Cloud Native Applications, Microservices Architecture, and REST APIs

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Objectives

The objectives of this class are to:

- Introduce the Microservice Architecture
- Learn why microservices are the disruptive trend
- Understand what makes a good microservices

Agility is the goal

- Smart experimentation
- Moving in–market with maximum velocity and minimum risk
- Gaining quick valuable insight to continuously change the value proposition and quality

Agility: The Three Pillars

Cultural Change
Automated Pipeline
Everything as Code
Immutable Infrastructure

Loose Coupling/Binding
RESTful APIs
Designed to resist failures
Test by break / fail fast

Portability
Developer Centric
Ecosystem enabler
Fast startup

The Perfect Storm

DevOps for speed and agility
Microservices for small deployments
Containers for ephemeral runtimes

THE PERFECT STORM: Microservices

Cultural Change
Automated Pipeline
Everything as Code
Immutable Infrastructure

Loose Coupling/Binding
RESTful APIs
Designed to resist failures
Test by break / fail fast

Portability
Developer Centric
Ecosystem enabler
Fast startup

"To fully leverage DevOps,
you need to **think** differently about application design."

High Resonanceproof Cassette Mechanism
EXTENDED RANGE•LOW DISTORTION
POSITION•HIGH
UD II 90
Mix Tape #1: The Old Days
N.R YES NO

AWESOME MIX VOL. 1
MARVEL
GUARDIANS OF THE GALAXY
ORIGINAL MOTION PICTURE SOUNDTRACK

Evolution of App Designs

C, C++	Java, J2EE	Ruby on Rails, Django	Python Flask, Node, Swift
Code and Manual Test	Manual Deployment	Automated Testing	Automated Deployment
Monolithic Programs	Tiered Applications	Service Oriented, RESTful	Stateless Microservices
Bare Metal	Virtual Machines	Platform As A Service	Docker Containers

Cloud Native

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What is Cloud Native?

- Cloud-native is an approach to building and running applications that exploits the advantages of the cloud computing delivery model that are built using multiple, independent microservices.
- DevOps drives the patterns of high performing organizations delivering software faster, consistently and reliably at scale
- Leveraging automation to improve human performance in a high trust culture, moving faster and safer with confidence and operational excellence

Core Elements

Architecture

Microservice-based

Practice:

Agile with DevOps & 12-factor methodology

Technology:

Containers / Kubernetes
CI / CD Tools

Cloud Native Applications

- The Twelve-Factor App describes patterns for cloud-native architectures which leverage microservices.
- Applications are designed as a collection of stateless microservices.
- State is maintained in separate databases and persistent object stores.
- Resilience and horizontal scaling is achieved through deploying multiple instances.
- Failing instances are killed and re-spawned, not debugged and patched.
- DevOps pipelines help manage continuous delivery of services.

https://www.nginx.com/blog/introduction-to-microservices/

Architecture: Microservices

What are Microservices?

"...the microservice architectural style is an approach to developing a single application as a **suite of small services**, each **running in its own process** and communicating with lightweight mechanisms, often an HTTP resource API. These services are **built around business capabilities** and **independently deployable** by fully automated deployment machinery."

- Martin Fowler and James Lewis

Monolith

Upload

Streaming

Subscriptions

Video Sharing Platform

Download

Transcode

Recommendations

Monolith

Upload

Streaming

Subscriptions

Video Sharing Platform

Download

Transcode

Recommendations

Microservices

Upload Service

Streaming Service

Transcode Service

Download Service

Recommendation Service

Subscription Service

Monolith vs Microservices Architecture

Monolith

All services combined into one build,
written in the same language and application framework

Microservices

- Agility
- Scalability
- Resilience

A microservice is a granular, decoupled component within a broader application

Microservice Architecture

An architecture style aimed to achieve flexibility, resiliency and control, based on the following principles:

- Single purpose Loose Coupling bounded context
- Independent life cycle: developed, deployed and scaled… and hopefully, fail independently
- Design for resiliency and owns it’s own data
- Polyglot — independent code base
- Built by autonomous teams with end-to-end responsibility, doing Continuous Delivery
- Communicates with other services over a well defined API

Advantages of Microservices

- Developed by a single team
- Developed independently
- Developed on its own timetable
- Each can be developed in a different language
- Manages its own data
- Scales and fails independently

Microservices are a paradise
RIGHT?

Beware There be Dragons

Microservice Challenges

- Developers must have significant operational and development skills (DevOps / Multiple languages)
- Service interfaces and versions
- Duplication of effort across service implementations
- Extra complexity of creating a distributed system with these issues, among others:
  - Network latency
  - Fault tolerance
  - Serialization

Microservice Challenges

- Designing decoupled non transactional systems is difficult
- Avoiding latency of large numbers of small service invocations
- Locating service instances
- Maintaining availability and consistency with partitioned data
- End-to-end automated testing

"Knowing **when** to use a technology is as important as knowing **how** to use it."

http://www.magnasoma.com/content/images/Magnasoma-Monolith-3-01.jpg

Monolithic Application Development

- Tightly coupled
- Mixed Concerns
- Large Deployment units
- Hard to Scale
- Long release cycles
- Slow on-boarding for new developers
- Slower feedback loop

Monolithic Application Deployment

- Cloud Enabled Model (VM Centric)
  - Single monolithic image
  - Configuration: “Hand crafted”
  - Changes: Performed in Change windows
  - Deployment: All or nothing
- Implications for operations:
  - Single point of failure & large maintenance surface
  - Error prone (many different configurations)
  - Heavy on Human tasks

Microservices

Microservice Application Development

- Loosely coupled
- Minimal responsibility per service
- Small Deployment units
- Easy to Scale
- Short release cycles
- Fast on-boarding for new developers
- Develop quickly with fast feedback

Microservice Application Deployment

- Cloud Native Model
  - Multiple microservices
  - Configuration: Automated and consistent
  - Changes: Performed in DevOps Pipeline
  - Deployment: Only what changes
- Advantages for operations
  - Resiliency through redundant services
  - Consistent configuration
  - Automated massive deployment

Microservice Design Enables Horizontal Scaling

Vertical Scaling (scaling up) ↑

Get bigger servers

Horizontal Scaling (scaling out) →

Add more servers

A Microservice Should Have

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High Cohesion (Bounded Context around a Business Domain)

- Does stuff that needs to change together occur together?

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- Does stuff that needs to change together occur together?

Low Coupling (Shared Nothing with Technology Agnostic API)

- Do you avoid making otherwise independent concerns dependent?

A Microservice Should Have

High Cohesion (Bounded Context around a Business Domain)

- Does stuff that needs to change together occur together?

Low Coupling (Shared Nothing with Technology Agnostic API)

- Do you avoid making otherwise independent concerns dependent?

Low Time to Comprehension (Small and Single Responsibility)

- Small enough for one person to understand quickly

Monolithic vs Microservices Architectures

Category	Monolithic architecture	Microservices architecture
Architecture	Built as a single logical executable	Built as a suite of small services
Modularity	Based on language features	Based on business capabilities
Agility	Changes to the system involve building and deploying a new version of the entire application	Changes can be applied to each service independently
Scaling	Entire application scaled when only one part is the bottleneck	Each service scaled independently when needed
Implementation	Typically entirely developed in one programming language	Each service can be developed in a different programming language
Maintainability	Large code base is intimidating to new developers	Smaller code bases easier to manage
Deployment	Complex deployments with maintenance windows and scheduled downtimes	Simple deployment as each service can be deployed individually, with minimal if not zero downtime

What makes a good Microservice?

- Microservices should have minimal outside dependancies
- Business Domains usually have well established boundaries
- Microservices should be broken up by Business Domains
  - With well defined interface
  - Limiting dependancies as much as possible

“Gather together those things that change for the same reason, and separate those things that change for different reasons.”

– Single Responsibility Principle by Robert C. Martin”

Domain Driven Design

- DDD is about designing software based on models of the underlying domain
- **Bounded Context** is a central pattern in Domain-Driven Design
- DDD deals with large models by dividing them into different Bounded Contexts and being explicit about their interrelationships.

https://martinfowler.com/bliki/BoundedContext.html

Domain Driven Design eCommerce Example

- "Item" takes on a different meaning in each of those contexts:
  - In the Catalog context, an Item means a sellable product
  - In Cart context, it means the item that the customer has added to their cart
  - In Fulfillment context, it means a Warehouse Item that will be shipped to the customer
- By separating and isolating these models within their respective boundaries, we can express the models freely and without ambiguity

https://medium.com/walmartlabs/building-domain-driven-microservices-af688aa1b1b8

Organizing for Microservices

Conway’s Law

Any organization that designs a system (defined broadly) will produce a design whose structure is a copy of the organization's communication structure

- Melvin Conway, Datamation, 1968

e.g., if you ask an organization with 4 teams to write a compiler… you will get a 4-pass compiler!

http://www.melconway.com/Home/Conways_Law.html

Traditional Organization around Technology (Bad)

Organization Structure

User Interface Team

Application Team

Database (DBA) Team

Application Structure

Traditional Organization around Technology (Bad)

Organization Structure

User Interface Team

Application Team

Database (DBA) Team

Application Structure

Organization around Business Domains (Good)

Login
Registration
Users

Account Team

Personalization

Personalization Team

Inventory
Shipping
Receiving

Warehouse Team

"If you are not going to organize your teams around **business domains**, you are not going to get the full benefit of DevOps"

Microservices: Designing for Failure

The Cloud*

* Picture taken from the glossy brochure
  Your mileage may vary

“The cloud is in a continuous state of partial failure”

“The cloud is in a continuous state of partial failure”

Does it matter if the customer never sees the failure?

Microservice Designs Must:

- Design for failure
- Move from:
  - How to avoid —> How to identify & what to do about it
  - Pure operational concern —> developer concern
- Plan to be throttled
- Plan to retry (with exponential backoff)
- Degrade gracefully
- Cache when appropriate

Retry Pattern

- Enable an application to handle transient failures when it tries to connect to a service or network resource, by transparently retrying a failed operation.
- Exponentially back-off delaying longer with each retry

1: Application invokes operation on hosted service. The request fails, and the service host responds with HTTP response code 500 (internal server error).
2: Application waits for a short interval and tries again. The request still fails with HTTP response code 500.
3: Application waits for a longer interval and tries again. The request succeeds with HTTP response code 200 (OK).

https://docs.microsoft.com/en-us/azure/architecture/patterns/retry

Retry Pattern Example in Python

```python
def retry(ExceptionToCheck, tries=4, delay=3, backoff=2, logger=None):
    """ Retry calling the decorated function using an exponential backoff. """
    def decorator(f):

        @wraps(f)
        def wrapper(*args, **kwargs):
            max_tries, max_delay = tries, delay
            while max_tries > 1:
                try:
                    return f(*args, **kwargs)
                except ExceptionToCheck, e:
                    msg = "%s, Retrying in %d seconds..." % (str(e), max_delay)
                    if logger:
                        logger.warning(msg)
                    else:
                        print msg
                    time.sleep(max_delay)  # wait before trying again
                    max_tries -= 1         # decrement retry count
                    max_delay *= backoff   # exponential delay more and more
            return f(*args, **kwargs)

        return wrapper  # true decorator

    return decorator
```

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        return wrapper  # true decorator

    return decorator
```

Heart of the retry logic

Using Python retry package

- For example if are getting: `HTTP 429 Client Error: Too Many Requests` with Cloudant, you can use the retry package

```
from retry import retry

    @retry(HTTPError, delay=1, backoff=2, tries=5)
    def delete(self):
        """ Removes a document from the database """
        try:
            document = self.database[self.id]
        except KeyError:
            document = None
        if document:
            document.delete()
```

This will catch any `HTTPError` and delay 1 second (`delay=1`), then 2 seconds, then 4 seconds, etc. (`backoff=2` by 2 seconds each time) until 5 tries are reached (`tries=5`)

Using Python retry package

- For example if are getting: `HTTP 429 Client Er` ... `ests` with Cloudant, you can use the retry package

Retry Decorator add to delete() function

```
from retry import retry

    @retry(HTTPError, delay=1, backoff=2, tries=5)
    def delete(self):
        """ Removes a document from the database """
        try:
            document = self.database[self.id]
        except KeyError:
            document = None
        if document:
            document.delete()
```

This will catch any `HTTPError` and delay 1 second (`delay=1`), then 2 seconds, then 4 seconds, etc. (`backoff=2` by 2 seconds each time) until 5 tries are reached (`tries=5`)

Circuit Breaker Pattern

- You wrap a protected function call in a circuit breaker object, which monitors for failures.
- Once the failures reach a certain threshold, the circuit breaker trips, and all further calls to the circuit breaker return with an error, without the protected call being made at all.
- Usually you'll also want some kind of monitor alert if the circuit breaker trips.

https://martinfowler.com/bliki/CircuitBreaker.html

Circuit Breaker Package in Python

PyPi has a library called circuitbreaker that you can install

```
$ pip install circuitbreaker
```

Just import the decorator function and use it to wrap your function

```
from circuitbreaker import circuit

@circuit(failure_threshold=10, expected_exception=ConnectionError)
def external_call():
    ...
```

https://pypi.org/project/circuitbreaker/

Bulkhead Pattern

- Isolates consumers and services from cascading failures.
  - An issue affecting a consumer or service can be isolated within its own bulkhead, preventing the entire solution from failing.
- This pattern is named Bulkhead because it resembles the sectioned partitions of a ship's hull
  - If the hull of a ship is compromised, only the damaged section fills with water, which prevents the ship from sinking.
- Allows you to preserve some functionality in the event of a service failure. Other services and features of the application will continue to work.

https://docs.microsoft.com/en-us/azure/architecture/patterns/bulkhead

Canary Testing

- Mitigates the risks of changes to applications in production
- Features are activated only for a small percentage of users, and the application performance and adoption results are measured
  - If those results indicate that the change is good, then it is ramped up to the rest of the user population
  - If the change is not good, it is rolled back

A/B Testing

- Some set of users are directed to one implementation of a feature, let's call it the A version, while a different set of users are directed to a different implementation of the feature, let's call that the B version
- This allows DevOps teams to evaluate different implementation options for a feature, and pick the one that works the best in the field, by measuring actual usage
- The data from usage analytics is then used to influence the priorities of the remaining stories in the backlog.

Feature Flags

- With Continuous Delivery, code can be tested and delivered into production with “Feature Flags” around the new code
- Using these techniques, those features can be made visible to specific audiences to allow testing of those features in a production environment
- The act of going Live can happen via a Release Event on a later date when the Feature Flags are turned on in a coordinated way across multiple components, and the new feature is made publicly visible.

Practice:

12-factor Methodology

The methodology was drafted by developers at Heroku and was first presented by Adam Wiggins circa 2011

The Twelve-Factor App

- The twelve-factor app is a methodology for building software-as-a-service apps that:
  - Use **declarative** formats for setup automation, to minimize time and cost for new developers joining the project;
  - Have a **clean contract** with the underlying operating system, offering **maximum portability** between execution environments;
  - Are suitable for **deployment** on modern **cloud platforms**, obviating the need for servers and systems administration;
  - **Minimize divergence** between development and production, enabling **continuous deployment** for maximum agility;
  - And can **scale up** without significant changes to tooling, architecture, or development practices.

12-factor Methodology

I. Codebase
One codebase tracked in revision control, many deploys

II. Dependencies
Explicitly declare and isolate dependencies

III. Config
Store config in the environment

IV. Backing services
Treat backing services as attached resources

V. Build, release, run
Strictly separate build and run stages

VI. Processes
Execute the app as one or more stateless processes

VII. Port binding
Export services via port binding

VIII. Concurrency
Scale out via the process model

IX. Disposability
Maximize robustness with fast startup and graceful shutdown

X. Dev/prod parity
Keep development, staging, and production as similar as possible

XI. Logs
Treat logs as event streams

XII. Admin processes
Run admin/management tasks as one-off processes

https://12factor.net/

I. Codebase

One codebase tracked in revision control, many deploys

- **There is always a one-to-one correlation between the codebase and the app**
- If there are multiple codebases, it's not an app – it's a distributed system.
  - Each component in a distributed system is an app, and each can individually comply with twelve-factor.
- Multiple apps sharing the same code is a violation of twelve-factor.
  - The solution here is to factor shared code into libraries which can be included through the dependency manager.

II. Dependencies

Explicitly declare and isolate dependencies

- Most programming languages offer a packaging system for distributing support libraries, such as Rubygems for Ruby, or PyPi for Python, or Maven for Java
  - Libraries installed through a packaging system can be installed system-wide (known as “site packages”) or scoped into the directory containing the app (known as “vendoring” or “bundling”)
- A twelve-factor app never relies on implicit existence of system-wide packages
  - It declares all dependencies, completely and exactly, via a dependency declaration manifest
  - Furthermore, it uses a dependency isolation tool during execution to ensure that no implicit dependencies “leak in” from the surrounding system. The full and explicit dependency specification is applied uniformly to both production and development

III. Config

Store config in the environment

- An app's config is everything that is likely to vary between deploys (staging, production, developer environments, etc). This includes:
  - Resource handles to the database, Memcached, and other backing services
  - Credentials to external services such as Amazon S3 or Twitter
  - Per-deploy values such as the canonical hostname for the deploy
- Apps sometimes store config as constants in the code. This is a violation of twelve-factor, which **requires strict separation of config from code**. Config varies substantially across deploys, code does not.

IV. Backing services

Treat backing services as attached resources

- A backing service is any service the app consumes over the network as part of its normal operation
- **The code for a twelve-factor app makes no distinction between local and third party services**
  - To the app, both are attached resources, accessed via a URL or other locator/credentials stored in the config
  - A deploy of the twelve-factor app should be able to swap out a local MySQL database with one managed by a third party (such as Amazon RDS) without any changes to the app's code

V. Build, release, run

Strictly separate build and run stages

- A codebase is transformed into a (non-development) deploy through three stages:
  - The **build** stage is a transform which converts a code repo into an executable bundle known as a build.
  - The **release** stage takes the build produced by the build stage and combines it with the deploy's current config.
  - The **run** stage (also known as "runtime") runs the app in the execution environment, by launching some set of the app's processes against a selected release.

- **The twelve-factor app uses strict separation between the build, release, and run stages**
  - For example, it is impossible to make changes to the code at runtime, since there is no way to propagate those changes back to the build stage.

VI. Processes

Execute the app as one or more stateless processes

- The app is executed in the execution environment as one or more processes
- In the simplest case, the code is a stand-alone script, the execution environment is a developer's local laptop with an installed language runtime, and the process is launched via the command line (for example, python my_script.py)
- On the other end of the spectrum, a production deploy of a sophisticated app may use many process types, instantiated into zero or more running processes
- **Twelve-factor processes are stateless and share-nothing.**
  - Any data that needs to persist must be stored in a stateful backing service, typically a database.

VII. Port binding

Export services via port binding

- **The twelve-factor app is completely self-contained** and does not rely on runtime injection of a webserver into the execution environment to create a web-facing service
- The web app **exports HTTP as a service by binding to a port**, and listening to requests coming in on that port.
- In a local development environment, the developer visits a service URL like `http://localhost:5000/` to access the service exported by their app
- In deployment, a routing layer handles routing requests from a public-facing hostname to the port-bound web processes.

VIII. Concurrency

Scale out via the process model

- **In the twelve-factor app, processes are a first class citizen**
- Processes in the twelve-factor app take strong cues from the unix process model for running service daemons
- Using this model, the developer can architect their app to handle diverse workloads by assigning each type of work to a process type
  - For example, HTTP requests may be handled by a web process, and long-running background tasks handled by a worker process.

IX. Disposability

Maximize robustness with fast startup and graceful shutdown

- **The twelve-factor app's processes are disposable, meaning they can be started or stopped at a moment's notice**
- This facilitates fast elastic scaling, rapid deployment of code or config changes, and robustness of production deploys
  - Processes should strive to minimize startup time
  - Ideally, a process takes a few seconds from the time the launch command is executed until the process is up and ready to receive requests or jobs
- Processes shut down gracefully when they receive a SIGTERM signal from the process manager.
  - For a web process, graceful shutdown is achieved by ceasing to listen on the service port (thereby refusing any new requests), allowing any current requests to finish, and then exiting..

X. Dev/prod parity

Keep development, staging, and production as similar as possible

- Historically, there have been substantial gaps between development (a developer making live edits to a local deploy of the app) and production (a running deploy of the app accessed by end users). These gaps manifest in three areas:
  - The **time gap**: A developer may work on code that takes days, weeks, or even months to go into production.
  - The **personnel gap**: Developers write code, ops engineers deploy it.
  - The **tools gap**: Developers may be using a stack like Nginx, SQLite, and OS X, while the production deploy uses Apache, MySQL, and Linux.

X. Dev/prod parity (continued)

Keep development, staging, and production as similar as possible

- **The twelve-factor app is designed for continuous deployment by keeping the gap between development and production small.**
- Looking at the three gaps described on the previous chart:
  - Make the time gap small: a developer may write code and have it deployed hours or even just minutes later.
  - Make the personnel gap small: developers who wrote code are closely involved in deploying it and watching its behavior in production.
  - Make the tools gap small: keep development and production as similar as possible.

XI. Logs

Treat logs as event streams

- Logs provide visibility into the behavior of a running app. In server-based environments they are commonly written to a file on disk (a “logfile”); but this is only an output format.
- **A twelve-factor app never concerns itself with routing or storage of its output stream**
  - It should not attempt to write to or manage logfiles
  - Instead, each running process writes its event stream, unbuffered, to stdout
  - During local development, the developer will view this stream in the foreground of their terminal to observe the app’s behavior

XII. Admin processes

Run admin/management tasks as one-off processes

- **One-off admin processes should be run in an identical environment as the regular long-running processes of the app**, such as:
  - Running database migrations (e.g. manage.py migrate in Django, rake db:migrate in Rails).
  - Running a console (also known as a REPL shell) to run arbitrary code or inspect the app's models against the live database.
  - Running one-time scripts committed into the app's repo (e.g. php scripts/fix_bad_records.php)
- They run against a release, using the same codebase and config as any process run against that release. Admin code must ship with application code to avoid synchronization issues.

“Microservices need a consistent way of communicating.”

REST Architecture and RESTful Services

Cloud Native Applications

- The Twelve-Factor App describes patterns for cloud-native architectures which leverage microservices.
- Applications are designed as a collection of stateless microservices.
- State is maintained in separate databases and persistent object stores.
- Resilience and horizontal scaling is achieved through deploying multiple instances.
- Failing instances are killed and re-spawned, not debugged and patched.
- DevOps pipelines help manage continuous delivery of services.

https://www.nginx.com/blog/introduction-to-microservices/

What is REST?

- **RE**presentational **S**tate **T**ransfer
  - A REST API describes a set of resources
  - A simple way to transfer and manipulate the state of a resource
- A service based on REST is called a RESTful service
- A RESTful service is exposed through a Uniform Resource Locator (URL)
- A client would issue a Hypertext Transfer Protocol (HTTP) request to manipulate it

REST Architecture

- REST is a **client-server** architecture
  - The client and the server provide a separation of concerns which allows both the client and the server to evolve independently as it only requires that the interface stays the same
- REST is **stateless**
  - The communication between the client and the server always contains all the information needed to perform the request. There is no session state in the server.
- REST is **cacheable**
  - The client, the server can cache resources in order to improve performance
- REST provides a **uniform interface** between components
  - All components follow the same rules to speak to one another
- REST is a **layered system**
  - Individual components cannot see beyond the immediate layer with which they are interacting

What Does It Mean To Be RESTful?

- Everything is represented as a Resource
- Resource identification through URI (Uniform Resource Identifier)
  - Uses HTTP verbs (`POST, GET, PUT, DELETE`)
  - e.g., `GET http://myservice.com/users/123`
- Uniform interface (I should be able to guess the interface given a resource name)
- Self-descriptive messages are used to represent Resources (usually XML or JSON)
- Stateful interactions through hyperlinks

A REST API describes a set of resources

- Example REST API for Customer resource

Resource Path	Description
`/customers`	All the customers in the database
`/customers/12345`	Customer #12345
`/customers/12345/orders`	All orders for customer #12345
`/customers/12345/orders/67890`	Order #67890 for customer #12345

What REST is Not

- REST is not a Remote Procedure Call (RPC) or just a bunch of verbs as URI's
- For example, these are NOT RESTful API's:

```
GET  http://api.myapp.com/getUser/123
POST http://api.myapp.com/addUser
GET  http://api.myapp.com/removeUser/123
```

- These are the RESTful equivalents:

```
GET    http://api.myapp.com/users/123
POST   http://api.myapp.com/users
DELETE http://api.myapp.com/users/123
```

REST API conventions

- Use REST API conventions to provide a consistent and easy to use interface for clients.
- REST API conventions define specific behavior for each type of HTTP method. Use the following guidelines as a starting point for designing your API.
  - **GET** (read) operations only query data. A GET request should never modify data.
  - **POST** (create) operations create new resource but do not modify existing resources.
  - **PUT** and **PATCH** (update) operations modify existing resources. (PUT is more common)
  - **DELETE** (delete) operations destroy resources.

Guidelines for Well Formed URI’s

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  - e.g., `/users` not `/user`

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  - e.g., `/users/123/agreement`

Guidelines for Well Formed URI's

- A plural noun should be used for collection names
  - e.g., `/users` not `/user`
- A singular noun should be used for document names
  - e.g., `/users/123/agreement`
- Variable path segments may be substituted with identity-based values
  - e.g., `/users/123/addresses/2`

Guidelines for Well Formed URI's

- A plural noun should be used for collection names
  - e.g., `/users` not `/user`
- A singular noun should be used for document names
  - e.g., `/users/123/agreement`
- Variable path segments may be substituted with identity-based values
  - e.g., `/users/123/addresses/2`
- CRUD function names should not be used in URIs
  - e.g., never use: `/getUsers/123`

URI Format Guidelines

- Forward slash separator (/) must be used to indicate a hierarchical relationship

```
http://api.myapp.com/users/{id}/addresses
```

URI Format Guidelines

- Forward slash separator (/) must be used to indicate a hierarchical relationship

```
http://api.myapp.com/users/{id}/addresses
```

- A trailing forward slash (/) should not be included in URIs

```
http://api.myapp.com/users/   <- not recommended
http://api.myapp.com/users    <- recommended
```

URI Format Guidelines

- Forward slash separator (/) must be used to indicate a hierarchical relationship

```
http://api.myapp.com/users/{id}/addresses
```

- A trailing forward slash (/) should not be included in URIs

```
http://api.myapp.com/users/   <- not recommended
http://api.myapp.com/users    <- recommended
```

- Hyphens (-) should be used to improve the readability of URIs

```
http://api.myapp.com/userGroups    <- not recommended
http://api.myapp.com/user-groups   <- recommended
```

URI Format Guidelines (cont)

- Underscores (_) should not be used in URIs

```
http://api.myapp.com/user_groups     <- not recommended
http://api.myapp.com/user-groups     <- recommended
```

URI Format Guidelines (cont)

- Underscores (_) should not be used in URIs

```
http://api.myapp.com/user_groups    <- not recommended
http://api.myapp.com/user-groups    <- recommended
```

- Lowercase letters should be preferred in URI paths

```
http://api.myapp.com/Groups/Reset    <- not recommended
http://api.myapp.com/groups/reset    <- recommended
```

URI Format Guidelines (cont)

- Underscores (_) should not be used in URIs

```
http://api.myapp.com/user_groups    <- not recommended
http://api.myapp.com/user-groups    <- recommended
```

- Lowercase letters should be preferred in URI paths

```
http://api.myapp.com/Groups/Reset    <- not recommended
http://api.myapp.com/groups/reset    <- recommended
```

- File extensions should not be included in URIs

```
http://api.myapp.com/users/123/adresses.json    <- not recommended
http://api.myapp.com/users/123/adresses         <- recommended
```

RESTful API for USER Resource

- Using the example of a User as a resource the API would be:

```
GET  /users            <- retrieve a list of Users
GET  /users?tag="sw"   <- retrieve a list of Users with a
                          tag of "sw"
GET  /users/123        <- retrieves the User with Id 123
POST /users            <- creates a new User
PUT  /users/123        <- updates the User with Id 123
DELETE /users/123      <- deletes the User with Id 123
```

Create with POST

- Use POST to Create a Resource
- If a resource has been created on the origin server, the response **SHOULD be 201** (Created) and contain an entity which describes the status of the request and refers to the new resource, and a Location header
- Hypertext Transfer Protocol -- HTTP/1.1
  - https://www.ietf.org/rfc/rfc2616.txt

Idempotence

- **PUT** and **DELETE** operations are **idempotent**
- If you DELETE a resource, it's gone. If you DELETE it again, it's still gone (i.e., do not throw a 404 Not Found error!)
- Some systems might want to send a 404 on DELETE if the original resource never existed (but this could be difficult to prove)
- If you use PUT to change the state of a resource, you can resend the PUT request and the resource state should remain the same.

Side-Effects

- GET must NEVER modify the resource
  - Never code: `GET https://api.del.icio.us/posts/delete`
- GET must have no side-effects (*see above*)
- GET should return a representation of the resource(s) it was called on... period!

Safety

- While GET means "Read"... (and is safe)
- POST is neither safe nor idempotent
- Making two identical POST requests to a resource will probably result in creating two resources containing the same information
- With overloaded POST’s that may have different behavior based on data passed in, all bets are off

Use HTTP Headers

- Information about what to send or accept should be expressed in HTTP headers
- Some examples are:

```
{
    'Accept': 'application/json',
    'Content-Type': 'application/json',
    'Authorization': 'bearer %s' % token
}
```

How to Handle Queries

- If the resource is a collection, you can implement a simple query using URL parameters
- Example: Find all pets that are poodles

```
GET http://api.myapp.com/pets?breed="poodle"&sort_by=created
```

Use Proper HTTP Return Codes

200	Indicates that the request was **completed** successfully. All GET requests that are successful should return 200
201	Indicates that a record was **created** successfully. All POST requests that successfully create a resource should return 201
204	Indicates that a record was **deleted** successfully. All DELETE requests that completed successfully should return 204 and the body should be empty.
40X (401, 404)	Status codes in the 400 range indicate a client error, such as 400 for invalid request syntax and 401 Unauthorized for not having proper credentials are probably the most common.
50X (500, 503)	Status codes in the 500 range indicate that a server error occurred. The client request may have been valid or invalid, but a problem occurred on the server that prevented it from processing the request.

Common REST API Return Codes

Code: 200 (“OK”) should be used to indicate nonspecific success
Code: 200 (“OK”) must not be used to communicate errors in the response body
Code: 201 (“Created”) must be used to indicate successful resource creation
Code: 202 (“Accepted”) must be used to indicate successful start of an asynchronous action
Code: 204 (“No Content”) should be used when the response body is intentionally empty
Code: 301 (“Moved Permanently”) should be used to relocate resources
Code: 302 (“Found”) should not be used
Code: 303 (“See Other”) should be used to refer the client to a different URI
Code: 304 (“Not Modified”) should be used to preserve bandwidth
Code: 307 (“Temporary Redirect”) should be used to tell clients to resubmit the request to another URI
Code: 400 (“Bad Request”) may be used to indicate nonspecific failure
Code: 401 (“Unauthorized”) must be used when there is a problem with the client’s credentials
Code: 403 (“Forbidden”) should be used to forbid access regardless of authorization state
Code: 404 (“Not Found”) must be used when a client’s URI cannot be mapped to a resource
Code: 405 (“Method Not Allowed”) must be used when the HTTP method is not supported
Code: 406 (“Not Acceptable”) must be used when the requested media type cannot be served
Code: 409 (“Conflict”) should be used to indicate a violation of resource state
Code: 412 (“Precondition Failed”) should be used to support conditional operations
Code: 415 (“Unsupported Media Type”) must be used when the media type of a request’s payload cannot be processed
Code: 422 ("Unprocessable entity") must be used if the server can not process the property, for example, if an image cannot be formatted or if required fields are missing from the payload
Code: 500 (“Internal Server Error”) should be used to indicate API malfunction

Responses (Happy Path)

- `GET /users`
  - 200 + Array of Users [{...},{...},{...}]
- `GET /users/12345`
  - 200 + User {...}
- `POST /users`
  - 201 + User {...}
  - Location Header for GET
- `PUT /users/12345`
  - 200 + User {...}
- `DELETE /users/12345`
  - 204 + empty body

Hands-On

“live session”

Key Takeaways

- Cloud native and microservices are the future; customers who don't take on these initiatives will be at a business disadvantage in the future.
- 12-Factor describes a set of best practices that should be adhered to in order to behave properly in a cloud native environment.
- Domain Driven Design plays a key role in achieving the proper microservice segmentation.
- We must reorganize our development teams around business domain boundaries.