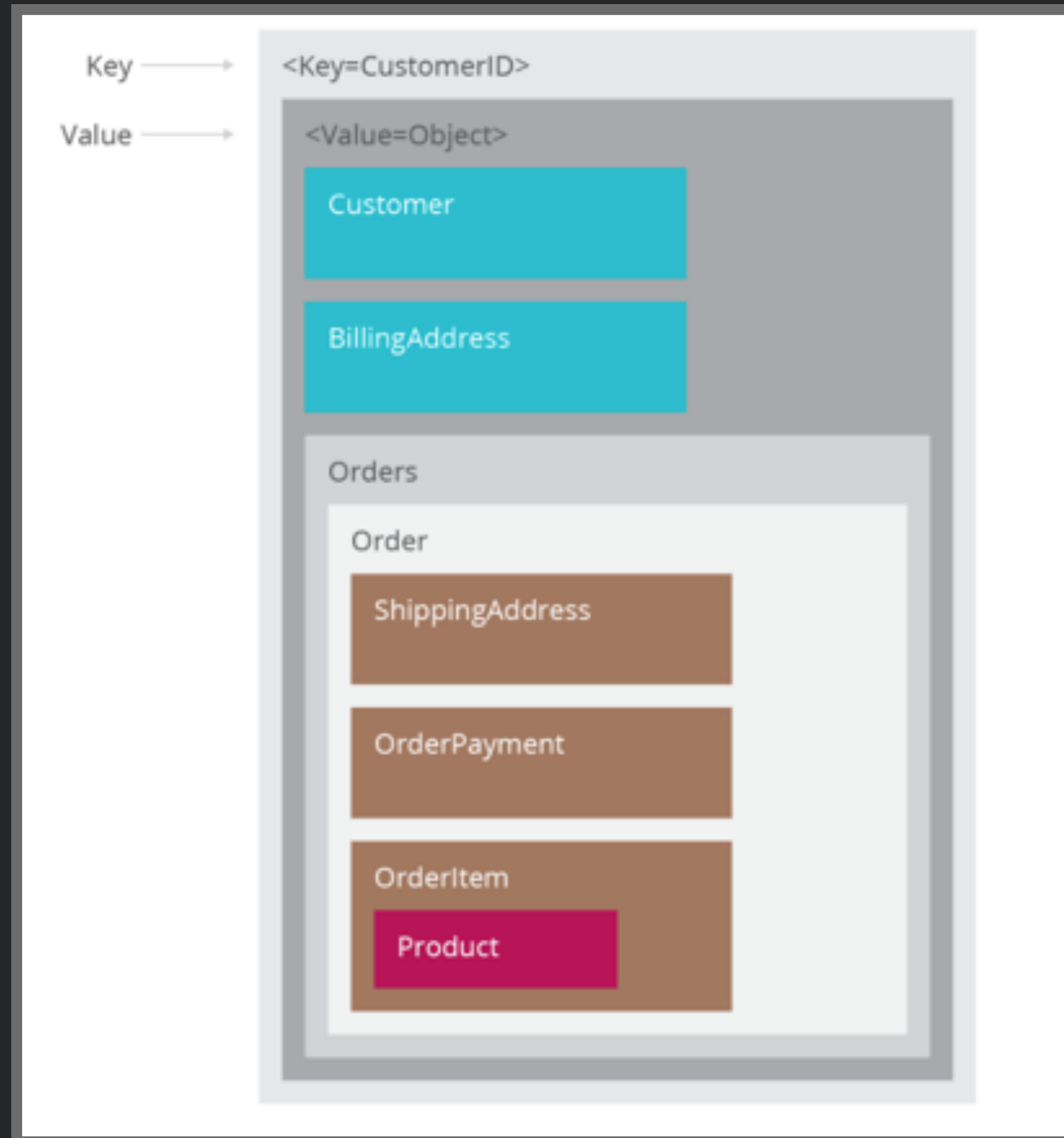
```
var express = require('express');
var app = express();
var port = process.env.port || 3000;

var counter = 0;
app.get('/', function (req, res) {
    res.send('Hello World has been said ' + counter + ' times!');
    counter++;
});

app.listen(port, function () {
    console.log('Example app listening on port' + port);
});
```

- Pros/cons?
  - Keep data between requests
  - *Goes away* when your server stops
    - Should use for transient state or as cache

NoSQL

- ***non SQL***, non-relational, "not only" SQL databases
- Emphasizes ***simplicity*** & ***scalability*** over support for relational queries
- Important characteristics
  - Schema-less: each row in dataset can have different fields (just like JSON!)
  - Non-relational: no structure linking tables together or queries to "join" tables
  - (Often) weaker consistency: after a field is updated, all clients *eventually* see the update but may see older data in the meantime
- Advantages: greater scalability, faster, simplicity, easier integration with code
- Several types. We'll look only at key-value.

Key-Value NoSQL



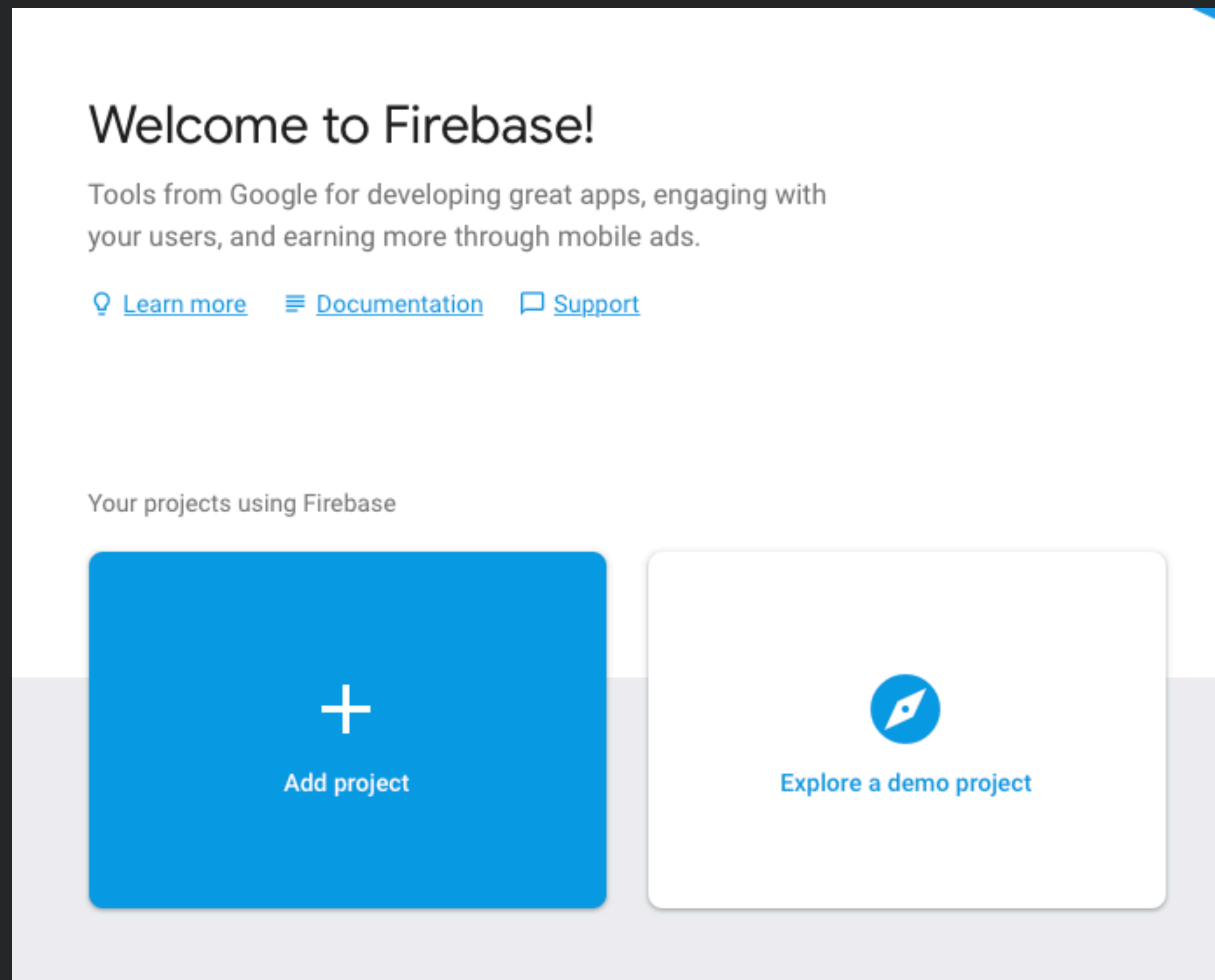
https://www.thoughtworks.com/insights/blog/nosql-databases-overview

Firebase Cloud Firestore

- Example of a NoSQL datastore
- Google web service
  - https://firebase.google.com/docs/firestore/
- “Realtime” database
  - Data stored to remote web service
  - Data synchronized to clients in real time
- Simple API
  - Offers library wrapping HTTP requests & responses
  - Handles synchronization of data
- Can also be used on frontend to build web apps with persistence without backend

Setting up Firebase Cloud Firestore

- Detailed instructions to create project, get API key
  - https://firebase.google.com/docs/firestore/quickstart



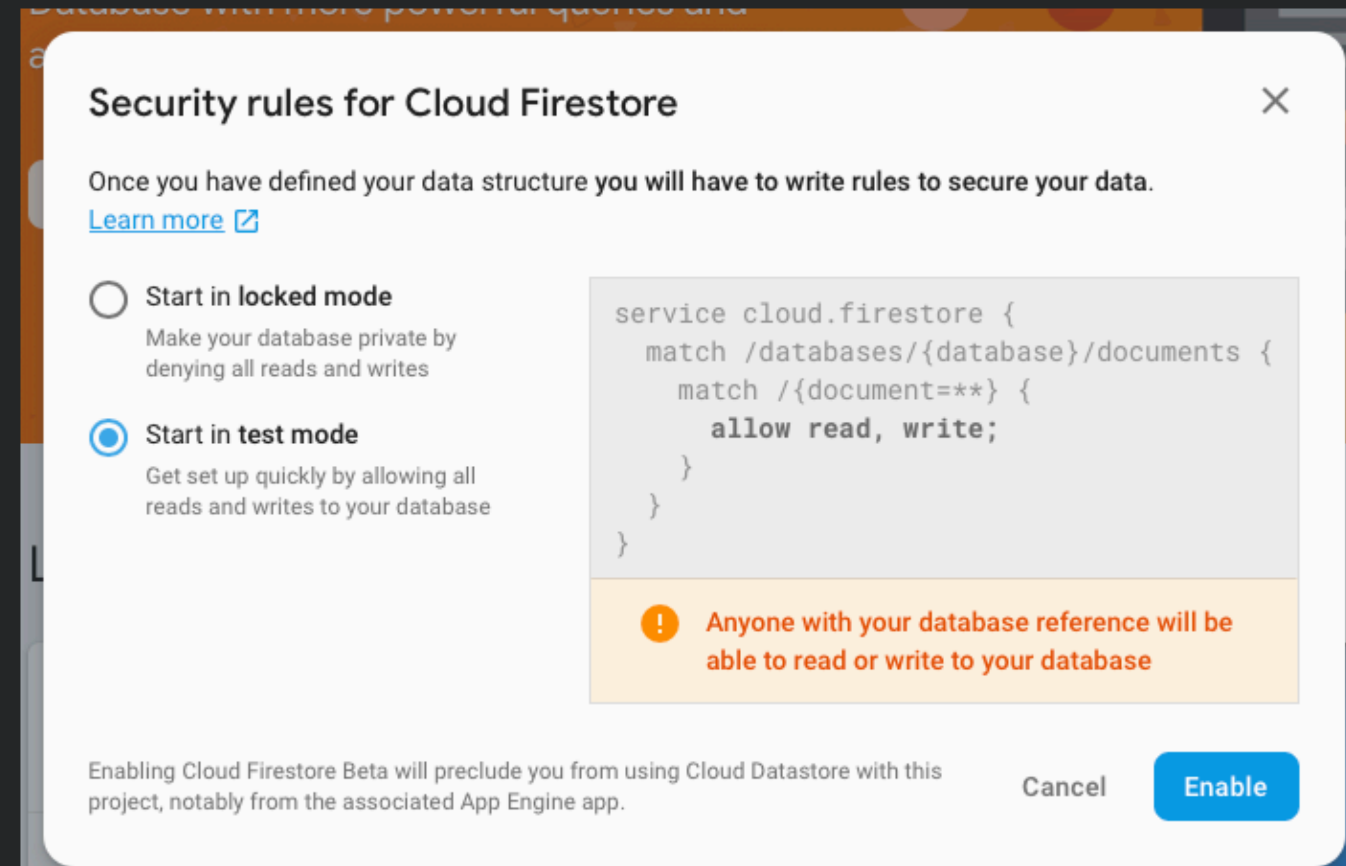
Setting up Firebase Realtime Database

- Go to https://console.firebase.google.com/, create a new project
- Install firebase module `npm install firebase-admin --save`
  - Go to IAM & admin > Service accounts, create a new private key, save the file.
  - Include Firebase in your web app

```
const admin = require('firebase-admin');

let serviceAccount = require('path/to/serviceAccountKey.json');

admin.initializeApp({
  credential: admin.credential.cert(serviceAccount)
});

let db = admin.firestore();
```

Permissions

- "Test mode" - anyone who has your app can read/write all data in your database
  - Good for development, bad for real world
- "Locked mode" - do not allow everyone to read/write data
  - Best solution, but requires learning how to configure security



Firebase Console

- See data values, updated in realtime
- Can edit data values

https://console.firebase.google.com

Project Overview

Develop

Authentication

Database

Storage

Hosting

Functions

ML Kit

Quality

Crashlytics, Performance, Test Lab

Analytics

Database Cloud Firestore BETA

Data Rules Indexes Usage

users > G000840381

swe432foobar | users | G000840381

+ Add collection | + Add document | + Add collection

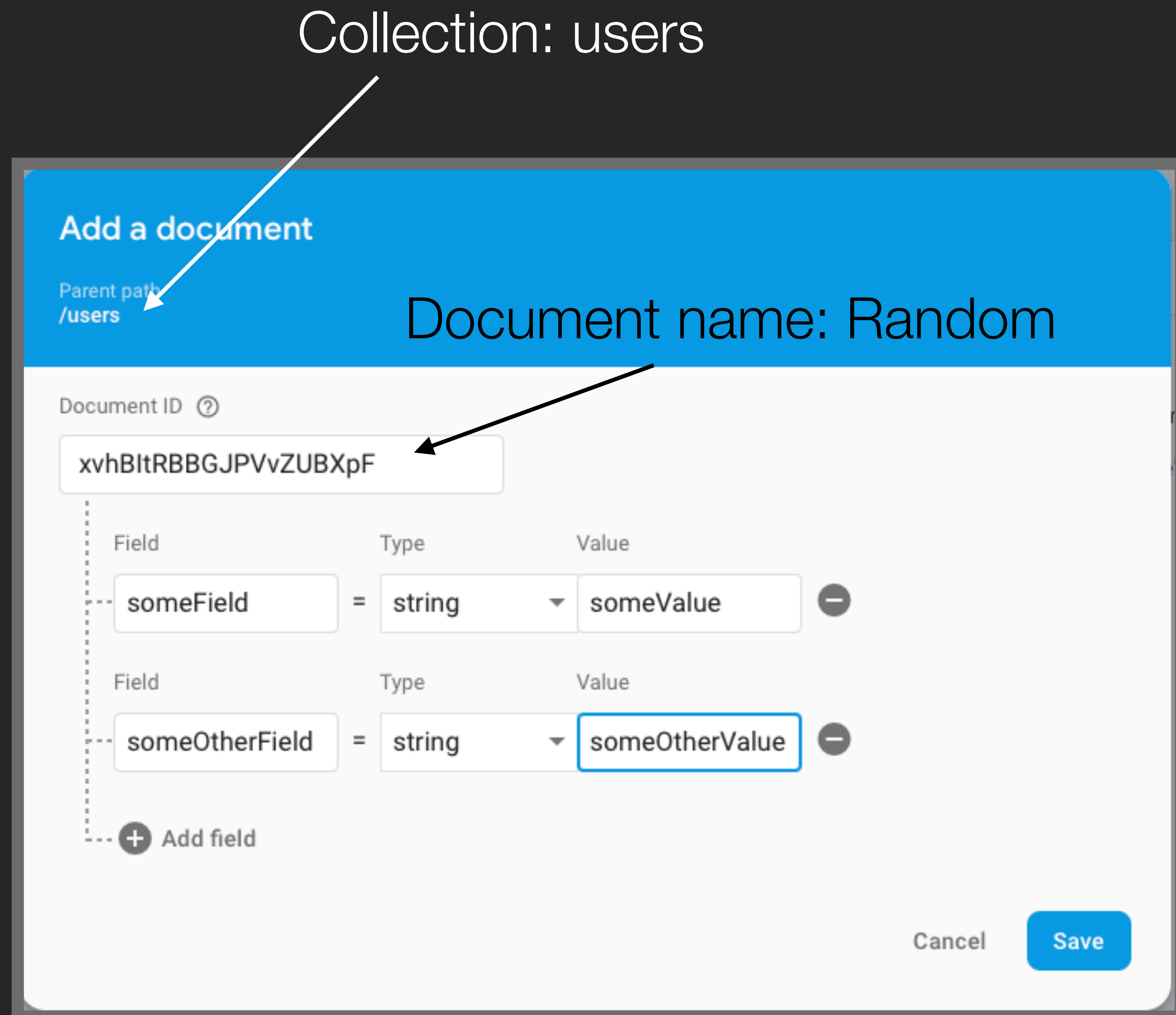
users > | G000840381 > | + Add field

email: "bitdiddle@masonlive.gmu.edu"

name: "Ben Bitdiddle"

Firebase Data Model: JSON

- **Collections** of JSON documents
  - Hierarchic tree of key/value pairs
  - Can view as one big object
  - Or describe path to descendent and view descendent as object



JSON is JSON…

users > G000840381

swe432foobar

+ Add collection

users >

users

+ Add document

G000840381 >

G000840381

+ Add collection

+ Add field

email: "bitdiddle@masonlive.gmu.edu"

location

city: "Fairfax"

state: "Virginia"

name: "Ben Bitdiddle"

Demo: Simple Test Program

- After successfully completing previous steps, should be able to replace config and run this script. Can test by viewing data on console.

```
const admin = require('firebase-admin');

let serviceAccount = require('[YOUR JSON FILE PATH HERE]’);

admin.initializeApp({
    credential: admin.credential.cert(serviceAccount)
});

let db = admin.firestore();

let docRef = db.collection('users').doc('alovelace');

let setAda = docRef.set({
    first: 'Ada',
    last: 'Lovelace',
    born: 1815
});
```

Demo: Simple Test Program

console.firebase.google.com

firebase-example – Overview – Firebase console

Firebase

Project Overview

Build
Authentication, Firestore Database, ...

Release & Monitor
Crashlytics, Performance, Test Lab, ...

Analytics
Dashboard, Realtime, Events, Conve...

Engage
Predictions, A/B Testing, Cloud Mes...

Extensions

Spark
Free $0/month

Upgrade

firebase-example

Go to docs

Receive email updates about new Firebase features, research, and events

Sign up

firebase-example

Spark plan

Get started by adding
Firebase to your app

iOS

</>

Add an app to get started

Store and sync app data in milliseconds

Demo: Simple Test Program

```
Firebase-Example — -bash — 88×21
Last login: Tue Sep 21 14:35:25 on ttys000
Legacy:Firebase-Example KevinMoran$
```

Demo: Simple Test Program

console.firebase.google.com

firebase-example – Cloud Firestore – Firebase console

Firebase

Project Overview

Build

Authentication
Firestore Database
Realtime Database
Storage
Hosting
Functions
Machine Learning

Release & Monitor
Crashlytics, Performance, Test Lab, ...

Analytics
Dashboard, Realtime, Events, Conve...

Engage
Predictions, A/B Testing, Cloud Mes...

Extensions

Spark
Free $0/month
Upgrade

firebase-example

Go to docs

Cloud Firestore

Data | Rules | Indexes | Usage

Prototype and test end-to-end with the Local Emulator Suite, now with Firebase Authentication **Get started**

users > alovelace

fir-example-3f211	users	alovelace
+ Start collection	+ Add document	+ Start collection
users	test	+ Add field

This document does not exist, it will not appear in queries or snapshots

Cloud Firestore location: us-east1

Structuring Data

- I want to build a chat app with a database
- App has chat rooms: each room has some users in it, and messages
- How should I store this data in Firebase? What are the collections and documents?

Structuring Data

- Should be considering what types of records clients will be requesting.
    - Do not want to force client to download data that do not need.
- Better to think of structure as **lists** of data that clients will retrieve

Storing Data: Set

(because firebase is asynchronous)

```
async function writeUserData(userID, newName, newEmail) {
    return database.collection("users").doc(userID).set({
        name: newName,
        email: newEmail
    });
}
```

Get the users collection

Create this one user by ID

Set the val

users > G000840381		
swe432foobar	users	G000840381
+ Add collection	+ Add document	+ Add collection
users	G000840381	+ Add field
		email: "bitdiddle@masonlive.gmu.edu"
		name: "Ben Bitdiddle"

Storing Data: Add

- Where does this ID come from?
    - It MUST be unique to the document
- Sometimes easier to let Firebase manage the IDs for you - it will create a new one uniquely automatically

```
async function addNewUser(newName, newEmail) {
    return database.collection("users").add({
        name: newName,
        email: newEmail
    });
}
async function demo(){
   let ref = await addNewUser("Foo Bar","fbar@gmu.edu")
    console.log("Added user ID " + ref.id)
}
```

Storing Data: Update

- Can either use “set” (with {merge:true}) or “update” to update an existing document (set will possibly create the document if it doesn’t exist)

```
database.collection("users").doc(userID).update({
    name: newName
});
```

Storing Data: Delete

```
database.collection("users").doc("ojtp4HrEeGB4Y9jErz0T").delete();
```

Removes a document

```
database.collection("users").doc(userID).update({
    name: firebase.firestore.FieldValue.delete()
});
```

Removes a field

- Can delete a key by setting value to null
  - If you want to store null, first need to convert value to something else (e.g., 0, '')

Fetching Data (One Time)

```
async function getUser(userId){
    return database.collection("users").doc(userId).get();
}
async function demo(){
   let user = await getUser("G000840381");
    console.log(user.data());
}
```

Can also call get directly on the collection

Listening to Data Changes

```
let doc = db.collection('cities').doc('SF');

let observer = doc.onSnapshot(docSnapshot => {
  console.log(`Received doc snapshot: ${docSnapshot}`);
  // ...
}, err => {
  console.log(`Encountered error: ${err}`);
});
```

“When values changes, invoke function”

Specify a subtree by creating a reference to a path. This listener will be called until you cancel it

- Read data by *listening* to changes to specific subtrees
- Events will be generated for initial values and then for each subsequent update

Ordering data

- Data is by, default, ordered by document ID in ascending order
  - e.g., numeric index IDs are ordered from 0…n
  - e.g., alphanumeric IDs are ordered in alphanumeric order
- Can get only first (or last) n elements

```
let firstThree = citiesRef.orderBy('name').limit(3);
```

- Can use where statements to query

```
citiesRef.where('population', '>', 2500000).orderBy('population');
```

In-Class Activity: Exploring Express

Try creating a few different endpoints with different response types!

replit.com

microservice-activity - Replit

kmoran / microservice-activity

Files

- index.js
- cities.json

Packager files

- package.json
- package-lock....

index.js

```
const express = require('express')
const fs = require('fs')
const app = express()
const port = 3000

var citiesJSON = fs.readFileSync('cities.json', 'utf-8')

app.get('/', (req, res) => {
  return res.json(citiesJSON)
})

app.listen(process.env.PORT || 3000, () => console.log("server starting on port 3000!"));
```

https://microservice-activity.kmoran.repl.co

"{ \"_type\": \"News\", \"readLink\": \"https://api.cognitive.microsoft.com/api/v5/news/search?q=washington+dc\", \"totalEstimatedMatches\": 1880000, \"value\": [{ \"name\": \"Cognizant Joins Washington DC Blockchain Lobby – Chamber of Digital Commerce\", \"url\": \"http://www.bing.com/cr?IG=B42CA9A86DAA4E66B4964D197B7580BD&CID=120B8D8E9D556BC91FCE84049C646A3F&rd=1&h=kHV6yUv5gLOsByoJ1Y6yM9r5vq9AuK4uSnKTZExtu6o&v=1&r=http%3a%2f%2fwww.financemagnates.com%2fcryptocurrency%2fnews%2fcognizant-joins-washington-dc-blockchain-lobby-chamber-of-digital-commerce%2f&p=DevEx,5025.1\", \"description\": \"Cognizant is engaged in an array of initiatives to test the potential of blockchain; including the creation of accelerators that design, prototype and test solutions for digital asset issuance and transfer, secure document exchange, digital identity, and ...\", \"about\": [{ \"readLink\":

Console | Shell

```
httpAllowHalfOpen: false,
timeout: 120000,
keepAliveTimeout: 5000,
maxHeadersCount: null,
headersTimeout: 60000,
_connectionKey: '6::::3000',
[Symbol(IncomingMessage)]: [Function: IncomingMessage],
[Symbol(ServerResponse)]: [Function: ServerResponse],
[Symbol(kCapture)]: false,
[Symbol(asyncId)]: 4
}
Hint: hit control+c anytime to enter REPL.
server starting on port 3000!
```

https://replit.com/@kmoran/microservice-activity#index.js

This will also be posted to Ed

Acknowledgements

Slides adapted from Dr. Thomas LaToza's SWE 632 course