Evaluation of Microservice Architecture Designs in an IoT-Context

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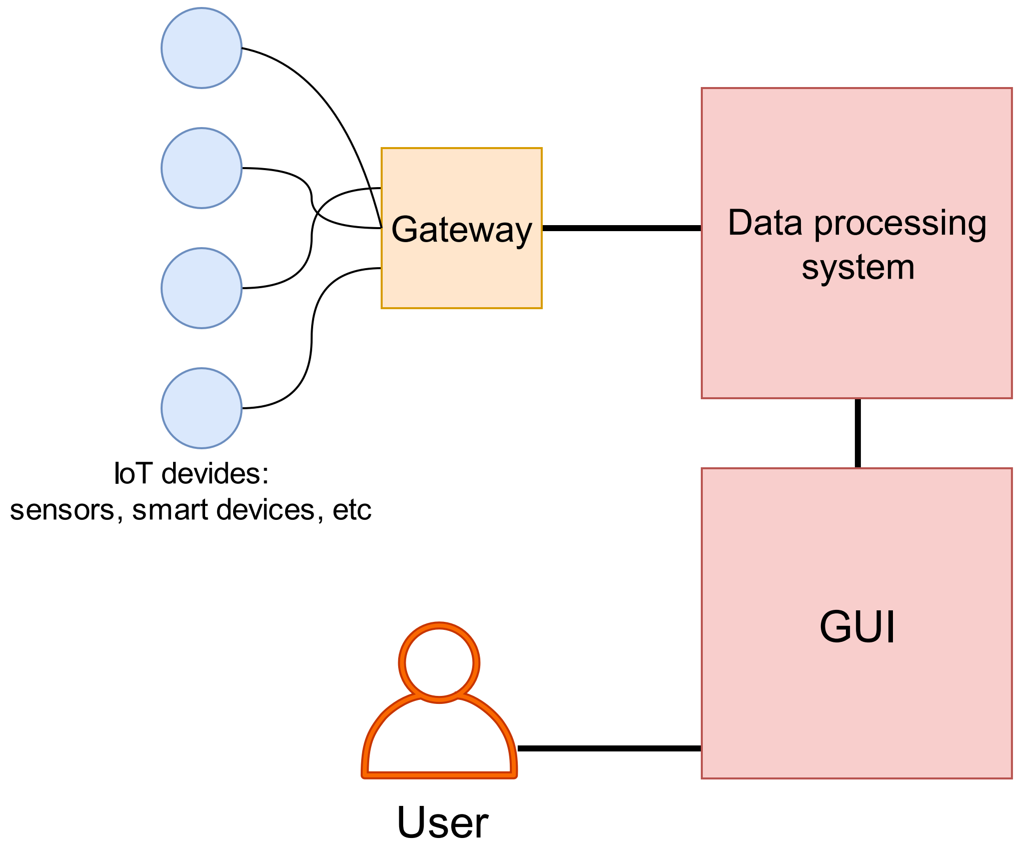
Content

Introduction

The Internet of Things

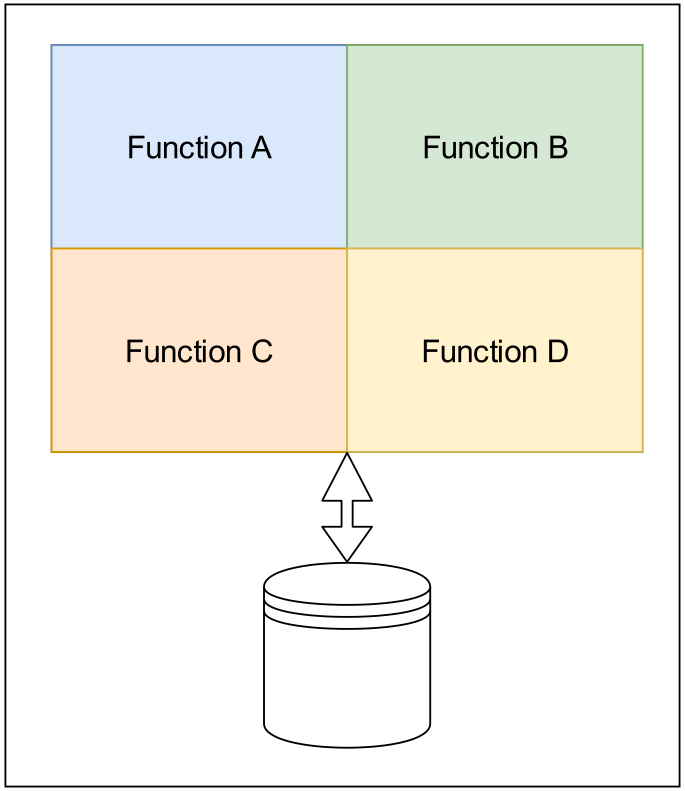


IoT architecture diagram.

IoT architecture elements:

- *Gateway* collects and transports IoT devices data.
- *DPS* is the main data processing system.
- *GUI* represents processed data to end users.

Monolithic architecture



Monolithic architecture example.

Drawbacks:

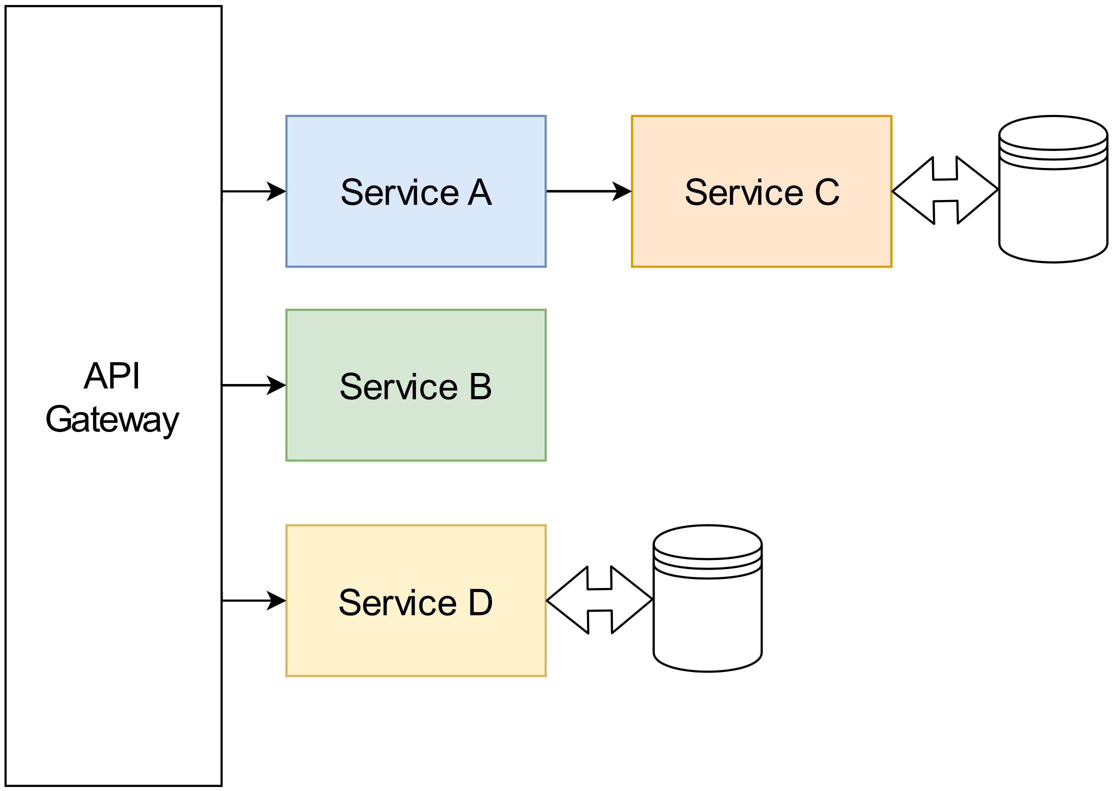
- Can not be horizontally scaled
- Modules share the same memory space
- A module bugs affect the whole application
- Continuous deployment is almost impossible

Advantages:

- Easy to develop and deploy

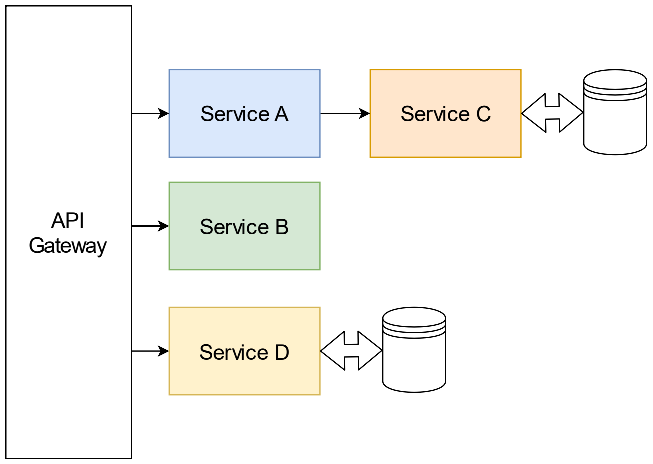
Suitable for lightweight and not multifunctional applications.

Microservices architecture



Microservices architecture example.

Microservices architecture



Microservices architecture example.

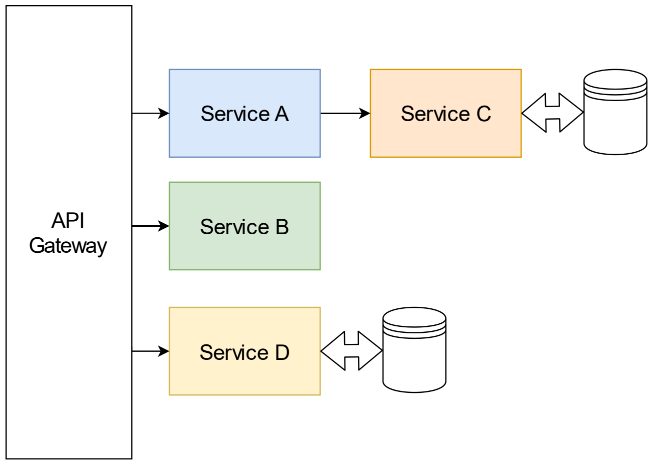
Advantages:

- Functional decomposition
- Each service can be scaled independently
- Services do not share the same memory space
- Each service is developed independently

Drawbacks:

- Complex deploying and testing
- Difficult interconnection process

Microservices architecture



Microservices architecture example.

Advantages:

- Functional decomposition
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- Services do not share the same memory space
- Each service is developed independently

Drawbacks:

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Suitable for high-loaded and multifunctional application such as IoT data processing system

The main goal

To find the most performable MSA architecture design in an IoT context.

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We compared:

► Interconnection methods

► Database management systems

► Load balancing strategies

What we have done

1. Analyzed the most demanded technologies in MSA context.
2. Built the MSA application, satisfying the most common requirements.
3. Developed a load generation, simulating IoT devices.
4. Implemented a monitoring system
5. Processed measurements.

Requirements

Functional requirements

1. Provide connectivity for IoT devices.
2. Transform IoT device data model to the system data model.

Non-functional Requirements

Qualitative

- Testable
- Reproducible
- Deployable

Non-functional Requirements

Qualitative

- Testable
- Reproducible
- Deployable

Quantitative

- Response time
- Scalable

State of the art

Basic articles

M. S. Hatem Hamad and R. Abed, “Performance evaluation of restful web services for mobile devices,” *Computer Engineering Department, Islamic University of Gaza, Palestine, International Arab Journal of e-Technology*, 2010.

In the article advantages of RESTful web services before SOAP web services are shown:

- RESTful web services provide less message size.
- RESTful web services provide less response time.

Basic articles

P. J. Amaral M. and C. D., “Performance evaluation of microservices architectures using containers.,” *IEEE 14th International Symposium on Network Computing and Applications*, 2015.

This article shows Server Virtualization provides performance improvement

- SV increases server throughput
- SV decreases server latency

Basic articles

- J. F. Kunhua Zhu and Y. Li, *Research the performance testing and performance improvement strategy in web application", 2nd international Conference on Education Technology and Computer.* 2010.

This article provides a survey about overall MSA based application testing :

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This article provides a survey about overall MSA based application testing :

- Functional and load testing of web MSA based web applications basis.
- Prediction of an application response time changing with an increasing user load.
- User load impact on application throughput.
- Possible bottlenecks caused by system utilization.

Not answered questions

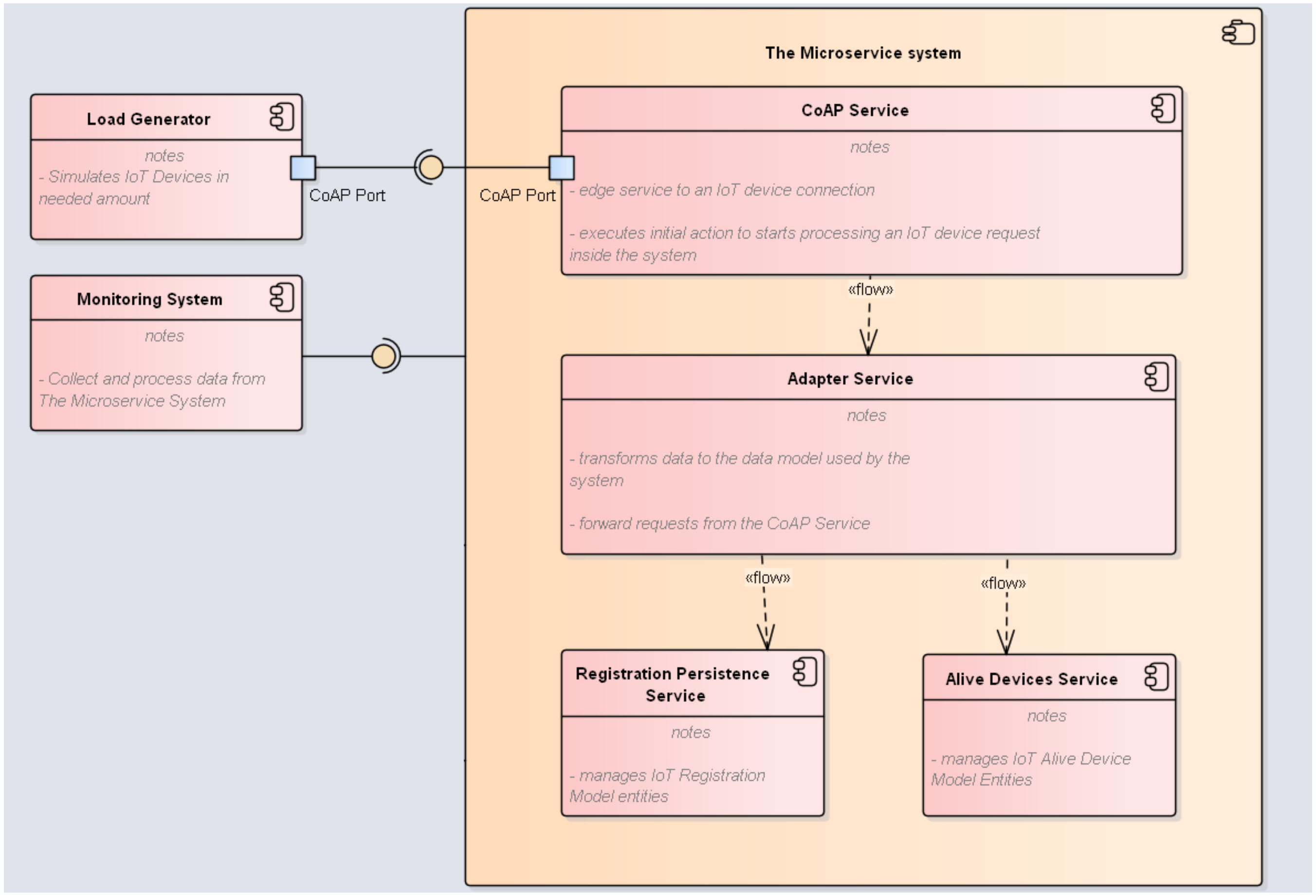
- Which design chooses we have to made to build MSA system in an IoT-device context?
- Which interconnection method fits a certain service functionality better?
- How to use load balancing according to services functionality?

The system overview

The system developing

- The MS system must provide connectivity, session management, and data model transformation.
- Response time is assessment criteria.
- The server virtualization and imaging
- Load generator simulates a given amount of IoT devices

The system developing


The Microservice system
Load Generator
notes
- Simulates IoT Devices in needed amount
CoAP Port
CoAP Port
CoAP Service
notes
- edge service to an IoT device connection
- executes initial action to starts processing an IoT device request inside the system
«flow»
Monitoring System
notes
- Collect and process data from The Microservice System
Adapter Service
notes
- transforms data to the data model used by the system
- forward requests from the CoAP Service
«flow»
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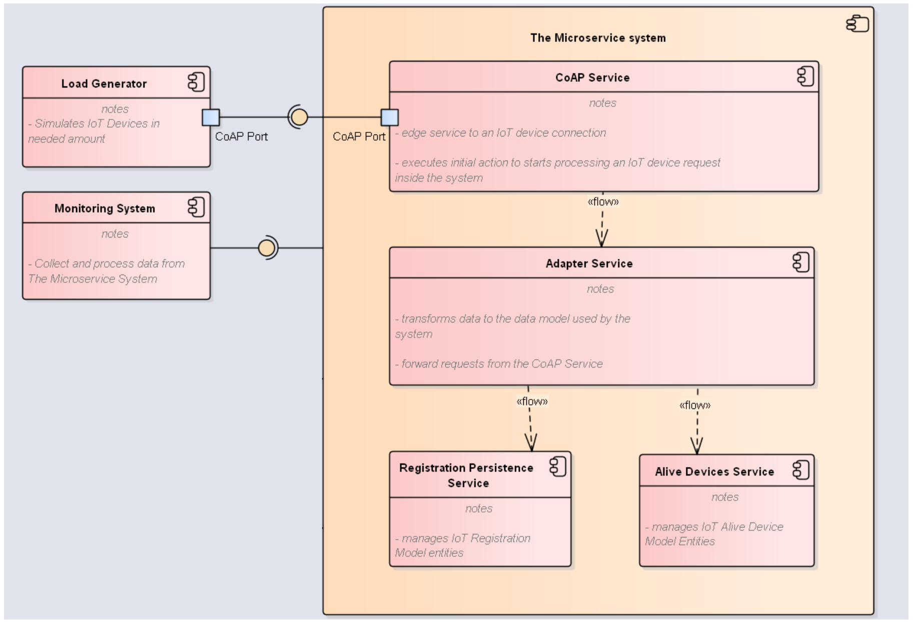
Registration Persistence Service
notes
- manages IoT Registration Model entities
Alive Devices Service
notes
- manages IoT Alive Device Model Entities

The system components diagram.

The system developing



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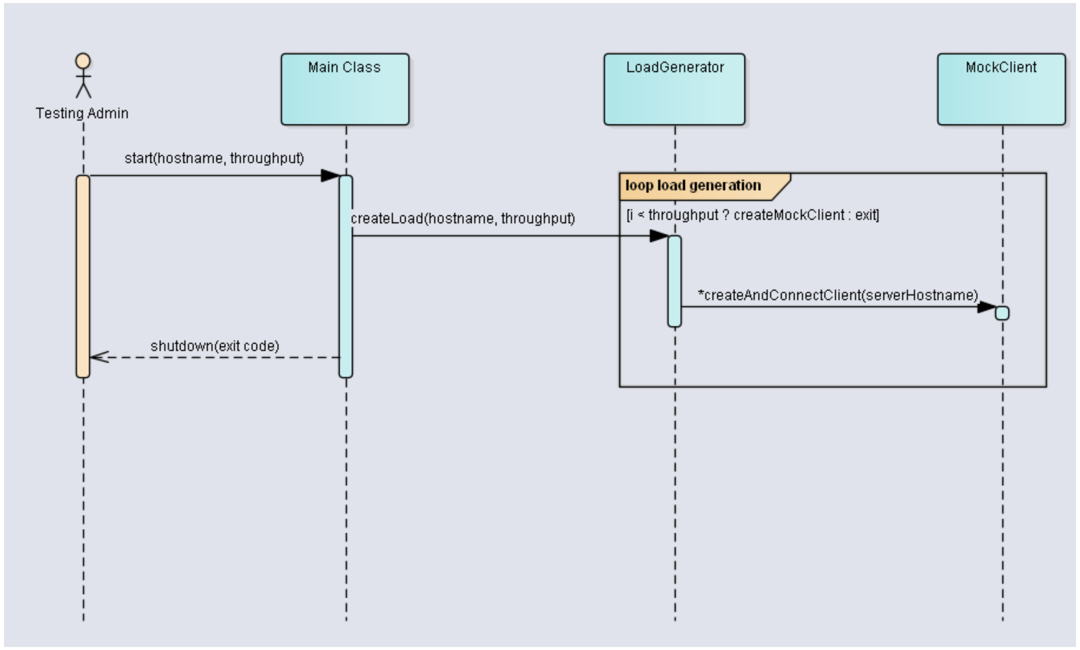
The system components diagram.

3 service types:

- Edge service – *CoAP service* provides connectivity for IoT devices
- Data transformation service – *Adapter service* generates the system data models for further their processing
- Persistence services – *Registration* and *Alive devices persistence* service ensure system object storing.

Load generation

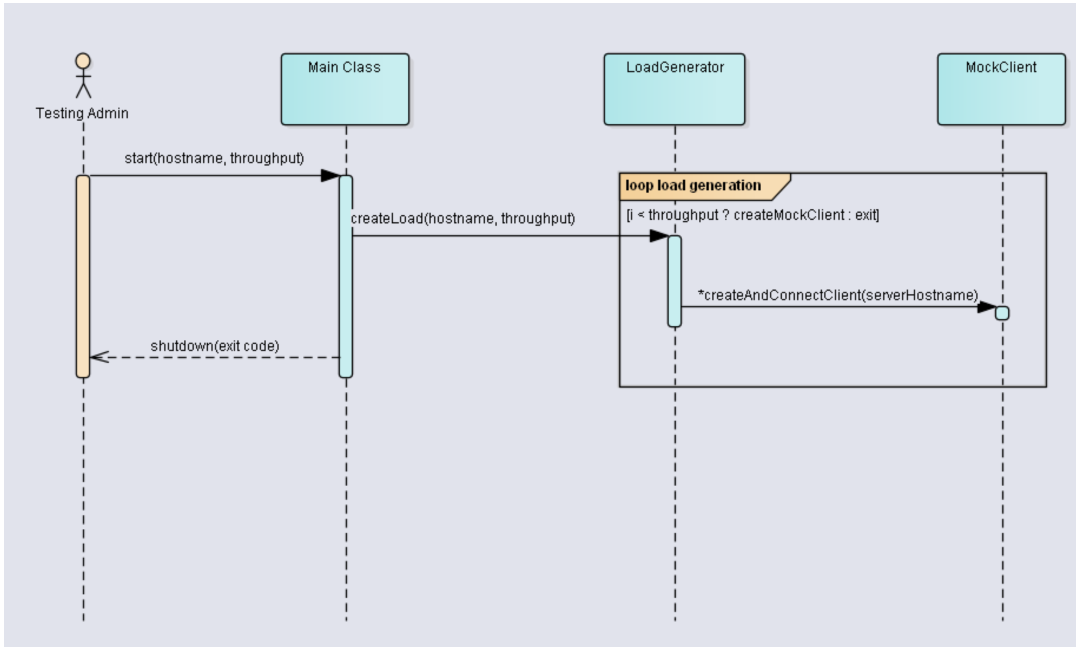

Testing Admin
Main Class
LoadGenerator
MockClient
start(hostname, throughput)
createLoad(hostname, throughput)
loop load generation
[i < throughput ? createMockClient : exit]
*createAndConnectClient(serverHostname)
shutdown(exit code)

Load generation sequence diagram.

For each of the interconnection type we generated load of approximately 50% system maximal throughput.

- HTTP(sync) – 10 devices.
- HTTP(async) – 90 devices.
- gRPC – 170 devices.
- RabbitMQ – 290 devices.

Load generation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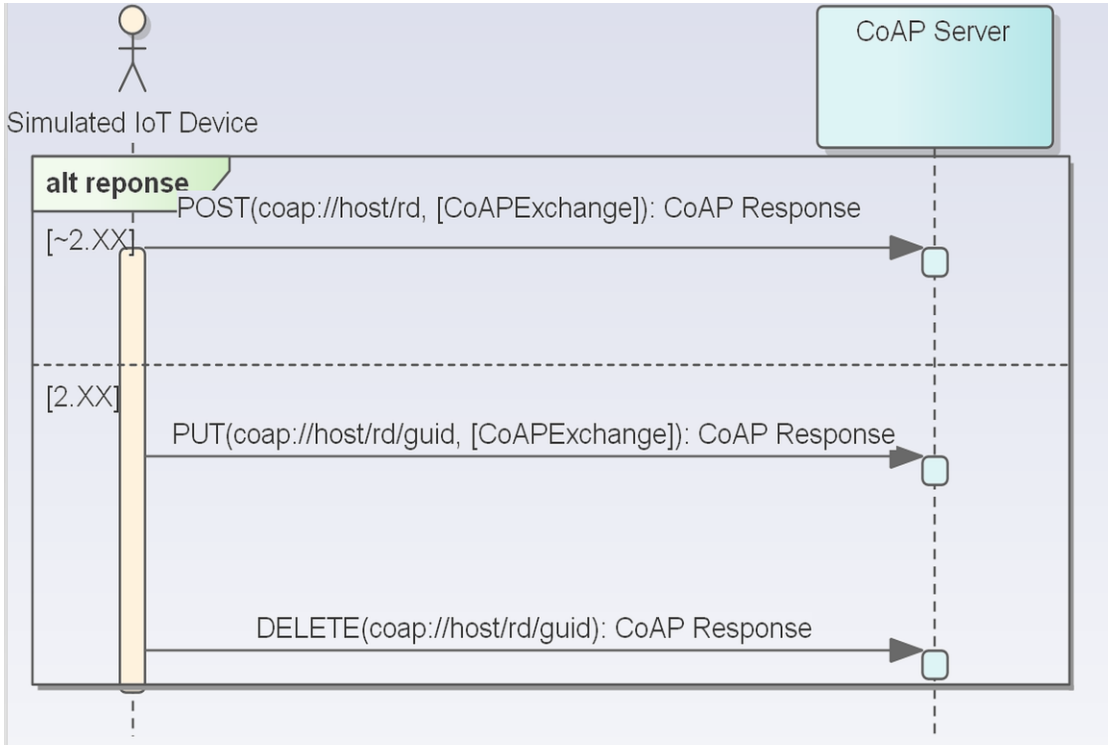
- gRPC – 170 devices.
- RabbitMQ – 290 devices.

We repeat every test run 30 times to ensure more accurate results.

Silmulated IoT device

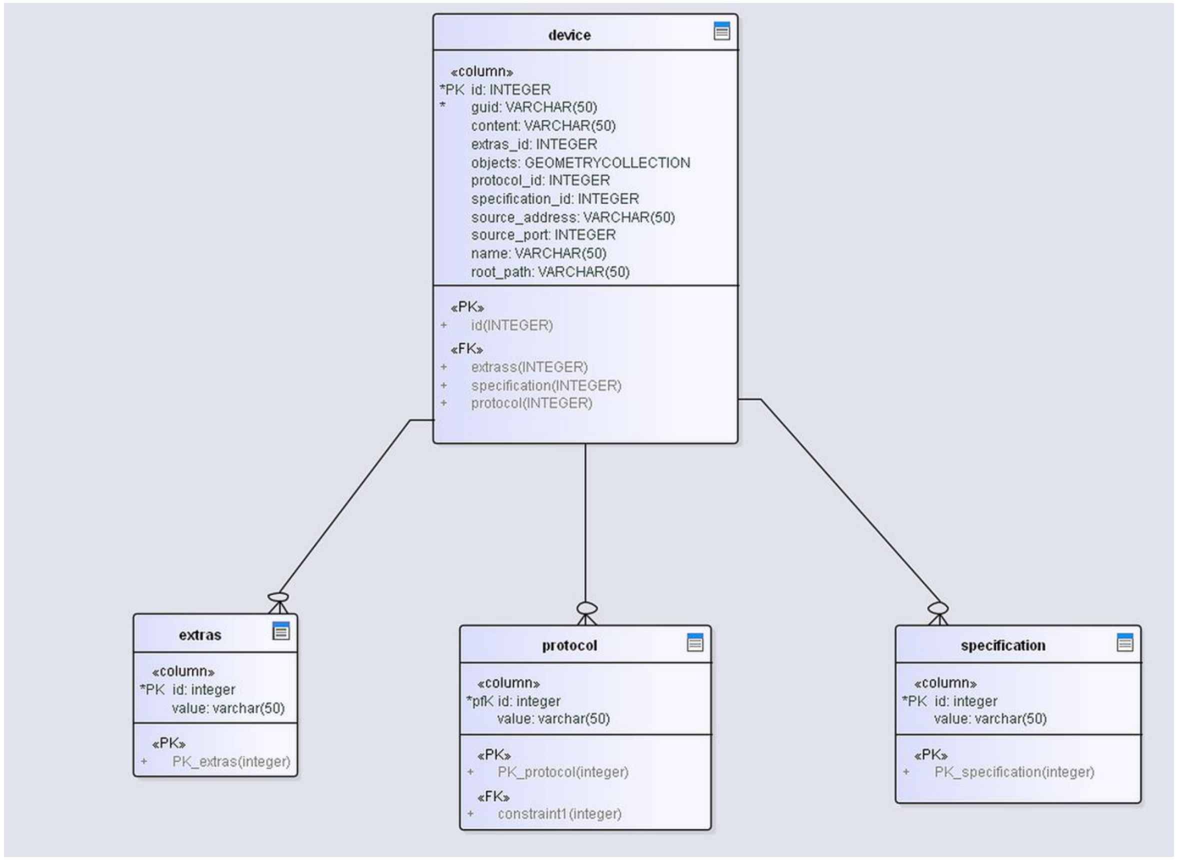

Simulated IoT Device
CoAP Server
alt reponse
[~2.XX]
POST(coap://host/rd, [CoAPExchange]): CoAP Response
[2.XX]
PUT(coap://host/rd/guid, [CoAPExchange]): CoAP Response
DELETE(coap://host/rd/guid): CoAP Response

Simulated IoT device lifecycle SD.

Requests:

- POST – to save IoT device on the given host
- PUT – to update information about IoT device on the given host
- DELETE – to delete information about IoT device on the given host

Registration data model

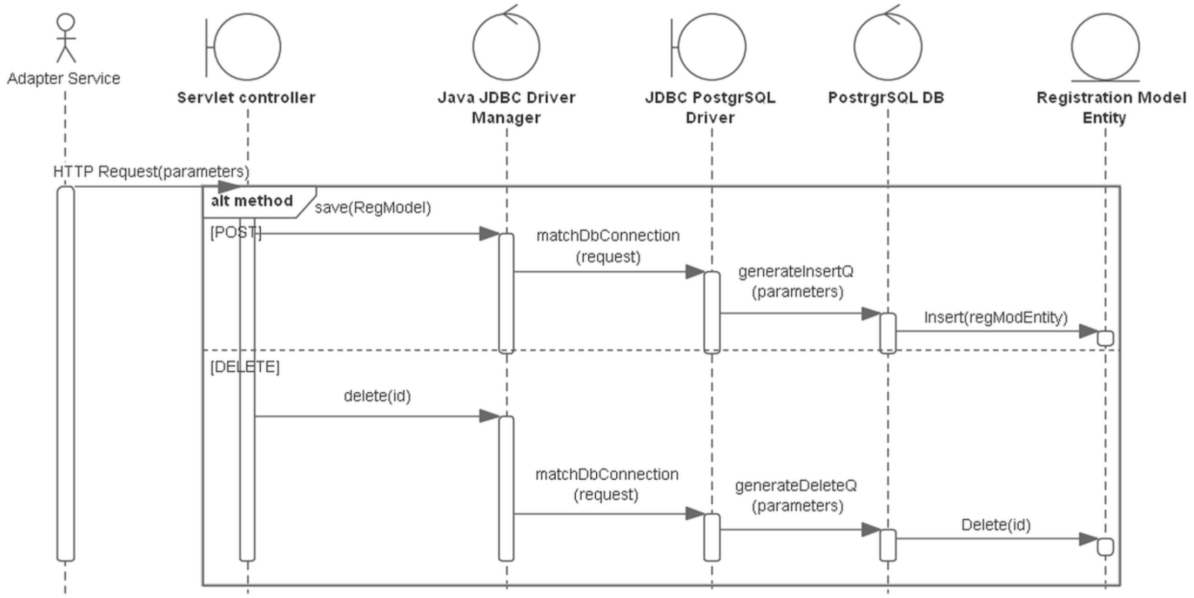


Registration data model diagram.

- Contains a device description.

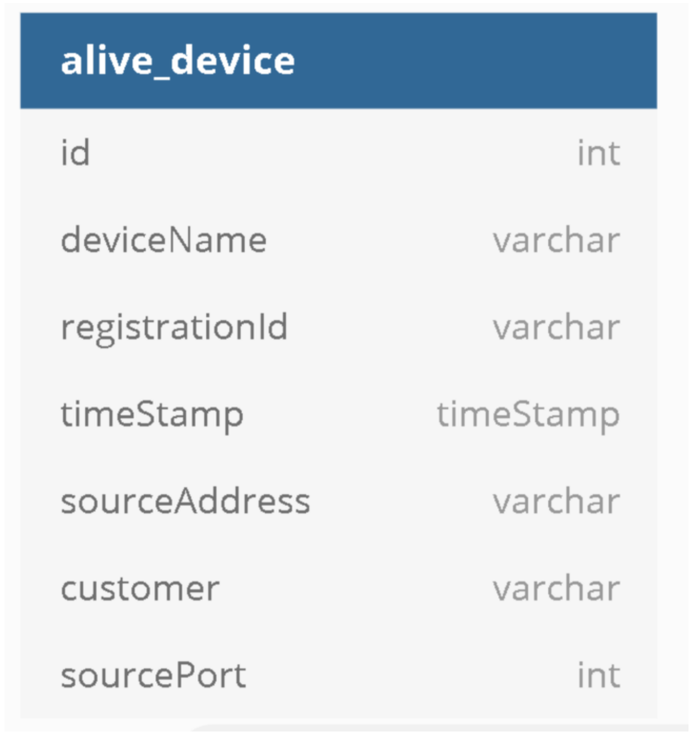
Registration persistence service

- Processes device registration in the system.
- Persists information about connected devices to the system.



Registration sequence diagram.

Alive devices model



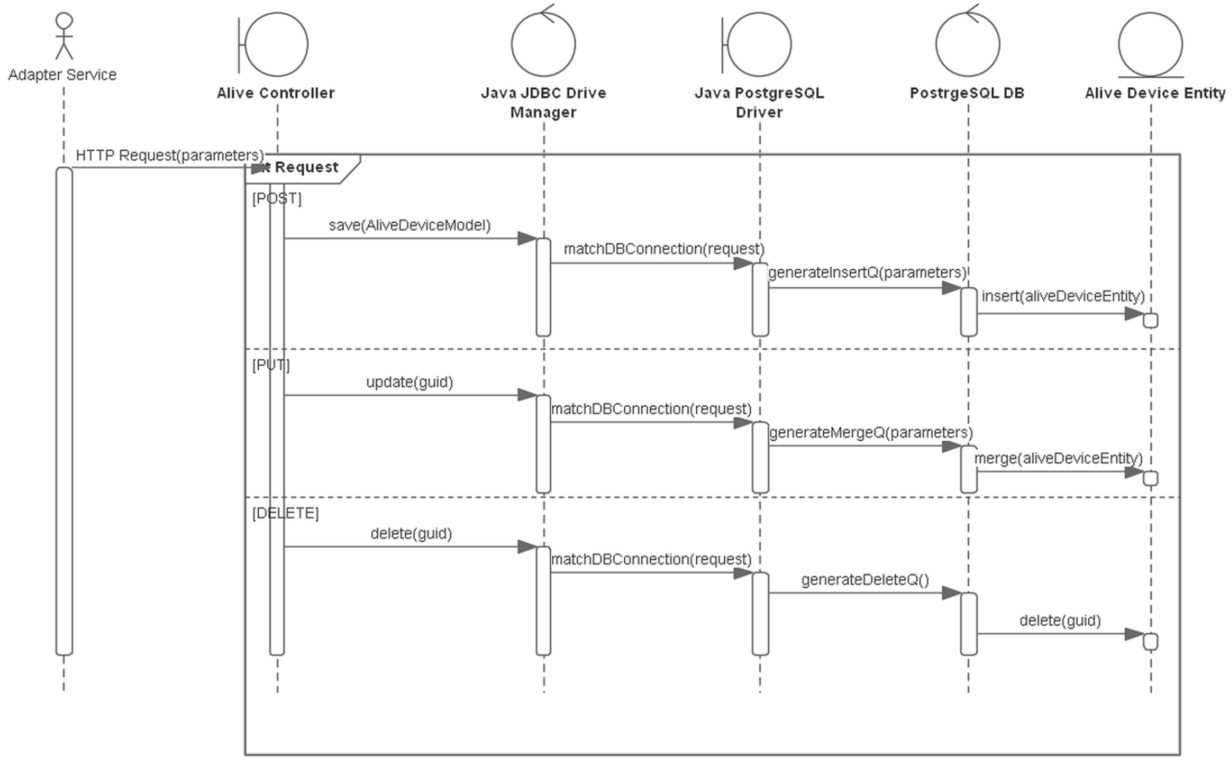
alive_device	
id	int
deviceName	varchar
registrationId	varchar
timeStamp	timeStamp
sourceAddress	varchar
customer	varchar
sourcePort	int

Alive device model diagram.

- Contains information about IoT devices current activity.

Alive devices service

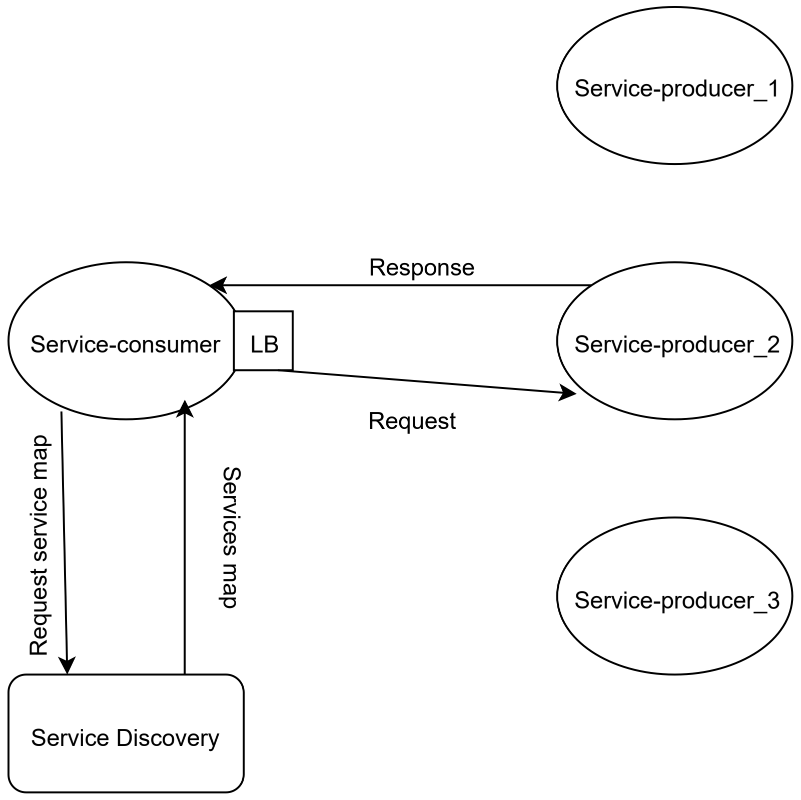
- Ensure alive device entity management



Alive devices service SD.

Client-side LB

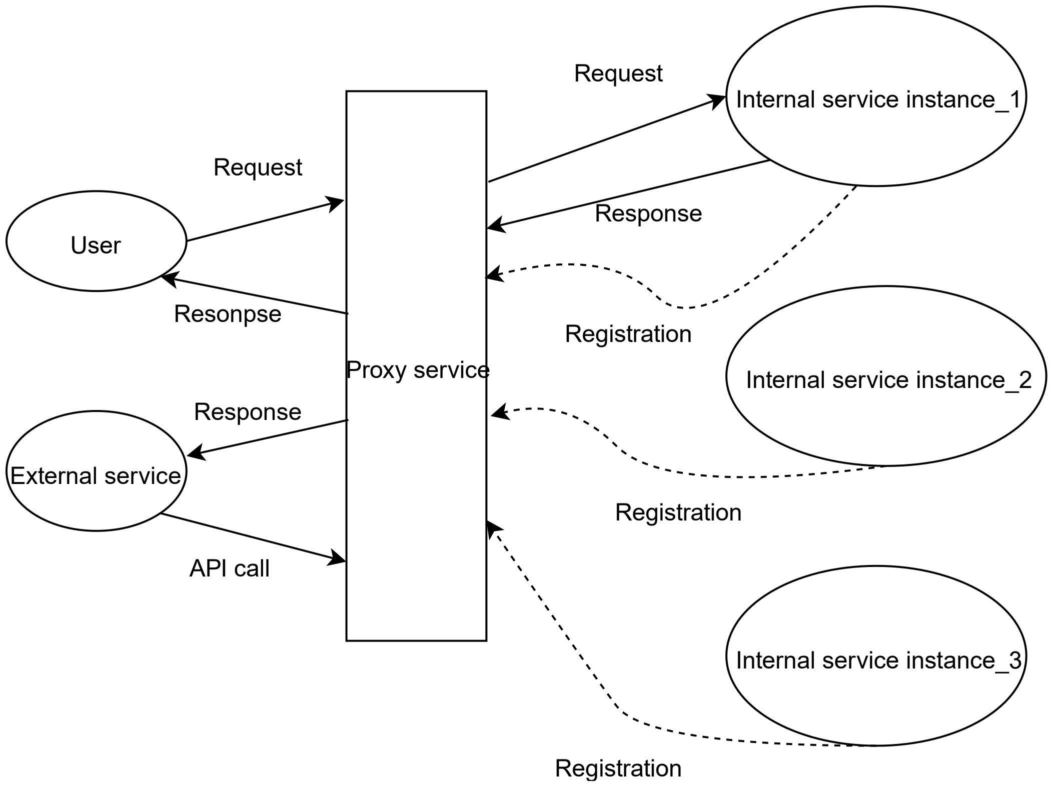
- Each service knows about other service instances.
- Every service instance must connect to service discovery.



Client-side LB diagram.

Server-side LB

- Each service instance knows only URI of requesting service.
- Every service instance has to connect to proxy/gateway service.

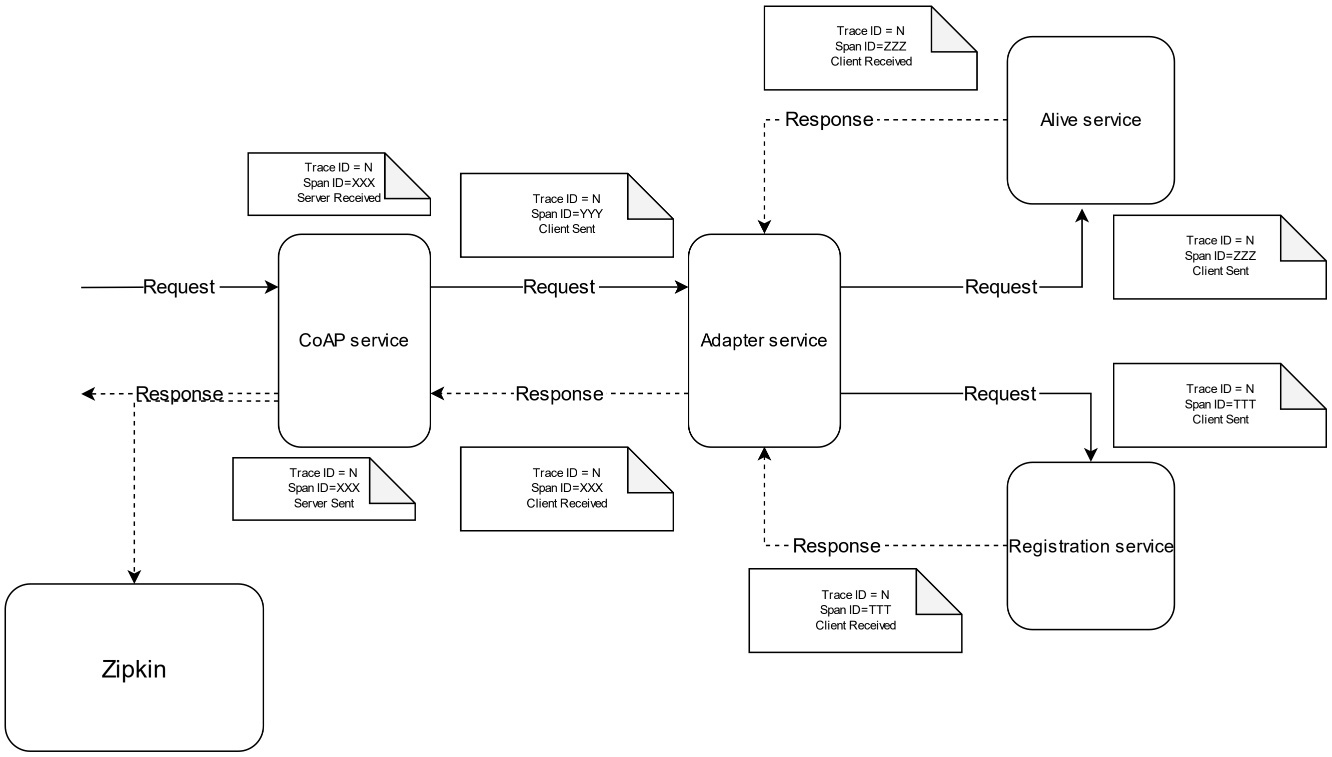


Server-side LB diagram.

Measuring system

- To measure response time we used *distributed tracing* system.
- We stored trace logs in *document-oriented* DB.
- We used Elasticsearch engine to retrieve and analyze logs

Measuring system

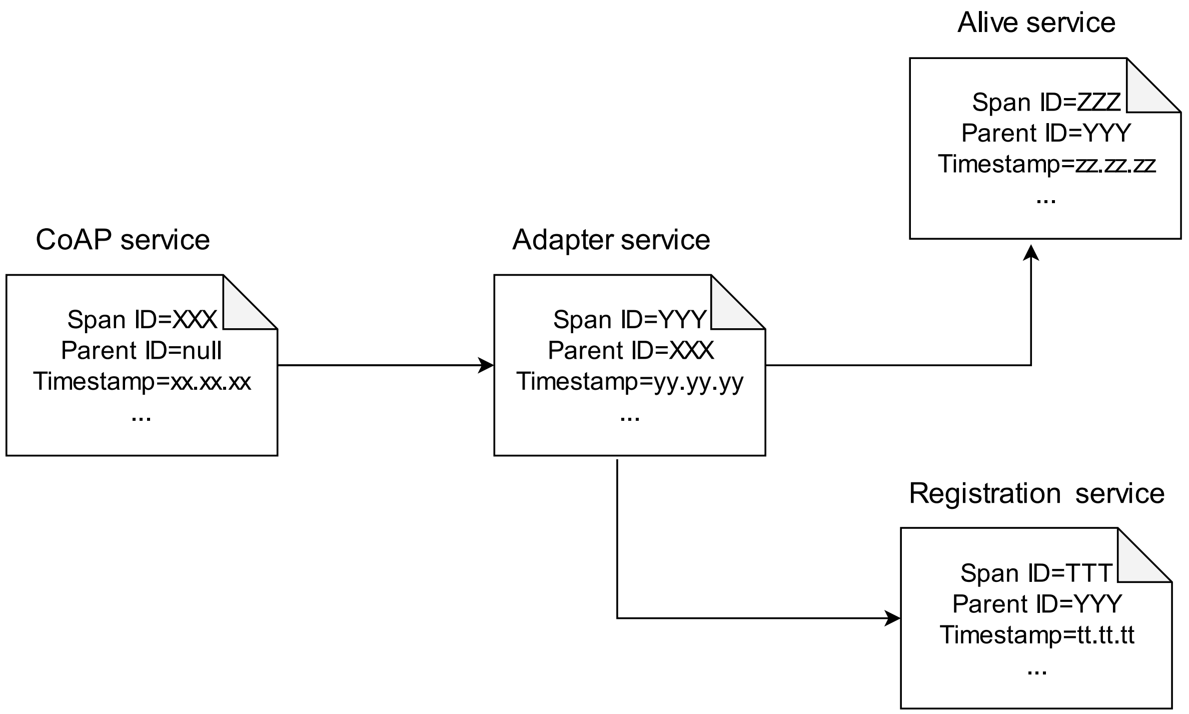


Measuring system diagram.

Measuring system

Each span contains:

- Its ID
- Trace ID
- Parent ID
- Timestamp
- Duration
- Endpoint info
- Custom Tags

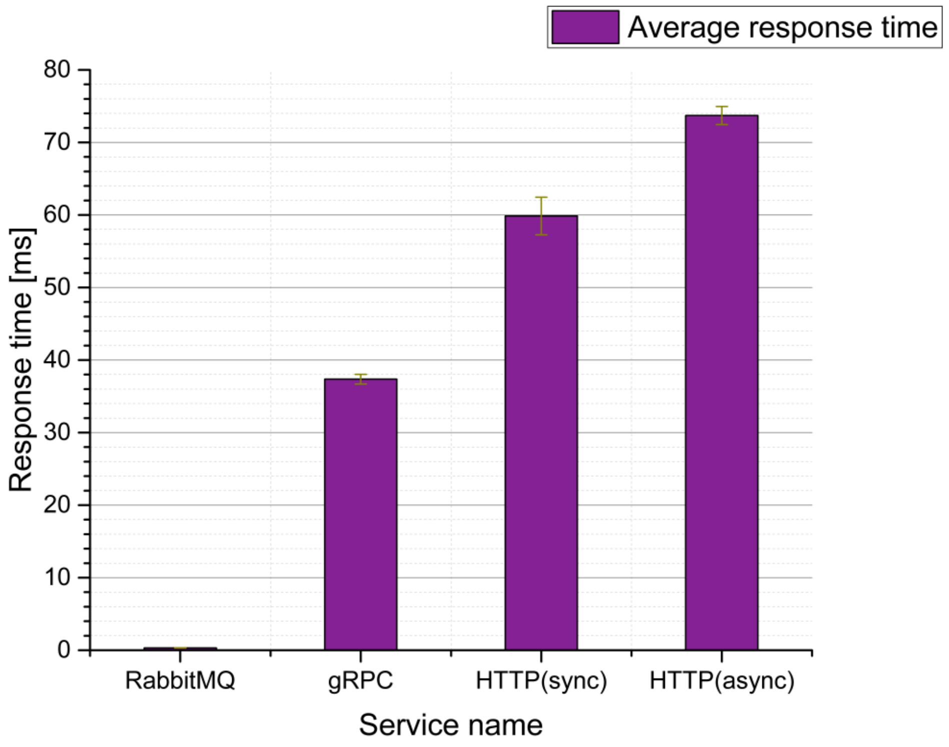


Span child-parent relationship diagram.

Results

Interconnection comparison

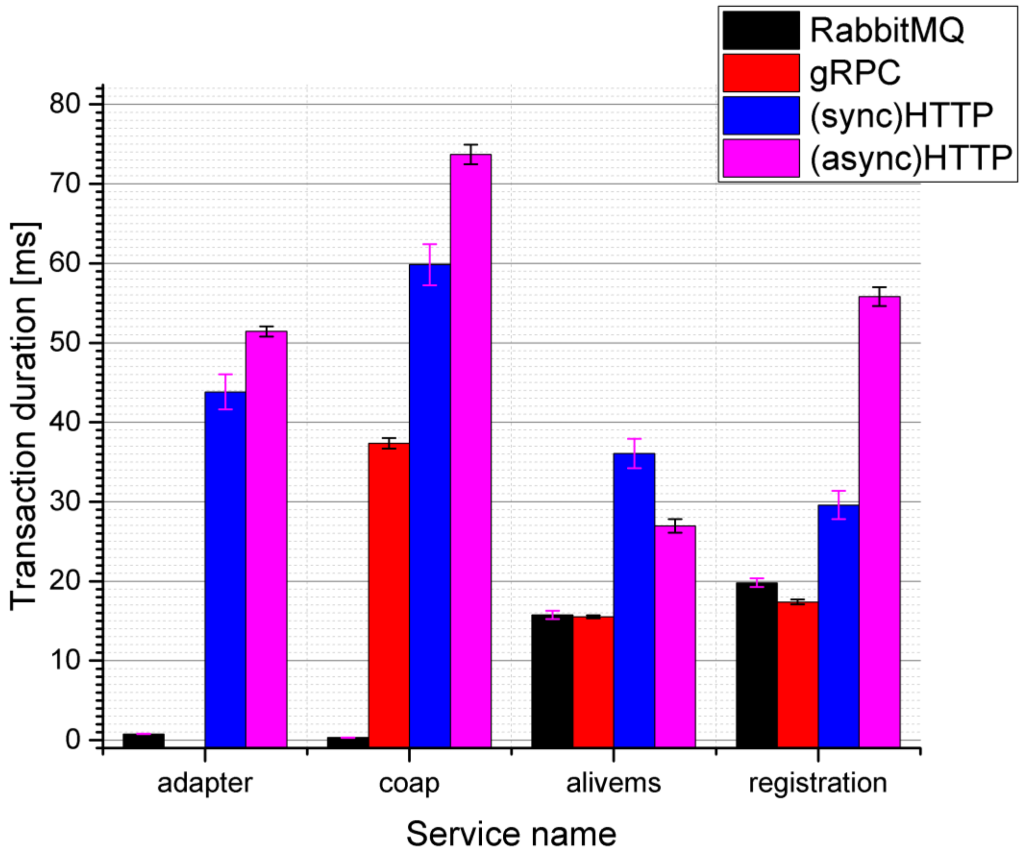
- RabbitMQ provides the lowest response time of less than 1 millisecond.
- Async. HTTP provides the highest response time, a bit higher 70 milliseconds.



Transaction duration by service

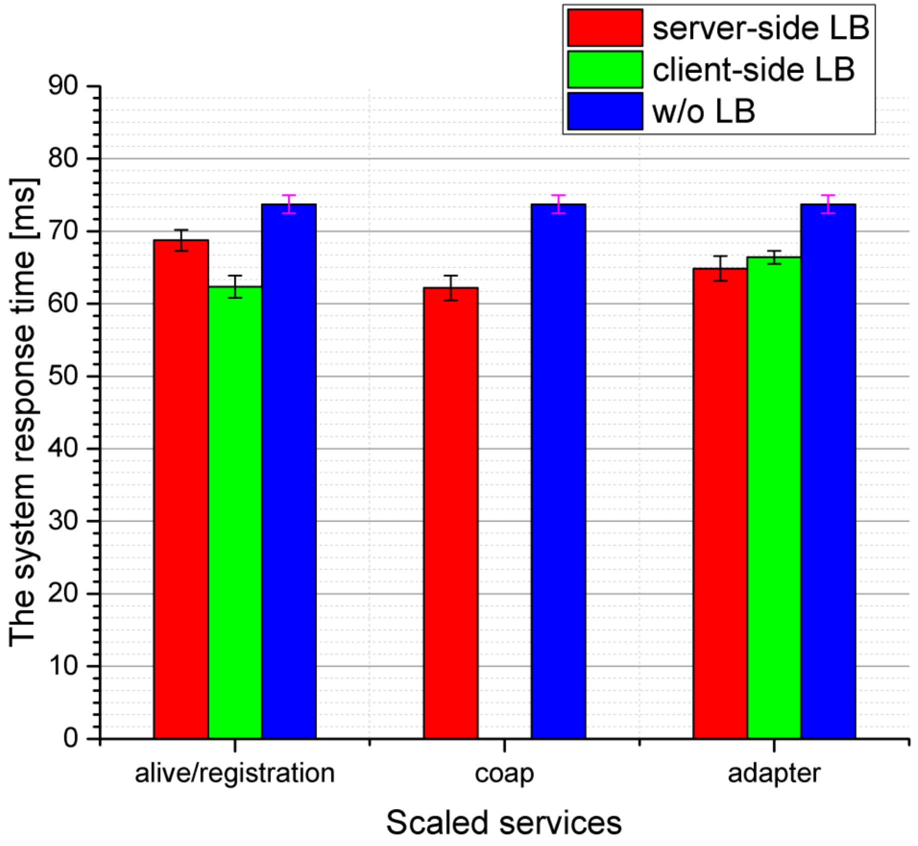
- gRPC interconnection provides lowest transaction duration time of the persistence services.

- RabbitMQ provides the lowest transaction duration time of the non-persistence services.



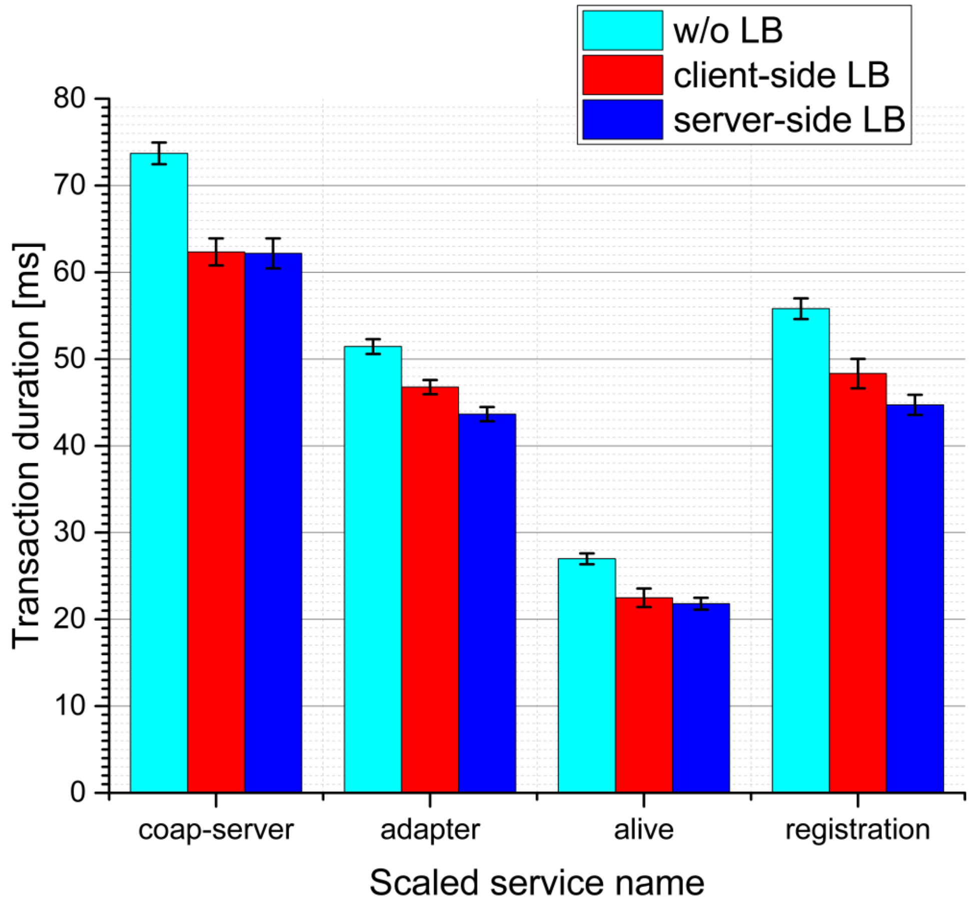
Load balancing strategies comparison

- Client-side LB strategy provides about 10% less a system response time, scaling persistency services.
- Server-side LB strategy improves the system response time by almost the same amount but by scaling edge service.



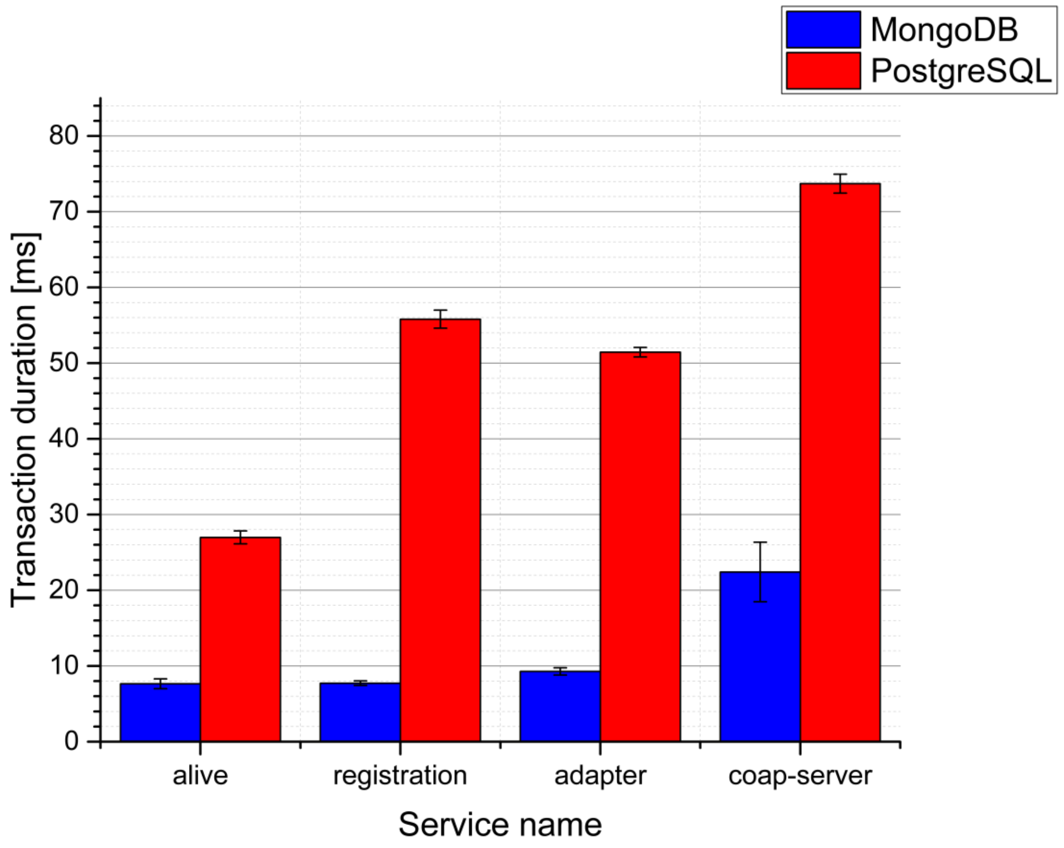
LB Impact on services

- Server-side LB provides slightly faster response time of each service.



DBMS comparison

- MongoDB requires significantly less time to execute database operations.
- To process a write DB operation, it needs 8 milliseconds, approximately.



Conclusion

Conclusion

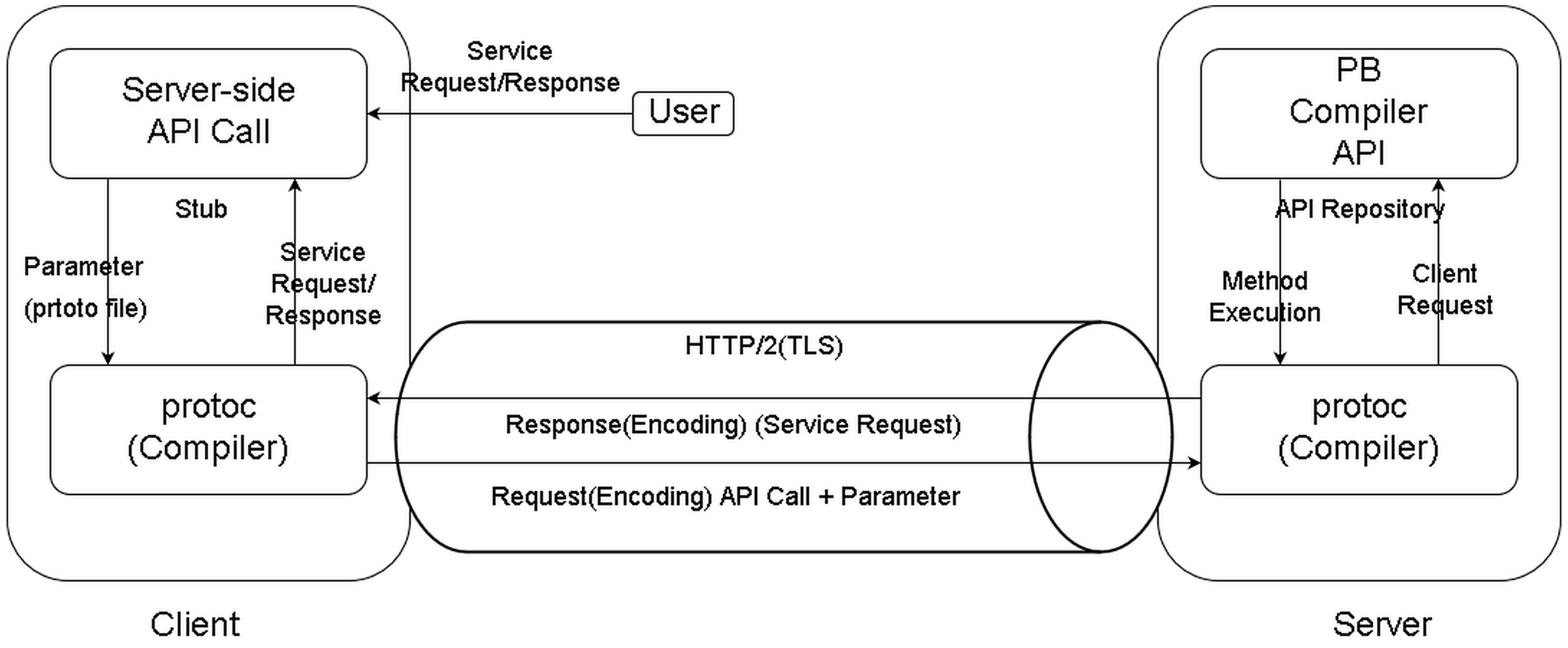
- Connect non-persistence services (CoAP/Adapter) via RabbitMQ and persistence services(Alive/Registration) via gRPC.
- Document-oriented DBMS can ensure the lowest transaction duration of persistence services.
- Load balancing strategy choice depends on which service has to be scaled. Also, server-side one provides a little faster response time.

Future work

- To test the microservice system with some additional requirements.
- Improve the load generator.
- Find out which caching strategy can fit the system in an IoT-contex.
- Prove our research for production usage.

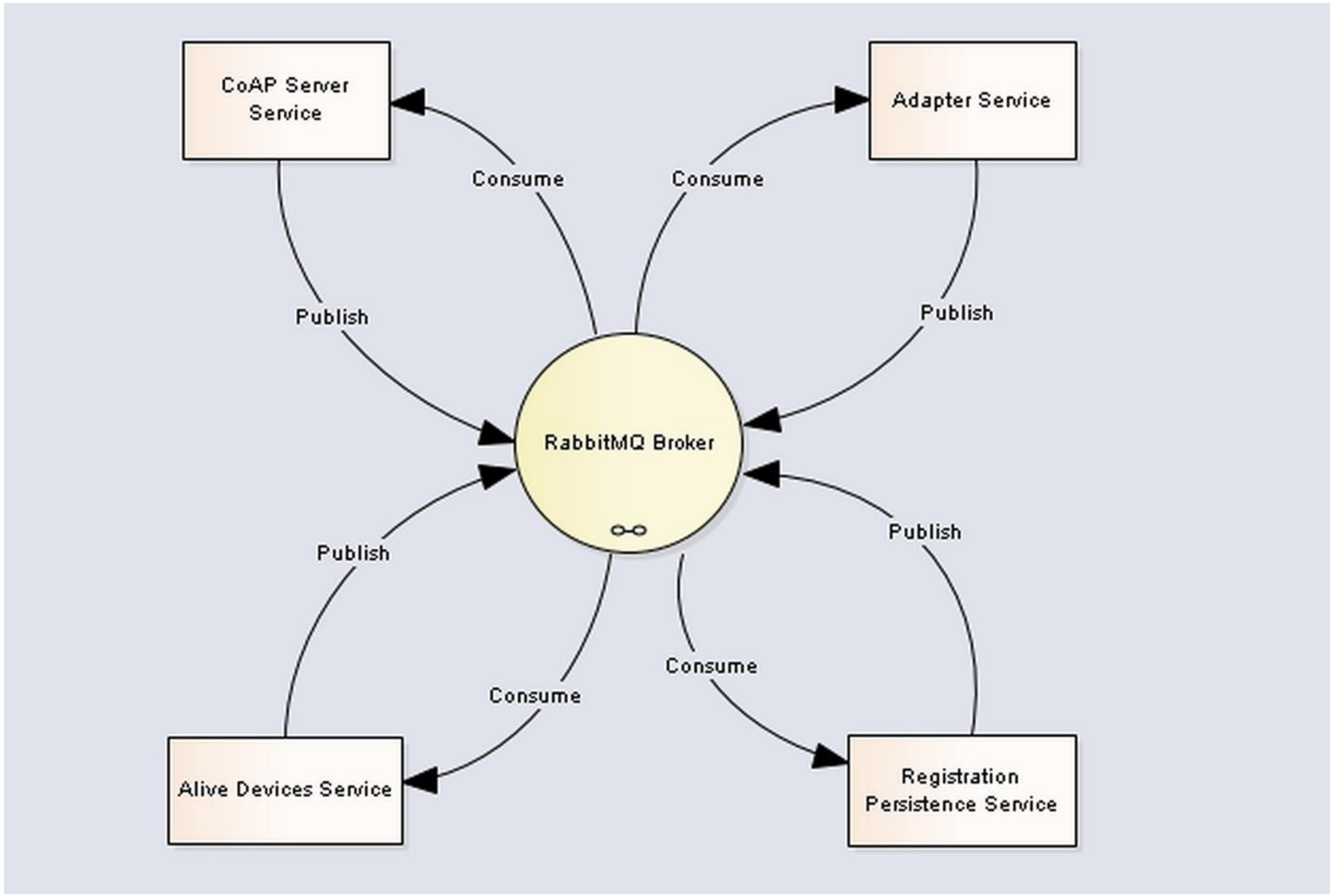
Thank you for your attention

gRPC



GRPC workflow diagram.

RabbitMQ



RabbitMQ dataflow.