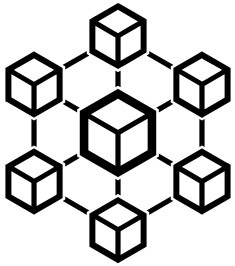
Microservices: From Theory to Practice



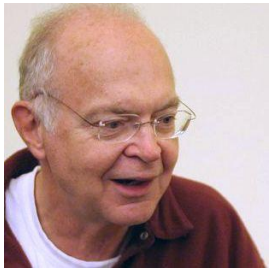
Guest Seminar Lecture
University of Southern Denmark

UNIVERSITÀ
DEGLI STUDI
DELL'AQUILA

October 2021

Presentation By:
Karthik Vaidhyanathan
University of L'Aquila, Italy

“In fact what I would like to see is thousands of computer scientists let loose to do whatever they want. That's what really advances the field”



Donald Knuth

Computer Scientist,
Turing Award winner,...

About Me

Postdoctoral Researcher, DISIM
University of L'Aquila, Italy
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- 2010-2014, B.Tech CSE at Amrita University, Kollam
- 4 months Internship at Infosys (J2EE), India
- 2014-2016, M.Tech CSE (Specialization: Machine Learning) at Amrita University, India
- 2014-2016, M.Sc. CS (Specialization: Software Architecture) at University of L'Aquila, Italy
- 2016-2017, Product Lead, Knowledge Lens, India
- 2017-2021, Ph.D. Computer Science, GSSI, Italy
- 2017-Present, Consultant ML architect [part time], FMS, India
- 2021-Present, Postdoctoral Researcher, University of L'Aquila, Italy

Goals of the lecture

Motivation behind Microservices

The theory of Microservices

Designing Microservices

Integrating Microservices

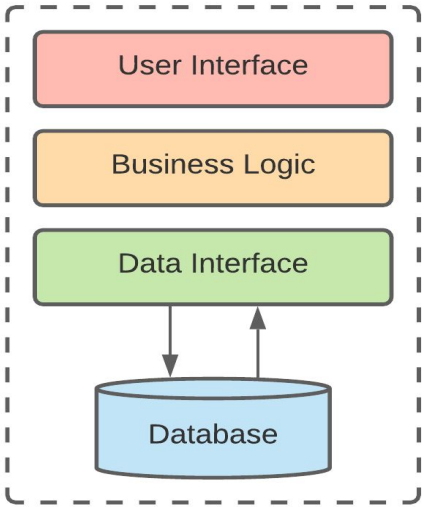
Deployment of Microservices

Microservices and Mobile Apps

To the world of Monoliths

Brief History - The World of Monoliths (90's)

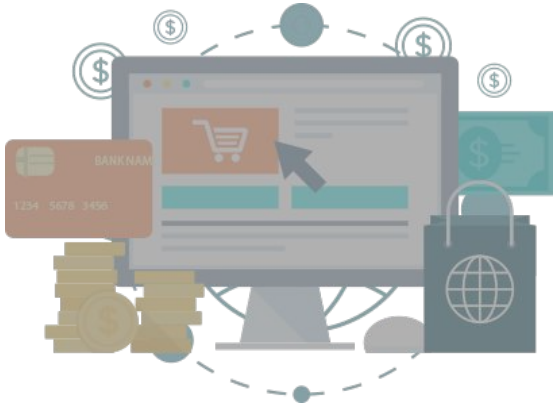
- Applications built as a single unit
- Traditional 2-tier, 3-tier applications - Separation of client, business logic and database
- Packaged as one bundle - eg: Entire application bundled into one WAR



Standard monolith application architecture

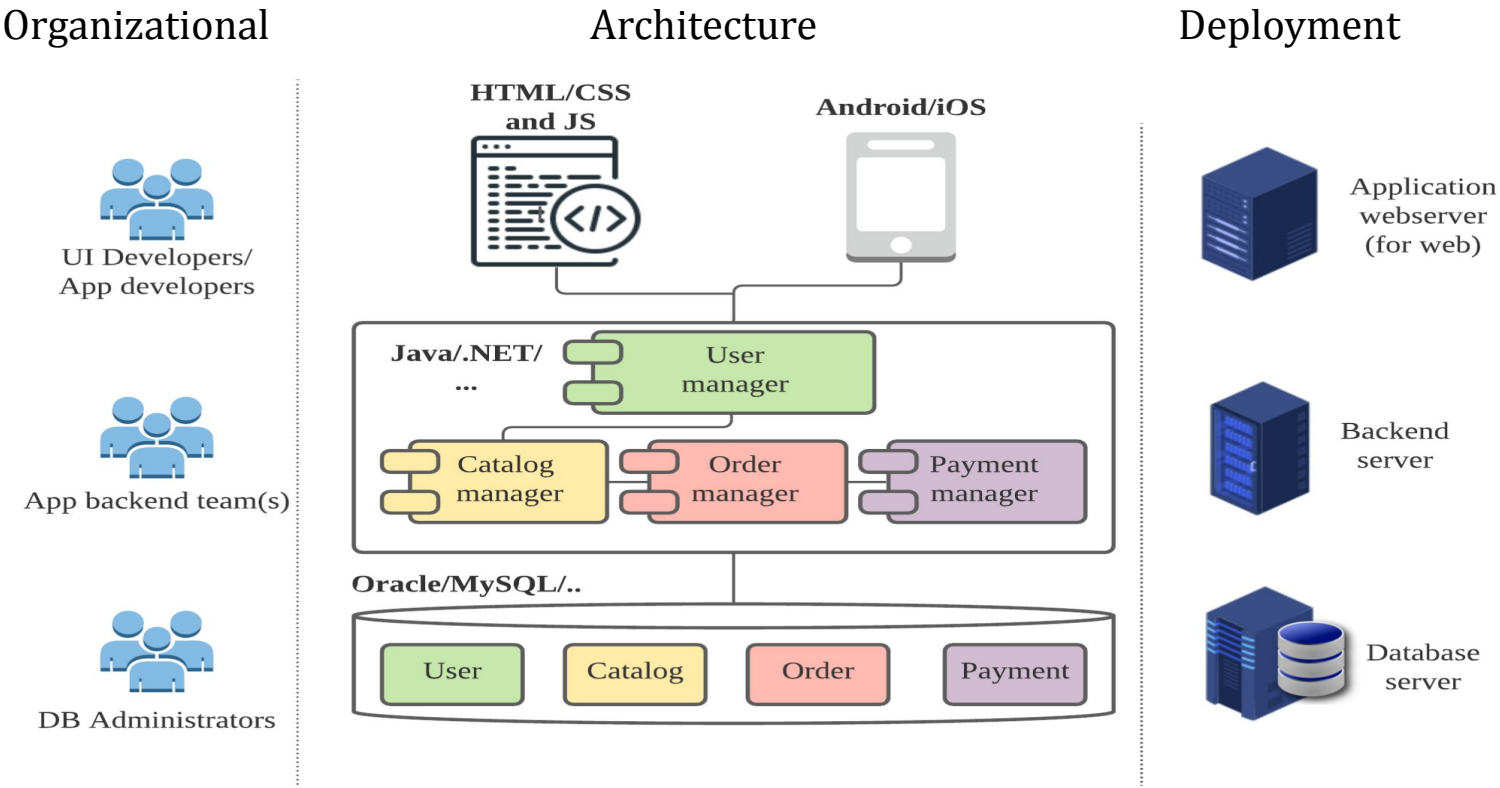
The World of Monoliths - An Example System

- Develop an E-commerce application with following features:
  - User registration and authentication
  - Browse catalog
  - Place orders
  - Add/modify delivery information
  - Add/modify billing information
  - Make payment



- How were such systems developed ?

The World of Monoliths - Monolithic Approach



The World of Monoliths - Monolithic Approach

- High degree of coupling - everyone needs to know everything !!!
- Change cycle and bug fix can take weeks - Modifiability and time to market
- Adding new feature can be challenging - Extensibility
- Separation of concerns via components with inherent coupling - Modularity
- Scaling system implies scaling the whole stack - Scalability
- Limited by the language of choice - eg: add recommendation feature to e-commerce (Java or Python ?)
- Database is centralized - addition or modification is a costly process

Monolith has its own advantages too!

Moving into SOA

The Age of Service Oriented Architectures (SOA)

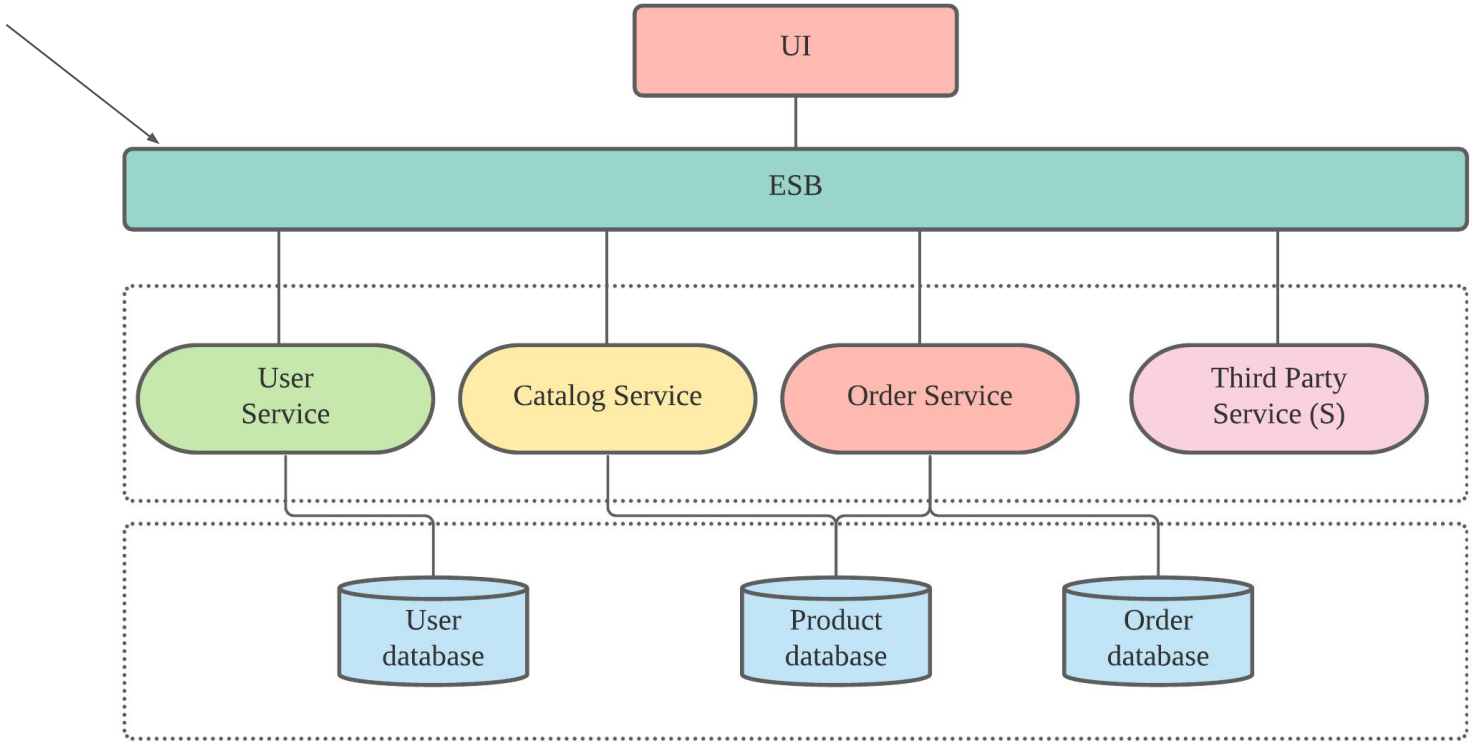
"SOA means too many different things to different people" -- Martin Fowler

- Very popular style for architecting systems from early 2000's
- Make software components reusable via service interfaces, accessible over network through standard communication protocols
- Services are loosely coupled
- Developers just focus on building services. Integration through Enterprise Service Bus (ESB)
- Services are more coarse grained - Small services to large applications (No clearly defined boundaries)
- It is more at an enterprise level - Eg: integrate multiple applications via ESB

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

SOA Approach to E-Commerce Application

Overhead !!



Time to Evolve: Make things more fine grained

Domain Driven Design

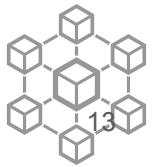
Large Scale Systems

Continuous Delivery

Infrastructure Automation

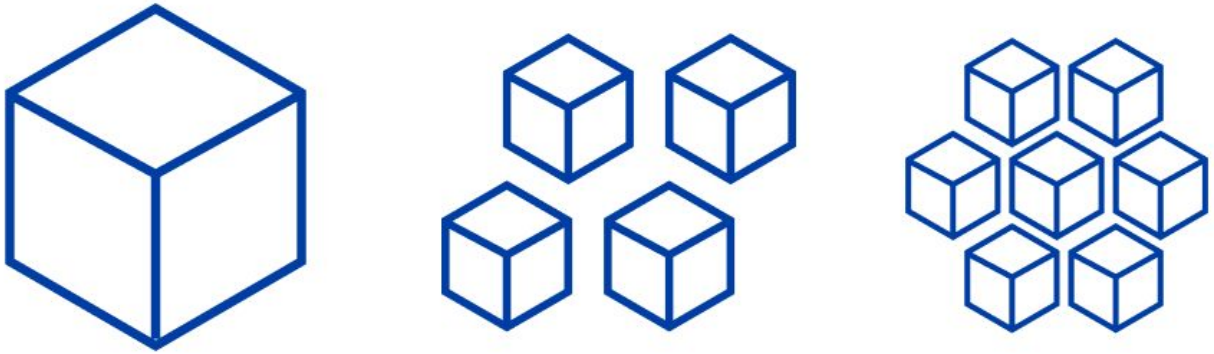
Small Autonomous Teams

Microservices



Into the world of Microservices

Moving Towards Microservices



MONOLITHIC
Single unit

SOA
Coarse-grained

MICROSERVICES
Fine-grained

1990

2000

2010

Microservices: What does it mean ?

"Small autonomous services that work together"

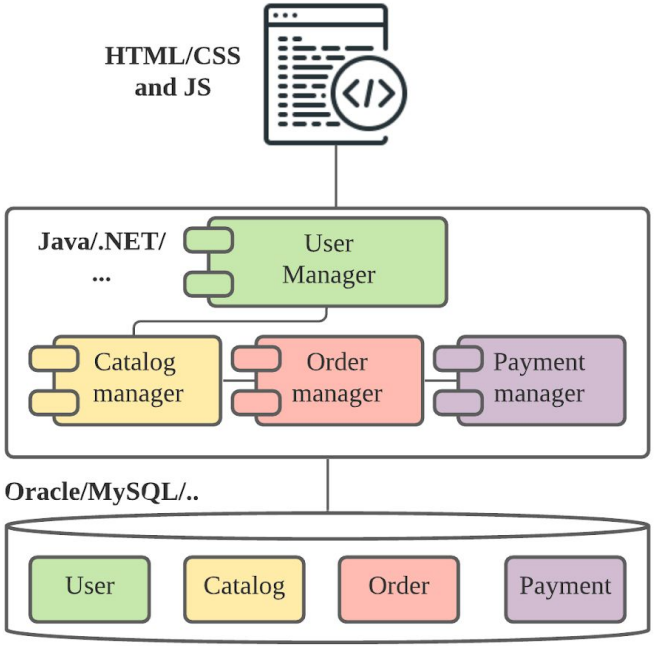
-- Sam Newman

"It 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"

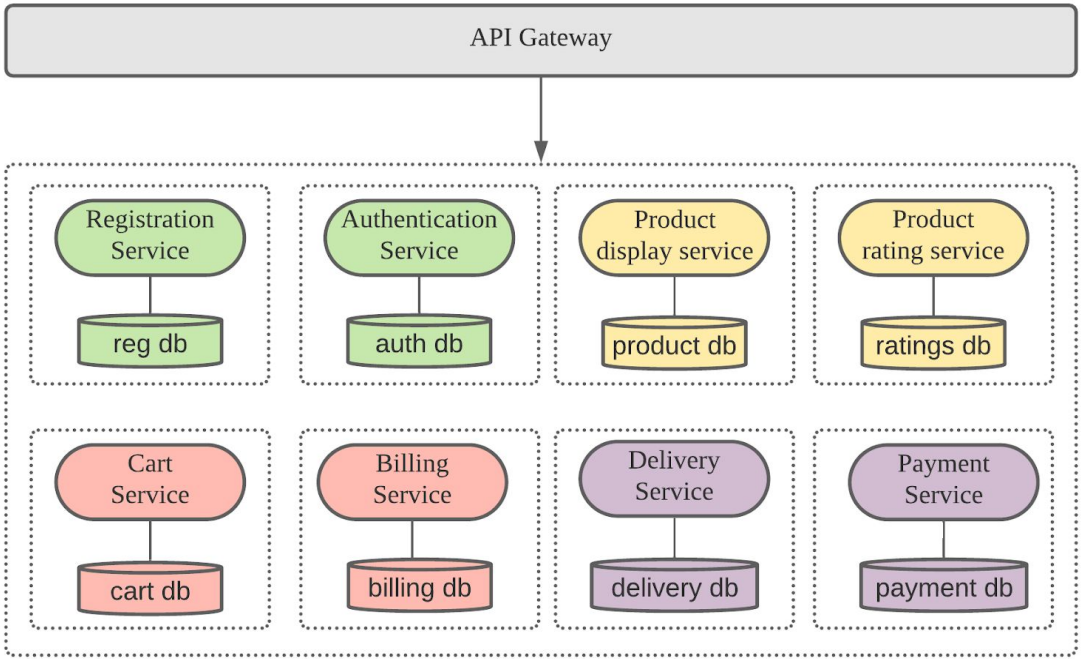
-- Martin Fowler

Microservices: What does it mean ?

Monolith version



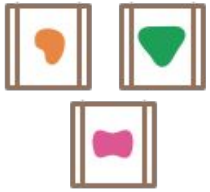
Microservices Version



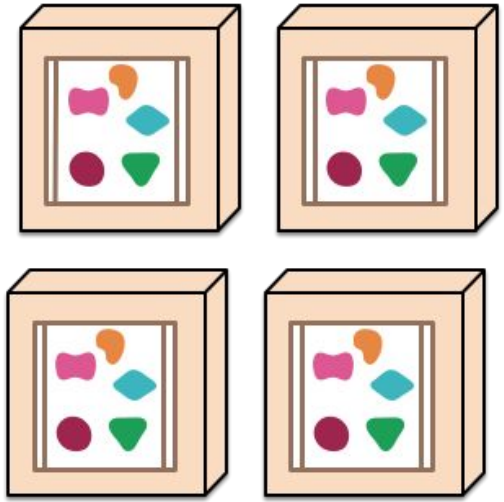
Microservices: What does it mean ?

A monolithic application puts all its functionality into a single process...

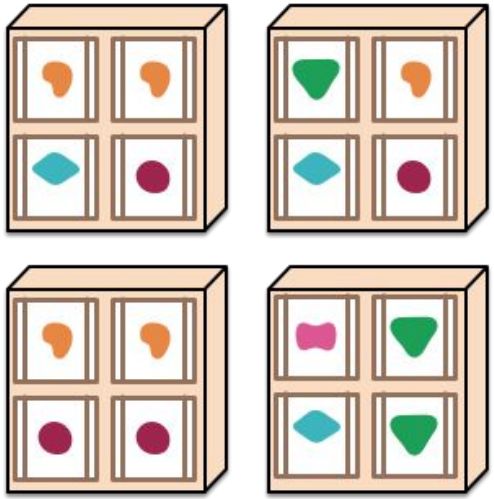
A microservices architecture puts each element of functionality into a separate service...



... and scales by replicating the monolith on multiple servers



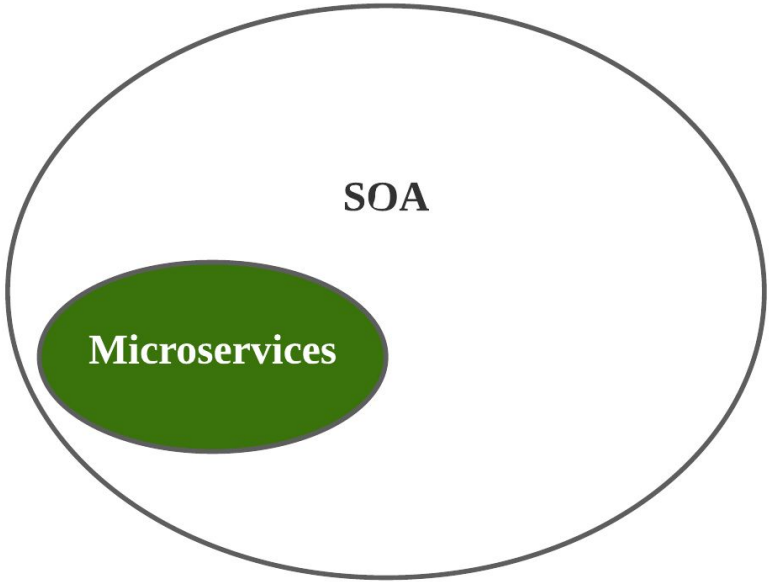
... and scales by distributing these services across servers, replicating as needed.



Source: https://martinfowler.com/articles/microservices.html

Microservices: Is it not SOA ?

- It is more SOA done in a more clear manner - Difference in scope
- Fine grained as opposed to Coarse grained - Small functional pieces



Microservices: Is it not SOA ?

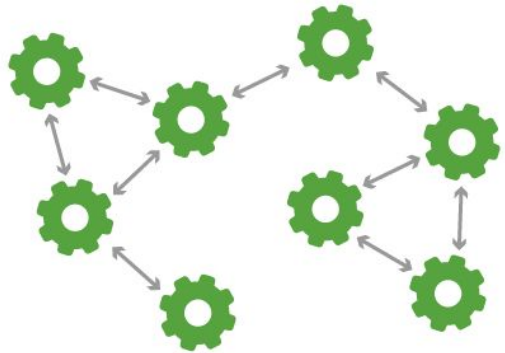
2000's

SERVICE ORIENTED ARCHITECTURE

SOA based applications are compromised of more loosely coupled components that use an Enterprise Services Bus messaging protocol to communicate between themselves.

2010's

MICROSERVICES ARCHITECTURE



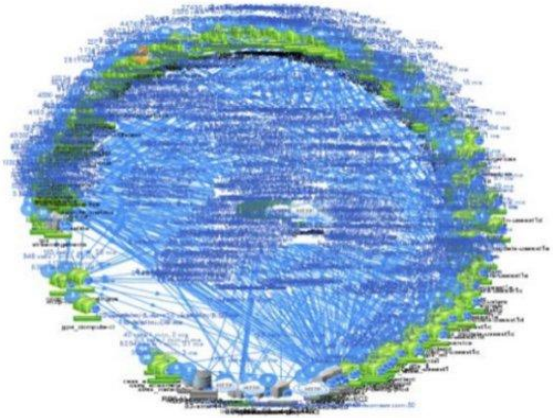
Microservices are a number of independent application services delivering one single functionality in a loosely connected and self-contained fashion, communicating through light-weight messaging protocols such as HTTP, REST or Thrift API.

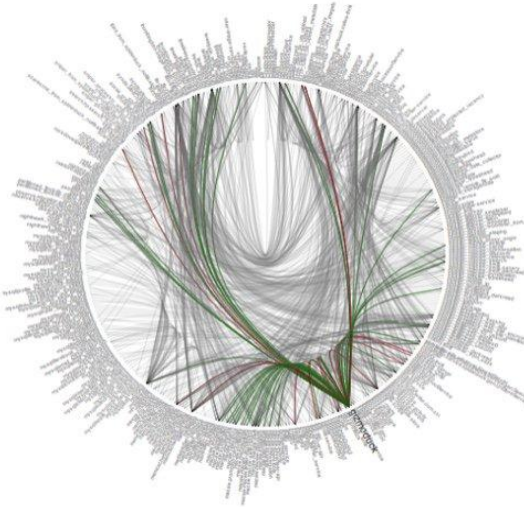
Source: https://dzone.com/articles/microservices-vs-soa-is-there-any-difference-at-al

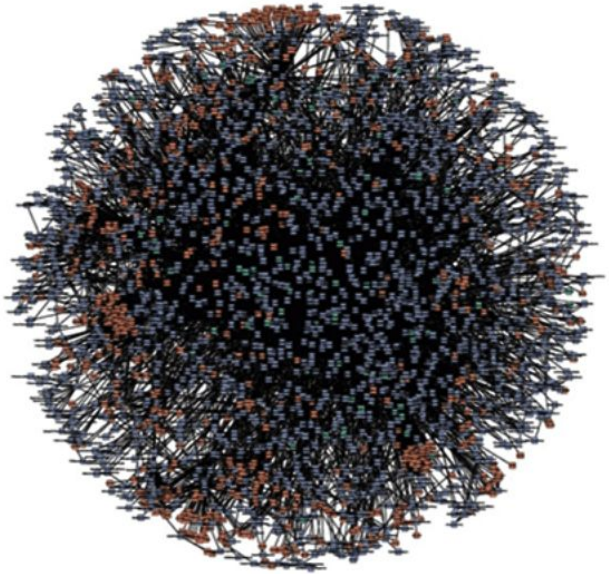
Microservices: Key Characteristics

- Compenization via Services
- Organized around business capabilities
- Highly maintainable and testable
- Decentralized governance and decentralized data management
- Widespread industry adoption in the last decade: Netflix, Uber, Google, etc

Microservices: Who Uses Them?







NETFLIX

amazon.com

source: tinyurl.com/3kswbtak (Twitter, Google images)

Microservices: Advantages

Scaling is Easy

- Scale only the required microservices
- Adding a new feature can be just adding one another microservice

Heterogeneity

- Each microservice can be developed in different technologies
- Experimenting with new technology is easy

Resilience

- Only specific microservices goes down
- Grouping microservices as critical and non-critical can be done to add more resilience

Microservices: Advantages

Organizational Alignment

- Easily distribute teams around microservices - eg: Amazon 2 pizza rule
- Minimize people working on one less codebase

Composability

- Easily compose microservices to get new functionality

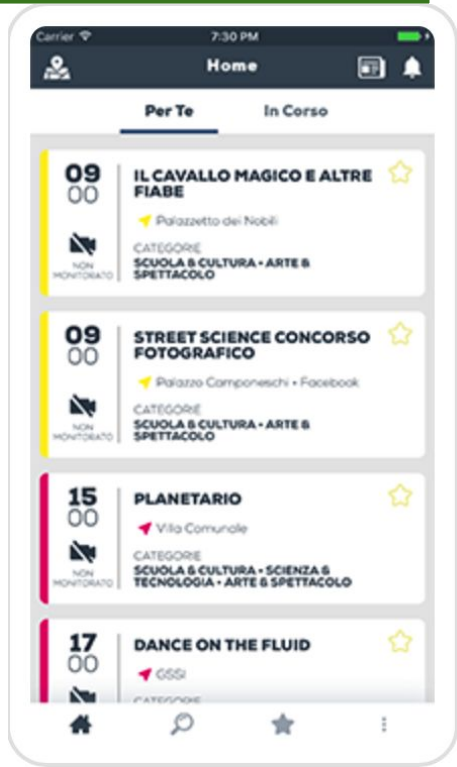
Replaceability

- Cost of replacement is small - should not take more than 2 weeks
- Imagine replacing a 25 year old legacy system !!

Ease of Deployment

- Check and rollback easily
- Continuous integration and deployment is easier - DevOps!!!

NdR: A Case Study



https://www.streetscience.it

NdR: A Case Study

Goal: Develop a microservice based mobile application for NdR

Features: User registration, book venues, book parking lots, provide venue and parking lot recommendation, priority booking based on small payment, check weather

Data Sources:

- Parking mats at entrances and exits of parking lot to get count of cars
- Handheld RFID readers to capture the count of people entering venue
- People counter at venue exits to count people exiting venue

Designing Microservices

Microservices: How to Design ?

Ensure loose coupling

- Minimize coupling between microservices
- Should be easy to change and deploy one without affecting others
- Each microservice needs to know as little as possible about others

Maintain high cohesion

- Bundle one end to end feature or complete part of it inside one microservice
- Promotes robustness and reliability
- One change should never require change in 10 different places

Follow the principle of bounded contexts

- Identify different contexts inside the main domain [organizational boundary]
- Only share what is important rest remains within context

Contexts within NdR System

IoT

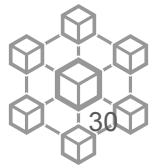
Booking

Weather

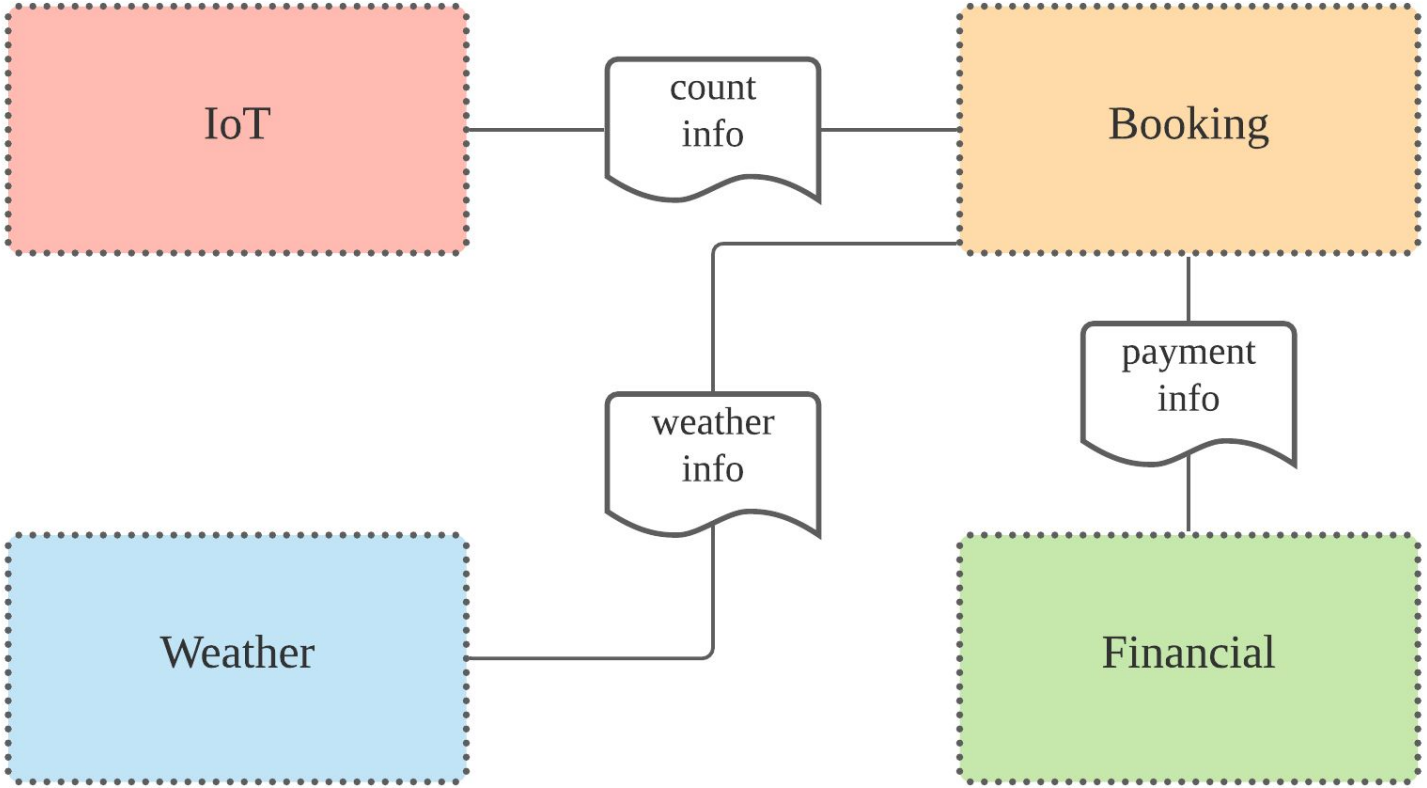
Financial

Bounded Context: Shared and Hidden Models

- Identify what needs to be shared
  - Eg: Sharing of information on people and car count to booking context
- Same things may have different meaning in different contexts
  - Eg: Sensor data in IoT context and booking context
- This process will facilitate avoiding of high coupling (Pitfall !!)
- Microservices should never be chatty !
  - Adds to performance issues
  - Lack of cohesion
  - Eg: too many back and forth communication between two microservices

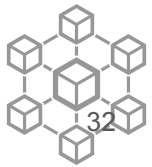


Shared Models in NdR System

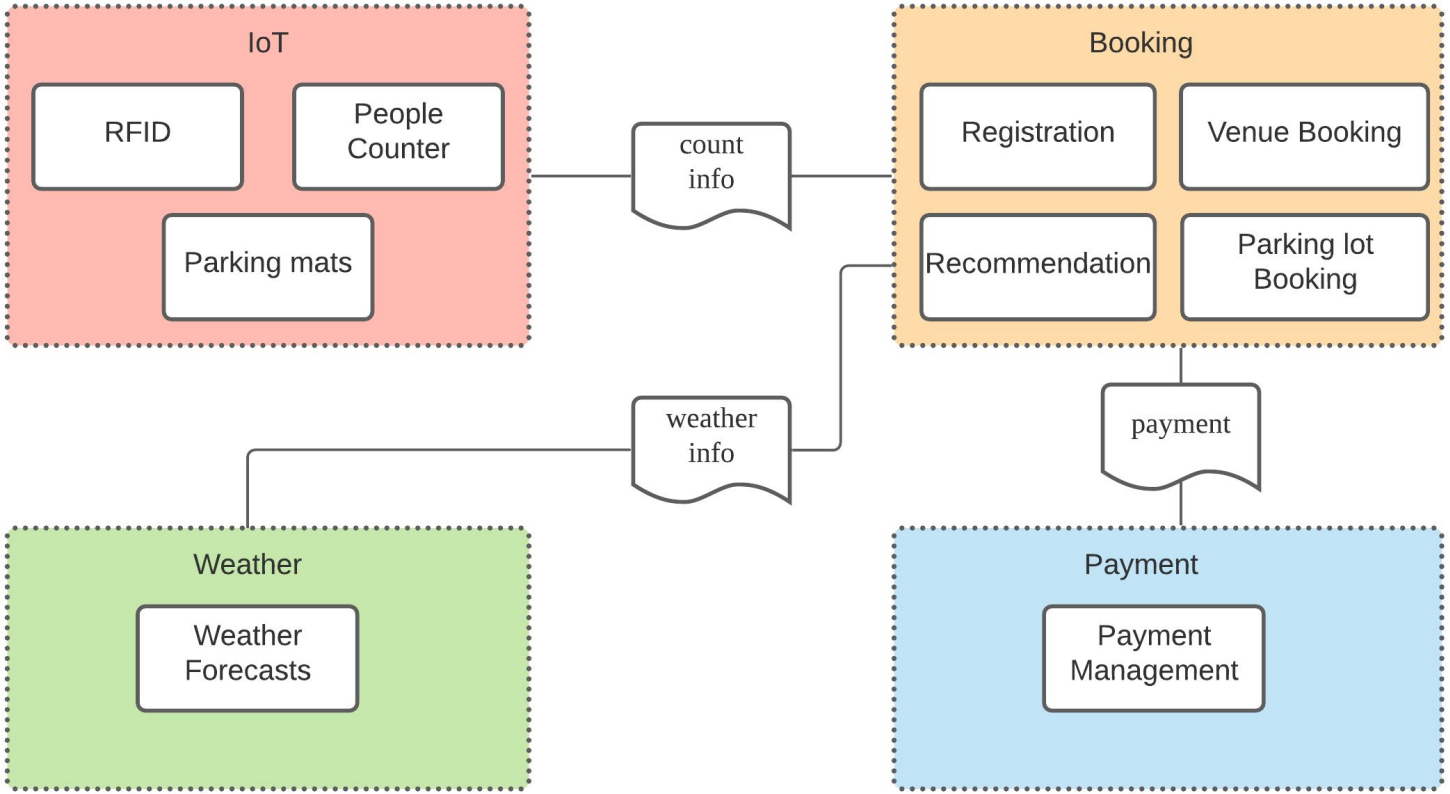


Bounded Context: Modules and Services

- Seperate the contexts into modules
  - Eg: Venue booking and Parking lot booking inside booking
- Use the help of hidden and shared models
  - Shared becomes the bridge and hidden becomes the separation points
- The modules becomes candidates for microservices
  - High Cohesion - Everything stays within context and modules are independant
  - Loose Coupling - Only what is needed is shared
- Avoid premature decomposition
  - Early decisions can be costly (eg: entire IoT inside one microservice)
  - Re-decomposition may take time, effort and expenditure



Modules and Services in NdR System



How to Integrate Microservices

Microservices: Integration

If done well, microservices works really well, if not then a disaster awaits

Avoid breaking changes

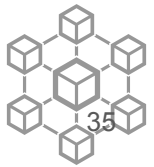
- Choose techniques and technologies wisely
- Eg: change in data sent from microservices should not cause change in all consumers

API's should be technology agnostic

- API's that integrates microservies should be technology agnostic
- If API is tied to technology, changing microservice implementation implies changing API usage and vice versa. Eg: Java and RMI

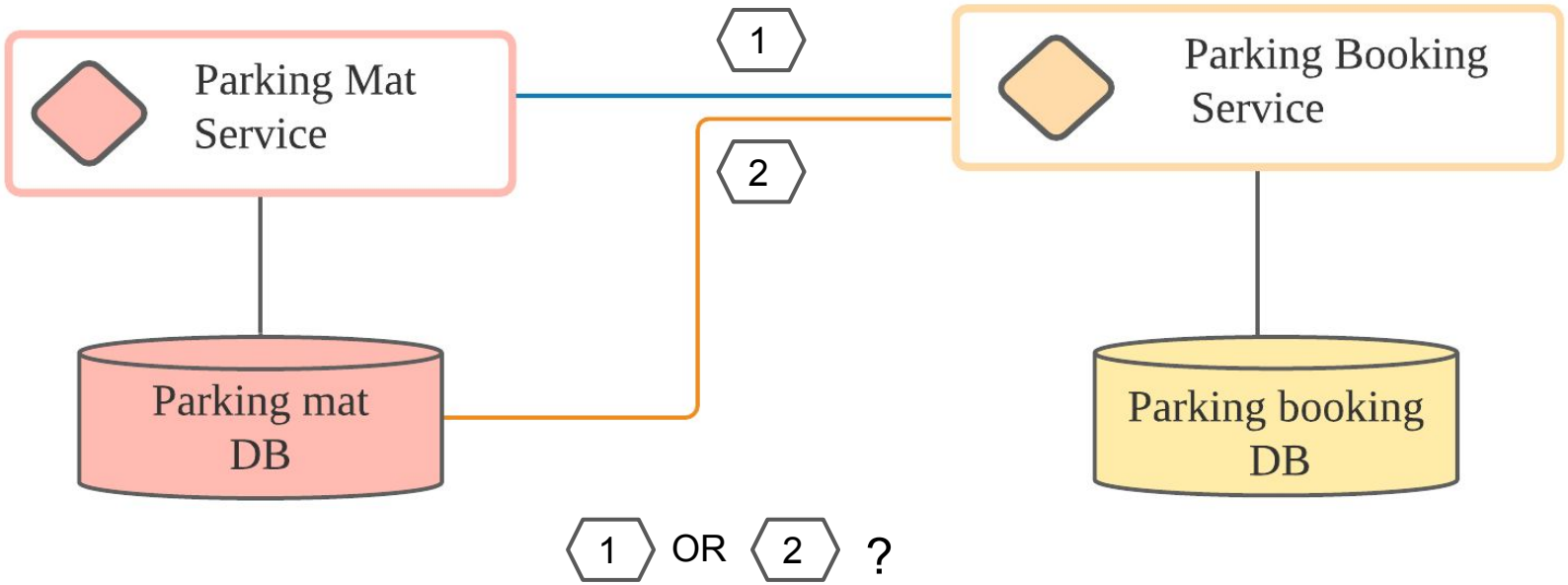
Make services simple for consumers

- Consumer should not worry about libraries to access API's
- If not well done, increases coupling !!



Integration with Shared DB ?

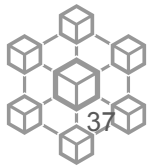
Scenario: When a user wants to book a parking lot, a request is sent to parking booking service which checks the status of availability from the parking mat data



Integration with Shared DB ?

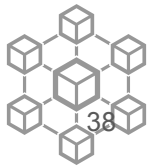
Avoid integration with shared db as much as possible:

- Changing DB schema based on one microservice need affects others
- Affects evolution of system eg: changing from relational to non-relational
- Choice of DB might constrain the choice of language for implementing microservice eg: Java might have more db driver available for MySQL
- Goodbye high cohesion and loose coupling !!!



Synchronous v/s Asynchronous Communication

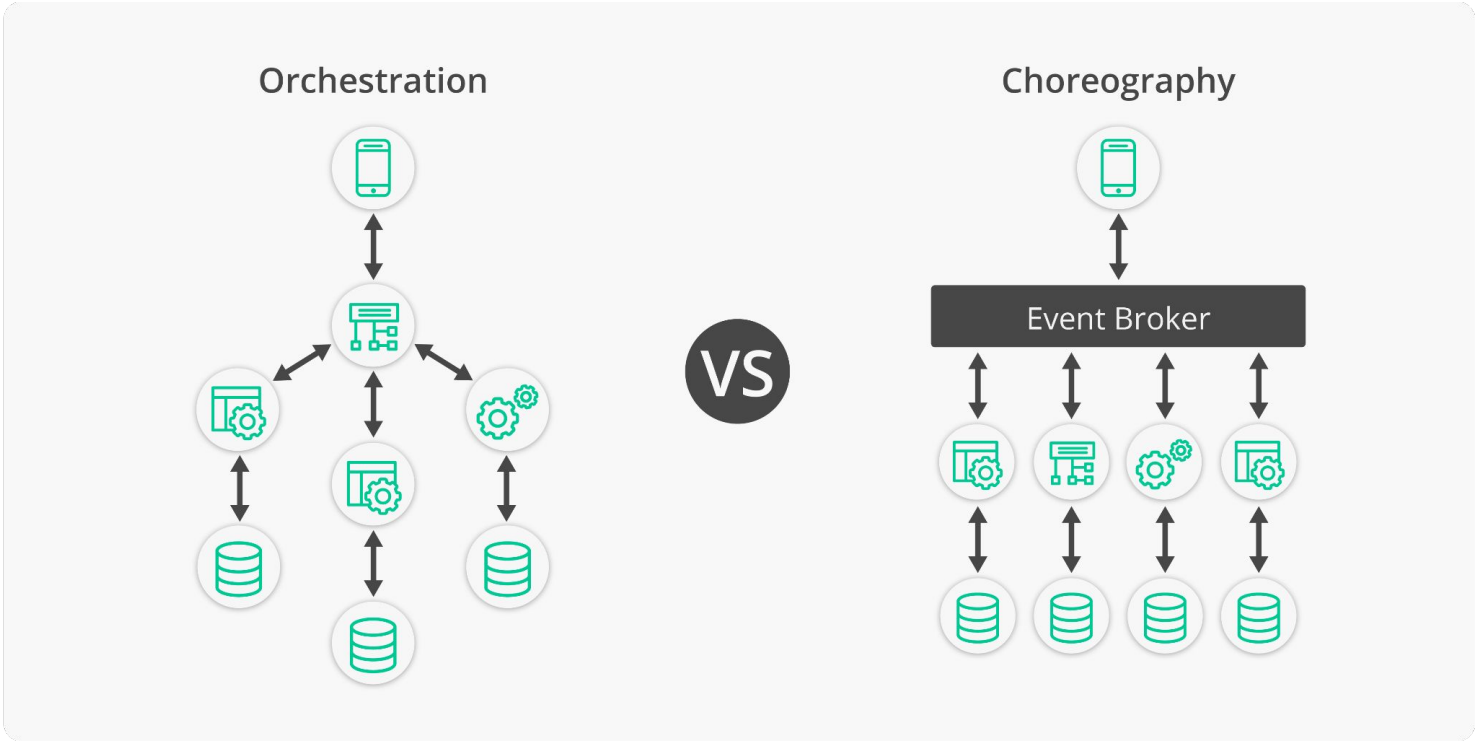
- Synchronous: request -> response based communication
  - Service A sends a request to Service B and waits for response
  - Request that triggers long running jobs can affect performance
- Asynchronous: request -> response or Event-based communication
  - Service A sends a request to Service B and does not wait for response (gets when available)
  - Suited very well for long running jobs
  - Implementation can be tricky also based on language of choice
  - Methods to implement: registering callbacks or event queues (pub sub)
  - eg: many modern applications use Event-driven Microservice Architectures
- Compare choices with complexity of system and use case before deciding



Orchestration v/s Choreography

Source: thoughtworks.com, myalltech.wordpress.com

Orchestration v/s Choreography



Source: solace.com

Orchestration v/s Choreography

- Orchestration: One central coordinator manages the flow
  - Too much governance: Coupling and chatty
  - Eg: A central service that first calls booking then based on response calls payment
- Choreography: Everyone knows what to do
  - More decoupled approach: every service subscribes to events
  - More asynchronous in nature
  - Sophisticated mechanisms to ensure that flow is executed properly
- General advice: Prefer choreography over orchestration
  - More flexible and loosely coupled in nature
  - Cost of change is less

Protocol and Data Exchange Format

- RPC or REST or simple HTTP or gRPC: What protocol to use ?
  - Avoid technology coupling with protocol eg: Java RMI (RPC)
  - Consider the network: which protocol is more network friendly
  - REST is more preferred: More decoupling and easy to understand and program
  - gRPC is more faster than REST (uses Protobuf - good for numerical data) [External integration]
- XML or JSON or Protobuf: What about data exchange format ?
  - JSON has more become a defacto standard ever since its introduction [Lightweight]
  - Structure is more in XML. Teams need to standardize JSON exchange (Exemplars or templates)
  - Using XML may create a technology coupling. For eg: Java has better ways to handle XML
  - Protbuf is more lightweight than JSON and has more structure associated [schema!]

Patterns for Integration

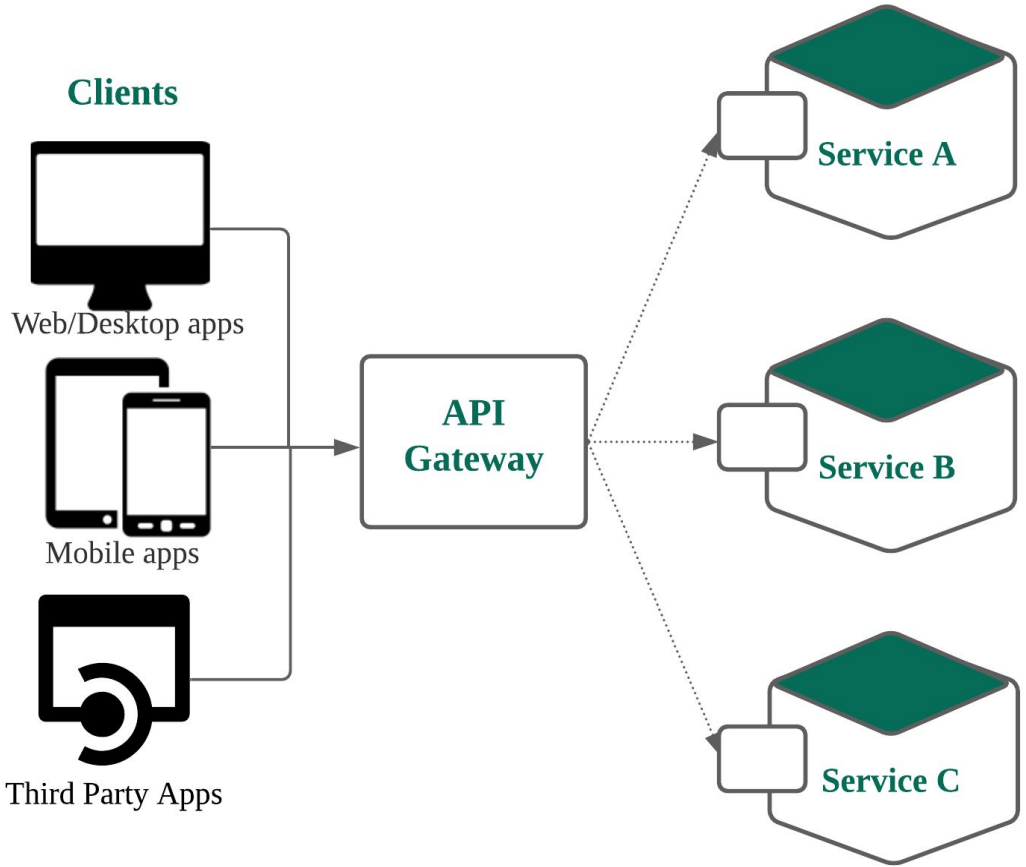
Integration Patterns: API Gateway Pattern

Scenario:

- Different type of request/response formats and protocols
- Offloading authentication from microservices

Uses:

- Single point entry for all microservice calls
- Efficiently handling request routing (Gateway routing pattern)
- Handle authentication effectively
- Can perform aggregation
- Can also provide a proxy for different types of client (Proxy pattern)



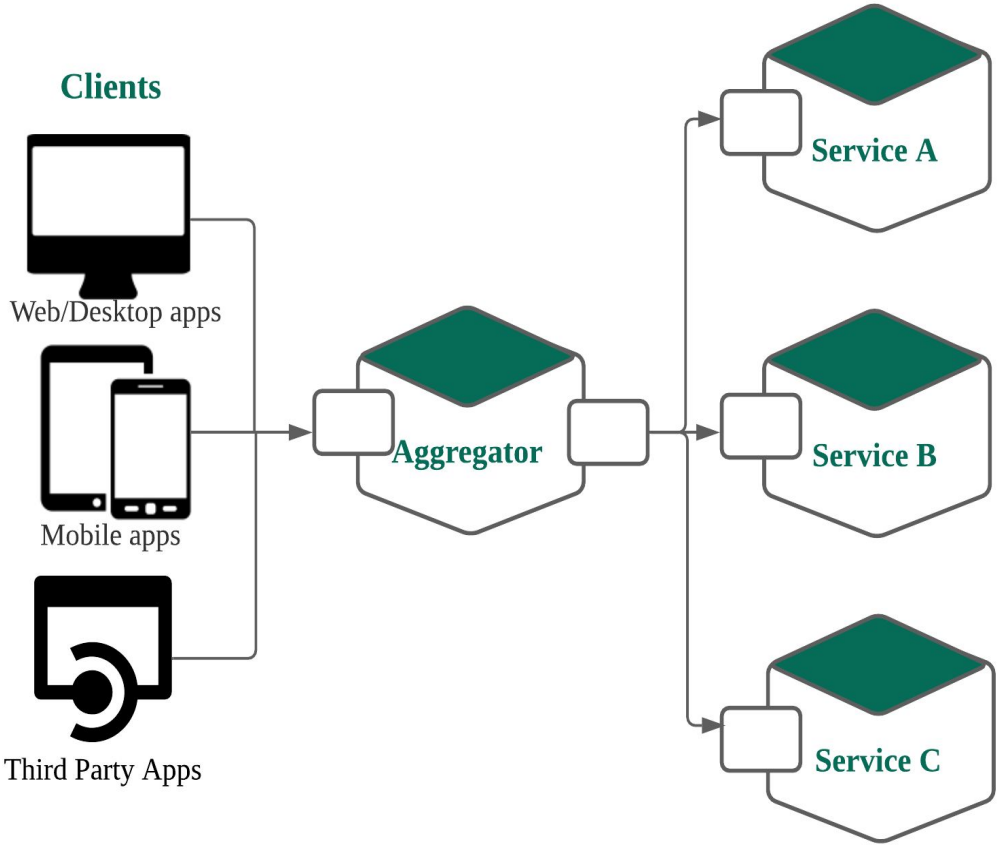
Integration Patterns: Aggregator Pattern

Scenario:

- Response from different microservice needs to be composed

Uses:

- Composite microservice, performs some business logic on responses from different microservices
- Aggregator can be a microservice or the API gateway itself
- If the operation is complex, better to use a microservice
- If it is a simple operation then aggregation can be at API gateway



Integration Patterns: Chained Microservice

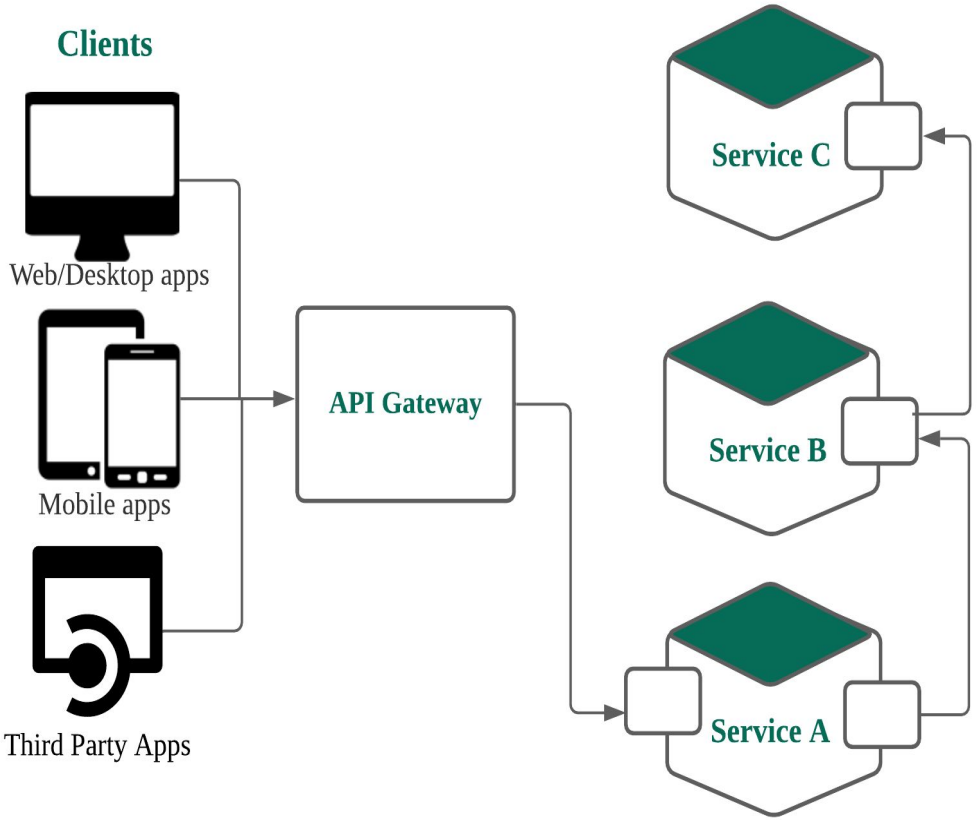
Scenario:

- Dependency of one microservice with another

Uses:

- One microservice might have to depend on another microservice to accomplish a functionality
- Communication happens in a sequential manner
- Eg: Booking microservice needs to communicate with sensor microservices to get real-time availability

Keep the length of sequence to minimal



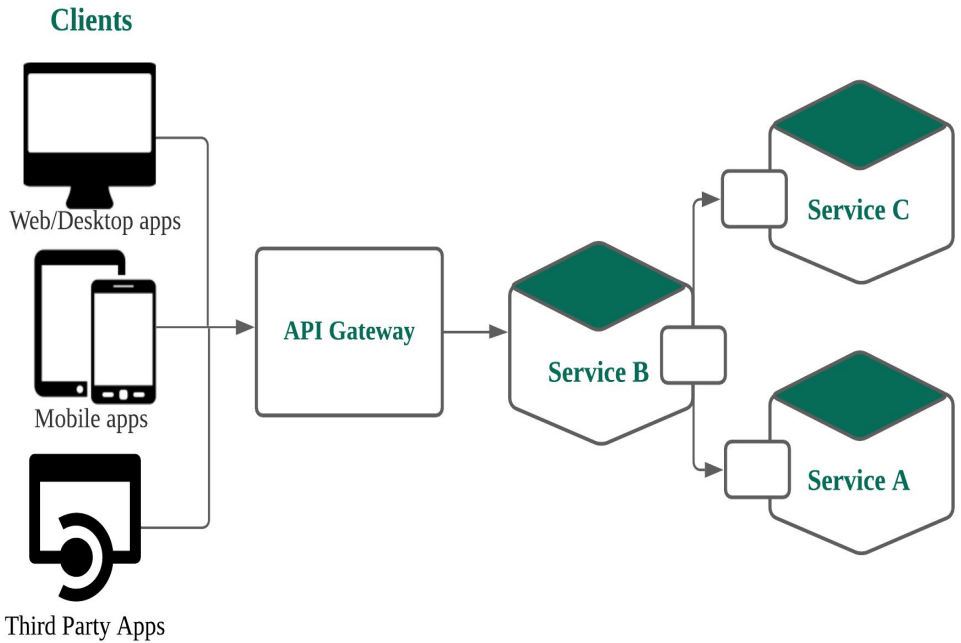
Integration Patterns: Branch Microservice

Scenario:

- One microservice might have to compose data obtained from different microservices

Uses:

- Mix of aggregator and chain pattern
- One microservice can make parallel calls to different microservice to obtain data and perform operations
- The participating microservices in turn may or may not have branches
- Eg: Parking recommendation requires data from weather and parking lot availability to make recommendations



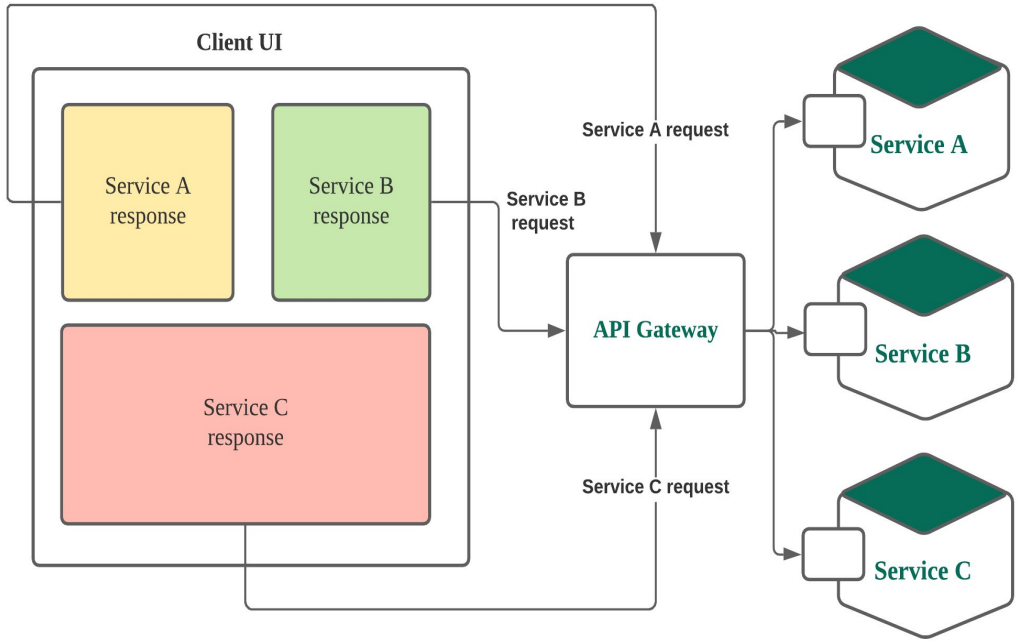
Integration Patterns: Client UI Composition

Scenario:

- User request is no longer driven by single backend request
- UI can be decomposed to different parts based on the required functionality

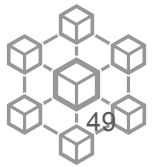
Uses:

- Multiple services are responsible for populating different parts of UI
- Even if one section of a page goes down due to one microservice other parts still work (think about monolithic scenario !!)
- Eg: Single page application in ReactJS or Angular JS



Database Integration: Patterns

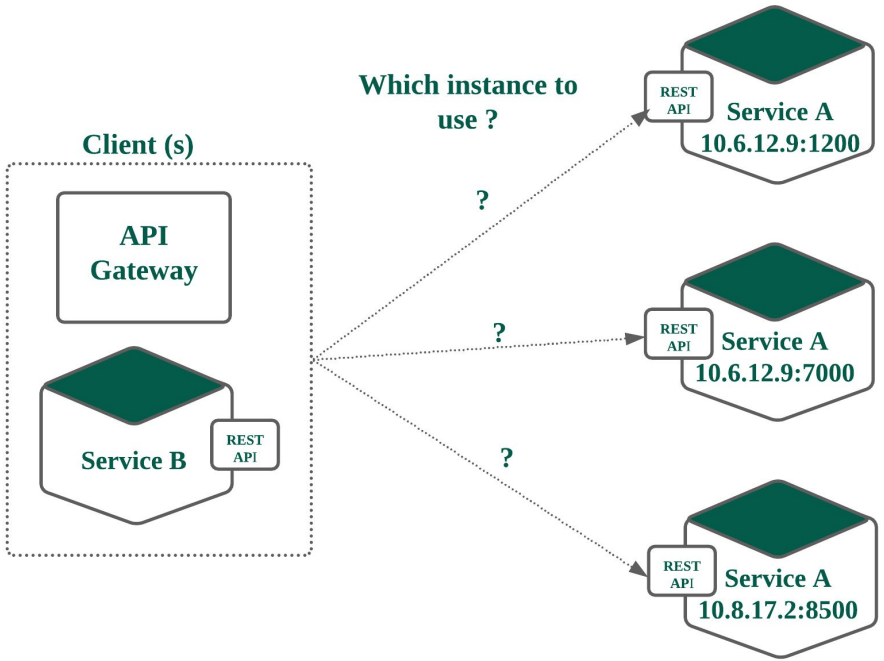
- Shared Database: Use if it is a brownfield application
  - Multiple microservices access the same database
  - Simpler to work with and data consistency can easily be ensured
  - High degree of coupling, use only if necessary between small set of services
- Database per service: The de-facto pattern (Greenfield applications)
  - Each service has its own private database with its own schema - access only via service API
  - Loose coupling - no need to depend on other service or database for data
  - Complexity to maintain different SQL and NoSQL databases
  - Transactions that requires updates/additions across different databases is hard to accomplish (use SAGA pattern)
  - Querying data from multiple databases is hard (API Composition, CQRS Pattern)



Microservice Deployment: Service Discovery

Service Discovery

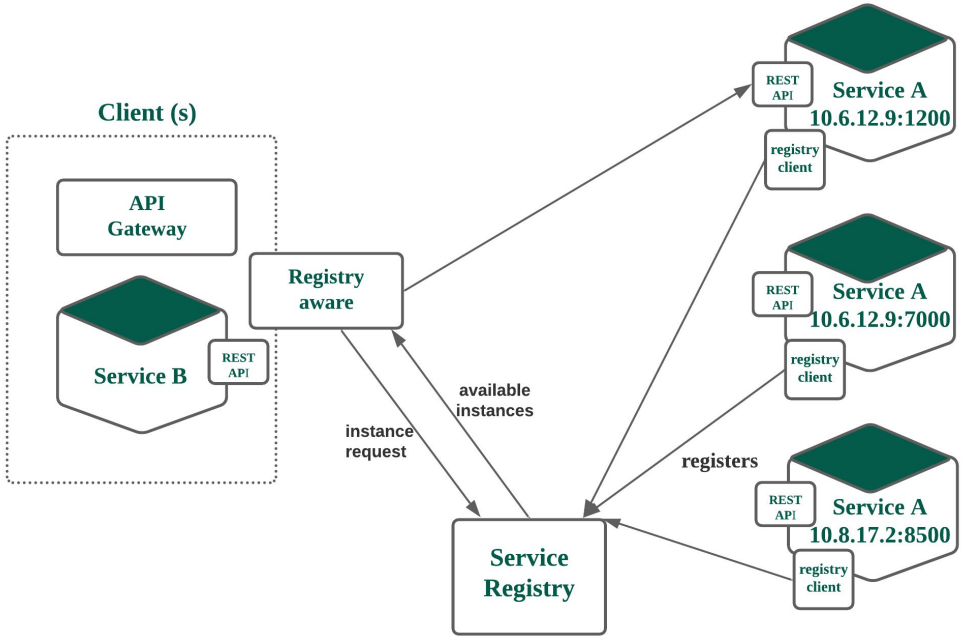
- Many instances of the same microservices are deployed in production for scalability, feature testing etc.
- Clients/third party services needs to discover instances of microservices
- Each microservice instance might be deployed in same/different machines (IP and Port)
- The service instances might appear and disappear dynamically



Use service registry !!!

Client Side Service Discovery

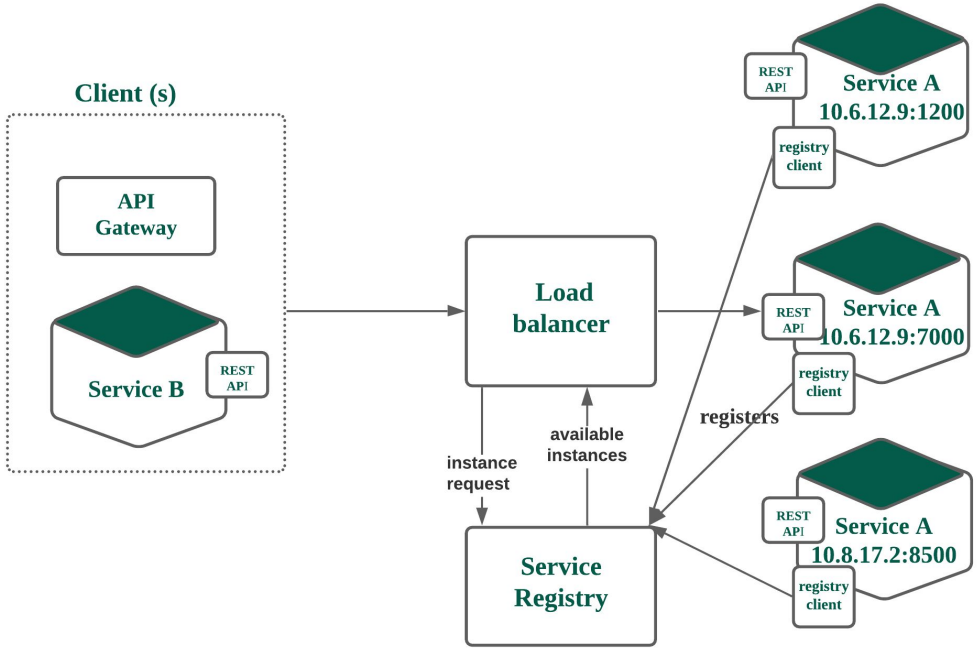
- Registry aware clients (sends request to service registry)
- Each microservice registers itself to service registry (as and when they are available)
- Service registry responds with the instance of the requested service to client
- Fewer network calls (just query service registry)
- Coupling between client and service registry



Eg: Netflix Eureka

Server Side Service Discovery

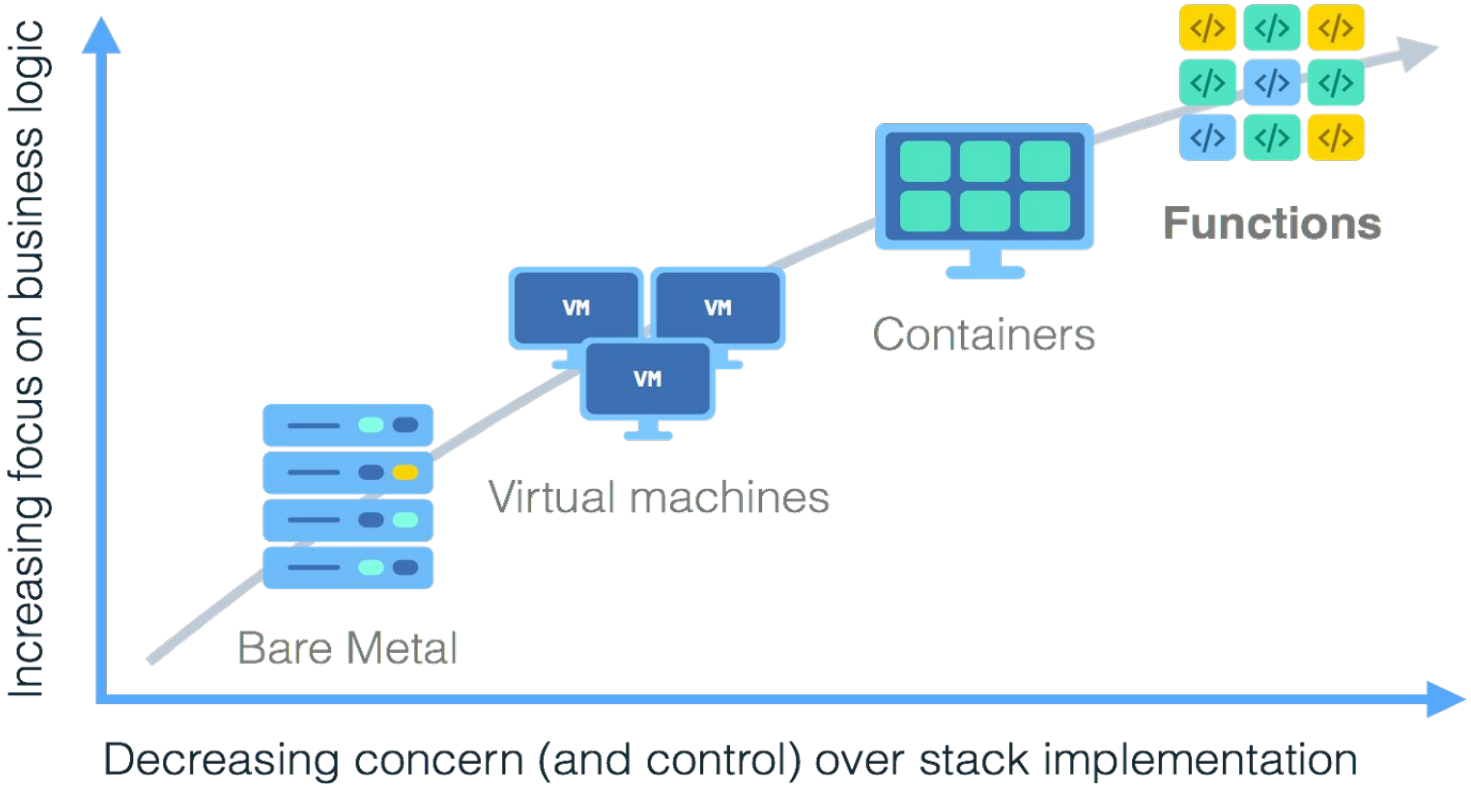
- Client (s) have no information on service registry (no coupling)
- Client (s) sends request to API gateway or load balancer
- The load balancer or API gateway uses Service registry to discover services
- Separation of logic from client
- Load balancer needs to be managed
  And replicated



Eg: Amazon ELB, Zookeeper

Microservice Deployment: How to Deploy ?

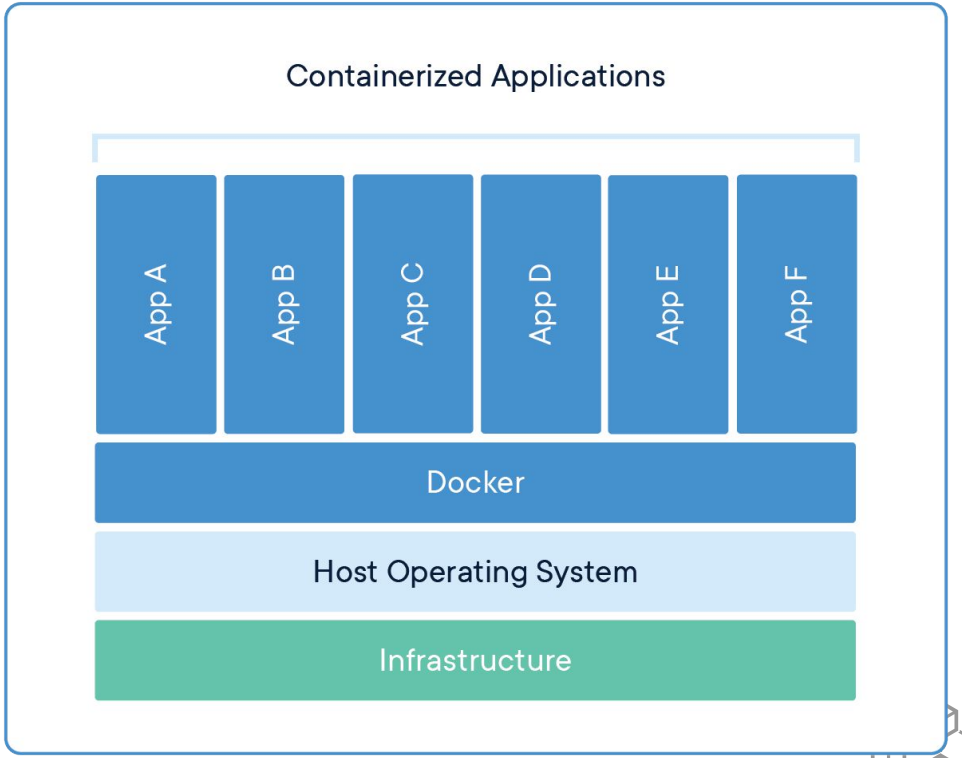
Deployment: Towards Containers



Source: Opening presentation of third international conference on serverless computing (WoSC), 2018

Deployment: Using Containers

- Bundle microservice and dependencies in one single unit
- Increases portability
- Fosters continuous integration and deployment (milliseconds)
- Scaling and lifecycle management of services becomes easier
- Lightweight (MB's in size), better isolation and security
- Containers need to be managed (Kubernetes, Docker Swarm, etc)



Eg: Docker, Redshift, Mesos, GKE, Amazon ECS, etc

Microservices for Mobile App Development

Microservices and User Interfaces

If done well, microservices works really well, if not then a disaster awaits

Need for a holistic view

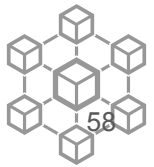
- It's not web or mobile anymore. Both or more needs to be considered
- Users needs to have seamless experience across platforms
- Adoption of more granular API's

Existence of dedicated Front-end teams

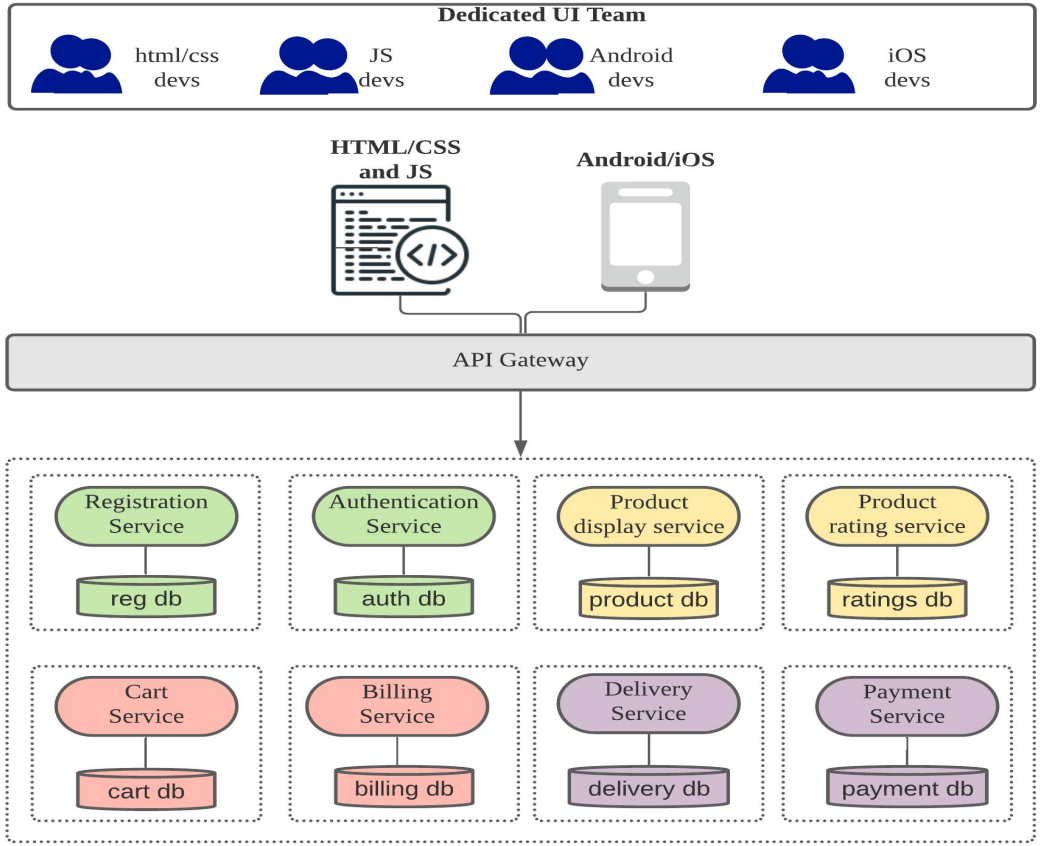
- Organizations tend to put all experts in a dedicated team
- Impacts development time and release cycle - **Time to market!!**

Shift focus to Stream aligned teams

- Each team will work independently and manage a feature end to end
- Focus will be more on delivering value than releasing more features



Why dedicated Front-end Teams Exist?



Why dedicated Front-end Teams Exist?

Sharing Specialists

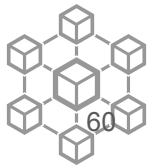
- Good developers are hard to find!!
- Sometimes we need dev's with web/android and iOS skills
- Better idea: Create an enabling team [enable others]

Ensuring Consistency

- Dedicated front-end team will ensure that UI has a consistent look and feel
- Better idea: Let enabling team ensure consistency or let it be [AWS!!]

Technical Challenges

- Same user interface (or similar look and feel) across devices (desktop, android, etc)
- Some types of technologies (e.g: SPA) are difficult to decompose
- **Pointer:** Try React native MiniApp



Constraints for Mobile App Development

Battery drain

Bandwidth

Support One hand use

1. **How to reduce network calls?**
2. **How to ensure only required data is sent back?**

Let us take an example

Scenario:
Display a screen with information about visitor and his/her venue bookings

Requirements

- Display basic visitor information
- Display list of booked venues in descending order of time

Solution

- Make a call to the Registration microservice
- Make a call to the Venue Booking microservice

Any potential issues?

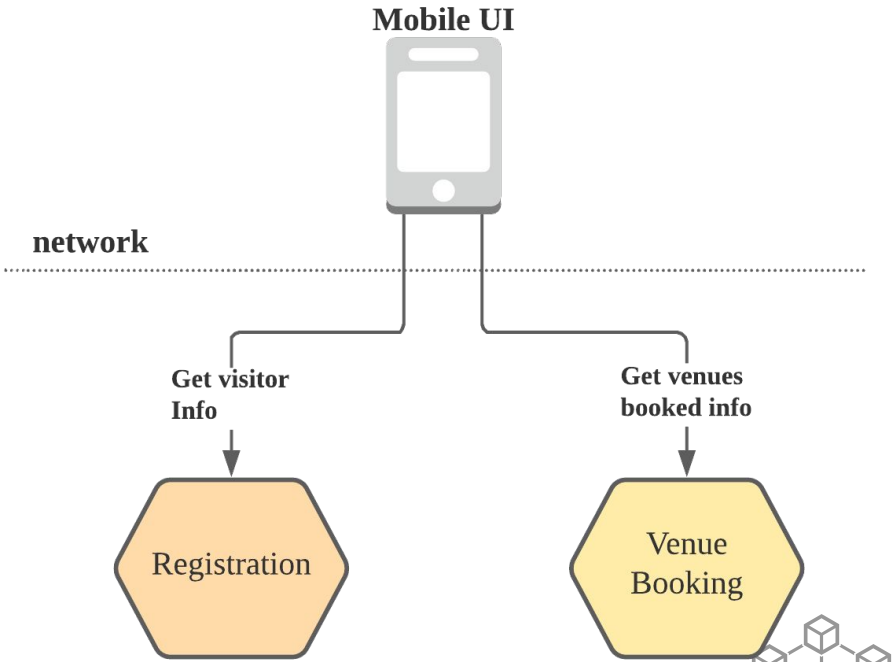


Image adapted from "Building Microservices" by Sam Newman, 2nd edition

Pattern 1: Central Aggregating Gateway

Scenario:
App has to make calls to multiple microservice to get data

Uses

- Single request from the App
- Gateway performs aggregation and filtering
- The gateway can also handle batch calls

Issues

- Gateway can be a bottleneck (who owns?)
- Not just about aggregation and filtering (API management, security, etc.)

Use when single team owns the entire stack

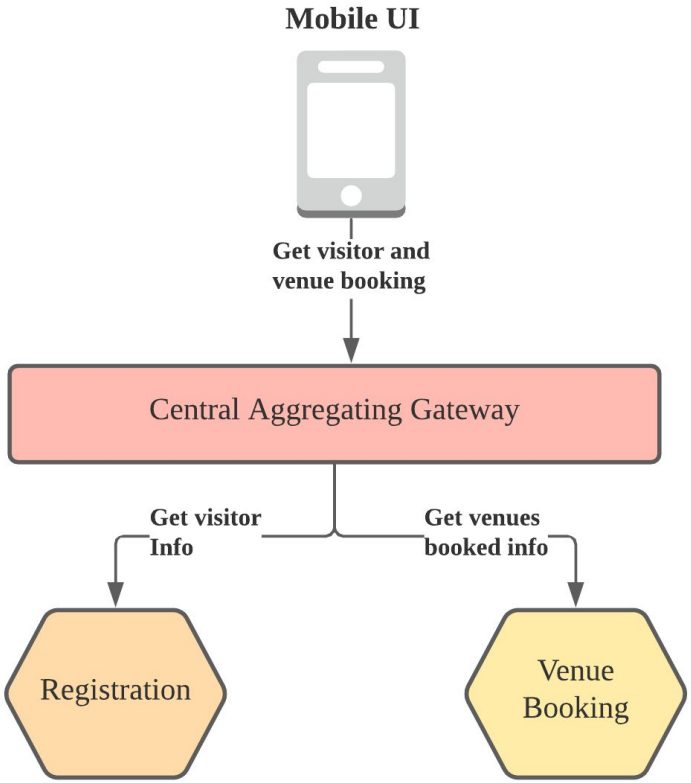


Image adapted from "Building Microservices" by Sam Newman, 2nd edition

Pattern 2: Backend for Front end (BFF)

Scenario:
App has to make calls to multiple microservice to get data

Uses

- Have one BFF per type of client or just one for mobile (eg: Soundcloud)
- Provide separate functionality to mobile UI and/or third party apps
- Cost of deploying an additional service is high

Issues

- Problem of too many BFF's may happen

Have one BFF per type of client - Web, mobile,..

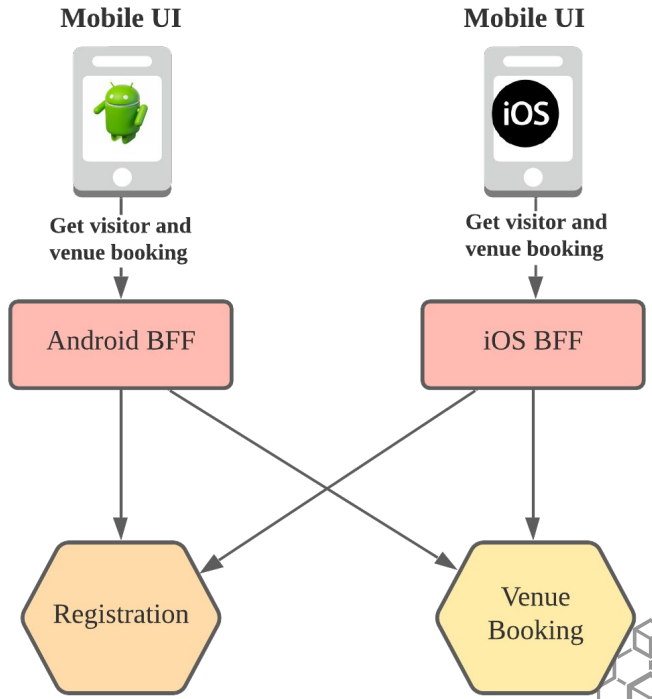


Image adapted from "Building Microservices" by Sam Newman, 2nd edition

Implementing BFF - GraphQL?

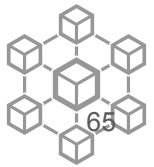
GraphQL: A query language that allows clients to access or modify data (think of SQL)

- Allow clients to dynamically change the information needed - Query API, not just call
- REST instead gets all the data and does not provide flexibility to client.
- A GraphQL resolver in the server resolves the query
- Provides more flexibility to client

```
{
  booking(id: 22) {
    time
    venue_name
    event
    user {
      name
      email_id
    }
  }
}
```

A GraphQL query to BFF

Hybrid approach can also be a very good way to go!



Microservices: So is it the holy grail

Some Funny yet Serious Facts

Honest Status Page @honest_update · Oct 8, 2015

We replaced our monolith with micro services so that every outage could be more like a murder mystery.

21 3K 2.6K

Gert de Pagter @BackEndTea · Jan 7

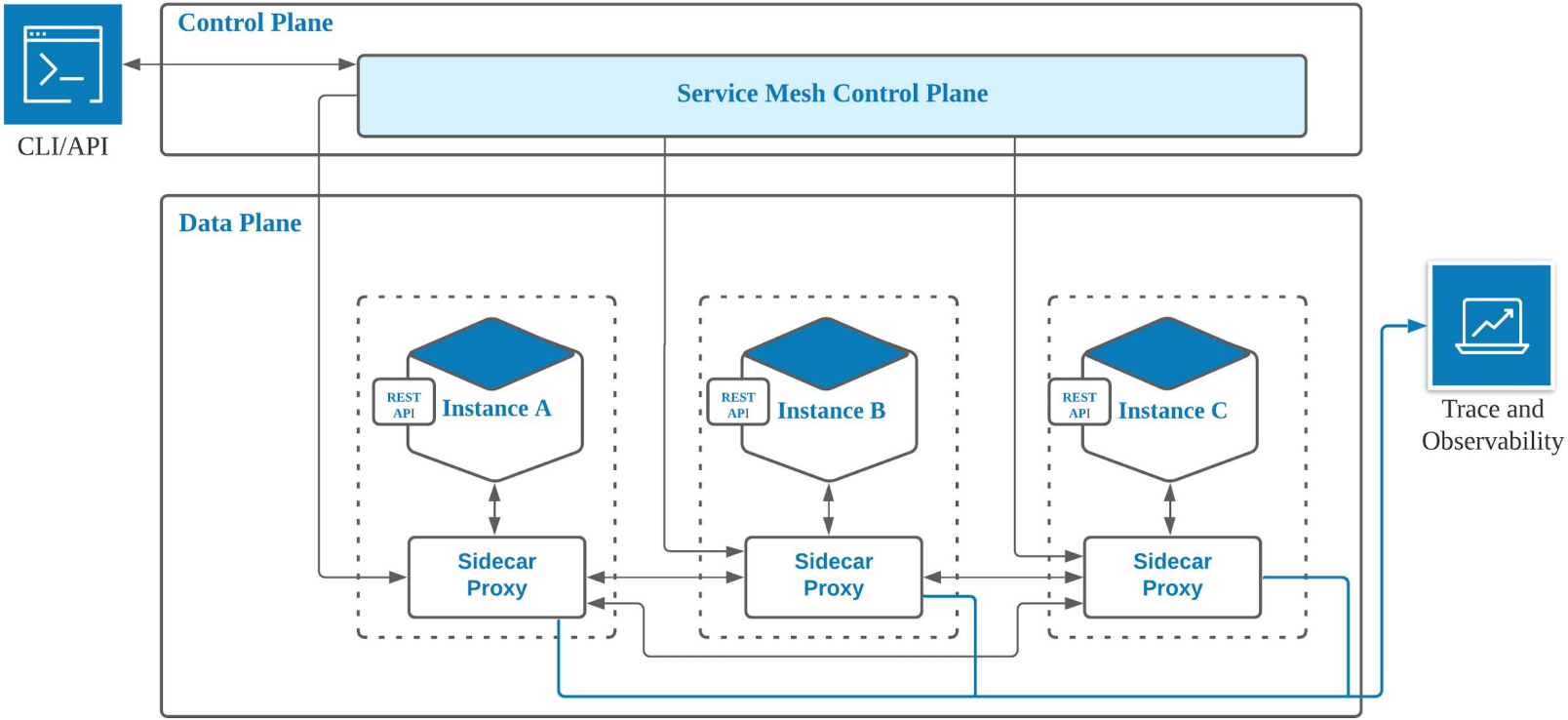
Thanks to **microservices**, our JOINS are now over HTTP.

39 345 1.4K

Monolith -> microservice but then we need docker, kubernetes, monitoring and what not !!!!

Source: Twitter

Microservices: Service Mesh

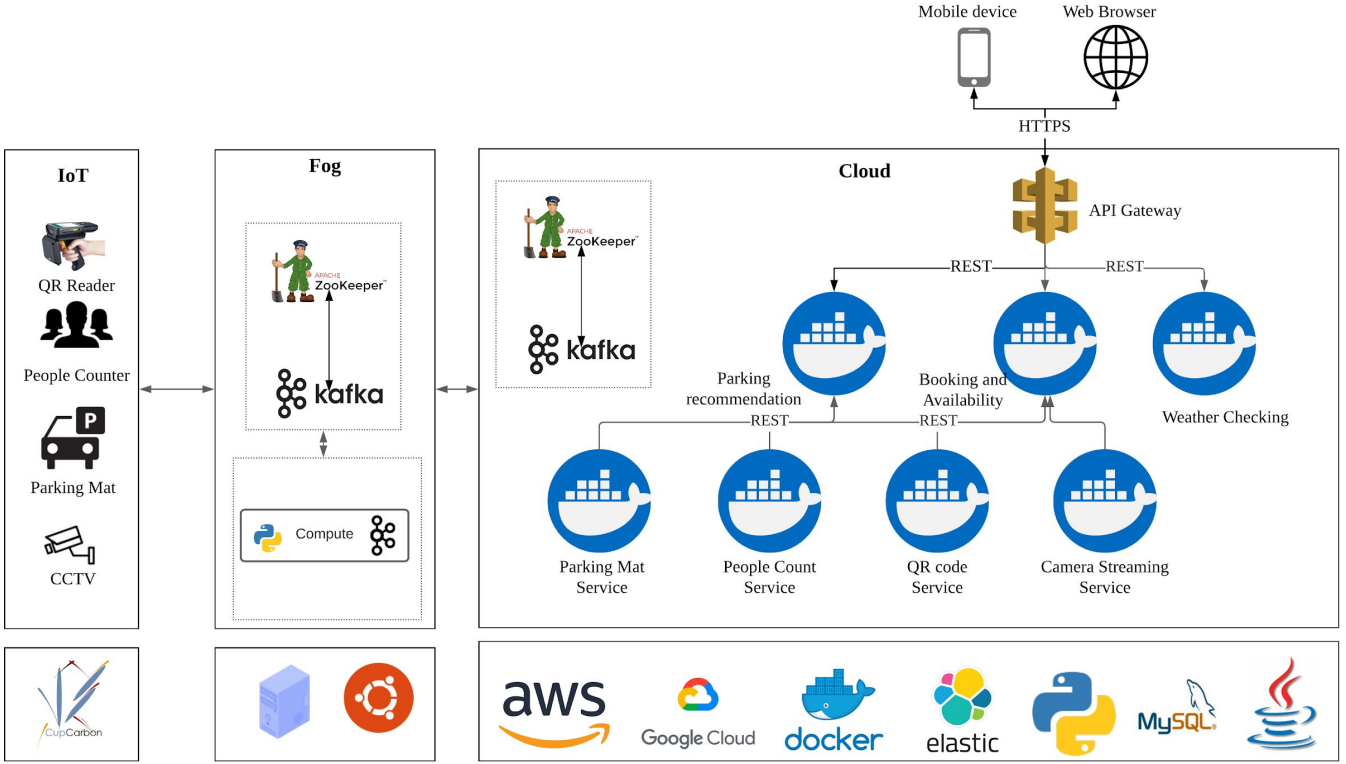


Gather performance metrics, traffic routing, load balancing, security, etc

Technologies: Istio, Envoy, etc

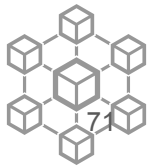
Microservices: Small Demo

Implementation of NdR Application



Suggested Materials

- Books
  - Building Microservices, Sam Newman (https://tinyurl.com/y5p5ajfl) - 2nd edition available
  - Microservices Patterns: with Java, Chris Richardson (https://tinyurl.com/yy9zyu9x)
- Websites/blogs
  - https://www.nginx.com/blog/microservices-at-netflix-architectural-best-practices/
  - https://microservices.io
  - https://martinfowler.com/articles/microservices.html
- Academic articles
  - https://link.springer.com/chapter/10.1007/978-3-319-67425-4_12
- Videos
  - https://www.youtube.com/watch?v=CZ3wIuvmHeM&t=1032s - Chaos Engineering at Netflix
  - https://www.youtube.com/watch?v=2yko4TbC8cI&t=169s - Martin Fowler, Thoughtworks



Thank You

Further queries:

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