Desenvolvimento de Aplicações com Arquitetura Baseada em Microservices

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[IF1007] - Tópicos Avançados em SI 4
https://github.com/IF1007/if1007

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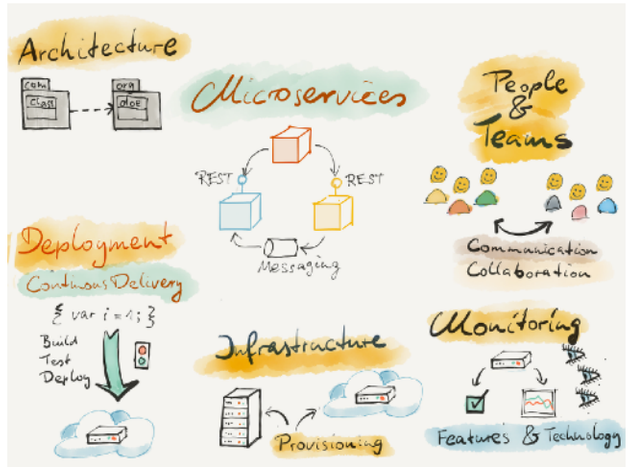
Resources

- There is no textbook required. However, the following are some books that may be recommended:
  - Building Microservices: Designing Fine-Grained Systems
  - Spring Microservices
  - Spring Boot: Acelere o desenvolvimento de microsserviços
  - Microservices for Java Developers A Hands-on Introduction to Frameworks and Containers
  - Migrating to Cloud-Native Application Architectures
  - Continuous Integration
  - Getting started guides from spring.io



Applying Microservices Concepts

Context

- Microservices are good, but can also be an evil if they are not properly conceived.
- Wrong microservice interpretations could lead to irrecoverable failures
- What are the technical challenges around practical implementations of microservices?
  - design decisions, solutions and patterns?

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Patterns and common design decisions

- Microservices are a vehicle for developing scalable cloud native systems, successful microservices need to be carefully designed to avoid catastrophes.
- Microservices are not the one-size-fits-all, universal solution for all architecture problems
- Generally speaking, microservices are a great choice for building a lightweight, modular, scalable, and distributed system of systems

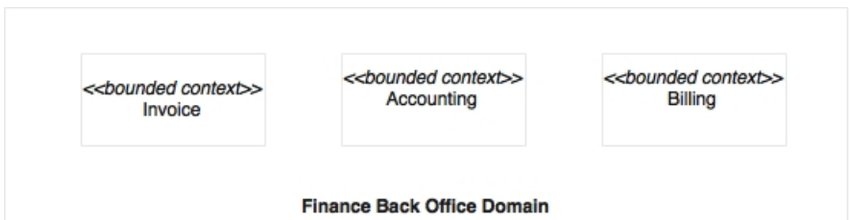
Over-engineering, wrong use cases, and misinterpretations could easily turn the system into a disaster. While selecting the right use cases is paramount in developing a successful microservice, it is equally important to take the right design decisions by carrying out an appropriate trade-off analysis.

Establishing appropriate microservice boundaries

- How big (mini-monolithic) or how small (nano service) can a microservice be, or is there anything like right-sized services?
  - Does size really matter?
- A quick answer could be
  - "one REST endpoint per microservice", or
  - "less than 300 lines of code", or
  - “a component that performs a single responsibility"

Establishing appropriate microservice boundaries

- Domain-driven design (DDD) defines the concept of a **bounded context**. A bounded context is a subdomain or a subsystem of a larger domain or system that is responsible for performing a particular function



In a finance back office, system invoices, accounting, billing, and the like represent different bounded contexts. These bounded contexts are strongly isolated domains that are closely aligned with business capabilities.

Establishing appropriate microservice boundaries

- A bounded context is a good way to determine the boundaries of microservices
  - Each bounded context could be mapped to a single microservice
  - In the real world, communication between bounded contexts are typically less coupled, and often, disconnected

Establishing appropriate microservice boundaries

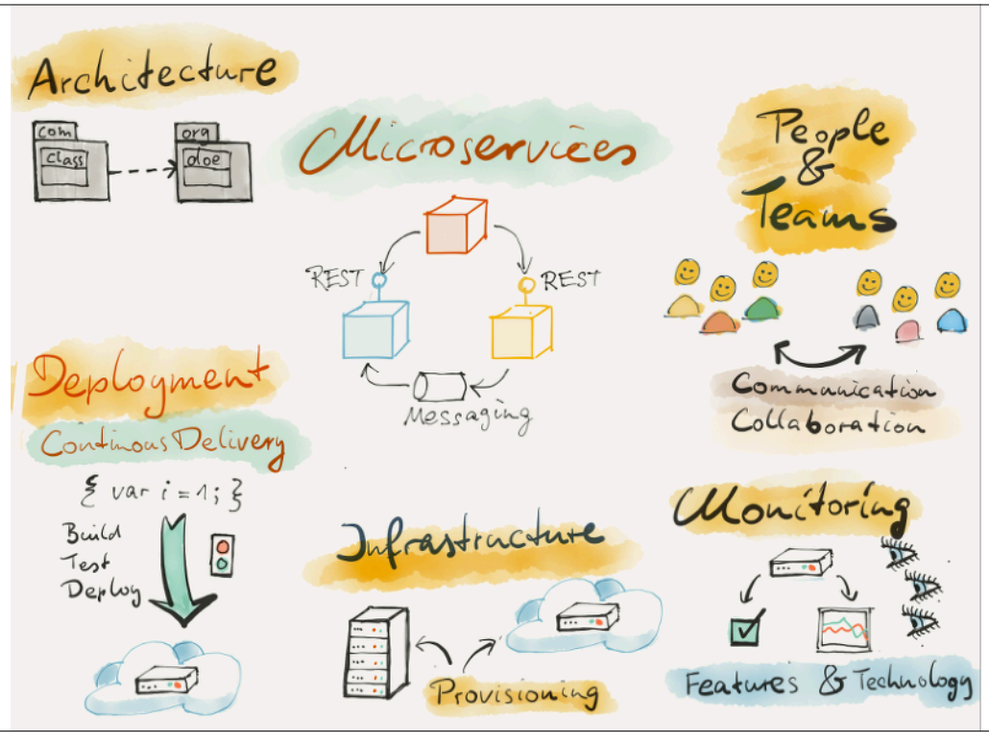
- There is no silver bullet to establish microservices boundaries
  - Establishing boundaries is much easier in the scenario of monolithic application to microservices migration, as the service boundaries and dependencies are known from the existing system.
  - On the other hand, in a green field microservices development, the dependencies are hard to establish upfront.
- The most pragmatic way to design microservices boundaries is to run a lot of scenarios

Scenarios could help in defining the microservice boundaries

- Autonomous functions
- Size of a deployable unit
- Most appropriate function or subdomain
- Polyglot architecture
- Selective scaling
- Small, agile teams
- Single responsibility (business capability or a technical capability)
- Replicability or changeability
- Coupling and cohesion
- Think microservice as a product

Autonomous functions: If the function under review is autonomous by nature, then it can be taken as a microservices boundary
Size of a deployable unit: Large deployment units pose challenges in automatic file copy, file download, deployment, and start up times
Single responsibility: As per the single responsibility principle, one responsibility cannot be shared by multiple microservices.
Replicability or changeability: each microservice is easily detachable from the overall system, with minimal cost of re-writing

Think microservice as a product



Autonomous functions
Size of a deployable unit
Most appropriate function or subdomain
Polyglot architecture
Selective scaling
Small, agile teams
Single responsibility (business capability or a technical capability)
Replicability or changeability
Coupling and cohesion

Designing communication styles

- Synchronous style communication
  - there is no shared state or object
  - When a caller requests a service, it passes the required information and waits for a response
  - Advantages and downsides?

An application is stateless, and from a high availability standpoint, many active instances can be up and running, accepting traffic. Since there are no other infrastructure dependencies such as a shared messaging server, there are management fewer overheads. In case of an error at any stage, the error will be propagated back to the caller immediately, leaving the system in a consistent state, without compromising data integrity.
The **downside** in a synchronous request-response communication is that the user or the caller has to wait until the requested process gets completed. As a result, the calling thread will wait for a response, and hence, this style could limit the scalability of the system.

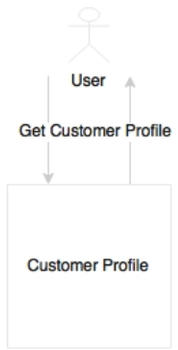
Designing communication styles

- Asynchronous style communication
  - The asynchronous style is based on reactive event loop semantics which decouple microservices.
  - This approach provides higher levels of scalability, because services are independent, and can internally spawn threads to handle an increase in load.
    - When overloaded, messages will be queued in a messaging server for later processing

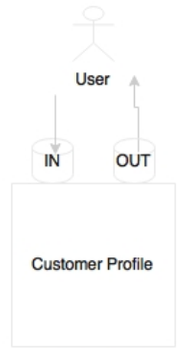
The downside is that it has a dependency to an external messaging server. It is complex to handle the fault tolerance of a messaging server. Messaging typically works with an active/passive semantics. Hence, handling continuous availability of messaging systems is harder to achieve. Since messaging typically uses persistence, a higher level of I/O handling and tuning is required.

How to decide which style to choose?

- Both approaches have their own merits and constraints
  - In principle, the asynchronous approach is great for building true, scalable microservice systems
  - However, attempting to model everything as asynchronous leads to complex system designs

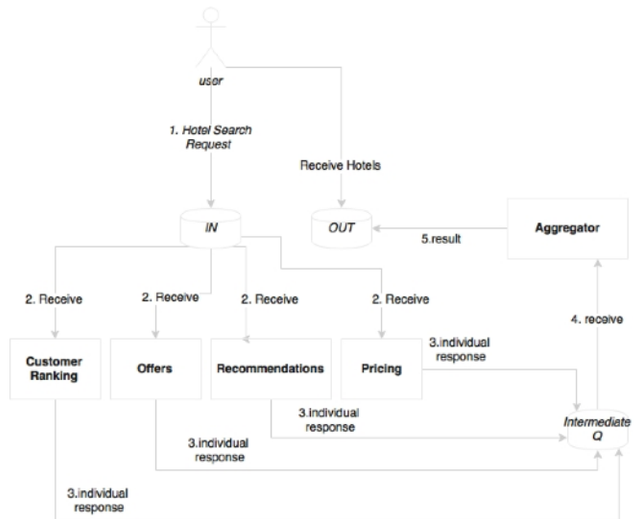


A) synchronous request - response



B) asynchronous request - response

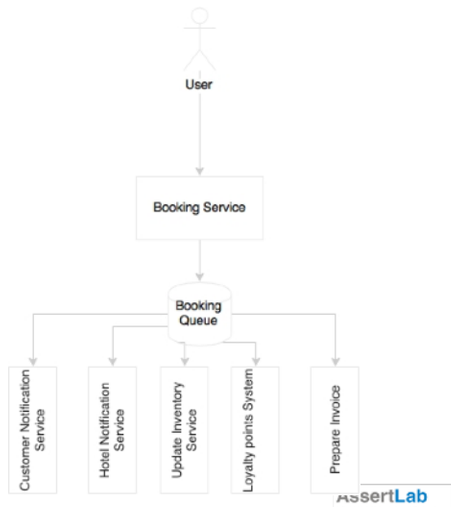
How to decide which style to choose?



An effective approach in this case is to start with a synchronous request response, and refactor later to introduce an asynchronous style when there is value in doing that.

How to decide which style to choose?

- The service is triggered when the user clicks on the booking function.
- It is again, by nature, a synchronous style communication.
- When booking is successful, it sends a message to the customer's e-mail address, sends a message to the hotel's booking system, updates the cached inventory, updates the loyalty points system, prepares an invoice, and perhaps more



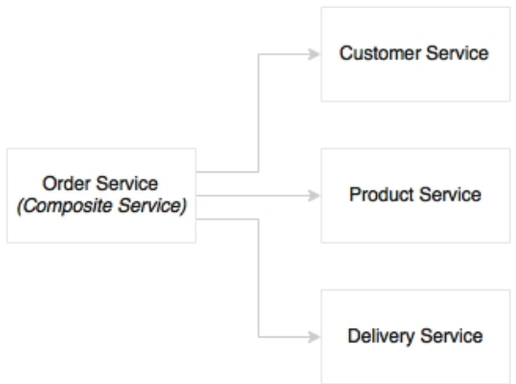
Let the user wait till a booking record is created by the Booking Service. On successful completion, a booking event will be published, and return a confirmation message back to the user. Subsequently, all other activities will happen in parallel, asynchronously.

Orchestration of microservices

- Composability is one of the service design principles
  - Who is responsible for the composing services?
- SOA use ESBs (act as a proxy in some cases)
  - The first approach is orchestration

Orchestration of microservices

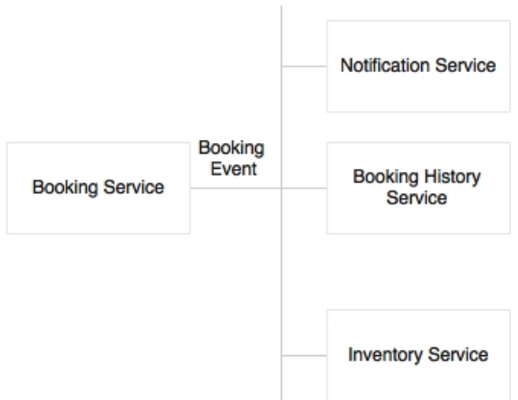
- Multiple services are stitched together to get a complete function. A central brain acts as the orchestrator
- In the SOA world, ESBs play the role of orchestration
- The orchestrated service will be exposed by ESBs as a composite service



As shown in the diagram, the order service is a composite service that will orchestrate other services. There could be sequential as well as parallel branches from the master process. Each task will be fulfilled by an atomic task service, typically a web service.

Orchestration of microservices

- The second approach is choreography, in where, there is no central brain
- In the SOA world, the caller pushes a message to the ESB, and the downstream flow will be automatically determined by the consuming services

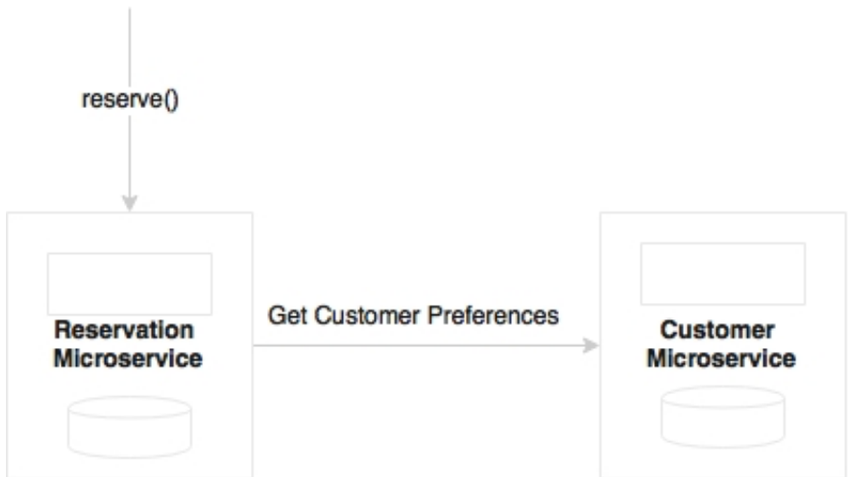


An event, a booking event in this case, is published by a producer, a number of consumers wait for the event, and independently apply different logics on the incoming event. Sometimes, events could even be nested where the consumers can send another event which will be consumed by another service

Orchestration of microservices

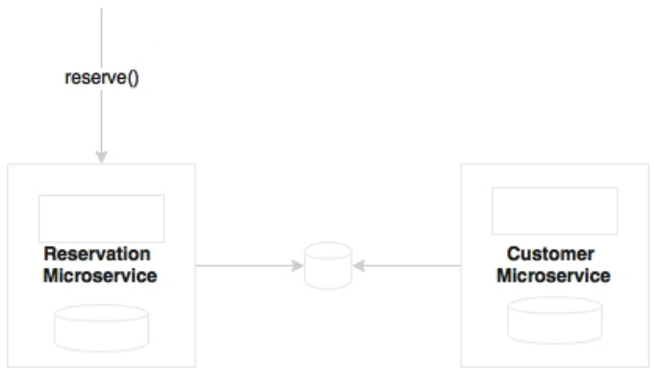
- Microservices are autonomous
  - all required components to complete their function should be within the service
- The service endpoints provide coarse-grained APIs
  - there are no external touch points required
  - microservices may need to talk to other microservices to fulfil their function

We can model choreography in all cases?



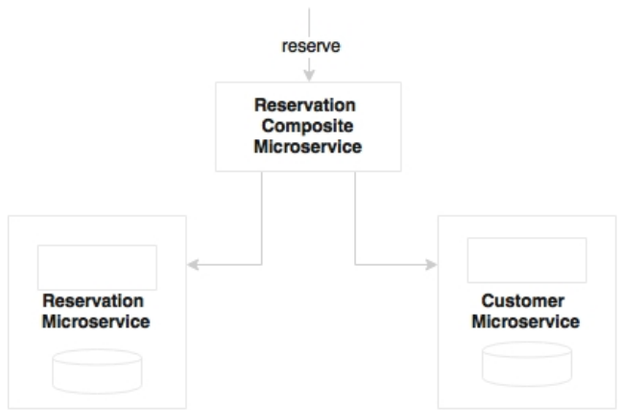
We can model choreography in all cases?

- Customer preference is required for Reservation to progress, and hence, it may require a synchronous blocking call to Customer
- Retrofitting this by modeling asynchronously does not really make sense.



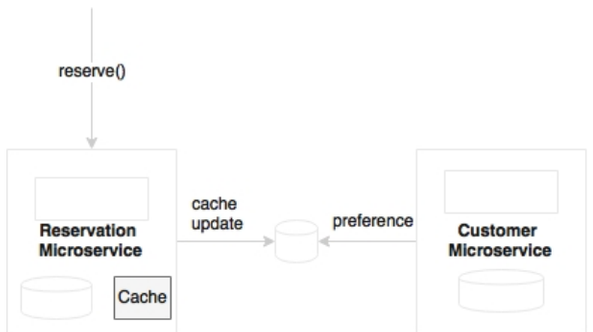
We can model choreography in all cases?

- This is acceptable in the approach for composing multiple components within a microservice
- But creating a composite microservice may not be a good idea.
- We will end up creating many microservices with no business alignment, which would not be autonomous, and could result in many fine-grained microservices



We can model choreography in all cases?

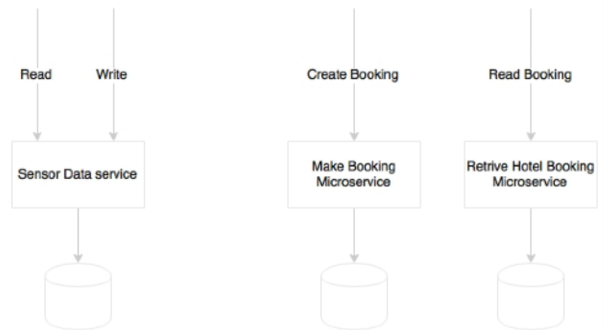
- Changes will be propagated whenever there is a change in the master
- Reservation can use customer preference without fanning out a call
- Today we replicate customer preference, but in another scenario, we may want to reach out to customer service to see whether the customer is black-listed from reserving



Changes will be propagated whenever there is a change in the master. In this case, Reservation can use customer preference without fanning out a call. It is a valid thought, but we need to carefully analyze this. Today we replicate customer preference, but in another scenario, we may want to reach out to customer service to see whether the customer is black-listed from reserving. We have to be extremely careful in deciding what data to duplicate. This could add to the complexity.

How many endpoints in a microservice?

- The question really is whether to limit each microservice with one endpoint or multiple endpoints
- Polyglot architecture could be another scenario where we may split endpoints into different microservices



The number of endpoints is not really a decision point. In some cases, there may be only one endpoint, whereas in some other cases, there could be more than one endpoint in a microservice.

One microservice per VM or multiple?

- Whether multiple microservices could be deployed in one virtual machine?
- The simplest way to approach this problem is to ask a few questions:
  - Does the VM have enough capacity to run both services under peak usage?
  - Do we want to treat these services differently to achieve SLAs (selective scaling)? For example, for scalability, if we have an all-in-one VM, we will have to replicate VMs which replicate all services.
  - Are there any conflicting resource requirements? For example, different OS versions, JDK versions, and others

One microservice could be deployed in multiple Virtual Machines (VMs) by replicating the deployment for scalability and availability. This is a no brainer.

If all your answers are No, then perhaps we can start with collocated deployment, until we encounter a scenario to change the deployment topology. However, we will have to ensure that these services are not sharing anything, and are running as independent OS processes.

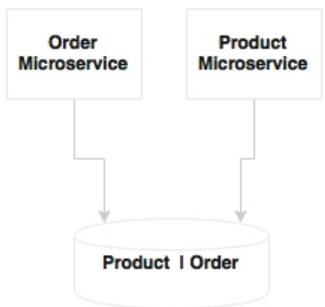
Rules engine – shared or embedded?

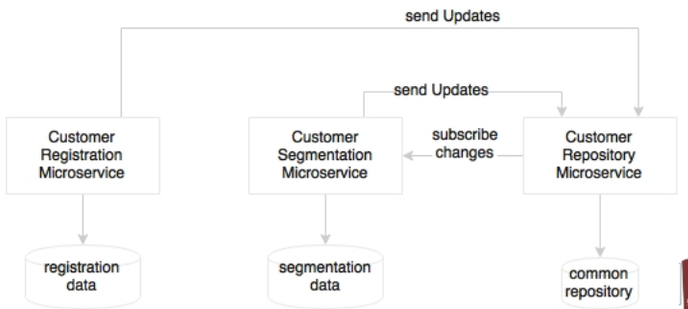
- Either we hand code rules, or we may use a rules engine
- Many enterprises manage rules centrally in a rules repository as well as execute them centrally
  - **Drools** is one of the popular open source rules engines

In the context of microservices, a central rules engine means fanning out calls from microservices to the central rules engine. This also means that the service logic is now in two places, some within the service, and some external to the service.

Can microservices share data stores?

- In principle, microservices should abstract presentation, business logic, and data stores.
- If the services are broken as per the guidelines, each microservice logically could use an independent database





Setting up transaction boundaries

- Is there a place for transactions in microservices?
  - It is appropriate to define transaction boundaries within the microsystem using local transactions
  - However, distributed global transactions should be avoided in the microservices context

Transactions in operational systems are used to maintain the consistency of data stored in an RDBMS by grouping a number of operations together into one atomic block. They either commit or rollback the entire operation

Altering use cases to simplify transactional requirements

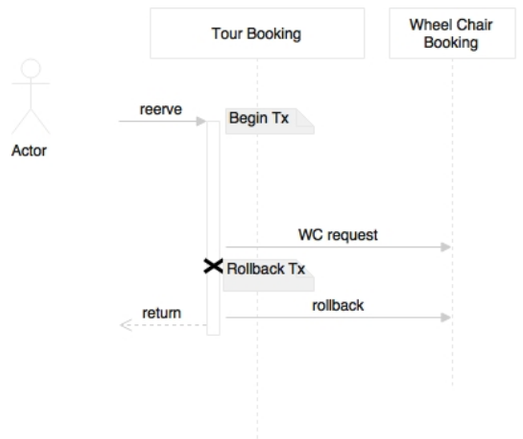
- Eventual consistency is a better option than distributed transactions that span across multiple microservices
  - reduces a lot of overheads
  - but application developers may need to re-think the way they write application code

A classical problem is that of the last room selling scenario in a hotel booking use case. What if there is only one room left, and there are multiple customers booking this singe available room?
Now consider the scenario where we are creating customer profiles in a NoSQL database like CouchDB. In more traditional approaches with RDBMS, we insert a customer first, and then insert the customer's address, profile details, then preferences, all in one transaction. When using NoSQL, we may not do the same steps. Instead, we may prepare a JSON object with all the details, and insert this into CouchDB in one go. In this second case, no explicit transaction boundaries are required.

Distributed transaction scenarios

- The ideal scenario is to use local transactions within a microservice if required, and completely avoid distributed transactions

- There could be scenarios where at the end of the execution of one service, we may want to send a message to another microservice



The first approach is to delay sending the message till the end. This ensures that there are less chances for any failure after sending the message. Still, if failure occurs after sending the message, then the exception handling routine is run, that is, we send a compensating message to reverse the wheelchair booking.

Service endpoint design consideration

- Service design has two key elements: contract design and protocol selection
- Contract design
  - A complex service contract reduces the usability of the service
    - KISS (Keep It Simple Stupid)
    - YAGNI (You Ain't Gonna Need It)
  - Evolutionary design is a great concept
    - Consumer Driven Contracts (CDC) and Postel's law (robustness principle)
      - Be conservative in what you send, be liberal in what you accept

When it comes to service design, service providers should be as flexible as possible when accepting consumer requests, whereas service consumers should stick to the contract as agreed with the provider

Service endpoint design consideration

- Protocol selection
  - In the SOA world, HTTP/SOAP, and messaging were kinds of default service protocols for service interactions
  - increases the communication cost; susceptible to network failures; could result in poor performance of services
    - Message-oriented services (asynchronous style of communication)
    - HTTP and REST endpoints (interoperability, protocol handling, traffic routing, load balancing, security systems…)
    - Optimized communication protocols
    - API documentations

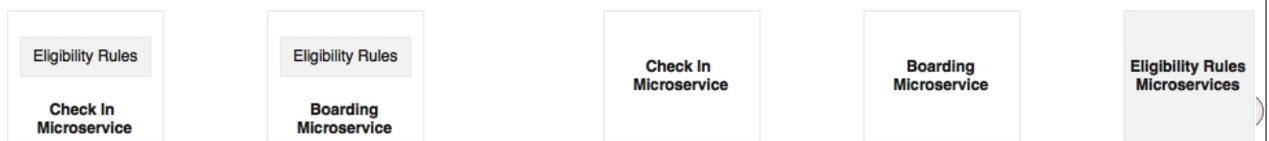
Optimized communication protocols: If the service response times are stringent, then we need to pay special attention to the communication aspects. In such cases, we may choose alternate protocols such as Avro, Protocol Buffers, or Thrift for communicating between services.

Homework 4.1

- What is the main concepts and principles of Consumer Driven Contracts (CDC)?
- How does it fit into the microservices approach?
- How Postel's law could be also relevant in this scenario?
- What are the main solutions (patterns, architectural styles, tools, etc.) to implement:
  - Message-oriented services;
  - HTTP and REST endpoints;
  - Optimized communication protocols;
  - API documentations

Handling shared libraries

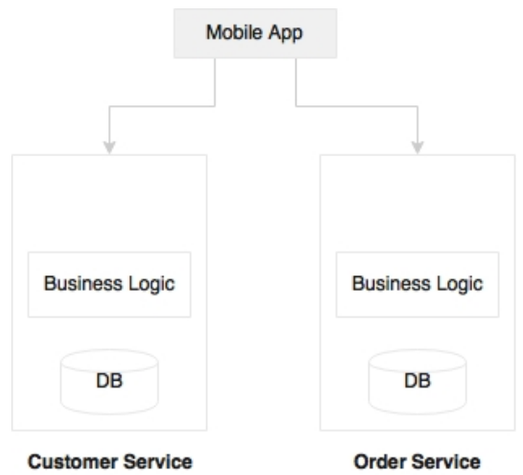
- Microservices: Autonomous and self-contained
  - duplicate code and libraries



An alternative option of developing the shared library as another microservice itself needs careful analysis.
The trade-off analysis is between overheads in communication versus duplicating the libraries in multiple services.

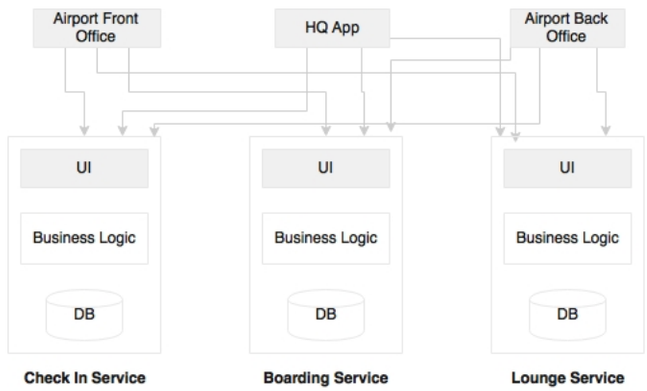
User interfaces in microservices

- The microservices principle advocates a microservice as a vertical slice from the database to presentation
  - build quick UI and mobile applications mashing up the existing APIs



User interfaces in microservices

- Build consolidated web applications targeted to communities
- One approach is to build a container web application or a placeholder web application, which links to multiple microservices at the backend
  - multiple placeholder web applications targeting different user communities



For example, the business may want to develop a departure control application targeting airport users. A departure control web application may have functions such as check-in, lounge management, boarding, and so on. These may be designed as independent microservices. But from the business standpoint, it all needs to be clubbed into a single web application. In such cases, we will have to build web applications by mashing up services from the backend.

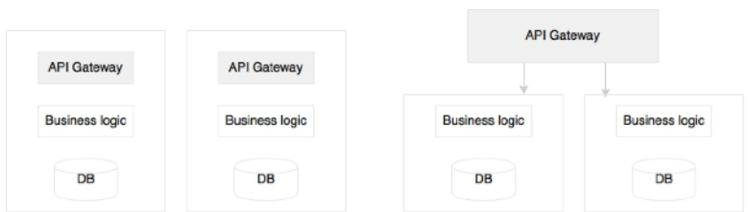
Use of API gateways in microservices

- With the advancement of client-side JavaScript frameworks, the server is expected to expose RESTful services
  - mismatch in contract expectations
    - minimal information is sent with links (HATEOAS)
  - multiple calls to the server to render a page
    - used when the client makes the REST call (also sends the required fields as part of the query string)

In the first approach, minimal information is sent with links as explained in the section on HATEOAS.
The second approach is used when the client makes the REST call; it also sends the required fields as part of the query string.

Use of API gateways in microservices

- Introduce a level of indirection
  - A gateway component sits between the client and the server, and transforms data as per the consumer's specification
    - do not compromise on the backend service contract
    - leads to UI services
  - In many cases, the API gateway acts as a proxy to the backend, exposing a set of consumer-specific APIs



A) API gateway is part of the micro service

B) Common API gateway

There are two ways we can deploy an API gateway. The first one is one API gateway per microservice as shown in diagram A. The second approach (diagram B) is to have a common API gateway for multiple services. The choice really depends on what we are looking for. If we are using an API gateway as a reverse proxy, then off-the-shelf gateways such as Apigee, Mashery, and the like could be used as a shared platform. If we need fine-grained control over traffic shaping and complex transformations, then per service custom API gateways may be more useful.

Use of ESB and iPaaS with microservices

- Theoretically, SOA is not all about ESBs, but the reality is that ESBs have always been at the center of many SOA implementations
- What would be the role of an ESB in the microservices world?
  - Microservices: fully cloud native systems, lightweight characteristics of microservices enable automation of deployments, scaling, and so on…
  - ESB: heavyweight in nature, not cloud friendly , protocol mediation, transformation, orchestration, and application adaptors ~> we may not need

The limited ESB capabilities that are relevant for microservices are already available with more lightweight tools such as an API gateway. Orchestration is moved from the central bus to the microservices themselves. Therefore, there is no centralized orchestration capability expected in the case of microservices. Since the services are set up to accept more universal message exchange styles using REST/JSON calls, no protocol mediation is required. The last piece of capability that we get from ESBs are the adaptors to connect back to the legacy systems. In the case of microservices, the service itself provides a concrete implementation, and hence, there are no legacy connectors required. For these reasons, there is no natural space for ESBs in the microservices world.

Use of ESB and iPaaS with microservices

- Enterprises have legacy applications, vendor applications, and so on
  - Legacy services use ESBs to connect with microservices
- With the advancement of clouds, the capabilities of ESBs are not sufficient to manage integration between clouds, cloud to on-premise, and so on.
  - Integration Platform as a Service (iPaaS) is evolving as the next generation application integration platform, which further reduces the role of ESBs.
  - In typical deployments, iPaaS invokes API gateways to access microservices

Homework 4.2

- How can we have the same features present in ESB's with lightweight tools in the universe of microservices? Justify your answer.

Service versioning considerations

- Versioning helps us to release new services without breaking the existing consumers
- There are three different ways in which we can version REST services:
  - URI versioning: version number is included in the URL itself

```
/api/v3/customer/1234
/api/customer/1234  - aliased to v3.

@RestController("CustomerControllerV3")
@RequestMapping("api/v3/customer")
public class CustomerController {

}
```

```
api/customer/100?v=1.5
```

  - Media type versioning: version is set by the client on the HTTP Accept header

```
Accept:  application/vnd.company.cus-
tomer-v3+json
```

Service versioning considerations

- A less effective approach for versioning is to set the version in the custom header

```
@RequestMapping(value = "/{id}", method
= RequestMethod.GET, headers = {"ver-
sion=3"})
public Customer getCustomer(@PathVari-
able("id") long id) {
     //other code goes here.
}
```

Service versioning considerations

In the URI approach, it is simple for the clients to consume services. But this has some inherent issues such as the fact that versioning-nested URI resources could be complex. Indeed, migrating clients is slightly complex as compared to media type approaches, with caching issues for multiple versions of the services, and others. However, these issues are not significant enough for us to not go with a URI approach. **Most of the big Internet players such as Google, Twitter, LinkedIn, and Salesforce are following the URI approach**.

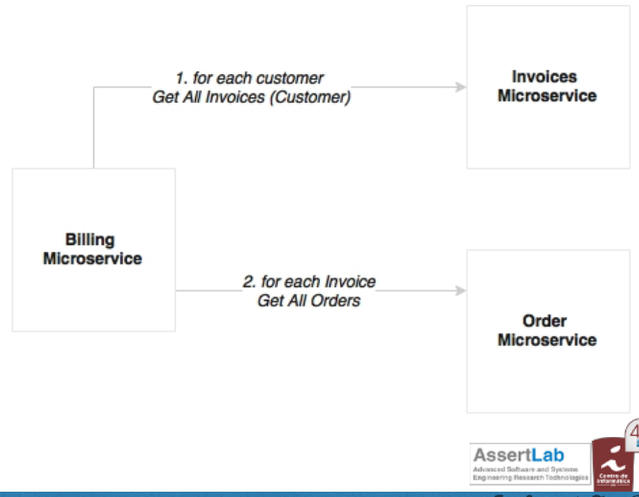
Design for cross origin

- Composite UI web applications may call multiple microservices for accomplishing a task, and these could come from different domains and hosts
- CORS allows browser clients to send requests to services hosted on different domains
  - One approach is to enable all microservices to allow cross origin requests from other trusted domains
  - The second approach is to use an API gateway as a single trusted domain for the clients

Microservices and bulk operations

- Since we have broken monolithic applications into smaller, focused services, it is no longer possible to use join queries across microservice data stores

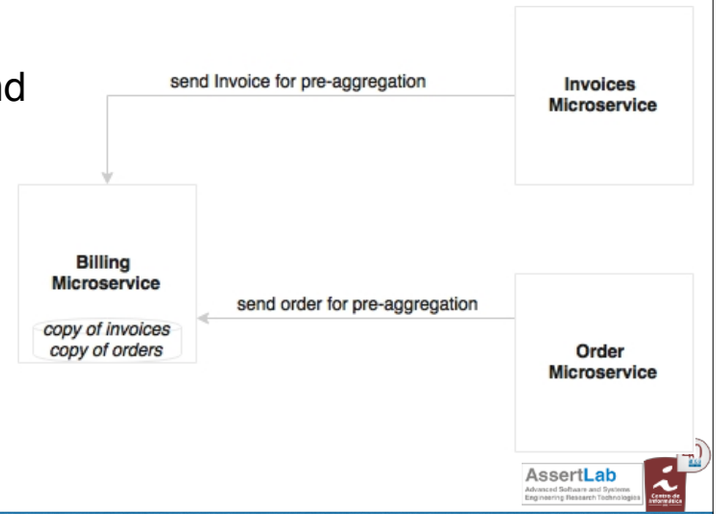
- The challenge that arises is that the **Billing** service has to query the **Invoices** service for each **customer** to get all the invoices, and then for each invoice, call the **Order** service for getting the orders



This could lead to situations where one service may need many records from other services to perform its function.

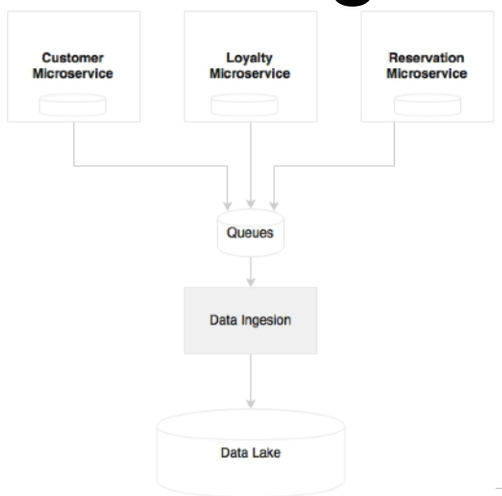
Microservices and bulk operations

- Pre-aggregate data as and when it is created
- Using of batch API
  - each batch further uses parallel threads



Microservices challenges

- Data islands
  - Fragmenting data into heterogeneous data islands
  - Traditional data warehouses like Oracle, Teradata, and others are used primarily for batch reporting
  - But with NoSQL databases (like Hadoop) and microbatching techniques, near real-time analytics is possible with the concept of data lakes



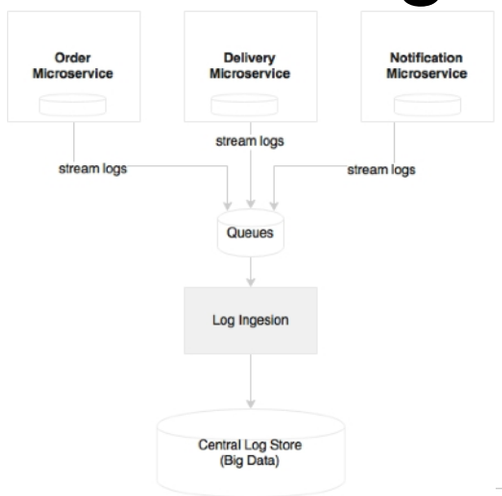
Unlike the traditional warehouses that are purpose-built for batch reporting, data lakes store raw data without assuming how the data is going to be used.

Homework 4.3

- How can be done data porting from microservices to a data lake or a data warehouse? Explain in details your answer.

Logging and monitoring

- Log files are a good piece of information for analysis and debugging
- When we scale services across multiple machines, each service instance could produce separate log files



When implementing microservices, we need a capability to ship logs from each service to a centrally managed log repository. With this approach, services do not have to rely on the local disk or local I/Os. A second advantage is that the log files are centrally managed, and are available for all sorts of analysis such as historical, real time, and trending. By introducing a correlation ID, end-to-end transactions can be easily tracked.

Dependency management

- Too many dependencies could raise challenges in microservices. Four important design aspects are stated as follows:
  - Reducing dependencies by properly designing service boundaries.
  - Reducing impacts by designing dependencies as loosely coupled as possible. Also, designing service interactions through asynchronous communication styles.
  - Tackling dependency issues using patterns such as circuit breakers.
  - Monitoring dependencies using visual dependency graphs.

Organization culture

- Agile development processes, continuous integration, automated QA checks, automated delivery pipelines, automated deployments, and automatic infrastructure provisioning…

Governance challenges

- Microservices impose decentralized governance, and this is quite in contrast with the traditional SOA governance
- There are number of challenges that comes with a decentralized governance model
  - How do we understand who is consuming a service?
  - How do we ensure service reuse?
  - How do we define which services are available in the organization?
  - How do we ensure enforcement of enterprise polices?

The first thing is to have a set of **standards**, **best practices**, and **guidelines** on how to **implement** better services.
The second important consideration is to have a **place** where all stakeholders can not only see all the services, but also their **documentations**, **contracts**, and **service-level agreements**.

Operation overheads

- Microservices deployment generally increases the number of deployable units and virtual machines (or containers)
  - the number of **configurable items** (CIs) becomes too high, and the number of servers in which these CIs are deployed might also be unpredictable

Testing microservices

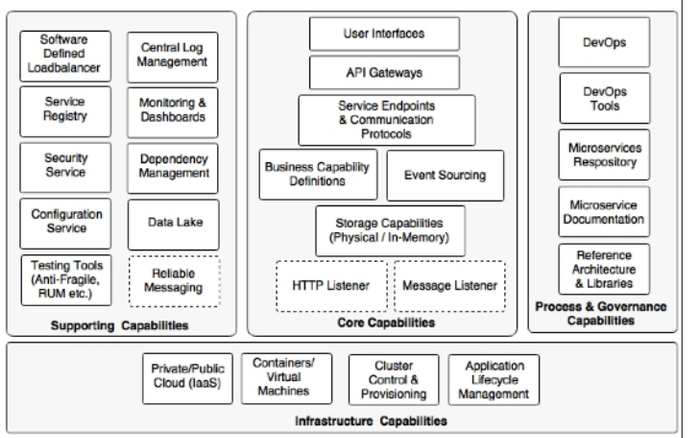
- The issue is how do we test an end-to-end service to evaluate its behavior?
  - Service virtualization or service mocking
  - Consumer driven contract
- Test automation, appropriate performance testing, and continuous delivery approaches such as A/B testing, future flags, canary testing, blue-green deployments, and red-black deployments, all reduce the risks of production releases

Infrastructure provisioning

- Manual deployment could severely challenge the microservices rollouts
- Microservices require a supporting elastic cloud-like infrastructure which can **automatically** provision VMs or containers, **automatically** deploy applications, adjust traffic flows, replicate new version to all instances, and gracefully phase out older versions

The microservices capability model

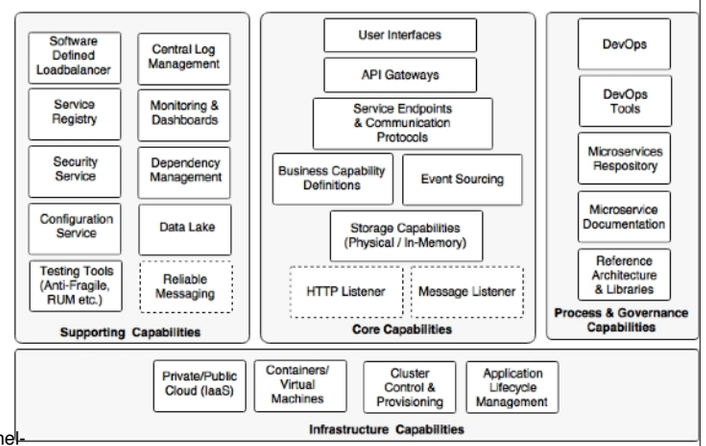
- The capability model is broadly classified in to four areas:
  - Core capabilities: These are part of the microservices themselves
  - Supporting capabilities: These are software solutions supporting core microservice implementations
  - Infrastructure capabilities: These are infrastructure level expectations for a successful microservices implementation
  - Governance capabilities: These are more of process, people, and reference information



A capability model for microservices based on the **design guidelines** and **common pattern** and **solutions**

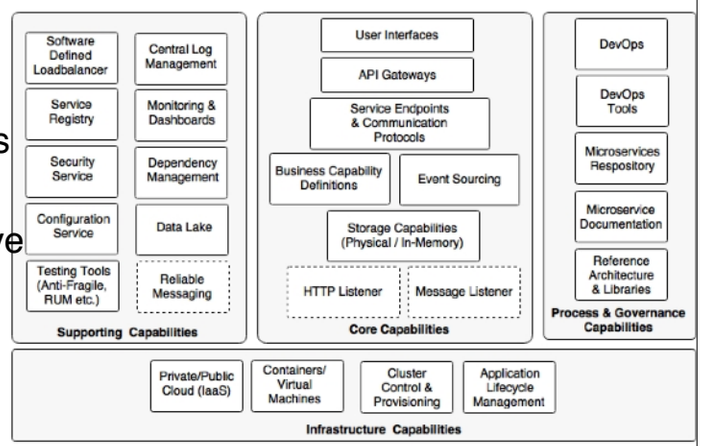
Core capabilities

- Service listeners (HTTP/messaging)
  - HTTP listener is embedded within the microservices, thereby eliminating the need to have any external application server requirement
- Storage capability
  - could be either a physical storage, or it could be an in-memory store
- Business capability definition
  - where the business logic is implemented
- Event sourcing
  - Microservices send out state changes
- Service endpoints and communication protocols
  - Define the APIs for external consumers to consume
- API gateway
  - useful for policy enforcements
- User interfaces
  - could be implemented in any technology, and are channel- and device-agnostic.



Infrastructure capabilities

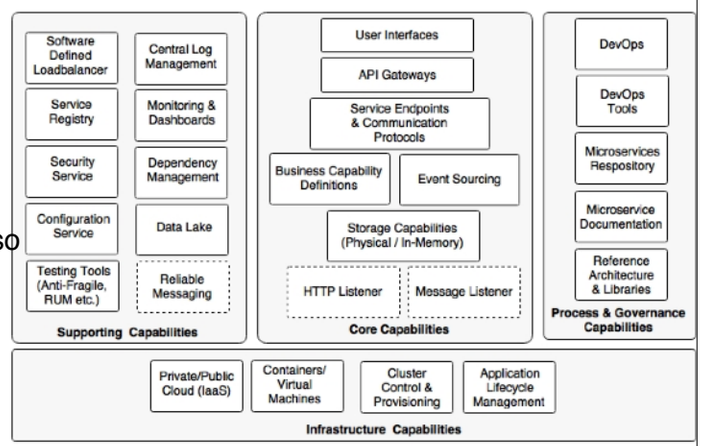
- Cloud
  - traditional data center???
- Containers or virtual machines
  - Managing large physical machines is not cost effective
- Cluster control and provisioning
- Application lifecycle management



Cluster control and provisioning: Once we have a large number of containers or virtual machines, it is hard to manage and maintain them automatically.
Application lifecycle management: Application lifecycle management tools help to invoke applications when a new container is launched, or kill the application when the container shuts down. Application life cycle management allows for script application deployments and releases.

Supporting capabilities

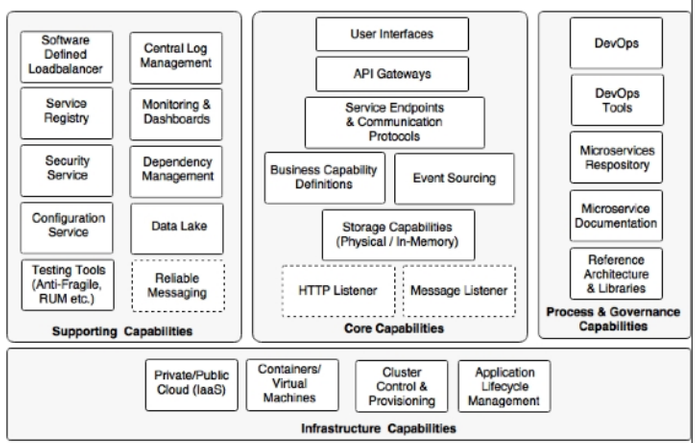
- Software defined load balancer
- Central log management
- Service registry
- Security service
- Service configuration
- Testing tools (anti-fragile, RUM, and so on)
- Monitoring and dashboards
- Dependency and CI management
- Data lake
- Reliable messaging



Software defined load balancer: The load balancer should be smart enough to understand the changes in the deployment topology, and respond accordingly
Service registry: A service registry provides a runtime environment for services to automatically publish their availability at runtime.
Security service: A distributed microservices ecosystem requires a central server for managing service security.
Service configuration: All service configurations should be externalized as discussed in the Twelve-Factor application principles.
Dependency and CI management: We also need tools to discover runtime topologies, service dependencies, and to manage configurable items.
Reliable messaging: If the communication is asynchronous, we may need a reliable messaging infrastructure service such as RabbitMQ or any other reliable messaging service.

Process and governance capabilities

- DevOps
- DevOps tools
- Microservices repository
- Microservices documentation
- Reference Architecture & Libraries



DevOps: The key to successful implementation of microservices is to adopt DevOps.
DevOps tools: DevOps tools for Agile development, continuous integration, continuous delivery, and continuous deployment are essential for successful delivery of microservices.
Microservices repository: A microservices repository is where the versioned binaries of microservices are placed.
Reference architecture and libraries: The reference architecture provides a blueprint at the organization level to ensure that the services are developed according to certain standards and guidelines in a consistent manner.

Homework 4

- 4.1. Service endpoint design consideration
- 4.2. Use of ESB and iPaaS with microservices
- 4.3. Microservices challenges - Data islands
- Submit in our Slack team, http://if1007-2018-1.slack.com, a MD file (LOGIN-HW4.md) containing your answer.
- Due **D+12** (Monday, 4/2), **23:59**.