D1.1 LAUNCH VERSION OF THE ASHVIN PLATFORM

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ABSTRACT

MFL deployed, in the cloud managed by Digital Ocean, an open-source, secure and scalable IoT platform that ensures device provisioning, connectivity and management, data accumulation and consumption. The platform is based on the microservices combined with Kubernetes orchestration mechanisms. The platform is available at https://iot.ashvin.eu. A set of user and technical manuals is provided in the appendix of this report. Deliverable 1.1. represents the launch version of the Ashvin platform that will be further improved throughout the project and a final version will be described in D1.6 Full Version of the Ashvin Digital Twin Platform.

KEYWORDS

IoT platform, microservices, cloud, user manuals, ABAC, edge computing, protocols, data formats

REVISIONS

Version	Submission date	Comments	Author
V0.1	28.12.2020	Initial draft	Mirko Teodorović (MFL)
V0.2	29.12.2020	Editing and formatting	Timo Hartmann (TUB)

DISCLAIMER

ACRONYMS & DEFINITIONS

IoT	Internet of Things
IIoT	Industrial Internet of Things
CERTH	Centre of Research & Technology - Hellas
DTT	DigitalTwin Technology GmbH
FAS	Przedsiebiorstwo Robót Elewacyjnych Fasada sp.zo.o.
ABAC	Attribute-based access control
CRUD	Create, read, update and delete
AIP	Ashvin Internet of Things Platform

ASHVIN PROJECT

ASHVIN aims at enabling the European construction industry to significantly improve its productivity, while reducing cost and ensuring absolutely safe work conditions, by providing a proposal for a European wide digital twin standard, an open source digital twin platform integrating IoT and image technologies, and a set of tools and demonstrated procedures to apply the platform and the standard proven to guarantee specified productivity, cost, and safety improvements. The envisioned platform will provide a digital representation of the construction product at hand and allow to collect real-time digital data before, during, and after production of the product to continuously monitor changes in the environment and within the production process. Based on the platform, ASHVIN will develop and demonstrate applications that use the digital twin data. These applications will allow it to fully leverage the potential of the IoT based digital twin platform to reach the expected impacts (better scheduling forecast by 20%; better allocation of resources and optimization of equipment usage; reduced number of accidents; reduction of construction projects). The ASHVIN solutions will overcome worker protection and privacy issues that come with the tracking of construction activities, provide means to fuse video data and sensor data, integrate geo-monitoring data, provide multi-physics simulation methods for digital representing the behavior of a product (not only its shape), provide evidence based engineering methods to design for productivity and safety, provide 4D simulation and visualization methods of construction processes, and develop a lean planning process supported by real-time data. All innovations will be demonstrated on real-world construction projects across Europe. The ASHVIN consortium combines strong R&I players from 9 EU member states with strong expertise in construction and engineering management, digital twin technology, IoT, and data security / privacy.

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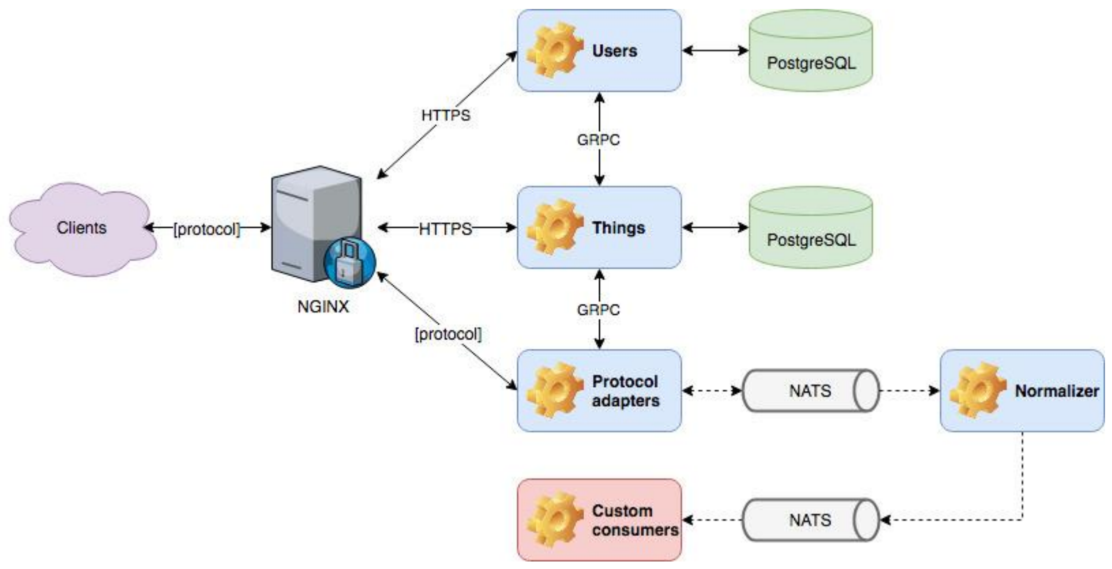
1 IOT PLATFORM

Ashvin IoT platform is based on Mainflux, a messaging middleware geared towards the Internet of things. Mainflux is a scalable, secure, open-source, and patent-free IoT cloud platform written in Go. It accepts connections over various network protocols (i.e. HTTP, MQTT, WebSocket, CoAP).

Mainflux IoT platform consists of multiple microservices with separate and well-defined responsibilities such as management of users and authentication concerns, management of things and channels - Mainflux IoT platform primitives used to build complex IoT topologies – and authorization concerns. These microservices can be run in many different ways according to the use case needs. They can be run locally or in the cloud, on premise or off-premise. They can be run as a composition of Docker containers (a lightweight, standalone operating system abstraction that includes everything needed to run an application) or as standalone applications on the local host computer.

Mainflux IoT as a core of the Ashvin IoT platform has a complex architecture. Blue boxes on the picture bellow show Mainflux primitive entities, such as users, things, adapters, etc. Green cylinders are databases where the messages are persisted.

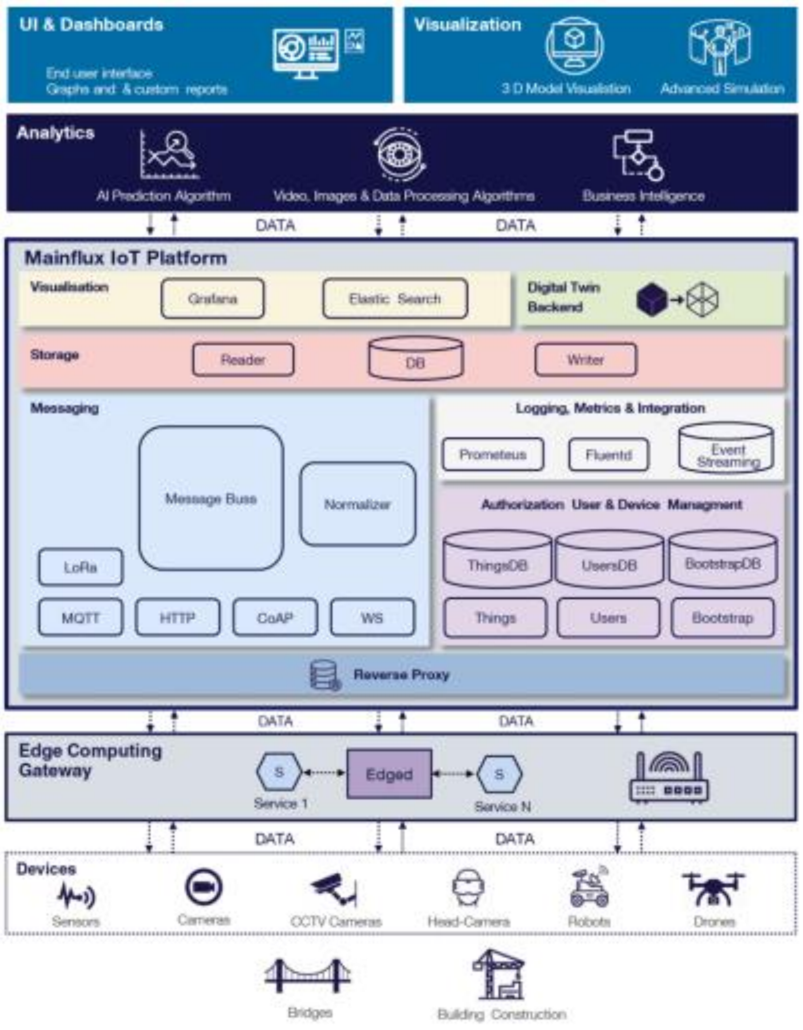


White cylinders are Mainflux internal message buses. They centralize different message pathways (data traveling *via* different protocols of communication). NGINX acts as Mainflux internal domain name server (reverse proxy) and forwards requests coming from the "outside world", i.e. from platform clients, to the corresponding services (users, things, etc.). Finally, the cloud icon refers to clients of the IoT platform - devices (data produces) and applications (data consumers).

For the first version of the Ashvin platform, we have chosen to install Mainflux IoT platform as a **Docker container composition orchestrated by Kubernetes**. Mainflux is installed in the cloud managed by DigitalOcean, a cloud infrastructure provider with data centres worldwide, including Europe. The servers of the Ashvin IoT platform are located in **Frankfurt**, but this can be changed easily. *NB: we will use Ashvin IoT platform and Mainflux IoT platform interchangeably in this report*.

1.1 Ashvin IoT platform in the context of the Ashvin toolkit

The Ashvin IoT platform (based on Mainflux) is the messaging (communication) core of the Ashvin toolkit. It is meant to connect data produces – usually, physical devices on the construction site – to the data consumers – Ashvin toolkit applications processing the data. Its role is also to store the data. The image below shows the Ashvin toolkit "stack". The IoT platform is in the middle of the stack, thus connecting the "south" end of the stack (data producers) with the "north" end of the stack (data consumers).



1.2 Platform features

The main and fully functional features of the deployed platform are following:

- **User management**, where the user represents the real (human) user of the system or an organization.
- **System provisioning**
  - Provisioning things, where things represent devices or applications connected to the platform.
  - Provisioning channels, where channels represent communication pathways between devices and/or applications. Channel serves as a message topic that abstracts away complexities of the underlying communication protocols. It is used by things to send and receive messages.
- **Messaging**
  - with supported protocols
    - HTTP
    - MQTT
    - WS
    - CoAP
    - LoRaWAN
    - OPC UA
  - Mutual TLS Authentication with X.509 Certificates over HTTPS, and MQTTS.
- **Storage** - platform supports various databases for message persistence (storing): - CassandraDB - MongoDB - InfluxDB - PostgreSQL

1.3 Platform Access

1.3.1 System management

Platform user can access the platform in multiple ways. For **user management** and system **provisioning** and **storage**, we use an **HTTP RESTful API**.

Some of the well-known RESTful API clients include command line tools such as CURL and GUI tools such as Postman. The use of these kinds of tools is documented in the Ashvin IoT platform user manual.

Mainflux IoT platform - a backbone of the Ashvin IoT platform - provides also a custom command line tool - **mainflux-cli** - as well as a custom GUI tool – **Ashvin IoT platform GUI**. The use of the latter is documented in the Ashvin IoT platform user manual ().

All of these tools are already fully functional and are ready for use in production as of this writing. Ashvin IoT platform experimental GUI can be accessed at the address https://iot.ashvin.eu/. The address iot.ashvin.eu itself can be used with any of the tools in order to use the Mainflux IoT platform for user management, system provisioning or messaging.

1.3.2 Messaging

Mainflux IoT platform is a messaging middleware. It is akin to a post office in the sense that it collects messages on the so-called south end or edge (fog) – where data producers reside – and relays messages to the so called north end (cloud) – where data consumers reside.

Once a channel is provisioned and a thing is connected to it, the latter can start publishing and receiving messages over the former. HTTP, MQTT, WS and CoAP are supported out of the box and don't require any special configuration. LoRaWAN requires that a device be connected to a LoRaWAN server. Once device is connected to the server, we can connect it with the Ashvin IoT platform. OPC UA works out of the box, but it is still in the experimental stage.

You can use command line tools such as CURL and GUI tools such as Postman to send messages *via* HTTP, the mosquitto_pub and mosquitto_sub MQTT clients to send and receive messages over MQTT. To send and receive messages over CoAP, you can use Copper CoAP user-agent. Naturally, those are only some of the well-known tools and are recommended by Mainflux Labs. The use of these tools with the Mainflux IoT platform will be documented in the Ashvin IoT platform user manual.

2 FINE-GRADED ACCESS

Mainflux team started an implementation of the fine-graded access based on the Attribute-based access control (ABAC) model. The **ABAC** model enables easy creation and management of **users, channels and things groups** as well as per group and per entity (user, channel or thing) permissions.

2.1 Current administration system

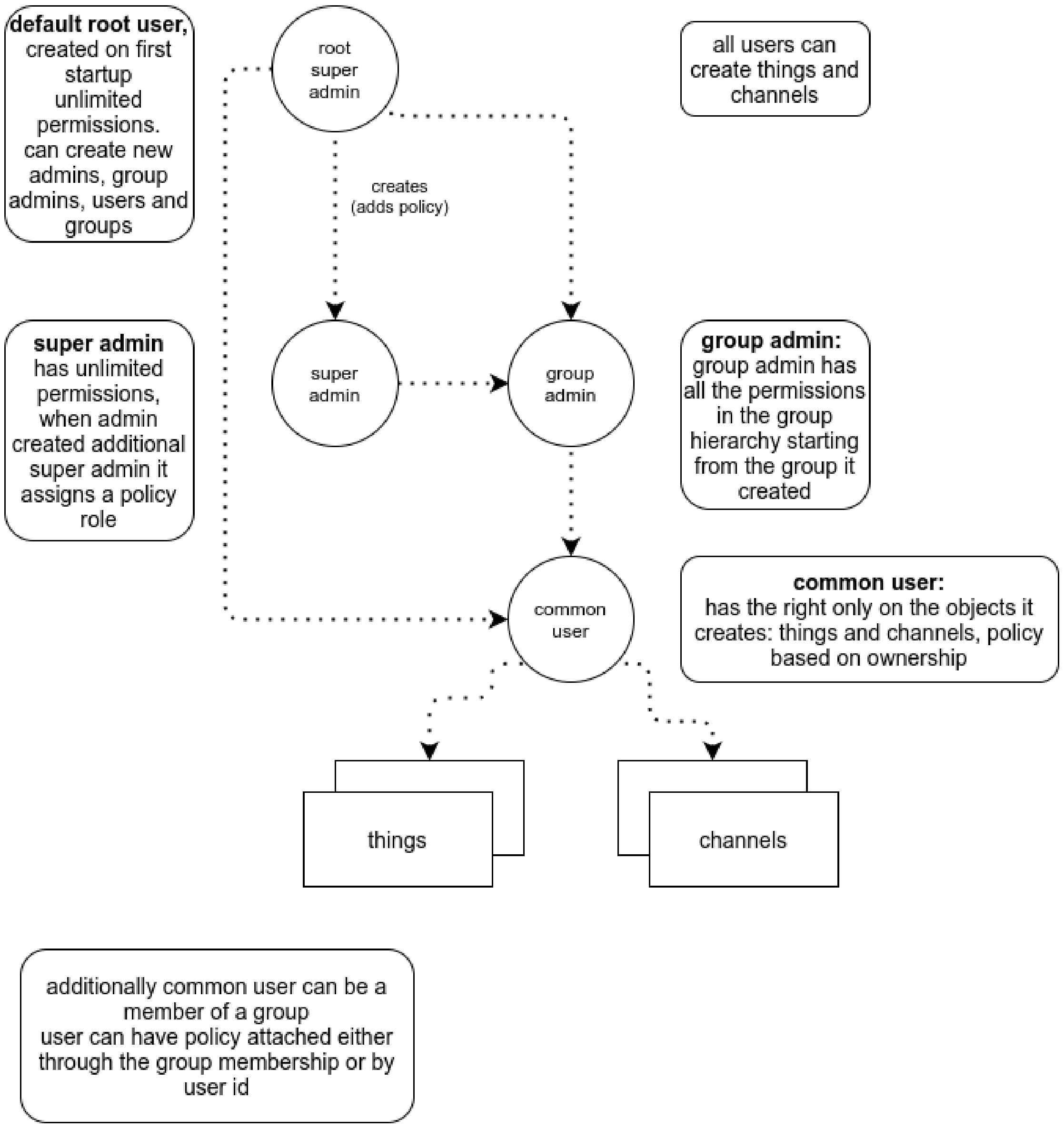
Currently, Mainflux users are represented by email and password. The latter are used as platform access credentials in order to obtain an access token, i.e. as a means of user authentication. Once logged into the system, the user can manage resources in a CRUD manner and define things-channels access control policies (authorization) by connecting things and channels. One should not confuse user authentication with the thing authorization. The former is used to authenticate a user and the latter is used to check whether a given thing can send messages to and receive messages from the given channel.

2.2 New administration system (work in progress)

The development of the new administration system is ongoing and is nearly done. In the new system there is a **root admin**. It is created by default and, so, there is always a root admin and there is a possibility to create additional **super admins**. This system is similar to UNIX root and regular users system.

The main role of the root admin and super admins is to organize users into groups to match the structure of business applications and to organize the access rights. User groups are further divided into subgroups so there is a **hierarchical** organization of parent, children and sibling **super- and subgroups** of an arbitrary depth.

User groups should be matched with things (devices and apps) groups. When adding devices or applications in the system, they should be organized so that organization matches the structure of company organization or some other real word organization structure (for example devices can be organized in flats, buildings, streets, cities, etc.).


default root user, created on first startup unlimited permissions. can create new admins, group admins, users and groups
root super admin
creates (adds policy)
all users can create things and channels
super admin has unlimited permissions, when admin created additional super admin it assigns a policy role
super admin
group admin
group admin: group admin has all the permissions in the group hierarchy starting from the group it created
common user
common user: has the right only on the objects it creates: things and channels, policy based on ownership
things
channels
additionally common user can be a member of a group user can have policy attached either through the group membership or by user id

2.3 Administration system development roadmap

Mainflux users and things groups have a hierarchy and various metadata. Groups can have parents and children. This opens up the possibility and need for complex queries of users, things and channels along the lines of metadata and hierarchical structure. Therefore, queries for traversing relationship trees are on the development roadmap.

2.4 State of development

The current state of development of the new administration system can be followed anytime at the address https://github.com/mainflux/mainflux/pull/1246 as well as at the address https://github.com/mainflux/mainflux/pull/1313. This development is nearly done, so as of this reading, it may be very well merged into the main version that can be found anytime here https://github.com/mainflux/mainflux.

Once the new version of Mainflux is out, it will be tested on an Ashvin demo deployment (found also on Digital Ocean) and if everything goes well, it will deployed on the https://iot.ashvin.eu/. Once deployed, all the existing users of the platform will be migrated to use the new administration system.

3 EDGE COMPUTING MECHANISMS

“Edge”, “fog” or “south-end” is an Industrial Internet of Things (IIoT) terminology used to refer to the very physical site where data sources are located. Data sources are various and tend to be numerous, even on a single production site. Even a single machine can use several protocols or means (such as CSV files) to emit measurement data and to receive control data.

This means two things. Firstly, there is a plethora of communication methods that need to be addressed by the IoT platform. Secondly, there is a high quantity of produced data. This data is collected by a gateway - a south-end hardware device that hosts an edge IoT platform and serves as a single point of collection of the production site messages. Usually, a gateway forwards this data to the cloud applications.

3.1 Edge connectivity

One of the special challenges of the Mainflux IoT platform is enabling the connectivity of the various types of devices over the gateway. Since there is no "one size fits all" solution, various services need to be developed that enable device-gateway communication. The Mainflux IoT platform supports several protocols - MQTT, WS, CoAP, HTTP, LoRaWAN and OPC UA - out of the box. If a device supports one of these protocols, this means that it can be directly connected to the platform. However, if a device is not connected to the internet or the device supports a specific communication protocol, a special software service (a “daemon”) must be written in order to enable one-way or two-way device-gateway communication.

3.2 Edge communication mechanisms

Mainflux IoT platform has, as an add-on, **export service**. The latter can send messages from one Mainflux cloud to another via MQTT, or it can send messages from edge gateway to Mainflux Cloud. The development of the export service is ongoing and can be found here https://github.com/mainflux/export.

Mainflux IoT **Agent** is a communication, execution and software management agent for Mainflux IoT platform that runs on the gateway. The development of the Agent is ongoing and can be found here https://github.com/mainflux/agent.

3.3 Rules engine

Rules engine is a **production rule system**. The rule-based approach is dependent on a **knowledge representation** that pertains to a specific domain. A rule has a **condition** and an **action**. Rules engine uses knowledge representation to encode a current state of the system. Based on the current state, the rules engine evaluates rules and takes appropriate actions if the rule conditions associated with these actions are met. This enables a real-time processing of production data on the IIoT edge and specifically, on a gateway. This is important for two reasons. Firstly, we want to save network bandwidth and storage costs. Secondly, we want to be able to do some kind of basic data analytics on the data production site.

3.4 Network bandwidth and storage costs

The amount of production site data is usually so huge that there are significant network bandwidth and storage costs associated with data fog-cloud transfer. One of the aims of rules engine is to transform and filter data in order to save network bandwidth and reduce storage requirements.

3.5 IoT data analytics

Edge lightweight IoT data analytics software such as rules engine is used for predictive maintenance and to improve system safety. By analysing and processing data from different data sources, various failures related to operation and safety can be predicted and a further insight into the system operation can be gained.

3.6 Ongoing research

We are currently analysing and testing two candidates for the rules engine that will be used on the edge. The candidates are Grule and EMQ X Kuiper. The idea is to integrate one of these two rules engines into the existing Mainflux IoT platform. Both of the rules engines are written in the programming language Go and are lightweight and are thus well adapted for the resource constrained edge devices such as gateways. The projected end of research is the end of December 2020. We should start the integration of the rules engine with the Mainflux IoT platform in the January 2021. However, if we decide that none of the existing rules engine matches the special needs of the Ashvin use cases and the internals of the Mainflux architecture, we will start the development of the custom in-house rules engine.

4 DATA GATHERING AND EXCHANGE MECHANISMS

4.1 Data exchange mechanisms

One of the problems that need to be solved is the data exchange mechanism between Mainflux IoT platform consumers - Ashvin tools, parts of the Ashvin toolkit - and the platform itself. Two things need to be taken into account. Firstly, we need to determine compatible **data formats**. Secondly, we need to address the multitude of **protocols** used to transfer messages or data.

Mainflux is collaborating closely with CERTH and DTT on defining the data format and the data exchange mechanisms. For now, the preferred way to transfer data is *via* the RESTful mechanisms and the preferred data format is JSON. Mainflux IoT platform has already well defined RESTful API that is thoroughly documented by means of OpenAPI specification documents and is ready to use.

4.2 Data gathering mechanisms

The exact details of the demo sites are still unknown. However, in close collaboration with FAS, Mainflux Labs created a detailed questionnaire for the demo site owners in order to gather as much details as possible about the data sources (various data producing devices such as sensors) existing on the demo sites. Also, there is an ongoing effort with the representatives of the Zadar airport to determine the best network and device setup for the demonstration site in question.

Mainflux also launched an independent research on the sensors typically used on construction sites and in buildings. The reason behind this research is not only to predict possible challenges on construction sites, but also to make a **recommendation document** that details how to connect, or enrich with connectivity, construction sites which are not connected, or are not sufficiently connected, to some sort of network (LAN, WAN, private, public, etc.) or are not sufficiently equipped with sensors.

5 MEETINGS

Mainflux Labs organized two meetings related to the work package 1. The first meeting was an initial meeting. The meeting was attended by the representatives of TUB, DTT, EUR, FAS and UPC. The second meeting, related to the planning and development of WP-1 and related WP-3 tasks was attended by DTT and UPC. Meeting minutes can be found in the https://nextcloud.ashvin.eu/ > Documents > WP1 > Meeting Minutes. Representatives of Mainflux Labs also participated in the numerous meetings organized by various Ashvin partners.

6 CONCLUSION

This accompanying report briefly describes Deliverable 1.1 of the Ashvin project – the launch version of the Ashvin IoT platform available at https://iot.ashvin.eu. The platform serves as basis for all technical development of the Ashvin project. Having an initial version of the platform available at the start of the project already allows for data collection from demonstration projects. The platform will be further improved throughout the project and a final version will be described in D1.6 Fulll Version of the Ashvin Digital Twin Platform.

7 APPENDIX 1: ABOUT ASHVIN IOT PLATFORM

7.1 What is Ashvin

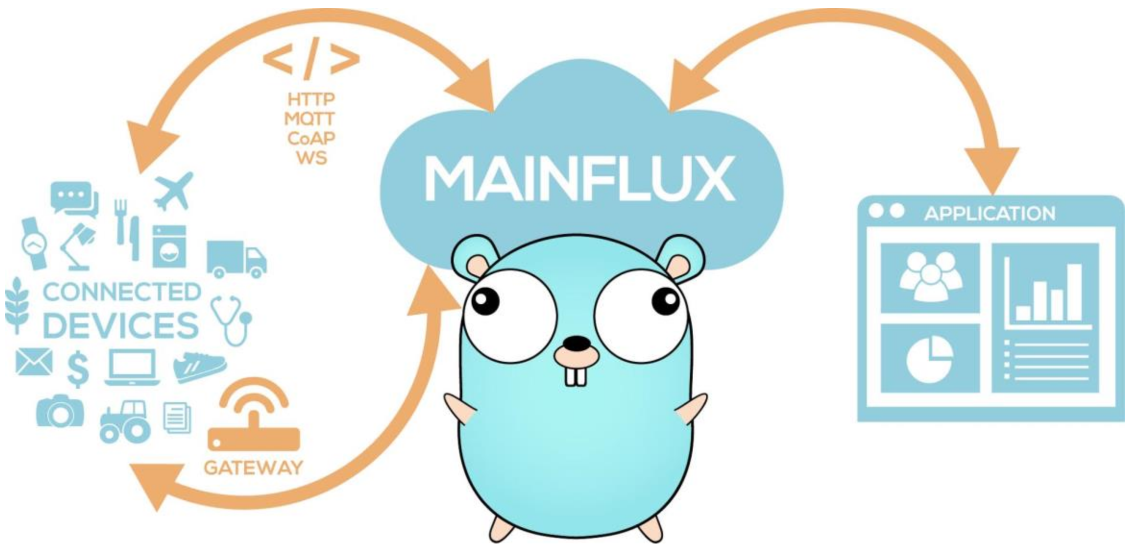
Ashvin strives to develop a solution that will place the European construction industry on the international stage as the number one example to follow. It will do this by employing the power of digitalization and the cutting-edge Digital Twin Technology.

Digitizing and transforming the European construction industry

7.2 What is Ashvin IoT platform (AIP)?

Ashvin IoT platform is a modern, scalable and secure IoT platform. It can be deployed in cloud or on premise. It is meant to be run on Linux machines, but can be also deployed on Mac and Windows machines natively. AIP accepts connections over various network protocols (i.e. HTTP, MQTT, WebSocket, CoAP) making a seamless bridge between devices and applications.

While Ashvin project aims at providing the **Ashvin platform**, i.e. “an open source digital twin platform integrating IoT and image technologies, and a set of tools and demonstrated procedures to apply the platform” (About Ashvin), **Ashvin IoT platform** (AIP) is the underlying layer of connectivity that enables the real-time device to device, app to app, device to app and app to device communication. Thus, AIP plays the role of a low-level enabler of the higher level (more abstract) and end-user oriented aspects of the Ashvin platform. In a nutshell, AIP is a messaging middleware backbone of the Ashvin platform. AIP is based on Mainflux, an open-source and patent-free IoT messaging middleware written in Go.



Mainflux messaging middleware written in GO

AIP is made and maintained by Mainflux Labs.

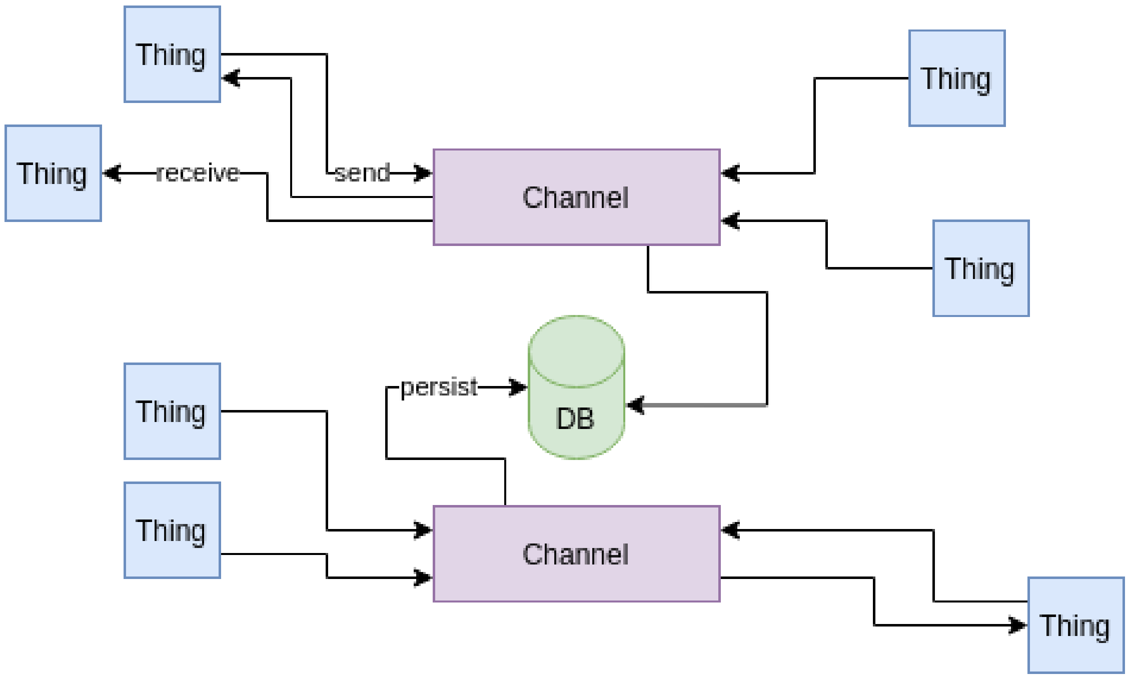
7.3 AIP Address

Ashvin IoT platform can be accessed at iot.ashvin.eu internet address. In order to use it, you need a valid user, i.e. you need access credentials. To get the credentials, please write an email to ashvin@mainflux.com.

8 APENDIX 2: ASHVIN IOT PLATFORM ENTITIES

AIP features two basic entities used to represent physical devices or software applications and their communication. Firstly, **things** represent hardware such as gateways and devices (sensors and actuators) as well as software such as visualization tools, rules engines, etc. Secondly, **channels** represent means of communications between things.

Things exchange **messages** via channels. Things can send or publish messages over channels. Things can receive or listen to channel for the incoming messages. A Thing has to be connected to a channel in order to send and receive messages via the respective channel. Messages sent over channels are persisted in a **database**.



Ashvin IoT platform architecture

8.1 Things

AIP Thing represents any data **source** or producer (provider). It can be a sensor based physical device, cloud based app that generates data or any edge located data source such as gateway.

Thing represents also any data **destination** or consumer. It can be an actuator based physical device, a cloud based app that receives data - e.g. data visualization tool such as Grafana - or an edge located app such as machine software, gateways etc.

8.2 Channels

Channels are **communication** pathways or data transmission mediums. AIP things communicate via channels by a) **sending** messages to and b) **receiving** messages from channels. Channels should be best thought of as pipes which let messages flow in both directions.

Channels abstract away complexities of low-level communication protocols (MQTT, HTTP, etc.) handling and offer a unified and easy to use interface to exchange messages.

8.3 Messages

Message consists of communication payload - information of interest - accompanied by a metadata such as who sent the message, when the message was sent, etc. AIP saves every message into a database of choice. DBs supported out of the box are MongoDB and InfluxDB.

AIP implements **publish** and **subscribe** model (pubsub model). Things publish messages over channels by means of HTTP, WebSocket, MQTT and CoAP protocols (other protocols are also supported). Things subscribe to channels by means of WebSocket, MQTT and CoAP protocols. Any thing can publish message to any channel and any thing can receive message from any channel. It is important to keep in mind that sending thing does not know anything about receiving things and *vice versa*, receiving things do not know anything about the sending thing - except for the sending thing's id. Things are generally only “aware” of channels and messages.

This is how a typical Mainflux message looks like when received in the JSON format:

```
{
  "channel": "038774f6-1d37-4dab-9107-487adc3466a4",
  "subtopic": "room3.occupancy",
  "publisher": "6d2d8ad1-87b1-4b72-9b6f-2c00ae8755a1",
  "protocol": "http",
  "name": "occupancy3",
  "time": 1608542793.263,
  "bool_value": false
}
```

The field `publisher` refers to the sending thing's AIP internal id and `time` refers to Unix time. Instead of `bool_value` message can also have a float, string or binary value.

8.4 Users

Users are AIP **tenants** and represent physical **persons** and **organizations**. Users **own** channels and things. Users provide authentication mechanisms to AIP, i.e. a secure access to things and channels and their manipulation.

User is represented via **e-mail** and **password**. The latter are used as platform access credentials in order to obtain an access **token**. Once logged into the system, user can manage his resources (i.e. things and channels) in CRUD fashion and define access control policies by connecting them.

There is an important distinction to keep in mind here. While user provides access rights to and allows one to perform CRUD operations on channels, things and their connections, thing's ID and key are used as credentials - a sort of username and password - to send and receive messages over channels.

8.5 Twins

Not to be confused with DTT's digital twin.

In the IoT terminology, **twin** refers to a **digital representation** of a **real world data system** consisting of possibly multiple data sources/producers and/or destinations/consumers (data agents).

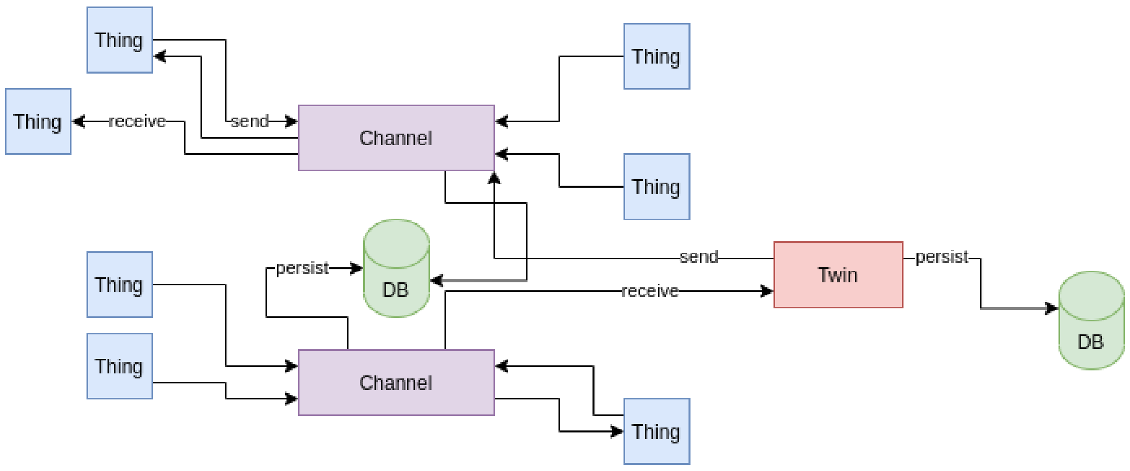
A machine can use multiple protocols such as MQTT and OPC UA, and a regularly updated, machine hosted CSV file to send measurement data - such as flow rate, material temperature, etc. - and state data - such as engine and chassis temperature, identity of the current human operator, etc. - as well as to receive control (messages) - such as, turn on/off light, increment/decrement borer speed, etc. On the cloud end of the IoT spectrum, an application can consume, but it can also generate data. There can be a whole series of logically interconnected applications that produce data.

Twin is an abstract digital replica of a real world system such as the machine we have just described or a series of logically interconnected applications, or both. It is used to store system's state snapshots, to compare system states over a given period of time - so-called diffs or deltas - as well as to control agents composing the system.

Twin entity is built on top of the Ashvin IoT platform and relies on its architecture and entities, more precisely, on users, things and channels. Ashvin IoT twin consists of three parts:

- General data about twin itself, i.e. **twin's metadata**,
- History of twin's **definitions**, including current definition,
- History of twin's **states**, including current state.

All twins and their states are persisted in the database. Currently, Ashvin IoT system supports MongoDB for twin persistence out of the box. (Messages can be persisted in MongoDB as well as in InfluxDB.)



AIP architecture with twin service

8.5.1 Twin's Anatomy

Twin's **general information** stores twin's owner email - owner is represented by an Ashvin IoT platform user -, twin's ID (internal unique identifier) and name (not necessarily unique), twin's creation and definition update times as well as twin's revision number - the sequential number of twin's definition.

Twin's **definition** is a semantic representation of system's data producers and consumers (data agents). Each data agent is represented by means of an **attribute**. An attribute consists of data agent's name, channel and subtopic. *Nota bene*: each attribute is uniquely defined by the combination of channel and subtopic and we cannot have two or more attributes with the same channel and subtopic in the same definition.

A typical twin's definition might look like this:

```
{
    "id": 6,
    "created": "2020-12-15T09:05:19.445Z",
    "attributes": [
        {
            "name": "room2 > temperature",
            "channel": "32628244-4569-45fa-84c8-a4ac4a77f258",
            "subtopic": "room2.temperature",
            "persist_state": true
        },
        {
            "name": "room2 > humidity",
            "channel": "32628244-4569-45fa-84c8-a4ac4a77f258",
            "subtopic": "room2.humidity",
            "persist_state": true
        },
        {
            "name": "room2 > occupancy",
            "channel": "32628244-4569-45fa-84c8-a4ac4a77f258",
            "subtopic": "room2.occupancy",
            "persist_state": true
        },
    ],
    "delta": 1000
}
```

A typical twin's state might look like this:

```
{
    "twin_id": "8905064a-af8d-4705-9970-bf6f6d49fe83",
    "id": 3501,
    "definition": 6,
    "created": "2020-12-15T12:23:13.556Z",
    "payload": {
        "room2 > humidity": 66.51826718978143,
        "room2 > occupancy": false,
        "room2 > temperature": 28.917830716862856
    }
}
```

9 APPENDIX 3: ASHVIN IOT PLATFORM RELATED TOOLS

Ashvin IoT platform (AIP) is at its core a messaging middleware. Except for the well-defined and comprehensive IoT entities CRUD and messaging oriented application programming interface, it does not offer much in terms of a user interface. However, there are many open source tools that can use AIP application programming interface in order to

- log in,
- perform create, read, update, and delete (CRUD) operations on AIP basic entities,
- send and receive messages.

Every interaction with the API requires a valid Ashvin IoT platform user.

9.1 Create, read, update, and delete (CRUD) entities

9.1.1 Ashvin IoT GUI

Ashvin IoT platform has a dedicated GUI for the platform operators. GUI is under development and can be used for all CRUD operations. GUI is not supposed to be used for messaging. In other words, it is used to create, read, update, and delete things and channels as well as their connections (for more information, please see entities). This is the easiest way to perform CRUD operations in AIP. You can get more information here.

9.1.2 Postman

Postman is the API Client that enables you to send HTTP requests and receive HTTP responses. Postman enables you to do manually what your browser is doing automatically for you. That means that you can use Postman to gain a greater and fine grain control over AIP CRUD operations. You can get more information here.

9.2 Send and receive messages

9.2.1 Mosquitto

Eclipse Mosquitto is an open source message broker that implements the MQTT protocol. The Eclipse Mosquitto project also hosts the development of the popular `mosquitto_pub` and `mosquitto_sub` command line MQTT clients. You can get more information here.

10 APPENDIX 4: ASHVIN IOT PLATFORM GUI

To operate AIP in an intuitive way, we use AIP dedicated graphical user interface (GUI). To be clear, this GUI is not a platform itself. It is only an external tool used to operate a platform. To understand why, please keep in mind that the AIP is at its core a messaging middleware that exposes a well-defined API to be used with various protocols such as HTTP, MQTT and CoAP.

AIP GUI leverages a RESTful web service design. In practice, this means that you can use HTTP methods, such as GET, HEAD, POST, PUT, etc. to perform create, read, update, and delete (CRUD) operations on the AIP entities and that is exactly what AIP GUI enable us to do.

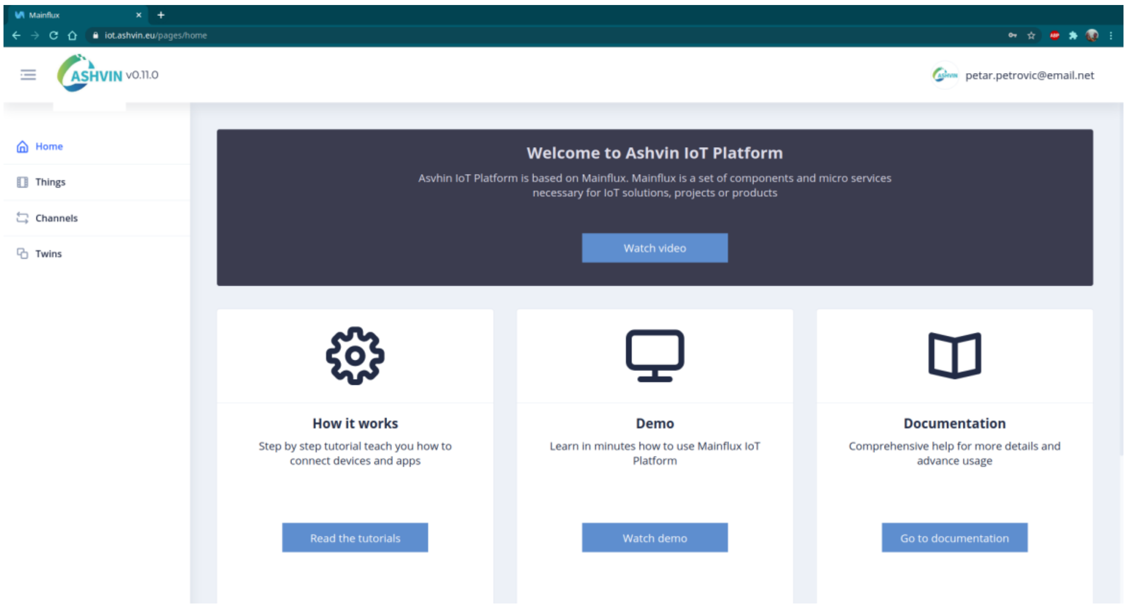
NB: AIG GUI is not meant to be used to send messages. You can use Mosquitto client to send and receive messages over AIP.

10.1 Login screen

AIP GUI is located at iot.ashvin.eu. Once you go there, you are presented with the login screen. To use it, you need to be a valid user, i.e. you need access credentials. Please see here how to get the credentials.

10.2 Dashboard

Once you are logged in, you are presented with the dashboard.


Mainflux
iot.ashvin.eu/pages/home
ASHVIN v0.11.0
petar.petrovic@email.net
Home
Things
Channels
Twins
Welcome to Ashvin IoT Platform
Asvhin IoT Platform is based on Mainflux. Mainflux is a set of components and micro services necessary for IoT solutions, projects or products
Watch video
How it works
Step by step tutorial teach you how to connect devices and apps
Read the tutorials
Demo
Learn in minutes how to use Mainflux IoT Platform
Watch demo
Documentation
Comprehensive help for more details and advance usage
Go to documentation

GUI dashboard

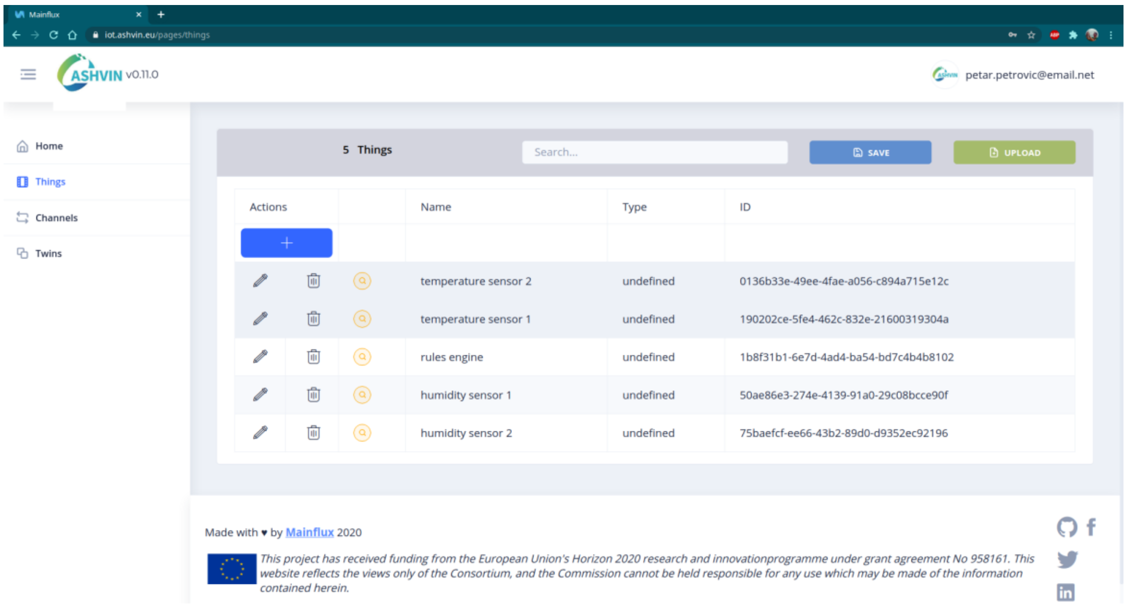
In the central panel you can see the description and some useful links, amongst others, link to this documentation.

The menu on the right shows you the top-level options. The majority of these options reflect

AIP entities and these options let you operate, in a CRUD fashion, these entities.

10.3 Things

If you select the `Things` menu option, you will be presented with the following screen:



5 Things

Actions	Name	Type	ID
	temperature sensor 2	undefined	0136b33e-49ee-4fae-a056-c894a715e12c
	temperature sensor 1	undefined	190202ce-5fe4-462c-832e-21600319304a
	rules engine	undefined	1b8f31b1-6e7d-4ad4-ba54-bd7c4b4b8102
	humidity sensor 1	undefined	50ae86e3-274e-4139-91a0-29c08bcce90f
	humidity sensor 2	undefined	75baefcf-ee66-43b2-89d0-d9352ec92196

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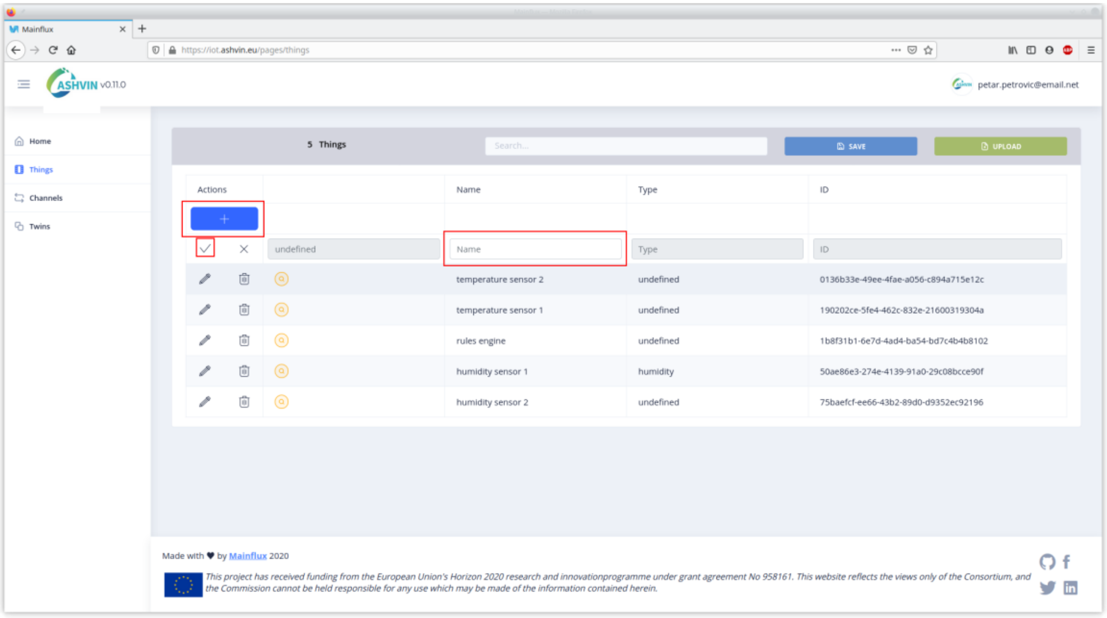
Things list

This is the list of the things that belong to your user, i.e. to the currently logged in user. To add a new thing, click on the plus sign, enter thing's name and click the check mark sign:



5 Things

Actions		Name	Type	ID
	undefined	Name	Type	ID
		temperature sensor 2	undefined	0136b33e-49ee-4fae-a056-c894a715e12c
		temperature sensor 1	undefined	190202ce-5fe4-462c-832e-21600319304a
		rules engine	undefined	1b8f31b1-6e7d-4ad4-ba54-bd7c4b4b8102
		humidity sensor 1	humidity	50ae86e3-274e-4139-91a0-29c08bcce90f
		humidity sensor 2	undefined	75baefcf-ee66-43b2-89d0-d9352ec92196

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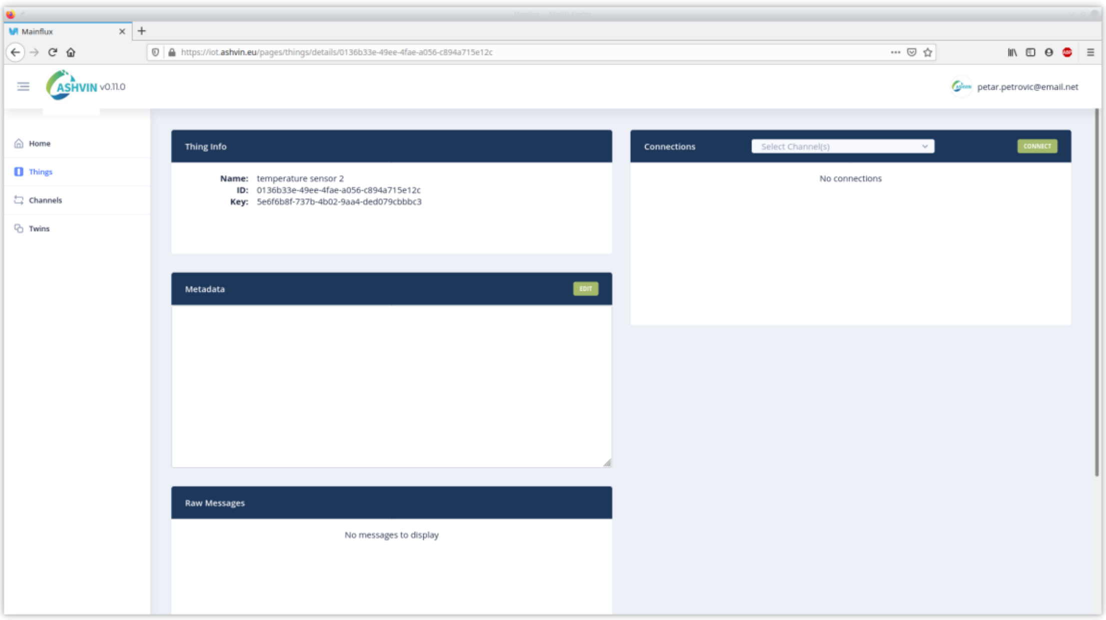
Add thing

The thing's ID will be automatically generated. Now you can click on the details icon (a magnifying glass) to see the details of your thing. You will be presented with the details screen:



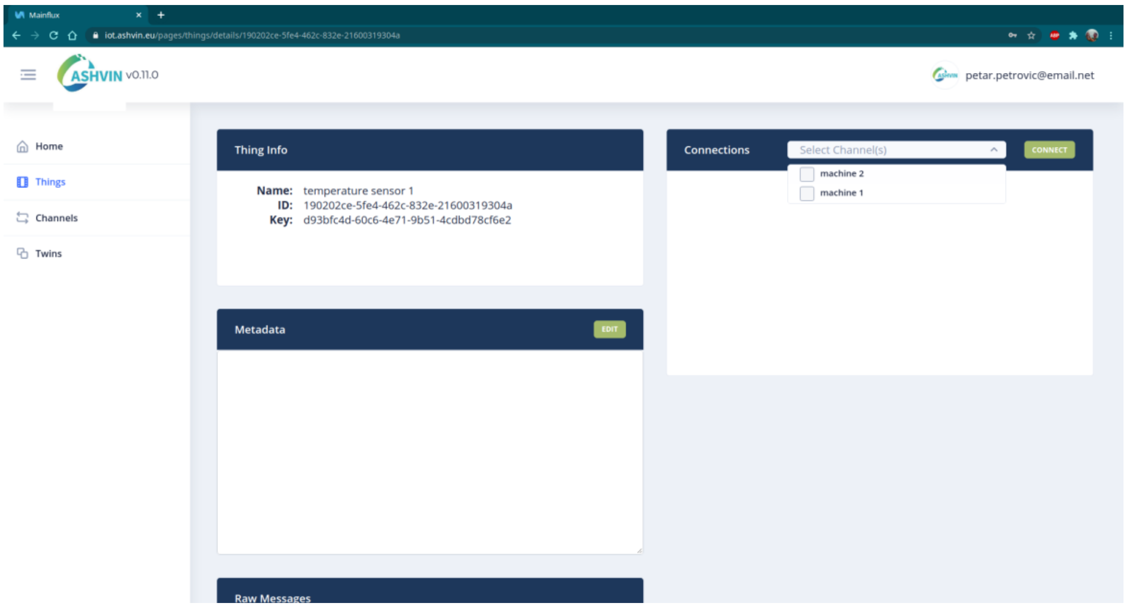
Name: temperature sensor 2
ID: 0136b33e-49ee-4fae-a056-c894a715e12c
Key: 5e6f6b8f-737b-4b02-9aa4-ded079cbbbc3

No connections

No messages to display

Thing's details

On the details screen, you can see thing's ID and thing's key. The former is the internal Ashvin IoT platform identifier. The latter is best understand as thing's password. You need this in order to send and receive messages with this thing. The thing's key is an AIP abstraction: it abstracts away complexities of different protocol authorization procedures. As things abstract away complexities of protocol authorization, channels abstract away complexities of protocol message "routing". In order to exchange messages via the thing in question, we need to connect the thing to the appropriate channel:



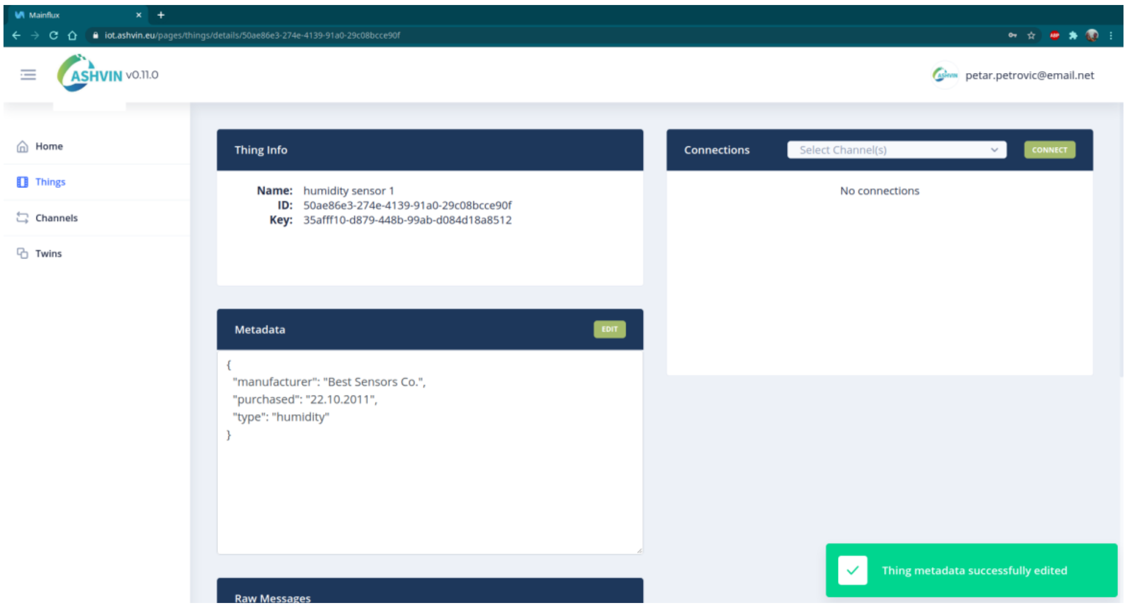
Name: temperature sensor 1
ID: 190202ce-5fe4-462c-832e-21600319304a
Key: d93bfc4d-60c6-4e71-9b51-4cdbd78cf6e2

Connect thing and channel

In the upper-right corner of the screenshot, we see the possible channels listed in the drop down menu.

In this particular example, the channel represent single machine's communication "route". Our hypothetical machine is endowed with many sensors represented by AIP things and all this sensors communicate with a cloud application via this single channel. (Naturally, there are other ways to represent the real data system by using AIP things and channels.) This single channel could stand for (and abstract away complexities of) an mqtt host and topic, for example.

To connect a thing to a channel, simply select the channels and click on the connect button. You can also edit the thing's metadata:



Thing Info

Name: humidity sensor 1
ID: 50ae86e3-274e-4139-91a0-29c08bcce90f
Key: 35afff10-d879-448b-99ab-d084d18a8512

No connections

Metadata

```
{
 "manufacturer": "Best Sensors Co.",
 "purchased": "22.10.2011",
 "type": "humidity"
}
```

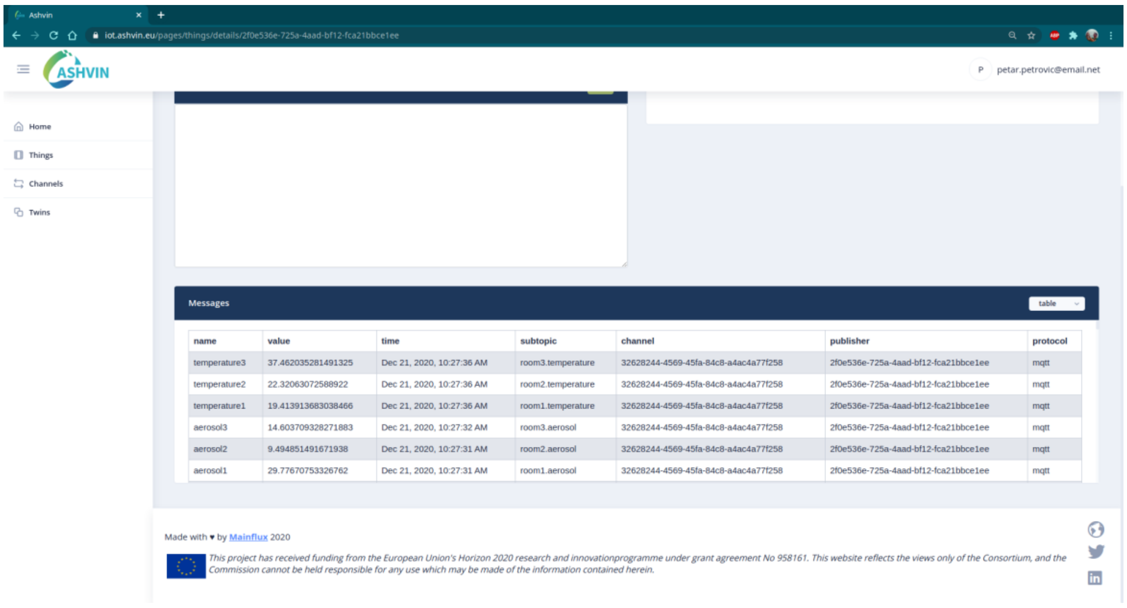
Thing metadata successfully edited

Thing's metadata

Metadata is used to add an arbitrary data to a thing. We normally add a type of the thing. For example, a type can be `device` or an `application`. You can have more precise types like `drilling machine`, etc. This kind of data is called metadata because - unlike thing's key and thing's ID which are AIP internal data necessary for the proper functioning of the AIP -, AIP does not understand anything about the metadata structure and semantics. It is a responsibility of a user - be it a real person or another application built on top of AIP - to figure out the organization and meaning of the metadata.

To add a metadata, simply type a valid JSON object in the `Metadata` card and click on the edit button. If your JSON is valid, which you can check beforehand, for example, here, you'll get a metadata edit success notification.

Finally, in the card `Messages`, you can see all messages sent or received by the current thing:



name	value	time	subtopic	channel	publisher	protocol
temperature3	37.462035281491325	Dec 21, 2020, 10:27:36 AM	room3.temperature	32628244-4569-45fa-84c8-a4ac4a77f258	2f0e536e-725a-4aad-bf12-fca21bbce1ee	mqtt
temperature2	22.32063072588922	Dec 21, 2020, 10:27:36 AM	room2.temperature	32628244-4569-45fa-84c8-a4ac4a77f258	2f0e536e-725a-4aad-bf12-fca21bbce1ee	mqtt
temperature1	19.413913683038466	Dec 21, 2020, 10:27:36 AM	room1.temperature	32628244-4569-45fa-84c8-a4ac4a77f258	2f0e536e-725a-4aad-bf12-fca21bbce1ee	mqtt
aerosol3	14.603709328271883	Dec 21, 2020, 10:27:32 AM	room3.aerosol	32628244-4569-45fa-84c8-a4ac4a77f258	2f0e536e-725a-4aad-bf12-fca21bbce1ee	mqtt
aerosol2	9.494851491671938	Dec 21, 2020, 10:27:31 AM	room2.aerosol	32628244-4569-45fa-84c8-a4ac4a77f258	2f0e536e-725a-4aad-bf12-fca21bbce1ee	mqtt
aerosol1	29.77670753326762	Dec 21, 2020, 10:27:31 AM	room1.aerosol	32628244-4569-45fa-84c8-a4ac4a77f258	2f0e536e-725a-4aad-bf12-fca21bbce1ee	mqtt

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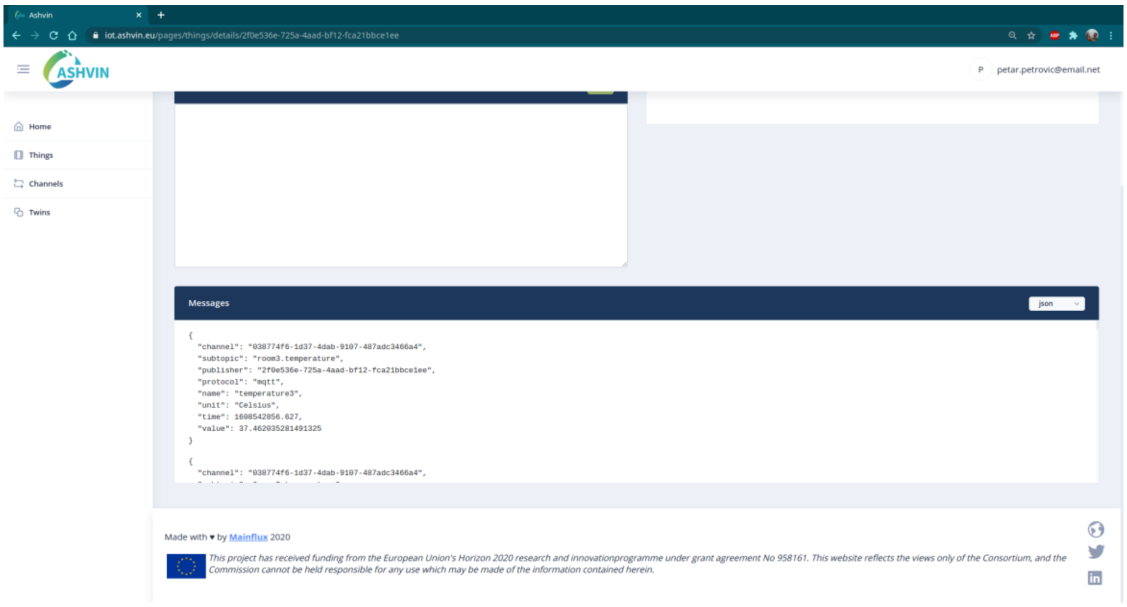
Thing's messages in table format

You can get a "raw" message list - messages formatted as a list of JSON objects - by clicking on the `table` dropdown menu and selecting `json`:


Ashvin
iot.ashvin.eu/pages/things/details/2f0e536e-725a-4aad-bf12-fca21bbce1ee
ASHVIN
petar.petrovic@email.net
Home
Things
Channels
Twins
Messages
json

```
{
  "channel": "038774f6-1d37-4dab-9107-487adc3466a4",
  "subtopic": "room3.temperature",
  "publisher": "2f0e536e-725a-4aad-bf12-fca21bbce1ee",
  "protocol": "mqtt",
  "name": "temperature3",
  "unit": "Celsius",
  "time": 1608542856.627,
  "value": 37.462035281491325
}

{
  "channel": "038774f6-1d37-4dab-9107-487adc3466a4",
```

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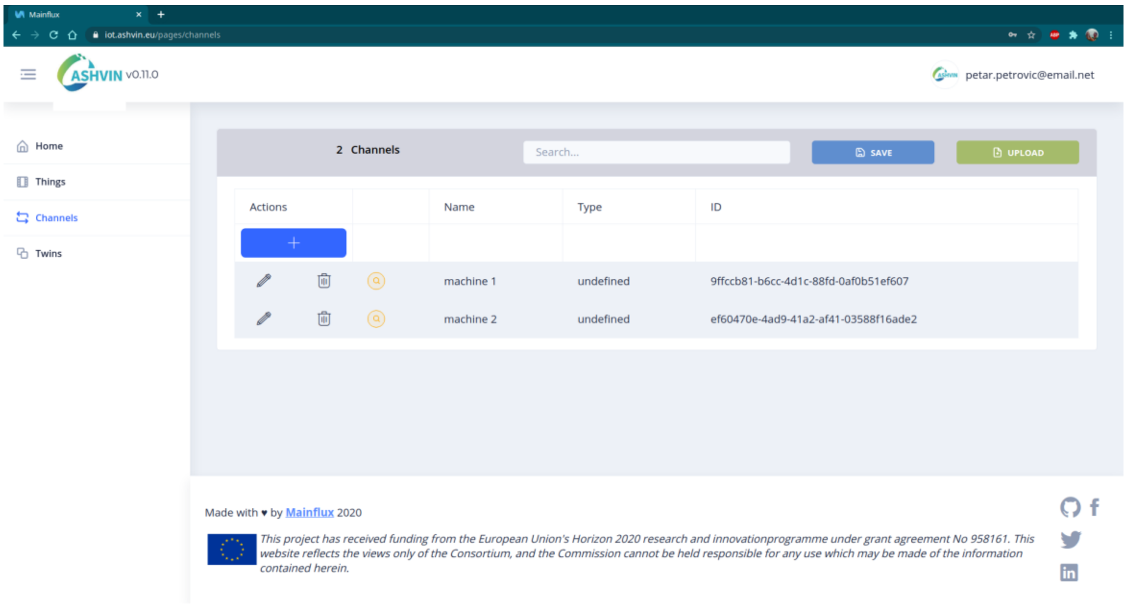
Thing's messages in JSON list format

A thing can be subscribed to multiple channels, and many things can be subscribed to one channel. To tell if a thing is a receiver or a sender of a message, just compare the `publisher` field of a particular message with thing's ID. If they are the same, than the current thing is the publisher of the message.

10.4 Channels

The interface part for CRUD operations on channels follows the same logic as the interface part related to things. Firstly, you can list channels that you (or your user) have by simply clicking on the `Channels` in the left hand side menu.



Actions		Name	Type	ID
		machine 1	undefined	9ffccb81-b6cc-4d1c-88fd-0af0b51ef607
		machine 2	undefined	ef60470e-4ad9-41a2-af41-03588f16ade2

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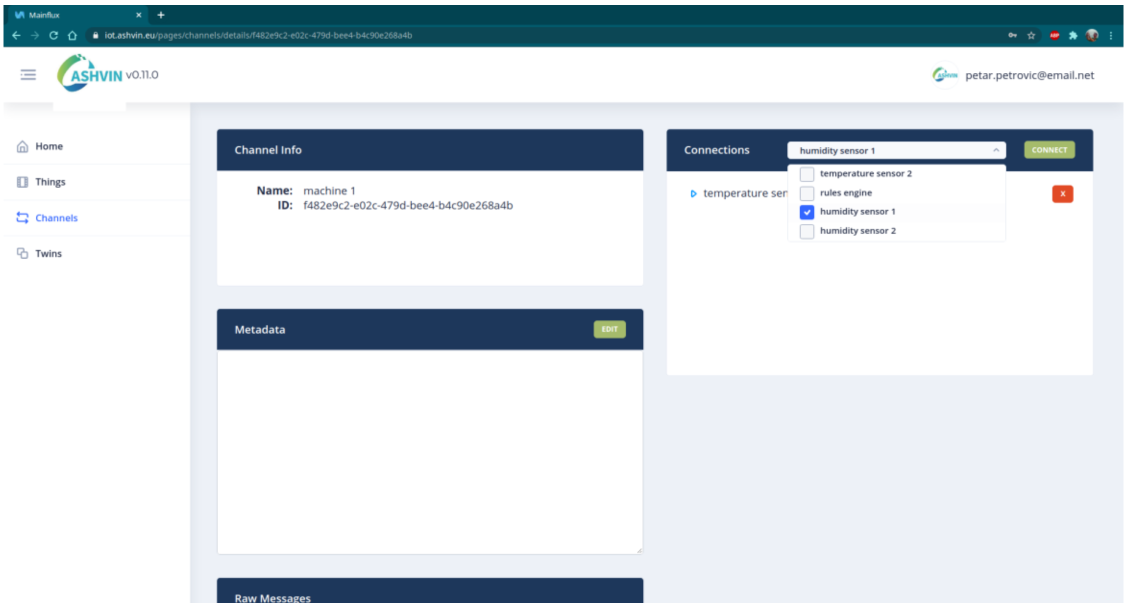
Channels list

From there on, you can create the new channel in the same way you create a new thing. Just click on the plus sign, enter channel's name and click the check mark sign. By clicking on the magnifying glass icon, you can visit particular channel's details page.

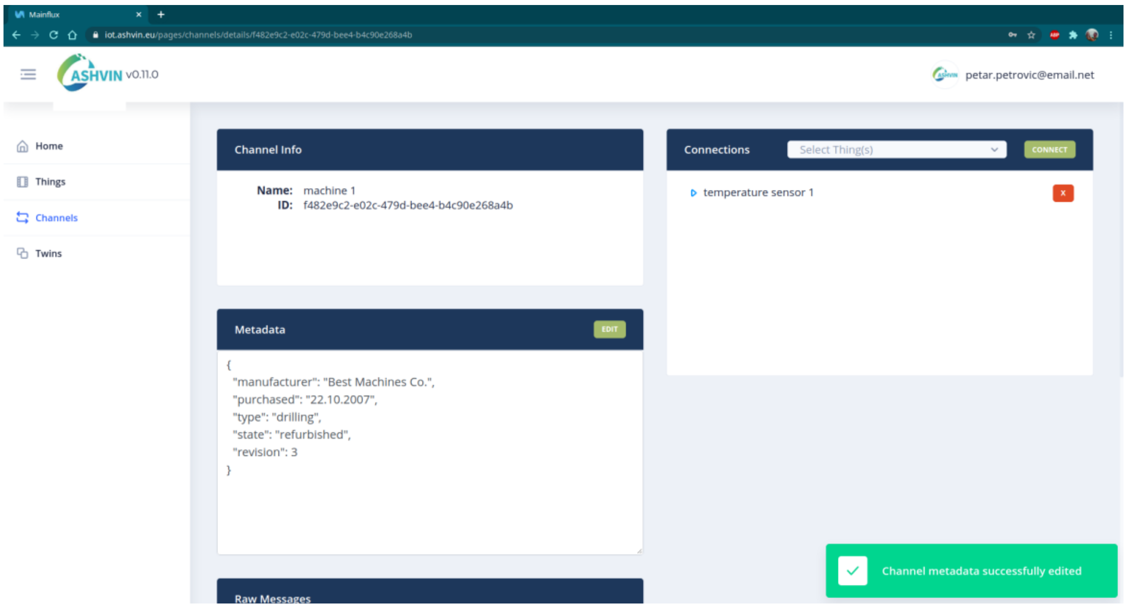
Ashvin IoT platform supports one-to-one, one-to-many, many-to-one and many-to-many connections between arbitrary things and channels. In other words, you can connect any thing to any channel and vice versa. You can connect things and channels either on thing's details page or on channel's details page. The procedure is the same:



Name: machine 1
ID: f482e9c2-e02c-479d-bee4-b4c90e268a4b

Connect thing and channel

You can edit channel's metadata in the same way you edit things metadata. Just enter a valid JSON object and click on the `Edit` button. If the JSON object is valid, you will get a success notification:



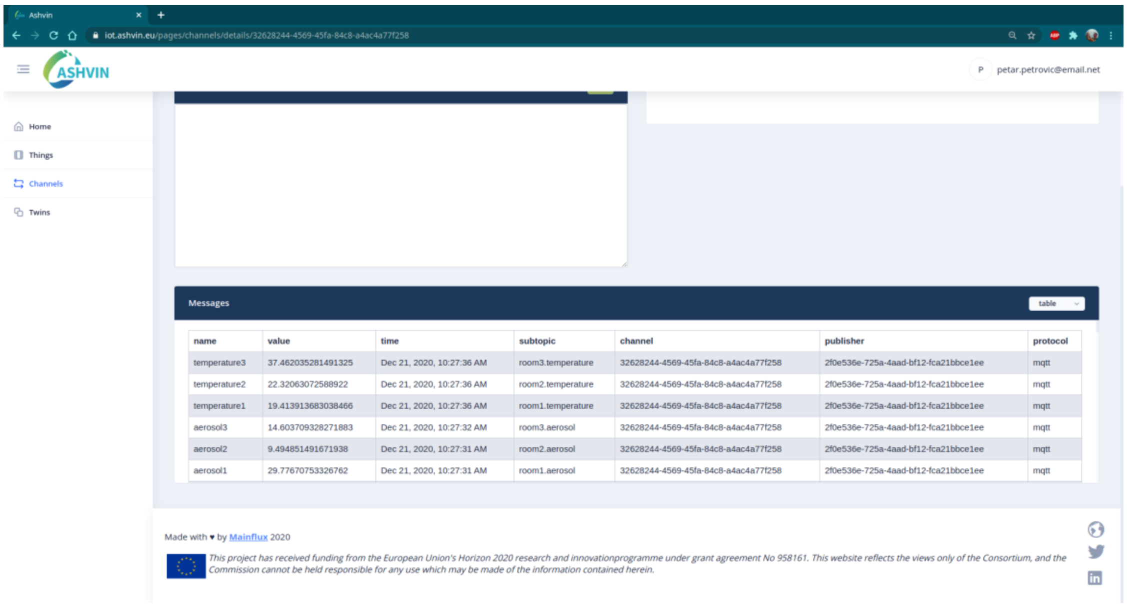
Name: machine 1
ID: f482e9c2-e02c-479d-bee4-b4c90e268a4b

```
{
  "manufacturer": "Best Machines Co.",
  "purchased": "22.10.2007",
  "type": "drilling",
  "state": "refurbished",
  "revision": 3
}
```

Channel metadata successfully edited

Channel's metadata

As with things, metadata is not related to internals of Ashvin IoT platform. Rather, it enables IoT system designers to make an IoT data system with a custom semantics and structure. Finally, you can also get a list of messages send or received over the channel in question by simply inspecting the card `Messages`:


Ashvin
iot.ashvin.eu/pages/channels/details/32628244-4569-45fa-84c8-a4ac4a77f258
ASHVIN
P
petar.petrovic@email.net
Home
Things
Channels
Twins
Messages
table

name	value	time	subtopic	channel	publisher	protocol
temperature3	37.462035281491325	Dec 21, 2020, 10:27:36 AM	room3.temperature	32628244-4569-45fa-84c8-a4ac4a77f258	2f0e536e-725a-4aad-bf12-fca21bbce1ee	mqtt
temperature2	22.32063072588922	Dec 21, 2020, 10:27:36 AM	room2.temperature	32628244-4569-45fa-84c8-a4ac4a77f258	2f0e536e-725a-4aad-bf12-fca21bbce1ee	mqtt
temperature1	19.413913683038466	Dec 21, 2020, 10:27:36 AM	room1.temperature	32628244-4569-45fa-84c8-a4ac4a77f258	2f0e536e-725a-4aad-bf12-fca21bbce1ee	mqtt
aerosol3	14.603709328271883	Dec 21, 2020, 10:27:32 AM	room3.aerosol	32628244-4569-45fa-84c8-a4ac4a77f258	2f0e536e-725a-4aad-bf12-fca21bbce1ee	mqtt
aerosol2	9.494851491671938	Dec 21, 2020, 10:27:31 AM	room2.aerosol	32628244-4569-45fa-84c8-a4ac4a77f258	2f0e536e-725a-4aad-bf12-fca21bbce1ee	mqtt
aerosol1	29.77670753326762	Dec 21, 2020, 10:27:31 AM	room1.aerosol	32628244-4569-45fa-84c8-a4ac4a77f258	2f0e536e-725a-4aad-bf12-fca21bbce1ee	mqtt

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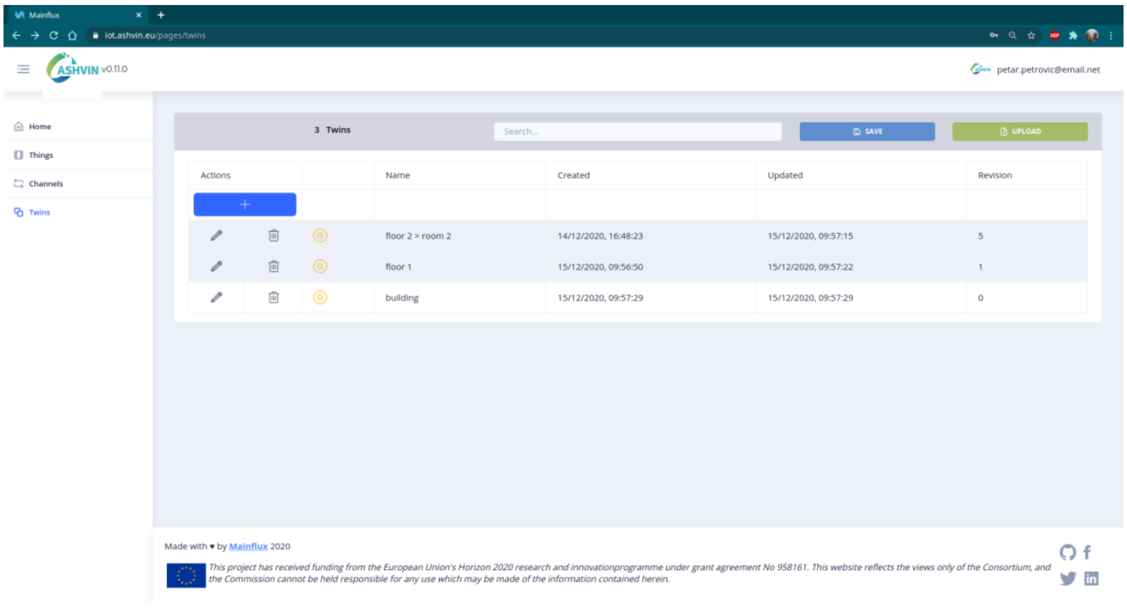
Channel's messages in table format

Obviously, `channel` attribute of a particular message will always be the same as the channel ID of the current channel.

10.5 Twins

Mainflux twin is a **digital representation** of a **real world data system** consisting of multiple data sources/producers and/or destinations/consumers. Its aim is to facilitate the logical or semantic grouping of physical devices and applications.

The interface part for CRUD operations on twins follows the same logic as the interface part related to things. Firstly, you can list twins that you (or your user) have by simply clicking on the `Twins` option in the left hand side menu.



3 Twins

Actions			Name	Created	Updated	Revision
+						
			floor 2 > room 2	14/12/2020, 16:48:23	15/12/2020, 09:57:15	5
			floor 1	15/12/2020, 09:56:50	15/12/2020, 09:57:22	1
			building	15/12/2020, 09:57:29	15/12/2020, 09:57:29	0

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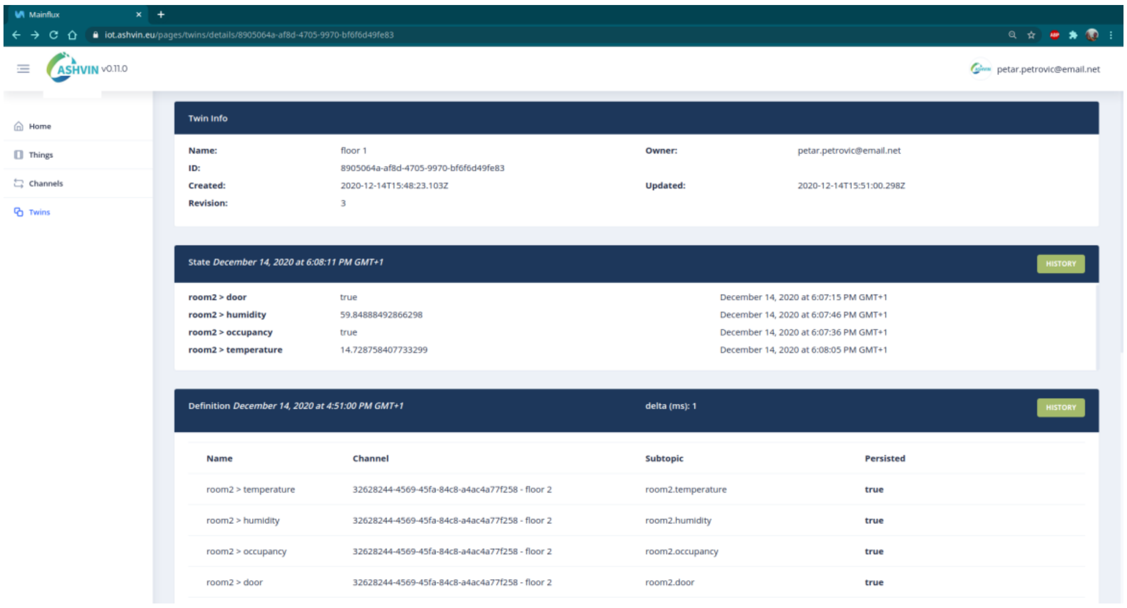
Twins list

You can create a new twin in the same way you create a new thing: click on the plus sign, enter twin's name and click the check mark sign. By clicking on the magnifying glass icon, you go to the particular twin's details page.



Twin Info

Name:	floor 1	**Owner:**	petar.petrovic@email.net
ID:	8905064a-af8d-4705-9970-bf6f6d49fe83		
Created:	2020-12-14T15:48:23.103Z	**Updated:**	2020-12-14T15:51:00.298Z
Revision:	3		

State *December 14, 2020 at 6:08:11 PM GMT+1*

room2 > door	true	December 14, 2020 at 6:07:15 PM GMT+1
room2 > humidity	59.84888492866298	December 14, 2020 at 6:07:46 PM GMT+1
room2 > occupancy	true	December 14, 2020 at 6:07:36 PM GMT+1
room2 > temperature	14.728758407733299	December 14, 2020 at 6:08:05 PM GMT+1

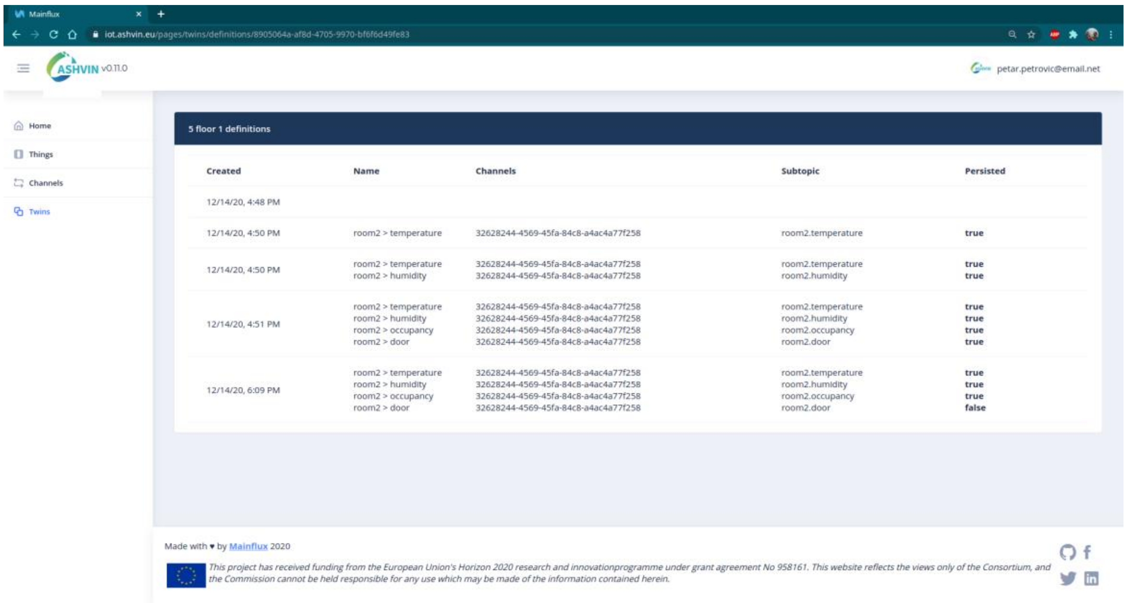
Definition *December 14, 2020 at 4:51:00 PM GMT+1* delta (ms): 1

Name	Channel	Subtopic	Persisted
room2 > temperature	32628244-4569-45fa-84c8-a4ac4a77f258 - floor 2	room2.temperature	**true**
room2 > humidity	32628244-4569-45fa-84c8-a4ac4a77f258 - floor 2	room2.humidity	**true**
room2 > occupancy	32628244-4569-45fa-84c8-a4ac4a77f258 - floor 2	room2.occupancy	**true**
room2 > door	32628244-4569-45fa-84c8-a4ac4a77f258 - floor 2	room2.door	**true**

Twin's details

`Twin info` card shows you the name and internal ID of the twin, owner and when it was created as well as when it was updated. To understand what twin update means, one needs to understand the anatomy of a twin. In a nutshell, the main part of a twin is it's definition which consists of a set of attributes, where each attribute is uniquely defined by a combination of channel and subtopic.

`Definition` card shows you the current definition of a twin. By clicking on the button `History`, you get a chronological list of successive twin's definitions.



Mainflux
iot.ashvin.eu/pages/twins/definitions/8905064a-af8d-4705-9970-bf6f6d49fe83
ASHVIN v0.11.0
petar.petrovic@email.net
Home
Things
Channels
Twins

5 floor 1 definitions

Created	Name	Channels	Subtopic	Persisted
12/14/20, 4:48 PM				
12/14/20, 4:50 PM	room2 > temperature	32628244-4569-45fa-84c8-a4ac4a77f258	room2.temperature	true
12/14/20, 4:50 PM	room2 > temperature room2 > humidity	32628244-4569-45fa-84c8-a4ac4a77f258 32628244-4569-45fa-84c8-a4ac4a77f258	room2.temperature room2.humidity	true true
12/14/20, 4:51 PM	room2 > temperature room2 > humidity room2 > occupancy room2 > door	32628244-4569-45fa-84c8-a4ac4a77f258 32628244-4569-45fa-84c8-a4ac4a77f258 32628244-4569-45fa-84c8-a4ac4a77f258 32628244-4569-45fa-84c8-a4ac4a77f258	room2.temperature room2.humidity room2.occupancy room2.door	true true true true
12/14/20, 6:09 PM	room2 > temperature room2 > humidity room2 > occupancy room2 > door	32628244-4569-45fa-84c8-a4ac4a77f258 32628244-4569-45fa-84c8-a4ac4a77f258 32628244-4569-45fa-84c8-a4ac4a77f258 32628244-4569-45fa-84c8-a4ac4a77f258	room2.temperature room2.humidity room2.occupancy room2.door	true true true false

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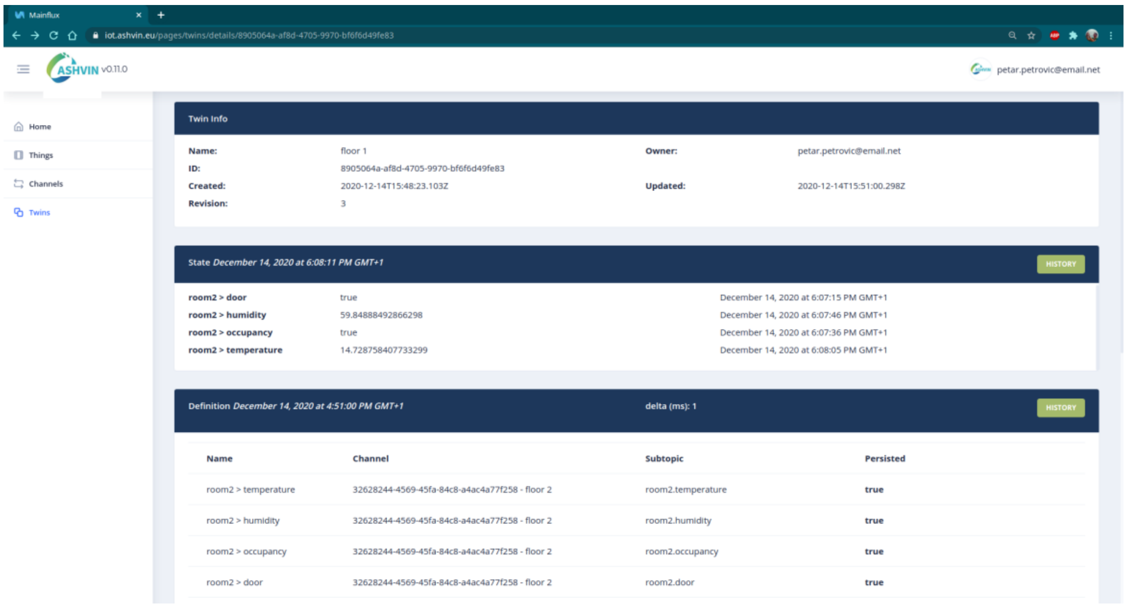
Twin's definition

The field `persisted` tells us whether an attribute is persisted in the database. This leads us to the question of twin's state. Twin's state is a snapshot in a certain point in time of a data agent represented by a twin. It stores the values of attributes in a certain point in time. The new snapshot occurs when any of the attributes change and if the time difference, `delta`, between the last snapshot and the snapshot being taken is greater than a set amount of time.

`State` on the twin's details page



Twin Info

Name:	floor 1	Owner:	petar.petrovic@email.net
ID:	8905064a-af8d-4705-9970-bf6f6d49fe83		
Created:	2020-12-14T15:48:23.103Z	Updated:	2020-12-14T15:51:00.298Z
Revision:	3		

State *December 14, 2020 at 6:08:11 PM GMT+1*

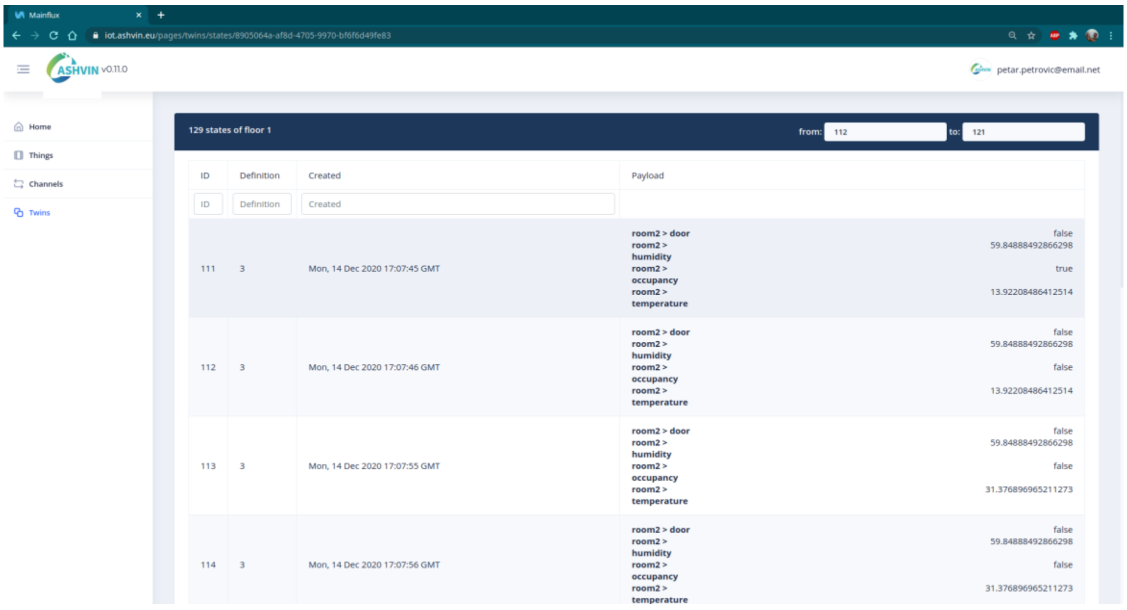
room2 > door	true	December 14, 2020 at 6:07:15 PM GMT+1
room2 > humidity	59.84888492866298	December 14, 2020 at 6:07:46 PM GMT+1
room2 > occupancy	true	December 14, 2020 at 6:07:36 PM GMT+1
room2 > temperature	14.728758407733299	December 14, 2020 at 6:08:05 PM GMT+1

Definition *December 14, 2020 at 4:51:00 PM GMT+1* delta (ms): 1

Name	Channel	Subtopic	Persisted
room2 > temperature	32628244-4569-45fa-84c8-a4ac4a77f258 - floor 2	room2.temperature	true
room2 > humidity	32628244-4569-45fa-84c8-a4ac4a77f258 - floor 2	room2.humidity	true
room2 > occupancy	32628244-4569-45fa-84c8-a4ac4a77f258 - floor 2	room2.occupancy	true
room2 > door	32628244-4569-45fa-84c8-a4ac4a77f258 - floor 2	room2.door	true

Twin's details

shows us the current values of the attributes whether they are persisted in a database (currently only MongoDB is supported) or not. By clicking on the `History` button, you go to the chronological list of states:


Mainflux
iot.ashvin.eu/pages/twins/states/8905064a-af8d-4705-9970-bf6f6d49fe83
ASHVIN v0.11.0
petar.petrovic@email.net
Home
Things
Channels
Twins

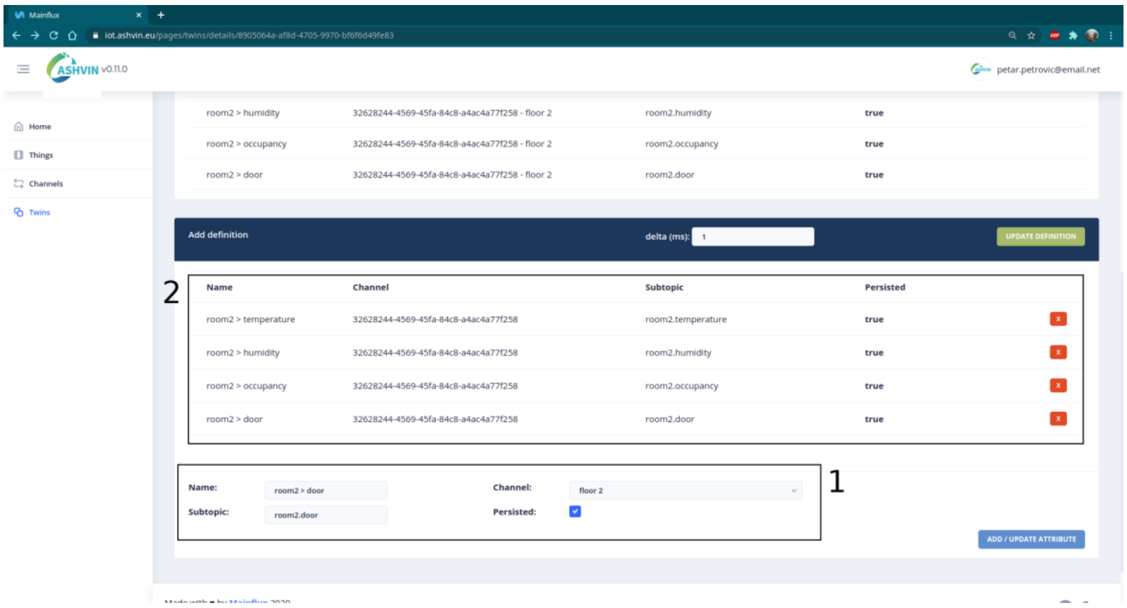
129 states of floor 1 from: 112 to: 121

ID	Definition	Created	Payload	
111	3	Mon, 14 Dec 2020 17:07:45 GMT	**room2 > door** **room2 > humidity** **room2 > occupancy** **room2 > temperature**	false 59.84888492866298 true 13.92208486412514
112	3	Mon, 14 Dec 2020 17:07:46 GMT	**room2 > door** **room2 > humidity** **room2 > occupancy** **room2 > temperature**	false 59.84888492866298 false 13.92208486412514
113	3	Mon, 14 Dec 2020 17:07:55 GMT	**room2 > door** **room2 > humidity** **room2 > occupancy** **room2 > temperature**	false 59.84888492866298 false 31.376896965211273
114	3	Mon, 14 Dec 2020 17:07:56 GMT	**room2 > door** **room2 > humidity** **room2 > occupancy** **room2 > temperature**	false 59.84888492866298 false 31.376896965211273

Twin's states

You see a total count of states and `from` and `to` fields, where you can enter the range of states (max range spans 100 states) to be displayed in the lower list. Each state has an ID - which is simply state's ordinal number - and a `Definition` field corresponding to a certain revision number of a twin, i.e. to a certain definition of twin. The date refers to the time when the state snapshot was made. Finally, the column `payload` shows us the attribute names and their corresponding values.

In the bottom of the twin's details page, you can find an attribute editor:



room2 > humidity	32628244-4569-45fa-84c8-a4ac4a77f258 - floor 2	room2.humidity	true
room2 > occupancy	32628244-4569-45fa-84c8-a4ac4a77f258 - floor 2	room2.occupancy	true
room2 > door	32628244-4569-45fa-84c8-a4ac4a77f258 - floor 2	room2.door	true

delta (ms): 1

Name	Channel	Subtopic	Persisted	
room2 > temperature	32628244-4569-45fa-84c8-a4ac4a77f258	room2.temperature	true	x
room2 > humidity	32628244-4569-45fa-84c8-a4ac4a77f258	room2.humidity	true	x
room2 > occupancy	32628244-4569-45fa-84c8-a4ac4a77f258	room2.occupancy	true	x
room2 > door	32628244-4569-45fa-84c8-a4ac4a77f258	room2.door	true	x

Name:	room2 > door	Channel:	floor 2
Subtopic:	room2.door	Persisted:	✓

Twin's attribute editor

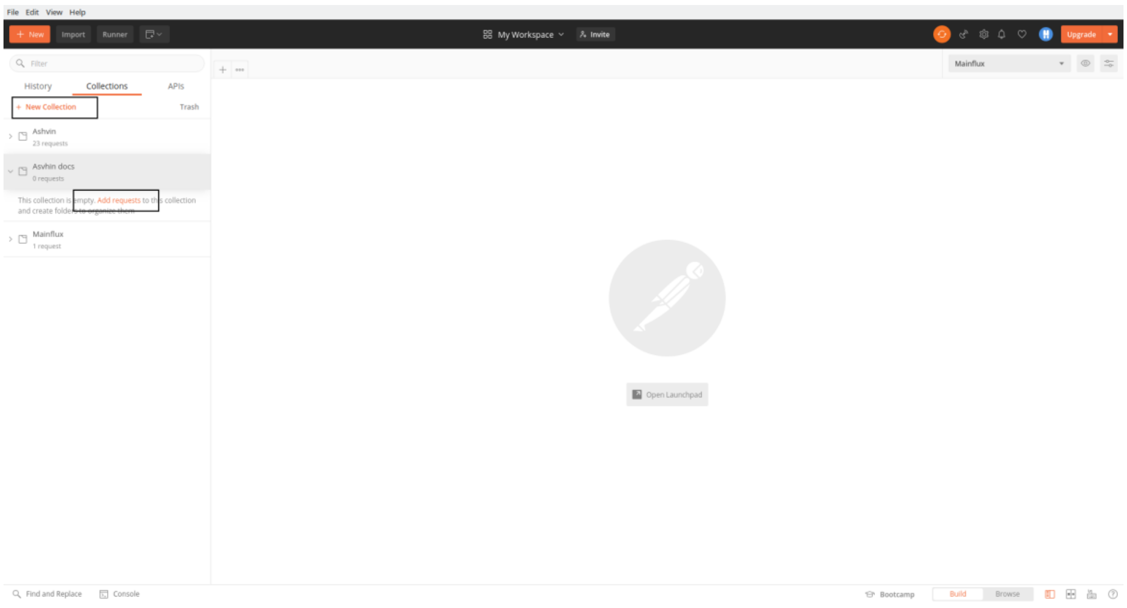
In the area outlined by rectangle 1, you can see an individual attribute editor. You can give a name, select a channel, enter a subtopic and select whether you want to persi st an attribute. By clicking on the Add/Update `Attribute` button, you add an attribute to an attribute list (or update it, if the attribute was already there). An attribute list itself, the area outlined by the rectangle 2, shows you the list of attributes and their properties. This list represents a set of attribute that will compose the future (next) definition of a twin. You can also set the time difference `delta` (see above). By clicking on `Update` definition button, you update the twin's definition, i.e. you turn the attribute list from the attribute editor in to the current twin's definition.

11 APPENDIX 5: POSTMAN

Postman is, amongst other, the API Client that enables you to send HTTP requests and receive HTTP responses. Postman enables you to do manually what your browser is doing automatically for you. This means that you can use Postman to gain a greater and fine grain control over AIP CRUD operations.

11.1 User authentication request

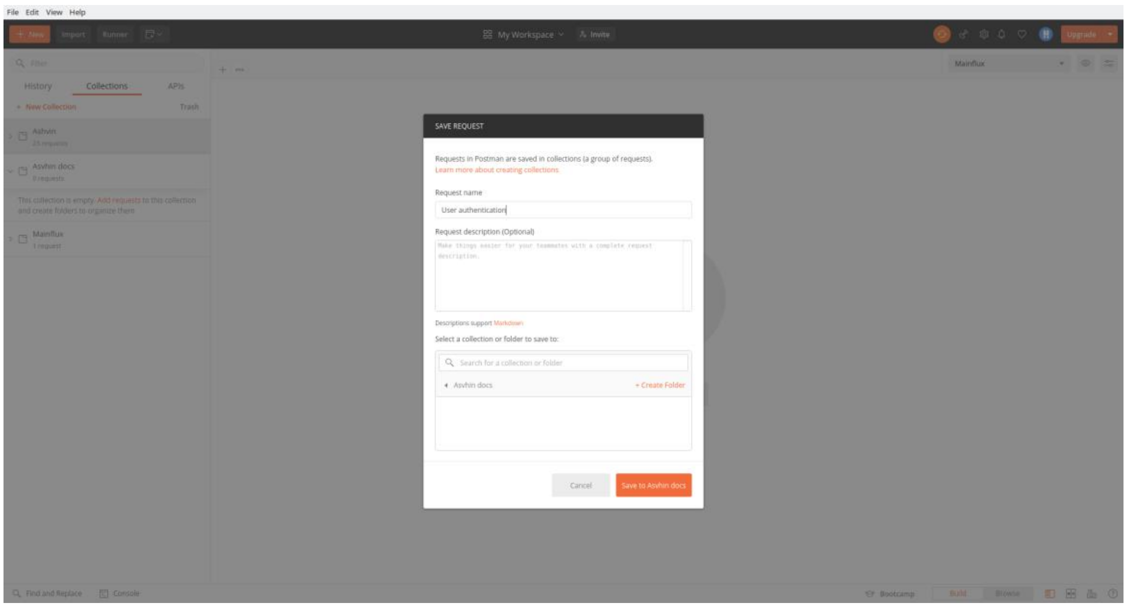
Let us now see how to create an HTTP request in Postman. Every Postman request is a part of a collection of requests. So we need to make a collection first.



This collection is empty. Add requests to this collection and create folders to organize them.

Postman Collection

Once you make a collection, click on the Add `requests` link and you will be presented with the request metadata (we will enter request HTTP data later) editor:


SAVE REQUEST

Requests in Postman are saved in collections (a group of requests).
Learn more about creating collections

Request name: User authentication

Request description (Optional): Make things easier for your teammates with a complete request description.

Descriptions support Markdown

Select a collection or folder to save to:

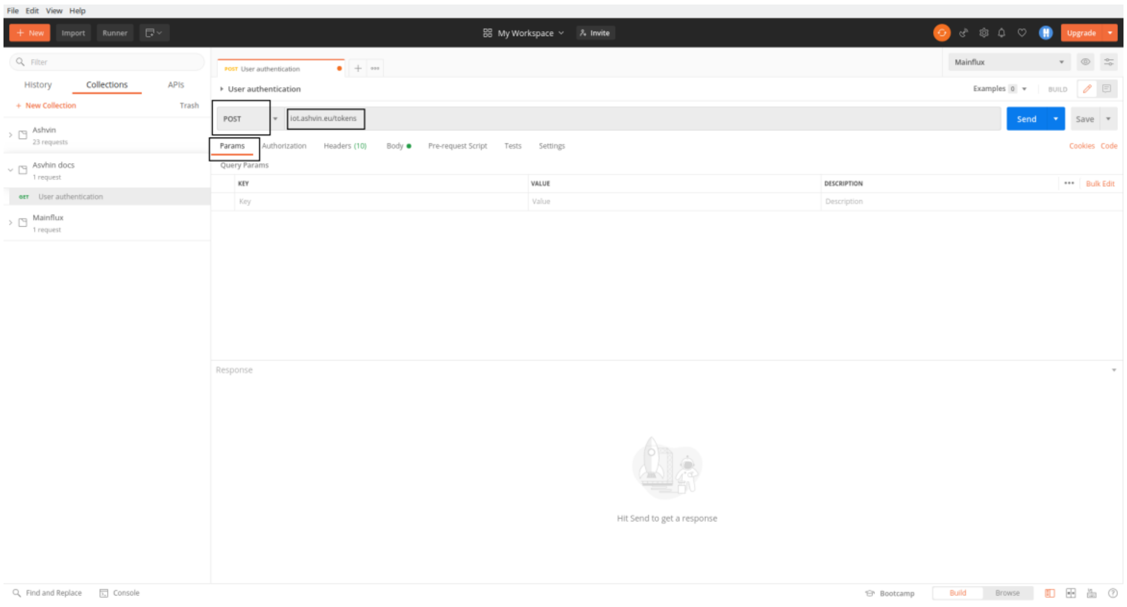
Search for a collection or folder

Asvhin docs + Create Folder

Cancel | Save to Asvhin docs

Postman Request

Enter the request name as "User authentication" and save the request to the collection. The first thing you want to do when interacting with the AIP is to get your user token. This token is then used in all other requests that you send to the AIP. Token is used by AIP to verify the authenticity of your requests. So let us set the Postman request that we have just made to request the user token. Go to the `Params` tab (it should be open by default), replace GET method by POST and enter the `iot.ashvin.eu/tokens` in the URL field.



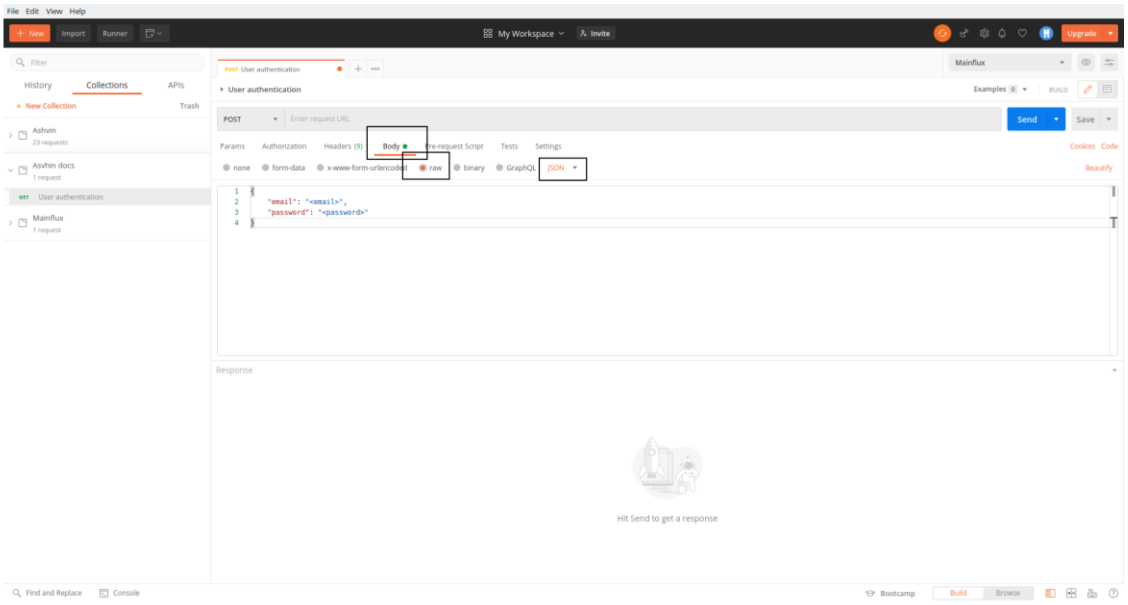
Method selection

Every request that you make via Postman is directed towards a certain address. Every request addressed to the AIP begins with `iot.ashvin.eu/`. We use the POST method of request sending in order to post our username and password in the request body.

To set a request body, go to Body tab, select `raw` body and from the dropdown menu select `JSON`. Then enter

```
{
    "email": "<email>",
    "password": "<password>"
}
```

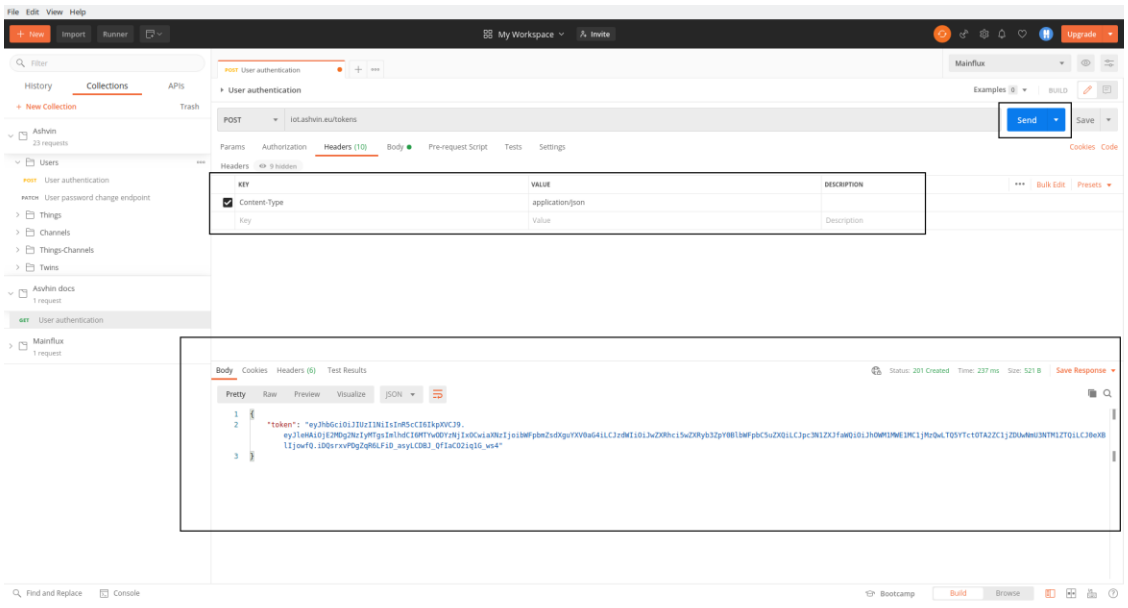
in the body text field, replacing `<email>` and `<password>` with the email and password that you used to create a user (pay attention to keep `"` around your email and password in order to respect how JSON format specifies strings).



```
{
    "email": "<email>",
    "password": "<password>"
}
```

Request body

When your done, you are almost ready to send a request. You need to put the information in your request that you are sending a JSON content in the request body. Go to `Headers` tab and enter `Content-type` in the first row and the KEY column and `application\json` in the first row and the `Value` column.



POST iot.ashvin.eu/tokens

	KEY	VALUE	DESCRIPTION
✓	Content-Type	application/json	

Status: 201 Created Time: 237 ms Size: 521 B

```
{
    "token": "eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9.eyJleHAiOjE2MDg2NzIyMTgsImlhdCI6MTYwODYzNjIxOCwiaXNzIjoibWFpbmZsdXguYXV0aG4iLCJzdWIiOiJwZXRhci5wZXRyb3ZpY0BlbWFpbC5uZXQiLCJpc3N1ZXJfaWQiOiJhOWM1MWE1MC1jMzQwLTQ5YTctOTA2ZC1jZDUwNmU3NTM1ZTQiLCJ0eXBlIjowfQ.iDQsrxvPDgZqR6LFiD_asyLCDBJ_QfIaC02iq1G_ws4"
}
```

Request headers

Now click on the Send button and, if everything went well, you should get something similar to this as a response body:

```
{
    "token": "eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9.eyJleHAiOjE2MDg2N
zU5MDQsImlhdCI6MTYwODYzOTkwNCwiaXNzIjoibWFpbmZsdXguYXV0aG4iLCJzdWIiO
iJwZXRhci5wZXRyb3ZpY0BlbWFpbC5uZXQiLCJpc3N1ZXJfaWQiOiJhOWM1MWE1MC1jM
zQwLTQ5YTctOTA2ZC1jZDUwNmU3NTM1ZTQiLCJ0eXBlIjowfQ.B-I464fhsneLAOJZdj
RgCJLIt1aDvymVrlDpWAkW-Fg"
}
```

Your token is this long cryptic word, in our case

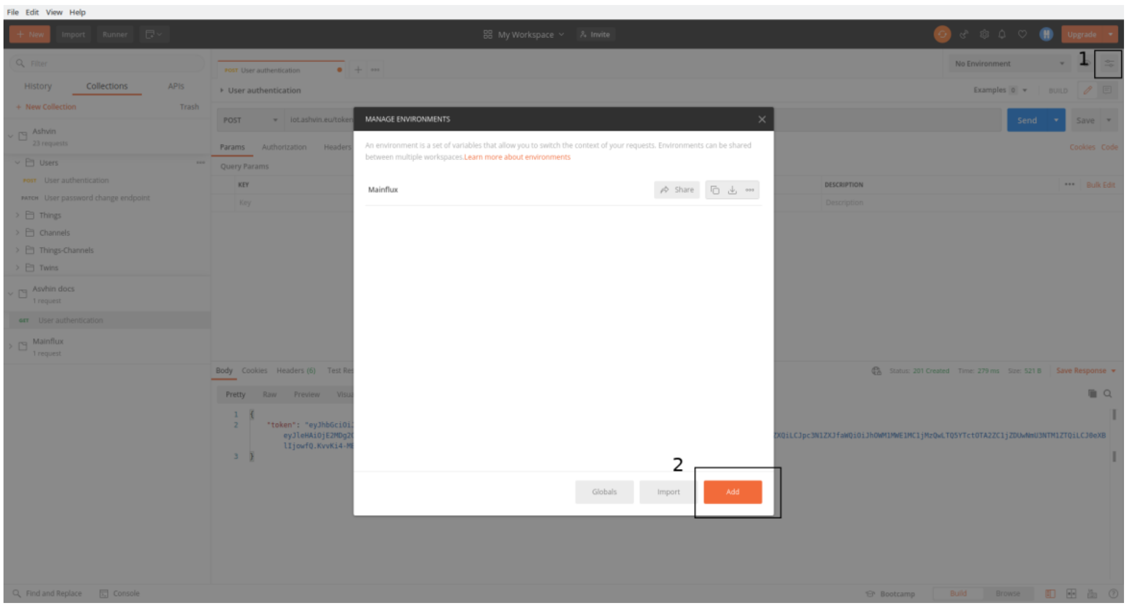
```
eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9.eyJleHAiOjE2MDg2NzU5MDQsImlhdCI
6MTYwODYzOTkwNCwiaXNzIjoibWFpbmZsdXguYXV0aG4iLCJzdWIiOiJwZXRhci5wZXR
yb3ZpY0BlbWFpbC5uZXQiLCJpc3N1ZXJfaWQiOiJhOWM1MWE1MC1jMzQwLTQ5YTctOTA
2ZC1jZDUwNmU3NTM1ZTQiLCJ0eXBlIjowfQ.B-I464fhsneLAOJZdjRgCJLIt1aDvymV
rlDpWAkW-Fg
```

We will use it to create our first thing. So note it down.

11.2 Postman environments

Better yet, let us use Postman itself to store the token (see above). This is a preferred alternative, since we will be able to reuse our stored token in multiple requests. When we start a new session and get a new token, we will simply update the value stored in Postman and we will not have to change any of our requests (see below).

Postman use **environments** to store logically related sets of values. To create an environment, click on the icon marked by 1 in the image below.

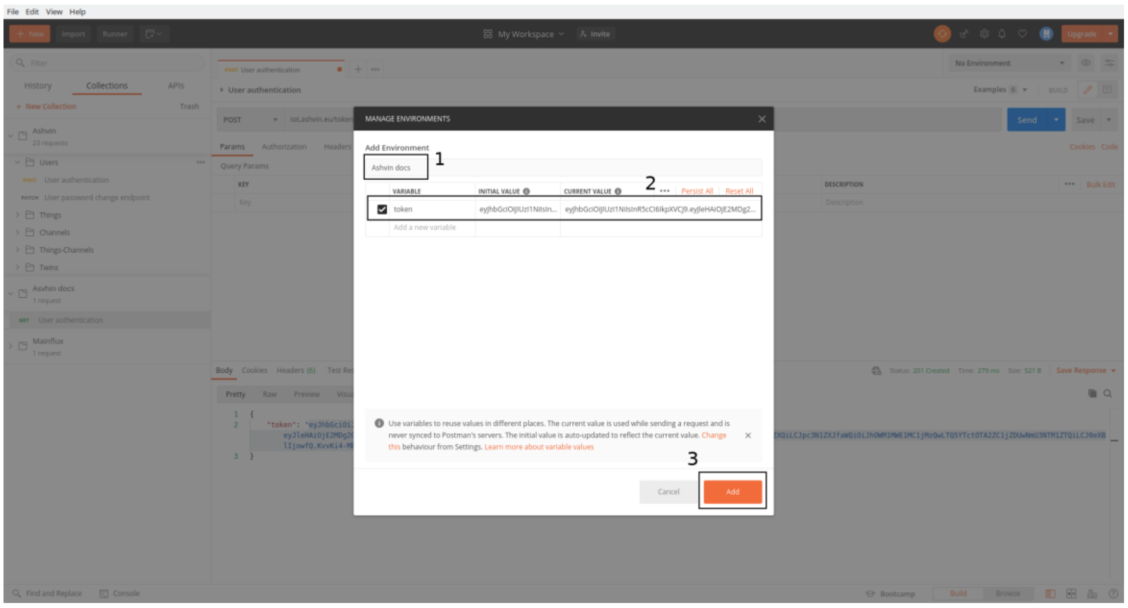

MANAGE ENVIRONMENTS

An environment is a set of variables that allow you to switch the context of your requests. Environments can be shared between multiple workspaces. Learn more about environments

Mainflux

Postman environment

After that, click on the button Add (2 on the image above) and you will presented with the following window:


MANAGE ENVIRONMENTS

Add Environment

Ashvin docs

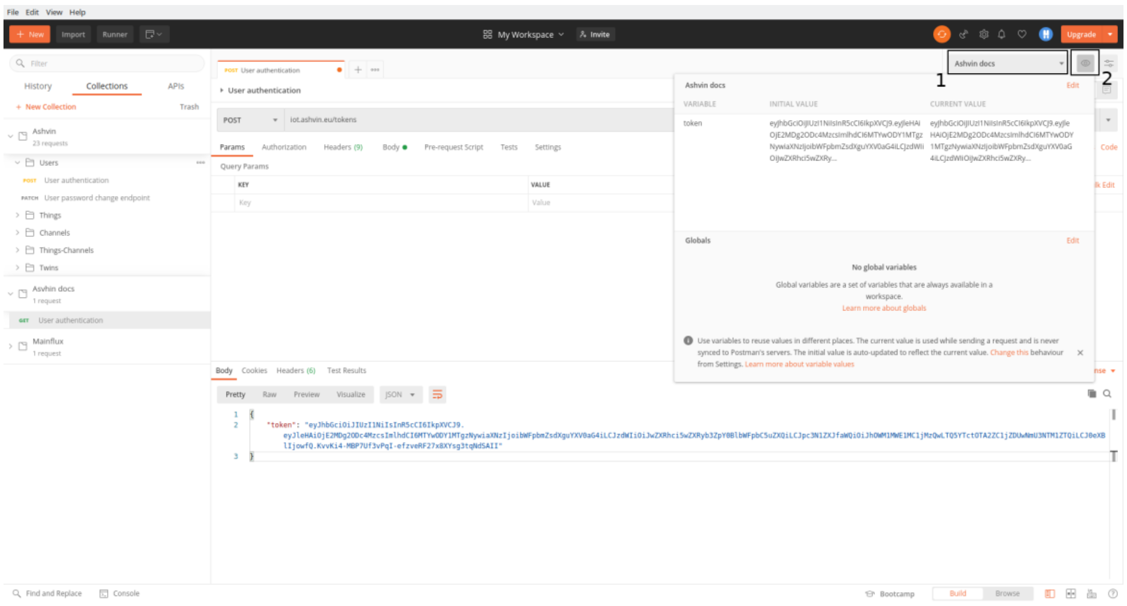
	VARIABLE	INITIAL VALUE	CURRENT VALUE
✓	token	eyJhbGciOiJIUzI1NiIsIn...	eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9.eyJleHAiOjE2MDg2...
	Add a new variable		

Use variables to reuse values in different places. The current value is used while sending a request and is never synced to Postman's servers. The initial value is auto-updated to reflect the current value. Change this behaviour from Settings. Learn more about variable values

Postman environment

Enter the environment name (1), enter token as a variable name (you can enter any name you like), fill in the initial and the current value of the variable - in our case, simply paste the token value in both fields (2) -, and finally click on the Add button (3).

To use your environment, simply select it from the dropdown list (1) and to visualize it and edit it, click on the eye icon button (2):



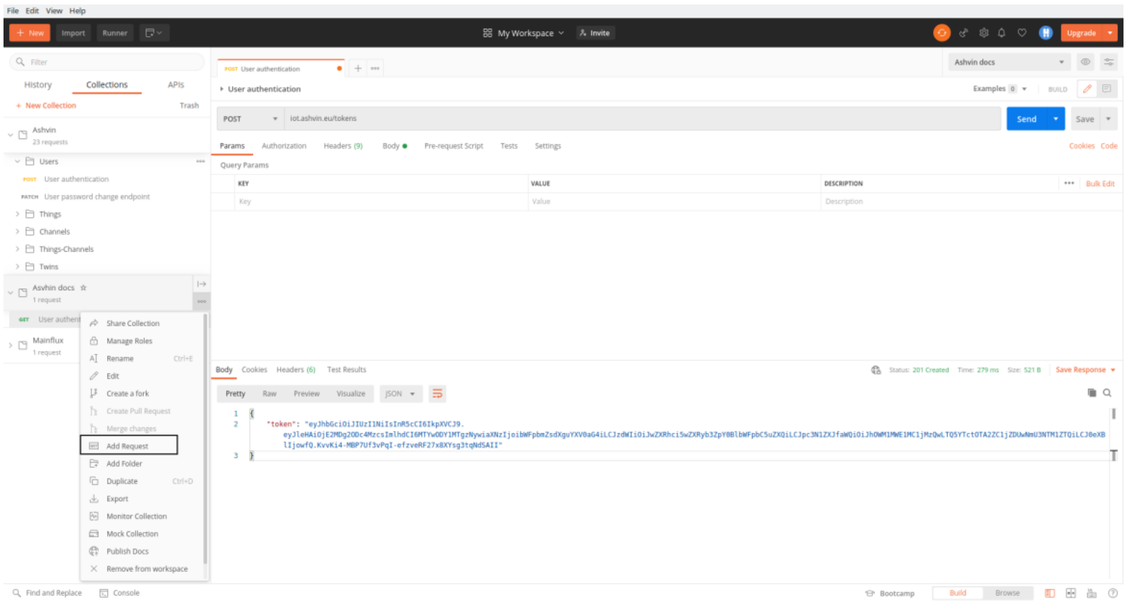
Use variables to reuse values in different places. The current value is used while sending a request and is never synced to Postman's servers. The initial value is auto-updated to reflect the current value. Change this behaviour from Settings. Learn more about variable values

```
{
    "token": "eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9.
      eyJleHAiOjE2MDg2ODc4MzcsImlhdCI6MTYwODY1MTgzNywiaXNzIjoibWFpbmZsdXguYXV0aG4iLCJzdWIiOiJwZXRhci5wZXRyb3ZpY0BlbWFpbC5uZXQiLCJpc3N1ZXJfaWQiOiJhOWM1MWE1MC1jMzQwLTQ5YTctOTA2ZC1jZDUwNmU3NTM1ZTQiLCJ0eXB
      lIjowfQ.KvvKi4-MBP7Uf3vPqI-efzveRF27x8XYsg3tqNdSAII"
}
```

Postman environment

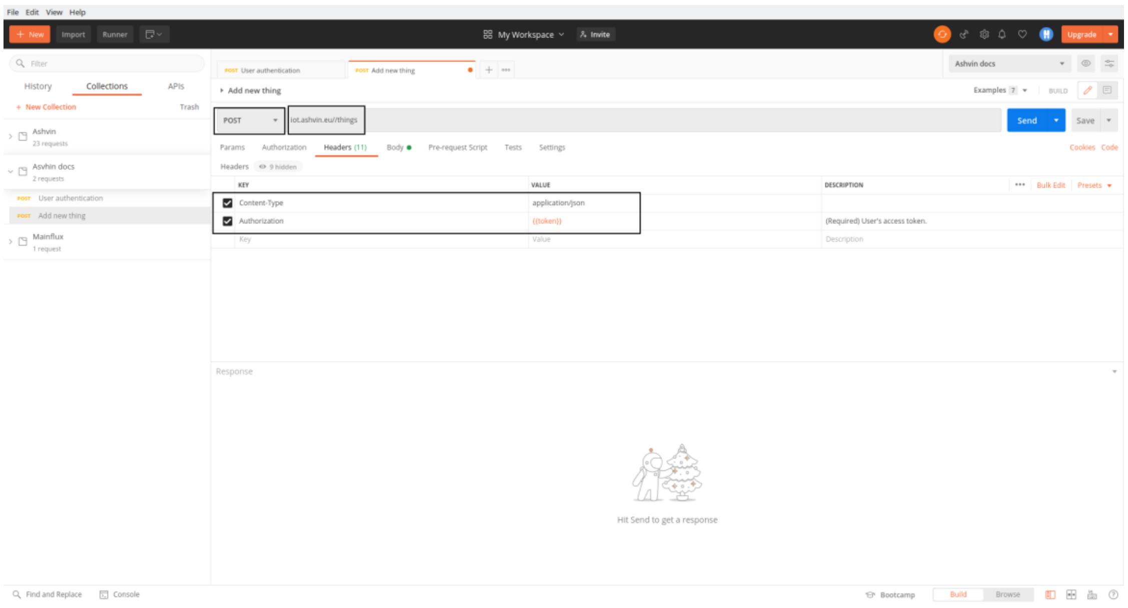
11.3 Create thing request

Now that we have set the environment, we can use our environment variable `token` to create another request. We will create a request that will instruct AIP to create a <u>thing</u> (a platform entity mostly used to represent a real world device or a software application). Add a new request to the collection:



Postman request

And give it a name `Adds new thing` (you can give it any name you like). Select POST as a request method and enter `iot.ashvin.eu//things` in the URL text field. In the headers tab, you need to add two rows: one with the key `Content-type` and the value `application/json` and the other with the key `Authoization` and the value `{{token}}`. The `{{<variable_name>}}` syntax tells to Postman to look for the value of `token` in the currently chosen environment - the `Ashvin docs` environment, in our case.



POST iot.ashvin.eu//things

KEY	VALUE	DESCRIPTION
☑ Content-Type	application/json	
☑ Authorization	{{token}}	(Required) User's access token.
Key	Value	Description

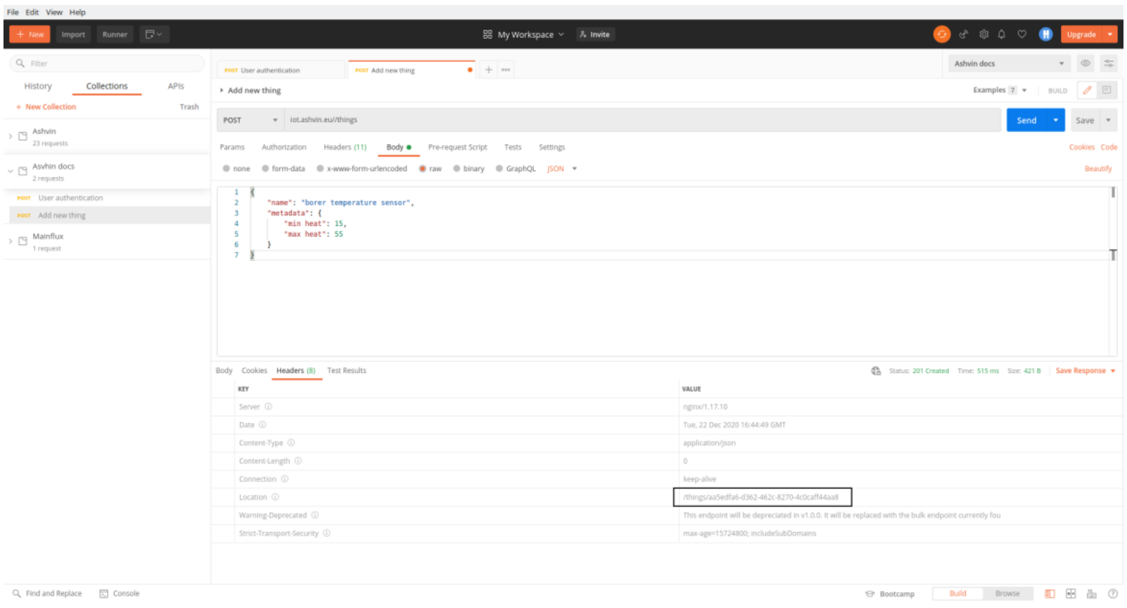
Postman request

Finally, switch to the tab Body, select `raw` as a body type and select `JSON` as a body type specifier from the dropdown list. In the Body text field, enter the name and the metadata of the thing you want to create, e.g.

```
{
    "name": "borer temperature sensor",
    "metadata": {
        "min heat": 15,
        "max heat": 55
    }
}
```

You can normally enter any kind of metadata you like as long as it follows JSON format. Also, the thing's name is arbitrary.

We should be all set now. If you click the Send button, you should get a response with a `Status: 201 Created`. Of special interest are the response headers of the response:



POST iot.ashvin.eu//things

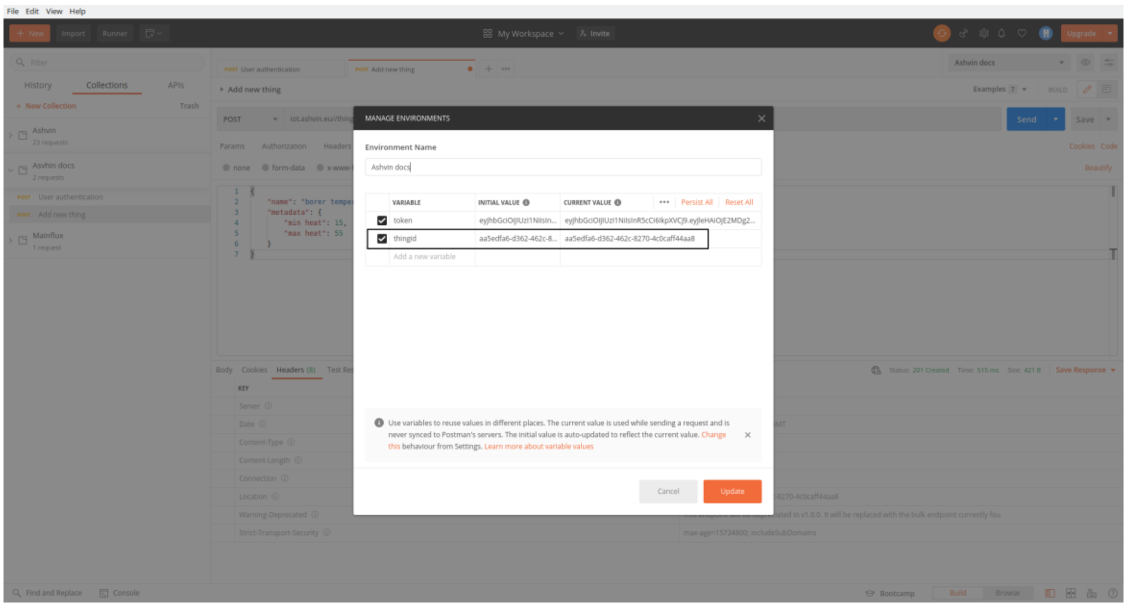
```
{
    "name": "borer temperature sensor",
    "metadata": {
        "min heat": 15,
        "max heat": 55
    }
}
```

Status: 201 Created Time: 515 ms Size: 421 B

KEY	VALUE
Server	nginx/1.17.10
Date	Tue, 22 Dec 2020 16:44:49 GMT
Content-Type	application/json
Content-Length	0
Connection	keep-alive
Location	/things/aa5edfa6-d362-462c-8270-4c0caff44aa8
Warning-Deprecated	This endpoint will be depreciated in v1.0.0. It will be replaced with the bulk endpoint currently fou
Strict-Transport-Security	max-age=15724800; includeSubDomains

Response headers

It is important to note the thing's id which you get in the `Location` header. It's a long number in a uuid format that follows the `/things/` prefix, e.g. `aa5edfa6-d362-462c-8270-4c0caff44aa8`. Please note it down, or better yet, let's add it to our Postman `Ashvin docs` environment. Click on the eye icon, and then on the button `Edit` and enter the variable name, initial and current value:



MANAGE ENVIRONMENTS

Environment Name: Ashvin docs

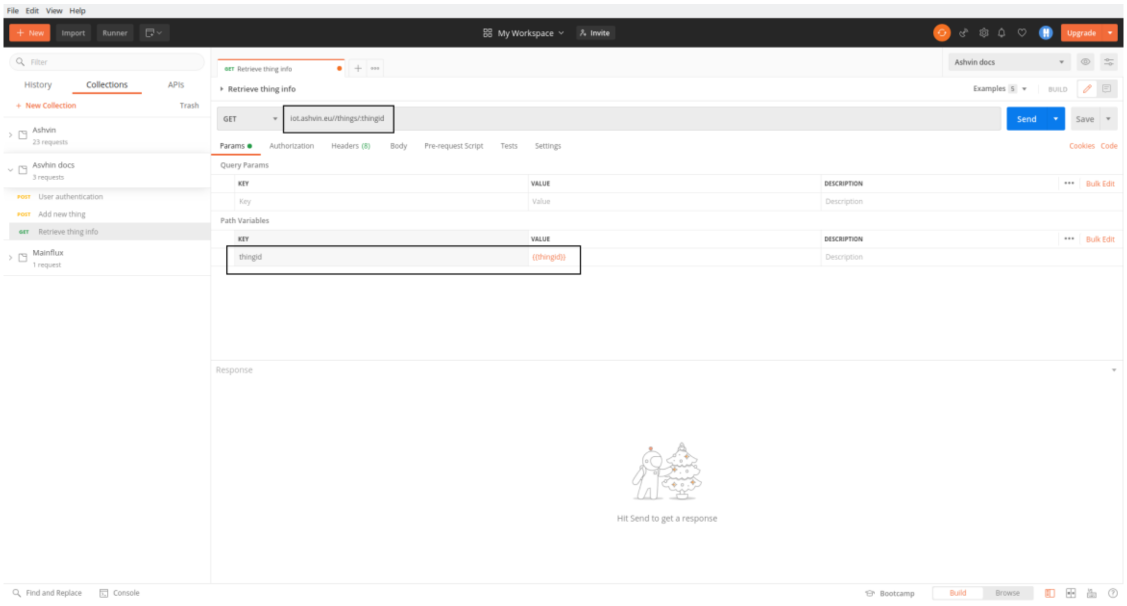
	VARIABLE	INITIAL VALUE	CURRENT VALUE
✓	token	eyJhbGciOiJIUzI1NiIsIn...	eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9.eyJleHAiOjE2MDg2...
✓	thingid	aa5edfa6-d362-462c-8...	aa5edfa6-d362-462c-8270-4c0caff44aa8
	Add a new variable		

Use variables to reuse values in different places. The current value is used while sending a request and is never synced to Postman's servers. The initial value is auto-updated to reflect the current value. Change this behaviour from Settings. Learn more about variable values

Postman environment

11.4 Retrieve thing request

Now we are ready to fetch our created thing and see it's properties. In order to do so, create another request and name it, for example, `Retrieve thing info`. Set requests method to GET. Our URL, `iot.ashvin.eu//things/:thingid` is a bit unusual this time, because it contains `:thingid`. This means that this part of the URL will be replaced by the value we put in the parameter row with a key `thingid`.



Retrieve thing info

GET	iot.ashvin.eu//things/:thingid

Query Params

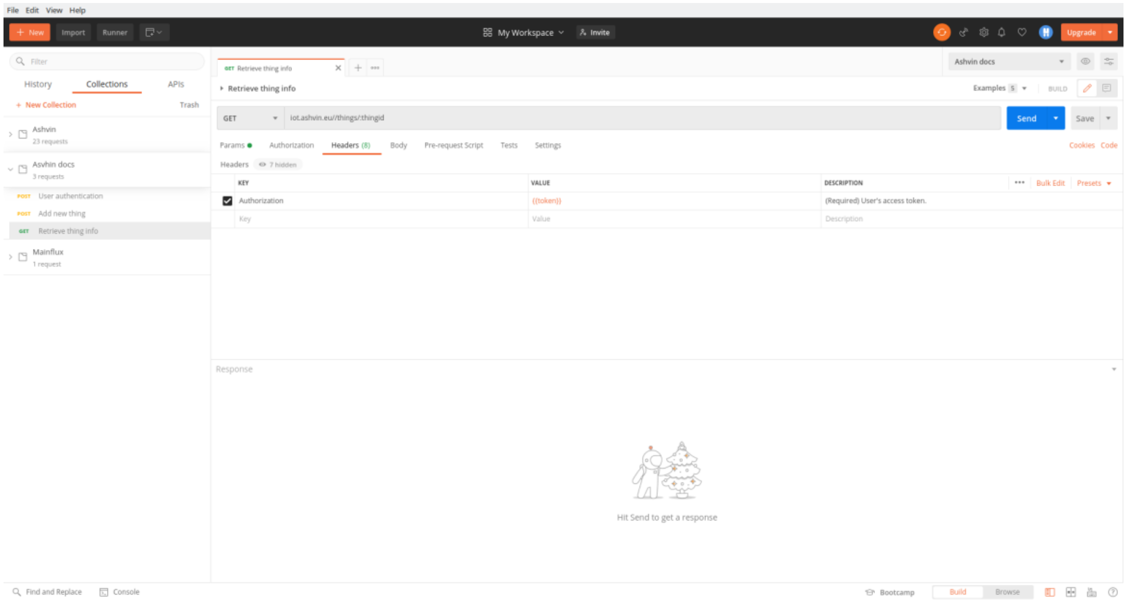
KEY	VALUE	DESCRIPTION
Key	Value	Description

Path Variables

KEY	VALUE	DESCRIPTION
thingid	{{thingid}}	Description

Parameters

We will put our environment variable `{{thingid}}` in the value column. We need to put our token environment variable in the Headers tab as we did for the create thing request:



Retrieve thing info

GET	iot.ashvin.eu//things/:thingid

Headers 7 hidden

	KEY	VALUE	DESCRIPTION
☑	Authorization	{{token}}	(Required) User's access token.
	Key	Value	Description

Headers

As explained (see above), this is needed in order to authenticate the platform user.
And we are ready to send a request. By clicking on the button Send, you should get a response with a body similar to this one:

```
{
    "id": "aa5edfa6-d362-462c-8270-4c0caff44aa8",
    "name": "borer temperature sensor",
    "key": "635c2084-60da-491f-b448-4df5ab6abfef",
    "metadata": {
        "max heat": 55,
        "min heat": 15
    }
}
```

You can see your thing's id, name, key and metadata.

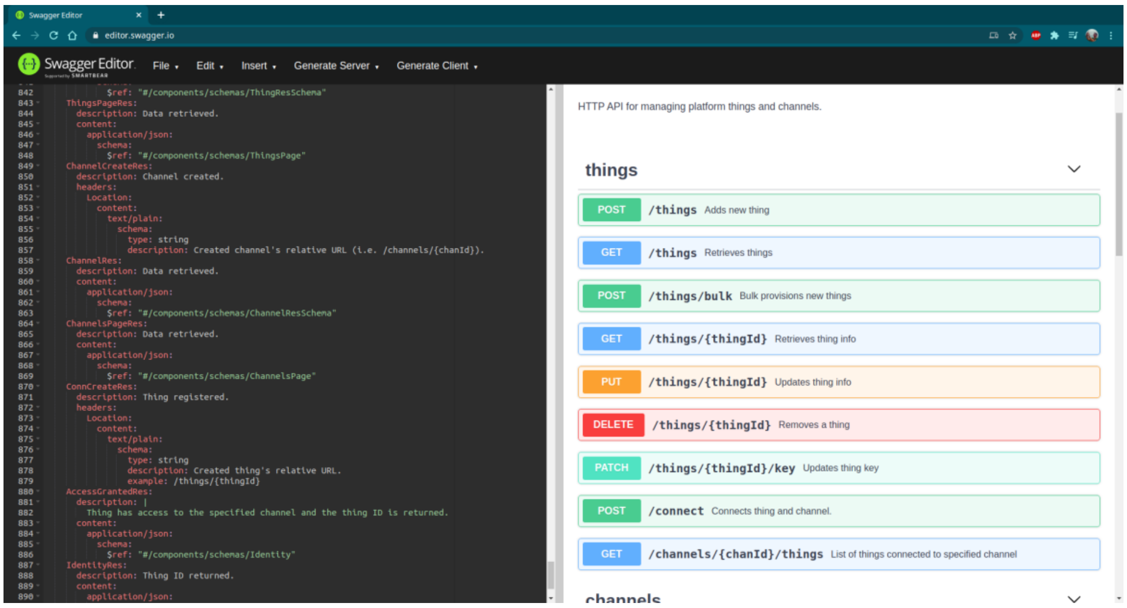
11.5 Requests specifications

We have added three requests so far, so one might ask how do we know all the data needed to create requests. What is more, how do we know what requests we can make? This is a general question, since it is not related specifically to Postman. Postman is just one of the tools we can use to make HTTP requests addressed to the the Ashvin IoT Platform (AIP). (One of the popular choices is curl, an open-source CLI HTTP client.)

AIP is based on Mainflux, a "scalable, secure, open-source, and patent-free IoT platform". Mainfluxes exposes a well defined HTTP API and that is the API that the Ashvin IoT platform is using. This API itself is described in the following files:

- users
- things
- twins

For a non-programmer, those files are rather cryptic. So, select the entire text in an individual file, copy it and head to the online Openapi specification editor. (Openapi is the name of the specification standard followed by the AIP (Mainflux) HTTP API specifications.) If everything went well, you should get a document similar to this one:



```
            $ref: "#/components/schemas/ThingResSchema"
    ThingsPageRes:
      description: Data retrieved.
      content:
        application/json:
          schema:
            $ref: "#/components/schemas/ThingsPage"
    ChannelCreateRes:
      description: Channel created.
      headers:
        Location:
          content:
            text/plain:
              schema:
                type: string
                description: Created channel's relative URL (i.e. /channels/{chanId}).
    ChannelRes:
      description: Data retrieved.
      content:
        application/json:
          schema:
            $ref: "#/components/schemas/ChannelResSchema"
    ChannelsPageRes:
      description: Data retrieved.
      content:
        application/json:
          schema:
            $ref: "#/components/schemas/ChannelsPage"
    ConnCreateRes:
      description: Thing registered.
      headers:
        Location:
          content:
            text/plain:
              schema:
                type: string
                description: Created thing's relative URL.
                example: /things/{thingId}
    AccessGrantedRes:
      description: |
        Thing has access to the specified channel and the thing ID is returned.
      content:
        application/json:
          schema:
            $ref: "#/components/schemas/Identity"
    IdentityRes:
      description: Thing ID returned.
      content:
        application/json:
```

HTTP API for managing platform things and channels.

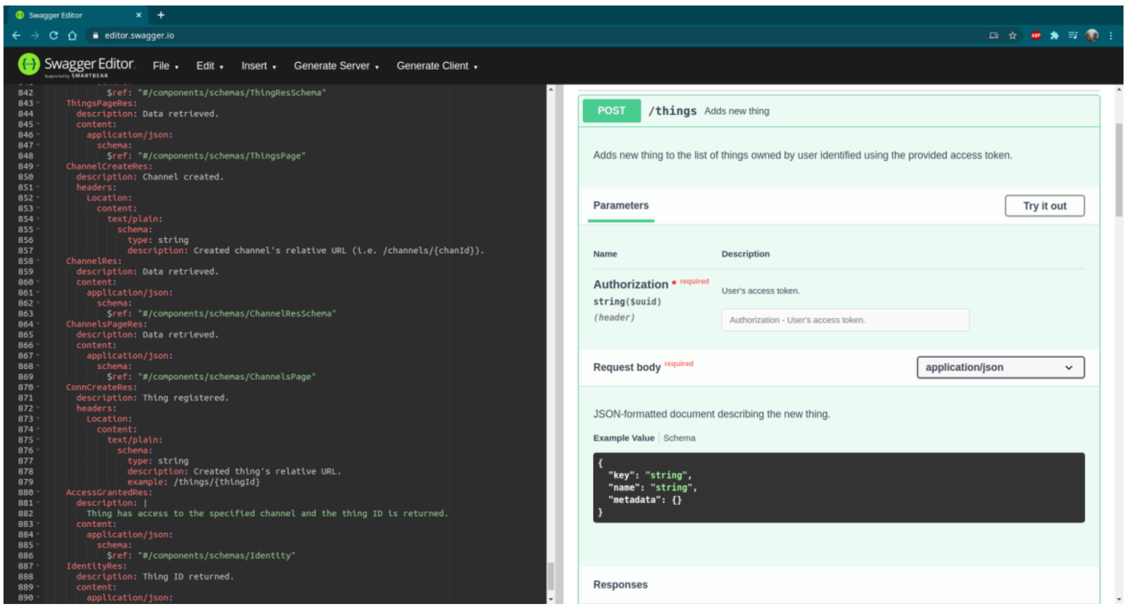
things

POST	/things	Adds new thing
GET	/things	Retrieves things
POST	/things/bulk	Bulk provisions new things
GET	/things/{thingId}	Retrieves thing info
PUT	/things/{thingId}	Updates thing info
DELETE	/things/{thingId}	Removes a thing
PATCH	/things/{thingId}/key	Updates thing key
POST	/connect	Connects thing and channel.
GET	/channels/{chanId}/things	List of things connected to specified channel

channels

Openapi specification

All the possible requests you can make are listed there. You can now unfold any of the request in order to see the data needed to construct a request (in Postman, or in any other HTTP client, such as curl):



```
            $ref: "#/components/schemas/ThingResSchema"
    ThingsPageRes:
      description: Data retrieved.
      content:
        application/json:
          schema:
            $ref: "#/components/schemas/ThingsPage"
    ChannelCreateRes:
      description: Channel created.
      headers:
        Location:
          content:
            text/plain:
              schema:
                type: string
                description: Created channel's relative URL (i.e. /channels/{chanId}).
    ChannelRes:
      description: Data retrieved.
      content:
        application/json:
          schema:
            $ref: "#/components/schemas/ChannelResSchema"
    ChannelsPageRes:
      description: Data retrieved.
      content:
        application/json:
          schema:
            $ref: "#/components/schemas/ChannelsPage"
    ConnCreateRes:
      description: Thing registered.
      headers:
        Location:
          content:
            text/plain:
              schema:
                type: string
                description: Created thing's relative URL.
                example: /things/{thingId}
    AccessGrantedRes:
      description: |
        Thing has access to the specified channel and the thing ID is returned.
      content:
        application/json:
          schema:
            $ref: "#/components/schemas/Identity"
    IdentityRes:
      description: Thing ID returned.
      content:
        application/json:
```

POST /things Adds new thing

Adds new thing to the list of things owned by user identified using the provided access token.

Parameters

Name	Description
Authorization * required string($uuid) (header)	User's access token. Authorization - User's access token.

Request body required — application/json

JSON-formatted document describing the new thing.

Example Value | Schema

```
{
  "key": "string",
  "name": "string",
  "metadata": {}
}
```

Responses

Openapi specification request

In the upper image, I have unfolded the request to add a new thing. We can see that request takes one parameter, `Authorization`. This parameter takes as a value our user token in the form of a uuid string. Furthermore, the request expects a JSON body with a following schema:

```
{
  "key": "string",
  "name": "string",
  "metadata": {}
}
```

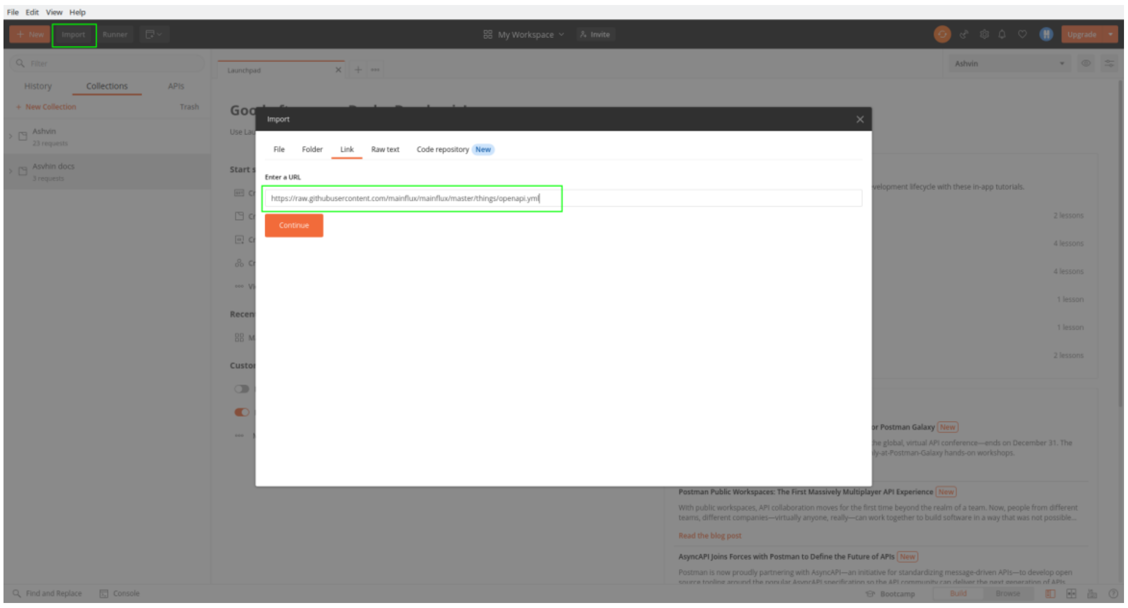
When we created a thing (see above), we have actually used the following JSON body:

```
{
    "name": "borer temperature sensor",
    "metadata": {
        "min heat": 15,
        "max heat": 55
    }
}
```

We left out `key` field and we, thus, let AIP to generate a thing key for us.

11.5.1 Automatic request generation

Postman allows us to automate the process of request creation by importing directly Openapi specifications. Click on the `Import` button, switch to `Link`, enter one of the URLs from the upper list and click on the button `Continue`.



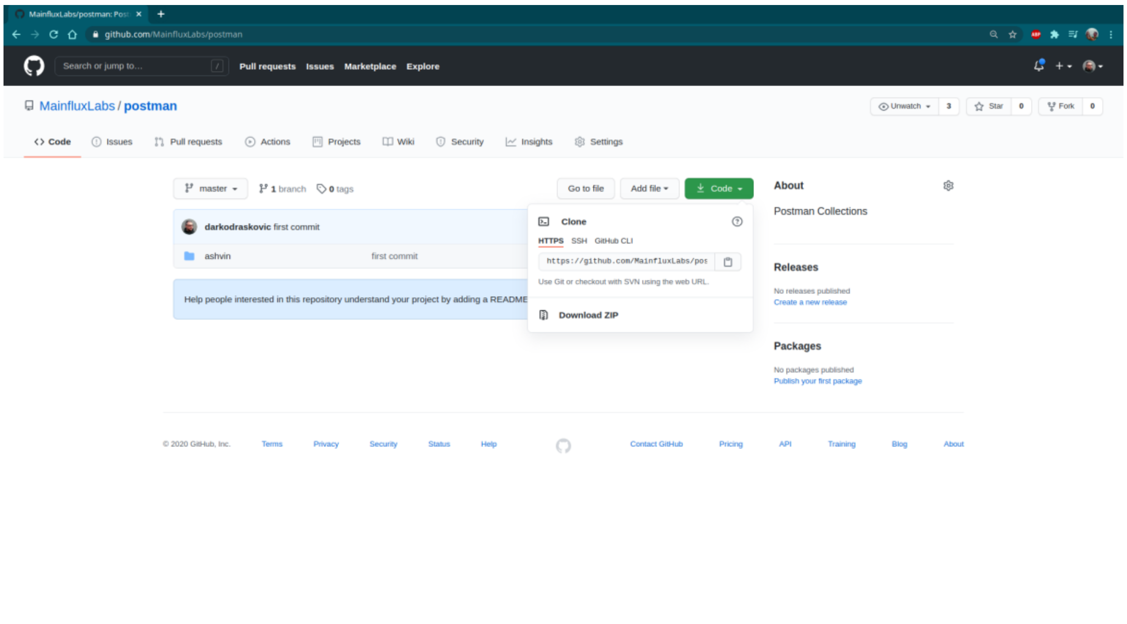
https://raw.githubusercontent.com/mainflux/mainflux/master/things/openapi.yml

Import Openapi specification

Finally, click on the button `Import` and `Close`, and you should get a collection of requests generated based on the Openapi specification. These requests are more or less ready to use. You should go through each request you want to use and fill in the missing info, such as the URL prefix, your user token, thing id, etc.

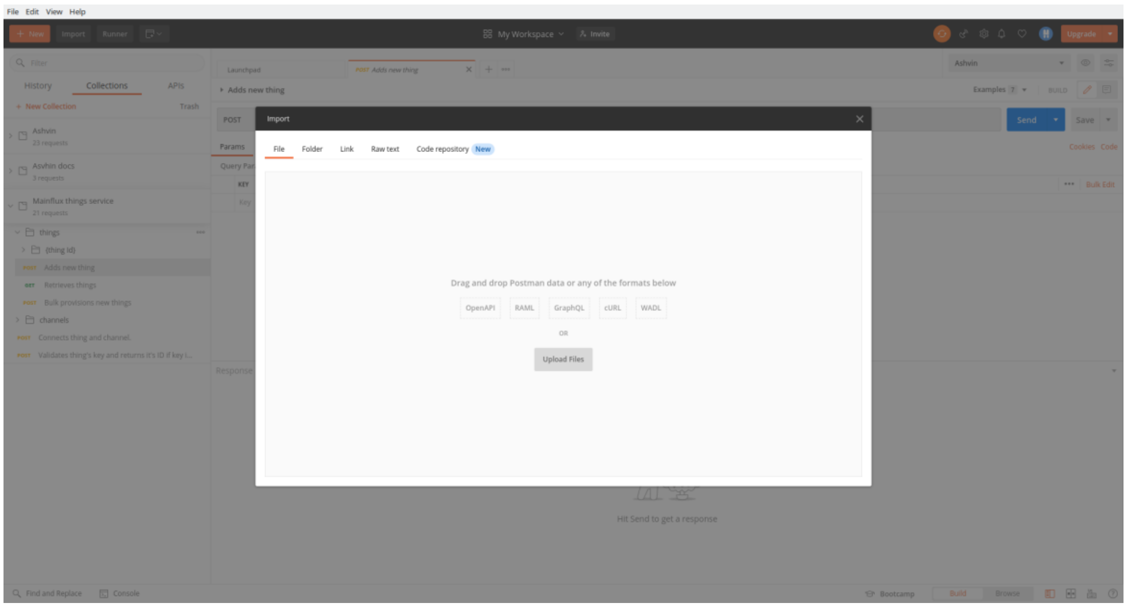
11.5.2 Ashvin Collection

If you don't want to generate the requests yourself, you can go here and download the request collection and the associated environment.



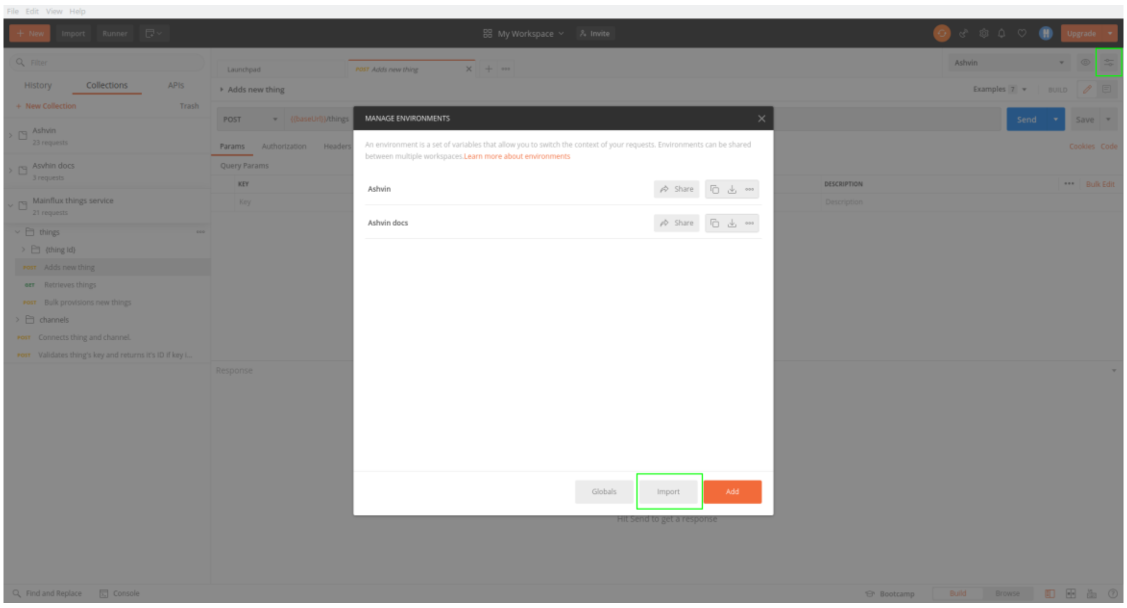
Github

Click on the Download zip button, unpack the zip archive. In the ashvin folder you will find two files, Ashvin.postman_environment.json and Ashvin.postman_collection.json. In order to import a collection, click on the Import button and then on the Upload files button.



Import Openapi specification

Select `Ashvin.postman_collection.json` and follow the procedure.
In order to import an environment, click on the environments button and then on the `Import` button.



An environment is a set of variables that allow you to switch the context of your requests. Environments can be shared between multiple workspaces. Learn more about environments

Import Openapi environment

Click on the `Choose Files` button, select `Ashvin.postman_environment.json` and follow the procedure.

You use Ashvin collection in conjunction with the Ashvin environment so be sure to select Ashvin environment from the environments dropdown list in order to activate it. Once you select environment, be sure to fill in the environment variables with your desired values for the URL prefix, your user token, thing id, etc.

12 APPENDIX 6: MOSQUITTO

12.1 MQTT client

Eclipse Mosquitto is an open source message broker that implements the MQTT protocol. Since the Ashvin IoT platform uses an MQTT message broker, amongst other brokers, to send and receive messages, You can use the AIP to send and receive messages over MQTT. Eclipse Mosquitto features `mosquitto_pub` and `mosquitto_sub` command line MQTT clients for sending and receiving messages over MQTT.

Since `mosquitto_pub` and `mosquitto_sub` are command line tools, you will need a terminal (or a console) in order to send and receive messages. Every major operating system comes with a terminal pre-installed, so you do not need to worry about that. You can find the installation instructions for `mosquitto` message broker here. This will also install `mosquitto` publish and subscribe clients, i.e. `mosquitto_pub` and `mosquitto_sub`.

12.2 Subscribe and publish

In order to publish messages via MQTT you need at least one thing and one channel. For the sake of clarity, we will use two things: one will publish messages to a channel and the other will listen for these messages on the same channel (please do note that the same thing can be used to publish and listen for messages on the same channel). Publishing and listening things need to be connected to the channel that will be used for the message transmission. To create things and channels and connect them, you can use an the AIP dedicated GUI or any other HTTP client, e.g. Postman.

So, now you have two things - one that will publish messages over mqtt, and the other that will receive them - and a channel used for message transmission. Both things need to be connected to the channel. Please note down both things' ID and key as well as the channel's ID (channels do not have key since they are used to route messages and not to authenticate senders and receives). We will need to use things' IDs and keys as means of authentication and the channel's ID to construct an MQTT topic.

To actually receive messages, we need first to subscribe to a channel. In order to do it, you use this general format of command:

```
mosquitto_sub -u <thing_id> -P <thing_key> -t channels/<channel_id>/
messages -h iot.ashvin.eu
```

Where you replace words in <> (together with <>) with concrete values. For example,

```
mosquitto_sub -u 5b8e259c-f69e-4da3-8cf8-266b4ad18d98 -P d87c90b7-00
00-4774-b2ab-0900f122a3e2 -t channels/44c669a4-7ebc-40c8-ab6d-5bf9ac
8398c5/messages -h iot.ashvin.eu
```

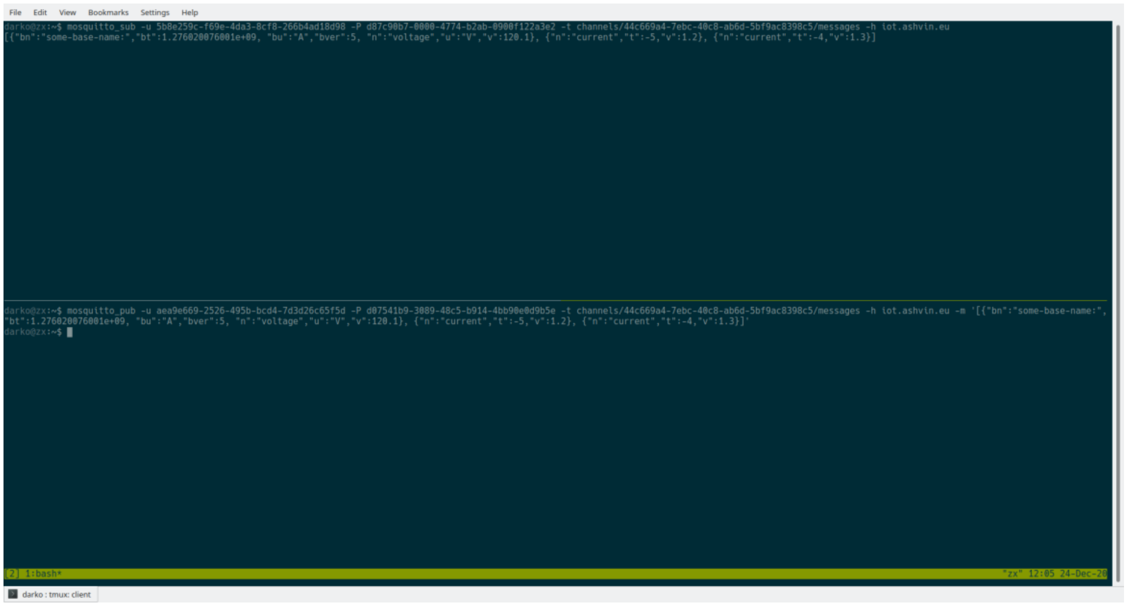
Please do notice how we do not use user's credentials in order to subscribe to a channel. Rather, we use thing's credentials, i.e. thing's ID and key. We do it in order to see whether a thing with the given credentials is authorised to publish and subscribe to a given channel. In the terminology of the AIP, we check whether the thing is connected to a given channel.

To publish a message over a channel, call the following command:

```
mosquitto_pub -u <thing_id> -P <thing_key> -t channels/<channel_id>/
messages -h localhost -m '[{"bn":"some-base-name:","bt":1.2760200760
01e+09, "bu":"A","bver":5, "n":"voltage","u":"V","v":120.1}, {"n":"c
urrent","t":-5,"v":1.2}, {"n":"current","t":-4,"v":1.3}]'
```

For example,

```
mosquitto_pub -u aea9e669-2526-495b-bcd4-7d3d26c65f5d -P d07541b9-30
89-48c5-b914-4bb90e0d9b5e -t channels/44c669a4-7ebc-40c8-ab6d-5bf9ac
8398c5/messages -h iot.ashvin.eu -m '[{"bn":"some-base-name:","bt":1.
276020076001e+09, "bu":"A","bver":5, "n":"voltage","u":"V","v":120.
1}, {"n":"current","t":-5,"v":1.2}, {"n":"current","t":-4,"v":1.3}]'
```



```
darko@zx:~$ mosquitto_sub -u 5b8e259c-f69e-4da3-8cf8-266b4ad18d98 -P d87c90b7-0000-4774-b2ab-0900f122a3e2 -t channels/44c669a4-7ebc-40c8-ab6d-5bf9ac8398c5/messages -h iot.ashvin.eu
[{"bn":"some-base-name:","bt":1.276020076001e+09, "bu":"A","bver":5, "n":"voltage","u":"V","v":120.1}, {"n":"current","t":-5,"v":1.2}, {"n":"current","t":-4,"v":1.3}]
```

```
darko@zx:~$ mosquitto_pub -u aea9e669-2526-495b-bcd4-7d3d26c65f5d -P d07541b9-3089-48c5-b914-4bb90e0d9b5e -t channels/44c669a4-7ebc-40c8-ab6d-5bf9ac8398c5/messages -h iot.ashvin.eu -m '[{"bn":"some-base-name:",
"bt":1.276020076001e+09, "bu":"A","bver":5, "n":"voltage","u":"V","v":120.1}, {"n":"current","t":-5,"v":1.2}, {"n":"current","t":-4,"v":1.3}]'
darko@zx:~$ 
```

```
[2] 1:bash*                                                        "zx" 12:05 24-Dec-20
```

Mosquito

In the upper pane of the console, I have first subscribed to a channel. Afterwards, in the lower pane of the console, I have sent a message. Finally, in the upper pane of the console, in the second line, I see that the message has successfully arrived and is echoed in the console.

12.3 SenML

In order to understand the structure of the message

```
[{"bn":"some-base-name:","bt":1.276020076001e+09, "bu":"A","bver":5,
 "n":"voltage","u":"V","v":120.1}, {"n":"current","t":-5,"v":1.2},
{"n":"current","t":-4,"v":1.3}]
```

we have sent and received with the upper commands, we need to get acquainted with the SenML. SenML is a format used for representing sensor measurements and device parameters. For example, a temperature sensor, could use it to send the measurements or receive the configuration.

Ashvin IoT platform uses preferably SenML format to send, receive and persist messages although an arbitrary formatted JSON message can also be used.

SenML message is an array with a series of measurements. In our upper example, we have three measurements. bt refers to the time offset of each measurement, so in order to get a time of a particular measurement, we add t (represented in floating point as seconds) to the bt (itself expressed in Unix time also as a floating point seconds number). v is a value field used to store a float type value. There are other fields for values of other data types: vs for a string value, vb for a boolean value and vd for a binary value. Here is a full table of an individual SenML measurement fields:

Name	Label	CBOR Label	JSON Type	XML Type
Base Name	bn	-2	String	string
Base Time	bt	-3	Number	double
Base Unit	bu	-4	String	string
Base Value	bv	-5	Number	double
Base Sum	bs	-6	Number	double
Base Version	bver	-1	Number	int
Name	n	0	String	string
Unit	u	1	String	string
Value	v	2	Number	double
String Value	vs	3	String	string
Boolean Value	vb	4	Boolean	boolean
Data Value	vd	8	String (*)	string (*)
Sum	s	5	Number	double
Time	t	6	Number	double
Update Time	ut	7	Number	double

(Source: tools.ietf.org)