Questions on the syllabus

RESTful services

1. How can we create/update/access resources in REST? Which are the pros and cons of REST?

   In REST a resource is created/updated/accessed ecc. using HTTP methods. Clients invoke methods such as GET, POST, PUT, DELETE and request and responses are used to trasnfer representaion of resources. Rest is resources centric and services are seen as reources identified by their URI.

PROS:

- Simplicity
  - Low learning curve
    - Rest uses well known standards such as HTTP and the necessary infrastructure is already pervasive
  - Minimal tooling necessary to deploy services
    - Similar to building a dynamic web site
    - no custom client-side software
    - Can begin testing using a simple web browser
  - Because of URIs and hyperlinks we can discover web based resources without complusory registration to a repository
- Efficiency
  - lightweight protocols and message formats
- Scalability
  - stateless RESTful web services can serve a very large amount of clients

CONS:

- Confusion on best practices(should i use POST OR PUT? What code should i return? What is the correct URI?)
- No commonly accepted marshalling merchanism, so it's challenging to encored complex data structures in a URI
- Not easy to extend restful services to support advanced functionalities in an interoperable manner
- Very easy to make decisions on restful services that can cause significan technical risks and development effort(e.g design of the specification of resources and URI addressing scheme)

2. What is OpenAPI?

OpenAPI is a open source specification that is used to describe, produce, consume, and visualize RESTful APIs and web services. It is a format and initiative for designing and creating machine readable interface files that are utilized in producing, describing, consumingm and visualizing RESTful APIs and web services. The open API file permits software developers to define their API's essential including:

- **Present endpoints and each endpoint's operations**
- **The input and output operation parametes**
- Authentication techniques
- Things like contact information, terms of use, license, and much more

The main advantage of using a standard definition is that the thid party users can interact with and understand the service with minimal implementation logic, as long as they are familiar with RESTful APIs basics. API specifications are either written in YAML or JSON, formats that are readable, and easy to understand for both machines and humans

Microservices

3. Why microservices?

The main two reasons for choosing a microservice architecture are:

- Shorten lead time for new features and updates
- More effective scaling (horizontal scaling)

4. Which are the main characteristics, and the main pros and cons, of microservice-based architectures?

- Service orientation:
  - Application as sets of services
  - each application has its own container
  - lightweight communication protocols (REST), can be synchronous (HTTP) or asynchronous(RABBITMQ, REDIS)
  - Polyglot services
- Organize services around business capabilities
  - Agile methods, cross funcitonal teams, flat set of servies managed by many teams
  - Different teams with separated roles introduces a delay of communications (context switching)
- Decentralized data
  - Each service has its own db, which will be smaller
  - Eventual consistency and compensations instead of distributed transactions
    - We accept some inconsistencies, but they ill be consistent some time in the future
- Independently deployed services

    - Ideally each service should be started without any dependency, should reduce coupling as much as possible
- Horizontal scalability
    - replicate only services that actually needs the scaling, not the entire application
        - Must be careful when dealing with endpoint based communication with other service (this is a smell, should be addressed with service discovery or a message router)
- Fault resilient services
    - Avoid cascading failures
    - Must have fault tolerant design
    - Any call can fail for any reason, must handle these as graceful as possible
    - Design for failure (chaos testing, fault injection)
- DevOps culture, you build it, you run it

CONS:

- Dont even consider microservices unless you have a system that's too complex to manage as a mnoloith

- Communication overhead

- Architecture complexity

- "wrong cuts", maybe you split it wrong and two services are tighlty coupled, very empirical process

- Very hard to avoid data duplication

- security managment very complex, attack surface broadesn (need effective way to handle authorization and authentication)

5. Which refactoring can be applied to resolve architectural smell X? How can we automate the generation of a model of a microservice-based architecture?

REFACTORING

PRINCIPLE	**SMELL**	**SOLUTION**
Independent deployability	Multiple services in one container	One service for each container
Horizontal scalability	endpoint based-service interactions	message broker(14%),message router(31%), service discovery(55%)
Horizontal scalability	no API gateway	add API gateway
isolation of failures	wobbly service interactions	bulkhead(20%), message broker(16%), timeouts(22%), circuit breaker (42%)

PRINCIPLE	SMELL	SOLUTION
decentralisation	shared persistence	merge services (9%), data manager (41%), split databse (50%)
decentralisation	ESB misuse	rightsize ESB -> smart endpoints, dumb pipes
decentralisation	single layer teams	split teams by services

MODEL GENERATION:

Use modelling tools for microservice architecture that gets in input a representation of the model (.tosca, similar to xml) and can generate (partial) concrete model specification (kubernetes images, istrio, a more complete .tosca file ecc.) ->

$$\mu Freshner$$

6. What is Flask? Flask is a lightweight WSGI web application micro framework. It is a python module that aims to simplify the development of web-based applicationa that communicate through HTTP. Micro does not mean that these apps are very small, but it means that flask tries to keep its core very simple but modular, with the possibility of adding many plugins and extensions (in fact many exists for different task such as form handling, interaciton with message brokers, testing ecc.). Tries to make as little decisions as possible, not enforcing any particular architecture or code style.

7. What is a container/image/volume in Docker? Which are the differences between a virtual machine and a container?

   Container:

   - A sandboxed process on a host machine that is isolated from all other processes on the machine , leveraging kernel namespaces and cgroups (very bound to posix machines). It is used to host a lightweight OS stack that supports running a SINGLE command. This single command can be any program compatible with the OS stack (usually a web app instance)-

   Image:

   - A docker image provides the custom filesystem that is needed for the isolated process (add libraries, dependencies, files ecc.). It can be seen as a “programmable” chroot, but a container extends this to not only files but also process resources. The image contains everything needed to run the application, and other configuration for container, such as environment variables a default command to run, user credentials for a specific service ecc.

   Volume:

- Data volumes persist data independent of a container's life cycle. When you delete a container, Docker engine does not delete any data volumes. You can share volumes across multiple containers. Moreover, you can share data volumes with other computing resources in your system.

8. What is the effect of docker build/run/commit? What is Docker Compose?

   Docker build build a new image based on a specification written in a Dockerfile. Docker run execute a command in a new container created on the basis of a specified image, using the default comand in the image (if exists) when a command is not provided. Commit creates a new image based on a container change to the image that it was built on.

Software testing

9. What is development/release/user testing? What is TDD? What is partition testing? What are "software inspections"?

   FIRST:

   1. Development testing: all testing activities that are carried out by the team developing the software. The tester is usually the programmer developing the software. Can be more formal for critical system, with a specific testing group in the developing team (general trends is agile methods, no separation between testers and devleopers).

   Three stages:

   - Unit testing , where individual functions or methods are tested. Unit testing should focus only on testing the functionality of these methods and functions.
   - Component testing, where several individual units are integrated to create composite components (modules). In this phase we should test the interface that provides access to these functions.
   - System testing, where some or all the components are integrated and the system is tested as a whole. Should focus on interactions between components.

   2. Release testing:

      - Testing release of system intended for use outside of development team

        Primary goal: convince system supplier that is good enough to use

        Black box tests derived from system specification

        It is a form of system testing:

        - Separate not developing team should be responsible

    - Objective of release testing is to check that the system meets its requirements and is good enough for external use (validation testing)

  Requirements-based testing

  Design test(s) for each requirement

  Validation testing

  Scenario testing

  Exploit typical scenarios of use to develop test cases

  A scenario is a (narrative) realistic story

  Performance testing

  Check that system can process its intended workload

  Operation profiles* employed to test whether performance requirements are being achieve

3. User testing

   - Users provide input and advice on system testing

     Essential, users real working environment can't be fully replicated but it can impact reliability/performance/usability of system

     Types of user testing:

     - **Alpha testing**
       - Users work with development team to test early releases of software
     - **Beta testing**
       - Release made available to larger group of users, allowing them to experiment and raise problems discovered to the system developers
     - **Acceptance testing**
       - Customers test a system to decide whether or not it is ready to be accepted from the system developers and deployed in the customer environment

Acceptance criteria should in principle be part of system contract (in practice requirments change during development)

```
Outcome of negotiations can be conditional acceptance, e.g deploy even with problems
```

SECOND:

Test Driven Development is a programming style where software design and implementation are driven by testing. You first write a test for the new functionality that you want, you check that it fails (as it should if the functionality was not intended before), then you write the code that implements the functionality, and rerun the test and verify that it succeed. You repeat this loop until the test passes. This has many benefits including incremental change, simpler solutions and easy to document functionalities (essentially the test should make clear what are the expected inputs and outputs).

PROS

- code coverage. Each code segment should have an associated test(not always true, usually a >90% coverage is the ideal targets)
- regression testing. When adding new code you can rerun all the tests and check that it does not break anything (no spaghetti code!)
- Simplified debugging, it's immediate to see where is the problem
- System documentation, the tests themselves are documentation

THIRD:

Partition testing is a technique used in unit testing to effecitvely test groups of related inputs that should be treated equally:

- Identify the groups
- Choose inputs from each groups
- Rule of thumb: take inputs at boundaries (edge cases) and in the middle(normal cases) of the group.

10. What is Locust?

Locust is a open source load testing python tool. It provides a python library and a simple web interface to generate a various number of API calls to stress test an application. A locustfile.py must be provided where some varius user api calls are defined. The number of these calls and the rate are dfined with the web interface

User stories

11. What is a user story? Which are the six main attributes for a good user story?

What is a user story:

User stories are short, simple descriptions of a feature told from the perspective of the person who desires the new capability, usually a user or customer of the system. They typically follow a simple template:

> As a < type of user >, I want < some goal > so that < some reason >.

User stories are often written on index cards or sticky notes, stored in a shoe box, and arranged on walls or tables to facilitate planning and discussion. As such, they strongly shift the focus from writing about features to discussing them. In fact, these discussions are more important than whatever text is written

Six main attributes (INVEST):

1. **Independent**: User stories should not have interdependencies between them. Otherwise, theyr are difficult to separate by priority, planning and estimation .

2. **Negotiable**: User stories should be flexible and can be negotiated in discussions between the customer and the development team during development. Remember that they're short description of features from the user perspective.

3. **Valuable to users**: user stories must provide description of features that are valuable to end users, and as such should not be focused on technological and programming aspects.

4. **Estimatable**: It is essential that the size of a story can be estimated by developers. The better the estimate of story points, the cleare will be the priority and implementation.

5. **Small**: A good story captures the essence, not the details. Over time the story may acquire, notes details, test ideas and so on but we don't need these to proiritize the story

6. **Testable**: A good story should be testable. "Writing a story card carries an implicit promise: I understand what I want well

   enough that i could write a test for it"

Business process modelling

12. What is a parallel/exclusive/inclusive gateway in BPMN?

13. What is a workflow net? What is a sound workflow net? What is a live/bounded Petri net?

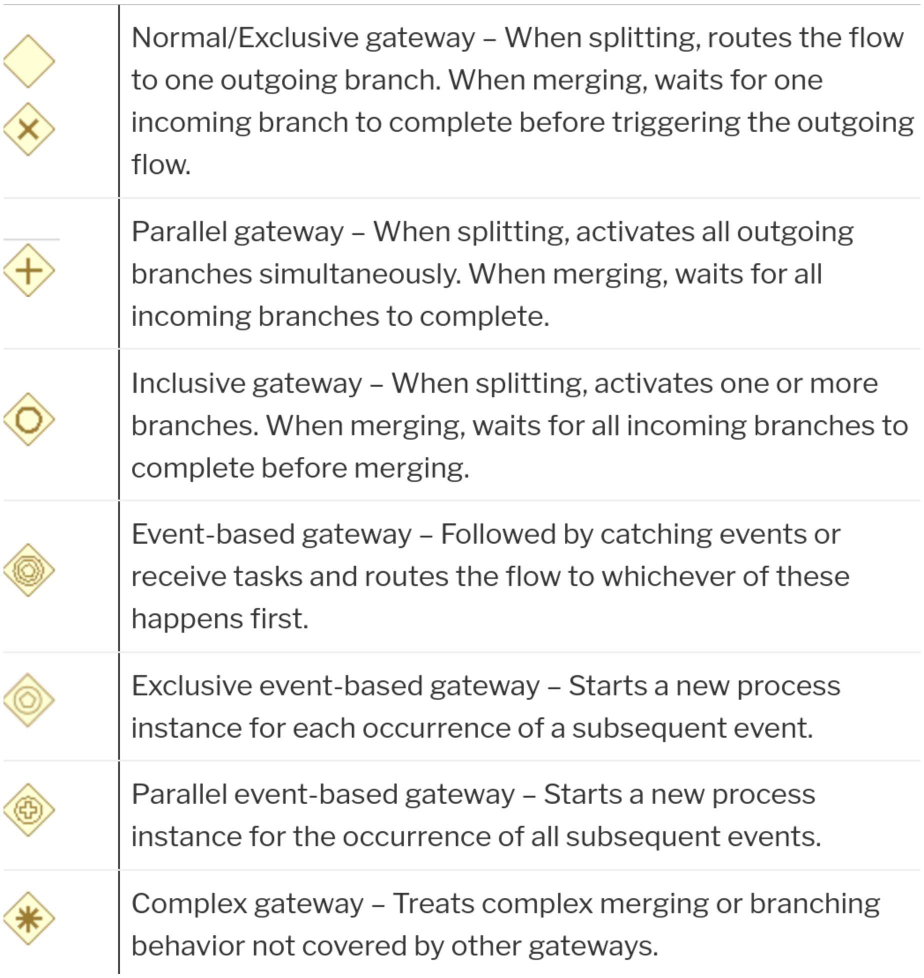
    What is a workflow net:

    Extension of petri nets.

    Petri nets consists of places, transitions and direct arcs connecting places to transitions. Transitions model activities, places and arcs model execution constraints.

    System dynamics represented by tokens, whose distribution over the places determines the state of the modelled system.

    A transition can *fire* if there is a token in each of its input places



◇ ✕	Normal/Exclusive gateway – When splitting, routes the flow to one outgoing branch. When merging, waits for one incoming branch to complete before triggering the outgoing flow.
+	Parallel gateway – When splitting, activates all outgoing branches simultaneously. When merging, waits for all incoming branches to complete.
○	Inclusive gateway – When splitting, activates one or more branches. When merging, waits for all incoming branches to complete before merging.
◎	Event-based gateway – Followed by catching events or receive tasks and routes the flow to whichever of these happens first.
⬠	Exclusive event-based gateway – Starts a new process instance for each occurrence of a subsequent event.
⊕	Parallel event-based gateway – Starts a new process instance for the occurrence of all subsequent events.
✳	Complex gateway – Treats complex merging or branching behavior not covered by other gateways.

Figure 1: image-20211211130851771

If a tranistion *fires*, one token is removed from each input place and one token is added to each output place.

A Petri net is a workflow net iff:

1. There is a unique source place, with no incoming edge
2. There is a unique sink place, with no outgoing edge
3. All places and transitions are located in at least one path from the initial place to the final place

What is a sound workflow net:

> A workflow net is sound iff:
>
> 1. every net execution starting from the initial state (one token in the source place, no tokens elsewhere) eventually leads to the final state (one token in the sink place, no tokens elsewhere)
>
> 2. every transition occurs in at least one net execution

What is a live/bounded petri net?:

> A Petri net (PN, M) is **live** if and only if for every reachable state M' and every transition t, there is a state M'' reachable from M' where t is enabled.
>
> A Petri net(PN, M) is **bounded** if and only if for each place p there is a n in N such that for each reachable state M' the number of tokens in p in M' is less than n
>
> Theorem: a workflow net N is sound if and only if (N',{i}) is live and bounded, where N' is N extended with a transition from the sink place o to the source place i

14. How can we model BPMN parallel/exclusive/inclusive gateways with workflow nets?

    INCLUSIVE GATEWAY:

15. What is Camunda? Which are the two "usage patterns" of Camunda?

What is Camunda:

Camunda is a framework supporting BPMN for workflow and process automation.

It provides a RESTful API which allows to use any language

Workflows are defined via BPMN and can be graphically modeled using Camunda Modeller

Usage Pattern:

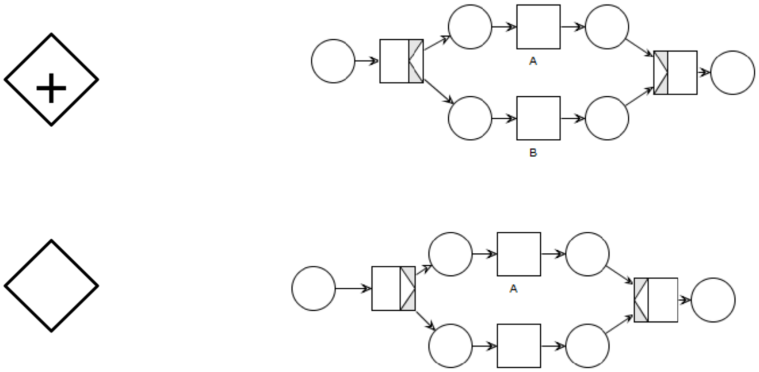


Figure 2: image-20211211132253322

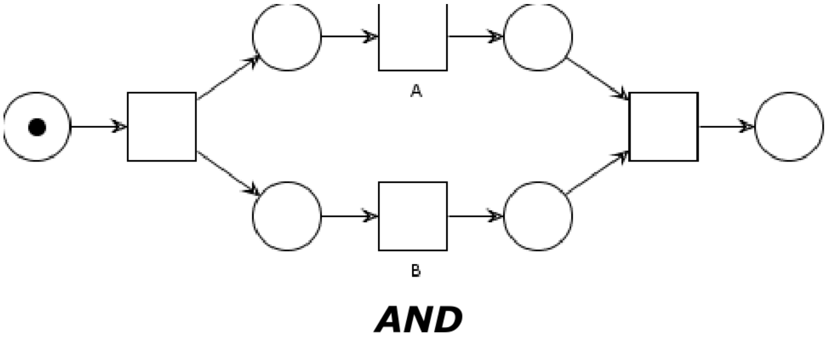


Figure 3: image-20211211132533902

1. **endpoint-based integration**:

   After defining a BPMN process , Camunda can directly call services via built-in connectors. It support REST and SOAP

2. **queue-based integration**

   Unit of work (tasks) are provided in a Topic Queue, the queue is polled by RESTful workers that can interact with services (better scaling).

Security and microservices

16. Which are the main challenges in securing microservices? Which are the main "smells" in microservices security?

    Challenges

The main challenges in securing microservices are embedded in the architecture itself. Since we have many services communicating with remote the number of entry points increases (broader surface attack) and the app is as secure as the weakest link. Other challenges:

- **Distributed security screening**: each microservice has to carry out independent security screenin:

  - May need to connect to a remote security token service
  - repeated, distributed security checks affects **latency and performance**

  Work around: trust-the-network (industring moving to 0 trust policies)

- **Bootstrapping trust among microservices**: Service to service communicatin must take place on protected channels. Suppose you are using certificates:

  - each microservice must be provisioned with a certificate (and private key) to authenticate itself to another microservice during interactions

  - Recipient microservice must know how to validate the certificate associated with calling microservice

  - Need to bootstrap trust

  - (need also to revoke and rotate certificates)

    Need automation for large scale deployments

- **Tracing requests spanning multiple microservices** A log records an event in a service. A set of logs can be aggregated to produce metrics

  Traces help you track a request from the point where it enters the system to the point where it leaves the system

  Challenging to correlate requests among microserives

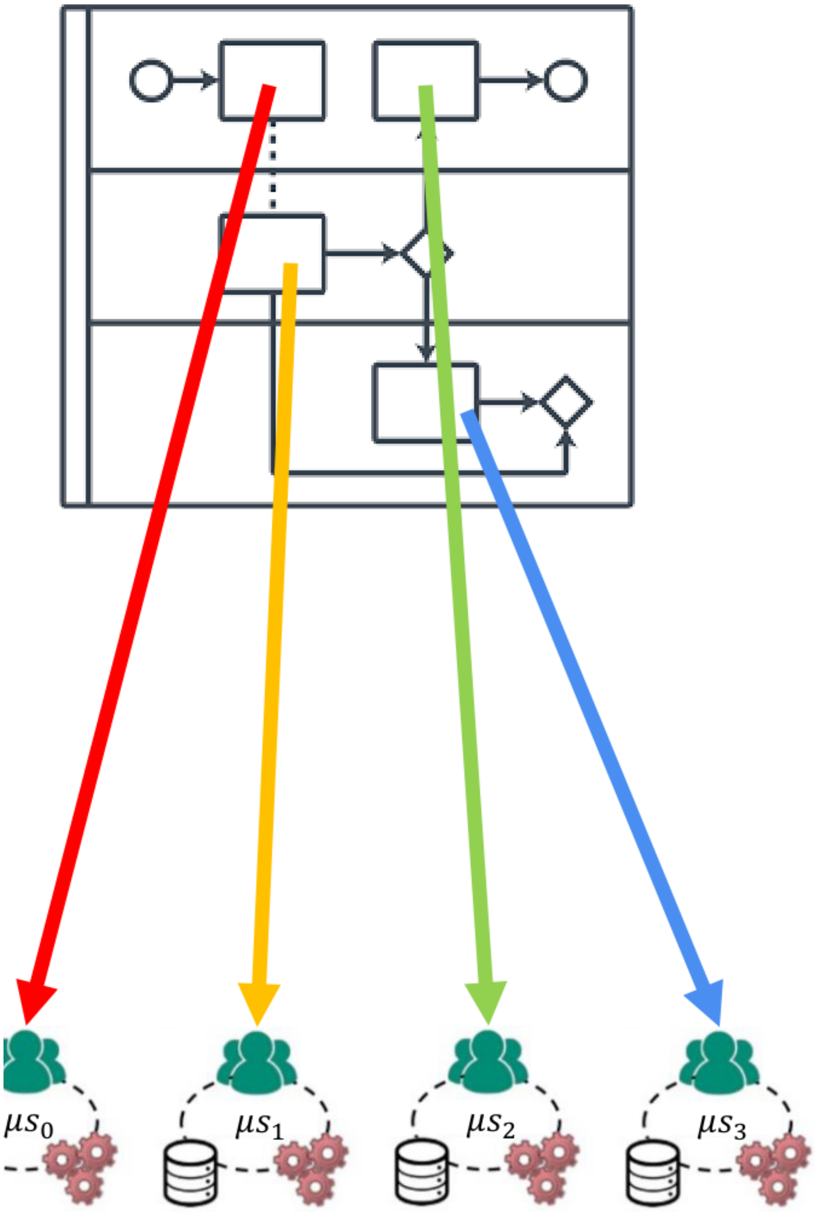


Figure 4: image-20211211133112650

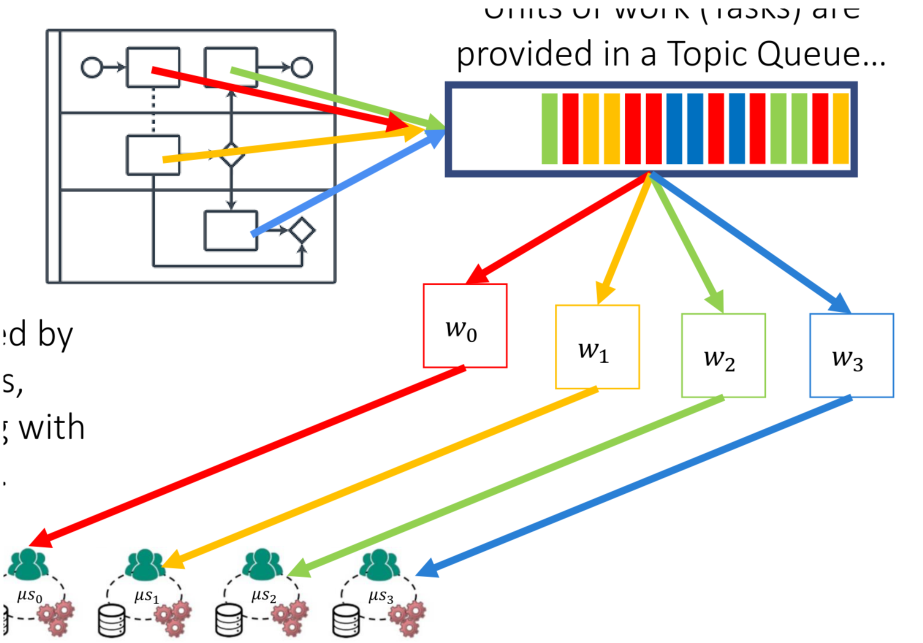


Figure 5: image-20211211133248481

- **Containers complicate credentials/policies handling** Containers are immutable servers that donìt change state after spin up

  But we need to mantain a dynamic list of allowed clients and a dynamic set of access control policies e.g get updated policies from some policy admin endpoint (push vcs pull model)

  Each service must also mantain its own credentials, which need to be rotated periodically e.g keep credentials in container filsystem and inject them at boot time

- **Distribution makes sharing user context harder**. User context has to be passed explicitly from a microservice to another. How can we build trust so that a receiving microserrvice accepts an incoming user context? Popular solution: use Json Web Token

- **Decentralised security responsabilities** Diffenrent teams can use different technlogoy stacks, and this can mean that they use different security practices and tools (i wish there was a unique solution) for static and dynamic analysis.

  Security responsabilites distributed across different teams.

  Usually hybrid approach with centralized security team

Smells

Property	SMELL	SOLUTION
Confidentiality	Insufficient access control	Use Oauth 2.0
Confidentiality	Publicly accessible microservices	Add API gateway
Confidentiality, Integrity	Unneccesary privileges to microservices	Follow the least privilege principe
Conf, Int, Auth	Home made crypto code	Use established encription techniques
Conf, Int, Auth	Non encrypted data exposure	Encrypt all sensitive data at rest
Conf, Int, Auth	Hardcoded secrets	Encrypt secrets at rest
Conf, Int, Auth	Non secured service-to-service comms	Use mutual TLS
Authenticity	Unauthenticated traffic	mutual TLS, openId Connect
Authenticity	Multiple user authentication	Api gateway, OpenId Connect, single sign on
Authenticity	Centralised authorization	Decentralise authorization

---

17. What is static/dynamic vulnerability analysis?

Static vulnerability analysis is a type of white box analysis that has full access to the source code. It uses static analysis techniques to find security vulenrabilities that are caused by the code itself(e.g hardcoded secrets, old libraries with known vulnerabilities, bad crypto practices).

Dynamic vulnerability tesating is a black box analysis. It tries to break the security control and find vulenrabilities by calling multiple applications API endpoints. Its purpose is to find bad designed authentication and authorization policies by exploiting a running application behaviour. IT casn find vulnerabilities such as no CSRF token, XSS, code injection problem, security misconfigs, unneccessary data exposusre ecc..

18. Which are the most frequent API security vulnerabilities?

    See pdf

19. What are authentication and authorization? What are SAML, OIDS and OAuth2.0?

Authentication and authorization

1. Authentication

   Authentication is the **act of confirming the truth** of an attribute of a single piece of data or entity (user of an application, for instance).

   In the digital worlds we tend to simplify the confirmation by using **username and password** (the assumption is that password is known only by the indended user, so specifying the right password you're demonstrating you actually are who you pretend to be).

2. Authorization

   Authorization is the function of **specifying access rights** to resources related to information security and computer security in general and to access control in particular

   - To authorize is to define an access policy

   In the digital world, defining the access rules user by user can be impractical

   Authorization is often implemented with the so called **Role-Based Access Control**(RBAC)

   - users are pooled in groups based on their organizational role (e.g payroll manager, project group A, …)
   - access rights are then asssociated to roles

   When a user access an application:

   - authenticates himself / herself
   - activate one or more roles (depending on the groups of belonging)
   - access services by leveraging RBAC authorization

What are SAML, OIDS and OAuth2.0?

1. SAML (Simple Assertion Markup Language) is a **standard** that **facilitates the exchange of security information**. It is an XML-based framework that enables different organizations (with different security domains) to securely exchange authentication and authorization information.

   To create a SAML infrastructure:

   - an Identity Provider (IdP) must be **installed on top of each organization directory** to permit user authentication in the federation
   - a Service Provider (SP) must be **installed on top of each application** to consume authentication and authorization information obtained from the federation.

2. OpenId Connect (OIDC) is a **standard** that **facilitates the exchange of security information**. OIDC is a framework that uses REST APIs

and JSON format. OIDC enables different organizations (with different security domains) to securely exchange authentication and authorization information.

To create an OIDC infrastructure:

- an openID provider (OP) must be **installed on top of each organization directory** to permit user authentication to the federation (similarly to IdP in SAML)
- a Relying Party (RP) must be **installed on top of each application** to consume authentication an authorization information obtained from the federation (similarly to SP in SAML)

3. OAuth 2.0 is an IETF standard for authorization. OAuth2 defines a mean to represent the authorization granted to the third party, the access token, and a set of flows and mechanisms to:

- obtain the authorization, that is the access token
- convey the authorization to a third-party application
- use the authorization on a protected resource

All on top of the HTTP protocol

OAuth2.0 Actors:

- Resource Owner (RO): the granting access entity, usually the user and his User Agent
- Resource Server (RS): the server hosting the resource to be accessed (e.g. an API)
- Client: the application to which the grant is entitled (a web app, a desktop app, a mobile app, a javascript-on-top-of-user-agent app …)
- Authorization Server (AS): register clients, authenticates users, and issues access tokens.

Access token: a sring representing an authorization issued to the lient (for which is usually opaque). OAuth 2.0 does not mandate the format nor the content of the access token

Refresh token: credentials used to obtain access tokens when the current access token becomes invalid or expires.

Scopes: set of rights delegated to the client on the Resource Server - expressed as a list of space-delimited, case sensitive strings.

```
**Protocol Endpoints**:
  - Authorization endpoint (Authorization Server)
  - Token endpoint (Authorization Server)
  - Redirection Endpoint (Client)\[<ins> SHOULD require the use of TLS by RFC 6749 </ins>\]

**OAuth 2.0 Flows**:
```

```
- Authorization Code Grant
  It is the main flow to obtain an access token, and mainly targeted to web applications.
  - client authentication
  - employ an intermediate authorization phrase represented by an authorization code
  - The access token is exchanged without the involvment of the Resource Owner User Agent
- Implicit Grant. A simplified authorization code flow optimized for clients implemented i
  - No client authentication
  - No intermediary code to obtain the access token
- Resource Owner Password Credentials Grant. It is a flow for highly trusted clients:
  - the resource owner credentials are used directly by the client to obtain an authorizat
```

Splitting the monolith

20. When and where to start splitting a monolith codebase? How to split databases?

When and where

We must start to split a monolith only *when* it becomes a problem. How to define when it becomes a problem is context dependant but there are some usal indicators:

- Codebase has fast pase of change and functionalities continously added
- A lot of code kept together is unrealted
- loose coupling impact performance and manteinance, monolith alwasy deployed all otgether

Where:

Find the seams: portion of code that can be treated in isolation and worked on without impacting the rest of the codease

Bounded context, exploit notion of software modules → create packages representing bounded conext and move existing code (refactor it !) in them

Which context to move first depends on the application and the motivations for splittin

typical drviers:

- pace of change
- team structure
- security
- technology
- tangled dependencies

How to split db

find the seams in the db. Understand which code read and writes db and detect constraints(e.g foreign key relationship used by different parts of code)

- Breaking foreign key relationship

  Services uses info of other service via db foreign key

  Solution: expose data via API in the checked service package

  - More overhead but foreign key lost, constraints managed at the service level, need to implement consinstency checks

- Shared static data

  - Duplicate tables (possible consistency problem)
  - Treat data as code (config files). Easier to update config files than db tables even with consistency issues
  - Expose a separate service (possibly overkill)

- Shared mutable data

  - Solution: move shared data in a new service that can be invoked through API

- Shared tables

  Solution: split table in two, move used contexts to each service needing it. Store two concepts separatelt

21. What is the CAP theorem? What is the SAGA pattern?

    CAP THEOREM: In presence of network partition, you cannot have both availability and consistency

    - Consistency any read operation beginning after a write operation must return that valure or the result of a later write operation

    - Availability: every request received from a non failing node must result in a response

    - Network partition: network can lose arbitrarily many messages sent from one group to another

    SAGA PATTERN:

    A pattern to implement distributed transactions in a lightweight manner.

    Implement each business transaction spanning multiple services as a saga

    A *saga* is a sequence of local transactions

    Each local transaction updates a database and triggers next local trnasactions in the saga

    If one local transaction fails the saga executes compensating transactions (rollback)

    Two ways to coordinate these:

- Coreography: each local transaction publishes event that triggers next transactions in the saga
- Orchestration, an orchestrator tells local participants the transaction to execute

Compensating transactions:

- Backward model, undo changes
- Forward model, retry later (possibly with timeouts and circuit breakers)

22. What is a (event) data pump?

    Data pumps are needed to keep updated the reporting db, which is usually kept as a copy of the actual db. Challenging to update when multiple dbs. When the db is updated, data is pushed to the reporting systems (possibly in bulks and not every individual transactions)

    Normal data pumps:

    - data pushed directly to the reporting system
    - data pump maps service db to the reporting schema
    - data pump version controlled together with service
    - coupling worth to makw reporting easier
    - data pump built & managed by the team managing serviceù

    Event data pumps:

    - Microservices emits events based on the state change of entities managed
    - write event subscribers listen for these events and pump data in the reporting database
    - no coupling with service
    - just binding to events meant to be exposed
    - event based is usually faster than periodically scheduled data pumps
    - can be managed independently
    - drawback: all info broadcasted as event, not very good scaling for large volumes of data

Cloud-IoT continuum

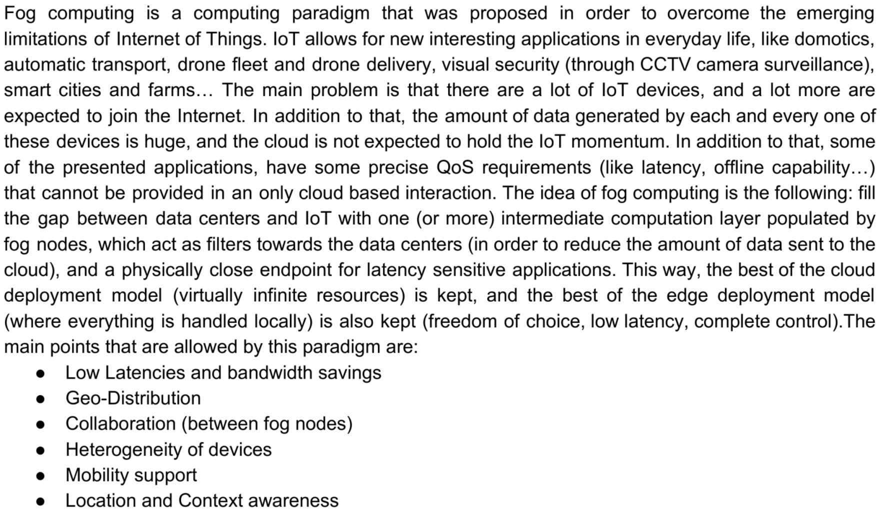
23. What is Fog computing? What are (declarative) application placement and continuous reasoning over the Cloud-IoT continuum?

    Declarative placement:

    App deployment becomes a very complex problem (NP Hard) in a Fog context. You have a set of App requirements (Hardware, Software, QoS) and a fog infrastructure (Heterogenenous, Large, Dynamic).

    How to decide the “best” place to deploy an application component?

    How to estimate a “good” placement?



Fog computing is a computing paradigm that was proposed in order to overcome the emerging limitations of Internet of Things. IoT allows for new interesting applications in everyday life, like domotics, automatic transport, drone fleet and drone delivery, visual security (through CCTV camera surveillance), smart cities and farms… The main problem is that there are a lot of IoT devices, and a lot more are expected to join the Internet. In addition to that, the amount of data generated by each and every one of these devices is huge, and the cloud is not expected to hold the IoT momentum. In addition to that, some of the presented applications, have some precise QoS requirements (like latency, offline capability…) that cannot be provided in an only cloud based interaction. The idea of fog computing is the following: fill the gap between data centers and IoT with one (or more) intermediate computation layer populated by fog nodes, which act as filters towards the data centers (in order to reduce the amount of data sent to the cloud), and a physically close endpoint for latency sensitive applications. This way, the best of the cloud deployment model (virtually infinite resources) is kept, and the best of the edge deployment model (where everything is handled locally) is also kept (freedom of choice, low latency, complete control).The main points that are allowed by this paradigm are:

- Low Latencies and bandwidth savings
- Geo-Distribution
- Collaboration (between fog nodes)
- Heterogeneity of devices
- Mobility support
- Location and Context awareness

Figure 6: image-20211214092725795

Especially challenging for mission critical applications.

A solution is to convert the problem to a *declarative problem*. You use a specific syntax to declare what constraint you want to satisy and you let an automatic solver find all the possible *placements*. We can model requirements as predicates and use Prolog.

You describe what you want in the solution, NOT how to achieve it.

A problem with this approach is the fact that fog structures are dynamic. Two main issues:

- Prolog is a fact based approach. Need to use a probabilistic approach to model the possibility of unexpected changes → Problog predicates
- Handling redeployments in the presence of infrastructure changes. Redeploying the entire system at any change is going to be too complex (NP Hard problem, exp worst time) and a waste of resources since we dont need to change placements not affected bu the infrastructure changes.

  We solve the last issue with continous reasoning:

  Continuous reasoning is a technique inspired by things like CI/CD and usually used in software enginnering to differentially analyse large-scale system by exploiting compositionality. We mainly focus on latest changes and reuse computed results as much as possible (e.g FB Infer, works on diff and not the entire source code all the time).

Continuous reasoning for application placement:

What for?

- Scale to larger instances of the placement problem
- Reduce time needed to make placement decisions at runtime
- Possibly reduce the number of management operations (stop, undeploy, deploy, start)
- How? Re-place only services affected by infrastructure and CI/CD changes

24. How can we assess the security level of an application deployment? How can we model trust?

Enforcing security in a fog context can be quite challenging. A fog architcture increase the attack surface by exposing a lot more of possible entry points and shares a lot of the threats with cloud computing (enforciing isolation, man in the middle ecc.)

It is also to exposed to more peculiar threats because fog nodes are physicially accessible (social engineering, access security in place ecc.)

We can use a declarative approach for security as well.

We first define a taxonomy of possible secruity measure that a Fog infrastructure can enforce. This ranges from mitigation measures for software vulnerabilities, access and communication control , sensitivie data control, Physical security ecc.

Fog infrastructure is managed by *multiple* operators. Indeed a fog deployment span various service providers. To manage and assess security we assume that each node self-describes its capabilities and effect against attacks with a node descriptor that uses the taxonomoy described. This allows us to have a complete view of the available security capabilities.

On the other hand we have an app operator that describes the app topology and its security requirements both at the component and application level leveraging the taxonomy.

Security requirements can be desscribed with custom security policies in terms of default security policies specified by the model (in this case SecFog). The app operator can also specify complete and partial deployment of application and the trust degrees towards different infrastructure operator.

This constitute the security requirements of the multi component app.

We leverage a reasoning enginge (problog) that takes as input the requirements and capabilities and outputs possible deployments annotating them with their security level.

Modeling trust:

We build a trust network where operators are nodes and directed arc between them are annotated with the associated trust level (opinions).

Default trust model:

- opinions along paths are combined via multiplication
- opinions across paths are combined via addition

Limitation in the default model:

1. It is monotonic, all paths toward a provider increases trust degree towards it

2. Unconditionally transitive (if A trusts B and B trusts C → A trusts C)

   We can use more sophisticated models using semirings

Commutative semiring

An algebraic data structure consisting of a 5-tuple:

$(S, \oplus, \otimes, 0, 1)$

where S is a set of elements and

$$\oplus$$

and

$$\otimes$$

are two binary operators defined over

$$S$$

such that:

- $$\oplus$$

  is commutative and associative, with 0 as its neutral element
- $$\otimes$$

  is associative, distributes over

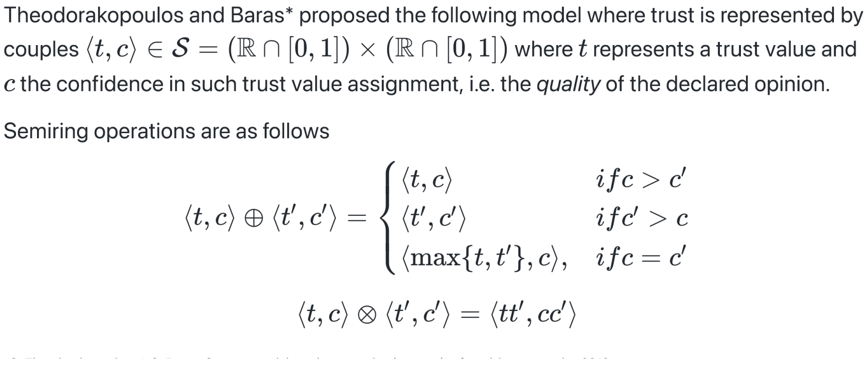
  $$\oplus$$

  and 1 and 0 are its neutral and absorbing element

A different trust model

Non monotonic and optimistic model. A pessimistic model takes the minimum instead.

Conditional transitivity



Theodorakopoulos and Baras* proposed the following model where trust is represented by couples $\langle t, c\rangle \in \mathcal{S} = (\mathbb{R} \cap [0,1]) \times (\mathbb{R} \cap [0,1])$ where t represents a trust value and c the confidence in such trust value assignment, i.e. the *quality* of the declared opinion.

Semiring operations are as follows

$$\langle t, c\rangle \oplus \langle t', c'\rangle = \begin{cases} \langle t, c\rangle & if c > c' \\ \langle t', c'\rangle & if c' > c \\ \langle \max\{t, t'\}, c\rangle, & if c = c' \end{cases}$$

$$\langle t, c\rangle \otimes \langle t', c'\rangle = \langle tt', cc'\rangle$$

Figure 7: image-20211214101225052

Limit transitivity to a radius. As an example, if we pick a radius of 3 a operator transitivitely trsuts only the next three operator along a path in the trust network.

25. What is secure FaaS orchestration?