DEI
DEPARTAMENTO
DE ENGENHARIA INFORMÁTICA
TÉCNICO LISBOA

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# IoTaaS
## The Internet-of-Things-as-a-Service

Project for IE 2021

## A. Internet of Things as a Service (IoTaaS)

Recently, the interest in the control of small and micro assets has been increasing in many industries, *e.g.*, cars, containers, home automation, *etc*. Those assets are usually named as *"things"* and are considered as working in a network. From here, a myriad of technological challenges is posed, starting from the low-level electronics or the things' energy supply, until the complex design of new business models that can offer completely new services to the end-users.

An internet of things (IoT) represents a comprehensive environment that consists of many smart devices interconnecting heterogeneous physical objects to the Internet (Chang et al., 2016). Combining this IoT concept with the cloud computing concepts a new class of system appears: The Internet-of-Things-as-a-service (IoTaaS), referring to a broader type of systems where the technological aspects are hand-to-hand with business services. The main idea is to decouple the technological aspects of telecommunication networks with any business service offer, from any industry, while in the background the usage is being registered and one will pay for the service according to the schema that best suits his needs.

Figure 1 depicts a typical layered representation of a IoTaaS landscape. In the top layer, many applications can be identified, *e.g.*, fleet management, connected cars (Callegati et al. 2018), payments, home automation, maintenance (Behera et al. 2019), *etc*. In a IoTaaS architecture, these example applications are considered the customers because they are the ones that will be using the available offers. Some examples of real industrial applications are described as follows.

| | |
|---|---|
| Fleet management | **USFleetTracking**<br>*"…tools for managing your vehicles, trailers or whatever your assets might be. Whether you are scaling up your current fleet, starting a new business or putting together an event, US Fleet Tracking's meticulously designed system with unmatched functionality helps you create the best possible solution for your goals. Hundreds of thousands of businesses having increased their efficiency by tracking with US Fleet Tracking",* https://www.usfleettracking.com/fleet-tracking/ |
| Shipping container tracking | **AirFinder**<br>*"At $1 per month per container, the cost is significantly less than GPS-based systems. Additionally, the cost of the hardware is also significantly less than you'll pay for GPS-based tracking applications, ranging from $10 to $20 instead of $50 to $300 for GPS.*<br>*The battery life is far greater than GPS-based systems. Using a technology like Bluetooth on your container tracking modules, the battery could last three or more years as opposed to a matter of months. That's because short-range wireless devices need to transmit the signal only to a nearby receiver, whereas GPS devices have to send the signal to a satellite or cellular network.",* https://www.airfinder.com/blog/shipping-container-tracking |
| Connected cars | **EVE Tesla apps**<br>*"EVE For Tesla is designed from the ground up to create a premier dashboard experience for your Tesla. Personalize your dashboard with up to four apps displayed at once. EVE For Tesla connects you to information on weather, stocks, news, and more on a single screen that is designed for optimal viewing and interaction as part of a complete connected car experience.",* https://teslaapps.net/en/ |
| Payment & POS | **Eseye**<br>*"…Eseye's relationships with global mobile networks, and understanding of local connectivity and data processing challenges, mean we can help businesses build connectivity into POS devices rather than installing it locally. Devices with Eseye connectivity work out-of-the-box anywhere in the world, reducing the need to maintain large local setup teams…",* https://www.eseye.com/iot-solutions/pos/ |
| Predictive maintenance | **Rolls Royce engines in aviation**<br>*"The data-driven approached has been changing the company's business model from traditional manufacturing to industrial Internet of Things. Rolls Royce deploys big data in three key functions: design, manufacturing and maintenance. In design, it uses terabytes of data to simulate how its products would perform in any conditions. In manufacturing, data analytics are deployed for each engine component produced. After products are sold, their performance is monitored, assessed and sold as a service. Increasingly, all three parts network and communicate with each other.*<br>*The new business model allowed Rolls Royce to emerge from financial struggle. Last year data analytics and maintenance contributed half of company's revenue of £14.6bn. A good example is the 5-year deal Rolls Royce singed with Singapore Airlines this year. The deal aims at decreasing fuel consumption across 137 aircrafts that use Rolls Royce Trent engine.",* https://digital.hbs.edu/platform-digit/submission/rolls-royce-internet-of-things-in-aviation/# |
| Home security and automation | **Thales**<br>*"Home security systems collect highly sensitive information – about when your customers are at home and can even film them about their daily activities. The data they collect and transmit must, therefore, be iron-clad….we strongly advocate for cellular-based systems over traditional WiFi connections because they are easy to install, secure, and highly reliable.",* https://www.thalesgroup.com/en/markets/digital-identity-and-security/iot/industries/home-automation |

*Table 1. Some examples of industrial IoT applications*

All these example IoT applications depend on a bottom layer telecommunications network provided by any telecommunication company owning his network with data and/or voice capabilities that could be offered to third parties.

Moreover, due to complexity a middle layer participant mediates the interactions between the customers and the telecommunication providers. These third-party companies that manage and mediate the offer of the IoT customer with the core telecommunication capabilities are named as IoT business process management (BPM). And are deployed in an architecture that can incorporate (i) multiple customers, where each one has a different set of business services to be offered and (ii) multiple telecommunication providers. Usually, an IoT BPM solution encompasses the following components: (i) a self-service customer relationship management, (ii) catalog, (iii) a rules engine, and (iv) analytics.

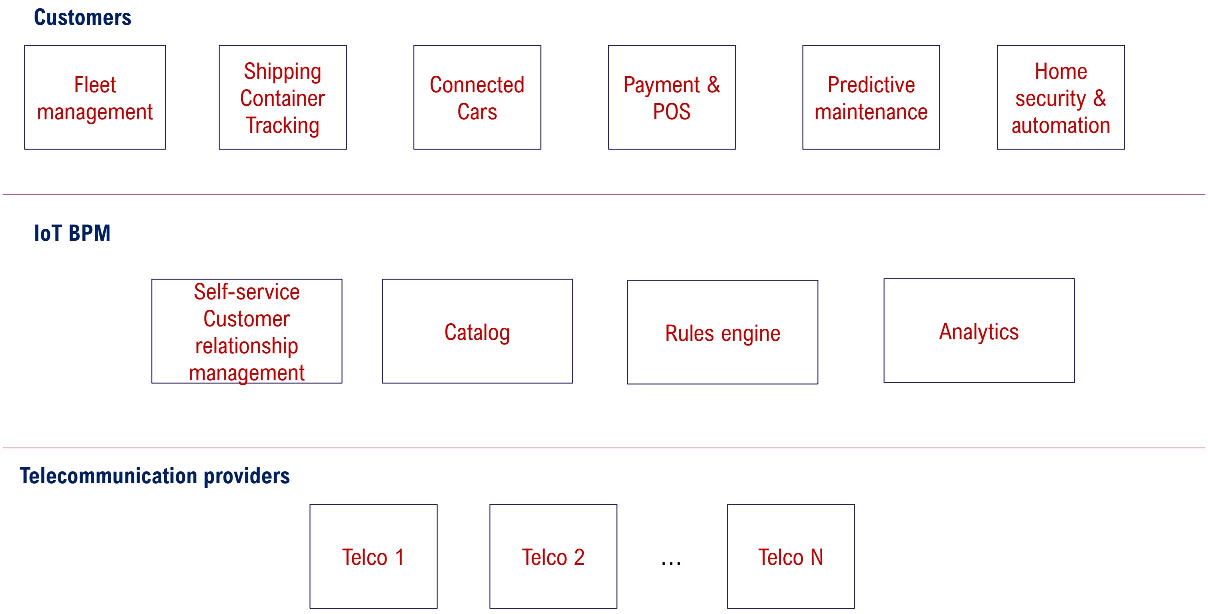


*Figure 1. Overall diagram of IoTaaS*

The main concepts used in IoTaaS are defined as follows.

## *A.1. Core concepts*

For a shared understanding, we recommend you to use these definitions throughout the development of your project.

Billing - the telecommunication provider application responsible to calculate the charge that each MSISDN identifier, of each Customer, must pay in each period of time. For that end, the abilities of aggregation and storage of data from mediation are demanded. The outcome consists in rating data to be consumed by the IoT BPM.

Customer – is a company that offers a value-added service in the scope of IoT and that depends on the IoT BPM. Each customer has many SIM cards that allows access to data and voice in any country and that are used in the scope of a given application. *See the examples in Table 1.*

Event – correspond to a telecommunication provider activity' in the scope of operation of a SIM card, namely, the SIM card status and any activity performed in the network with a SIM card (*e.g.*, data exchange or voice call). The events are provided by the radio network, consumed, and aggregated by the mediation and delivered to the IoT BPM.

HLR – the Home Location Register is a database that contains various information about all of the mobile subscribers of a mobile network such as the mobile numbers, service and similar information. It contains the association between SIM card and MSISDN identifier.

IoT – the Internet of things describes the network of physical objects— "things"—that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the Internet.

Mediation – the telecommunication provider application responsible to translate the radio network logs in a more Human readable format. For that end, the abilities of aggregation, storage and transformation are demanded. Two other applications use its outcomes: the Billing and the IoT BPM.

MSISDN identifier – the Mobile Station International Subscriber Directory Number is a number uniquely identifying a subscription in a Global System for Mobile communications or a Universal Mobile Telecommunications System mobile network.

Rating – correspond to the outcome of the Billing processing cycle (considering each period of time) and is used to charge the owners of each MSISDN identifier, of each Customer.

SIM card - a subscriber identity module or subscriber identification module (SIM), widely known as a SIM card, is an integrated circuit that is intended to securely store the international mobile subscriber identity (IMSI) number and its related key, which are used to identify and authenticate subscribers on mobile telephony devices (such as mobile phones and computers). Each SIM card is associate to a single MSISDN identifier.

# B. Project Objective and Context

The main components of the required IoTaaS are depicted in *Table 2* and the overall architecture in Figure 2.

| Participant | Functionalities |
|---|---|
| Customer(s) | Some examples of customers are: Fleet management, Shipping Container Tracking, Connected Cars, Payment & POS, Predictive maintenance, Home security & automation, Health care, *etc*.<br><br>Each group should choose a customer to implement (*see expected deliverables in section C.1*). |
| IoT business process management | The core functionalities are:<br>Self-service Customer relationship management<br>Catalog<br>Rules engine<br><br>A project improvement that will be considered as extra evaluation is:<br>Analytics<br><br>However, each group accordingly with the customer chosen could need to implement other functionalities. |
| Telecommunication provider(s) | The following APIs should be provided for all Customers. Therefore, all groups need to implement them:<br>SIM card Provisioning<br>Activate MSISDN / Customer<br>Delete MSISDN<br>Suspend MSISDN<br>Event configuration update MSISDN<br>Mediation (MSISDN transformation by event)<br><br>A project improvement that will be considered as extra evaluation is:<br>Billing (by Customer) |
| | Moreover, the core radio network operation (by MSISDN) contains a set of back-end functionalities that all groups need also to implement. |

*Table 2. IoTaaS components organized by functionalities.*

Figure 2 depicts the three-layer architecture for the fleet management application. The technologies included within each blue box are recommendations for your implementation.

The telecommunication provider offers a set of services that is used by all the Customer. Therefore, all the groups need to implement this layer of the architecture with the same capability as specified in *Table 2*.

The bottom yellow box, in Figure 2, consists in a tool available for your project development (https://github.com/Enterprise-Integration-IST-2021/IoTaaSSimulator). The goal is to simluate radio network activity that will be consumed by your implementation. The tool produce activity for the provisioned MSISDNs at HLR, therefore a previous defined instance should be deployed by your team.

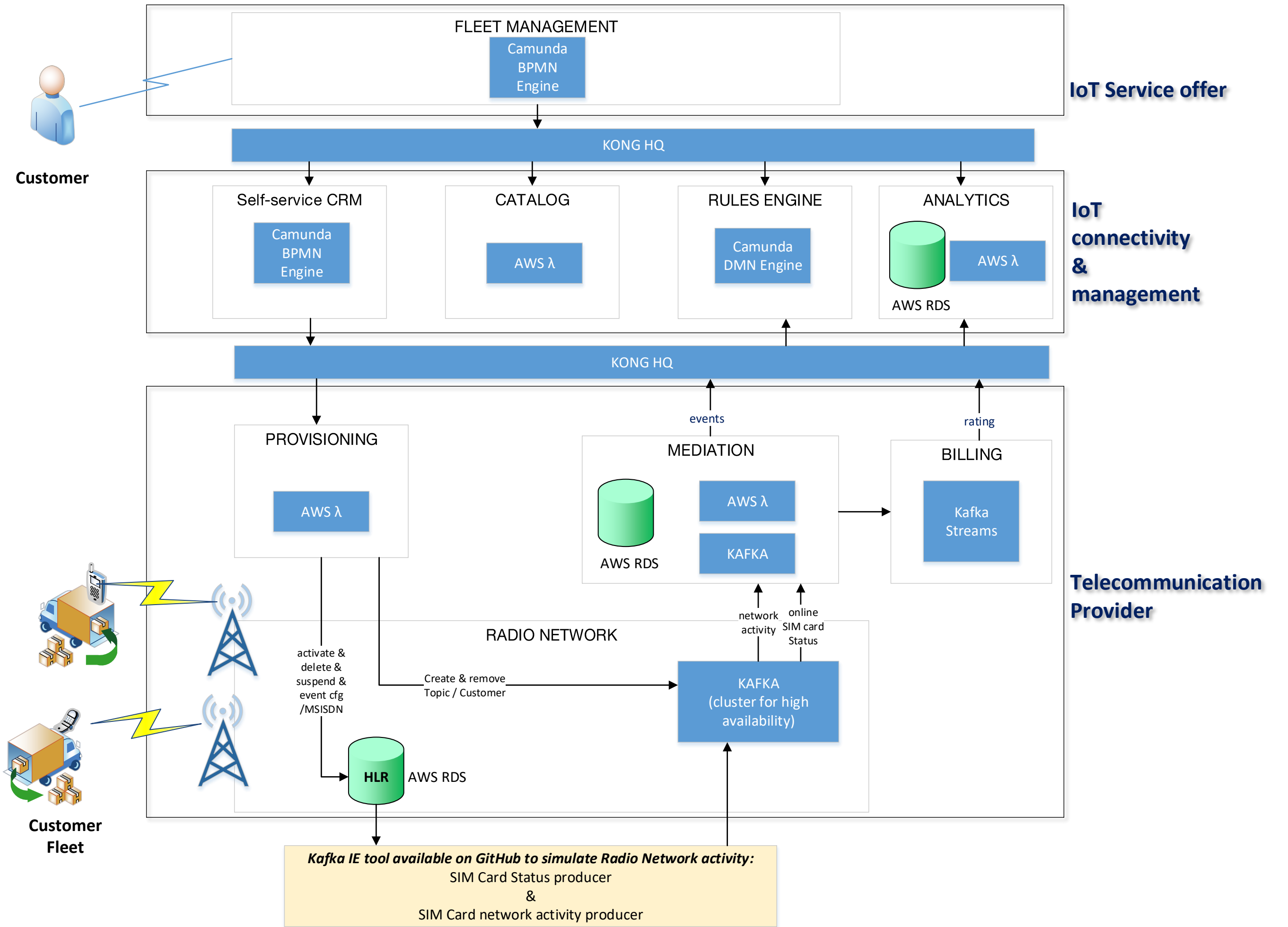


*Figure 2. Overall architecture of IoTaaS for a fleet management customer. In this example the IoT BPM encompasses the connectivity and the management of SIM cards.*

# C. 1ST SPRINT

The initial sprint consists in the definition of each group project, namely, the business context, the main informational entities, the main services, and the expected functionalities.

In specific the following deliverables are expected.

## *C.1. Expected deliverables*

- Proposal of the IoTaaS Customer to be implemented in your project.
    - Students can choose one of the presented examples but are also challenged to search for other IoTaaS customers different than the ones introduced in this document. If needed discuss your ideas with IE 2021 faculties.
    - Each group choose a different IoTaaS customer, as a deadline

The faculties need to approve your proposal, to that end submit in fénix a movie with 5 minutes – maximum – explaining your IoTaaS Customer proposal and the business processes overall idea until **12/3/2021 23:55**.

- Identify, with textual description, the business processes for the IoTaaS Customer and for the IoT BPM.

- Identify the objectives and KPIs for the IoTaaS Customer.

- Design of the business processes to be implemented at the IoTaaS Customer and at the IoT BPM levels. (using the Camunda modeller).

- Identification of the main information entities for each one of the two layers of the IoTaaS Customer and at the IoT BPM levels, considering the IoTaaS customer previous definition (using UML domain model or ER model or other representation using a legend).

## *C.2. Submission*

The submissions will be made via Fénix, in a single ZIP file containing the report PDF and the developed code artifacts.

## *C.3. Deadlines*

19/3/2021 23:55 – submission of all the sprint 1 deliverables

and

26/03/2021 23:55 – submission of a video (maximum 10 minutes) explaining your sprint 1 achievements.

# D. 2ND SPRINT

The second sprint is focused on the implementation details of the telecommunication provider following the details provided in Figure 2.

## D.1. *Expected deliverables*

- Design an information flow considering the overall architecture of IoTaaS, using XML or JSON format.
  a. We suggest you to define the Kafka topics and partitions.

- Implementation of the Radio Network considering high availability mechanism.
  use the following technologies: *KAFKA cluster* and *AWS RDS*

- Implementation of the Provisioning.
  use the following technologies: *AWS λ* and/or *JAVA javax.jws.WebService*

- Implementation of the Mediation
  use the following technologies: *(AWS λ and/or JAVA javax.jws.WebService)* and *AWS RDS* and *KAFKA*

- Documentation of tests considering all the previous deliverables.

- Documentation for the source code, installation, parametrization, and operation.

## D.2. *Submission*

The submissions will be made via Fénix, in a single ZIP file containing the report PDF and the developed code artifacts.

## D.3. *Deadlines*

<u>16/4/2021 23:55 – submission of all the sprint 2 deliverables</u>

and

<u>23/04/2021 23:55 – submission of a video (maximum 10 minutes) explaining your sprint 2 achievements.</u>

## D.4. *Other comments*

To facilitate the generation of Kafka messages, a tool is made available to be used in the project as simulator of radio network activity performing actions in the IoTaaS platform.

Follow the link with instructions:

https://github.com/Enterprise-Integration-IST-2021/IoTaaSSimulator

# E. 3RD SPRINT

## *E.1. Expected deliverables*

The objective of this sprint is to implement the IoT BPM layer. A strategic decision was taken that the architecture of the new operator should follow a microService approach to integrate with the telecommunications provider. Thus, your group objectives are:

- Definition for each the microServices needed for the IoT BPM integration with telecommunications provider. This implies a careful analysis of the data stores and functions that each module will have.

  *Deliverable:* description of the behavior for each microservice using pseudo-code.

- Implementation of the microServices needed for the IoT BPM integration with telecommunications provider

  *Deliverable:* source code and configurations from both environments: KONG configurations, AWS λ and/or JAVA javax.jws.WebService library should be used – one for each microservice. Moreover, the AWS RDS should be used for database, and thus all the configurations and SQL scripts should be included.

- Functional testing using the applications that generate the events that should exercise the functions within the microService and provided evidence of their accurate executions in the persistent state of the microServices

  *Deliverable:* textual description, and analytics, of the obtained test results.

- Implementation and functional testing of the IoT BPM components:
  - Self-service Customer relationship management
  - Catalog
  - Rules engine

  *Deliverable:* Camunda executable business processes with required configuration, Camunda DMN model and configuration, AWS λ and/or JAVA javax.jws.WebService library services and AWS RDS data models and scripts.

- Identity & authorization management solution implementation considering the integration between Camunda engine and KONG API.

## *E.2. Submission*

The submissions will be made via Fénix, in a single ZIP file containing the report PDF and the developed code artifacts.

## *E.3. Deadlines*

<u>14/05/2021 23:55 – submission of all the sprint 3 deliverables</u>

and

<u>21/05/2021 23:55 – submission of a video (maximum 10 minutes) explaining your sprint 3 achievements.</u>

# F. 4TH SPRINT

## *F.1. Expected deliverables*

The objective of this sprint is to implement the Customer layer. Again, a strategic decision was taken that the architecture of the new operator should follow a microService approach to integrate with the IoT BPM. Thus, your group objectives are:

- Definition for each the microServices needed for the Customer integration with the IoT BPM. This implies a careful analysis of the data stores and functions that each module will have.

  *Deliverable:* description of the behavior for each microservice using pseudo-code.

- Implementation of the microServices needed for the Customer integration with the IoT BPM.

  *Deliverable:* source code and configurations from both environments: KONG configurations, AWS λ and/or JAVA javax.jws.WebService library should be used – one for each microservice. Moreover, the AWS RDS should be used for database, and thus all the configurations and SQL scripts should be included.

- Functional testing using the applications that generate the events that should exercise the functions within the microService and provided evidence of their accurate executions in the persistent state of the microServices

  *Deliverable:* textual description, and analytics, of the obtained test results.

- Implementation and functional testing of the Customer business processes.

  *Deliverable:* Camunda executable business processes with required configuration and/or Camunda DMN model.

- Implementation of the Billing in the Telecommunication provider *(as project improvement that will be considered as extra evaluation)*

- Implementation and functional testing of the IoT BPM components *(as project improvement that will be considered as extra evaluation)*
  a. Analytics

## *F.2. Submission*

The submissions will be made via Fénix, in a single ZIP file containing the report PDF and the developed code artifacts.

## *F.3. Deadlines*

<u>28/05/2021 23:55 – submission of all the sprint 4 deliverables</u>

and

<u>4/06/2021 23:55 – submission of a video (maximum 10 minutes) explaining your sprint 4 achievements.</u>

# Bibliographic References

Chang, C., Srirama, S. N., & Buyya, R. (2016). Mobile cloud business process management system for the internet of things: a survey. ACM Computing Surveys (CSUR), 49(4), 1-42.

Callegati, F., Giallorenzo, S., Melis, A., & Prandini, M. (2018). Cloud-of-Things meets Mobility-as-a-Service: An insider threat perspective. Computers & Security, 74, 277-295.

Behera, S., Choubey, A., Kanani, C. S., Patel, Y. S., Misra, R., & Sillitti, A. (2019, April). Ensemble trees learning based improved predictive maintenance using iiot for turbofan engines. In Proceedings of the 34th ACM/SIGAPP Symposium on Applied Computing (pp. 842-850).