SEMIoTICS

Deliverable D5.10
Demonstration and validation of SARA-Health Use Case (Cycle 2)

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Acronyms Table	
Acronym	**Definition**
AE	Auto Encoder
AI	Artificial Intelligence
AWS	Amazon Web Services
BPTT	Back Propagation Through Time
CEP	Complex Event Processor
CGNN	Causal Generative Neural Network
DoA	Description of Action
eBPF	extended Berkley Packet Filter
ETC	Event Triggered Causality
FPR	False Positive Rate
GAN	Generative Adversarial Network
GUI	Graphical User Interface
IIoT	Industrial Internet of Things
IoT	Internet of Things
KPI	Key Performance Indicator
LLDP	Link Layer Discovery Protocol
LOOCV	leave-out-one-device cross validation
LSTM	Long-Short-Term-Memory network
MC	Monitoring Component
MCU	Micro Controller Unit
ML	Machine Learning
NMS	Network Management System
NSGI	Next Generation Service Interface
ODL	OpenDayLight
OF	OpenFlow
OMP	Orthogonal Matching Pursuit algorithm
PaaS	Platform-as-a-Service

PO	Pattern Orchestrator
QoS	Quality of Service
RC	Recipe Cooker
RNN	Recurrent Neural Network
SDK	Software Development Kit
SDN	Software Defined Network
SNMP	Simple Network Management Protocol
SNS	Simple Notification Service
SPDI	Security, Privacy, Dependability, Interoperability
SR	Sparse Representation
SVDD	Support Vector Data Description
TPR	True Positive Rate
VM	Virtual Machine
WoT	Web of Thing

1. INTRODUCTION

1.1. Overview

This deliverable provides the validation of the SEMIoTICS technologies in the context of the development of a solution in the domain of Ambient assisted living.

The aims of SARA, this is the name of the solution, is to integrate a number of assistive technologies to address the diverse problems that older people face when living independently with the support of their community.

In particular, the SARA solution is being developed around the concept of Assistive Task (AT). An Assistive Task is a coherent set of SARA functionalities addressing a specific risk related to the independent living of elderly people affected by Mild Cognitive Impairment (MIC) or mild Alzheimer's disease (AD).

The Assistive Tasks being developed in SARA address risks related to four areas: physical decline, cognitive decline, medication management, and psychological needs.

We selected two assistive tasks to validate how and to what extent the SEMIoTICS technologies can facilitate the implementation of a system like SARA. The selected ATs are the Fall Management and the Remote Gait Analysis. The *Falls Management Assistive Task* aims to reduce the consequences of fall events of elderly living at home. The *Gait Analysis Assistive Task* aims to support remote gait quality assessment by means of specific exercises executed by the patient using a Robotic Rollator and under the remote supervision of a Doctor.

The implementation of each SARA Assistive Task requires the integration of multiple mobile (mobotic) and static (domotic, or home automation) robotic elements working in tandem with wearable health monitors, personal smart devices (phones and tablets) and various (proprietary and third party) computational and information services. All these devices that are not specifically designed to work together.

This integration effort requires to cope with a number of challenges arising in each of the main areas addressed by the SEMIoTICS project:

- **security, privacy, dependability and safety**: all stored personal data must be securely encrypted with protected access only by authorized and authenticated individuals and/or system processes; all communications with personal data as content must be securely encrypted with authenticated endpoints; the treatment of patient health data must comply with healthcare domain standards and national and international regulations concerning security and privacy; all actuator control signals (whether originating 'on device 'or 'over the network') must be protected from malicious interference;
- **semantic interoperability:** the different devices consume and produce different kinds and quantities of data, in diverse formats, and support different modes of network communication (Bluetooth, Wi-Fi, wired ethernet, can-bus, etc.). Moreover, for reliability, critical data is collated from multiple redundant sources (several components monitoring the same features) and shared through multiple redundant channels;
- **embedded intelligence:** to ensure timely responses of robotic elements, AI intense computations are executed concurrently throughout the system, with operations dynamically dispatched to the nearest available computing resources (including edge devices);
- **trustworthy network management:** system components and technologies must be configured on a reliable network to avoid service interruptions; high-priority communications, e.g. incident alerts, must be transmitted by reliable means (e.g. multiple identical transmissions over multiple channels) and given network priority; network configurations are not static: mobile devices move around and may temporarily go out of range of Wi-Fi; mains powered devices (e.g. Wi-Fi base stations, domotic servers) are lost during power outages, while battery powered devices (e.g. robots and phones) will need periodic recharging; and wearable health monitors can be removed (e.g. when taking a bath).

In this document, the validation of the benefits brought by the SEMIoTICS technologies to the development and operation of SARA is presented by means of five sub use cases. Each sub use case focuses a subset of the challenges in one the areas presented and represents a different view on the very same system. The five sub use cases are:

- **Moving Intelligence to the Edge** demonstrating how SEMIoTICS Local Embedded Intelligence can be deployed on the SARA Robotic Rollator and utilized in the implementation of the SARA Remote Gait Analysis Assistive Task.
- **Automated, trustworthy healthcare connectivity** show how NFV along with the pattern related components, offer a flexible solution to deal with the heterogeneous traffic flows of SARA. Also, how they reduce the manual intervention in the networking configuration and management, thus yielding a network management automation solution.
- **Enforcement and Monitoring of GDPR-compliant access Control to confidential and sensitive data** presenting how SEMIoTICS can be used to address security, privacy, dependability and safety challenges.
- **Controlling bulbs and robots** demonstrates how the SEMIoTICS Semantic Interoperability technologies can help the developers of the SARA solution to interface heterogeneous devices ranging from light bulbs to semi-autonomous robots.
- **Monitoring Activities of Daily Life** show how the SEMIoTICS Monitoring, Prediction and Diagnosis Mechanisms (MPD) component developed in the context of Task 4.2, can be used to support the Human-Robot Interaction in the context of the SARA Remote Gait Analysis Assistive Task.

1.2. Methodology and document structure

The overall development of SARA in SEMIoTICS proceeded in three phases:

- the initial phase took place during the first year of the project and concerned the establishment of both business requirements and requirements of SARA towards the SEMIoTICS framework.
- the second phase, during the second year of the project, saw the set-up of the initial infrastructure, the selection of the ATs to be used for the evaluation, and the development of a first version of the Fall Management AT without the use of SEMIoTICS technologies (still under development at that time). This development served to establish a baseline for the subsequent developments based on the SEMIoTICS technologies. This first implementation was shown during the first formal review of the project.
- the third phase started with the third year of the project and is concerning both the re-engineering of Fall Management AT and the development of the new Remote Gait Analysis AT. Both this development are based on the adoption of the SEMIoTICS technologies as illustrated by means of four sub use cases presented in the present deliverable.

This deliverable D5.10 accounts for the intermediate results achieved during the third phase of the development and is organised as follows: section 2 presents the Assistive Tasks selected for the evaluation of the SEMIoTICS technologies (section 2.1), the challenges subsumed by the implementation of selected ATs (section 2.2), and introduces the aspects addressed by each of the five sub use cases (section 2.3). Sections 3, 4, 5, 6 and 7 go in the details of each sub use case. The KPIs and requirement related to this use case are presented in Section 8. Finally, the Ethics Guidelines are provided in Section 9.

This deliverable D5.10 is the result of the joint effort by all contributing partners during the development of the SARA prototype. At the beginning of the third phase bi-weekly meetings were run to keep aligned each partner about the work of the others, share results of experimentations and take design decisions. Later on the meetings were run weekly.

1.3. D5.10 Content updates compared to D5.5

D5.10 is the second cycle of Deliverable D5.5 Demonstration and validation of SARA - Health (Cycle 1). Compared to the D5.5, in this cycle, a number of different updates were included such as:

- Updates in Section 1 and 2 to be in line with the updated status of the different use cases and the content of the deliverable
- Updates and evaluation of the four different sub use cases (sections 3-6)
- Inclusion of an additional new sub use case in section 7 (Monitoring activities of daily life),
- Extensive validation of the different KPIs related to this use case in section 8,
- Collection and evaluation of the requirements in one common table (Table 5) in Section 8, following a similar approach with the other use case final deliverables.
- Provision of Ethics Guidelines in Section 9.

2. USE CASE DESCRIPTION

As described in Deliverable 2.2, the use case 2 is from the domain of Ambient Assisted Living and focuses on the development of the SARA distributed application running on the CLOE-IoT platform.

The global trend for increased life expectancy is expected to be accompanied by a rapid rise in the number of people affected by Mild Cognitive Impairment (MIC) or mild Alzheimer's disease (AD). Aging and dementia lead to a significant chronic loss in physical/cognitive capacities and a decline in functional ability, resulting in increased dependency and need for caregiving, with substantial medical, social, psychological, and financial burdens placed on patients, their families, and their communities. Indeed, the kind of continuous, holistic and integrated care required by people with dementia cannot be satisfied by the current 'specialist' model, and the gap between the number of people in need of care and those able to provide it is expected to grow. People also prefer to live in their own homes for as long as possible rather than being institutionalized in sheltered/nursery homes when age-related problems appear. Leading, for example, to propose "Aging in place" - allowing older adults to age in the least restrictive environment of their choice - as a more desirable and viable care model.

Home automation and robotics systems can help relieve the caregiving burden and make 'ageing in place' a reality by providing physical and cognitive assistance to the elderly in the common tasks of daily home living, helping them maintain their autonomy longer and delay the need for social/health service interventions. Advances in artificial intelligence (AI) and IoT technologies are rapidly converging to make such solutions both technically and economically feasible. In this light, Engineering is extending its current commercial AREAS® suite - an Enterprise Resource Planning solution for the Health sector - with SARA (Socially Assistive Robotic Solution for Ambient assisted living), a robotic system aimed at providing automated health/incident monitoring and home assistance to elderly people with mild cognitive impairments.

As its name indicates, SARA is a Socially Assistive Robotics (SAR) solution. SAR solutions resides at the intersection of Assistive Robotics (AR) - typically robots that provide physical assistance (e.g. rehabilitation robots, wheelchair robots, mobility aids, manipulator arms) - and Socially Interactive Robotics (SIR) - whose main task is some form of social interaction with humans (e.g. engaging in conversation, understanding gestures, role taking, task collaboration). SAR aims to assist humans through social interaction – an ambitious goal given that social interaction is arguably the most complex of all human behaviours. A socially competent robot, for example, should be able to: communicate with high-level dialog; use natural cues (gaze, gesture, etc.); express and/or perceive emotions; learn/recognise models of other agents; exhibit distinctive personality and character; establish and maintain social relationships; (possibly) learn/develop social competences.

Achieving human level competence in these areas is well beyond even the best of contemporary AI technologies, so with SARA our goal is more pragmatic. We aim to develop an expandable platform that initially exhibits only trivial social capabilities (well within current technological limits), while yet providing a solid foundation for future expansion to more sophisticated human-like interactions.

The design of SARA integrates a number of assistive technologies to address the diverse problems that older people face when living independently with the support of their community. More specifically, it comprises multiple mobile (mobotic) and static (domotic, or home automation) robotic elements working in tandem with wearable health monitors, personal smart devices (phones and tablets) and various (proprietary and third party) computational and information services, to continuously monitor and assist elderly subjects (and their caregivers) in their normal daily activities in and around the home. The technical components of SARA are as follows:

- backend **AREAS Cloud Services** (ACS): serving primarily as a repository of medical records and an offline store for monitored bio-medical data;
- a **Body Area Network** (BAN) comprising wearable health monitors (e.g. for heart-rate, blood pressure, breathing rate, stress levels, balance and fall detection) worn by the elderly subject and communicating via Bluetooth to their personal device (phone or tablet);
- a **Robotic Rollator** (RR): a smart wheeled walking frame providing physical support for standing, sitting and walking, and capable of monitoring its user's posture and gait, and of (limited) autonomous navigation;

- a **Robotic Assistant** (RA): a mobile humanoid robot - specifically Softbank's humanoid "Pepper" robot[1] - capable of autonomous navigation, face recognition, scripted dialog and adopting life-like human poses (e.g. to perform arm/hand gestures);
- various **AI Services**: computational resources providing machine learning (ML), mapping, route planning and reasoning capabilities (among others);
- a **Smart Home**: a home incorporating intelligent objects, utilizing wired or wireless networks and having the capacity to analyse patterns of activities to manage appliances in anticipation of human needs or to provide adaptive cues for human occupants.

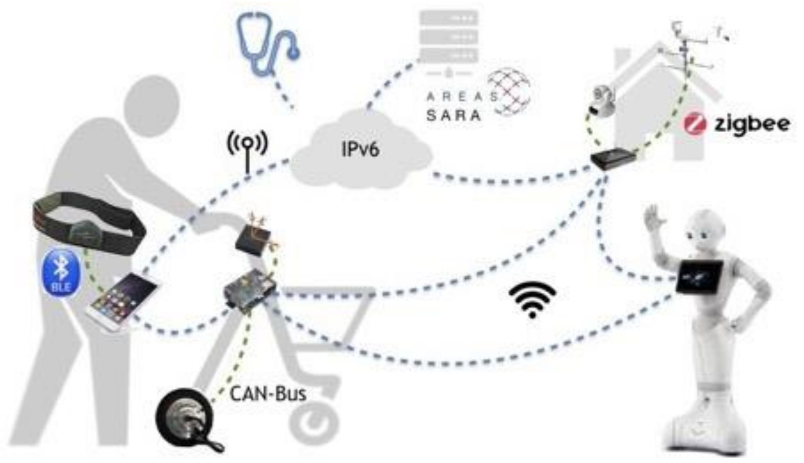


FIGURE 1: SARA MAIN TECHNICAL COMPONENTS AND COMMUNICATION SYSTEM

With the exception of the ACS and RR (both developed in house by Engineering) these components are all off-the-shelf devices that are not specifically designed to work together. The different devices consume and produce different kinds and quantities of data, in diverse formats, and support different modes of network communication (Bluetooth, Wi-Fi, wired ethernet, can-bus, etc.). Moreover: for reliability, critical data is collated from multiple redundant sources (several components monitoring the same features) and shared through multiple redundant channels; to ensure timely responses of robotic elements, AI intense computations are executed concurrently throughout the system, with operations dynamically dispatched to the nearest available computing resources (including edge devices); network configurations are not static: mobile devices move around and may temporarily go out of range of Wi-Fi; mains powered devices (e.g. Wi-Fi base stations, domotic servers) are lost during power outages, while battery powered devices (e.g. robots and phones) will need periodic recharging; and wearable health monitors (BAN devices) can be removed (e.g. when taking a bath).

The SARA solution is built on top of on the CIoE-IoT platform. The CIoE - IoT platform[2] aims to simplify the integration of highly distributed, complex and robust IoT solutions exploiting computational resources both in the cloud and at the edge.

2.1. Generic storylines

The SEMIoTICS technologies are validated in the context of a re-engineering process of the SARA prototype being developed by ENG. This re-engineering process concerns both the business logic layer (i.e. the assistive tasks provided by SARA to its end users) and the middleware layer (i.e. the CIoE-IoT services).

At the business logic layer two assistive tasks are chosen: Fall Management and Gait Analysis.

2.1.1. FALL MANAGEMENT ASSISTIVE TASK

[1] https://www.softbankrobotics.com/emea/en/robots/pepper
[2] Staring from January 2020 the CIoE-IoT platform is part of the Digital Enabler ecosystem. https://www.eng.it/en/our-platforms-solutions/digital-enabler

The Fall Management Assistive Task is one of the Assistive Task contributing to the fulfilment of requirements of the SARA Use case and described in deliverable D2.2 - "SEMIoTICS usage scenarios and requirements".

- The SARA system MUST (via SARA Hub devices) continuously monitor the Patient to detect, and raise an alert in case of, incidents (i.e. critical medical events such as falls, heart attacks, etc.).
- The SARA system MUST reliably and rapidly notify assigned Caregivers of Patient incidents.
- The SARA system MUST (for reasons of privacy) notify the Patient whenever a telepresence session has started/ended, and also inform the Patient of the identity of the remote operator.
- The SARA system MUST reliably and rapidly respond appropriately to health-critical events (in particular incident alerts).

The *Falls Management Assistive Task* aims to reduce the consequences of fall events of elderly living at home. In particular:

1. SARA continuously monitors the patient by means of the devices (e.g. smart phone/smart watch) within her Body Area Network;
2. whenever the fall detection software hosted by the BAN detects a possible fall, it raises (both via cellular and Internet connectivity) an early warning towards a remote assistance Call Centre. This warning message carries also information about the location/area where the event was detected. The fall detection software identifies the location of the event using iBeacon technology.
3. using the local Wi-Fi network the warning message is also forwarded to the Robotic Assistant (i.e. a Pepper robot in the current prototype).
4. as soon as the Robotic Assistant receives a fall event message it starts to navigate toward the location indicated in the message. The Robotic Assistant relies on the navigation and localization cloud services of the SARA solution to autonomously reach the location of the event.
5. once reached the location of the event the Robotic Assistant may interact with the Smart Environment to better prepare the environment for the telepresence session initiated by the Call Centre operator later on (see next steps in this scenario). As an example the Robotic Assistant might decide to turn on the lights or open the shades if on board sensors report a low level of enlightenment in the room.
6. the call distributor software operating at the Call Centre dispatches the message to one of the operators logged into the system. The call distributor software forwards to an operator only those messages originating from a certified device. Moreover the call distributor also filters out duplicated messages related to the same event.
7. the Operator Console web application retrieves from the Electronic Patient Healthcare record service of the AREAS® platform the relevant clinical data of the patient indicated in the warning message**.** The Operator Console web application presents, in a coherent way, both the information carried by the warning message and that retrieved from the Electronic Patient Health Record.
8. once all the relevant information has been presented, the Call Centre operator can assess the actual situation at patient's home starting a telepresence session with the Robotic Assistant using the cameras on board of it.
9. if the position reached autonomously by the Robotic Assistant is not satisfactory for an assessment of the scene of the event, the Call Centre operator can also initiate a teleoperation session to move the Robotic Assistant to a better point of view.

2.1.2. REMOTE GAIT ANALYSIS ASSISTIVE TASK

The Remote Gait Analysis Assistive Task is one of the Assistive Task contributing to the fulfilment of requirements of the SARA Use case and described in deliverable D2.2 - "SEMIoTICS usage scenarios and requirements"

- The SARA system MUST (via the SARA Hubs) continuously monitor the Patient's daily activities.
- The SARA system MUST assist the Patient in performing a variety of physical rehabilitation exercises.
- The SARA system MUST provide (via the SARA Hubs) the GP remote access to real-time (Hub monitored) Patient biomedical data.
- The SARA system SHOULD facilitate the integration of legacy and new IoT Devices (Hubs, Sensors & Actuators) - e.g. through standardised low-level API conformance.

The *Gait Analysis Assistive Task* aims to support remote gait quality assessment by means of specific exercises executed by the patient using the Robotic Rollator and under the remote supervision of a Doctor. In particular:

1. The Doctor schedules the timeframe for the execution of the assessment session using the SARA Agenda service. As an example a Doctor could schedule a periodic assessment session to be executed during the third week of every month.
2. At the start of the period scheduled by the Doctor (e.g. the third week of the month) the SARA Agenda service notifies a remainder to the Robotic Assistant.
3. Once received the notification the Robotic Assistant autonomously navigates to the location where the patient is. For the navigation and localization the Robotic Assistant relies on the navigation and localization cloud services of the SARA solution (see also previous Fall Management scenario).
4. Once reached the patient the Robotic Assistant initiates a dialog with the patient to engage him/her in the execution of the gait assessment session. For the execution of the dialog the Robotic Assistant relies on the Dialog Manager cloud service of SARA and other third party AI services (e.g. speech to text).
5. If the patient accepts to do the gait assessment session a notification is sent to the Doctor. If the patient refuses, the session is rescheduled.
6. Upon the reception of the acceptance by the patient the Doctor starts a remote supervision session using the Gait Analysis web application from the SARA solution.
7. At the beginning of the session the Doctor starts a telepresence session using the camera on board of the Robotic Assistant. Using this session the Doctor can do a visual assessment of the gait of the patient. The doctor can use the Gait Analysis web application also to teleoperate the Robotic Assistant and move it to a better pint of view if the current one does not allow a clear view of the scene. The Doctor may also decide to keep a video recording of the execution of the exercises for subsequent analysis.
8. The patient executes the exercises as requested by the Doctor. During the execution of the Gait Encoder software hosted by the controller of the Robotic Rollator segments and encode the time series generated by various sensors embedded within the Robotic Rollator (e.g. IMU, Lidar, handlebars).
9. As the encoded time series are produced by Gait Encoder they are sent to the Gait Clustering cloud service part of the SARA solution.
10. The Gait Clustering service clusters the time series received by the Gait Encoder and presents the resulting clusters to the Doctor using the Gait Analysis web application. The Doctor uses this clusters to make his/her assessment about the condition of the patient. The Gait Clustering service also attaches the result of the clustering to the Health record of the patient.

2.2. Challenges and objectives

The smart end-to-end IoT interoperability, connectivity and security technologies developed by the SEMIoTICS project can play a critical role in addressing the key challenges entailed in the development of SARA.

In particular, already the implementation of the two assistive tasks described in the section 2.1 requires to address a number of challenges arising in the area of:

- **End-to-end security, privacy, dependability and safety:** the development and operation of SARA need means to accurately assess the impact of varying system configurations on the security, privacy, dependability and safety properties of the system: to verifiably ascertain, for example, if using a particular device for a particular purpose, or a particular configuration of devices, exposes the system to an unacceptable level of risk.
- **IoT Semantics Interoperability:** SARA system relies on a distributed network of sensors and actuators, employing diverse wired and wireless communications technologies. The nodes in the network are highly heterogenous, ranging from basic inertial measurement units (IMU - e.g. for balance and fall detection), presence sensors (e.g. cameras equipped with motion detection and face/object recognition), to sophisticated robotic devices with their own internal sensor/actuator systems and onboard computers. The sensor/actuator network also communicates with backend cloud services to access and store events (e.g. 'fall detected', 'telepresence session initiated') and monitored health data (e.g. detailed time-sequenced measurements from BAN devices). Accordingly, the system must deal with a wide range of device semantics (different kinds of devices with different functions), data formats (syntactic representations), measurement unit conventions (for sensor readings), and communications protocols (e.g. Wi-Fi, ZigBee, Bluetooth). Various key aspects of SARA functionality, moreover, require that data from multiple sources is collated, aggregated and/or analyzed in a coherent collective fashion. The reliable detection of 'fall incidents', for example, may involve the continuous comparative evaluation of data from wearable IMU devices, RR handle-mounted pressure sensors and RA video cameras (among others).
- **Embedded Intelligence and local analytics**: SARA is an application of Socially Assistive Robotics (SAR), and is thus fundamentally an artificial intelligence system. SARA requires the continuous operation of a range of perceptual systems. This means multiple AI/ML processes working concurrently to extract different features from the sensory input in a timely fashion - i.e. without any significant network latency. Thus there is a strong need for an IoT infrastructure that supports computationally intensive, distributed AI processing at the edge of the IoT network.
- **Trustworthy Network Management**: SARA is a distributed application where different computing entities continuously communicate and synchronize their activities to collectively generate the overall functionality of the system. Many of these distributed computations, due to their near real-time nature, are subject to strong time constraints – which can only be met by a network infrastructure capable of guaranteeing trustworthy, low latency, reliable communications between all participating components. The SARA robotic nodes, moreover, have (quasi)autonomous behaviours driven to a large extent by uncertain and unpredictable events in the environment – with a corresponding uncertainty and unpredictability in the generated computational load. Such variability prohibits the advance determination of optimal configurations of networking resources for trust guarantees. Indeed, dealing with such dynamic run-time variability entails adopting correspondingly dynamic and flexible mechanisms for trustworthy network management.

2.3. SEMIoTICS sub use cases

In this document the validation of the benefits brought by the SEMIoTICS technologies to the development and operation of SARA is presented by means of five sub use cases. Each sub use case focuses a subset of the challenges in one the areas presented in section 2.2 and represents a different view on the very same system. The five use cases are:

- **Moving Intelligence to the Edge** demonstrates how the time series clustering algorithm part of the SEMIoTICS Local Embedded Intelligence component developed in the context of Task 4.3, can be deployed on the SARA Robotic Rollator and utilized in the implementation of the SARA Remote Gait Analysis Assistive Task.
- **Automated, trustworthy healthcare connectivity** shows how NFV along with the pattern related components, offer a flexible solution to deal with the heterogeneous traffic flows of SARA. Also, how they

reduce the manual intervention in the networking configuration and management, thus yielding a network management automation solution.

- **Enforcement and Monitoring of GDPR-compliant Access Control to Confidential and Sensitive Data** shows how the interaction of the SEMIoTICS Security & Privacy components is able to address, realize and monitor the enforcement of all security- and privacy-relevant properties of user-related data. Especially in this sub use case, the data relates to the medical conditions and thus is privacy sensitive data. SEMIoTICS enforces the GDPR-compliant controlled access to that data by enforcing and monitoring access control through policies as well as through encryption to enable GDPR-compliant data handling also during transfer and storage even beyond the system's boundary.
- **Controlling bulbs and robots** demonstrates how the SEMIoTICS Semantic Interoperability technologies developed in the context of Task 3.3 can help the developers of the SARA solution to interface heterogeneous devices ranging from light bulbs to semi-autonomous robots while keeping the application logic independent from the underlying hardware and transport protocols as much as possible.
- **Monitoring Activities of Daily Life** shows how the SEMIoTICS Monitoring, Prediction and Diagnosis Mechanisms (MPD) component developed in the context of Task 4.2, can be used to support the Human-Robot Interaction in the context of the SARA Remote Gait Analysis Assistive Task.

The reader can find in Appendix A the mapping between the sub use cases introduced by this section and the requirements posed by the SARA-Health use case towards the SEMIoTICS framework. This set of requirement was initially presented in deliverable D2.3 - ”Requirements specification of SEMIoTICS framework”.

3. SUB USE CASE 1: SEMIOTICS-ENABLED GAIT ANALYSIS WEB APP

3.1. Scope and Objectives

This sub use case aims to demonstrate how various SEMIoTICS technologies developed in the context of WP3 and WP4 can help to implement one of the SARA functionalities: the Gait Analysis Assistive Task described in section 2.1.2. This sub use case represents an evolution of the sub use case 1 that was named “Moving intelligence to the edge”.

In particular this sub use case aims to demonstrate how the SEMIoTICS Local Embedded Intelligence technologies (more specifically the time series clustering algorithm) developed in the context of Task 4.3 can help to reduce the amount of raw data required to be transmitted from field devices to cloud services.

The SARA Gait Analysis Web Application is the application utilized by a Doctor to remotely supervise a Gait Analysis examination session performed by a patient at home. The SARA Gait Analysis Web Application allows a Doctor to schedule gait analysis sessions, to run a telepresence session using a Pepper Robot, receive and store gait data collected by means of Robotic Rollator and, to review data after the end of a session.

The Figure 2 shows the page offered by the GA Web App to supervise a gait analysis session. The widget at the center of the page shows the video stream generated by the camera on board of robotic assistant (i.e. the Pepper robot). A Doctor can select the point of observation using the controls on the right part of the page: the buttons allow positioning the robot and fixing the posse of its head. The controls on the bottom part of the page allow start/stop recording the gait data collected by means of the Robotic Rollator.

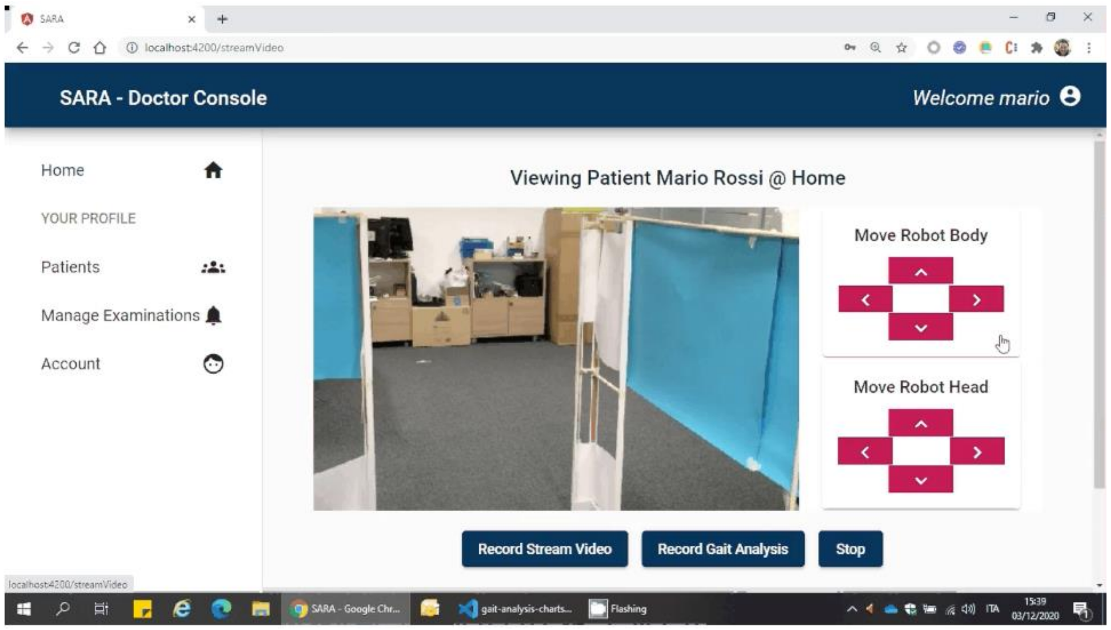


FIGURE 2: THE SARA INTERFACE SUPPORTING THE SUPERVISION OF A REMOTE GA SESSION

3.2. Interaction with SEMIoTICS framework

Figure 3 shows the SEMIoTICS components involved during the runtime for the execution of the Gait Analysis AT.

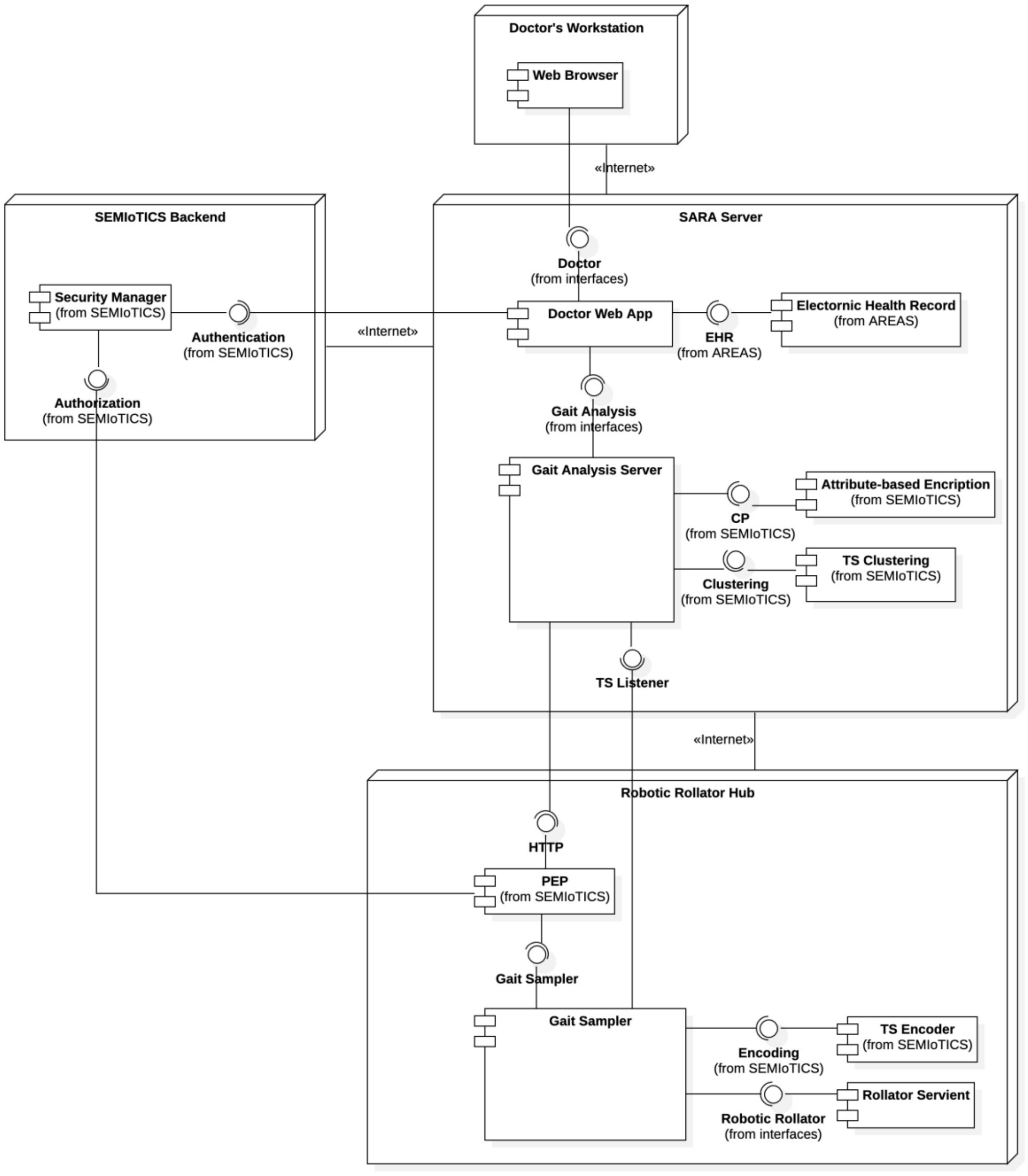

Doctor's Workstation
Web Browser
«Internet»
SEMIoTICS Backend
Security Manager (from SEMIoTICS)
Authentication (from SEMIoTICS)
Authorization (from SEMIoTICS)
«Internet»
SARA Server
Doctor (from interfaces)
Doctor Web App
EHR (from AREAS)
Electronic Health Record (from AREAS)
Gait Analysis (from interfaces)
Gait Analysis Server
CP (from SEMIoTICS)
Attribute-based Encription (from SEMIoTICS)
Clustering (from SEMIoTICS)
TS Clustering (from SEMIoTICS)
TS Listener
«Internet»
Robotic Rollator Hub
HTTP
PEP (from SEMIoTICS)
Gait Sampler
Gait Sampler
Encoding (from SEMIoTICS)
TS Encoder (from SEMIoTICS)
Robotic Rollator (from interfaces)
Rollator Servient

FIGURE 3: SEMIOTICS COMPONENTS USED BY DOCTOR WEB APP

The Doctor Web App is a web application residing on the SARA Server. A Doctor can access the Doctor Web App across the Internet using a standard Web Browser.

The Doctor Web App uses the SEMIoTICS Security Manager to authenticate a user. The Doctor Web App relies on the Electronic Health Record from AREAS® to retrieve/store information about patients.

The SARA Gait Analysis Server offers to the Doctor Web App the operations to manage a Gait Analysis session.

Whenever a Doctor requests to start the recording of data, the Gait Analysis Server communicates with the Gait Sampler application hosted by the Robotic Rollator assigned to the patient.

The Gait Sampler uses the Rollator Servient to obtain the time series representing the distances of patient's legs from the back of the rollator (Figure 4). This operation is done putting an observation on the resources legR and legL exposed by the rollator servient (see also section 6.3.1). The Rollator Servient is the SARA component that virtualizes the Robotic Rollator as a "Thing" in the sense defined by the WoT standard.

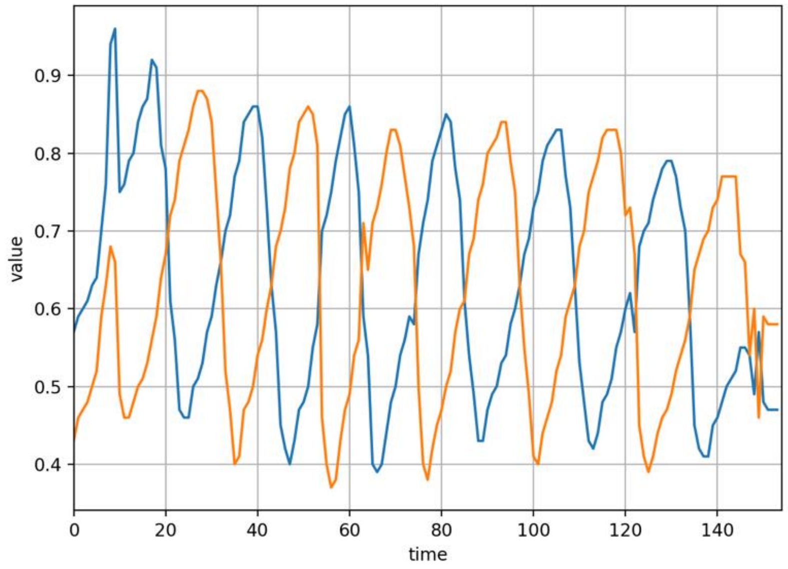


FIGURE 4: AN EXAMPLE OF TIME SERIES RECEIVED BY THE GAIT SAMPLER

The Gait Sampler extracts the time series representing a single gait from the time series received from the servient (Figure 5). Each time series accounting for a single gait is encoded using the SEMIoTICS Time series encoder. The encoded time series are sent back to the Gait Analysis server via the TS Listener interface.

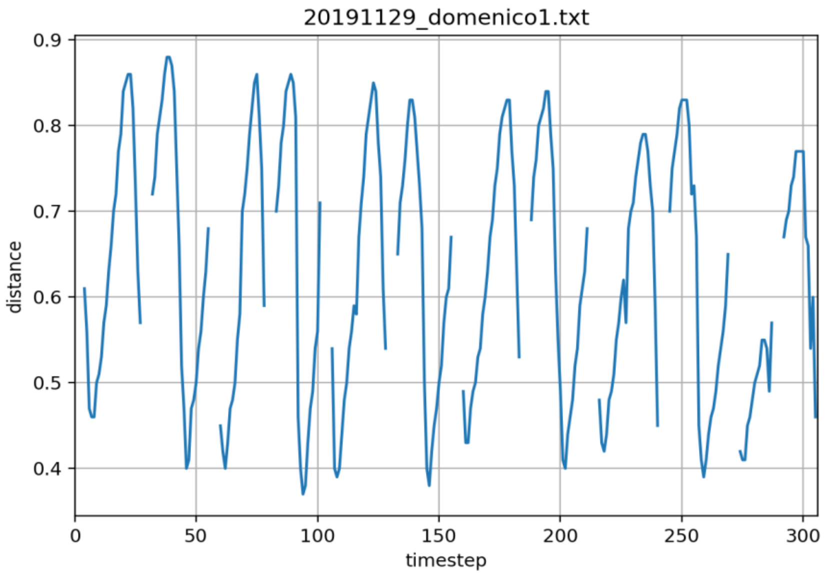


FIGURE 5: EXAMPLE OF TIME SERIES SENT TO THE TS ENCODER

Whenever a Doctor requests to stop the recording of data, the Gait Analysis Server uses the SEMIoTICS Timeseries clustering component to assign each buffered time series to cluster. The **TS Classifier** allows Gait Analysis Server to compute the probability that a gait cycle belongs to one of the possible predefined cluster (Figure 6).

The GAIT analysis charts as presented in the figures Figure 4 and Figure 5, are visible to the doctor side and the interpretation by the user/patient is not required. However, the commercialization of the described SARA application will include the improvement of the interface suitable to be used by the doctors and personnel offering assistive living healthcare domain.

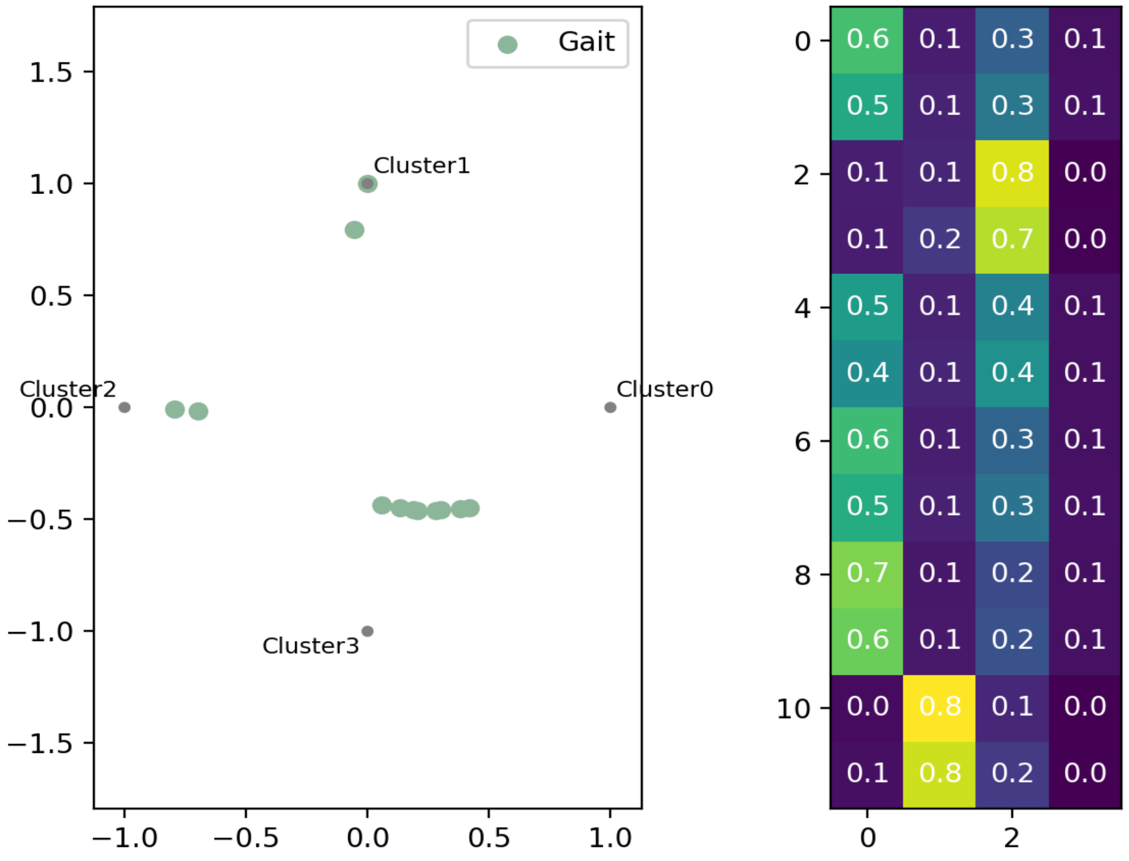


FIGURE 6: AN EXAMPLE OF ASSIGNMENT PRODUCED BY THE TS CLASSIFIER

The result of the clustering is sent back to the Doctor Web App that presents it in the web interface of the Doctor.

At the end of a session the SARA Gait Analysis Server persists an encrypted version of the results of the clustering: The encryption is done using the SEMIoTICS Attribute-Based Encryption component.

The Figure 7 shows more precisely the interactions occurring between components during the execution of Gait Analysis Task.

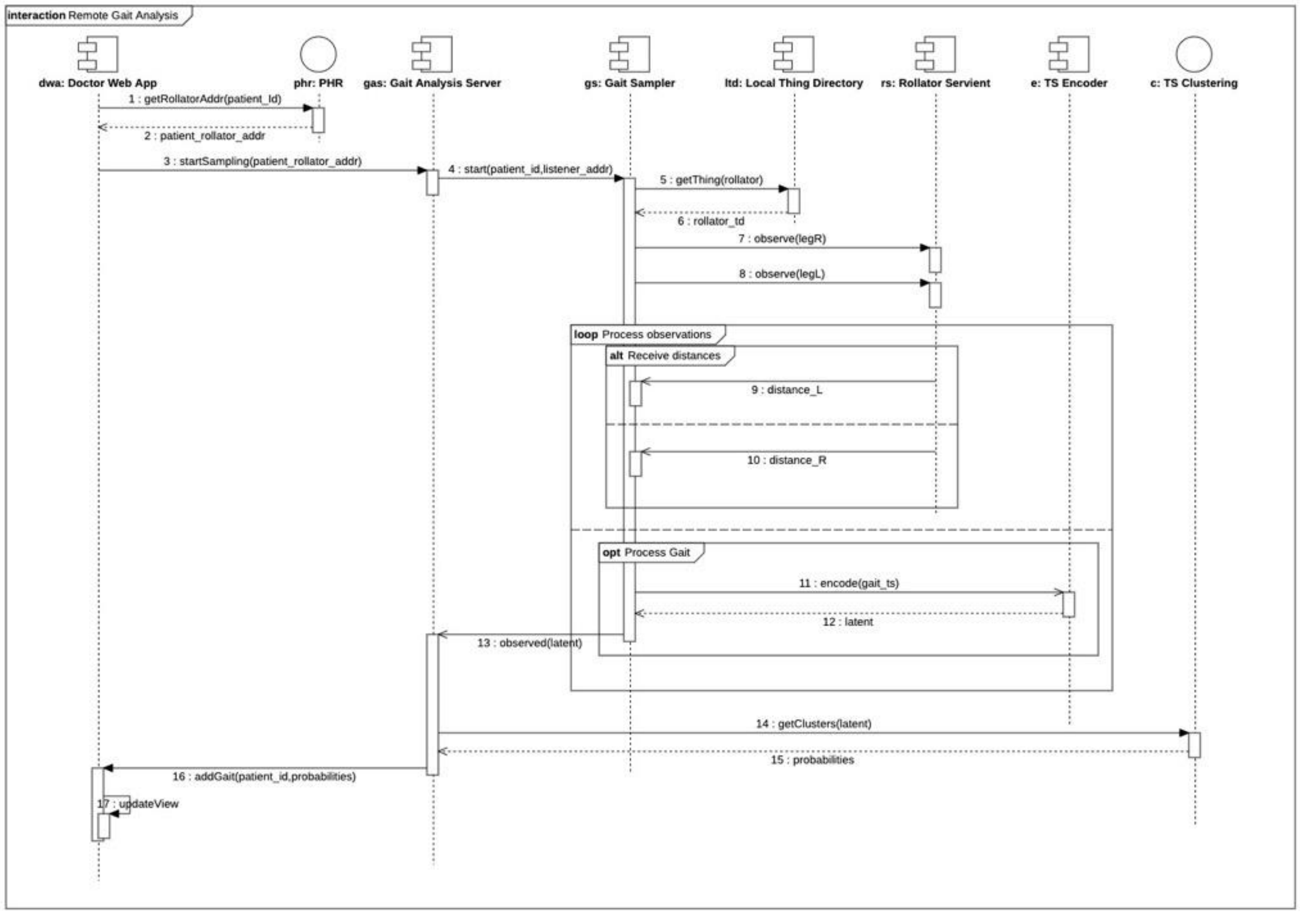


FIGURE 7: INTERACTIONS BETWEEN COMPONENTS

In particular:

1. The Doctor Web Application requests the address of the patient’s rollator to the Electronic Health Record (EHR).
2. The EHR return the rollator’s address to the Doctor Web Application.
3. The Doctor Web Application requests to the Gait Analysis Server to start the sampling of the patient’s gaits.
4. The Gait Analysis Server requests to the Gait Sampler to start sampling process.
5. The Gait Sampler requests to the Local Thing Directory (a SEMIoTICS component) the descriptor of the Rollator.
6. The Local Thing Directory returns the descriptor of the Rollator to the Gait Sampler component.
7. The Gait Sampler requests to the Rollator Servient to notify periodically the distance of the right leg.
8. The Gait Sampler requests to the Rollator Servient to notify periodically the distance of the left leg. Once both observations (left leg and right leg) are in place the Gait Sampler repeats continuously the steps 9-13 described below:
9. The Gait Sampler receives (asynchronously) from the Rollator Servient the distance of the left leg, or
10. the Gait Sampler receives (asynchronously) from the Rollator Servient the distance of the right leg.

11. The Gait Sampler, whenever detects that a gait cycle is complete, requests to the TS Encoder (a SEMIoTICS component) the encoding of the two times series accounting for the distance of the left and right legs from the rollator.
12. The Gait Sampler receives from the TS Encoder the encoded versions (latent representations) of the two time series.
13. The Gait Sampler forwards to the Gait Analysis Server the time series received by the TS Encoder.
14. The Gait Analysis Server requests to the TS Clustering component (a SEMIoTICS component) to assign to each time series the probability to be in one of the predefined gait clusters.

3.3. Setup testbed and integration

The tested of sub use case 1 utilizes three hosts (see also Figure 3):

- **Doctor's workstation** implemented by a standard PC running Window 10 OS.
- **SARA server's** software components are deployed both on a standard personal computer and on a virtual machine (running Linux OS) available from the FiwareLab[3] node operated by ENG in its data center located in Vicenza (Italy).
- **Robotic Rollator Hub** implemented by a Raspberry Pi 3 running Raspbian OS. This host is the same host used by sub use case 4 (see section 6). The Robotic Rollator Hub is realized using a Raspberry Pi 3 which is a clone of the one on board of the actual Robotic Rollator. During the second half of the year it was required to rely on a clone to cope with the impossibility to access the actual Robotic Rollator because of the Covid-19 pandemics.

The components presented in Figure 3 are implemented as follows:

- **Doctor Frontend** is realized by a Chrome Web browser executing the JavaScript served by the Doctor Web App hosted by the SARA server. This script implements the GUI of the Doctor Web Application.
- **Doctor Web App** is implemented by a web application written in Angular 8 and Typescript running on a Tomcat web server and uses the angular-oauth2-oidc[4] support to interact with the SEMIoTICS Security Manager instance operated by University of Passau[5] (Figure 8).

[3] https://www.fiware.org/developers/fiware-lab/
[4] https://www.npmjs.com/package/angular-oauth2-oidc
[5] http://semiotics-security.sec.uni-passau.de:3002/

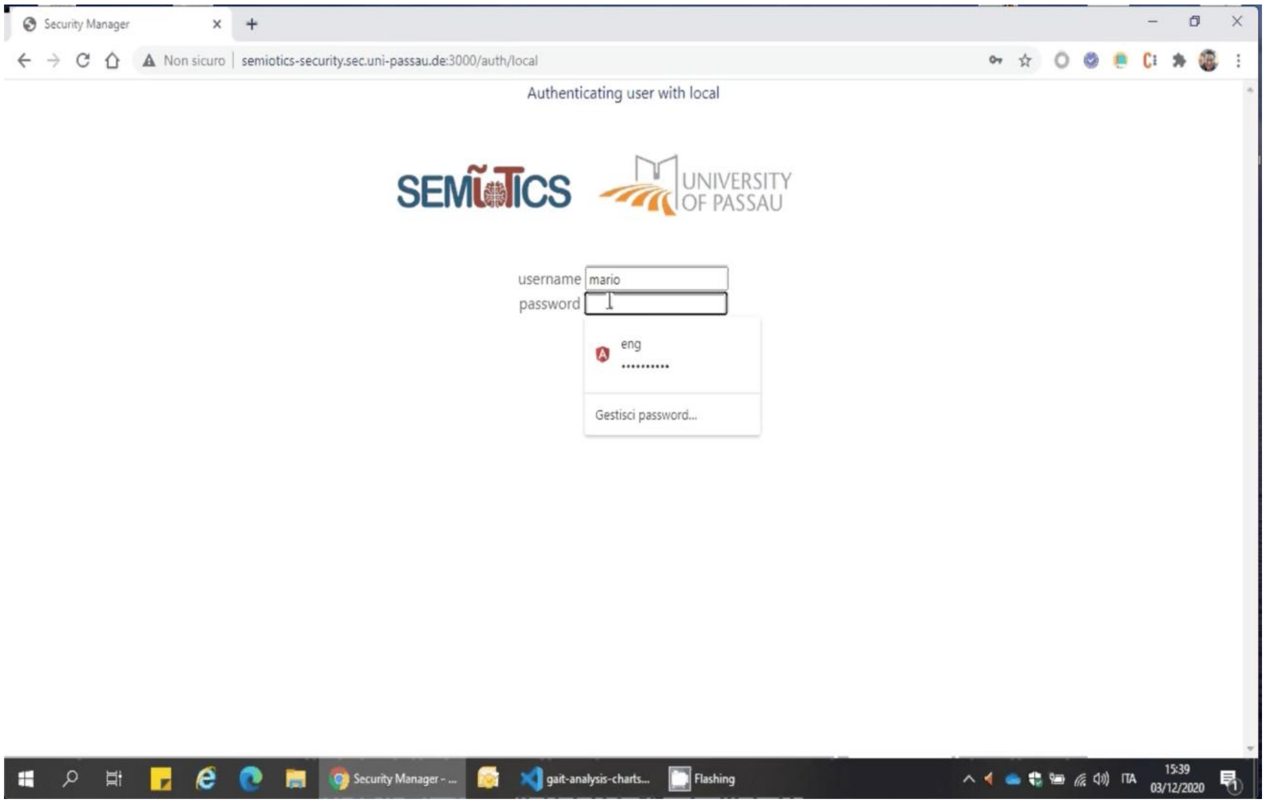


FIGURE 8: THE AUTHENTICATION PAGE PRESENTED BY THE SEMIOTICS SECURITY MANAGER

- **Electronic Health Record** is realized by a database from AREAS®. The Electronic Health Record from the AREAS® is a development instance that does not contain any sensible data related to any real individual.
- **TS Clustering** is realized by the Keras library and the SEMIoTICS time series clustering model described in deliverable D4.10 and trained using data collected by means of the Robotic Rollator before the Covid-19 lockdown (i.e. same data used by sub use case 4 described in section 6).
- **Gait Analysis Server** is realized by a REST service developed in Python 3.8 making use of Flask framework[6]. The Gait Analysis Server uses the Keras 2.4.3 and Tensorflow 2.3.0 to load and execute the SEMIoTICS Clustering Model. The SEMIoTICS Clustering Model is deployed on the SARA server as an HDF5 (.h5) file.
- **TS Encoder** is realized by the Keras library and the SEMIoTICS time series encoder model described in deliverable D4.10 and trained using data collected by means of the Robotic Rollator before the Covid-19 lockdown (i.e. same data used by sub use case 4 described in section 6). Similarly to the Gait Analysis Server the time series encoder is rest service developed in Python 3.8 making use of Flask framework[7]. The Gait Sampler uses Tensorflow Lite runtime to exploit the Timeseries encoder model. The Robotic Rollator Hub hosts a Tensorflow Lite version of the regular Timeseries encoder model.

[6] https://flask.palletsprojects.com/en/1.1.x/
[7] https://flask.palletsprojects.com/en/1.1.x/

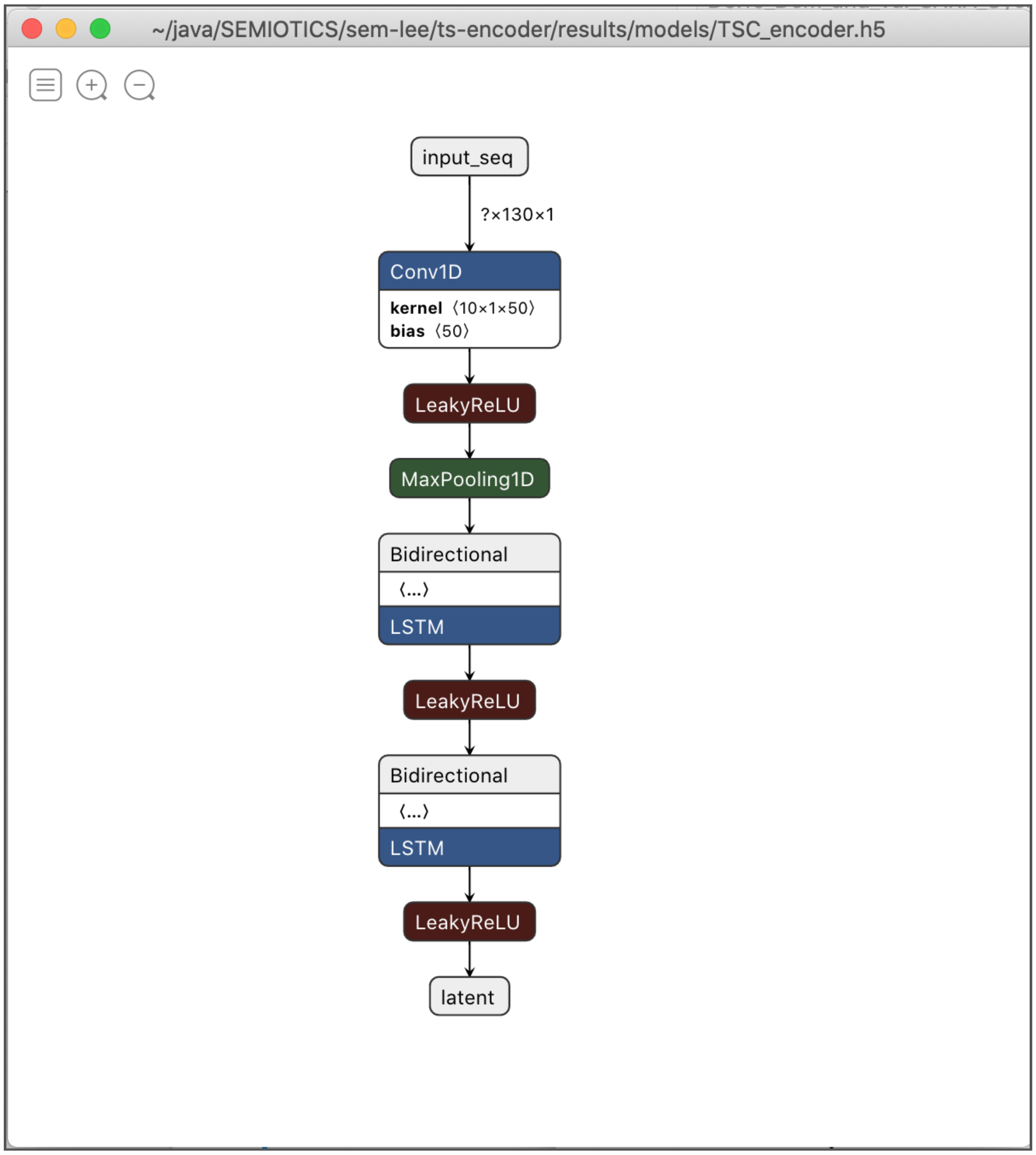


FIGURE 9: THE MODEL UTILIZED BY THE TIMESERIES ENCODER

- **Rollator Servient** is the WoT servient virtualizing the Robotic Rollator as a “Thing” in the sense of the WoT standard and is described more in details in section 6).
- **Gait Sampler** is realized by a REST service implemented in the Java programming language. Figure 10 shows a snapshot of the window used to debug the Gait Sampler component.

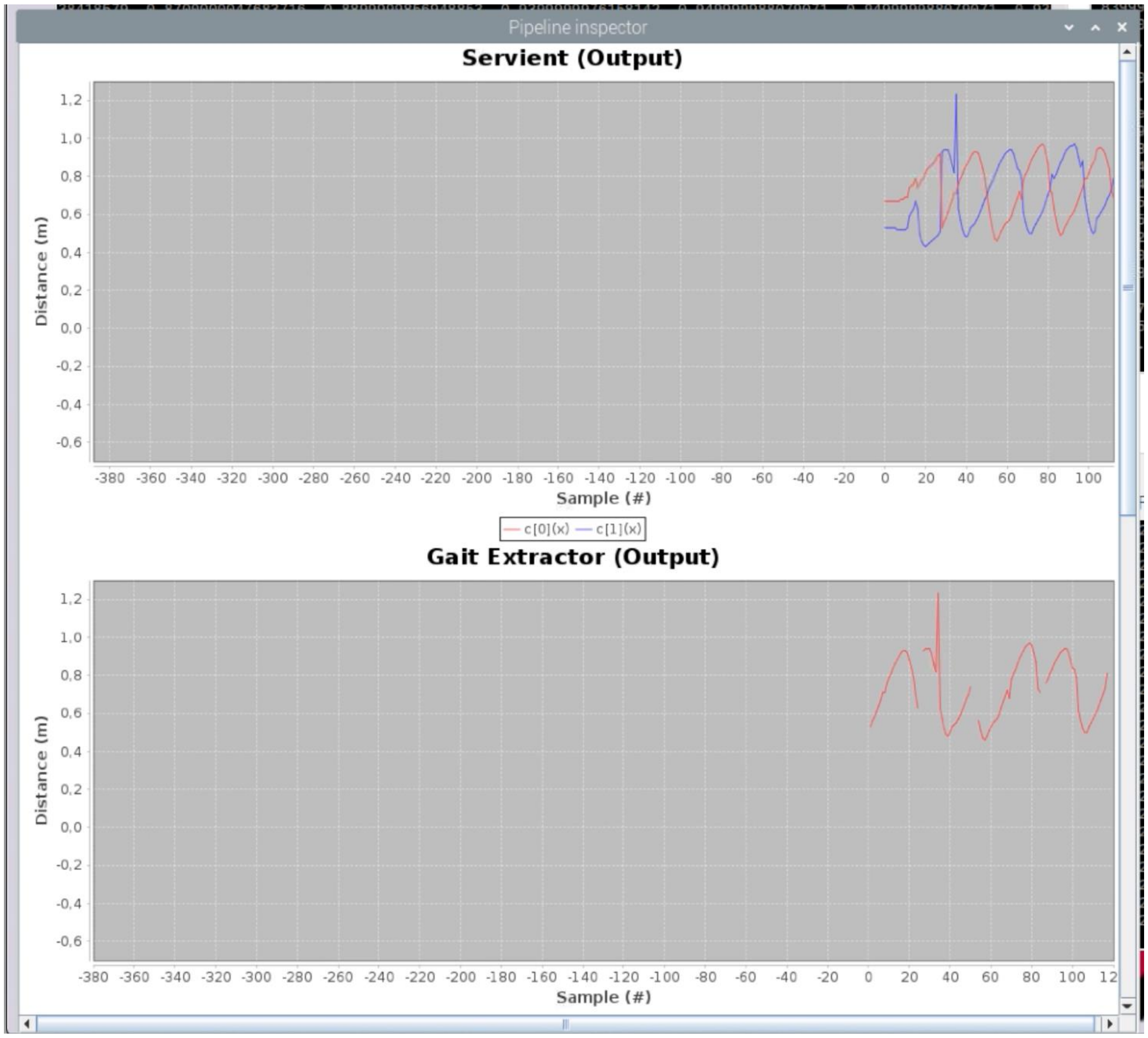


FIGURE 10: GAIT SAMPLER: INPUT FROM THE SERVIENT (TOP) AND EXTRACTED GAIT TIME SERIES (BOTTOM)

4. SUB USE CASE 2: AUTOMATED, TRUSTWORTHY HEALTHCARE CONNECTIVITY

4.1. Scope and Objectives

The SARA system generates traffic with heterogeneous features, stemming from the diversity of IoT devices embedded in the different SARA components such as the robotic rollator, the robot or the Body Area Network (BAN). Namely, the traffic will have different requirements in terms of priority:

- Low priority. For instance, traffic from appliances within the smart home during ordinary activities.
- High priority. Traffic generated by those Assistive Tasks like the Fall Management AT described in section 2.1.1, which are related to potential health problems of the elderly people under control, e.g. abnormal change in his breathing, in his heart rate or in his gait.

Moreover, the SARA use case involves data related to a health application. Thereby, it involves several trust levels that have to be considered for their processing at the networking layer:

- Low trust. For instance, the traffic generated by the mobile phone.
- Medium trust. For instance, the traffic from sensors at the smart home.
- High trust. For instance, the traffic generated by the robot assistant.

The heterogeneity in the traffic requires a flexible network that is capable to process the traffic accordingly. Moreover, the heterogeneity of the traffic leads to an increased network complexity, as it can lead to more configurations to adapt the network to the traffic features. In order to cope with the traffic heterogeneity and with the increased network complexity we adopt herein the Network Function Virtualization (NFV) framework. NFV provides a flexible network, as it relies on the virtualization of the computing, storage and networking resources yielding the so-called Network Function Virtualization Infrastructure (NFVI). Thereby, the network functions can be deployed on top of this NVFI in the form of the so-called Virtual Network Functions (VNF). This provides a flexible networking approach as the virtual resources can be allocated easily according to the network services ' needs. Moreover, the VNFs can be chained to form the so-called Service Function Chains (SFC). For instance, one can form an SFC consisting of a Firewall (FW) and a Load Balancer (LB). Another example is an SFC consisting of a FW, a Deep Packet Inspection (DPI) and Intrusion Detection System (IDS). Thereby, NFV provides flexibility and the proper means to deal with traffic heterogeneity. Last, but not least, the configuration and lifecycle management of the VNFs along with the virtualized infrastructure management, are automated thanks to the NFV Management and Orchestration (NFV MANO) sub block within the NFV framework.

Considering the above, there is significant motivation to leverage the flexibility provided by SFC to define specific service chains for each type of traffic. By applying the previous described procedure of chain instantiation, the SARA solution can support traffic forwarding through specific service functions. That includes the traffic forwarding for the different type of traffic exchanged between the different actors as following:

- *Chain 1 – Mobile Phone:* Firewall -> DPI -> IDS -> Output.
- *Chain 2 – Robotic Rollator:* Firewall -> IDS -> Load Balancer -> Output.
- *Chain 3 – Smart Home:* Firewall -> IDS -> Output.
- *Chain 4 – Robotic Assistant:* Firewall -> Load Balancer -> Output.
- Chain 5 - Malicious: Firewall -> Honeypot.

The above scenario sketches a complex environment, requiring support for integration of heterogeneous devices and communication protocols, high degrees of interoperability, and support for distributed services and applications (each with its own set of intrinsic requirements), while guaranteeing the safety of the patient and the security and privacy of her patient data. This use case is visualized in Figure 11, which depicts the various types of devices, their interactions, and the involved communication technologies.

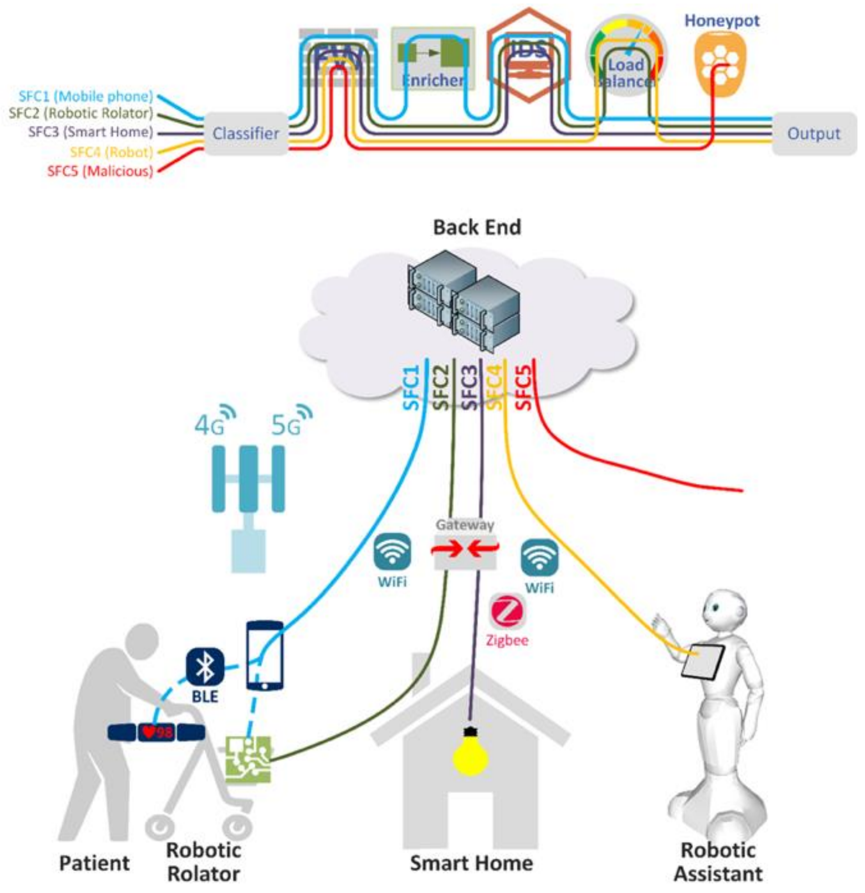


FIGURE 11: SARA-HEALTH SCENARIO AND TRAFFIC CLASSIFICATION

The instantiation of a sequence of functions can constitute a service chain. Similar to the insertion of service functions in the SFC manager through the exposed service function REST interface, service chains can be inserted. In the list of the service functions, the firewall, the DPI, the IDS and the Load Balancer have been defined as the most crucial ones to enable the SPDI properties required by each chain to guarantee. Each VNF has a unique IP address which is required for the configuration and integration with the other functions interacting also with the use case devices and apps. Pattern Orchestrator is responsible to forward the SFC request to the Pattern Engine in order to verify or instantiate SFC requests.

By leveraging the NFV framework, herein several SFC will be deployed on top of the virtual resources exposed by the NFVI. Namely, first a traffic classifier splits the incoming traffic from the SARA IoT field devices into several data flows. Then, these data flows are processed by the most proper SFC according to the traffic features.

The main objectives of this sub use case are summarized as follows:

- Show how NFV along with the pattern related components, offer a flexible solution to deal with the heterogeneous traffic flows of SARA. Also, how they reduce the manual intervention in the networking configuration and management, thus yielding a network management automation solution.
- Provide an NFV testbed to process, at the networking level, the different data flows of the SARA use case, according to their heterogeneous requirements.
- Provide the NFV MANO components that control the lifecycle management of the VNF along with the management of the virtualized infrastructure to deploy the VNFs. Thus, the NFV MANO leads to the automation of the virtual resources and the network functions management.

4.2. Interaction with SEMIoTICS framework

The components of the SEMIoTICS 'framework that are used in this sub use case are highlighted in Figure 12 and their interaction is detailed in the following subsections.

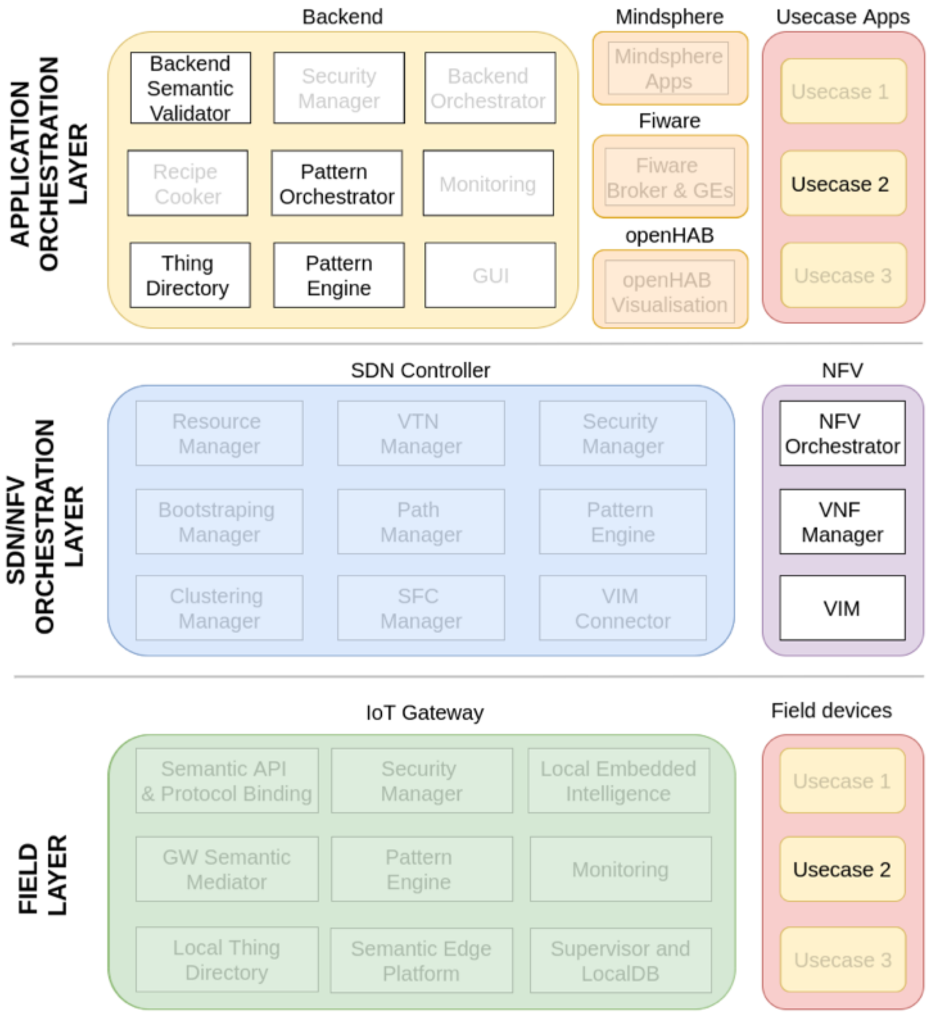


FIGURE 12: SEMIOTICS' COMPONENTS USED IN SUB USE CASE 2

4.2.1. INTERACTION WITH NFV

The SEMIoTICS 'NFV component is a fundamental part of the sub use case presented in this section. The NFV component allows to virtualize the computing, the networking and the storage resources at the cloud level yielding the so-called NFVI. Thereby, the VNFs that compose the SFC can be deployed as VMs that leverage those virtual resources. Moreover, the NFV component has the role to manage the whole lifecycle of the VNFs, through the NFV MANO subcomponent, see Figure 13. Thereby, it controls their onboarding within the NFV framework. Also, it provides configuration files that allow to automatize the instantiation of the VNFs, e.g. by defining the features and configuration of the VMs that hold the VNFs. Moreover, it allows the termination of the VMs that hold the VNFs. Next, more details on the role of the NFV component are given.

4.2.2. NFV ORCHESTRATOR AND VNF MANAGER

These are the sub blocks of the NFV component that manage the lifecycle of the VNF. Namely, the NFV orchestrator provides templates of configuration files to allow the end-user to describe the features and functionalities of the Network Services (NS) and their associated VNFs. These configuration files are so-called

VNF descriptors and NS descriptors. Note that this explanation is assuming that we use an OSM implementation of the NFV MANO, thereby a VNF is always within the context of a NS. Also, a cloud init file can be included to indicate the initial behavior, configuration and software installations of the VM that will hold the VNF. Once these configuration files are edited, we can onboard to the library of the OSM the VNF and NS packages that define the VNFs and the NS. Then, one can trigger the instantiation of the NS and their associated VNFs. This provokes that the NFV orchestrator communicates internally with the VNF manager, note that both blocks are implemented by the OSM. Then, the VNF Manager communicates internally with the VIM to trigger the instantiation or termination of the VNF. Thereby, it triggers the management of the virtual resources in the VIM to deploy the VMs that hold the VNFs.

4.2.3. VIRTUAL INFRASTRUCTURE MANAGEMENT

This block is the responsible for managing the NFVI, i.e. the virtual computing, storage and networking resources that allow to deploy the VNFs at the cloud level. The VNF manager and the NFV orchestrator manage the communication with the VIM internally. In other words, the end-users or applications that are external to the NFV framework do not need to communicate with the VIM, as the NFV orchestrator provides a high level interface through the configuration files mentioned above and through REST API interfaces. Thereby, as an example, the VIM creates or terminates the VM that holds the VNF, when the instantiation or termination of the VNF is triggered at the NFV orchestrator. The instantiation or termination process implies the allocation or release of the virtual resources from the NFVI to create or terminate the VM. Note that herein the VIM and NFVI are implemented by means of the OpenStack software, see section 4.4.

4.2.4. PATTERN ORCHESTRATOR

Pattern Orchestrator is responsible for automated configuration, coordination, and management of different patterns and their deployment. Moreover, it is used for processing a received requirement in order to translate it to Drools facts. The result of the said processing enables the Pattern Orchestrator to choose which Pattern Engine should receive the corresponding Drools facts in order to reason with them.

4.2.5. PATTERN ENGINE

Pattern Engine at the application layer, includes the pattern rules in the form of Drools rules, responsible for verifying and instantiating VNFs and SFCs. With the said rules the Pattern Engine is able to reason whether a new VNF is needed to be instantiated in order to complete a specific SFC. Moreover, if an SFC is not instantiated at all, the rules allow the instantiation of the SFC after having gathered all the necessary VNFs. Due to the fact that the Pattern Engine at the application layer, has a global view of the pattern facts across all layers, it makes it appropriate for providing up to date information on a graphical interface designed specifically for SFC management in a higher level. This interface is called SFC GUI and extracts all the information depicted directly from the Pattern Engine.

4.2.6. THING DIRECTORY

Thing Directory at the application layer represents a global repository for all the registered Things and is used to browse Things based on their Thing Description. The information extracted from Thing Directory is used from the Backend Semantic Validator to verify the interoperability between two Things. Moreover, it is used from the SFC GUI to populate the available nodes that can be used as source and destination of a flow.

4.2.7. BACKEND SEMANTIC VALIDATOR

The Backend Semantic Validator component is responsible for semantic validation mechanisms at the backend layer. It receives from the Pattern Engine the source and destination of a flow in order to verify the interoperability between them. When the interoperability between source and destination is not present, The Backend Semantic Validator informs the Pattern Engine so that the latter can take appropriate actions.

4.2.8. GUI

The GUI component is responsible for the visualization of SPDI pattern monitoring and pattern details. It receives from the Pattern Orchestrator information regarding the source and destination of a chain as well as the current state of the SPDI properties for the said chain.

4.3. Setup testbed and integration

4.3.1. NFV TESTBED

Herein, we leverage CTTC's NFV testbed for several purposes. First, to host the VNFs that process the traffic stemming from the SARA's IoT GW. Second, those VNFs are chained yielding the so-called Service Function Chains (SFC), which pave the way to support the trustworthy healthcare service. Third, a Virtual Private Network (VPN) has been configured at CTTC to let other partners access the NFV testbed from outside CTTC. Fourth, as it is detailed below, the NFV testbed exposes a northbound interface (NBI). That interface allows external entities, such as the pattern orchestrator or the SFC GUI, to control remotely the whole lifecycle of the SFC, NS or VNFs and to enforce the proper patterns dynamically. In the next Figure 13, we show a block diagram of the NFV testbed along with its interaction with the external entities through the NBI.

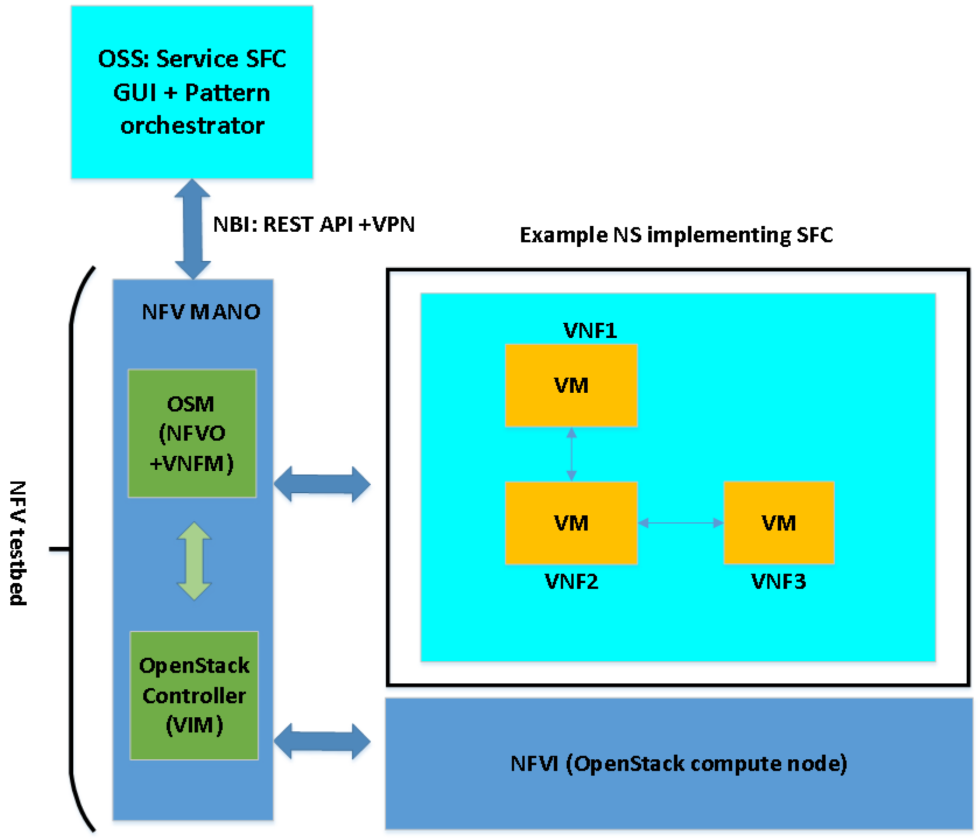

OSS: Service SFC GUI + Pattern orchestrator
NBI: REST API +VPN
Example NS implementing SFC
NFV testbed
NFV MANO
OSM (NFVO +VNFM)
OpenStack Controller (VIM)
VNF1
VM
VM
VM
VNF2
VNF3
NFVI (OpenStack compute node)

FIGURE 13: NFV TESTBED AT CTTC AND ITS INTERACTION WITH THE SFC GUI AND THE PATTERN ORCHESTRATOR

More specifically, this testbed consists of the next functional blocks according to the ETSI's NFV standard [1]. First, the VNFs are deployed on top of a virtualized infrastructure that exposes virtual computing, networking and storage resources. This infrastructure is so-called Network Function Virtualization Infrastructure (NFVI) and is one of the fundamental blocks of the NFV framework. Second, the whole NFV framework is managed by the so-called NFV Management and Orchestration (NFV MANO). More specifically, the NFV MANO is responsible for the whole lifecycle of the NS, the VNFs and the SFC, i.e. their creation, deployment and termination. The NFV MANO consists of three sub blocks. The NFV Orchestrator (NFVO), the VNF Manager (VNFM) and the Virtualized Infrastructure Manager (VIM). The virtualized resources and the whole NFVI are controlled by the VIM. The whole lifecycle of the VNF is managed by the NFVO and the VNFM, which have the responsibility to provide northbound API interfaces to interact with the end-user. This allows the end-user to edit the VNF features in terms of computing, storage or networking requirements. Also, it permits to onboard the VNF within the NFV framework, i.e. as part of the library of available VNFs. Moreover, the NFVO/VNFM blocks let the end-user to trigger the VNF instantiation or termination on top of the NFVI. In this regard, it is worth mentioning that the NFVO communicates downwards with the VNFM and the VNFM in turn communicates downwards with the VIM. Similarly, it is the NFVO that controls the whole lifecycle of the NS and the SFC and communicates downwards with the VIM to implement the required operations of the lifecycle such as instantiation or termination. In fact, note that a NS contains or embeds one or more VNFs. More insights on NFV for the SEMIoTICS purposes are given in the SEMIoTICS 'deliverable D3.8 [2].

The above-mentioned NFV blocks are implemented in CTTC's NFV testbed by using the next software:

- OSM (Open Source MANO) [3]. It implements the NFVO along with the VNFM blocks.
- OpenStack [4]. The OpenStack controller implements the VIM, the OpenStack compute node implement the NFVI.

The NFV testbed, mentioned above, has the topology described in Figure 14. More specifically, the NFV MANO consists of two functional blocks. Thus, on the one hand, the OSM implements the NFVO and VNFM. On the other hand, the NFV MANO contains another sub block, the OpenStack controller node, which implements the VIM. The NFVI is composed of one functional block, an OpenStack compute node that exposes its virtualized resources to instantiate the VNFs. A switch is leveraged for the communications between all the functional blocks mentioned above.

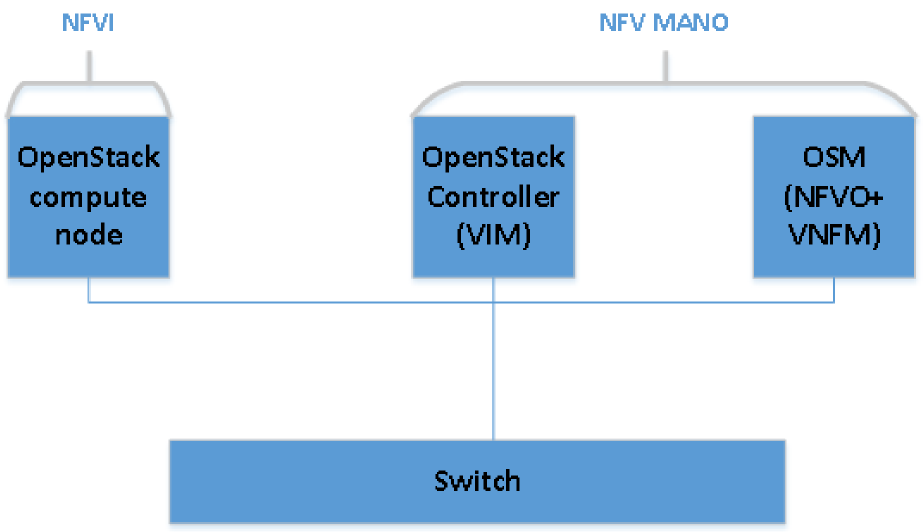


FIGURE 14: TOPOLOGY OF THE CTTC's NFV TESTBED.

In order to implement the NFVI and NFV MANO functional blocks described in Figure 14 we have deployed VMs within the servers available at the CTTC premises. Namely, each functional block of Figure 14 is a VM. Moreover, the computing, storage and RAM memory of the VM have been set up according to the requirements of each of the software components. Next, we describe the features of each VM and the switch:

- VM containing the OSM.
  - Storage of 98 GB.
  - RAM of 8 GB.
  - 4 CPU cores.
  - Operative system is the Ubuntu 18.04.4 LTS.
- VM containing the OpenStack controller node.

    - Storage of 98 GB.
    - RAM of 32 GB.
    - 6 CPU cores.
    - Operative system is the Ubuntu 18.04.4 LTS.
- VM containing the OpenStack compute node.
    - Storage of 10 GB.
    - RAM of 8 GB.
    - 4 CPU cores.
    - Operative system is the Ubuntu 18.04.4 LTS.
- The switch is a 10GBASE-T programmable switch.

Moreover, it is important to note that OSM version 7 has been installed, following the guidelines in [5]. Regarding the OpenStack, the Train version has been installed and set up in our NFV testbed. To this end, a devOps approach has been adopted. More specifically, OpenStack Ansible has been leveraged to ease and to automate the installation of the application and the configuration process of the underlying infrastructure that will support the OpenStack. We have followed the OpenStack Ansible guidelines in [6] to install and configure OpenStack Train in our NFV testbed. It is worth noting that Ansible is a type of configuration-management software, which follows an infrastructure as code approach. Thereby, it relies on an inventory, i.e. a set of configuration files that describe the nodes that can be accessed by Ansible. Moreover, Ansible relies on a set of files that permit to carry out operations on the managed nodes, thus these files are so-called Playbooks. Note that each Playbook maps a group of hosts to a set of roles.

Regarding the NFV testbed, it is also important to mention that the capability to support SFC in OpenStack has been enabled. To this end, we have installed the "networking-SFC" plugin for the OpenStack Neutron sub-block[8]. This plugin provides APIs to support SFC directly from OpenStack Networking (i.e. Neutron). Moreover, a set of constraints must be taken into account to enable SFC in OpenStack:

- First, each compute node of the NFVI must reserve a dedicated network interface for connecting VNFs to VLAN provider networks.
- Second, VXLAN are the only supported network technology for SFC data planes.
- Third, the data plane interconnecting VNFs in the SFC must support OpenFlow.

Additionally in FORTH's premises, the Pattern Orchestrator, Pattern Engine, Backend Semantic Validator and SFC GUI are deployed also in VMs. An Intel NUC (Figure 15) is used with 32GB RAM, 500GB storage and a CPU i7-6770HQ 2.60GHz with 8 cores. Proxmox Virtual Environment is installed in the Intel NUC which hosts the aforementioned VMs

- VM containing the Pattern Orchestrator.
    - Storage of 10 GB.
    - RAM of 4 GB.
    - 4 CPU cores.
    - Operative system is the Ubuntu 18.04.4 LTS.
- VM containing the Pattern Engine.
    - Storage of 10 GB.
    - RAM of 4 GB.

[8] "Service Function Chaining Extension for OpenStack Networking.," [Online]. Available: https://docs.openstack.org/networking-sfc/latest/. [Accessed December 2020].

  - 4 CPU cores.
  - Operative system is the Ubuntu 18.04.4 LTS.
- VM containing the Backend Semantic Validator.
  - Storage of 15 GB.
  - RAM of 2 GB.
  - 2 CPU cores.
  - Operative system is the Ubuntu 18.04.5 LTS.
- VM containing the SFC GUI.
  - Storage of 20 GB.
  - RAM of 2 GB.
  - 4 CPU cores.
  - Operative system is the Ubuntu 18.04.4 LTS

FIGURE 15: INTEL NUC AT FORTH TESTBED

Last, but not least, it is important to expose that the interface between the NFV and the SFC GUI-Pattern orchestrator is done through REST APIs and http requests, according to the ETSI GS NFV-SOL 005[9]. In fact, this document describes the standardized implementation for the Os-Ma-NFVO reference point, which is ETSI-NFV compliant [1] and defines the interface between the NFV MANO and external Operational Support Systems (OSS). Thereby, in our case, the SFC GUI-Pattern Orchestrator are considered as OSS and are fully compliant with the ETSI-NFV framework.

The detailed procedure used to validate the NFV testbed described in this section can be found in Appendix A.

4.3.2. SERVICE FUNCTION CHAINING PATTERNS VALIDATION

Service Function Chaining Patterns provide the ability to define an ordered list of security network services (e.g. firewalls, DPIs, IDS) for security in network infrastructures by creating chains at design and by updating functions in chains based on available ones at runtime. SFC patterns should cover the placement, security and scalability

[9] ETSI, "Network Functions Virtualisation (NFV) Release 2; Protocols and Data Models; RESTful protocols specification for the Os-Ma-nfvo Reference Point," ETSI GS NFV-SOL 005, 2018.

aspect of SEMIoTICS network infrastructures. The deployment of network service functions can be used to guarantee specific network security and dependability properties. However, stitched them into chains can satisfy more than one SPD properties. One of the innovative approaches supported by this work, is the dynamic instantiation of SFCs based on the predefined SFC patterns. When there is a request for an SFC instantiation containing service functions, the depicted in Figure 16 procedure should be followed. If the SFC does not exist, the instantiation of the respective SFC is deployed through the identification of the requested VNFs. If the VNFs exist in the service nodes, the SFC is updated including these VNFs. If the VNFs do not exist, the service node with the available resources is requested to instantiate the respective VNFs. The procedure is ended when all the requested VNFs are included in the SFC.

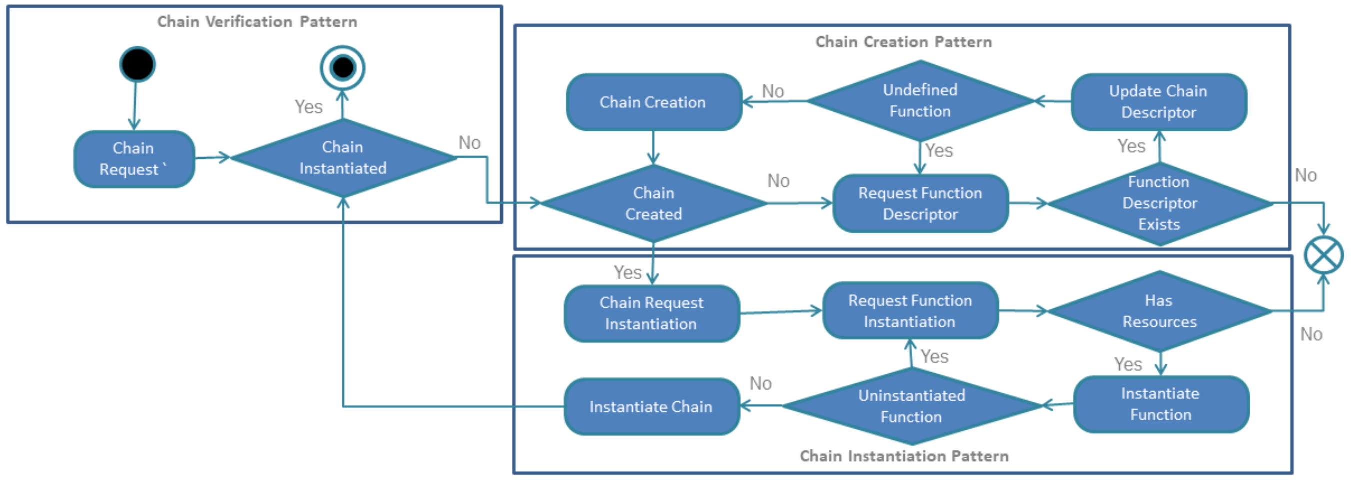


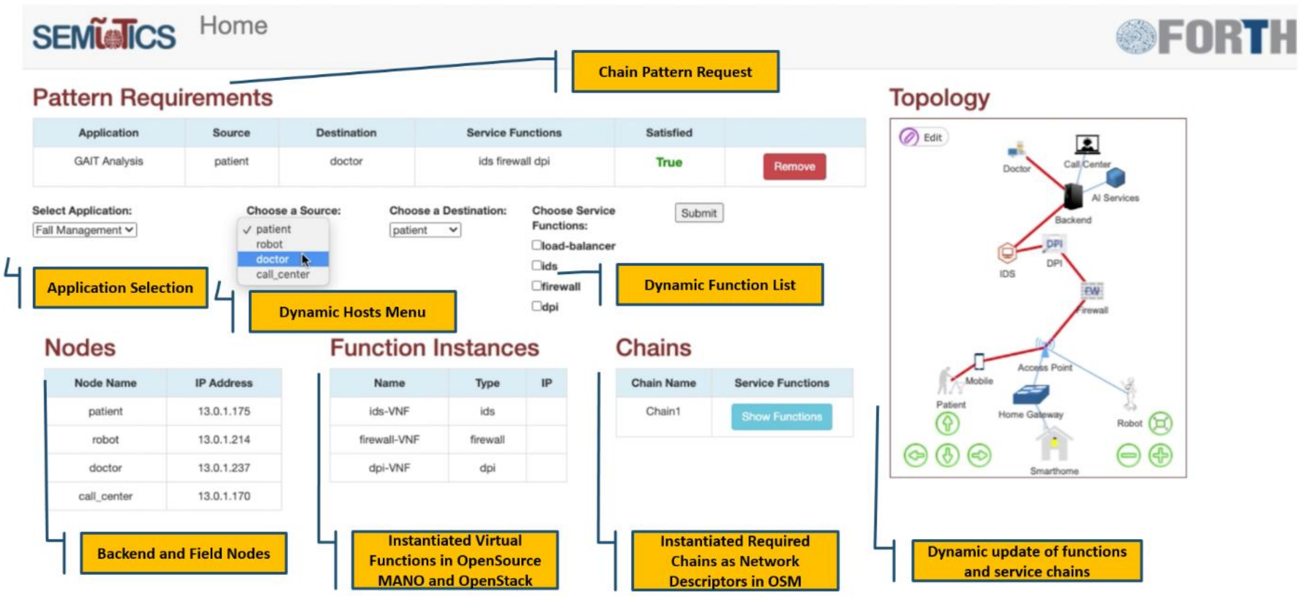
FIGURE 16: VNF INSTANTIATION BASED ON SFC REQUEST

To proceed to the above description, SFC patterns are developed to achieve the requirement for end to end guarantees by the traffic forwarding through different security service functions. The patterns can be expressed as Drools rules[10] to enforce the following requirements:

- Verify service function chains on chain requests.
- Instantiate service function chains, if the required functions have been already instantiated.
- Verify functions to insert them in the request chain.
- Instantiate not defined service functions to satisfy service function chain requests.

The ultimate goal of the SFC GUI is to enable the Administrators of the SARA solution to interact with the system that provides a secure networking infrastructure, via the associated proactive and reactive security mechanisms, such as the deployment of network security services and the continuous monitoring and intrusion detection. In Figure 17 the SFC GUI is presented which gathers in one screen all the necessary information.

[10] Drools Business Rules Management System https://www.drools.org



Application	Source	Destination	Service Functions	Satisfied	
GAIT Analysis	patient	doctor	ids firewall dpi	True	Remove

Node Name	IP Address
patient	13.0.1.175
robot	13.0.1.214
doctor	13.0.1.237
call_center	13.0.1.170

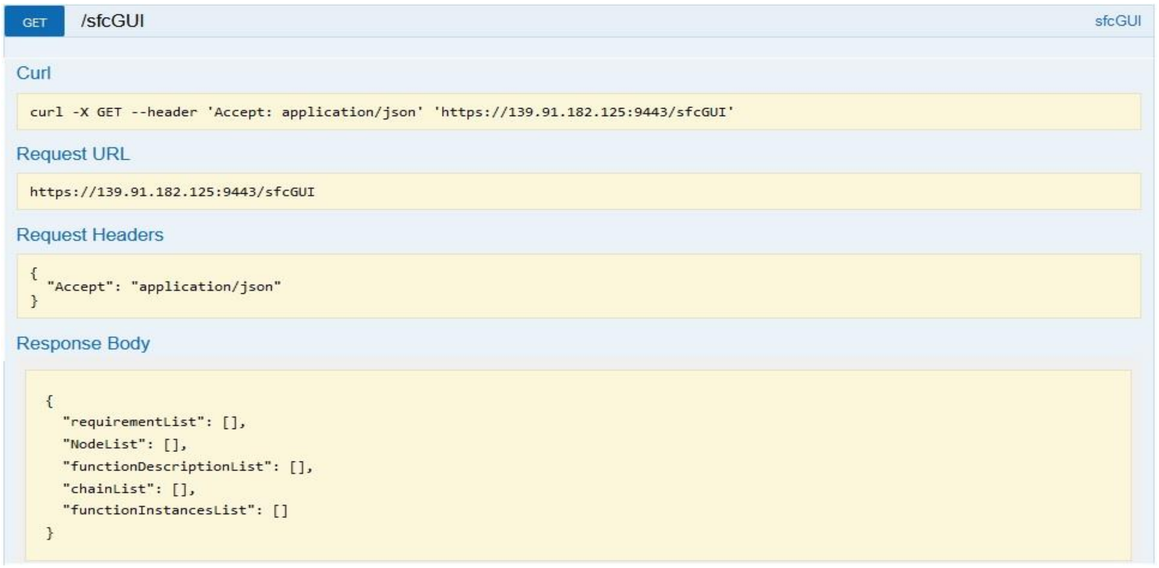
Name	Type	IP
ids-VNF	ids	
firewall-VNF	firewall	
dpi-VNF	dpi	

Chain Name	Service Functions
Chain1	Show Functions

FIGURE 17: SFC GUI

All information depicted in SFC GUI is gathered from Backend Pattern Engine with a simple http-GET request (Figure 18).

- Backend Pattern Engine gathers information from:
  - Thing Directory (Nodes)
  - OSM (Function List and Function Instances)
  - SFC Requests (Chains)
  - Pattern Requirement (user input)


GET /sfcGUI sfcGUI

Curl

```
curl -X GET --header 'Accept: application/json' 'https://139.91.182.125:9443/sfcGUI'
```

Request URL

```
https://139.91.182.125:9443/sfcGUI
```

Request Headers

```
{
  "Accept": "application/json"
}
```

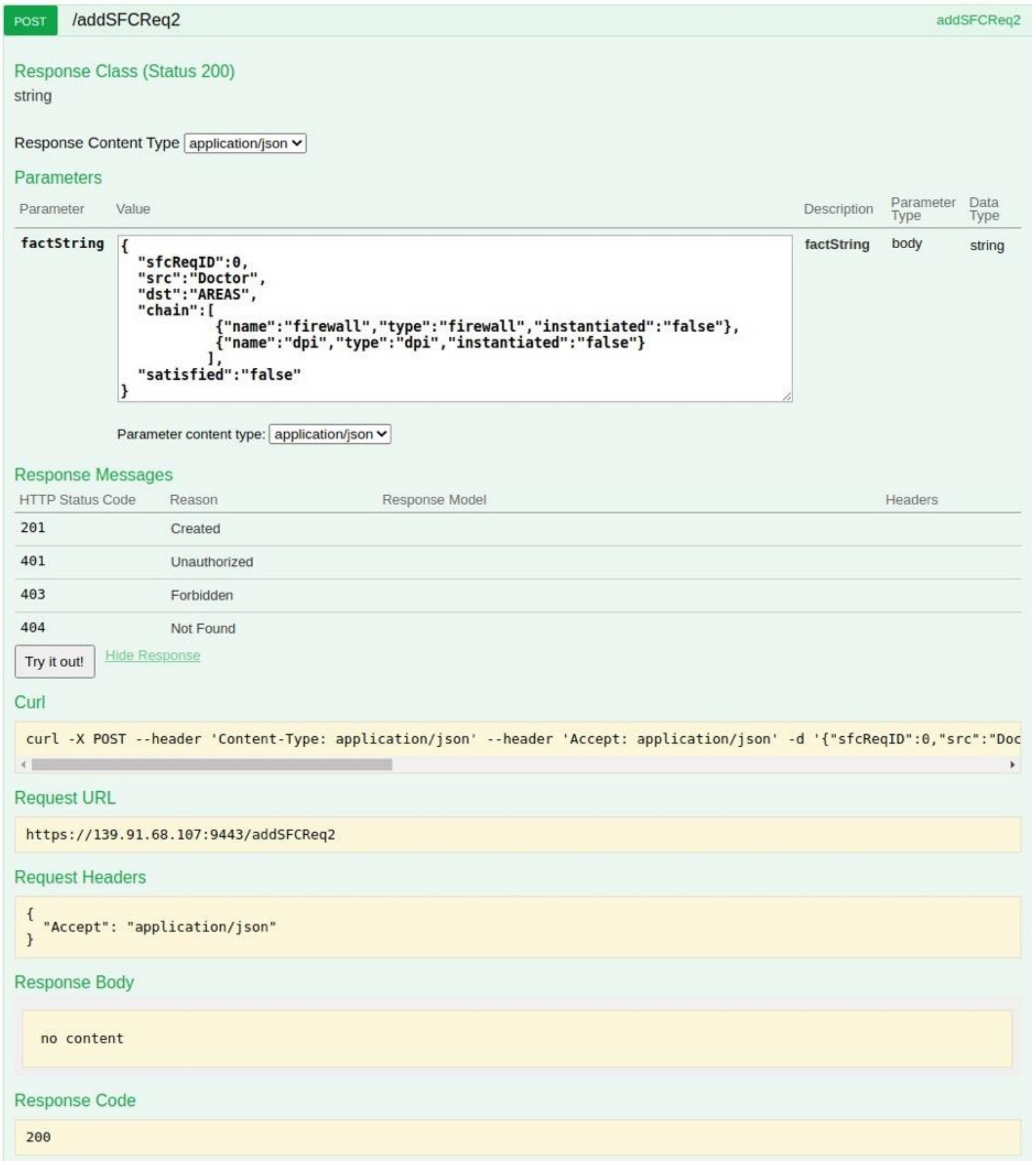
Response Body

```
{
  "requirementList": [],
  "NodeList": [],
  "functionDescriptionList": [],
  "chainList": [],
  "functionInstancesList": []
}
```

FIGURE 18: PATTERN ENGINE REST FOR SFC GUI

A user can request for specific VNFs to be applied in a flow of a specific source and destination such as the end hosts such the robot, patient or backend services such as AREAS, AI services. The list of sources and destination will be populated on the next cycle based on the information retrieved from the Thing Directory or manually in case of backend services. The VNFs that the user can choose from, is dynamically populated with information provided by the OSM.

Upon clicking on the submit button a new Pattern Requirement is created that is sent directly to the Pattern Engine and is consumed by the addSFCReq endpoint (Figure 19 and Figure 20).



Response Class (Status 200)
string

Response Content Type: application/json

Parameters

Parameter	Value	Description	Parameter Type	Data Type
factString	(see below)	factString	body	string

```
{
  "sfcReqID":0,
  "src":"Doctor",
  "dst":"AREAS",
  "chain":[
            {"name":"firewall","type":"firewall","instantiated":"false"},
            {"name":"dpi","type":"dpi","instantiated":"false"}
           ],
  "satisfied":"false"
}
```

Parameter content type: application/json

Response Messages

HTTP Status Code	Reason	Response Model	Headers
201	Created		
401	Unauthorized		
403	Forbidden		
404	Not Found		

Curl

```
curl -X POST --header 'Content-Type: application/json' --header 'Accept: application/json' -d '{"sfcReqID":0,"src":"Doc
```

Request URL

```
https://139.91.68.107:9443/addSFCReq2
```

Request Headers

```
{
  "Accept": "application/json"
}
```

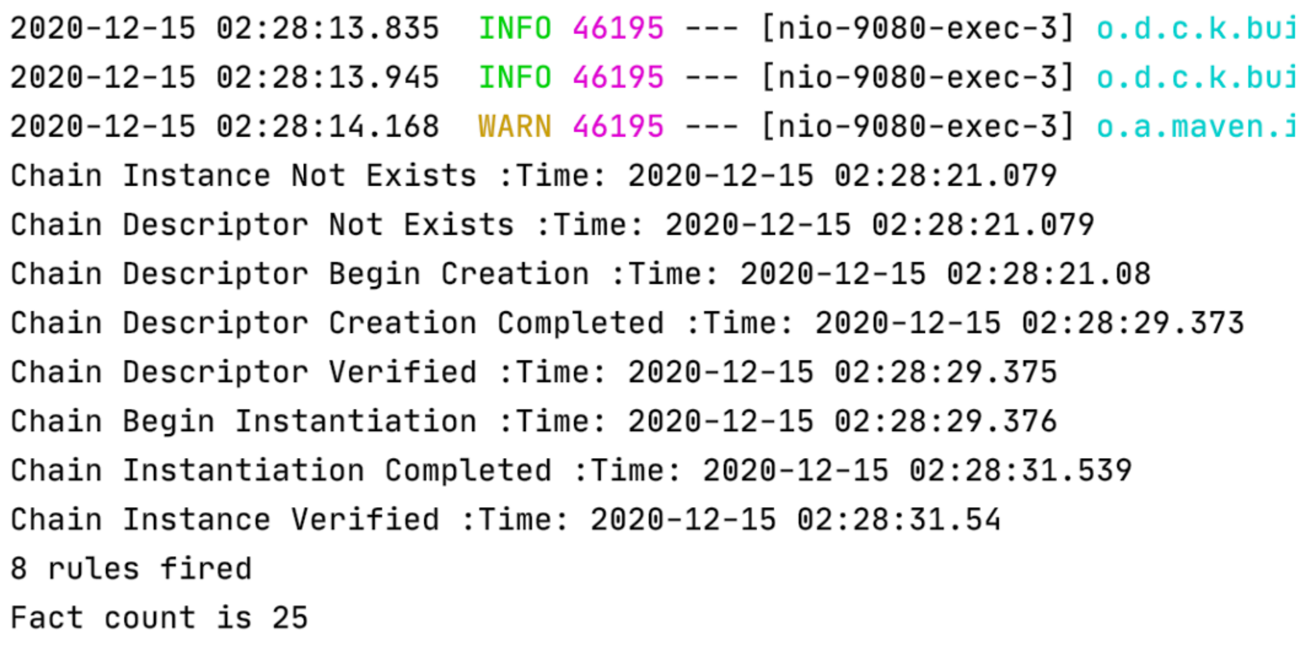
Response Body

```
no content
```

Response Code

```
200
```

FIGURE 19: PATTERN ENGINE REST FOR SUBMIT BUTTON OF SFC GUI



```
2020-12-15 02:28:13.835  INFO 46195 --- [nio-9080-exec-3] o.d.c.k.bui
2020-12-15 02:28:13.945  INFO 46195 --- [nio-9080-exec-3] o.d.c.k.bui
2020-12-15 02:28:14.168  WARN 46195 --- [nio-9080-exec-3] o.a.maven.i
Chain Instance Not Exists :Time: 2020-12-15 02:28:21.079
Chain Descriptor Not Exists :Time: 2020-12-15 02:28:21.079
Chain Descriptor Begin Creation :Time: 2020-12-15 02:28:21.08
Chain Descriptor Creation Completed :Time: 2020-12-15 02:28:29.373
Chain Descriptor Verified :Time: 2020-12-15 02:28:29.375
Chain Begin Instantiation :Time: 2020-12-15 02:28:29.376
Chain Instantiation Completed :Time: 2020-12-15 02:28:31.539
Chain Instance Verified :Time: 2020-12-15 02:28:31.54
8 rules fired
Fact count is 25
```

FIGURE 20: PATTERN ENGINE FIRING SFC RELATED RULES

After the new requirement has been consumed by the Pattern Engine, the pattern rules (Figure 21 to Figure 25) are fired causing the verification and instantiation of VNFs and SFCs.

```
rule "Chain Verification Pattern Rule"
salience 10
when
 $chain: Chain($functions: functions, instantiated==true)
 $PR: Req($src:src,$dst:dst, pro.chain.functions==$functions,
satisfied==false)
then
 System.out.println("Chain Verified");
 modify($PR){satisfied=true};
end
```

FIGURE 21: SERVICE FUNCTION CHAIN VERIFICATION

```
rule "Chain Instantiation Pattern"
salience 20
when
 $chain: Chain($functions: functions, instantiated==false)
 $PR: Req($src:src, $dst:dst,  pro.chain.functions== $functions,
satisfied==false)
then
 Orch orch=new Orch();
 orch.instantiateChain($chain.id, $chain.name);
 modify($chain){instantiated=true};
 System.out.println("Chain Instantiated");
end
```

FIGURE 22: SERVICE FUNCTION CHAIN INSTANTIATION

```
rule ”Chain Creation Pattern"
salience 30
when
 $PR: Req($src:=src, $dst:=dst, $pro: pro, satisfied== false)
 not Chain($functions: functions, $functions:= $PR.pro.chain.functions,
instantiated==false)
then
 Orch = new Orch();
String idd = orch.createChain($PR.pro.chain.functions, "chain",
$src.address, $src.port, $dst.address, $dst.port);
 Chain chain = new Chain(idd, "chain", $PR.pro.chain.functions,false);
 insert(chain);
 System.out.println("Chain Descriptor Created");
end
```

FIGURE 23: SERVICE FUNCTION CHAIN CREATION

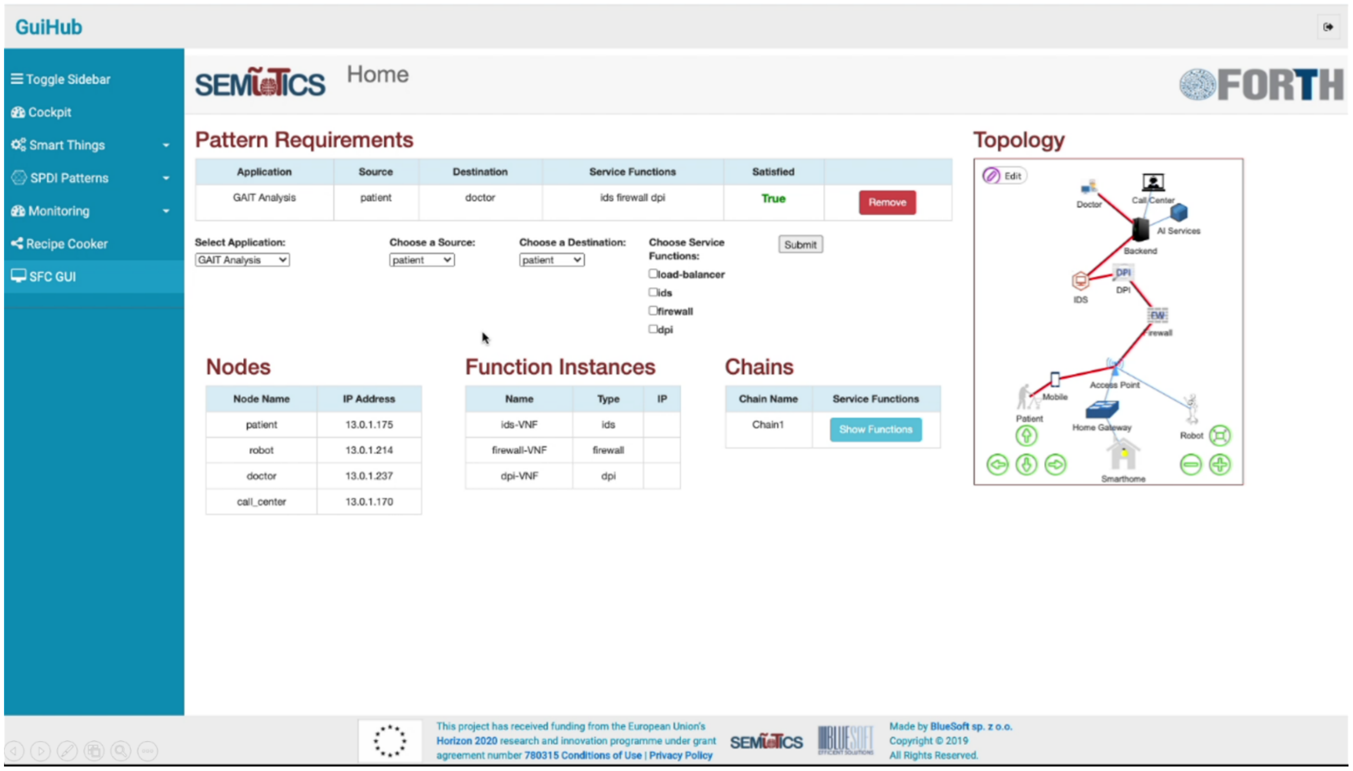
```
rule "Virtual Service Network Function Verification"
ruleflow-group "SFC"
salience 40
when
 $function: Function($type:=type, instantiated==true)
 $chain: Chain($functions: functions, $functions not contains
$function, instantiated==false)
 $PR: Property($src:=src, $dst:=dst,
$reqFunctions:=property.chain.functions, satisfied== false)
 Function($type==type) from $reqFunctions
then
 System.out.println("Verification of Function");
 $chain.addFunction($function);
     update($chain);
end
```

FIGURE 24: SERVICE FUNCTION VERIFICATION

```
rule "Virtual Service Network Function Instantiation"
ruleflow-group "SFC"
salience 50
when
    $function: Function($type:=type, instantiated==false)
    not Function($type:=type, instantiated==true)
    $chain: Chain($functions: functions, $functions not contains
$function, instantiated==false)
    $PR: Property($src:=src, $dst:=dst,
$reqFunctions:=property.chain.functions, satisfied== false)
    Function($type==type) from $reqFunctions
then
    System.out.println("Instantiation of Function");
    Function function = new Function($function.type);
    modify($function){instantiated=true};
end
```

FIGURE 25: SERVICE FUNCTION INSTANTIATION

In use case 2, the main two applications are the Gait analysis and Fall management. More specifically, for the gait analysis the requirement include the instantiation of a chain for the traffic forwarding from the patient to the doctor including a firewall, a DPI and an IDS. Upon submitting the requirement, the appropriate rules are fired at the pattern engine, forcing the instantiation of the required functions in OpenStack and the formation of the chain in the OSM. As soon as all rules have finished, all information is available in the SFC GUI Figure 26.



Pattern Requirements

Application	Source	Destination	Service Functions	Satisfied	
GAIT Analysis	patient	doctor	ids firewall dpi	True	Remove

Select Application: GAIT Analysis
Choose a Source: patient
Choose a Destination: patient
Choose Service Functions:
☐load-balancer
☐ids
☐firewall
☐dpi
Submit

Nodes

Node Name	IP Address
patient	13.0.1.175
robot	13.0.1.214
doctor	13.0.1.237
call_center	13.0.1.170

Function Instances

Name	Type	IP
ids-VNF	ids	
firewall-VNF	firewall	
dpi-VNF	dpi	

Chains

Chain Name	Service Functions
Chain1	Show Functions

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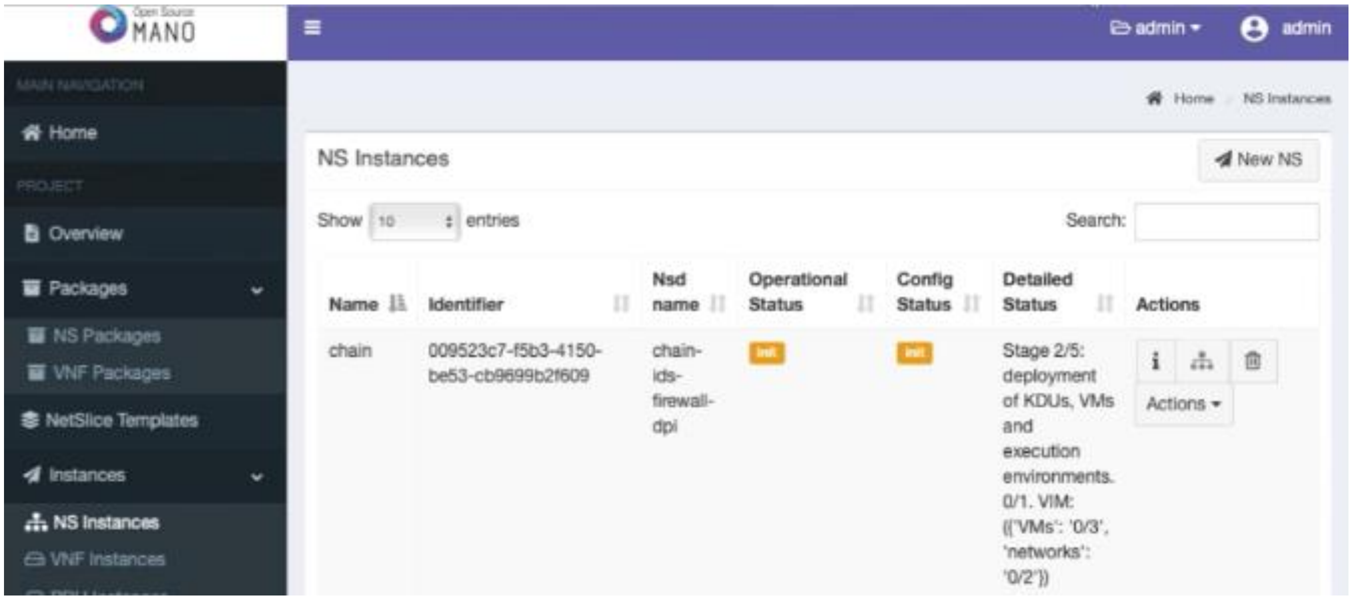
FIGURE 26: GAIT ANALYSIS SCENARIO (1)

The procedure includes the verification of a chain based on the described patterns. If the chain is not instantiated, the pattern will trigger the instantiation of a new chain based on an existing chain descriptor as can be seen in Figure 27 and Figure 28. If the chain descriptor exists, the patterns are able to trigger the creation of the chain before its instantiation of the required functions in the OpenStack, as can be seen in and Figure 29.

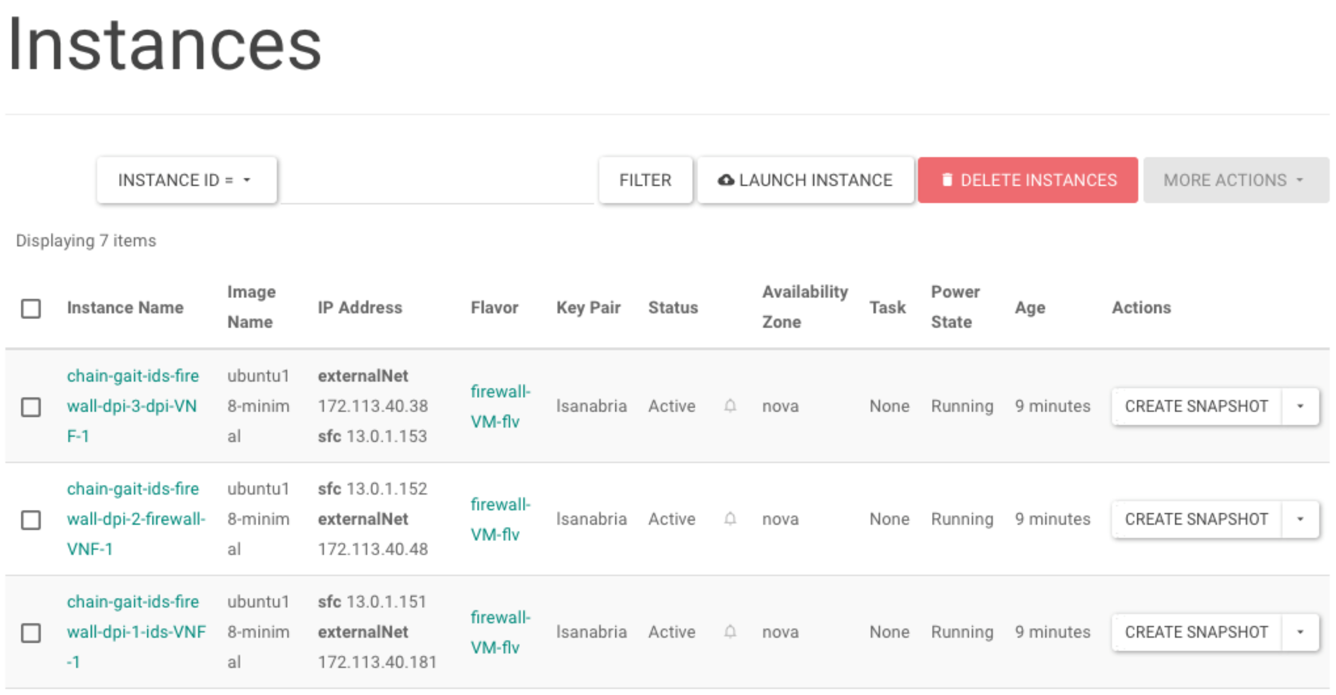


NS Instances

Show 10 entries Search:

Name	Identifier	Nsd name	Operational Status	Config Status	Detailed Status	Actions
chain	009523c7-f5b3-4150-be53-cb9699b2f609	chain-ids-firewall-dpi	init	init	Stage 2/5: deployment of KDUs, VMs and execution environments. 0/1. VIM: {'VMs': '0/3', 'networks': '0/2'}	Actions

FIGURE 27 INSTANTIATION OF SERVICE CHAIN IN OSM



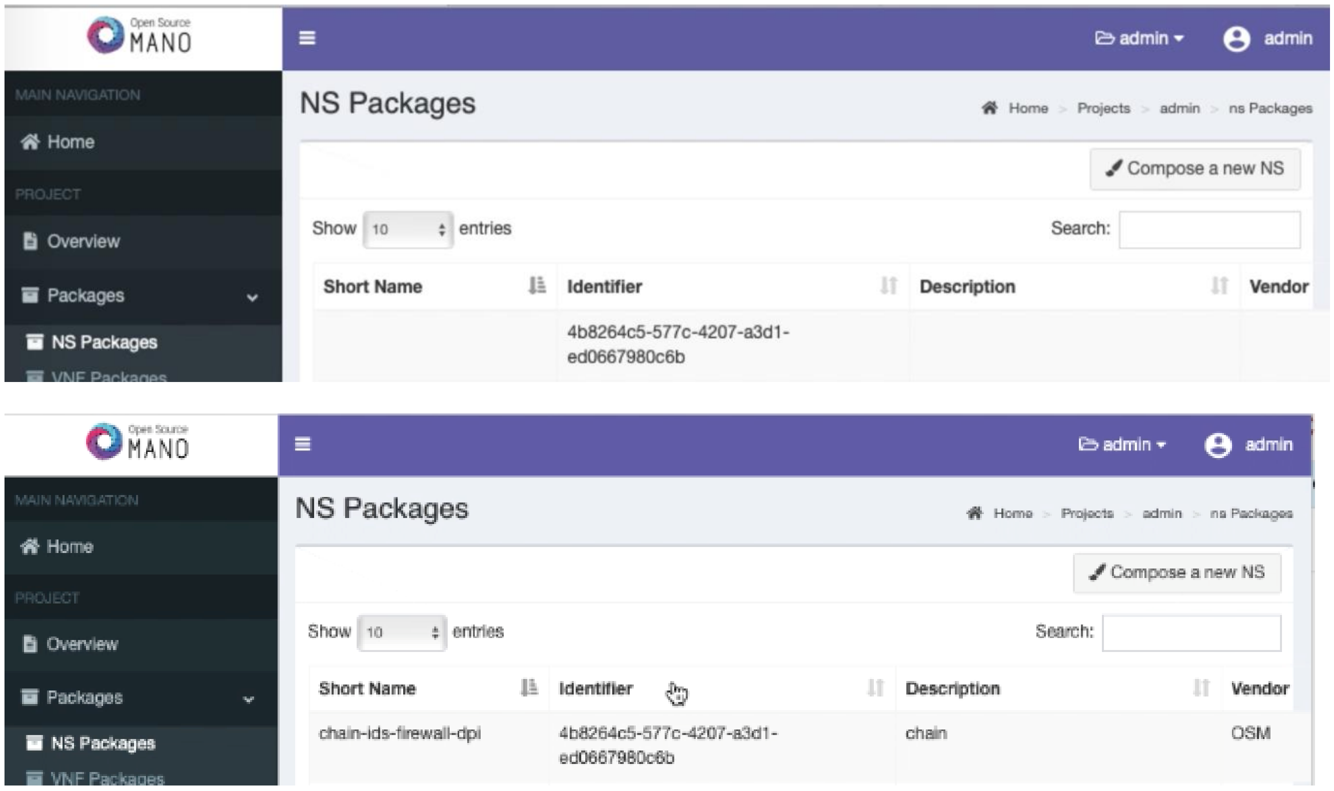
Instances

INSTANCE ID = | FILTER | LAUNCH INSTANCE | DELETE INSTANCES | MORE ACTIONS

Displaying 7 items

Instance Name	Image Name	IP Address	Flavor	Key Pair	Status		Availability Zone	Task	Power State	Age	Actions
chain-gait-ids-firewall-dpi-3-dpi-VNF-1	ubuntu18-minimal	externalNet 172.113.40.38 sfc 13.0.1.153	firewall-VM-flv	Isanabria	Active		nova	None	Running	9 minutes	CREATE SNAPSHOT
chain-gait-ids-firewall-dpi-2-firewall-VNF-1	ubuntu18-minimal	sfc 13.0.1.152 externalNet 172.113.40.48	firewall-VM-flv	Isanabria	Active		nova	None	Running	9 minutes	CREATE SNAPSHOT
chain-gait-ids-firewall-dpi-1-ids-VNF-1	ubuntu18-minimal	sfc 13.0.1.151 externalNet 172.113.40.181	firewall-VM-flv	Isanabria	Active		nova	None	Running	9 minutes	CREATE SNAPSHOT

FIGURE 28 INSTANTIATION OF SERVICE FUNCTIONS IN OPENSTACK



NS Packages

Home > Projects > admin > ns Packages

Compose a new NS

Show 10 entries   Search:

Short Name	Identifier	Description	Vendor
	4b8264c5-577c-4207-a3d1-ed0667980c6b		

NS Packages

Home > Projects > admin > ns Packages

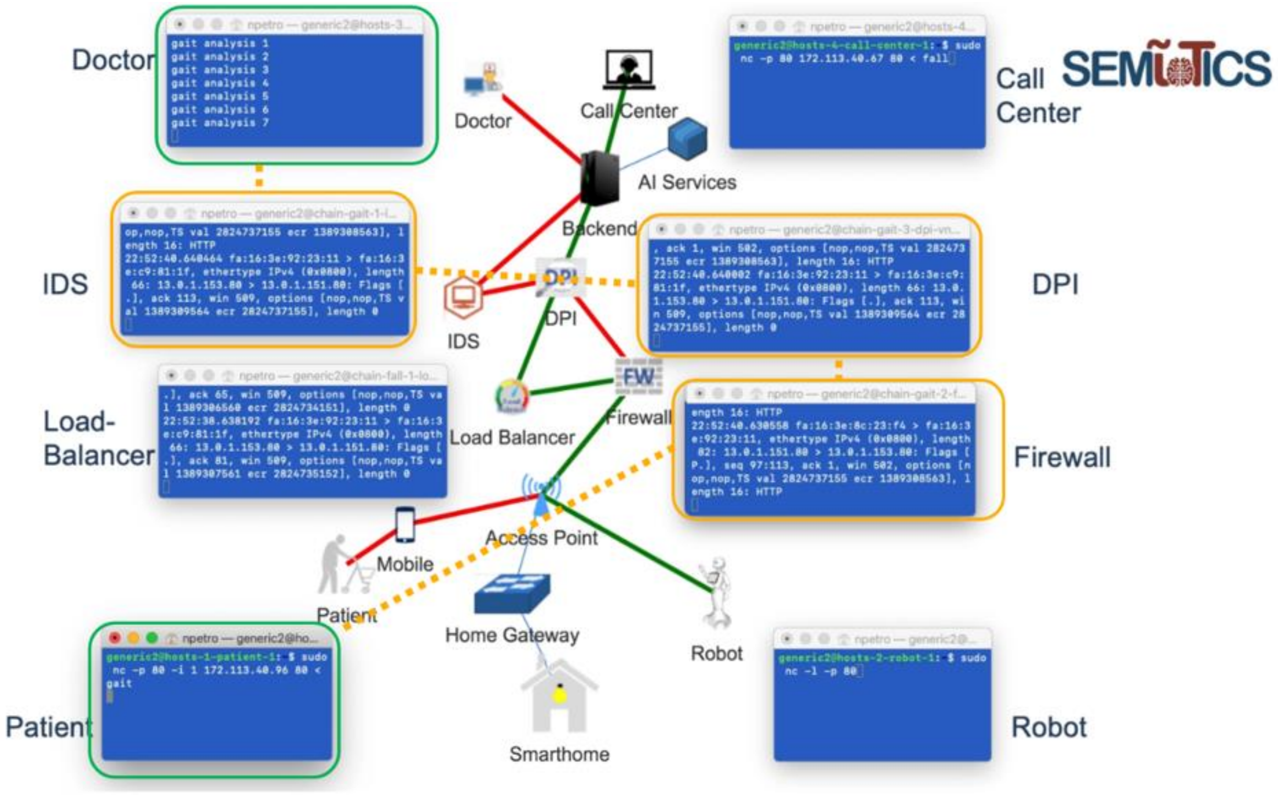
Compose a new NS

Show 10 entries   Search:

Short Name	Identifier	Description	Vendor
chain-ids-firewall-dpi	4b8264c5-577c-4207-a3d1-ed0667980c6b	chain	OSM

FIGURE 29 CREATION OF SERVICE CHAIN DESCRIPTOR IN OSM

To evaluate the developed solution, different experiments for forwarding traffic through the different chains such as for the Gait Analysis application and the Fall management. The patient sends data to the doctor via the instantiated chain including a firewall a dpi and an ids service functions. As can be seen from the tcp dump data capture in FIGURE 30, each service function forwards the traffic to the next node, offering different security guarantees in each chain.



```
gait analysis 1
gait analysis 2
gait analysis 3
gait analysis 4
gait analysis 5
gait analysis 6
gait analysis 7
```

```
generic2@hosts-4-call-center-1:~$ sudo
 nc -p 80 172.113.40.67 80 < fall
```

```
op,nop,TS val 2824737155 ecr 1389308563], l
ength 16: HTTP
22:52:40.640464 fa:16:3e:92:23:11 > fa:16:3
e:c9:81:1f, ethertype IPv4 (0x0800), length
 66: 13.0.1.153.80 > 13.0.1.151.80: Flags [
.], ack 113, win 509, options [nop,nop,TS v
al 1389309564 ecr 2824737155], length 0
```

```
, ack 1, win 502, options [nop,nop,TS val 282473
7155 ecr 1389308563], length 16: HTTP
22:52:40.640002 fa:16:3e:92:23:11 > fa:16:3e:c9:
81:1f, ethertype IPv4 (0x0800), length 66: 13.0.
1.153.80 > 13.0.1.151.80: Flags [.], ack 113, wi
n 509, options [nop,nop,TS val 1389309564 ecr 28
24737155], length 0
```

```
.], ack 65, win 509, options [nop,nop,TS va
l 1389306560 ecr 2824734151], length 0
22:52:38.638192 fa:16:3e:92:23:11 > fa:16:3
e:c9:81:1f, ethertype IPv4 (0x0800), length
 66: 13.0.1.153.80 > 13.0.1.151.80: Flags [
.], ack 81, win 509, options [nop,nop,TS va
l 1389307561 ecr 2824735152], length 0
```

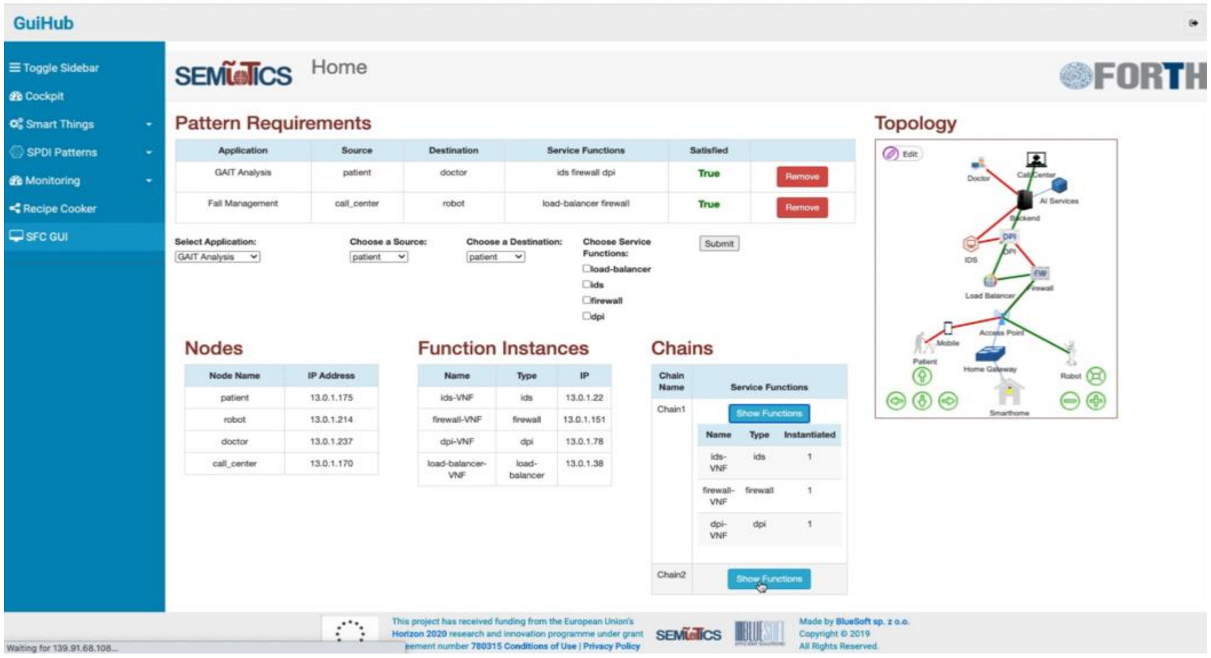
```
ength 16: HTTP
22:52:40.630558 fa:16:3e:8c:23:f4 > fa:16:3
e:92:23:11, ethertype IPv4 (0x0800), length
 82: 13.0.1.151.80 > 13.0.1.153.80: Flags [
P.], seq 97:113, ack 1, win 502, options [n
op,nop,TS val 2824737155 ecr 1389308563], l
ength 16: HTTP
```

```
generic2@hosts-1-patient-1:~$ sudo
 nc -p 80 -i 1 172.113.40.96 80 <
gait
```

```
generic2@hosts-2-robot-1:~$ sudo
 nc -l -p 80
```

FIGURE 30 GAIT ANALYSIS SCENARIO (2)

Similarly, for the fall management, when there is an emergency, a connection between the Call center and the robot will be opened to exchange data and guidelines. Figure 31 and Figure 32 present the traffic forwarding from call center to robot through the instantiated chain including a load balancer and a firewall.


GuiHub
Toggle Sidebar
Cockpit
Smart Things
SPDI Patterns
Monitoring
Recipe Cooker
SFC GUI
SEMIoTICS
Home
FORTH
Topology
Edit
Doctor
Call Center
AI Services
Backend
IDS
DPI
FW
Firewall
Load Balancer
Access Point
Mobile
Patient
Home Gateway
Robot
Smarthome
Waiting for 139.91.68.108...
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 780315 Conditions of Use | Privacy Policy
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Pattern Requirements

Application	Source	Destination	Service Functions	Satisfied	
GAIT Analysis	patient	doctor	ids firewall dpi	True	Remove
Fall Management	call_center	robot	load-balancer firewall	True	Remove

Select Application: GAIT Analysis
Choose a Source: patient
Choose a Destination: patient
Choose Service Functions:
☐ load-balancer
☐ ids
☐ firewall
☐ dpi
Submit

Nodes

Node Name	IP Address
patient	13.0.1.175
robot	13.0.1.214
doctor	13.0.1.237
call_center	13.0.1.170

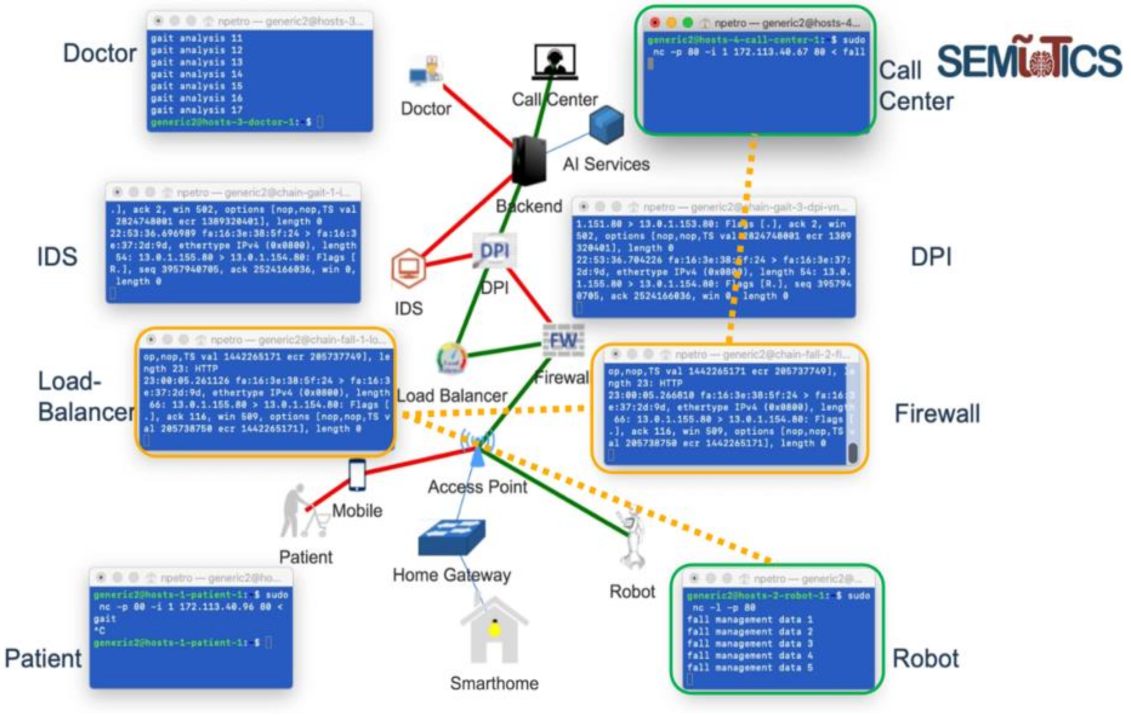
Function Instances

Name	Type	IP
ids-VNF	ids	13.0.1.22
firewall-VNF	firewall	13.0.1.151
dpi-VNF	dpi	13.0.1.78
load-balancer-VNF	load-balancer	13.0.1.38

Chains

Chain Name	Service Functions		
Chain1	Show Functions		
	Name	Type	Instantiated
	ids-VNF	ids	1
	firewall-VNF	firewall	1
	dpi-VNF	dpi	1
Chain2	Show Functions		

FIGURE 31 FALL MANAGEMENT SCENARIO (1)


Doctor
Call Center
SEMIoTICS
AI Services
Backend
IDS
DPI
Load-Balancer
Load Balancer
FW
Firewall
Access Point
Mobile
Patient
Home Gateway
Robot
Smarthome
npetro — generic2@hosts-3...
npetro — generic2@hosts-4...
npetro — generic2@chain-gait-1-i...
npetro — generic2@chain-gait-3-dpi-vn...
npetro — generic2@chain-fall-1-lo...
npetro — generic2@chain-fall-2-fi...
npetro — generic2@ho...
npetro — generic2@...

```
gait analysis 11
gait analysis 12
gait analysis 13
gait analysis 14
gait analysis 15
gait analysis 16
gait analysis 17
generic2@hosts-3-doctor-1:~$
```

```
generic2@hosts-4-call-center-1:~$ sudo
 nc -p 80 -i 1 172.113.40.67 80 < fall
```

```
.], ack 2, win 502, options [nop,nop,TS val
 2824748001 ecr 1389320401], length 0
22:53:36.696989 fa:16:3e:38:5f:24 > fa:16:3
e:37:2d:9d, ethertype IPv4 (0x0800), length
 54: 13.0.1.155.80 > 13.0.1.154.80: Flags [
R.], seq 3957940705, ack 2524166036, win 0,
 length 0
```

```
1.151.80 > 13.0.1.153.80: Flags [.], ack 2, win
502, options [nop,nop,TS val 2824748001 ecr 1389
320401], length 0
22:53:36.704226 fa:16:3e:38:5f:24 > fa:16:3e:37:
2d:9d, ethertype IPv4 (0x0800), length 54: 13.0.
1.155.80 > 13.0.1.154.80: Flags [R.], seq 395794
0705, ack 2524166036, win 0, length 0
```

```
op,nop,TS val 1442265171 ecr 205737749], le
ngth 23: HTTP
23:00:05.261126 fa:16:3e:38:5f:24 > fa:16:3
e:37:2d:9d, ethertype IPv4 (0x0800), length
 66: 13.0.1.155.80 > 13.0.1.154.80: Flags [
.], ack 116, win 509, options [nop,nop,TS v
al 205738750 ecr 1442265171], length 0
```

```
op,nop,TS val 1442265171 ecr 205737749], le
ngth 23: HTTP
23:00:05.266810 fa:16:3e:38:5f:24 > fa:16:3
e:37:2d:9d, ethertype IPv4 (0x0800), length
 66: 13.0.1.155.80 > 13.0.1.154.80: Flags [
.], ack 116, win 509, options [nop,nop,TS v
al 205738750 ecr 1442265171], length 0
```

```
generic2@hosts-1-patient-1:~$ sudo
 nc -p 80 -i 1 172.113.40.96 80 <
gait
^C
generic2@hosts-1-patient-1:~$
```

```
generic2@hosts-2-robot-1:~$ sudo
 nc -l -p 80
fall management data 1
fall management data 2
fall management data 3
fall management data 4
fall management data 5
```

FIGURE 32 FALL MANAGEMENT SCENARIO (2)

Finally, ac can be seen during the evaluation of the two scenario, both experiments can prove the flexibility and applicability of our developed solution to offer traffic forwarding to enable end to end SPD properties.

4.3.3. BACKEND SEMANTIC VALIDATOR AND THING DIRECTORY VALIDATION

Backend Semantic Validator (BSV) is able to verify whether two endpoints, a.k.a. source and destination such as end hosts (robot, patient, smart home) or backend services (doctor, AREAS, AI Services), are semantically interoperable. Figure 33 shows how the Backend Semantic Validator is involved in the flow and Figure 34 show a closer look to that process. The main idea here is to feed the BSV with a pair of end nodes that represent the source and destination. Their Thing Description is looked up in the Thing Directory and based on the result the BSV is capable to respond whether interoperability exists between them.

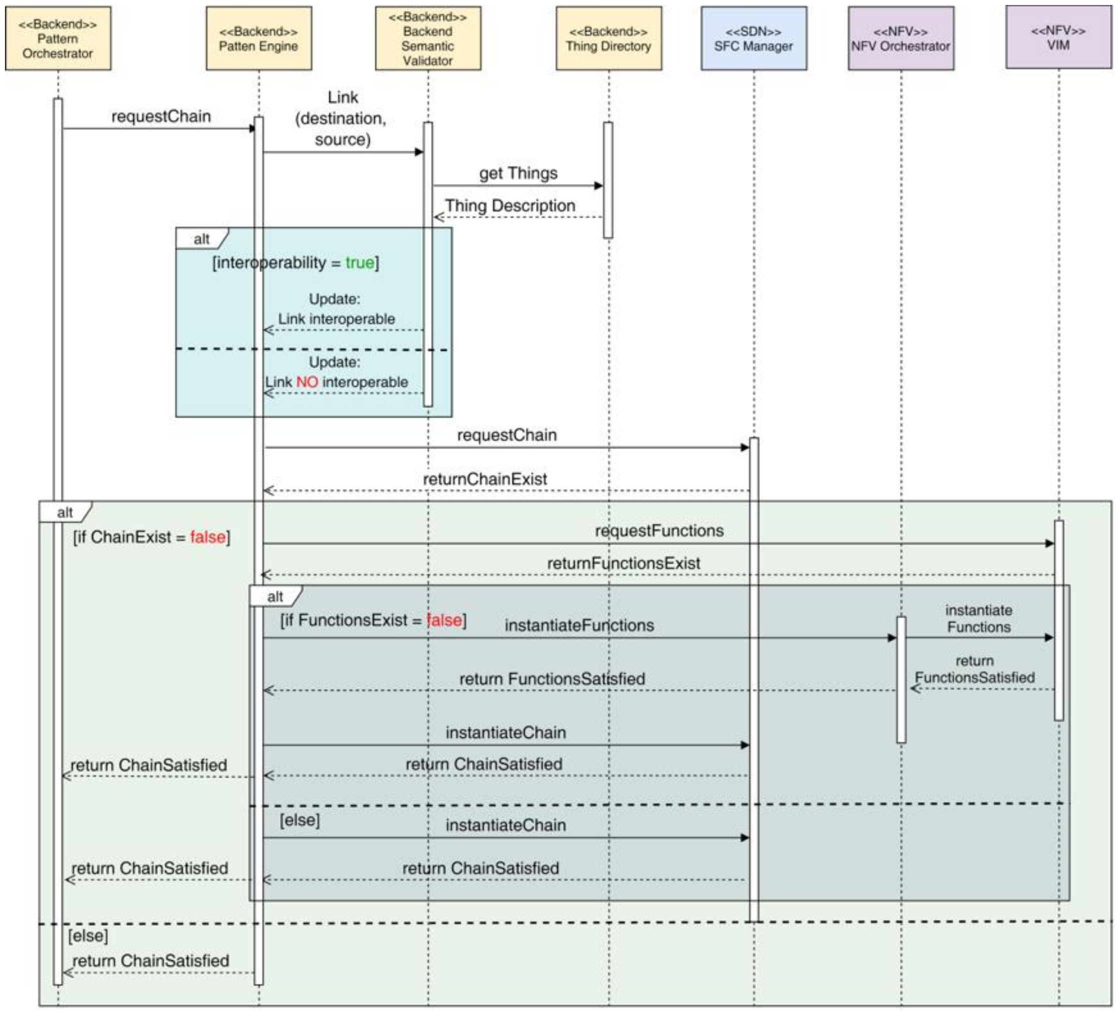


FIGURE 33: BSV INTEGRATION

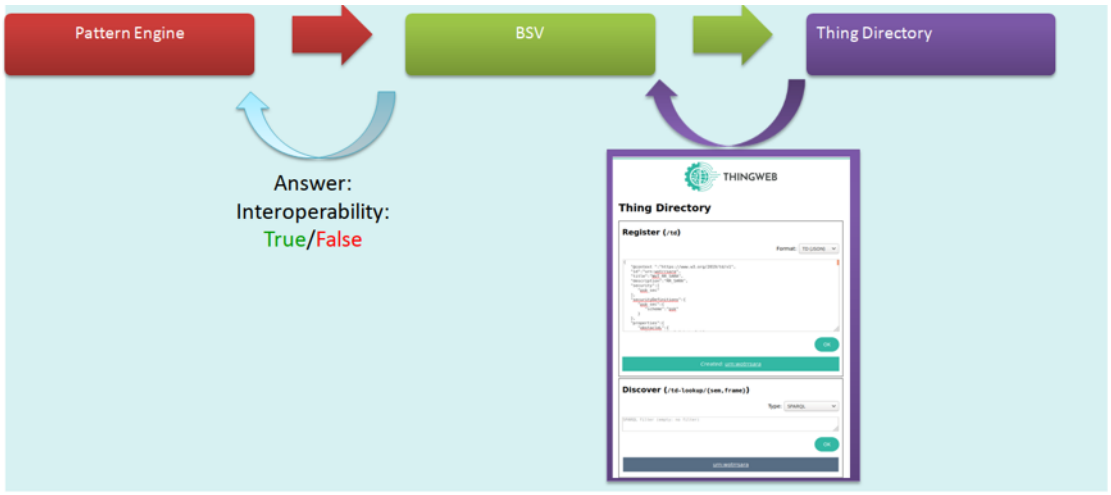
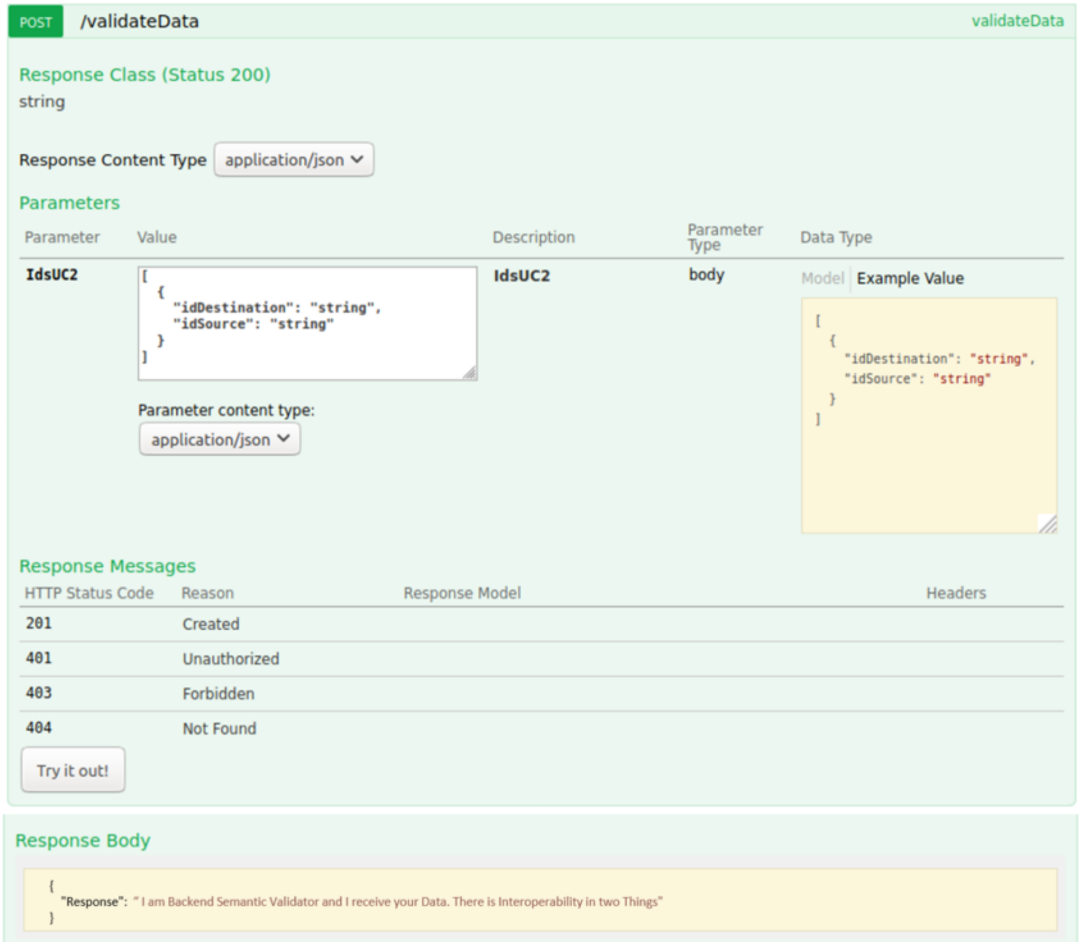


FIGURE 34: BSV AND THING DIRECTORY INTERACTION

All the above are possible by the REST endpoint “validateData” (Figure 35) of the BSV which receives the source and destination in order to lookup their Thing Description in Thing Directory



POST /validateData validateData

Response Class (Status 200)

string

Response Content Type application/json

Parameters

Parameter	Value	Description	Parameter Type	Data Type
IdsUC2	`[ { "idDestination": "string", "idSource": "string" } ]` Parameter content type: application/json	IdsUC2	body	Model Example Value `[ { "idDestination": "string", "idSource": "string" } ]`

Response Messages

HTTP Status Code	Reason	Response Model	Headers
201	Created		
401	Unauthorized		
403	Forbidden		
404	Not Found		

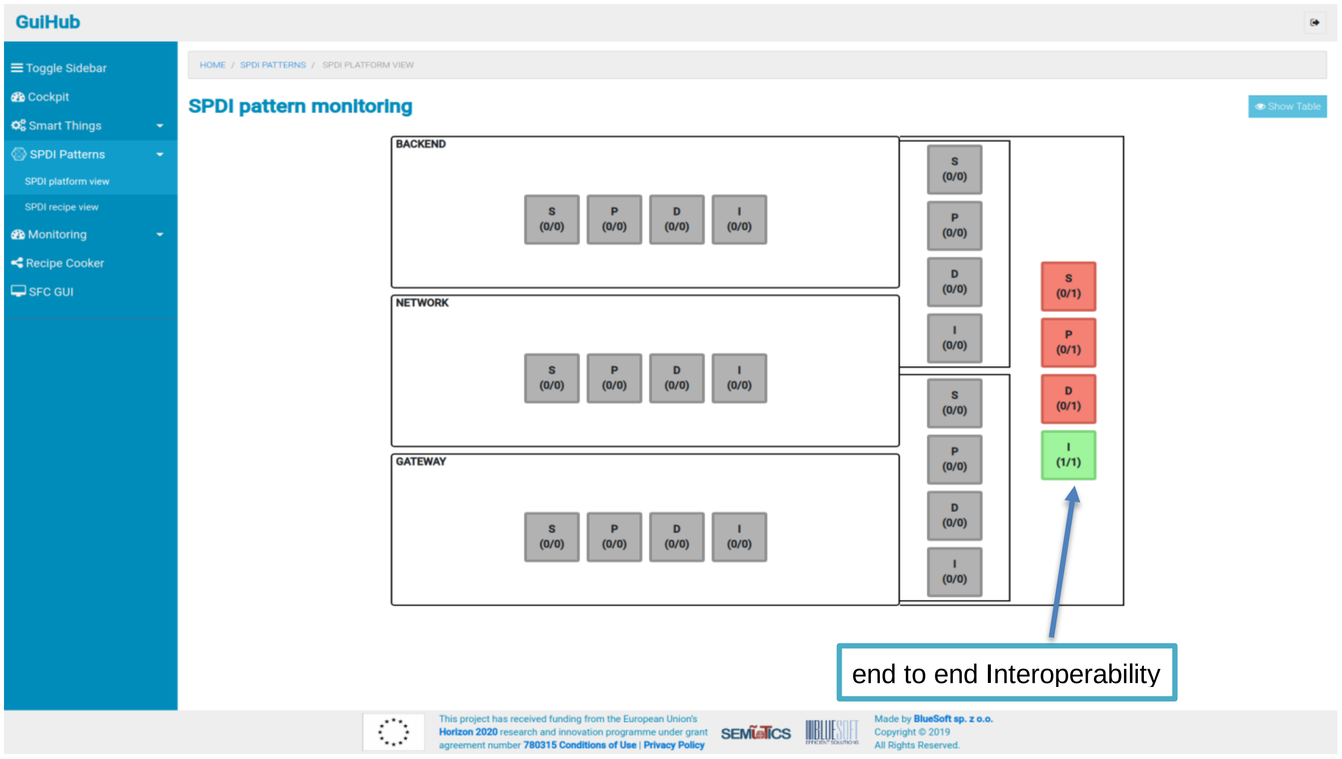
Try it out!

Response Body

```
{
  "Response": " I am Backend Semantic Validator and I receive your Data. There is Interoperability in two Things"
}
```

FIGURE 35: BSV “VALIDATEDATA” ENDPOINT

The result of the interaction between the Backend Pattern Engine and the Backend Semantic Validator is visualized in the SPDI monitoring view, where the end to end Interoperability property becomes green as can be seen in Figure 36.


GuiHub
Toggle Sidebar
Cockpit
Smart Things
SPDI Patterns
SPDI platform view
SPDI recipe view
Monitoring
Recipe Cooker
SFC GUI
HOME / SPDI PATTERNS / SPDI PLATFORM VIEW
SPDI pattern monitoring
Show Table
BACKEND
S (0/0) P (0/0) D (0/0) I (0/0)
NETWORK
S (0/0) P (0/0) D (0/0) I (0/0)
GATEWAY
S (0/0) P (0/0) D (0/0) I (0/0)
S (0/0) P (0/0) D (0/0) I (0/0)
S (0/0) P (0/0) D (0/0) I (0/0)
S (0/1) P (0/1) D (0/1) I (1/1)
end to end Interoperability

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 780315 Conditions of Use | Privacy Policy

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FIGURE 36: END TO END INTEROPERABILITY

The evaluation of the SFC approach in the SARA use case was presented in this section. The SDN/NFV-enabled test-bed setup for service function chaining was tested in the NFV-enabled architecture for the dynamic VNF instantiation enabling the interaction between the pattern engine to instantiate VNF through the OpenSource MANO (OSM) and OpenStack.

5. SUB USE CASE 3: ENFORCEMENT AND MONITORING OF GDPR-COMPLIANT ACCESS CONTROL TO CONFIDENTIAL AND SENSITIVE DATA

5.1. Scope and Objectives

We would like to highlight a very important topic of security and privacy: the protection of personal data. Not only with the advent of the GDPR, the protection of confidentiality and also integrity of personal data has become of paramount importance. Especially in a medical use case, such as UC2. However, we would like to note that when we speak of confidentiality protection for GDPR-compliance we can as well map the technical protection mechanisms of SEMIoTICS to protect the confidentiality of trade-secrets. Following the definition in TRIPS from the World Trade Organization, trade secrets describe information that is considered to have a commercial value due to its secrecy and that its secrecy must be protected against third parties. So, when we can prohibit that information is made available or disclosed to unauthorized individuals, which is the more technical definition of confidentiality from ISO 27000, then we can protect both personal data to comply with the GDPR or trade-secrets. In use case 2 the former is the more important case, due to which we decided to put GDPR in the title.

The challenges we face are that the GDPR requires you to limit the amount of data you collect to what you actually need and further limit the access to the information already collected to the authorized entities.

The access to data needs to be managed in a very generic fashion to make it usable at large scale but also at very fine-grained levels in order to allow the SEMIoTICS framework to be adapted to many different usage scenarios. To fulfil this objective the access control is attribute-based which allows Role-based access control (RBAC), e.g. you allow or deny access based on an attribute that specifies a role, e.g. like entity with the attribute “doctor” which shall be given to those with the role of a medical doctor in our hospital use case. Using attributes enables fulfilling two GDPR-requirements, first and most obvious they allow to specify policies which control and thus allow to restrict access to the sensitive data. Second, it allows that selected individuals, which have the attribute, could gain access without having to reveal more than their attribute, i.e. a more privacy-friendly form of access control can be implemented. So instead of having to tell the system that one has to state that one is the doctor “John Doe” one would only need to reveal to the system that one has the correct set of attributes, e.g. being a “doctor”. This limits the data being collected.

Another challenge was to ensure the confidentiality of medical data even when that data becomes stored or transported outside of SEMIoTICS perimeter. To address this challenging objective, SEMIoTICS facilitates a cryptographic mechanism, known as attribute-based encryption (ABE). This is like normal cryptographic encryption, e.g., we encrypt data and unless you have the correct decryption key you cannot read the data. However, in many applications it is not a-priori known who the authorized recipient will be. Instead, one might only know certain attributes of authorized entities and all those entities who possess the right attributes would form a group. This means that encryption can happen, e.g., data should only be read by entities that are doctors, without knowing nor without needing to know who a doctor at the time of retrieval is. SEMIoTICS achieves this loose coupling and still enforces confidentiality for data even if it is stored on systems outside the realm of SEMIoTICS.

To enforce one of the most sought-after features of GDPR-compliance, that of retention times, the attribute-based encryption capabilities of SEMIoTICS are combinable with a time-variant attribute. That means that the patient’s system might generate date, e.g., a video stream or a location, which is encrypted not only for doctors (see our previous example), i.e., using an attribute “doctor” during encryption, but with an additional attribute that encodes that this data can only be accessed for a certain time frame, e.g., 48h is an often-used retention period for videos. The technical details have been discussed in D4.12.

Last but not least, the challenge is to monitor that the system correctly enforces the intended behaviour, for this we describe how SEMIoTICS monitoring is used as a solution for periodical self-audit capabilities by monitoring for pattern-compliance.

5.2. Interaction with SEMIoTICS framework

5.2.1. AUTHORIZATION POLICY MANAGEMENT

Figure 37 shows the workflow of the Remote Gait Analysis Assistive Task (see section 2.1.2): the workflow starts with the scheduling of the Gait Analysis session. The data shared by devices can only be provided to systems or users who have the appropriate privileges at the moment, specifically, the patient's data can only be accessible by his or her doctor during the specified period (e.g., during the exercises). Changing policies for accessing specific devices will take place before and after exercise. The design shown in Figure 37 fulfils data protection principles like purpose limitation – the data is processed only for the legitimate purposes specified explicitly to the patient, the data processing is done in such a way which ensures appropriate security, integrity and confidentiality.

The exercise can be either postponed or started. If the patient postpones the exercise, it is rescheduled (i.e., for the next day) and it's one end of the flow. If the patient chooses otherwise, SARA sends an HTTP request to Pattern Orchestrator informing that the exercises have already started, and the doctor should get permission to get the patient's data for the time of exercises. Pattern Orchestrator transforms the request and sends it to Backend Pattern Engine. Then, using the Security Manager's API Backend Pattern Engine updates the policies to give the doctor access to the data. As soon as the patient finishes exercises, the flow is repeated but the only difference is the update of policies takes away privileges to inspect the patient's data instead of giving them.

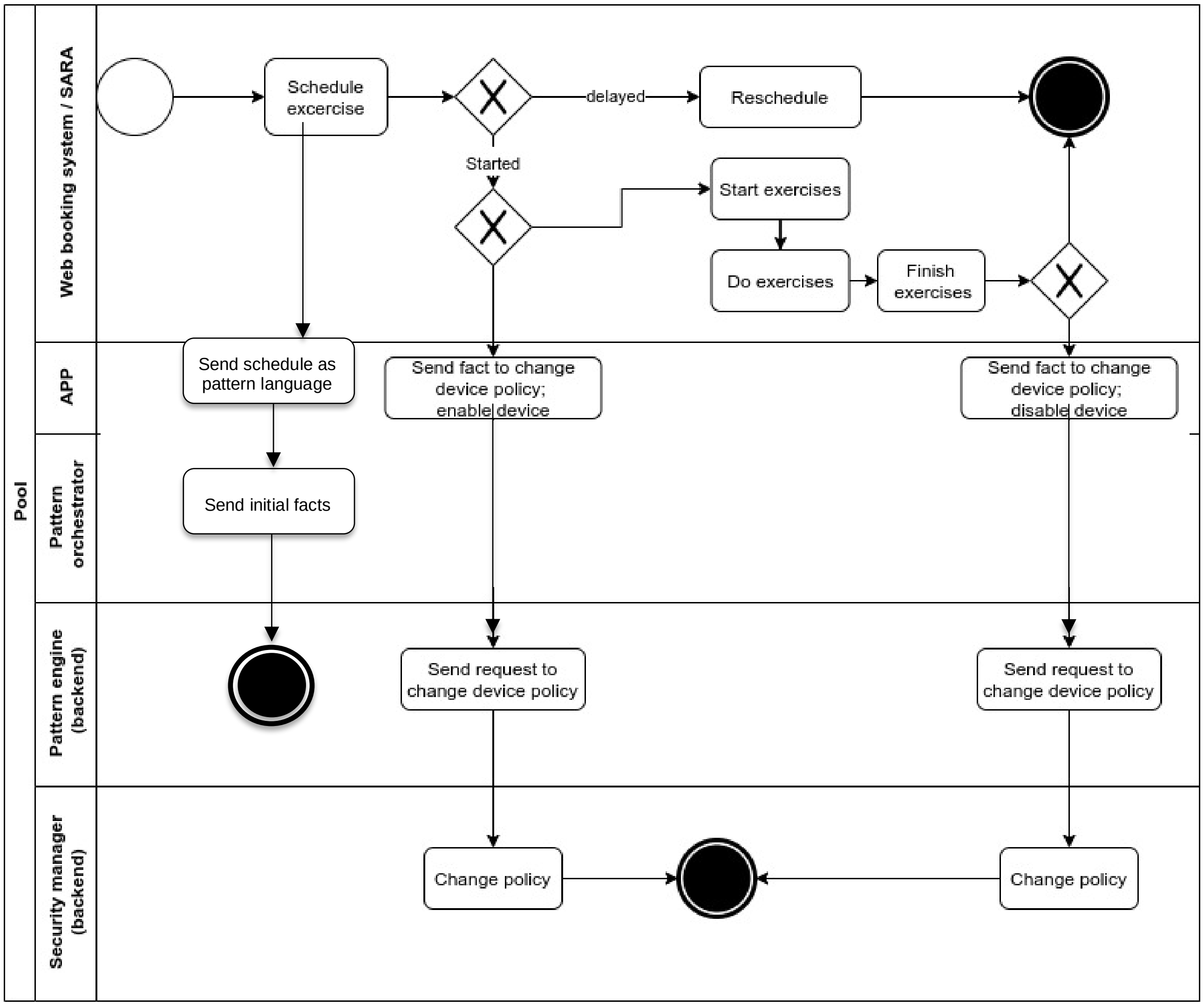

Pool
Web booking system / SARA
APP
Pattern orchestrator
Pattern engine (backend)
Security manager (backend)
Schedule excercise
delayed
Reschedule
Started
Start exercises
Do exercises
Finish exercises
Send schedule as pattern language
Send fact to change device policy; enable device
Send fact to change device policy; disable device
Send initial facts
Send request to change device policy
Send request to change device policy
Change policy
Change policy

FIGURE 37: REMOTE GAIT ANALYSIS WORKFLOW

- **SARA:** The component is responsible for interaction with the patient. SARA's main role in the use case will be to trigger the request to update the doctor's policies after the patient starts exercises and as soon as they are finished.
- **Security Manager (backend):** The component will be used in the sub-use case both as the security provider and policy management point. It will serve to generate an authentication token using SARA's credentials and later on, to verify entities based on their token. The second role of Security Manager will be to alter doctor's permission, either to allow him to get access to the patient's data during the exercises or to take away privileges after the exercises are finished.
- **Pattern Orchestrator:** Pattern Orchestrator receives the HTTP request from SARA and transforms it into facts that will later send to the Backend Pattern Engine.
- **Backend Pattern Engine:** Backend Pattern Engine reasons based on the received facts and sends HTTP request to Security Manager to change the doctor's privileges.

5.2.2. AUTHENTICATION MANAGEMENT

To authenticate SARA, to every HTTP request an authorization token is added. The Token is generated based on SARA's unique client identification number and client secret. All incoming request to the device will be intercepted by Policy Enforcement Point which verifies whether the owner of the request has sufficient permission to get access to the data. If it does, the request is forwarded to its original destination, if not an error is thrown due to lack of privileges (according to standard RFC 7519).

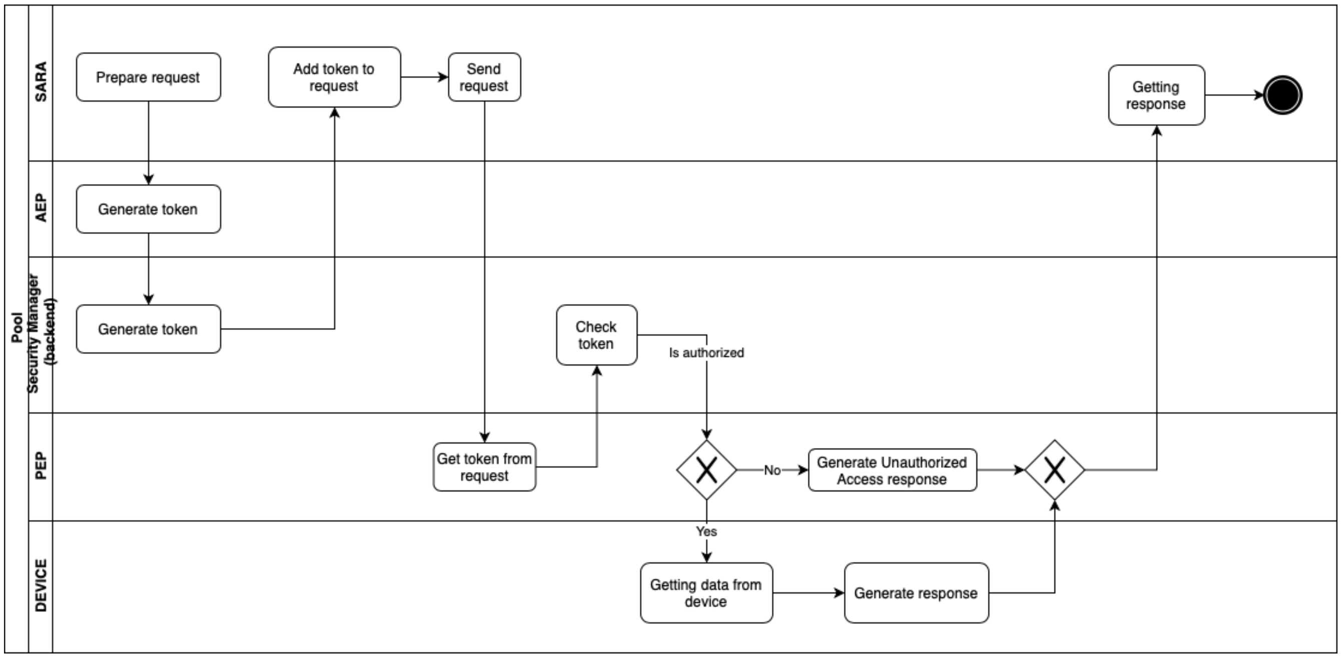


FIGURE 38: AUTHENTICATION MANAGEMENT PROCESS

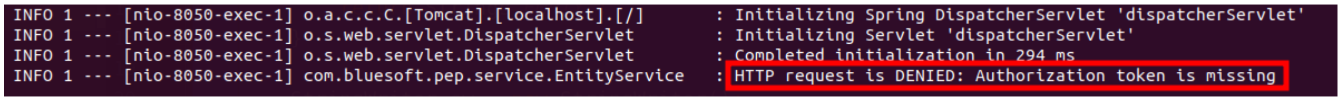
- **AEP (Authentication Enforcement Point)** Authentication Enforcement Point is a stand-alone application which generates an authentication token that adds it to every HTTP request that is coming out of SARA. To apply a valid token, AEP uses Security Manager's OAuth 2.0 Clients Credentials Grant flow using SARA's client-id and client secret. Using these values, Security Manager can generate a unique token for the component, which is added to the HTTP request header in order to not be rejected by Policy Enforcement Point. This component supports also the automatic addition of token to all outgoing HTTP requests and it is supported when it runs in the backend layer.
- **PEP (Policy Enforcement Point)** In order to secure access to the components' resources, the APIs of a device is protected by Policy Enforcement Point. PEP provides security in two ways. Firstly, it is deployed as a sidecar along with the primary application. They both share the same network allowing them to

communicate through localhost. The main application is only accessible from within local network, because it does not expose its port outside the device, only PEP does that, meaning that in order to get the resource of the main application all HTTP traffic must go through PEP. Secondly, the HTTP request must bear a valid authorization token and the client which makes an HTTP call has to be authorized to do so. To evaluate client authorization, PEP uses the Security Manager's Policy Decision Point. After the evaluation of the client's policy, HTTP call is either allowed to reach the main application or it is rejected due to the insufficient permission.

- **Device** The device is a generic component which is compliant to the WoT standard and has an API. The device shares the data through its API.

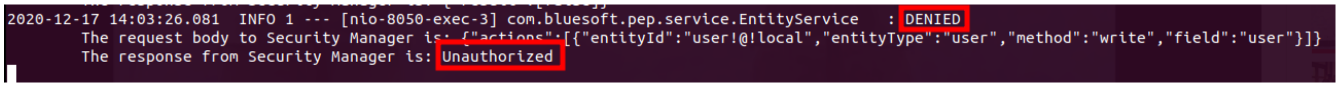
As stated before, PEP is a generic component that can be used in every setup which involves guarding REST API. In the following scenario, PEP is used to secure communication between GUI and Monitoring Component. PEP was deployed along with Monitoring Component, as its sidecar whereas AEP was deployed with GUI. Four possible outcomes might be distinguished:

- HTTP request does not bear any authorization token



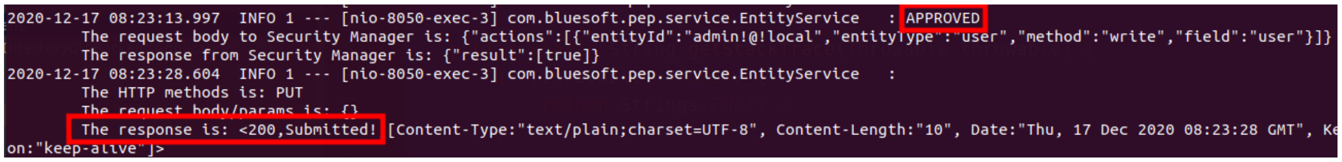
```
INFO 1 --- [nio-8050-exec-1] o.a.c.c.C.[Tomcat].[localhost].[/]       : Initializing Spring DispatcherServlet 'dispatcherServlet'
INFO 1 --- [nio-8050-exec-1] o.s.web.servlet.DispatcherServlet        : Initializing Servlet 'dispatcherServlet'
INFO 1 --- [nio-8050-exec-1] o.s.web.servlet.DispatcherServlet        : Completed initialization in 294 ms
INFO 1 --- [nio-8050-exec-1] com.bluesoft.pep.service.EntityService   : HTTP request is DENIED: Authorization token is missing
```

- HTTP request does have authorization token though it is invalid



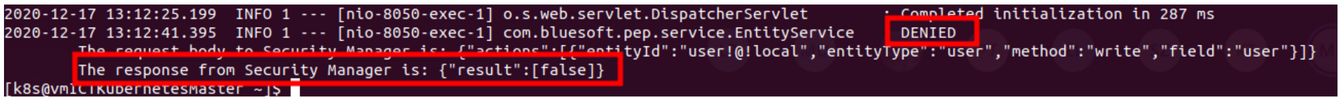
```
2020-12-17 14:03:26.081  INFO 1 --- [nio-8050-exec-3] com.bluesoft.pep.service.EntityService   : DENIED
        The request body to Security Manager is: {"actions":[{"entityId":"user!@!local","entityType":"user","method":"write","field":"user"}]}
        The response from Security Manager is: Unauthorized
```

- HTTP request has a valid authorization token and the entity is authorized to get the resource



```
2020-12-17 08:23:13.997  INFO 1 --- [nio-8050-exec-3] com.bluesoft.pep.service.EntityService   : APPROVED
        The request body to Security Manager is: {"actions":[{"entityId":"admin!@!local","entityType":"user","method":"write","field":"user"}]}
        The response from Security Manager is: {"result":[true]}
2020-12-17 08:23:28.604  INFO 1 --- [nio-8050-exec-3] com.bluesoft.pep.service.EntityService   :
        The HTTP methods is: PUT
        The request body/params is: {}
        The response is: <200,Submitted! [Content-Type:"text/plain;charset=UTF-8", Content-Length:"10", Date:"Thu, 17 Dec 2020 08:23:28 GMT", Ke
on:"keep-alive"]>
```

- HTTP request has a valid authorization token but the entity does not have required permissions to get the resource



```
2020-12-17 13:12:25.199  INFO 1 --- [nio-8050-exec-1] o.s.web.servlet.DispatcherServlet        : Completed initialization in 287 ms
2020-12-17 13:12:41.395  INFO 1 --- [nio-8050-exec-1] com.bluesoft.pep.service.EntityService   : DENIED
       The request body to Security Manager is: {"actions":[{"entityId":"user!@!local","entityType":"user","method":"write","field":"user"}]}
       The response from Security Manager is: {"result":[false]}
[k8s@vmICTKubernetesMaster ~]$
```

5.3. Setup testbed and integration

There are 4 main steps for enforcing and monitoring that are taking place in several components spread over all layers of the SEMIoTICS architecture:

- First, setup tasks, as well as later management tasks, establish the policies and users as well as their attributes.
- Second, the actual enforcement of access control.
- Third, we dynamically adapt the access control to react, e.g., to emergency situations like in the fall assistance task.
- Forth, monitoring for compliance, e.g., GDPR-conformance.

In the remaining text we will detail how these main steps are happening within the generic storyline of UC2 we will highlight which components' interactions are facilitated to reach our objectives.

5.3.1. SETUP STEPS

SEMIoTICS is built upon the concept that each participating entity has their own identity and their own set of attributes. If you think about human users, the name would be “John Doe” and an attribute could be “doctor”. To ensure that only particular entities are able to obtain certain attributes, the identity management must initially setup administrative users who can change those attributes or create new users, and the system could also gradually enforce administrative restrictions, by enforcing access control on the ability to modify (create, change, delete) attributes or new entities. Further, there are policies which govern which access is allowed and which access is restricted. This follows the general principle of access control policies, e.g., an entity is given the right to access an object in a certain manner, e.g., an entity with the attribute doctor is allowed to read Hans Meier’s medical records. These policies are created initially as part of the system’s setup and the use of patterns allows to create those even faster. We explained the usage and technical backgrounds of attribute-based policies as well as entity related policies in D4.12 Section 2.2.4.1. These policies are defined individually as required by the respective application or use case. In order to provide a more user-friendly way to define the policies defined by config files, there is the possibility to set the policies through the currently deployed graphical user interface (GUI). Our GUI is implemented as a node.js based application, which facilitates the Security Manager API and can also be used to showcase how to interact with the Security Manager. All necessary functionality of the Security Manager’s API is made available via the GUI and can be accessed via the interface. This removes the hurdle of having to write complicated configuration files to initially setup the Security Manager.

Furthermore, one of the initial steps during the system setup is to define the patient’s privacy settings. As each patient may have other privacy concerns, we can individually enforce different privacy settings for each patient. This can range from defining how long each private and sensitive data should be accessible, by whom it should be accessible to defining several characteristics of the person that can access the data (e.g., gender, age, language, country). These settings can, of course, be later changed manually by the patient him-/herself.

5.3.2. ENFORCING ACCESS CONTROL

The SEMIoTICS framework allows us to enforce access control on privacy sensitive data in two different ways:

- **By means of access control**: When an entity with the role “doctor” tries to access the patient’s data, the request is intercepted by the Policy Enforcement Proxy (PEP) (see Section 5.2.6 and D4.12 Section 3.2.4.1 for detailed information) which then forwards this request to the Security Manager. In this context the Security Manager functions as a Policy Decision Point (PDP), that then either allows or rejects the access to the patient’s data, based on the entity’s attributes (see Section 5.2.6 and D4.12 Section 3.2.1.1). For Use-Case 2, this mechanism is especially used for step 7 of the Remote Gait Analysis Assistive Task.
- **By means of encryption**: During an emergency case, the patient’s data is accessible by anyone of the role “doctor” (enforced by the Security Manager and PEP). However, the SEMIoTICS framework is also able to enforce the patient’s previously defined privacy settings. This is done by encrypting the patient’s data with the help of Attribute Based Encryption (see D4.12 Section 3.2.1.4). Due to the encryption, the privacy sensitive data is now only accessible by an entity that fulfils all conditions that the patient wants to be enforced (e.g., gender of the doctor, language, age). Additionally, the maximum availability of the data can also be enforced by this technique. E.g., the patient can control how long the data can be decrypted, by defining a maximum lifetime of the data which is then part of the encryption. When this time-window expires nobody will be able to decrypt this data anymore. For Use-Case 2, this mechanism will be especially helpful for step 7 of the Fall Management Assistive Task.

5.3.3. DYNAMIC POLICY ADAPTATION

We assume the following case:

Alice is a Call Centre Operator who normally is not able to get Bob's location. In an emergency (e.g. during the execution of Fall Management AT), however, Alice should be able to retrieve it. The SM offers the possibility to dynamically adjust access rights very quickly through the policies. If Bob falls, the application changes the policy via the API of the Security Manager dynamically. Now it is possible for Alice to get the location (see Figure 39).

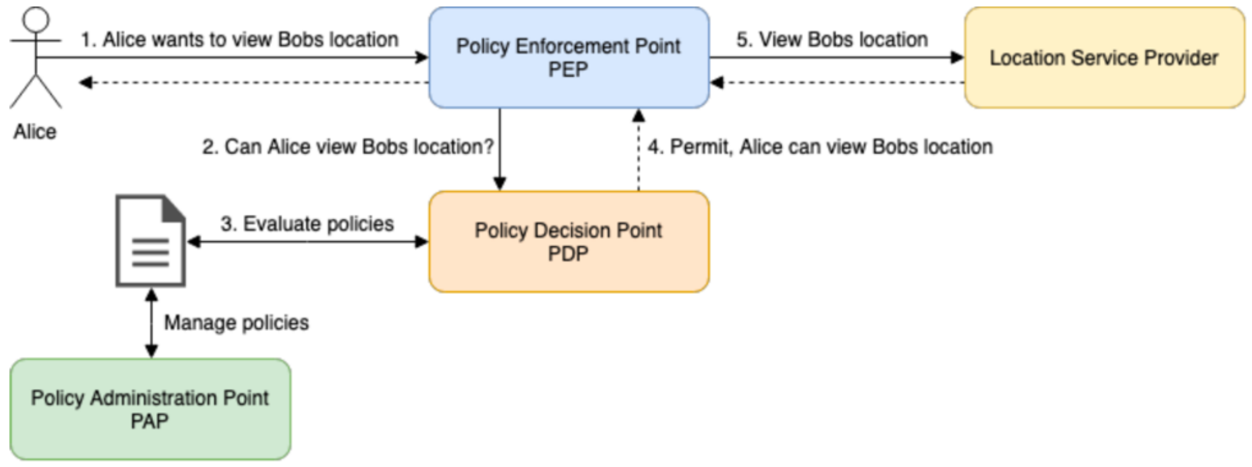

1. Alice wants to view Bobs location
Alice
Policy Enforcement Point PEP
5. View Bobs location
Location Service Provider
2. Can Alice view Bobs location?
4. Permit, Alice can view Bobs location
3. Evaluate policies
Policy Decision Point PDP
Manage policies
Policy Administration Point PAP

FIGURE 39: DYNAMIC POLICY ADAPTATION

5.3.4. MONITORING COMPLIANCE

It is important that in complex systems we not only set policies and enforce them, but that we also –at least- periodically monitor that the system is still conforming to the intended behaviour; this is especially true in a system where the policies will get dynamically updated to adapt to changes in the environment as supported by SEMIoTICS. In UC2 this dynamicity happens to adapt to medical emergency situations, in which case access is granted to aid in such emergency situations.

As an example, let us explain a bit more details about the Fall Management Assistive task of UC2. Here we allow logging of and access to a patient's geo location, in order to correctly assist the patient, but only in case the patient fell down (dynamic policy update).

In order to ensure compliance SEMIoTICS is capable, and we take advantage of this functionality in UC2, to check actively if the intended policies are enforced. This allows to detect suspicious access capabilities or changes to the policy which were not reverted. This self-audit capability is based on checking periodically the current access capabilities and compare them with expected values, and this checking is based on the SPDI patterns, here especially the security (S) and privacy (P) related patterns are of concern. To stay within the general storyline, there is a pattern on privacy that states that only patients normally have access to their location. Thus, in SEMIoTICS there is a periodic question to the security manager asking to list all entities who are not patients which have access to location data, and if this answer is not an empty list, then the privacy pattern is violated, and an alarm is raised. Of course, in emergency cases, like the fall of a patient, this default privacy setting is dynamically overruled. But, only for those patients that fell and only for the duration of the emergency. Thus, the monitoring component should not have to constantly alert the data protection officers.

So, by creating patterns that implement GDPR-compliant behaviour SEMIoTICS allows the systems administrators to enable the system to self-check itself.

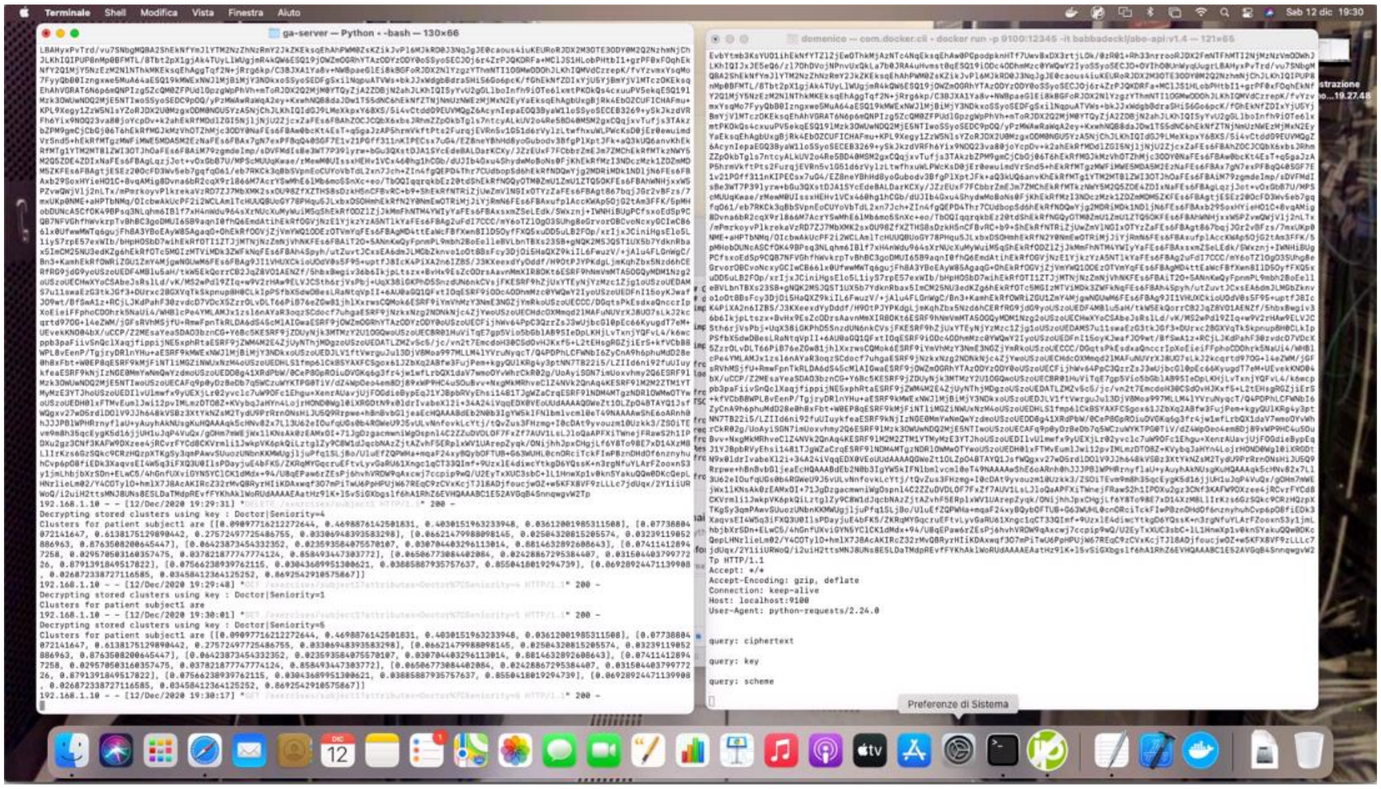
5.3.5. ATTRIBUTE-BASED ENCRYPTION

As described in D4.12, the SEMIoTICS framework supports the use of Attribute-Based Encryption (ABE). The ABE is a relatively recent cryptographic approach that reconsiders the concept of public-key cryptography. For instance, in common public-key cryptography, a message is encrypted for a specific receiver using the receiver's public-key. Identity-based cryptography and in particular identity-based encryption (IBE) modified the established structure of public-key cryptography by changing the public-key in an arbitrary string, the email address of the receiver. The ABE goes one-step further and determines the identity not as an individual but as a set of attributes (user roles). Due to that, the encryption of the messages is achieved by using the subsets of attributes –key policy ABE (KP- ABE) – or the policies, which are defined over a set of attributes –ciphertext policy ABE (CP- ABE). In comparison with the IBE, the ABE has meaningful benefit, because it offers flexible one-to-many encryption instead of one-to-one; it is considered as a promising method to manipulate the issue of secure and fine-grained data sharing and decentralized access control.

In UC2, we applied this technique to the Gait Analysis Scenario, by encrypting the privacy sensitive data of the patient when sending it to the doctor/monitoring person during the exercise session of the patient. With the help of SEMIoTICS' Attribute-Based Encryption, the patient can determine his/her privacy requirements before the session starts. Those privacy requirements will then be translated into specific attributes, which will be used for encrypting the patient-related data.

If the doctor/monitoring person wants to access the patient's data, he/she first has to create a user-specific decryption key with the help of 1) the SEMIoTICS Security Manager (hosted at the premises of University of Passau), which also provides an Attribute-Based Encryption endpoint or 2) the locally deployed Attribute-Based-Encryption component, which is included in the SEMIoTICS framework as a dockerized component.

A decryption is possible if and only if the monitoring person's decryption key satisfies all privacy requirements that were previously defined by the patient, i.e. their attributes match, otherwise, no data will be revealed.


Terminale
Shell
Modifica
Vista
Finestra
Aiuto
Sab 12 dic 19:30
ga-server — Python • -bash — 130×66
domenico — com.docker.cli • docker run -p 9100:12345 -it babbadeckl/abe-api:v1.4 — 121×65
Preferenze di Sistema

```
[illegible]
192.168.1.10 - - [12/Dec/2020 19:29:31] "DELETE /exercises/subject1 HTTP/1.1" 200 -
Decrypting stored clusters using key : Doctor|Seniority=4
Clusters for patient subject1 are [[0.09097716212272644, 0.4698876142501831, 0.403015196323394 8, 0.0361200198531150 8], [0.07738804
072141647, 0.6138175129890442, 0.2757249772548675 5, 0.03306948393583298], [0.06621479988098145, 0.02504320815205574, 0.03239119052
886963, 0.8763508200645447], [0.06423873454332352, 0.02359358407557010 7, 0.0307044032961130 14, 0.8814632892608643], [0.07411412894
7258, 0.029570503160357475, 0.03782187774777 4124, 0.858493447303772], [0.06506773084402084, 0.02428867295384407, 0.031504403799772
26, 0.8791391849517822], [0.07566238939762115, 0.03043689951300621, 0.03885887935757637, 0.8550418019294739], [0.06928924471139908
, 0.026872338727116585, 0.03458412364125252, 0.8692542910575867]]
192.168.1.10 - - [12/Dec/2020 19:29:48] "GET /exercises/subject1?attributes=Doctor%7CSeniority=4 HTTP/1.1" 200 -
Decrypting stored clusters using key : Doctor|Seniority=1
Clusters for patient subject1 are
192.168.1.10 - - [12/Dec/2020 19:30:01] "GET /exercises/subject1?attributes=Doctor%7CSeniority=1 HTTP/1.1" 200 -
Decrypting stored clusters using key : Doctor|Seniority=5
Clusters for patient subject1 are [[0.09097716212272644, 0.4698876142501831, 0.4030151963233948, 0.0361200198531150 8], [0.07738804
072141647, 0.6138175129890442, 0.2757249772548675 5, 0.03306948393583298], [0.06621479988098145, 0.02504320815205574, 0.03239119052
886963, 0.8763508200645447], [0.06423873454332352, 0.023593584075570107, 0.03070440329611301 4, 0.8814632892608643], [0.07411412894
7258, 0.029570503160357475, 0.037821877747774124, 0.858493447303772], [0.06506773084402084, 0.02428867295384407, 0.031504403799772
26, 0.8791391849517822], [0.07566238939762115, 0.03043689951300621, 0.03885887935757637, 0.8550418019294739], [0.06928924471139908
, 0.026872338727116585, 0.03458412364125252, 0.8692542910575867]]
192.168.1.10 - - [12/Dec/2020 19:30:17] "GET /exercises/subject1?attributes=Doctor%7CSeniority=5 HTTP/1.1" 200 -
```

```
[illegible]
Tp HTTP/1.1
Accept: */*
Accept-Encoding: gzip, deflate
Connection: keep-alive
Host: localhost:9100
User-Agent: python-requests/2.24.0


query: ciphertext

query: key

query: scheme
```

FIGURE 40: DEMONSTRATION OF ATTRIBUTE-BASED-ENCRYPTION IMPLEMENTATION ON THE ROLLATOR

For this specific use-case scenario, we decided to deploy the Attribute-Based Encryption component directly onto the rollator, which also determines the patient-related gait analysis data. When the rollator starts recording the patient's data (left side of Figure 40), the first step is to forward the data to the locally deployed Attribute-Based Encryption component. The ABE component then uses the previously defined privacy requirements of the patient to encrypt the data (right side of Figure 40) and transfer it back to the rollator, which then makes the data available for the monitoring person.

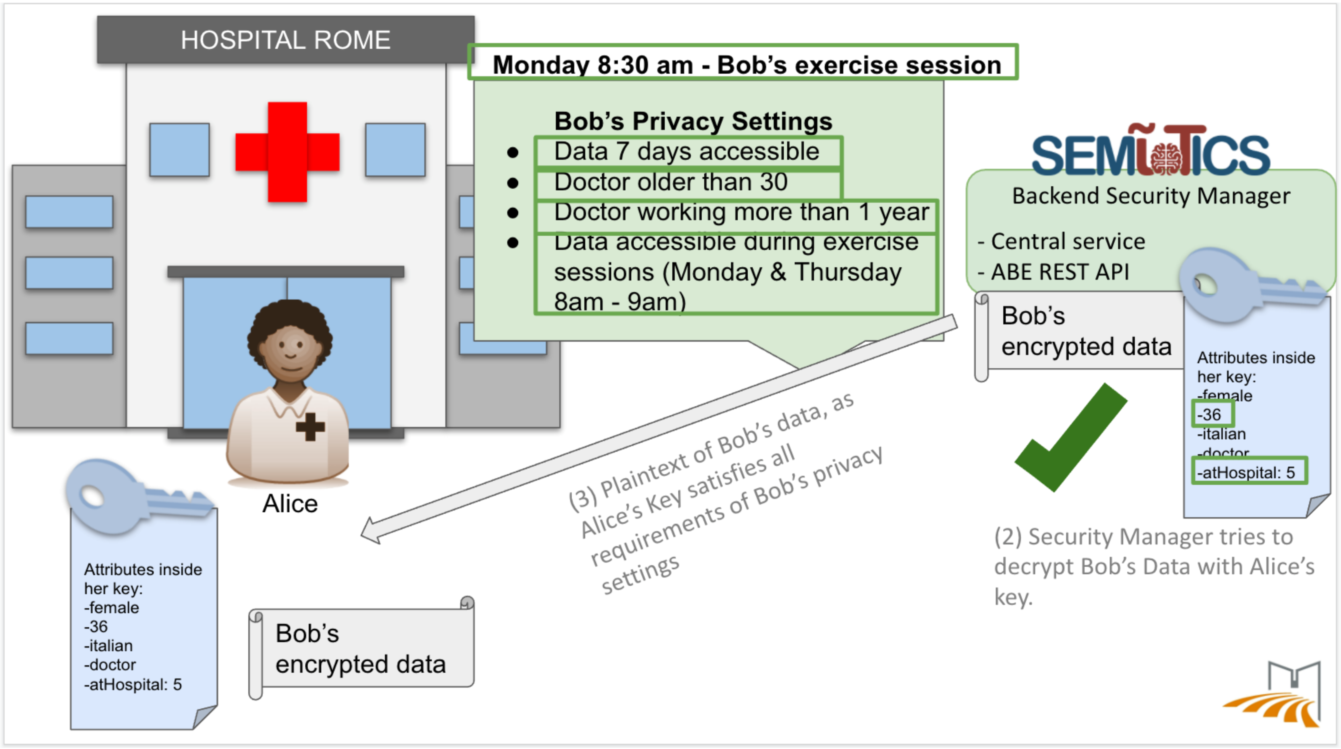

HOSPITAL ROME
Monday 8:30 am - Bob's exercise session
Bob's Privacy Settings
Data 7 days accessible
Doctor older than 30
Doctor working more than 1 year
Data accessible during exercise sessions (Monday & Thursday 8am - 9am)
SEMIoTICS
Backend Security Manager
- Central service
- ABE REST API
Bob's encrypted data
Attributes inside her key: -female -36 -italian -doctor -atHospital: 5
Alice
(3) Plaintext of Bob's data, as Alice's Key satisfies all requirements of Bob's privacy settings
(2) Security Manager tries to decrypt Bob's Data with Alice's key.
Attributes inside her key: -female -36 -italian -doctor -atHospital: 5
Bob's encrypted data

FIGURE 41: SUCCESSFUL DECRYPTION OF PATIENT-RELATED DATA

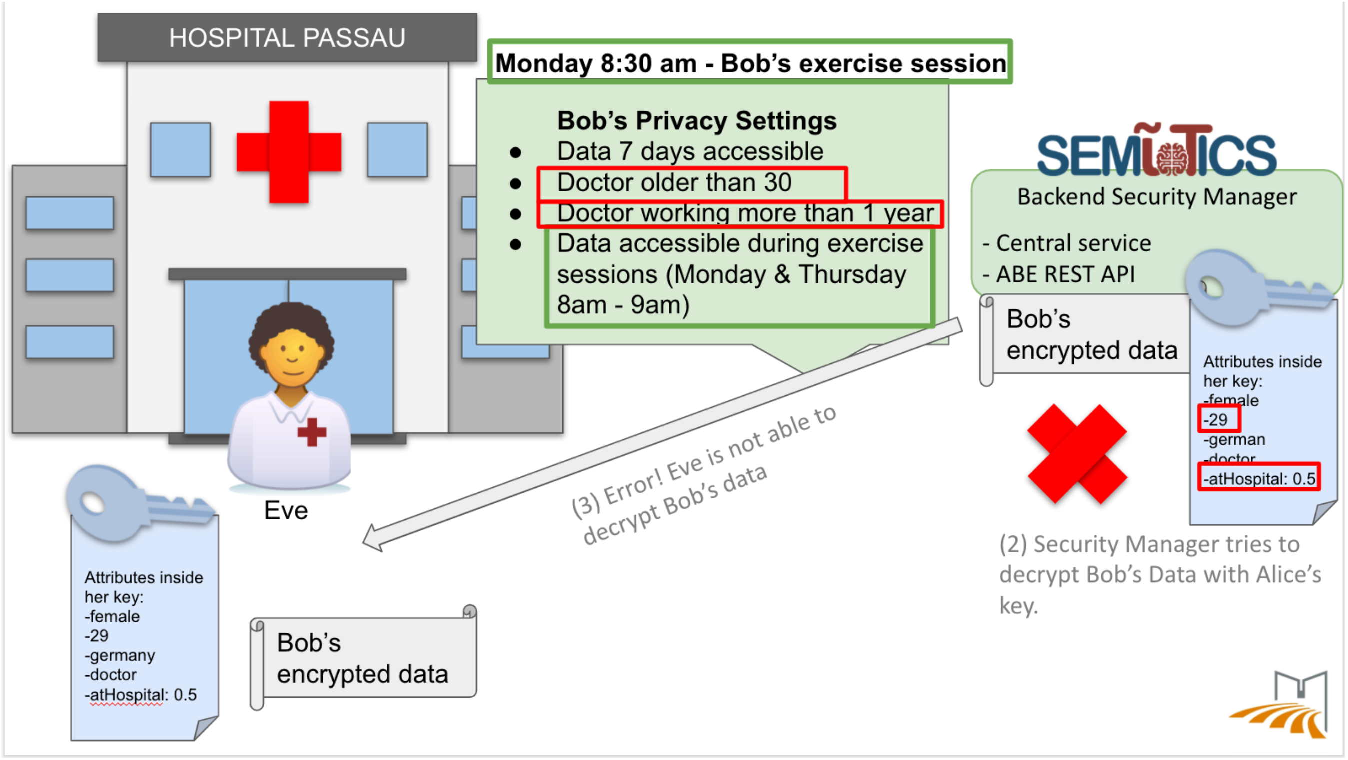

HOSPITAL PASSAU
Monday 8:30 am - Bob's exercise session
Bob's Privacy Settings
Data 7 days accessible
Doctor older than 30
Doctor working more than 1 year
Data accessible during exercise sessions (Monday & Thursday 8am - 9am)
SEMIoTICS
Backend Security Manager
- Central service
- ABE REST API
Bob's encrypted data
Attributes inside her key: -female -29 -german -doctor -atHospital: 0.5
Eve
(3) Error! Eve is not able to decrypt Bob's data
(2) Security Manager tries to decrypt Bob's Data with Alice's key.
Attributes inside her key: -female -29 -germany -doctor -atHospital: 0.5
Bob's encrypted data

FIGURE 42: UNSUCCESSFUL DECRYPTION OF PATIENT-RELATED DATA

Afterwards, the monitoring person, can use the SEMIoTICS Security Manager or his/her own locally deployed Attribute-Based Encryption component to decrypt the data. We demonstrate this functionality with two fictional examples:

1. In Figure 41, we have Alice, a Doctor, 36 years old. She's been working at the Hospital in Rome for 5 years. On Monday at 8:30 am, during Bob's exercise session, she receives the encrypted data of Bob. With her user-specific Key, which she previously generated with the help of SEMIoTICS' Attribute-Based Encryption API, she tries to decrypt the received data, by sending a decryption request to the Backend Security Manager. The Security Manager then checks whether Alice's key satisfies all privacy requirements of Bob. As she's accessing the data on the same date, the requirement that the data should only be accessible for 7 days, is fulfilled. Furthermore, Alice is older than 30 years old and has been working at the hospital for more than a year. And the time of access is during Bob's exercise session. Therefore, the security manager can successfully decrypt Bob's data with Alice's key and forwards the data back to her. Alice can now work with Bob's data.
2. In Figure 42, we have Eve, a doctor, who is 29 years old and has been working at the hospital of Passau for roughly 6 months. On Monday at 8:30 am, during Bob's exercise session, she receives the encrypted data of Bob. As Alice did in the first scenario, she sends her key and the encrypted data of Bob to the Backend Security Manager. Even though she's accessing Bob's data during his exercise session, her personal key does not satisfy the privacy requirements of Bob. He clearly stated, that the doctor must be older than 30 AND must have been working at the hospital for at least a year. Therefore, the Security Manager fails at decrypting Bob's data and sends an error message to Eve. She's not able to access Bob's data.

A demonstration and further explanation of the software components and their deployment can be found in D4.12 or in the video about sub-use case 3 as part of the overall Security & Privacy functionality of SEMIoTICS.

6. SUB USE CASE 4: CONTROLLING BULBS AND ROBOTS

6.1. Scope and Objectives

This sub use case aims to demonstrate how the SEMIoTICS Semantic Interoperability technologies developed in the context of Task 3.3 can help the developers of the SARA solution to interface heterogeneous devices ranging from light bulbs to semi-autonomous robots.

As should be evident from the description of the Assistive Tasks given in section 2.1, in general, a SARA Assistive Task is realized through the interaction of various devices. As an example the Fall Management AT requires that the Robotic Assistant interacts with the lighting system of the Smart Home whilst the Gait Analysis AT requires the Doctor Web Application, interacts across the Internet, with a remote Robotic Rollator (Figure 43).

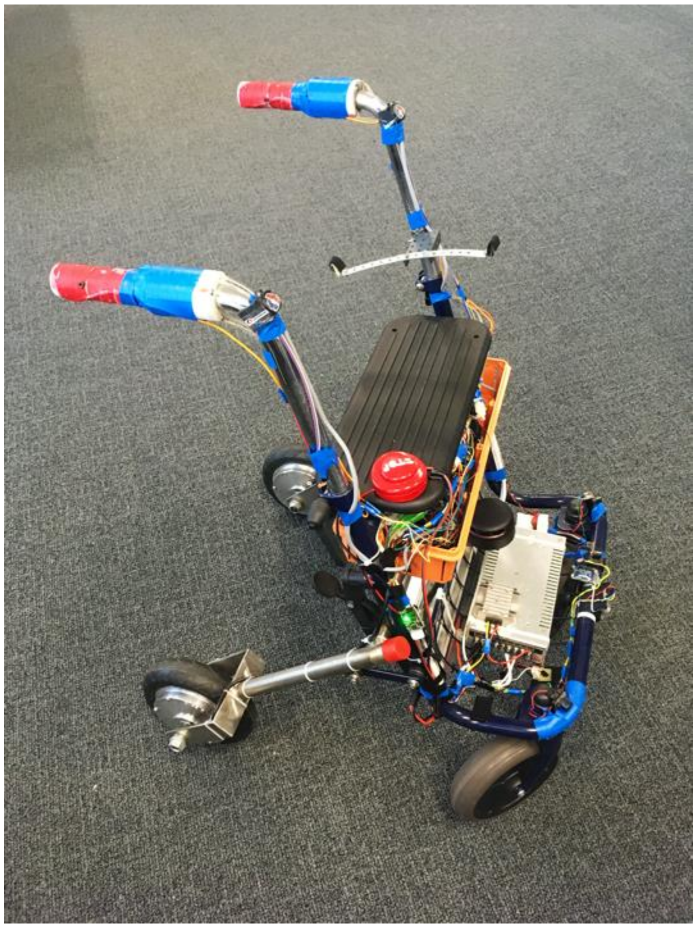


FIGURE 43: THE ROBOTIC ROLLATOR BEING USED BY THE SARA PROTOTYPE

In the Fall Management AT the Robotic Assistant needs to discover which are the lights available in the room where the possible fall event occurred and then request their activation to illuminate the scene. Once the available lights are discovered the interaction between the robot and the lights bulbs may occur using different protocols (e.g. ZigBee, Bluetooth, Z-wave). This need is reflected in the SARA requirements R.UC2,5 and R.UC2.11.

In the development of SARA there is the general requirement to keep the application logic independent from the underlying hardware as much as possible. As an example, in the context of the Gait Analysis AT, we wish to keep the application logic deployed on board of the Robotic Rollator independent from the specificities of the rollator used for the prototyping. This general requirement is reflected in the requirement R.UC2.6.

6.2. Interaction with SEMIoTICS framework

In relation to interconnection between different devices, and the requirements previously described, we followed the KPI-2.1, that it is the semantic descriptions for different types of smart objects, that we described on the D5.1. The semantic descriptions for all the types of smart objects are based on W3C Web of Things (WoT) standard; in particular we used the WoT Thing Description standardized format for describing IoT things. Each sensor, actuator or thing from all SEMIoTICS use cases were identified and for each smart object one Thing Description (TD) was provided. We used iotschema.org to semantically annotate each TD.

The goal was to enable smart objects to become interoperable. For the UC2 we focused on the sensors/actuators on board of the Robotic Rollator (RR), such as the Handlebar, Inertial Measurement Unit (IMU), LiDAR, Range Sensors (obstacle sensors) and Motorised Hub Wheels.

Figure 44 shows the SEMIoTICS Semantic Interoperability technologies involved in the implementation of the SARA solution.

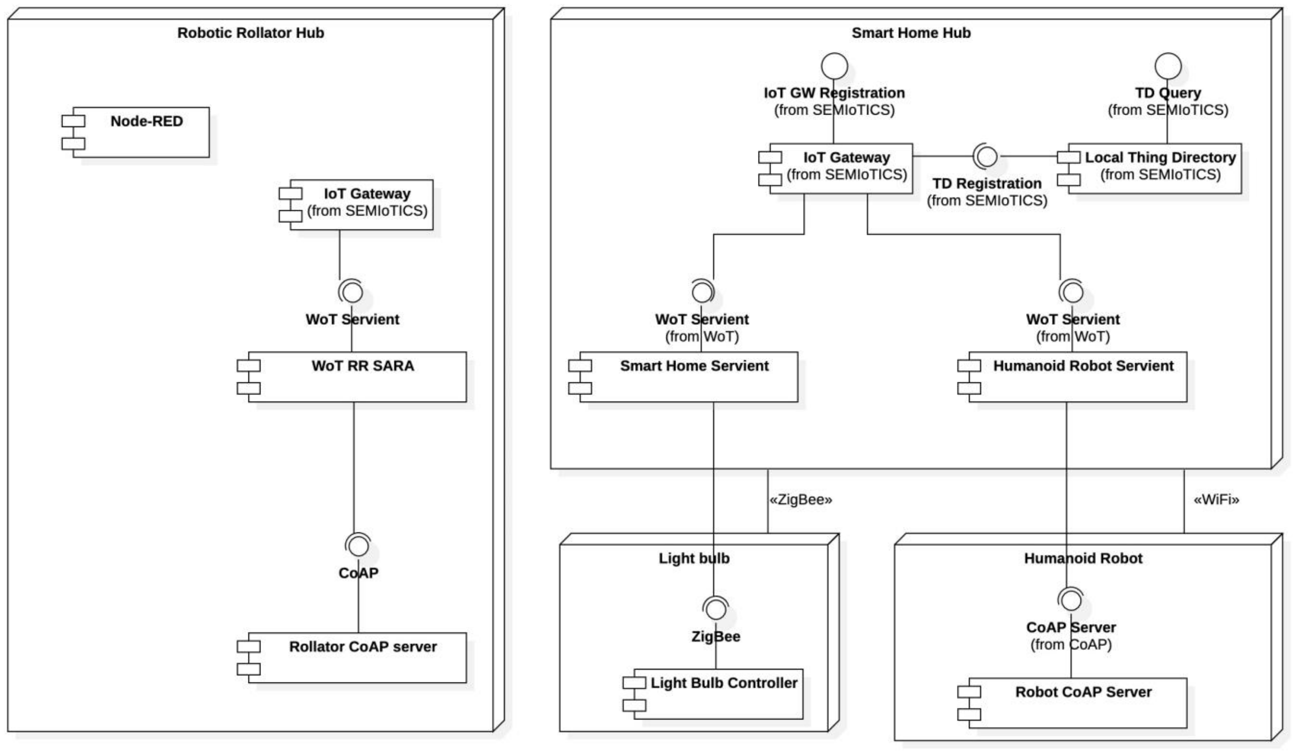
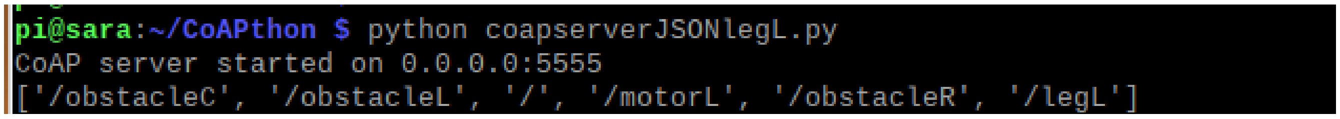


FIGURE 44: SEMANTICS INTEROPERABILITY COMPONENTS IN SARA FIELD DEVICES

6.3. Setup testbed and integration

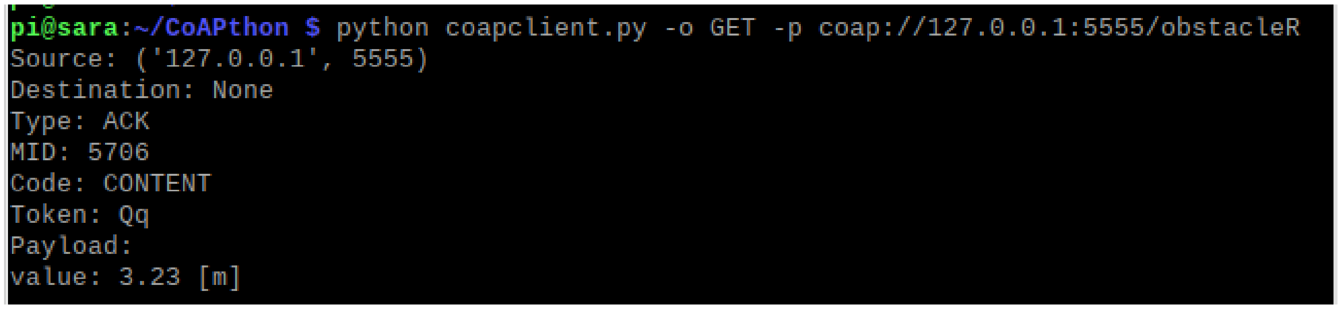
6.3.1. VIRTUALIZATION OF THE ROBOTIC ROLLATOR

The first step that we did to make the Robotic Rollator available as a "Thing" (in the sense of the WoT standard) it was to expose all the sensors onboard of the RR, through the CoAP protocol. This because CoAP is one of the protocol supported from the WoT (as described in details in D3.9). To do that, we implemented a CoAP server running on the Raspberry Pi that it is the device acting as Robotic Rollator Hub, i.e. in charge of controlling all the sensors/actuators. The Raspberry Pi used by the Robotic Rollator is a Raspberry Pi 3b with 1Gb RAM, 16GB SSD and Raspian OS.



```
pi@sara:~/CoAPthon $ python coapserverJSONlegL.py
CoAP server started on 0.0.0.0:5555
['/obstacleC', '/obstacleL', '/', '/motorL', '/obstacleR', '/legL']
```

Following an example of REQUEST to the CoAP server previously shown:



```
pi@sara:~/CoAPthon $ python coapclient.py -o GET -p coap://127.0.0.1:5555/obstacleR
Source: ('127.0.0.1', 5555)
Destination: None
Type: ACK
MID: 5706
Code: CONTENT
Token: Qq
Payload:
value: 3.23 [m]
```

FIGURE 45: A SENSOR VALUE RETURNED BY THE COAP SERVER FO THE ROBOTIC ROLLATOR

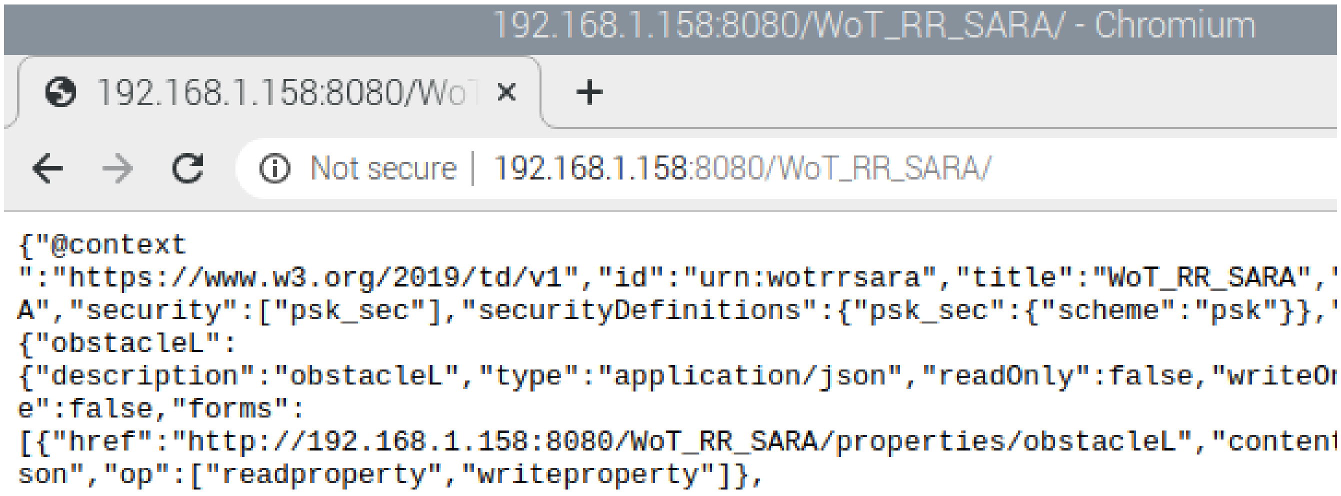
After that, we created the node-wot servient; this one allows to show the RR as a Thing. To do that we utilized the ThingWeb's node-wot implementation of the WoT standard[11].

We create a TD for the RR, linking all the sensors to the related CoAP connection; so that, if we want the value of the obstacleR (obstacle sensor put on the right front on the RR), the node-wot servient provide a GET REQUEST to the related CoAP link, in this case *"coap://127.0.0.1:5555/obstacleR"*.

To summarise we developed two main programs running on the RR:

- the CoAP server, that exposed all the sensors compliant with the CoAP protocol and
- the node-wot servient, that made the RR as a Thing in the WoT, for this reason we named it as "WoT_RR_SARA".

If both those programs are running properly on the RR, it is possible to open a browser in a PC connected on the same networks, pointing to the RR's ip address followed by the port 8080 (where the WoT Servient is listening for incoming requests) and all the sensors are been shown as a property of the RR (Figure 46).


192.168.1.158:8080/WoT_RR_SARA/ - Chromium
192.168.1.158:8080/Wo
Not secure | 192.168.1.158:8080/WoT_RR_SARA/

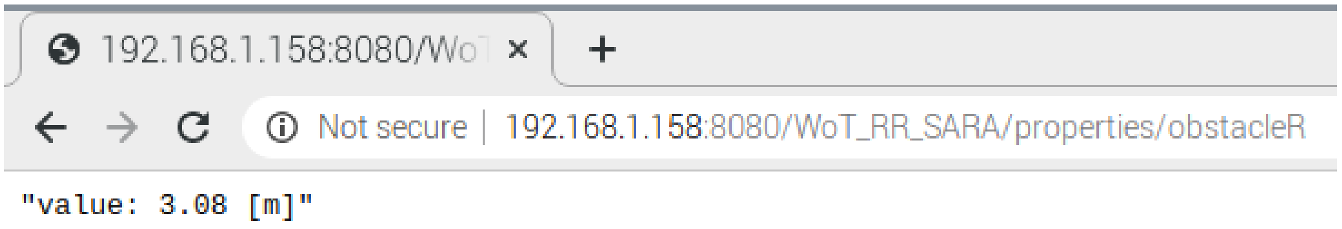
```
{"@context
":"https://www.w3.org/2019/td/v1","id":"urn:wotrrsara","title":"WoT_RR_SARA",'
A","security":["psk_sec"],"securityDefinitions":{"psk_sec":{"scheme":"psk"}},'
{"obstacleL":
{"description":"obstacleL","type":"application/json","readOnly":false,"writeOı
e":false,"forms":
[{"href":"http://192.168.1.158:8080/WoT_RR_SARA/properties/obstacleL","content
son","op":["readproperty","writeproperty"]},
```

FIGURE 46: THE TD OF ROBOTIC ROLLATOR AS RETURNED BY THE WOT_RR_SARA SERVIENT

As it is possible to see from Figure 46, the RR is described as a Thing and exposed all the sensors following the iotschema.org, that it was our scope.

[11] https://github.com/eclipse/thingweb.node-wot/

If we wish to get the data of a single sensor, we need to add "/properties/obstaleR" to the completed link previously explained as following:

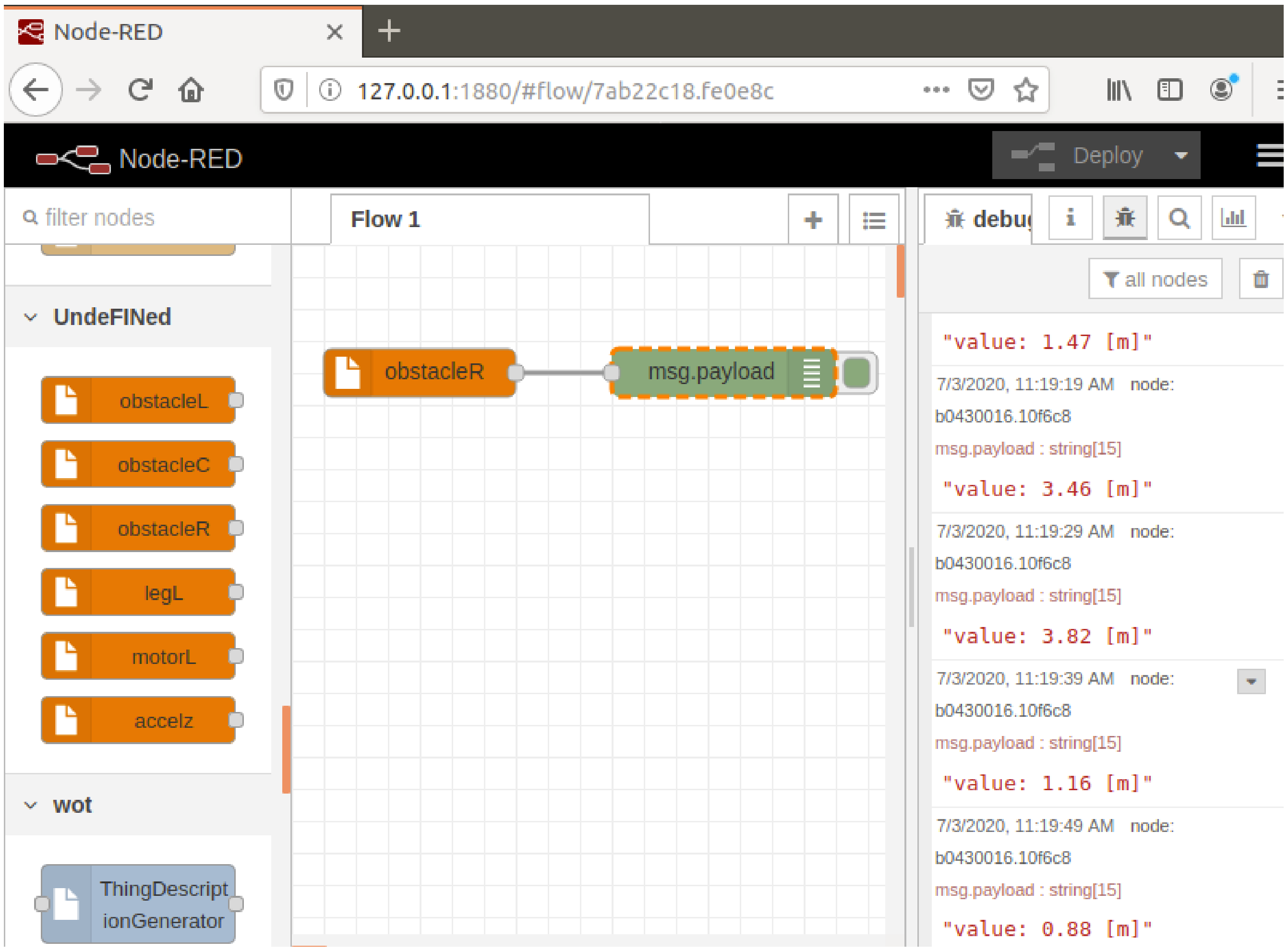


```
"value: 3.08 [m]"
```

FIGURE 47: A SENSOR VALUE RETURNED BY THE WOT_RR_SARA SERVIENT

In addition to that, we deployed the Semantic-IoT-Gateway developed by Siemens in the context of the SEMIoTICS project. Using this component, it is possible to make the Robotic Rollator available as a node within a Node-RED instance running on the Robotic Rollator hub. This enable the possibility to use the Node-RED graphical environment to develop node.js applications that make use of the vitalized sensors and actuators of the Robotic Rollator.

In the Figure 48 it is shown a simple Node-RED flow that visualizes the value of the obstacleR sensor every 10 seconds by means of a GET request.



```
"value: 1.47 [m]"
7/3/2020, 11:19:19 AM   node: b0430016.10f6c8
msg.payload : string[15]
"value: 3.46 [m]"
7/3/2020, 11:19:29 AM   node: b0430016.10f6c8
msg.payload : string[15]
"value: 3.82 [m]"
7/3/2020, 11:19:39 AM   node: b0430016.10f6c8
msg.payload : string[15]
"value: 1.16 [m]"
7/3/2020, 11:19:49 AM   node: b0430016.10f6c8
msg.payload : string[15]
"value: 0.88 [m]"
```

FIGURE 48: A SIMPLE NODE-RED FLOW USING A SENSOR OF THE ROBOTIC ROLLATOR

To the date, due to the impossibility to access the actual Robotic Rollator because of the Covid-19 pandemics, all the steps previously listed in detail have been carried out with a Raspberry Pi simulator. All the validations steps will be repeated with the actual physical device as soon as it will be possible to access again the ENG premise where the Robotic Rollator is.

The data used for this first validation round comes from traces recorded with the actual rollator before the Covid-19 lock down.

6.3.2. VIRTUALIZATION OF ZIGBEE LIGHT BULBS

The Smart Home Hub is realized using a Raspberry 4. The connectivity with ZigBee devices enabled by an XBee module connected to the Raspberry via USB. The light bulb used for the validation is a Philips Hue lamp (Figure 49).

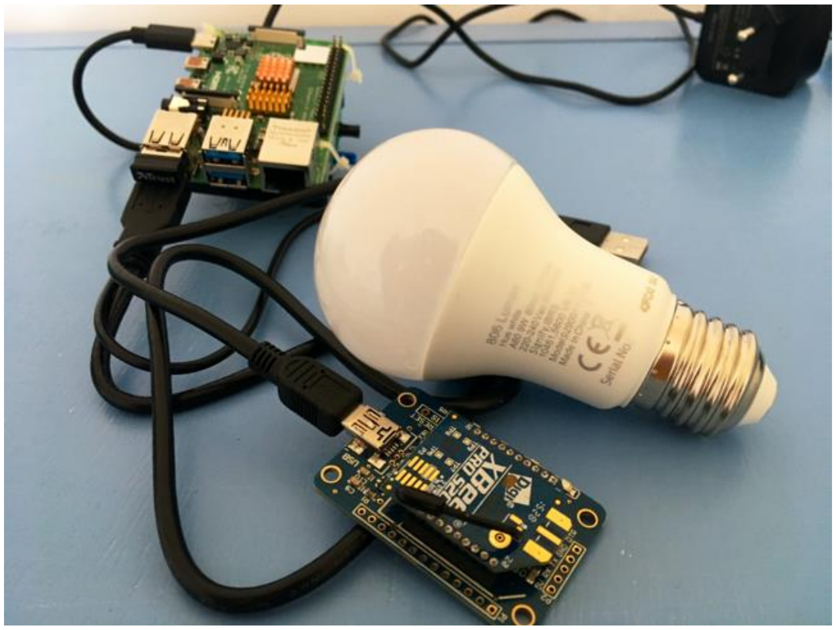


FIGURE 49: THE HARDWARE USED FOR THE VALIDATION OF THE SMART HOME HUB

The WoT Servient is implemented using the SANE Web of Things Servient[12]. The SARA ZigBee Servient uses DigiKey's library[13] to control the XBee module.

The SARA ZigBee Servient creates an http binding for the Hue hence it is possible to control the light bulb using standard REST call over http for turning the light on (e.g. http://10.0.1.29:8080/ZigBeeBulb/actions/on) and off (e.g. http://10.0.1.29:8080/ZigBeeBulb/actions/off).

6.3.2. VIRTUALIZATION OF SOFTBANK'S PEPPER ROBOT

The humanoid robot used for the validation is a SoftBank's Pepper Robot (Figure 50). A CoAP server enables the communication between the robot and the other components of SARA. The CoAP server is implemented using the Californium[14] library. Differently from other components (e.g. Robotic Rollator) in the system the Robotic Assistant Hub does not host any of the SEMIoTICS Field components (e.g. Local Thing Directory, IoT Gateway). This design decision is motivated by the need to reduce as much as possible the drain of computational resources from the robot's processor. This requirements stems from the fact that the robot's processor is in charge for the execution of all the processes controlling the mechanics of the robot. An overload of the processor with extra process could have an impact on the responsiveness of the robot and the fluidity of its movements and, hence, in a worsen User Experience (UX).

[12] https://github.com/sane-city/wot-servient
[13] https://www.digi.com/resources/documentation/digidocs/90001438/Default.htm
[14] https://www.eclipse.org/californium/

The SARA Pepper CoAP server creates a CoAP binding for a Pepper robot and hence it is possible to observe current status robot's resources (e.g. speed of front wheel via the resource coap://192.168.1.10:5683/wheelFL/speed/sensor/value) and to activate/deactivate robot's behaviours (e.g. activate navigation behavior coap://192.168.1.10:5683/behaviour/navigation/start).

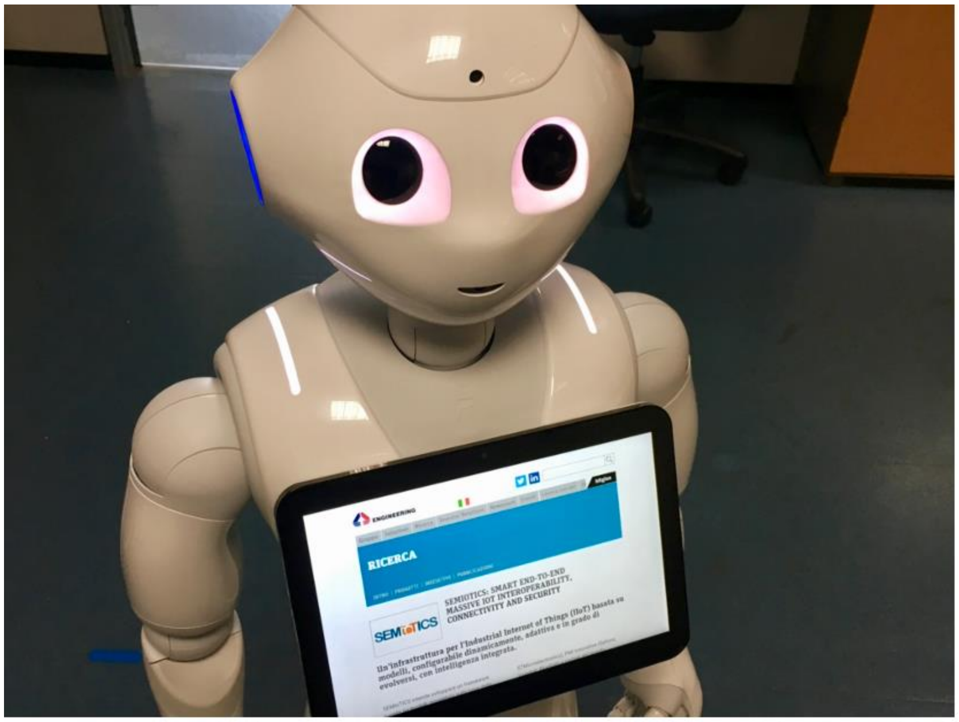


FIGURE 50: THE PEPPER ROBOT USED FOR THE VALIDATION OF THE SMART ASSISTANT HUB

The robot is not able to serve its own Thing Descriptor since it does not host a WoT compliant servient. Therefore in a typical SARA field configuration the TD of the robot is available from the Local Thing Directory deployed on the Smart Home Gateway. Below is shown a snippet of the TD describing the robot used for the SARA validation:

```
{
    "id": "urn:robotic-assistant-0",
    "title": "SARA Robotic Assistant",
    "@context": [
        "https://www.w3.org/2019/wot/td/v1",
        {
        "iot": "http://iotschema.org/",
      "schema": "http://schema.org/",
      "sara":"http://www.eng.it/sara/"
        },
        {
            "@language": "en"
        }
    ],
    "@type": "Thing",
    "security": [
        "nosec_sc"
    ],
    “properties”:{…}

    "actions":{
        "startNavigation":{
            "@type":"StartNavigation",
            "iot:capability":"sara:MobileBase",
            "description":"Start navigation of robot",
            "idempotent": false,
            "safe": false,
            "forms":[{
                    "href": "coap://192.168.1.10:5683/behaviour/navigation/start",
                    "contentType": "application/json",
                    "op": [
                        "invokeaction"
                    ]
                }
            ]
        },
        "stopNavigation":{"@type":"StartNavigation",
            "iot:capability":"sara:MobileBase",
            "description":"Start navigation of robot",
            "idempotent": false,
            "safe": false,
            "forms":[{
                    "href": "coap://192.168.1.10:5683/behaviour/navigation/stop",
                    "contentType": "application/json",
                    "op": [
                        "invokeaction"
                    ]
                }
            ]
        }
    }
}
```

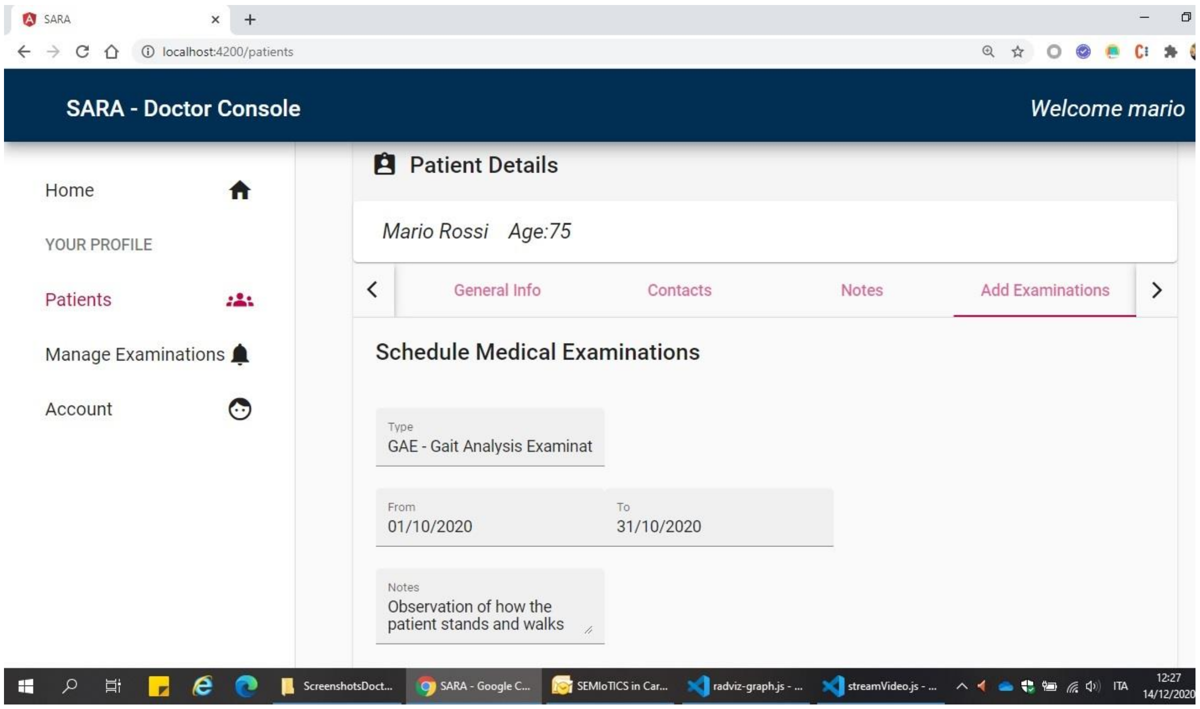
7. SUB USE CASE 5: MONITORING ACTIVITIES OF DAILY LIFE

7.1. Scope and Objectives

This sub use case aims to demonstrate how the SEMIoTICS Monitoring, Prediction and Diagnosis component (MPD) can be used for the monitoring of Activities of Daily Life (ADL) performed by the elderly while at home. Examples of ADL include cooking, eating, sleeping, relaxing etc.. For the SARA solution understanding which activity is being performed by the patient is a key capability. As an example this information can be used to drive the interaction between the humanoid (Pepper) robot and the patient. In particular it can be used as indicator of the availability of the patient to interact and hence to reduce the risk that the patient refuses the social interaction.

In the context of the Gait Analysis Task this need occurs during the engagement of the patient (steps 2-4 described in section 2.1.2).

A Doctor uses the SARA Gait Analysis Web Application (introduced in the context of sub use case 1) to schedule a gait analysis session. The Figure 51 shows the page offered by the GA Web App to schedule a remote gait analysis session.



Mario Rossi Age:75

Schedule Medical Examinations

Type
GAE - Gait Analysis Examinat

From
01/10/2020

To
31/10/2020

Notes
Observation of how the patient stands and walks

FIGURE 51: THE SARA INTERFACE SUPPORTING THE SCHEDULING OF A REMOTE GA SESSION

It is important to note that, also as evidenced by the figure, at this stage the Doctor does not fix a precise date to run the session. Instead the Doctor fixes a range of dates (typically one week) when the examination should occur and the robotic assistant is delegated to engage the patient and remind him/her to fix a precise date.

In order to reduce the risk that patient refuses the interaction it is important for the robotic assistant to understand when it is the “right” way and time to successfully engage the user.

A basic awareness of the type of activity being carried on by the patient can help the robotic assistant’s software to decide whether to start a successful social interaction. In fact we can expect that, depending on the patient, there will be activities that he/she is more prone to interrupt in order to interact with the robot.

This awareness can be created by using the SEMIoTICS Monitoring component to infer the kind of activity being carried on from the stream of events generated by the appliances within the smart home.

7.2. Interaction with SEMIoTICS framework

Figure 52 shows the SEMIoTICS components utilized for the scheduling of a Remote Gait Analysis AT.

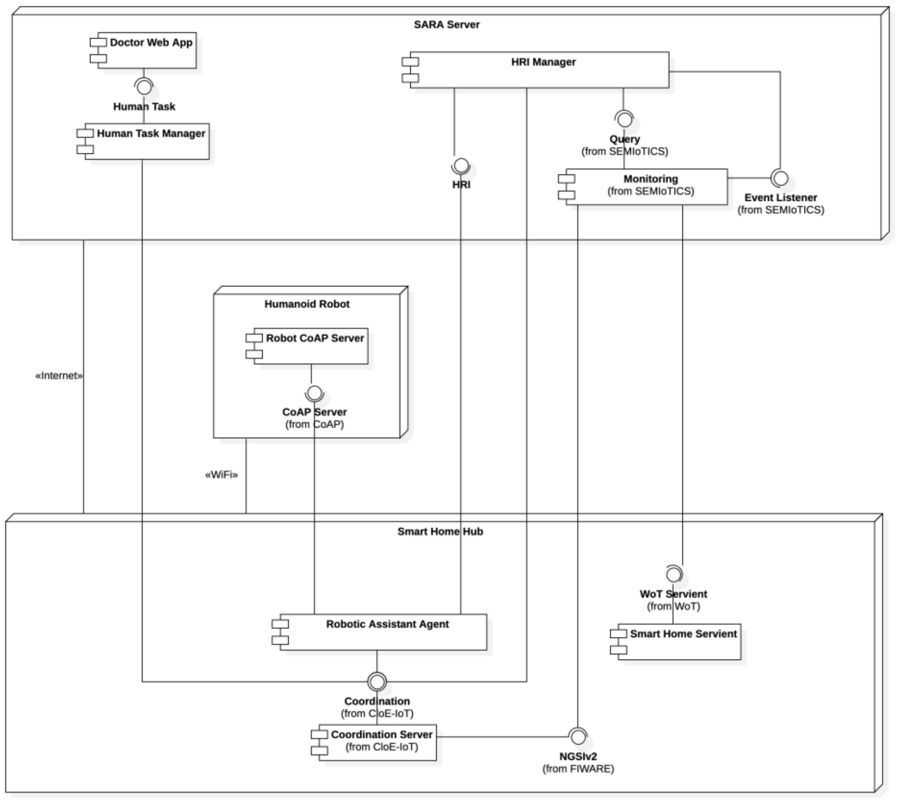


FIGURE 52: SEMIOTICS COMPONENTS SUPPORTING THE SCHEDULING OF A REMOTE GA SESSION

The Doctor Web Application (already introduced for the sub use case 1 described in chapter 3) relies on the Human Task Manager to create and assign tasks to human agents. In the particular in the context of the Gait Analysis the Doctor Web Application uses the Human Task Manager to assign to the patient the task to fix date and time of the examination. The start deadline and the completion deadline of the task are set to the dates specified by the Doctor by means of the interface presented in Figure 52.

At the start date set for the task the Human Task Manager creates a notification for the patient. The notification is realized by writing a corresponding tuple within the Coordination Server deployed on the hub of patient’s Smart Home.

The Coordination Server notifies the potentially interested clients about the availability of a new tuple representing the goal to finalize the examination scheduling. The potential clients could be the patient’s smartphone, the caregiver’s smartphone or the Robotic Assistant Agent. Each of the notified clients can decide to remove the tuple from the server indicating with this action that it is going to take care of the achievement of the goal. For the purposes of this section we consider only the case of the tuple goal being removed by the Robotic Assistant Agent.

The Robotic Assistant Agent is the software component controlling the activation/deactivation of the social behaviours of the robot. For the evaluation of the precondition of the user engagement behavior the Robotic Assistant agent relies on the Human-Robot Interaction (HRI) Manager residing within the SARA backend server. The RA Agent requests to the HRI Manager to be notified when the patient can be approached and the social interaction can start.

The HRI Manager uses the SEMIoTICS Monitoring component to infer the ADL being performed by the patient and, based on this, to decide whether the patient can be potentially interrupted by the robot interaction (i.e. the robot is likely to succeed with user engagement).

More specifically the HRI Manager submits to the Monitoring component a collection of queries each defining an ADL as a pattern over the stream of events generated by the Smart Home Servient (described in section 6.3.2).

The HRI Manager requests to the robot to approach the patient whenever the HRI Manager receives the notification that the patient is performing a potentially interruptible activity (i.e. whenever the Monitoring component matches one of the patterns defining an ADL). The HRI Manager makes the request towards the robot by writing a specific tuple within the Coordination Server.

The writing in the Coordination Server of a tuple representing the goal to approach the user, results in the Robotic Assistant Agent requesting the robot to move towards the user. The RA Agent starts the navigation towards the patient by activating the navigation behavior of the robot via the Robot CoAP Server.

7.3. Setup testbed and integration

The tested of sub use case 5 utilizes three hosts (see also Figure 52):

- **SARA server:** as in sub use 1 was the software components part of the SARA server and are deployed both on a standard personal computer and on a virtual machine (running Linux OS) available from the FiwareLab[15] node operated by ENG in its data center located in Vicenza (Italy).
- **Humanoid robot**: it is a SoftBank's Pepper Robot. It is the same device utilized in sub use case 4. The configuration of this host is described in section 6.3.3.
- **Smarthome hub**: is Raspberry Pi v4. It is the same device utilized in sub use case 4.

The components presented in Figure 52 are implemented as follows:

- The **Human Task Manager** is a Springboot application exposing a REST API to manage human tasks. In this context a human task is a data structure describing an activity supposed to be performed by a human. A human task carries indication of the person in charge of the execution of the activity, the start and completion deadlines, as well as the escalation action to undertake in case deadlines are missed. Using the Human Task operations users can change the state of task (e.g. move the state from “not started” to “started”). The Human Task Manager takes care of the management of the lifecycle of a task: it monitors the state changes of a task and may initiate actions (e.g. send a reminder to the owner of the task if a deadline is missed).
- **Monitoring** is the SEMIoTICS Monitoring, Diagnosis and Prediction (MDP) component developed in the context of WP4 and described in deliverable D4.9.
- **Human-Robot Interaction (HRI) Manager** is a Springboot application. It runs various computational intensive algorithms driving the social interaction between robots and humans. These algorithms are accessible to robotic field devices via a REST API. For the purposes of the sub use case 5 it implements a basic algorithm that allows the humanoid robot to decide whether to initiate an interaction with a patient. The algorithm allows the humanoid robot to start an interaction only if it evaluates that the ADL ongoing within the smart home can be interrupted (i.e. that the probabilities that the user refuses to interact are low). The HRI Manager uses the SEMIoTICS monitoring component to monitor the ADL ongoing within the smart home. The HRI Manager submits a query for each type of ADL. For the experimentation we defined queries for “cooking”, “relaxing”, “housekeeping” and “leaving home”.
- **Robotic Assistant Agent:** it manages the goals of the robotic assistant. Goals are represented as tuples within the CloE-IoT Coordination Service. The RA agent continuously monitors the Coordination Service and selects from it the next goal for the robot.

[15] https://www.fiware.org/developers/fiware-lab/

- **Coordination Server** offers the components of a CloE - IoT distributed application the capability to coordinate their activities using the tuple space (or blackboard) paradigm. Following this paradigm the various components of a distributed application undertake their specific activities driven by the availability of specific data (tuples) in a shared memory space (tuple space). Besides writing tuples in the shared space an application can read/remove tuples matching a tuple template. The operations to read/remove tuples from the tuplespace come in two flavours: blocking and non-blocking. Blocking operations blocks the control flow of the caller until an instance of the requested tuple appears in the tuplespace. The shared tuplespace can be accessed whether via a proprietary interface (Coordination) or an interface following the FIWARE NGSIv2 standard. In the latter case tuples are presented as contexts to the client application.

For the purpose of the experimentation we supposed the sensors were deployed within an apartment having the layout shown in Figure 53.

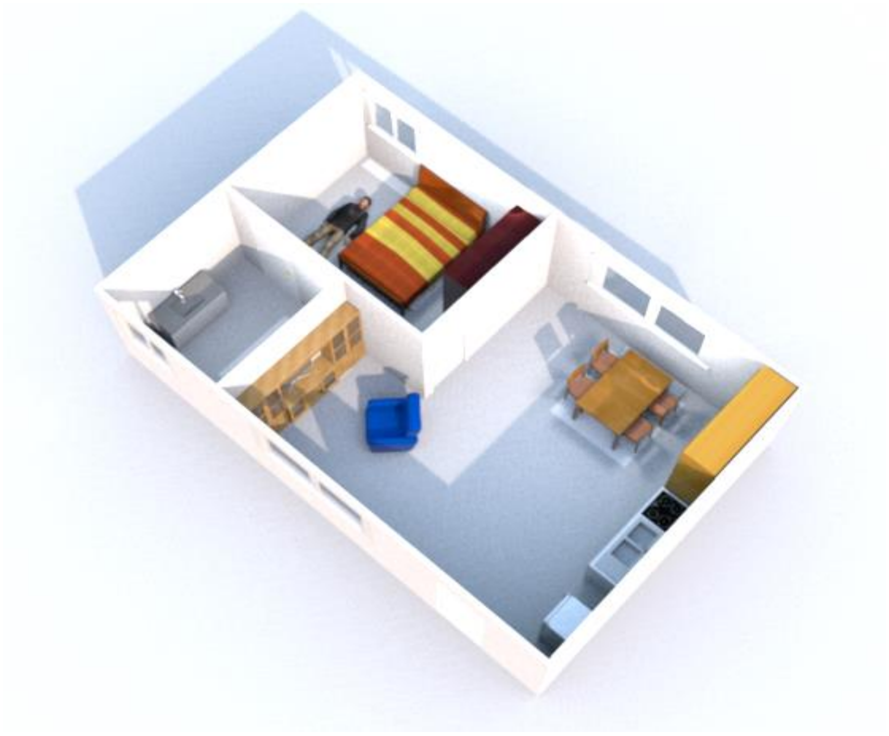


FIGURE 53: SUB USE CASE 5 VIRTUAL APARTMENT

The measurements of the apartment were chosen to be compatible with the demo room at ENG facility in Rome. The demo room was equipped with light panels simulating the walls of the apartment (Figure 54). These mock ups served the purpose to force both the robot and experimenters impersonating a user to follow as much as possible the trajectories they would have followed within the real apartment. This was important in order to generate sensors activation pattern as much as possible close to those generated in a corresponding real apartment.

For the SARA use case we assumed the smart home was able to generate their types of events:

- time events H0…H23 representing hours of the day
- location events (e.g. ENTRANCE, LIVING, KITCHEN) indicating the presence of a user in a specific area of the apartment
- powering events indicating that an appliance (e.g. light bulb, oven) is turned on/off
- opening/closing events indicating the opening/closing of drawers and doors (of cupboard, wardrobe, main entrance)

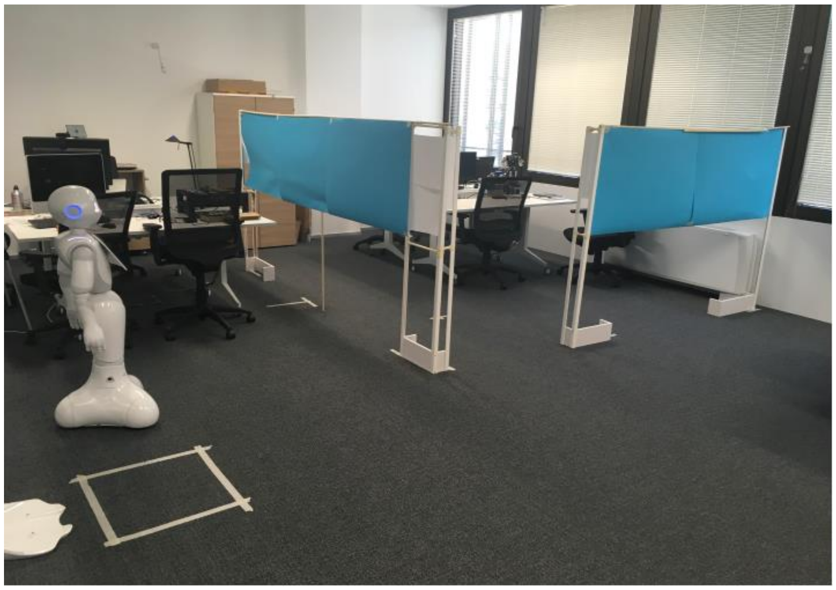


FIGURE 54: ENG DEMO ROOM EQUIPPED WITH MOCKUPS STAYING FOR WALLS

We considered a subset of the ADLs typically used in this kind of experimentation: “Leaving home”, “Cooking”, “Relaxing”, “Taking medication”, “Eating”, “Sleeping”, “Bathing”, “Toilet”.

We experimented the use of SEMIoTICS MPD predictive queries [9] to characterize each ADL in term of the events emitted by the smart environment.

We defined a type of event (e.g. “CookingEvent”) for each of the ADL considered in the experiments (e.g. “Cooking”). The MDP notifies to the HRI one of these event whenever it infers the execution of a specific ADL is ongoing.

The query request to notify an event of type “Cooking” to the endpoint “http://saraserver:9090/hri/notifications” (i.e. the HRI Server) whenever the causal model used by the MPD let to infer that the activation of the location sensor in the kitchen (i.e. “http://homegateway:9090/kitchen”) immediately followed by the ignition of the oven (i.e. “http://homegateway:9090/oven”) is caused (with likelihood 70%) by an (undetected) event of type “PrepareMealTask” within the SARA Human Task Manager.

```
{ "id":3100,
    "events":[
        {"name":"CookingEvent",
        "eventsPattern":{
            "name":"CookingEventPattern",
            "condition":{"type":"location",
                        "source":{"wot":"http://homegateway:9090/kitchen"}
                },
            "next":{
                "name":"TurnOnOven",
                “condition":{"type":"switchOn",
                            "source":{"wot":"http://homegateway:9090/oven"}
                },
                "causedBy":{
                    "name":"PrepareMealTaskAssignment",
                                  "condition":{"type":"PrepareMealTask",
                                              "source":{"source":"http://saraserver:9191/tasks/"},
                                              "likelihood":70.0
                                              }
                                  }
                              }
                          }
                      }
                  ],
                  "listeners":["http://saraserver:9090/hri/notifications"]
              }
```

QUERY 1 : EVENTS PATTERN DESCRIBING COOKING ACTIVITY

The COVID-19 pandemics did not allow using the ENG Demo Room to run the experiments imaged to discover and exploit the causal model needed by the MDP to infer ongoing ADL.

Therefore we decided to introduce an activity simulator within the architecture. Figure 55 shows how the simulator is connected to the rest of the architecture of this sub use case:

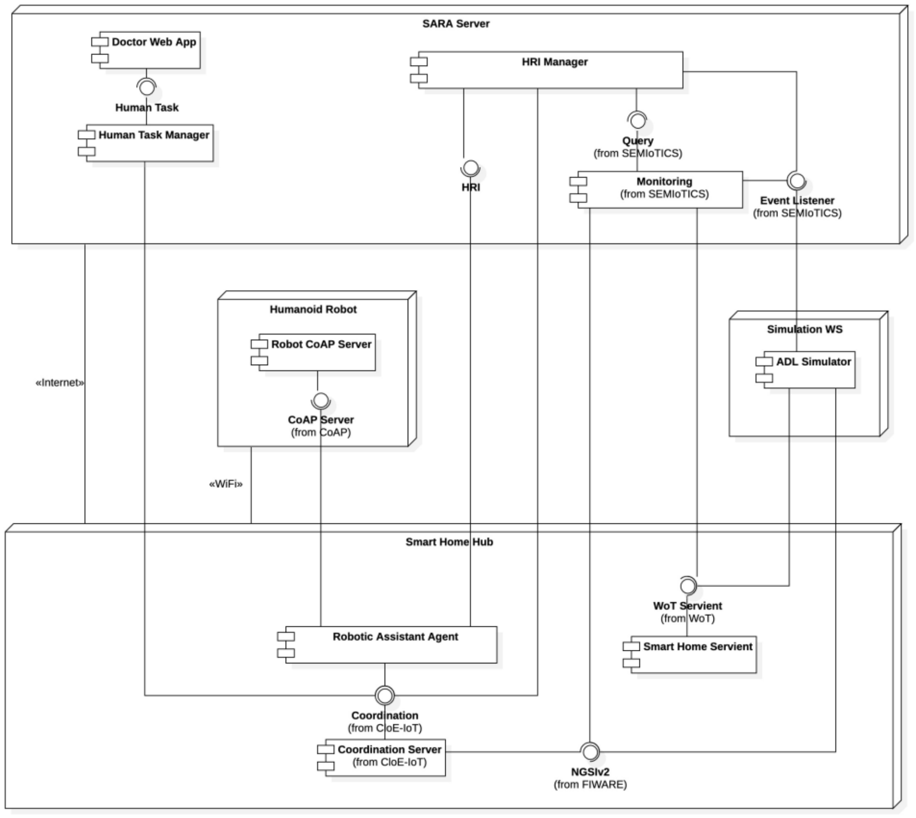
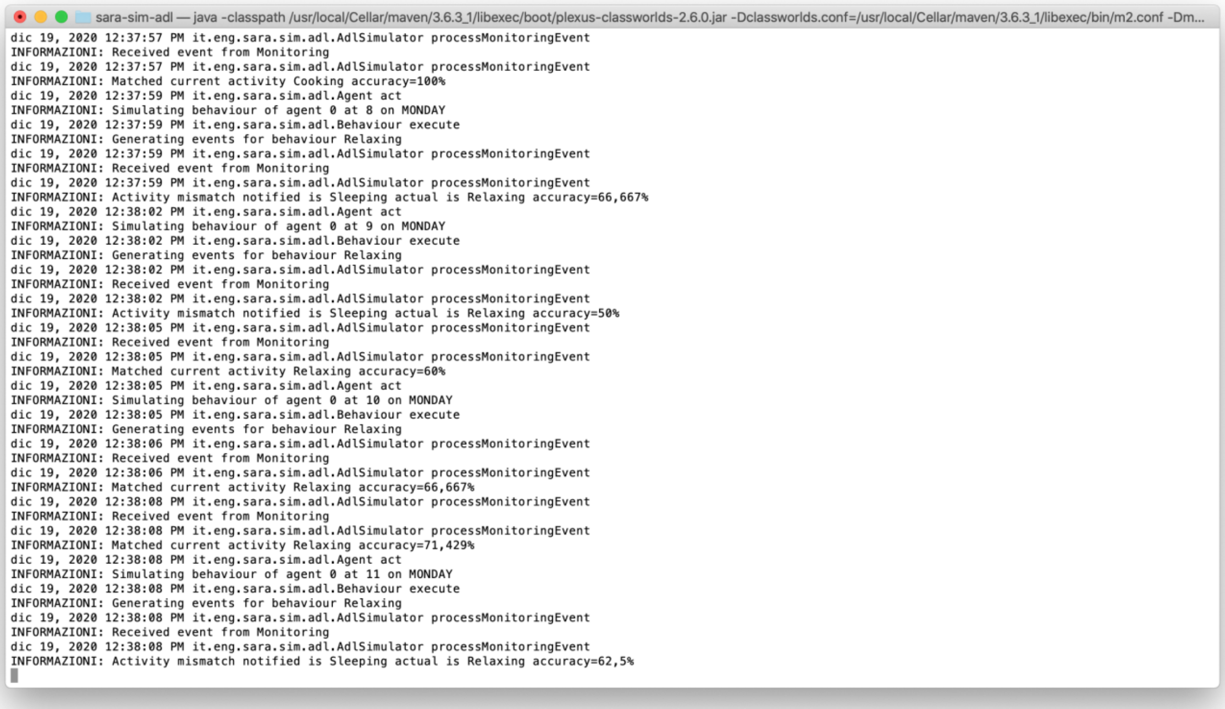


FIGURE 55: ARCHITECTURE EXTEND WITH SIMULATOR

The ADL Simulator uses the WoT Servient interface to operate on the (simulated) appliances managed by the Smart Home Servient. The operations of ADL Simulator have the effect that the Smart Home servient produces powering events towards the Monitoring component.

The ADL Simulator uses the Fiware NGSIv2 to publish the location of the simulated agent.



```
sara-sim-adl — java -classpath /usr/local/Cellar/maven/3.6.3_1/libexec/boot/plexus-classworlds-2.6.0.jar -Dclassworlds.conf=/usr/local/Cellar/maven/3.6.3_1/libexec/bin/m2.conf -Dm...
dic 19, 2020 12:37:57 PM it.eng.sara.sim.adl.AdlSimulator processMonitoringEvent
INFORMAZIONI: Received event from Monitoring
dic 19, 2020 12:37:57 PM it.eng.sara.sim.adl.AdlSimulator processMonitoringEvent
INFORMAZIONI: Matched current activity Cooking accuracy=100%
dic 19, 2020 12:37:59 PM it.eng.sara.sim.adl.Agent act
INFORMAZIONI: Simulating behaviour of agent 0 at 8 on MONDAY
dic 19, 2020 12:37:59 PM it.eng.sara.sim.adl.Behaviour execute
INFORMAZIONI: Generating events for behaviour Relaxing
dic 19, 2020 12:37:59 PM it.eng.sara.sim.adl.AdlSimulator processMonitoringEvent
INFORMAZIONI: Received event from Monitoring
dic 19, 2020 12:37:59 PM it.eng.sara.sim.adl.AdlSimulator processMonitoringEvent
INFORMAZIONI: Activity mismatch notified is Sleeping actual is Relaxing accuracy=66,667%
dic 19, 2020 12:38:02 PM it.eng.sara.sim.adl.Agent act
INFORMAZIONI: Simulating behaviour of agent 0 at 9 on MONDAY
dic 19, 2020 12:38:02 PM it.eng.sara.sim.adl.Behaviour execute
INFORMAZIONI: Generating events for behaviour Relaxing
dic 19, 2020 12:38:02 PM it.eng.sara.sim.adl.AdlSimulator processMonitoringEvent
INFORMAZIONI: Received event from Monitoring
dic 19, 2020 12:38:02 PM it.eng.sara.sim.adl.AdlSimulator processMonitoringEvent
INFORMAZIONI: Activity mismatch notified is Sleeping actual is Relaxing accuracy=50%
dic 19, 2020 12:38:05 PM it.eng.sara.sim.adl.AdlSimulator processMonitoringEvent
INFORMAZIONI: Received event from Monitoring
dic 19, 2020 12:38:05 PM it.eng.sara.sim.adl.AdlSimulator processMonitoringEvent
INFORMAZIONI: Matched current activity Relaxing accuracy=60%
dic 19, 2020 12:38:05 PM it.eng.sara.sim.adl.Agent act
INFORMAZIONI: Simulating behaviour of agent 0 at 10 on MONDAY
dic 19, 2020 12:38:05 PM it.eng.sara.sim.adl.Behaviour execute
INFORMAZIONI: Generating events for behaviour Relaxing
dic 19, 2020 12:38:06 PM it.eng.sara.sim.adl.AdlSimulator processMonitoringEvent
INFORMAZIONI: Received event from Monitoring
dic 19, 2020 12:38:06 PM it.eng.sara.sim.adl.AdlSimulator processMonitoringEvent
INFORMAZIONI: Matched current activity Relaxing accuracy=66,667%
dic 19, 2020 12:38:08 PM it.eng.sara.sim.adl.AdlSimulator processMonitoringEvent
INFORMAZIONI: Received event from Monitoring
dic 19, 2020 12:38:08 PM it.eng.sara.sim.adl.AdlSimulator processMonitoringEvent
INFORMAZIONI: Matched current activity Relaxing accuracy=71,429%
dic 19, 2020 12:38:08 PM it.eng.sara.sim.adl.Agent act
INFORMAZIONI: Simulating behaviour of agent 0 at 11 on MONDAY
dic 19, 2020 12:38:08 PM it.eng.sara.sim.adl.Behaviour execute
INFORMAZIONI: Generating events for behaviour Relaxing
dic 19, 2020 12:38:08 PM it.eng.sara.sim.adl.AdlSimulator processMonitoringEvent
INFORMAZIONI: Received event from Monitoring
dic 19, 2020 12:38:08 PM it.eng.sara.sim.adl.AdlSimulator processMonitoringEvent
INFORMAZIONI: Activity mismatch notified is Sleeping actual is Relaxing accuracy=62,5%
```

FIGURE 56: OUTPUT OF THE ADL SIMULATOR

The Monitoring component uses the WoT signaler to receive events from the Smart Home Servient and the Fiware signaler [9] to receive events from the Coordination Server. This configuration allowed verifying the capability of the MDP to fuse events from two different platforms (i.e. WoT and Fiware).

The ADL Simulator receives the notifications about the detected events by implementing the Event Listener interface. The ADL Simulator uses this notification to verify that the activity detected by the MPD matches that being simulated and compute the accuracy of the detection.

8. OVERALL KPIS AND REQUIREMENTS (ALL)

This section aims to provide a summary of requirements and KPIs relevant for evaluation in Use Case 2. The five presented Sub Use Cases, together with the remaining Use Cases 1 & 3 aim to address and validate the requirements presented in Table 1, while the relevant KPIs are presented in Table 5.

Further information on use case -specific requirements related to Use Case 2 are provided in D2.3. The original methodology of KPI evaluation contained in D5.1 was updated where required and is mostly summarized here for brevity.

8.1. Related KPIs

In this sub section, we list the SEMIoTICS 'KPIs related to the use case 2.

TABLE 1 KPIS RELATED TO UC2

KPI ID	KPI description	Role in this KPI
KPI-1.1	Number of SPDI Patterns	SFC patterns and privacy patterns are used in this use case
KPI-1.2	Machine-processable language for pattern	The pattern language is used for processing patterns
KPI-2.1	Semantic descriptions for 6 types of smart objects	The description of the semantics related to this use case are also defined
KPI-2.2	Data type mapping and ontology alignment	The interoperability mechanisms are intervened in order to ensure that the data format and data alignment in use case 2.
KPI-2.3	Semantic interoperability with 3 IoT platforms	The development of a specific signaller was used to make the CloE-IoT platform observable by the SEMIoTICS
KPI-3.1.1	Generating monitoring strategies in the 3 targeted IoT platforms	The SARA use case monitors events generated by two IoT platforms: SEMIoTICS and CloE-IoT
KPI-3.1.2	Fuse results from these monitors	The query language of the SEMIoTICS MPD component allowed us to define cross-platform queries
KPI-3.1.3	Performing predictive monitoring with an average accuracy of 80%	The SEMIoTICS MPD Component supports both prediction and diagnostic queries.
KPI-3.2	Delivery of a monitoring language	The SEMIoTICS MPD Component provides a language to define high-level events that should be produced as result of the monitoring activity.
KPI-4.2	Delivery of mechanisms with adaptation time of 15ms	The developed SFC patterns were used as a sufficient adaptation mechanism to offer proactive adaptations as evaluated in this use case

KPI-4.3	Delivery of adaptations mechanisms enabling improvement by at least 20%	the developed SFC patterns were used as a sufficient adaptation mechanism to offer reactive adaptations by means of monitoring and intelligence analytics, as evaluated in this use case
KPI-4.6	Development of new security mechanisms/controls	From an NFV perspective, SFC is leveraged to guarantee security procedures for each kind of traffic in UC2. This is done by concatenating different security enforcers (firewalls, Intrusion Detection Systems, Honeypots) and forcing traffic to travers them. As each element is configured with specific security rules according to the expected traffic, only authorized packets are expected to go through to the services' endpoints.
KPI-5.1	Deployment of a multi-domain SDN orchestrator	Multi-domain SDN orchestration is supported in this use cases by the deployment of the SDN/NFV-enabled SEMIoTICS architecture in multiple-locations around different countries of Europe.
KPI-5.2	Service Function Chaining (SFC) of a minimum 3 VNFs	This KPI aims at the orchestration of SFC able to provide security by the chaining of at least 3 VNFs. That is, from a centralized position in the SEMIoTICS architecture, the NFV component should be able to build and configure the SFC for each kind of traffic.
KPI-6.1	Reduce manual interventions required for bootstrapping of smart object in each use case domain by at least 80%.	The bootstrapping service for the smart objects involves the availability of other functional blocks, e.g. at the networking level the VNFs and SFC that allow to forward the traffic from the smart objects towards the backend. An implementation of these functional blocks, at the networking level, in the form of VNFs automates its availability for the bootstrapping process. In this regard, note that the NFV MANO automatizes the creation of the VNFs and its deployment on top of the NFVI in the form of VMs. Also, it automatizes the configuration, software installation and programs executions in the VM at boot time. Therefore, such operations are expected to eliminate user intervention completely.
KPI-6.2	Leveraging upon FIWARE assets in developing the SEMIoTICS framework	The SARA Health Scenario uses KNOWAGE applications as part of SEMIoTICS GUI
KPI-6.3	Delivery of 3 prototypes of IIoT/IoT applications	The SARA use case delivered a first prototype of the SARA solution empowered with SEMIoTICS technology
KPI-7.1	Provision the SEMIoTICS building blocks	The provision of the components that are used in SARA use case

8.1.1. Objective 1 - Security, Privacy, Dependability and Interoperability (SPDI) Patterns

8.1.1.1. KPI-1.1: Number of SPDI Patterns

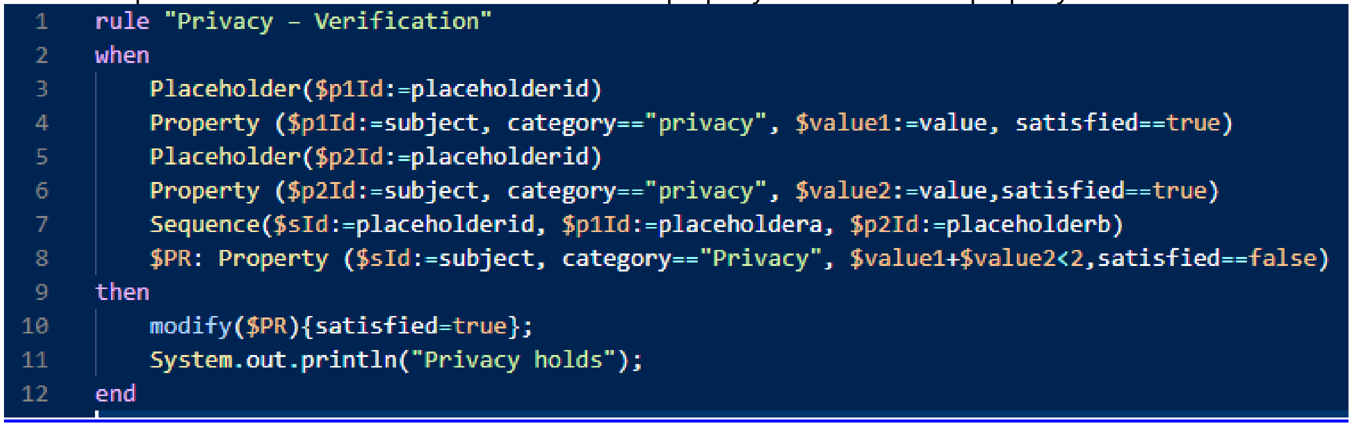
The developed SPDI patterns are specified in a document format, and are detailed in the deliverable D4.8 – “SEMIoTICS SPDI Patterns (final)”. In the context of UC2, SFC related patterns were used to support the dynamic instantiation of SFCs as well as privacy related. These patterns were preinstalled in the Backend Pattern Engine (as presented in the Section 4).

Apart from the SFC patterns, the Privacy pattern is modified in such a manner to take into account the facts modified by the Security Manager.

The **when** part of the rule specifies:

1. Two Placeholder that act as the two endpoints. The Placeholder is a parent class for Host, IoTSensor, IoTGateway etc, which enables the rule to be more abstract without the need to specify a new rule for every class.
2. A sequence of the Placeholder indicating their interaction.
3. Two properties on for each Placeholder
4. The orchestration property that can be guaranteed through the application of the pattern, i.e., the privacy property in this case ($PR).

The **then** part modifies the status of the orchestration property to state that the property holds.



```
rule "Privacy - Verification"
when
    Placeholder($p1Id:=placeholderid)
    Property ($p1Id:=subject, category=="privacy", $value1:=value, satisfied==true)
    Placeholder($p2Id:=placeholderid)
    Property ($p2Id:=subject, category=="privacy", $value2:=value,satisfied==true)
    Sequence($sId:=placeholderid, $p1Id:=placeholdera, $p2Id:=placeholderb)
    $PR: Property ($sId:=subject, category=="Privacy", $value1+$value2<2,satisfied==false)
then
    modify($PR){satisfied=true};
    System.out.println("Privacy holds");
end
```

FIGURE 57: PRIVACY PATTERN

8.1.1.2. KPI-1.2 - Machine-processable language for pattern

The verification of delivery of the SEMIoTICS Pattern Language and its usability for defining machine-processable patterns is achieved through document review of deliverable D4.8 – “SEMIoTICS SPDI Patterns (final)”. The verification of the format of the derived machine-processable patterns is achieved through verification of the correct functionality of a Drools rules reasoning engine.

In more detail, a Drools rule that encodes a pattern includes the inputs of the pattern’s components and the required property in Left Hand Side (LHS). When the conditions in the LHS are satisfied, then the rule is fired to execute the actions as described in its Right-Hand Side (RHS). In the RHS, the new requirements of the compositions or atomic components can be inserted, updated or deleted.

In Table 2, a few semantics are presented related to SFC patterns. In the LHS, the components which constitute the topology of the pattern are defined. Different facts such as Virtual Service Functions and Service Function Chains are included in the list. Moreover, the Req represents the constraints of the topology and the required property. In the RHS, the pattern provides the solution by inserting, modifying, updating or retracting facts from the knowledge base which will also update the inventory list in the controller. Each component is converted through the respective Java class to an understandable format to the Pattern Engine.

TABLE 2: PATTERN RULE CONSTRUCTS

Type	Syntax	Description
rule	rule "name"	name of the rule
Left Hand Side (LSH)		
when	**Pattern Elements (Facts)**	
	Function (type, instantiated)	match Virtual Service Network Functions
	Chain(functions)	match Service function chains
	Req (src, dest, category, satisfied)	match requirements of pattern such as source, destination, property category and satisfied
	Conditional Elements	
	==	match conditions
	contains	contains object (logical)
	not	not match (logical)
	!=	not match (arithmetic)
Right Hand Side (RSH)		
then	**Actions**	
	modify (\$fact)\{pro=pro'\}	modify knowledge base fact
	retract (\$fact)	retract knowledge base fact
	insert (new Fact ())	insert knowledge base fact
	update (\$fact)	update knowledge base fact
	Java commands	other Java language syntax

8.1.2. Objective 2 - Semantic Interoperability

8.1.2.1. KPI-2.1 - Semantic descriptions for 6 types of smart objects

Semantic descriptions for all the types of smart objects have been provided based on W3C Web of Things (WoT) standard. In parallel, the iotschema.org was used to semantically annotate each TD. The analysis and description of semantic models with the TD for the sensors that were used in SEMIoTICS UCs have been presented in D4.11-“Semantic Interoperability Mechanisms for IoT (final)”. Particularly, in case of UC2, the following Table 3 highlights the main properties, data types and actions for Things.

TABLE 3: DESCRIPTION OF A SUBSET OF SENSORS ON BOARD USED IN UC2

Sensor	Properties	Data Types
Ultrasonic range	obstacleL (ObstacleSensors)	Meters
	obstacleC (ObstacleSensors)	Meters
	obstacleR (ObstacleSensors)	Meters
Accelerometer	Acceleration	Number (float)
	Resolution	Number (float)

The SEMIoTICS components that are involved in semantic description of UC2 sensors/actuators, are detailed and explained in subsection 6.2 - “Interaction with SEMIoTICS framework”. An example of the updated version of JSON-LD for the UC2 is following:

```
{
   "id":"urn:robotic-rollator-0",
   "title":"SARA Robotic Rollator",
   "@context":[
      "https://www.w3.org/2019/wot/td/v1",
      {
         "iot":"http://iotschema.org/",
         "schema":"http://schema.org/",
         "sara":"http://www.eng.it/sara/"
      },
      {
         "@language":"en"
      }
   ],
   "@type":"Thing",
   "security":[
      "nosec_sc"
   ],
   "properties":{
      "legR":{
         "@type":"iot:Distance",
         "iot:capability":"sara:RightLegProximitySensing",
         "description":"Current distance of the user's right leg from the back side of the rollator.
",
         "observable":true,
         "readOnly":true,
         "writeOnly":false,
         "type":"integer",
         "schema:minValue":0.0,
         "schema:maxValue":1.5,
         "iot:distanceUnitCode":"iot:Meters",
         "forms":[
            {
               "href":"coap://sara-rollator.ddns.net:5683/robotic-rollator-0/events/legR",
               "op":[
                  "subscribeevent"
               ],
               "contentType":"application/json"
            },
            {
               "href":"http://sara-rollator.ddns.net:8081/robotic-rollator-0/events/legR",
               "op":[
                  "subscribeevent"
               ],
               "subprotocol":"longpoll",
               "contentType":"application/json"
            }
         ],
         "data":{
            "type":"number"
         }
      },
      "legL":{
         "@type":"iot:Distance",
         "iot:capability":"sara:LeftLegProximitySensing",
         "description":"Current distance of the user's left leg from the back side of the rollator."
,
         "observable":true,
         "readOnly":true,
         "writeOnly":false,
         "type":"integer",
         "schema:minValue":0.0,
         "schema:maxValue":1.5,
         "iot:distanceUnitCode":"iot:Meters",
         "forms":[
            {
               "href":"coap://sara-rollator.ddns.net:5683/robotic-rollator-0/events/legL",
               "op":[
                  "subscribeevent"
               ],
               "contentType":"application/json"
            },
            {
               "href":"http://sara-rollator.ddns.net:8081/robotic-rollator-0/events/legL",
               "op":[
                  "subscribeevent"
               ],
               "subprotocol":"longpoll",
               "contentType":"application/json"
            }
         ],
         "data":{
            "type":"number"
         }
      }
   },
   "events":{
      "onchange":{
         "forms":[
            {
               "href":"coap://sara-rollator.ddns.net:5683/robotic-rollator-0/events/onchange",
               "op":[
                  "subscribeevent"
               ],
               "contentType":"application/json"
            },
            {
               "href":"http://sara-rollator.ddns.net:8081/robotic-rollator-0/events/onchange",
               "op":[
                  "subscribeevent"
               ],
               "subprotocol":"longpoll",
               "contentType":"application/json"
            }
         ],
         "data":{
            "type":"integer"
         }
      },
      "legR":{
         "@type":"iot:Distance",
         "iot:capability":"sara:RightLegProximitySensing",
         "description":"Current distance of the user's right leg from the back side of the rollator.
",
         "observable":true,
         "readOnly":true,
         "writeOnly":false,
         "type":"integer",
         "schema:minValue":0.0,
         "schema:maxValue":1.5,
         "iot:distanceUnitCode":"iot:Meters",
         "forms":[
            {
               "href":"coap://sara-rollator.ddns.net:5683/robotic-rollator-0/events/legR",
               "op":[
                  "subscribeevent"
               ],
               "contentType":"application/json"
            },
            {
               "href":"http://sara-rollator.ddns.net:8081/robotic-rollator-0/events/legR",
               "op":[
                  "subscribeevent"
               ],
               "subprotocol":"longpoll",
               "contentType":"application/json"
            }
         ],
         "data":{
            "type":"number"
         }
      },
      "legL":{
         "@type":"iot:Distance",
         "iot:capability":"sara:LeftLegProximitySensing",
         "description":"Current distance of the user's left leg from the back side of the rollator."
,
         "observable":true,
         "readOnly":true,
         "writeOnly":false,
         "type":"integer",
         "schema:minValue":0.0,
         "schema:maxValue":1.5,
         "iot:distanceUnitCode":"iot:Meters",
         "forms":[
            {
               "href":"coap://sara-rollator.ddns.net:5683/robotic-rollator-0/events/legL",
               "op":[
                  "subscribeevent"
               ],
               "contentType":"application/json"
            },
            {
               "href":"http://sara-rollator.ddns.net:8081/robotic-rollator-0/events/legL",
               "op":[
                  "subscribeevent"
               ],
               "subprotocol":"longpoll",
               "contentType":"application/json"
            }
         ],
         "data":{
            "type":"number"
         }
      }
   }
}
```

8.1.2.2. KPI-2.2 - Data type mapping and ontology alignment

The data type mapping and ontology alignment was described in D4.11. “Semantic Interoperability Mechanisms for IoT (final)” with three scenarios focusing on the use cases considered in SEMIoTICS, which include data flow between smart objects and are linked in the composition structure defined by the SPDI patterns in T4.1. Namely, for the UC2 the above procedure is included in phase that the Robotic Assistant should reach the location where the (possible) fall event occurred (D2.5 – Figure 21). This phase is initiated by the Smart Environment sending to the Robot the request to move to the location of the event. Before this step, the interoperability mechanisms, that are triggered by the corresponding pattern rule, are intervened in order to ensure that the data format for the location between UC2 Smart Environment and UC2 Robot is the same, in order to achieve the target of the system (for example use both Degrees Minutes Seconds (DMS) or Decimal Degrees). The SEMIoTICS components and the interactions between them that are involved in this technique are highlighted in the sequence diagram (see Figure 55).

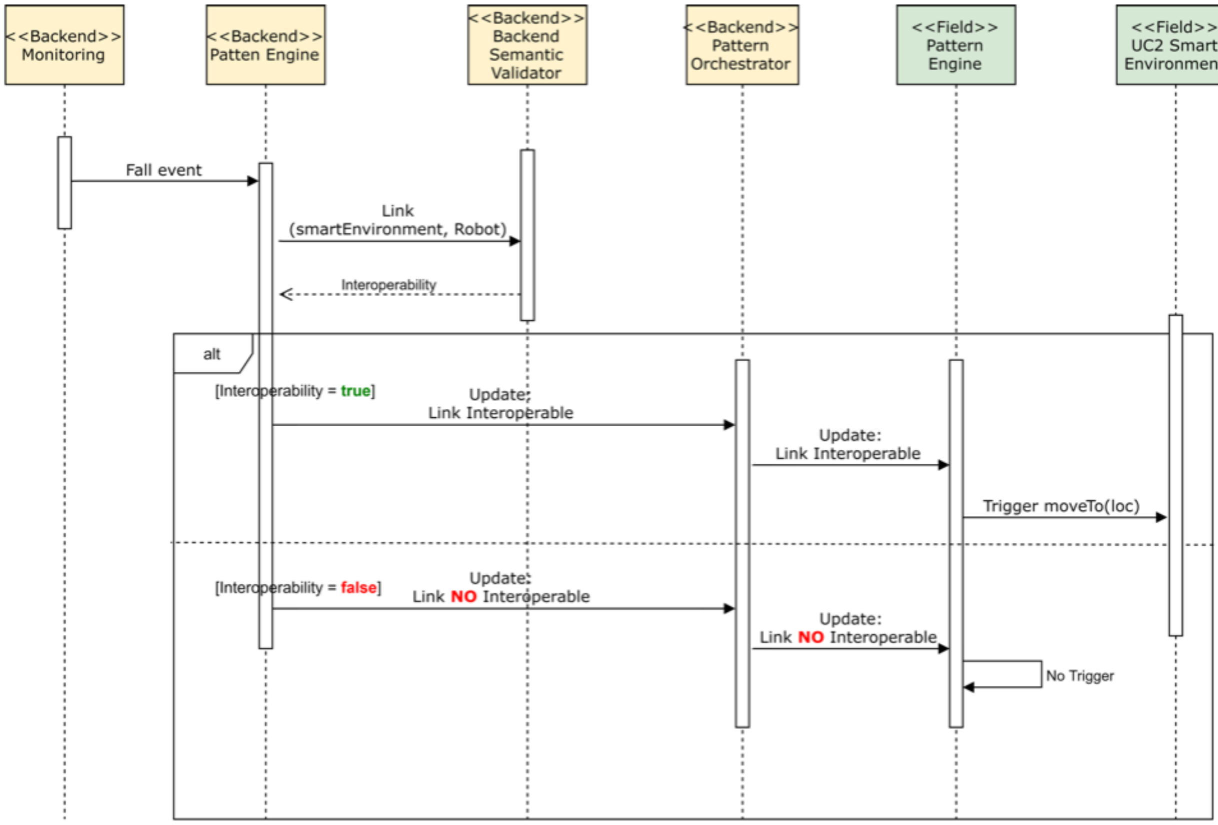

<<Backend>> Monitoring
<<Backend>> Patten Engine
<<Backend>> Backend Semantic Validator
<<Backend>> Pattern Orchestrator
<<Field>> Pattern Engine
<<Field>> UC2 Smart Environment
Fall event
Link (smartEnvironment, Robot)
Interoperability
alt
[Interoperability = true]
Update: Link Interoperable
Update: Link Interoperable
Trigger moveTo(loc)
[Interoperability = false]
Update: Link NO Interoperable
Update: Link NO Interoperable
No Trigger

FIGURE 58: UC2 DATA MAPPING APPROACH

Furthermore, the demonstration of data type mapping and ontology alignment is part of the sub use case 2: Automated, Trustworthy Healthcare Connectivity (see subsection 4.2.6). For instance, the SFC GUI uses the Thing Directory component to discover the available nodes that can be used as source and destination of a flow (end points). Before the instantiation of a service function chain, Pattern Engine component sends a request to Backend Semantic Validator component to verify the interoperability between the end points. When the interoperability between source and destination is not present, the Backend Semantic Validator informs the Pattern Engine so that the latter can take appropriate actions (see Figure 59).

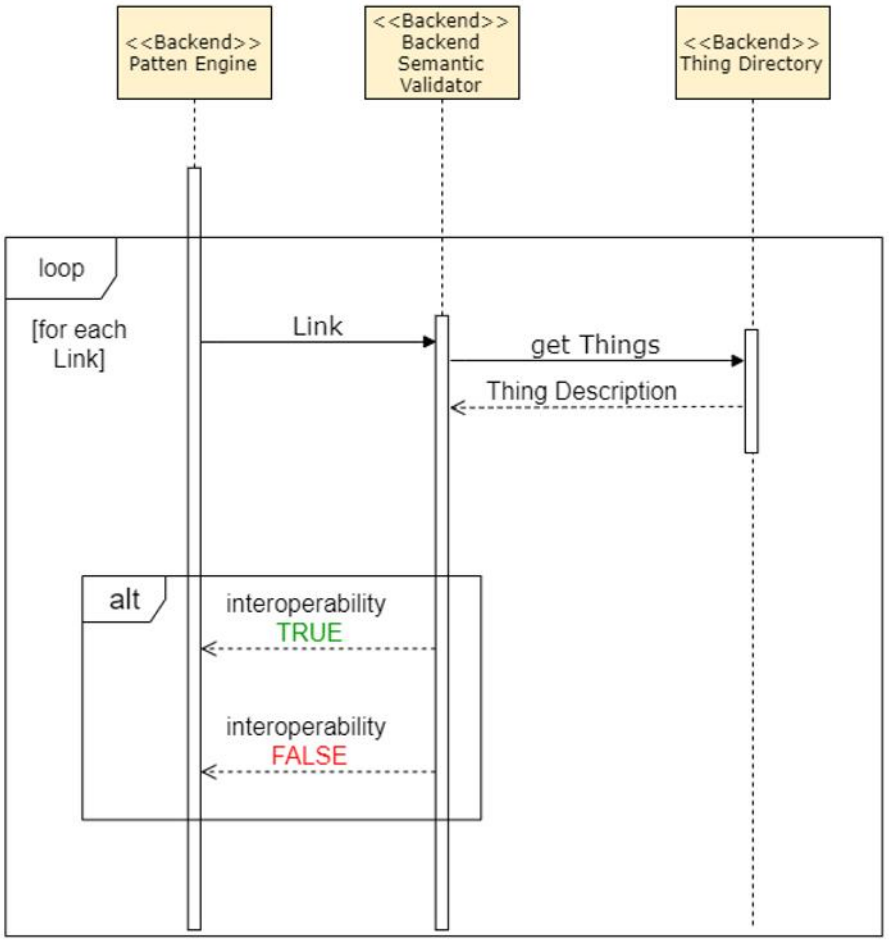


FIGURE 59: SUB USE CASE 2 – INTEROPERABILITY MECHANISMS

8.1.2.3. KPI-2.3 – Semantic Interoperability with 3 IoT Platforms

As it was mentioned in D4.9 – "SEMIoTICS Monitoring, prediction and diagnosis mechanisms (final)", the development of a specific signaller was used to make the CloE-IoT platform observable by the SEMIoTICS Monitoring Component. In fact, the said signaller was leveraged by the SEMIoTICS Monitoring Component in order to observe events generated by the CloE-IoT Event Manager via the FIWARE NGSI v2 interface. Furthermore, SEMIoTICS TDs are serialized to JSON-LD, which enables JSON data to be interlinked and structured based on semantic (D3.9 – "Bootstrapping and interfacing SEMIoTICS field level devices (final)". At the same time, FIWARE introduced the NGSI-LD, which is an evolution of the FIWARE NGSI v2 information model and has been updated/improved to support linked data (entity relationships), property graphs and semantics (exploiting the capabilities offered by JSON-LD)[16]. This aforementioned link has given rise to further investigation of data mapping and the interconnection between FIWARE and SEMIoTICS semantic concept (Table 4), as it was analysed in D4.11 – "Deliverable D4.11 Semantic Interoperability Mechanisms for IoT (final)".

[16] https://fiware-datamodels.readthedocs.io/en/latest/ngsi-ld_faq/index.html

TABLE 4: OVERVIEW OF MAPPING FIWARE DATA MODEL TO IOTSCHEMA.ORG

FIWARE Data Model	SEMIoTICS based on iotschema.org
Entity	Thing Description
Id of Entity	Id of Thing Description
Type of Entity	Type of Thing Description
Attributes	Properties

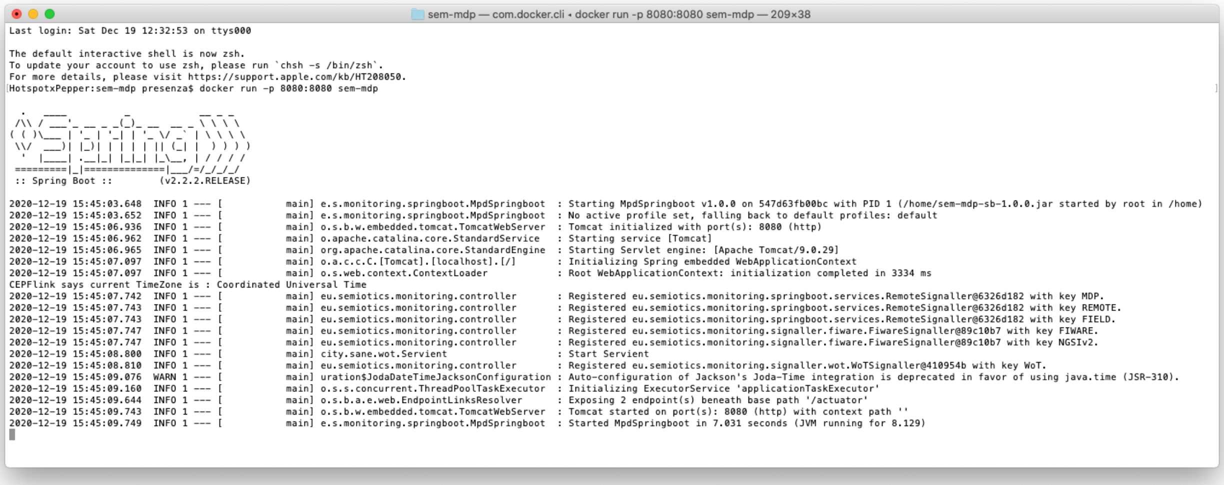
8.1.3. Objective 3 – Monitoring Mechanisms

8.1.3.1. KPI-3.1 - Delivery of a Monitoring Management Layer

8.1.3.1.1.KPI-3.1.1 - Generating monitoring strategies in the 3 targeted IoT platforms

As presented in section 7 the SARA use case needs to monitor events generated by two IoT platforms: SEMIoTICS and CloE-IoT. In particulars SARA monitors the location of the patient using the Fiware NGSI v2 interface offered by the CloE-IoT Coordination Server. SARA also monitors the usage of the appliances (Field Devices) within the monitored apartment using the Web Of Thing (WoT) interface offered by the Smart Home servient developed in SEMIoTICS.

The SEMIoTICS Monitoring, Prediction and Diagnosis (MPD) components allowed monitoring both target platforms thanks to the Fiware signaler and the WoT signaler described in [9]. Figure 60 shows the messages confirming the registration of the two signallers within the MPD instance used for the SARA UC.


sem-mdp — com.docker.cli ◂ docker run -p 8080:8080 sem-mdp — 209×38

```
Last login: Sat Dec 19 12:32:53 on ttys000

The default interactive shell is now zsh.
To update your account to use zsh, please run `chsh -s /bin/zsh`.
For more details, please visit https://support.apple.com/kb/HT208050.
HotspotxPepper:sem-mdp presenza$ docker run -p 8080:8080 sem-mdp

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 \\/  ___)| |_)| | | | | || (_| |  ) ) ) )
  '  |____| .__|_| |_|_| |_\__, | / / / /
 =========|_|==============|___/=/_/_/_/
 :: Spring Boot ::        (v2.2.2.RELEASE)

2020-12-19 15:45:03.648  INFO 1 --- [           main] e.s.monitoring.springboot.MpdSpringboot  : Starting MpdSpringboot v1.0.0 on 547d63fb00bc with PID 1 (/home/sem-mdp-sb-1.0.0.jar started by root in /home)
2020-12-19 15:45:03.652  INFO 1 --- [           main] e.s.monitoring.springboot.MpdSpringboot  : No active profile set, falling back to default profiles: default
2020-12-19 15:45:06.936  INFO 1 --- [           main] o.s.b.w.embedded.tomcat.TomcatWebServer  : Tomcat initialized with port(s): 8080 (http)
2020-12-19 15:45:06.962  INFO 1 --- [           main] o.apache.catalina.core.StandardService   : Starting service [Tomcat]
2020-12-19 15:45:06.965  INFO 1 --- [           main] org.apache.catalina.core.StandardEngine  : Starting Servlet engine: [Apache Tomcat/9.0.29]
2020-12-19 15:45:07.097  INFO 1 --- [           main] o.a.c.c.C.[Tomcat].[localhost].[/]       : Initializing Spring embedded WebApplicationContext
2020-12-19 15:45:07.097  INFO 1 --- [           main] o.s.web.context.ContextLoader            : Root WebApplicationContext: initialization completed in 3334 ms
CEPFlink says current TimeZone is : Coordinated Universal Time
2020-12-19 15:45:07.742  INFO 1 --- [           main] eu.semiotics.monitoring.controller       : Registered eu.semiotics.monitoring.springboot.services.RemoteSignaller@6326d182 with key MDP.
2020-12-19 15:45:07.743  INFO 1 --- [           main] eu.semiotics.monitoring.controller       : Registered eu.semiotics.monitoring.springboot.services.RemoteSignaller@6326d182 with key REMOTE.
2020-12-19 15:45:07.743  INFO 1 --- [           main] eu.semiotics.monitoring.controller       : Registered eu.semiotics.monitoring.springboot.services.RemoteSignaller@6326d182 with key FIELD.
2020-12-19 15:45:07.747  INFO 1 --- [           main] eu.semiotics.monitoring.controller       : Registered eu.semiotics.monitoring.signaller.fiware.FiwareSignaller@89c10b7 with key FIWARE.
2020-12-19 15:45:07.747  INFO 1 --- [           main] eu.semiotics.monitoring.controller       : Registered eu.semiotics.monitoring.signaller.fiware.FiwareSignaller@89c10b7 with key NGSIv2.
2020-12-19 15:45:08.800  INFO 1 --- [           main] city.sane.wot.Servient                   : Start Servient
2020-12-19 15:45:08.810  INFO 1 --- [           main] eu.semiotics.monitoring.controller       : Registered eu.semiotics.monitoring.signaller.wot.WoTSignaller@410954b with key WoT.
2020-12-19 15:45:09.076  WARN 1 --- [           main] uration$JodaDateTimeJacksonConfiguration : Auto-configuration of Jackson's Joda-Time integration is deprecated in favor of using java.time (JSR-310).
2020-12-19 15:45:09.160  INFO 1 --- [           main] o.s.s.concurrent.ThreadPoolTaskExecutor  : Initializing ExecutorService 'applicationTaskExecutor'
2020-12-19 15:45:09.644  INFO 1 --- [           main] o.s.b.a.e.web.EndpointLinksResolver      : Exposing 2 endpoint(s) beneath base path '/actuator'
2020-12-19 15:45:09.743  INFO 1 --- [           main] o.s.b.w.embedded.tomcat.TomcatWebServer  : Tomcat started on port(s): 8080 (http) with context path ''
2020-12-19 15:45:09.749  INFO 1 --- [           main] e.s.monitoring.springboot.MpdSpringboot  : Started MpdSpringboot in 7.031 seconds (JVM running for 8.129)
```

FIGURE 60: REGISTRATION OF FIWARE AND WOT SIGNALERS WITHIN THE MPD COMPONENT.

8.1.3.1.2.KPI-3.1.2 - Fuse results from these monitors

For the purpose of monitoring of ADLs the SARA solutions needs to match patterns defined over events generated by a Fiware source (the CloE-IoT Coordination Server) and a WoT source (the Smart Home servient).

The query language of the SEMIoTICS MPD component allowed us to define cross-platform queries [9]. Query 1 in section 7.3 is an example of the cross-platform queries used for the implementation of the ADL monitoring.

8.1.3.1.3.KPI-3.1.3 - Performing predictive monitoring with an average accuracy of 80%

The SEMIoTICS MPD Component supports both prediction and diagnostic queries [9]. Prediction queries produce an event whenever the observation of a pattern of events let to infer, with a given likelihood, that a monitored source is going to emit an event of a given type. Diagnostic queries produce an event whenever the observation of a pattern of events let to infer, with a given likelihood, that a monitored source emitted an (unobserved) event of a given type. Both type of queries are supported by a causal model that the MPD discovers by means of the observation of the streams of events generated by the monitored event sources. Both types of queries pose the problem of the accuracy of the inference.

In the context of SARA use case we experimented the use of diagnostic queries to infer the ADL ongoing within a Smart Home (see chapter 7). The measurement of the accuracy for the type of inference done by diagnostic queries was done using streams of events generated by a simulated environment using the setting shown in Figure 55. The use of a simulated environment is motivated both by the COVID 19 pandemic and the fact that the use of a real environment would have required long periods of observations.

The training of the model was done using a supervised approach: for each type of ADL we defined a possible sequence of events. Each sequence of events was prefixed with a special type of event (TaskAssignement) carrying the identifier of the ADL represented by the subsequent events (e.g. [“Cooking”,”Kitchen”,”SwitchOvenOn”]). The TaskAssignment event at the beginning of each sequence acted as label for the rest of the sequence. The model was discovered by playing back the sequences by means of the simulator.

The actual measurements were taken by playing back the sequences with the exception of their first event (i.e. the label) and verifying the matching between the event generated by the MPD and the label of the sequence being played back. Figure 56 presents an example of output produced by the ADL simulator during a measurement run.

In the context of the simulated experiments the average measured accuracy was 78.7% .

8.1.3.2. KPI-3.2 - Delivery of a monitoring language (ENG)

The SEMIoTICS MPD Component provides a language to define high-level events that should be produced as result of the monitoring activity [9].

In the context of SARA use case the MDP query language was used to define the queries characterizing an ADL in terms of the events produced by the Smart Environment described in chapter 7. The following query 2 is an example of a query used in the SARA use case. The query 2 is a predictive query describing the pattern of events generated during the execution of the “Leave home” activity. The query 1 in chapter 7 is another example of MPD query defined for the purposes of the SARA use case.

More in general, the MDP Query language was suitable to express all the queries needed for the purposes of the SARA use case.

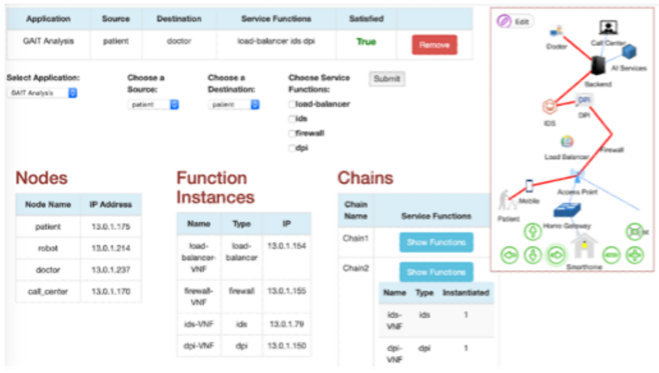
```
{
    "id":8100,
    "events":[
        {“name":"Leave home",
         "eventsPattern":{
                "name”:"Move to bedroom",
                "condition":{"type":"location",
                             "source":{"fiware":"http://homegateway:9090/bedroom"}
                           },
                  "next":{
                      ‟name":"Open wardrobe",
                      ‟condition":{"type":"open",
                                     "source":{"wot":"http://homegateway:9090/wardrobe"}
                              },
                      "next":{
                          ‟name":"Move to entrance”,
                          "condition":{"type":"location",
                                "source":{"fiware":"http://homegateway:9090/entrance"}
                              },
                     "causedBy":{
                                "name":"GoForAWalkTaskAssignment",
                                "condition":{"type":"GoForAWalkTask",
                                            ‟source":{"source":"http://saraserver:9191/tasks/"},
                                            "likelihood":70.0
                                            }
                                }
                            }
                      }
                  }
              }
          }
      ],
      ‟listeners":["http://localhost:8181/sara/securityalerts"]
}
```

QUERY 2: AN EXAMPLE OF SARA UC DIAGNOSTIC QUERY

8.1.4. Objective 4 – Multi-layered Embedded Intelligence

8.1.4.1. KPI-4.2 - Delivery of mechanisms with adaptation time of 15ms

To achieve the main goal of this KPI, the developed SFC patterns were used as a sufficient adaptation mechanism to offer proactive adaptations as evaluated in this use case. To accomplish the goal, the procedure begins from the time that a requirement is inserted until the triggering of the required adaptation steps toward the satisfaction of the requirement. To proceed to the evaluation of this KPI and investigate whether the goal of 15ms can be achieved, the time was measured under two different conditions: when there was the need to instantiate a chain and when both the creation and the instantiation of a chain was needed, based on the insertion of a requirement. The time was measured by monitoring the timestamps of the time of the requirement insertion and the time until the instantiation of an unistantiated chain in OpenSource MANO. More specifically, the time of requirement insertion, adaptation triggering and complete was evaluated for the service function instantiation.
The first experiment is related to the instantiation of a chain when the descriptor exists. As can be seen in the Figure 61, when a chain descriptor exists, the required time from the verification of the requirement regarding the instantiation of a chain until the begin of the adaptation triggering is measured at 1ms, achieving the KPI for less than 15ms adaptation time. However, the time required to finalize the instantiation of the respective VNFs in the OpenStack is measured to almost 3sec, but this is related to the number of requested VNFs and resource capabilities of the devices holding the OpenStack.



Application	Source	Destination	Service Functions	Satisfied	
GAIT Analysis	patient	doctor	load-balancer ids dpi	True	Remove

Select Application: GAIT Analysis
Choose a Source: patient
Choose a Destination: patient
Choose Service Functions: load-balancer, ids, firewall, dpi
Submit

Nodes

Node Name	IP Address
patient	13.0.1.175
robot	13.0.1.214
doctor	13.0.1.237
call_center	13.0.1.170

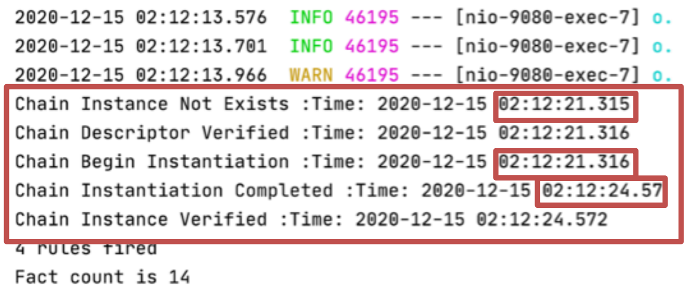
Function Instances

Name	Type	IP
load-balancer-VNF	load-balancer	13.0.1.154
firewall-VNF	firewall	13.0.1.155
ids-VNF	ids	13.0.1.79
dpi-VNF	dpi	13.0.1.150

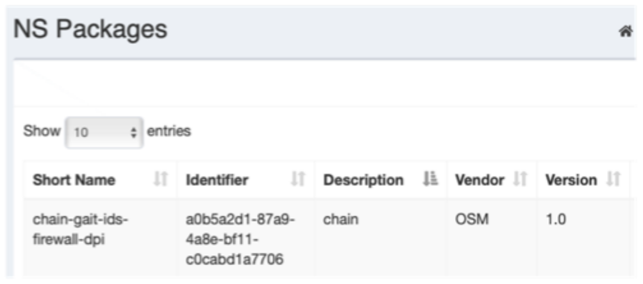
Chains

Chain Name	Service Functions
Chain1	Show Functions
Chain2	Show Functions

Name	Type	Instantiated
ids-VNF	ids	1
dpi-VNF	dpi	1



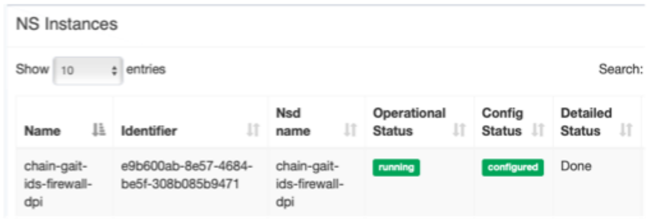
```
2020-12-15 02:12:13.576  INFO 46195 --- [nio-9080-exec-7] o.
2020-12-15 02:12:13.701  INFO 46195 --- [nio-9080-exec-7] o.
2020-12-15 02:12:13.966  WARN 46195 --- [nio-9080-exec-7] o.
Chain Instance Not Exists :Time: 2020-12-15 02:12:21.315
Chain Descriptor Verified :Time: 2020-12-15 02:12:21.316
Chain Begin Instantiation :Time: 2020-12-15 02:12:21.316
Chain Instantiation Completed :Time: 2020-12-15 02:12:24.57
Chain Instance Verified :Time: 2020-12-15 02:12:24.572
4 rules fired
Fact count is 14
```



NS Packages

Show 10 entries

Short Name	Identifier	Description	Vendor	Version
chain-gait-ids-firewall-dpi	a0b5a2d1-87a9-4a8e-bf11-c0cabd1a7706	chain	OSM	1.0



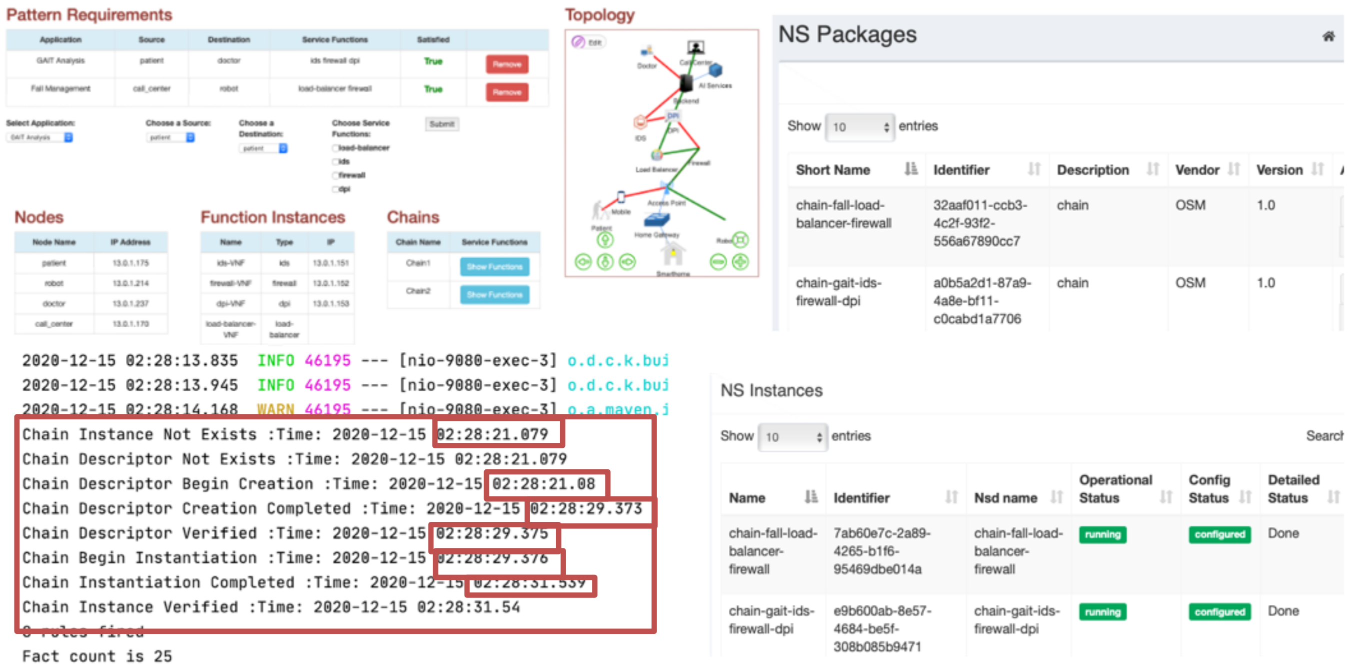
NS Instances

Show 10 entries Search:

Name	Identifier	Nsd name	Operational Status	Config Status	Detailed Status
chain-gait-ids-firewall-dpi	e9b600ab-8e57-4684-be5f-308b085b9471	chain-gait-ids-firewall-dpi	running	configured	Done

FIGURE 61: CHAIN INSTANTIATION FROM AN EXISTING NETWORK DESCRIPTOR

The second experiment is focusing on the instantiation of a chain when the descriptor does not exist. As can be seen in the Figure 62, when a chain descriptor does not exist the required time from the verification of the requirement regarding the creation and the instantiation of a chain until the begin of the adaptation triggering is measured again at 1ms achieving the requirement for less than 15ms adaptation time. In addition, the time required to finalize the creation of the chain descriptor is less than 2ms. However, the instantiation of the respective VNFs is measured less than 3sec, but this is related again to the number of requested VNFs and resource capabilities of the devices holding the OpenStack.



Pattern Requirements

Application	Source	Destination	Service Functions	Satisfied	
GAIT Analysis	patient	doctor	ids firewall dpi	True	Remove
Fall Management	call_center	robot	load-balancer firewall	True	Remove

Select Application: GAIT Analysis
Choose a Source: patient
Choose a Destination: patient
Choose Service Functions: load-balancer, ids, firewall, dpi
Submit

Nodes

Node Name	IP Address
patient	13.0.1.175
robot	13.0.1.214
doctor	13.0.1.237
call_center	13.0.1.170

Function Instances

Name	Type	IP
ids-VNF	ids	13.0.1.151
firewall-VNF	firewall	13.0.1.152
dpi-VNF	dpi	13.0.1.153
load-balancer-VNF	load-balancer	

Chains

Chain Name	Service Functions
Chain1	Show Functions
Chain2	Show Functions

NS Packages

Show 10 entries

Short Name	Identifier	Description	Vendor	Version
chain-fall-load-balancer-firewall	32aaf011-ccb3-4c2f-93f2-556a67890cc7	chain	OSM	1.0
chain-gait-ids-firewall-dpi	a0b5a2d1-87a9-4a8e-bf11-c0cabd1a7706	chain	OSM	1.0

```
2020-12-15 02:28:13.835  INFO 46195 --- [nio-9080-exec-3] o.d.c.k.bui
2020-12-15 02:28:13.945  INFO 46195 --- [nio-9080-exec-3] o.d.c.k.bui
2020-12-15 02:28:14.168  WARN 46195 --- [nio-9080-exec-3] o.a.maven.i
Chain Instance Not Exists :Time: 2020-12-15 02:28:21.079
Chain Descriptor Not Exists :Time: 2020-12-15 02:28:21.079
Chain Descriptor Begin Creation :Time: 2020-12-15 02:28:21.08
Chain Descriptor Creation Completed :Time: 2020-12-15 02:28:29.373
Chain Descriptor Verified :Time: 2020-12-15 02:28:29.375
Chain Begin Instantiation :Time: 2020-12-15 02:28:29.376
Chain Instantiation Completed :Time: 2020-12-15 02:28:31.539
Chain Instance Verified :Time: 2020-12-15 02:28:31.54
8 rules fired
Fact count is 25
```

NS Instances

Show 10 entries · Search

Name	Identifier	Nsd name	Operational Status	Config Status	Detailed Status
chain-fall-load-balancer-firewall	7ab60e7c-2a89-4265-b1f6-95469dbe014a	chain-fall-load-balancer-firewall	running	configured	Done
chain-gait-ids-firewall-dpi	e9b600ab-8e57-4684-be5f-308b085b9471	chain-gait-ids-firewall-dpi	running	configured	Done

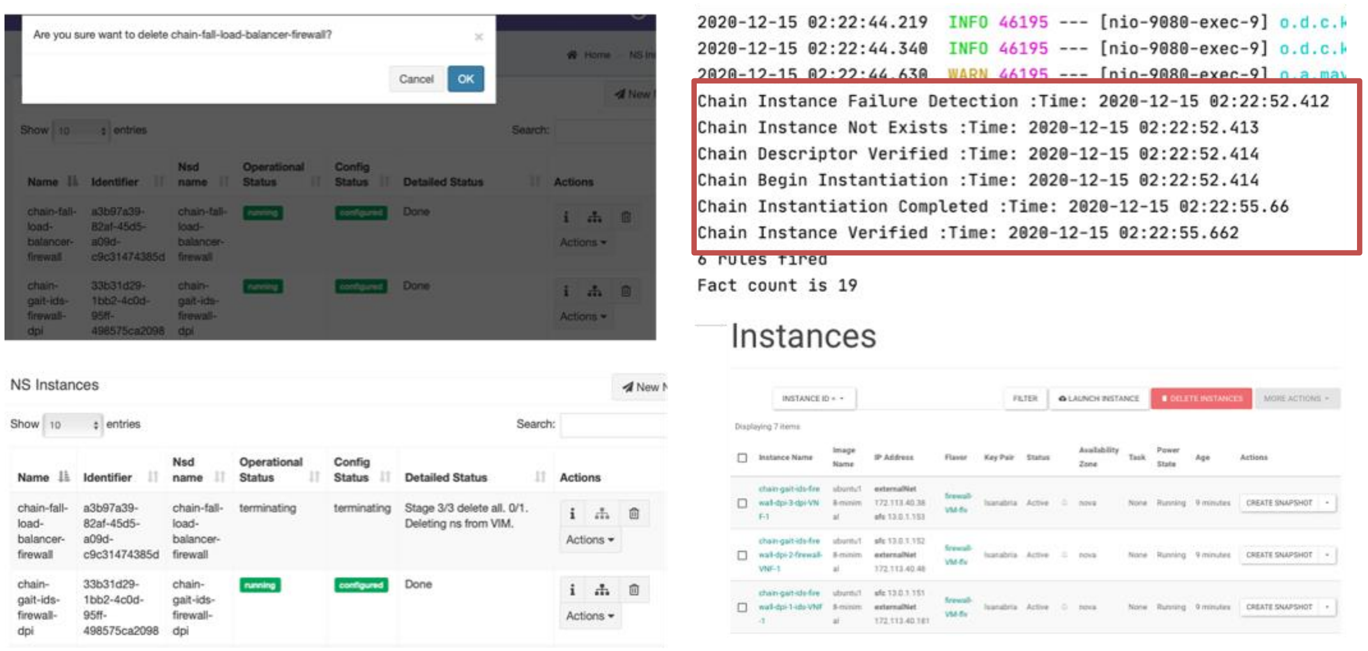
FIGURE 62: CHAIN CRETION AND INSTANTIATION

8.1.4.2. KPI-4.3 - Delivery of adaptations mechanisms enabling improvement by at least 20%

This KPI aims to improve past adaptations by means of monitoring and intelligence analytics. In order to accomplish this, the existing adaptations will be measured beginning from the time that a failure has been detected until the time that it was required to restore the above failure. The described methodology is based on two scenarios for achieving the required KPI. The first scenario is that, after a failure, there is no adaptation and this is the behavior prior to SEMIoTICS. In the second scenario there is an existing adaptation mechanism, which SEMIoTICS tries to improve upon. In the first scenario any future adaptation mechanism provided by SEMIoTICS will automatically imply 100% improvement given the fact that prior to SEMIoTICS there was no adaptation at all. In the second scenario the improvement of the new mechanisms, will be measured by using appropriate metrics based on the use cases.

For the delivery of evolution mechanisms enabling the detection and analysis of the effects of past adaptations the improvement of future adaptations, SFC patterns were used as well. More specifically, the developed SFC patterns were used as a sufficient adaptation mechanism to offer reactive adaptations by means of monitoring and intelligence analytics, as evaluated in this use case. To accomplish the goal, the procedure begins from the time that an event such as a failure is required until the triggering of the required adaptation steps to the end of the restoration of the updated action. To do so, it was measured the time between two different conditions the detection of an event such a failure starting from the detection of the failure until the triggering of the instantiation of a new one. For instance, when a failure has been identified such as the failure of a service function, the result will be related to the not satisfaction of the requirement inserted in the past for end to end traffic forwarding through the respective chain, resulting the lack of end to end connectivity.

The first experiment includes the detection of a failure of an instantiated chain and the time required to instantiate a new one based on the existing descriptor. As can be seen in the Figure 63, when a chain instance is deleted, the failure is detected triggering the patterns to trigger the adaptation procedure based on the inserted requirement.


Are you sure want to delete chain-fall-load-balancer-firewall?

Name	Identifier	Nsd name	Operational Status	Config Status	Detailed Status	Actions
chain-fall-load-balancer-firewall	a3b97a39-82af-45d5-a09d-c9c31474385d	chain-fall-load-balancer-firewall	running	configured	Done	Actions
chain-gait-ids-firewall-dpi	33b31d29-1bb2-4c0d-95ff-498575ca2098	chain-gait-ids-firewall-dpi	running	configured	Done	Actions

NS Instances

Name	Identifier	Nsd name	Operational Status	Config Status	Detailed Status	Actions
chain-fall-load-balancer-firewall	a3b97a39-82af-45d5-a09d-c9c31474385d	chain-fall-load-balancer-firewall	terminating	terminating	Stage 3/3 delete all. 0/1. Deleting ns from VIM.	Actions
chain-gait-ids-firewall-dpi	33b31d29-1bb2-4c0d-95ff-498575ca2098	chain-gait-ids-firewall-dpi	running	configured	Done	Actions

```
2020-12-15 02:22:44.219  INFO 46195 --- [nio-9080-exec-9] o.d.c.k
2020-12-15 02:22:44.340  INFO 46195 --- [nio-9080-exec-9] o.d.c.k
2020-12-15 02:22:44.630  WARN 46195 --- [nio-9080-exec-9] o.a.mav
Chain Instance Failure Detection :Time: 2020-12-15 02:22:52.412
Chain Instance Not Exists :Time: 2020-12-15 02:22:52.413
Chain Descriptor Verified :Time: 2020-12-15 02:22:52.414
Chain Begin Instantiation :Time: 2020-12-15 02:22:52.414
Chain Instantiation Completed :Time: 2020-12-15 02:22:55.66
Chain Instance Verified :Time: 2020-12-15 02:22:55.662
6 rules fired
Fact count is 19
```

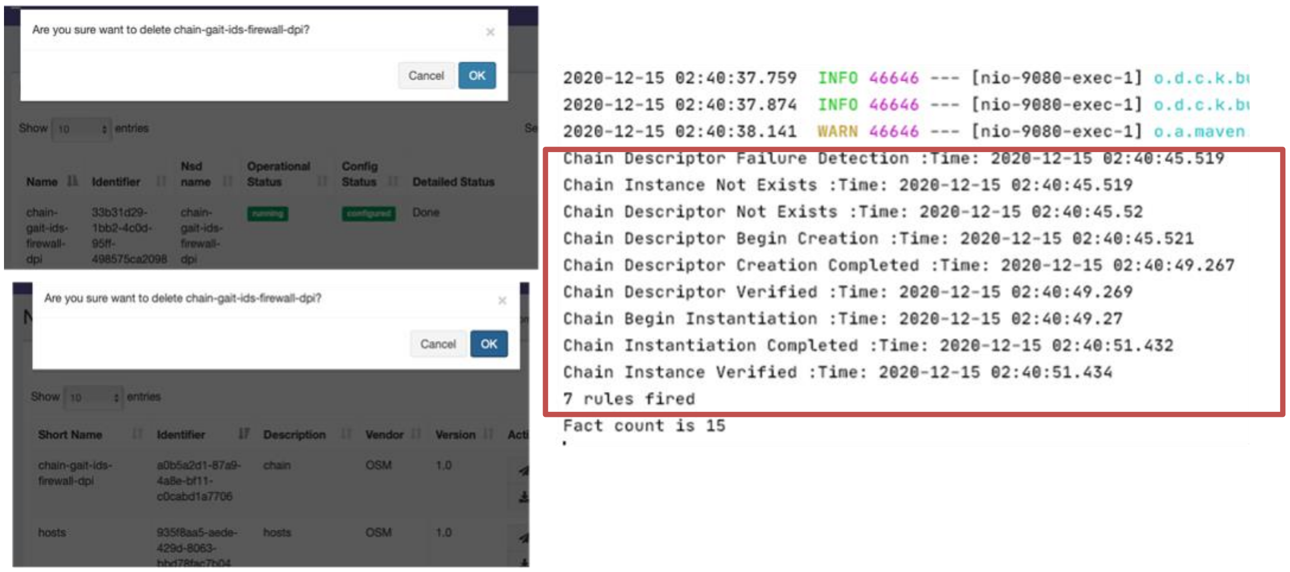
Instances

Displaying 7 items

Instance Name	Image Name	IP Address	Flavor	Key Pair	Status		Availability Zone	Task	Power State	Age	Actions
chain-gait-ids-firewall-dpi-3-dpi-VNF-1	ubuntu18-minimal	externalNet 172.113.40.38 sfc 13.0.1.153	firewall-VM-flv	lsanabria	Active		nova	None	Running	9 minutes	CREATE SNAPSHOT
chain-gait-ids-firewall-dpi-2-firewall-VNF-1	ubuntu18-minimal	sfc 13.0.1.152 externalNet 172.113.40.48	firewall-VM-flv	lsanabria	Active		nova	None	Running	9 minutes	CREATE SNAPSHOT
chain-gait-ids-firewall-dpi-1-ids-VNF-1	ubuntu18-minimal	sfc 13.0.1.151 externalNet 172.113.40.181	firewall-VM-flv	lsanabria	Active		nova	None	Running	9 minutes	CREATE SNAPSHOT

FIGURE 63: CHAIN INSTANTIATION AFTER THE DELETION OF AN INSTANTIATED CHAIN

The second experiment includes both the deletion of a chain instance and the deletion of the respective descriptor procedure followed by the creation and the instantiation of a new one. As can be seen in the Figure 64, when a chain instance is deleted, the failure is detected triggering the patterns to trigger the adaptation procedure based on the inserted requirement.


Are you sure want to delete chain-gait-ids-firewall-dpi?

Name	Identifier	Nsd name	Operational Status	Config Status	Detailed Status
chain-gait-ids-firewall-dpi	33b31d29-1bb2-4c0d-95ff-498575ca2098	chain-gait-ids-firewall-dpi	running	configured	Done

Are you sure want to delete chain-gait-ids-firewall-dpi?

Short Name	Identifier	Description	Vendor	Version
chain-gait-ids-firewall-dpi	a0b5a2d1-87a9-4a8e-bf11-c0cabd1a7706	chain	OSM	1.0
hosts	935f8aa5-aede-429d-8063-bbd78fac7b04	hosts	OSM	1.0

```
2020-12-15 02:40:37.759  INFO 46646 --- [nio-9080-exec-1] o.d.c.k.bu
2020-12-15 02:40:37.874  INFO 46646 --- [nio-9080-exec-1] o.d.c.k.bu
2020-12-15 02:40:38.141  WARN 46646 --- [nio-9080-exec-1] o.a.maven
Chain Descriptor Failure Detection :Time: 2020-12-15 02:40:45.519
Chain Instance Not Exists :Time: 2020-12-15 02:40:45.519
Chain Descriptor Not Exists :Time: 2020-12-15 02:40:45.52
Chain Descriptor Begin Creation :Time: 2020-12-15 02:40:45.521
Chain Descriptor Creation Completed :Time: 2020-12-15 02:40:49.267
Chain Descriptor Verified :Time: 2020-12-15 02:40:49.269
Chain Begin Instantiation :Time: 2020-12-15 02:40:49.27
Chain Instantiation Completed :Time: 2020-12-15 02:40:51.432
Chain Instance Verified :Time: 2020-12-15 02:40:51.434
7 rules fired
Fact count is 15
```

FIGURE 64: CHAIN CREATION AND INSTANTIATION WHEN A NETWORK DESCRIPTOR AFTER THE DELETION OF THE RESPECTIVE INSTANCE AND DESCRIPTOR

As can be observed by both experiments, the adaptation mechanism provided by SEMIoTICS imply 100% improvement given the fact that prior to SEMIoTICS, there was no adaptation at all in the described use case.

Finally, the capability for adaptation improvements based on patterns strengthen the importance of the implemented framework.

8.1.5. Objective 5 – IoT-aware Programmable Networks

8.1.5.1. KPI-5.1 - Deployment of a multi-domain SDN orchestrator

Multi-domain SDN orchestration is supported in this use cases by the deployment of the SEMIoTICS architecture in multiple-locations around different countries of Europe. The development of multiple cross-layer SEMIoTICS component deployed in different locations can be seen in the map in the Figure 65. The location of components and the associated tools included in this use case are evaluated and demonstrated under the different sub-uses in this deliverable, deployed as follows:

- The field devices such as the robot and the rollator located in the users/patients' place are deployed at Engineering Premises in Rome (ENG), where the backend services of use case specific apps such as Doctor Services, Areas services and Fiware Lab are deployed at Engineering Premises in Vincenza in Italy.
- The network orchestration is applied through the NFV architecture located in CTTC premises in Barcelona that is able to enable traffic forwarding as described in this deliverable through the different end hosts in countries such as Italy and Greece.
- The different components of SEMIoTICS architecture in the backend layer such as the Pattern Orchestrator/Engine and GUI, are deployed in the BlueSoft premises Warsaw in Poland.
- The security manager which is able to authorize users to provide a sufficient description of the multiple domain orchestration under this use case. is done in University of Passau Premises in Germany
- Finally, the role of the end user, able to orchestrate the configuration and the testing of trustworthy connectivity, is done from FORTH premises in Heraklion, Greece.

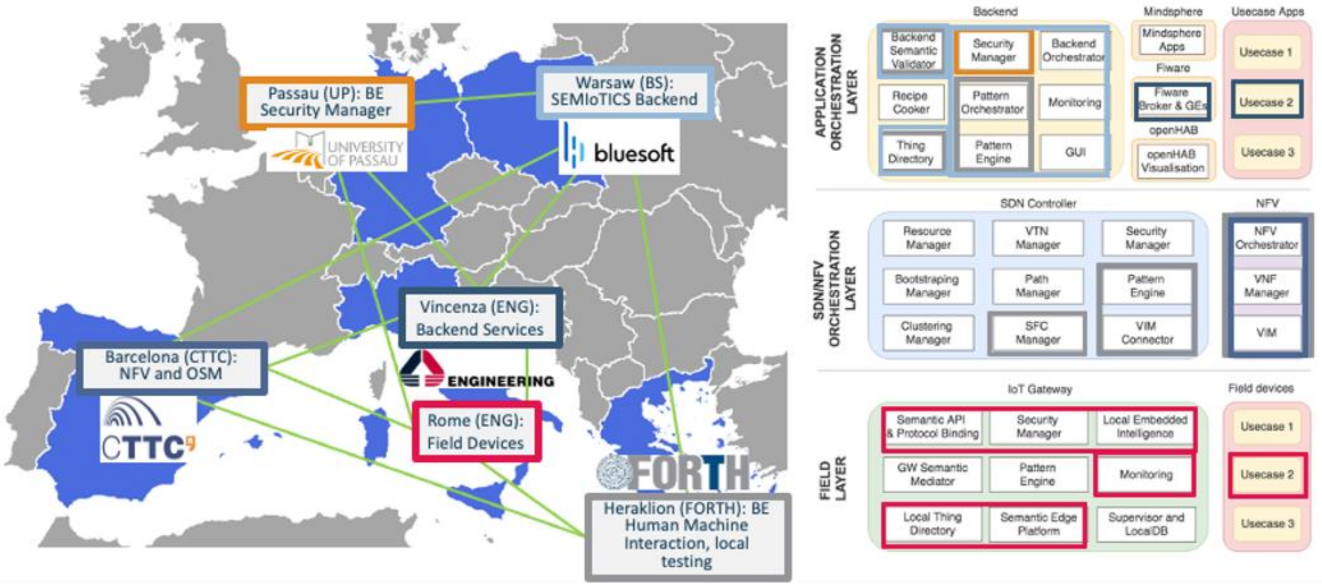


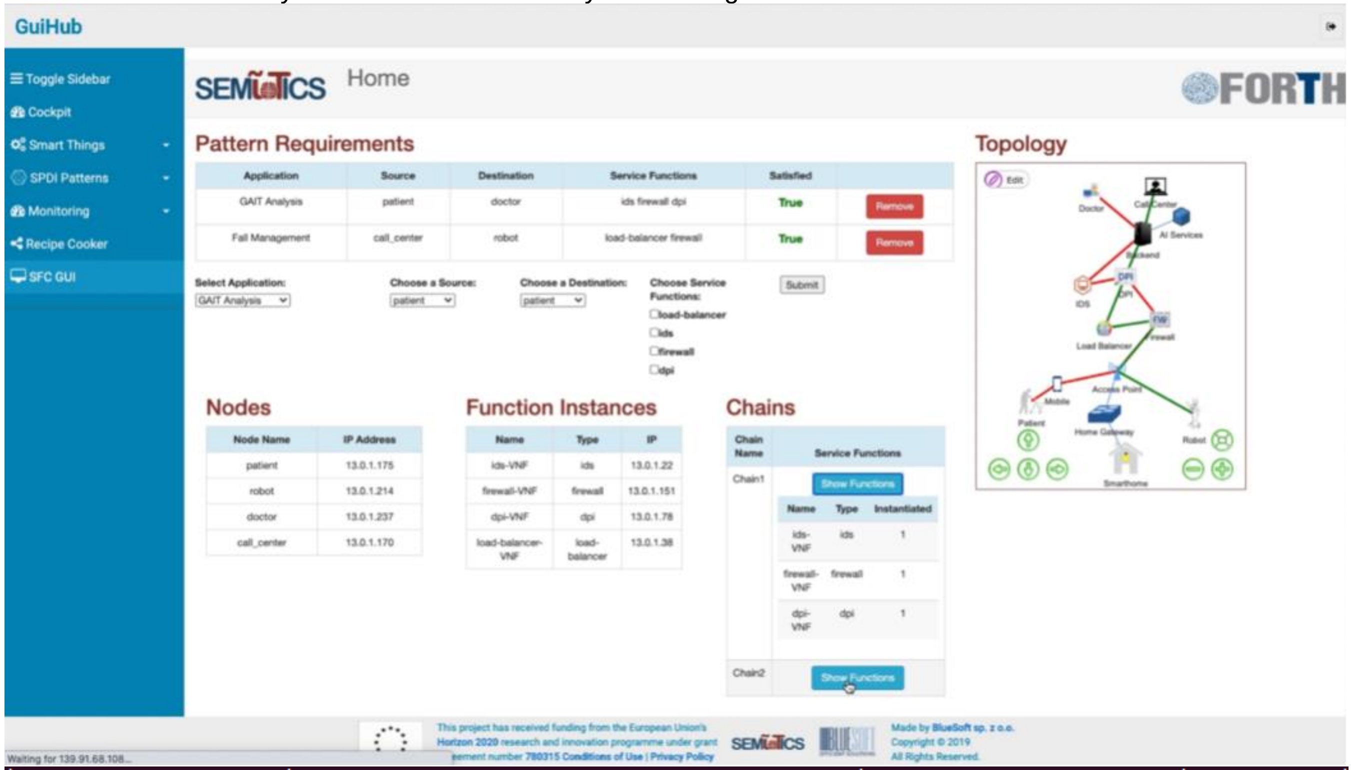
FIGURE 65: MULTI-DOMAIN USE CASE COMPONENT ORCHESTRATION AND DISTIRBUTION

The scalability capabilities of SEMIoTICS framework can be extended in the assisted living use case by the inclusion of additional users to provide healthcare services. Especially with the inclusion of NFV framework, more virtual computing and storage resources can be easily allocated when needed for the scalability purposes in intra but also in inter multi-domain capabilities. As can be shown in the map topology, additional users/patients can be added as well together with the Rome (ENG) Field Devices under the same map. However, the addition of additional users, although they can be supported under the same infrastructure, other parameters, such as available field devices (ie rollators, pepper robots), increase complexity and cost going beyond the main scope and the objectives of this use case.

During the evaluation of this use case, all the components included in this map were evaluated due to the need for successful validation of the different sub-use case presented in the deliverable. Based on the evaluation of the components included in this use case, the multi-domain orchestration in use case 2 can guarantee the TRL5 since all the involved components in the workflow including the SDN controller in OpenStack in combination with the respective VNFs can guarantee the TRL5 level requirement.

8.1.5.2. KPI-5.2 - Service Function Chaining (SFC) of a minimum 3 VNFs

This KPI has been fulfilled, as we have commented above in sub use case 2. Namely, we have created SFCs that have three VNFs, which is onboarded and instantiated properly in the NFV testbed. Thereby, the NFV MANO component is able to build and configure the SFC for each kind of traffic properly. In the next figures, we show how the SFC have effectively three VNFs and that they are running in the NFV testbed.



Pattern Requirements

Application	Source	Destination	Service Functions	Satisfied	
GAIT Analysis	patient	doctor	ids firewall dpi	True	Remove
Fall Management	call_center	robot	load-balancer firewall	True	Remove

Select Application: GAIT Analysis
Choose a Source: patient
Choose a Destination: patient
Choose Service Functions: ☐load-balancer ☐ids ☐firewall ☐dpi
Submit

Nodes

Node Name	IP Address
patient	13.0.1.175
robot	13.0.1.214
doctor	13.0.1.237
call_center	13.0.1.170

Function Instances

Name	Type	IP
ids-VNF	ids	13.0.1.22
firewall-VNF	firewall	13.0.1.151
dpi-VNF	dpi	13.0.1.78
load-balancer-VNF	load-balancer	13.0.1.38

Chains

Chain Name	Service Functions		
Chain1	Show Functions		
	Name	Type	Instantiated
	ids-VNF	ids	1
	firewall-VNF	firewall	1
	dpi-VNF	dpi	1
Chain2	Show Functions		

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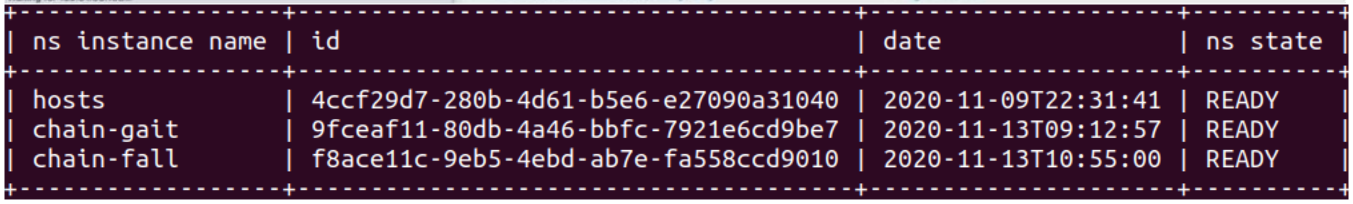
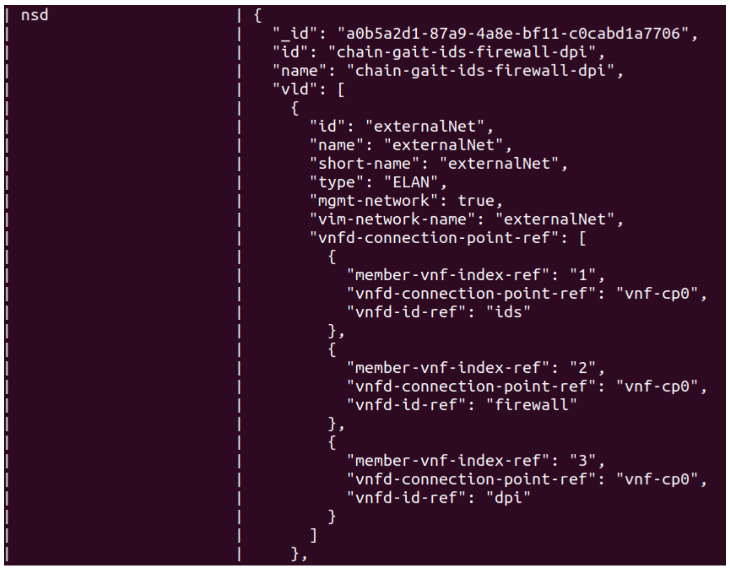
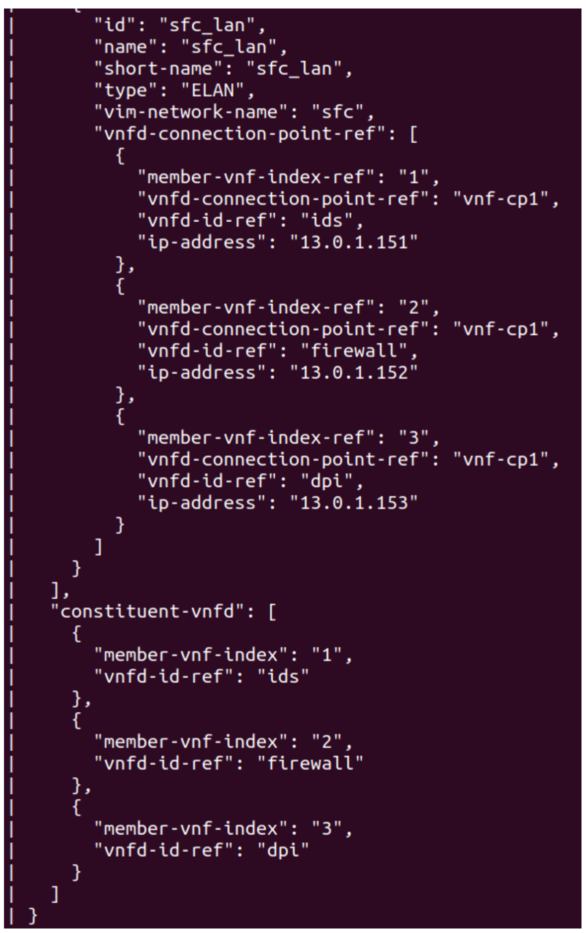
Waiting for 139.91.68.108...



```
+------------------+-------------------------------------+-----------------------+----------+
| ns instance name | id                                   | date                  | ns state |
+------------------+-------------------------------------+-----------------------+----------+
| hosts            | 4ccf29d7-280b-4d61-b5e6-e27090a31040 | 2020-11-09T22:31:41 | READY    |
| chain-gait       | 9fceaf11-80db-4a46-bbfc-7921e6cd9be7 | 2020-11-13T09:12:57 | READY    |
| chain-fall       | f8ace11c-9eb5-4ebd-ab7e-fa558ccd9010 | 2020-11-13T10:55:00 | READY    |
+------------------+-------------------------------------+-----------------------+----------+
```



```
| nsd                          | {
|                              |   "_id": "a0b5a2d1-87a9-4a8e-bf11-c0cabd1a7706",
|                              |   "id": "chain-gait-ids-firewall-dpi",
|                              |   "name": "chain-gait-ids-firewall-dpi",
|                              |   "vld": [
|                              |     {
|                              |       "id": "externalNet",
|                              |       "name": "externalNet",
|                              |       "short-name": "externalNet",
|                              |       "type": "ELAN",
|                              |       "mgmt-network": true,
|                              |       "vim-network-name": "externalNet",
|                              |       "vnfd-connection-point-ref": [
|                              |         {
|                              |           "member-vnf-index-ref": "1",
|                              |           "vnfd-connection-point-ref": "vnf-cp0",
|                              |           "vnfd-id-ref": "ids"
|                              |         },
|                              |         {
|                              |           "member-vnf-index-ref": "2",
|                              |           "vnfd-connection-point-ref": "vnf-cp0",
|                              |           "vnfd-id-ref": "firewall"
|                              |         },
|                              |         {
|                              |           "member-vnf-index-ref": "3",
|                              |           "vnfd-connection-point-ref": "vnf-cp0",
|                              |           "vnfd-id-ref": "dpi"
|                              |         }
|                              |       ]
|                              |     },
```



```
|        "id": "sfc_lan",
|        "name": "sfc_lan",
|        "short-name": "sfc_lan",
|        "type": "ELAN",
|        "vim-network-name": "sfc",
|        "vnfd-connection-point-ref": [
|          {
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|            "vnfd-connection-point-ref": "vnf-cp1",
|            "vnfd-id-ref": "ids",
|            "ip-address": "13.0.1.151"
|          },
|          {
|            "member-vnf-index-ref": "2",
|            "vnfd-connection-point-ref": "vnf-cp1",
|            "vnfd-id-ref": "firewall",
|            "ip-address": "13.0.1.152"
|          },
|          {
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|            "vnfd-connection-point-ref": "vnf-cp1",
|            "vnfd-id-ref": "dpi",
|            "ip-address": "13.0.1.153"
|          }
|        ]
|      }
|    ],
|    "constituent-vnfd": [
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|      },
|      {
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|      },
|      {
|        "member-vnf-index": "3",
|        "vnfd-id-ref": "dpi"
|      }
|    ]
| }
```

8.1.6. Objective 6 – Development of a Reference Prototype

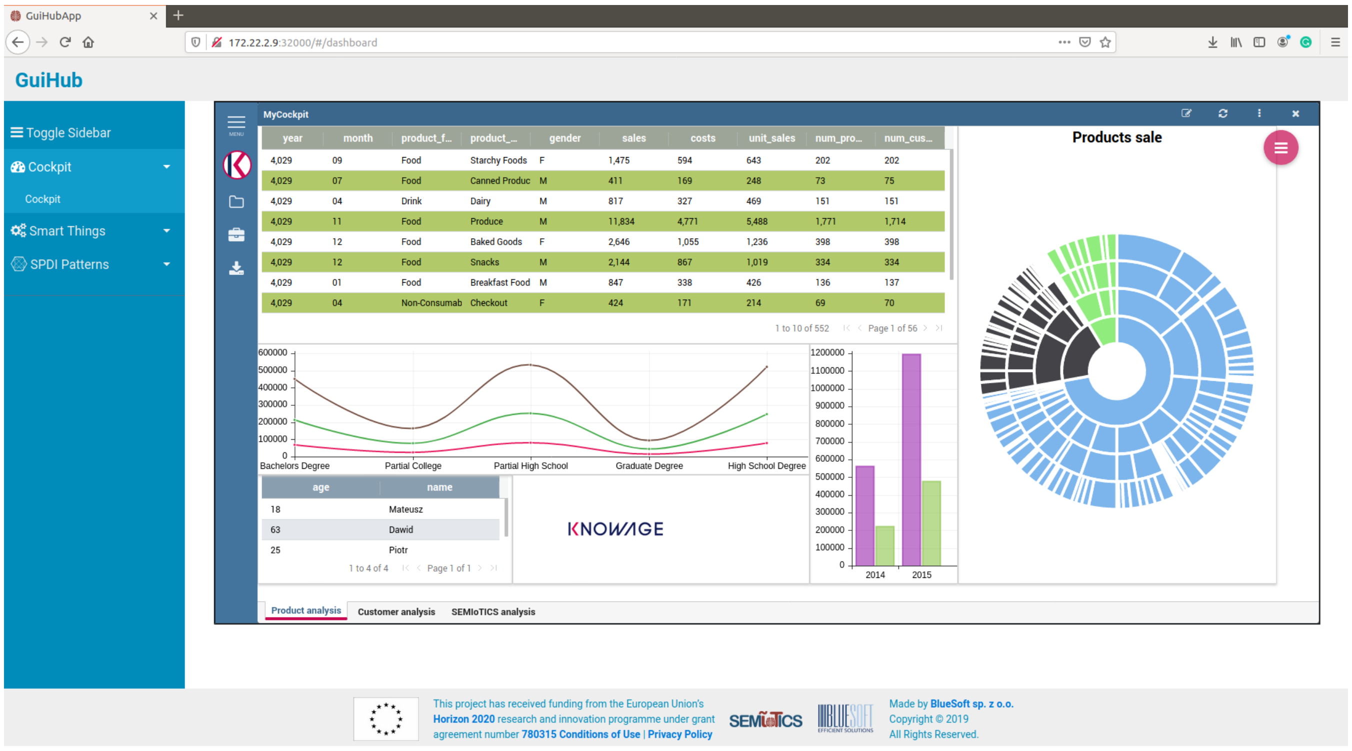
8.1.6.1. KPI-6.1 Reduce manual interventions required for bootstrapping of smart object in each use case domain by at least 80%.

As commented above, the bootstrapping service for the smart objects involves the availability of other functional blocks, e.g. at the networking level the VNFs and SFC that allow to forward the traffic from the smart objects towards the backend.

The NFV MANO automatizes the creation and instantiation of the VNFs on top of the NFVI in the form of VMs. Also, it automatizes the configuration, software installation and programs executions in the VM at boot time. In the annex B we illustrate these automation processes thoroughly. Namely, we show how the OSM, automates the creation, onboarding and instantiation of the SFC and VNF, and it only requires that the user fills some configuration files. Thereby, the manual intervention is almost avoided. Moreover, as explained in the annex B, the cloud init files associated to the VNFs allow to define the software packages and the initial configuration of the VM that implements the VNFs. Thereby, the manual intervention is almost avoided as well.

8.1.6.2. KPI-6.2 - Leveraging upon FIWARE assets in developing the SEMIoTICS framework

The aim of this KPI was to analyse the General Enablers developed in the project FIWARE for their possible use in the SEMIoTICS project. The possibility study integration of the FIWARE General Enablers integration with the SEMIoTICS has been performed. The analysis included all FIREWARE components in total. The result of this analysis is described in Deliverable 5.2 in section 4.2. In the SARA Health Scenario is used only one FIWARE General Enabler - Knowage. It is the open source business analytics suite that provides the creating various types of visualizations starting from simple tables, through many types of graphs ending on interactive maps. It offers many business analytics tools like periodic reporting, business predictions, and interactive cockpit. In the following figures you will find an example of KNOWAGE applications as part of SEMIoTICS GUI.



year	month	product_f...	product_...	gender	sales	costs	unit_sales	num_pro...	num_cus...
4,029	09	Food	Starchy Foods	F	1,475	594	643	202	202
4,029	07	Food	Canned Produc	M	411	169	248	73	75
4,029	04	Drink	Dairy	M	817	327	469	151	151
4,029	11	Food	Produce	M	11,834	4,771	5,488	1,771	1,714
4,029	12	Food	Baked Goods	F	2,646	1,055	1,236	398	398
4,029	12	Food	Snacks	M	2,144	867	1,019	334	334
4,029	01	Food	Breakfast Food	M	847	338	426	136	137
4,029	04	Non-Consumab	Checkout	F	424	171	214	69	70

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age	name
18	Mateusz
63	Dawid
25	Piotr

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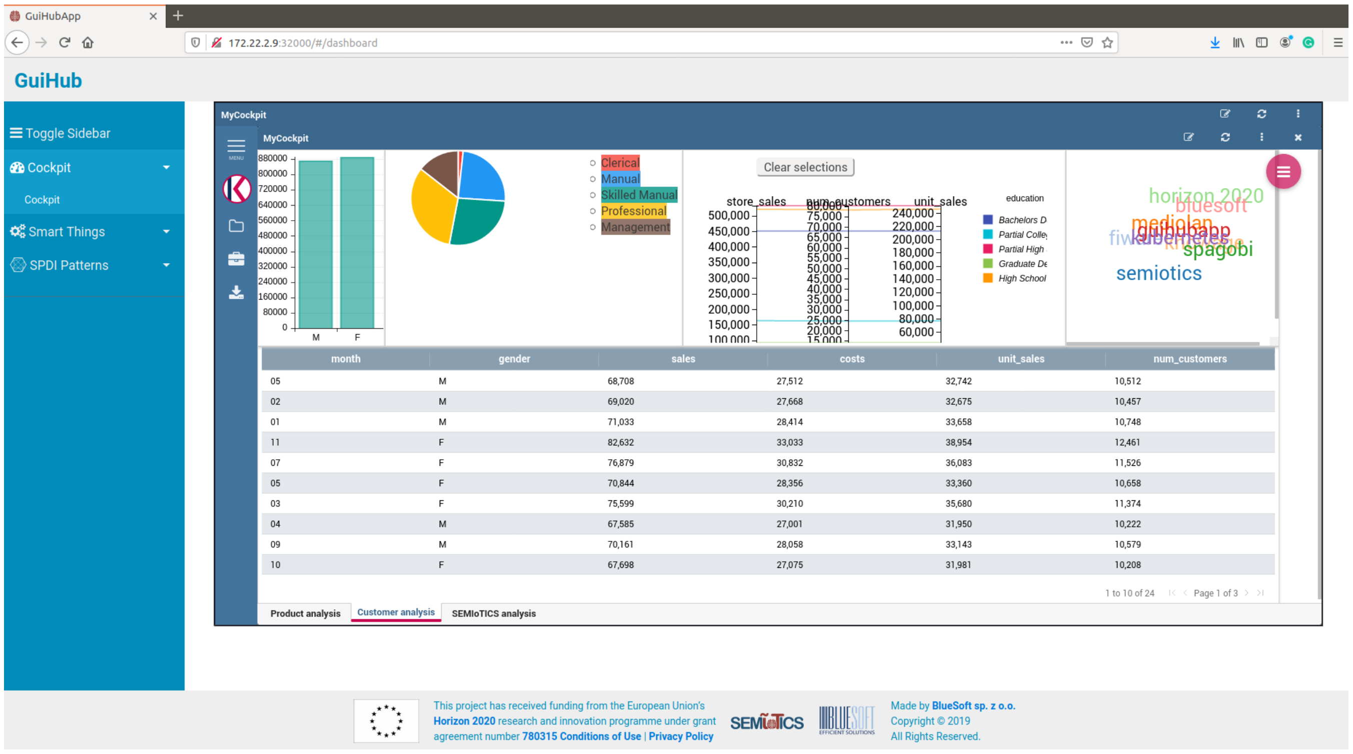

month	gender	sales	costs	unit_sales	num_customers
05	M	68,708	27,512	32,742	10,512
02	M	69,020	27,668	32,675	10,457
01	M	71,033	28,414	33,658	10,748
11	F	82,632	33,033	38,954	12,461
07	F	76,879	30,832	36,083	11,526
05	F	70,844	28,356	33,360	10,658
03	F	75,599	30,210	35,680	11,374
04	M	67,585	27,001	31,950	10,222
09	M	70,161	28,058	33,143	10,579
10	F	67,698	27,075	31,981	10,208

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Product analysis Customer analysis SEMIoTICS analysis

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8.1.6.3. KPI-6.3 - Delivery of 3 prototypes of IIoT/IoT applications

The SARA use case delivered a first prototype of the SARA solution empowered with SEMIoTICS technology. Sub use case 1 presents some of the GUI presented by SARA to the Doctor in the context of the Gait Analysis Assistive Task. The other sub use cases demonstrate how other SEMIoTICS are deployed within SARA.

8.1.7. Objective 7 – Promote the Adoption of EU Technology Offerings Internationally

8.1.7.1. KPI-7.1 - Provision the SEMIoTICS building blocks

This KPI will provide the key technological building blocks at TRL 6, 5 or 4. The following tables show the achieved TRL level of components used in SARA-Health Scenario.

Component	Layer	Baseline TRL	Target TRL	Current TRL	References
Backend orchestrator	Application	N/A (new)	6	6	D4.13
Backend Semantic Validator	Application	N/A (new)	4	4	Section 4.2.7, D4.13
GUI	Application	N/A (new)	6	6	D.4.13
Local embedded intelligence	Field	2	4	4	Section 3, D.4.13

Local thing directory	Field	6 (w/o adaptations)	6	6	D.4.13
Monitoring	Application	N/A (new)	4	4	D.4.13
NFV Orchestrator	NFV	6 (w/o adaptations)	6 (w/ adaptations)	6	Section 4.2.2, D3.8
Pattern Engine	Application	N/A (new)	4	4	Section 4.2.5, D.4.13
Pattern Orchestrator	Application	N/A (new)	4	4	Section 4.2.4, D.4.13
Security Manager	Field	4 (w/o adaptations)	5	5	D.4.13
Security Manager	Application	4 (w/o adaptations)	5	5	D.4.13
SFC Manager	SDN	6 (w/o adaptations)	6 (w/ adaptations)	6	D3.8, D3.11
Thing Directory	Application	6 (w/o adaptations)	6 (unchanged)	6	D.4.13
VIM Connector	SDN	6 (w/o adaptations)	6 (unchanged)	6	D3.7
Virtualized Infrastructure Manager	NFV	6 (w/o adaptations)	6 (w/ adaptations)	6	Section 4.2.3, D3.8
VNF Manager	NFV	6 (w/o adaptations)	6 (w/o adaptations)	6	Section 4.2.2, D3.8

8.2. Related framework requirements

In this section we consider the set of requirements that were described in deliverable D2.3 within the context of the SEMIoTICS's framework. Thereby, we list the subset of requirements from D2.3 that are relevant for this sub use case and we indicate in which part of the functional block architecture they are needed.

TABLE 5 REQUIREMENTS RELATDED TO UC2

Req-ID	Description	Reference	Fulfilment
R.GP.2	Scalable infrastructure due to the fast-paced growth of IoT devices.	Section 4	The architecture tackled herein is highly scalable. Thanks to the NFV framework, more virtual computing and storage resources can be easily allocated when needed for the scalability purposes.

R.NL.1/ R.BC.1	Controller Node requirement: At least 6 CPU cores and 32 GB RAM.	Section 4	This is in line with the requirements that have already reported above e.g. the OpenStack controller or the OSM, see section 4.4. Note that, in addition, it is required that the controller nodes have around 100 GB of storage memory,
R.NL.2/ R.BC.2	Controller Node requirement: At least 2 Network interfaces.	Section 4	This is a requirement applicable to the computer holding the controller, e.g. the OpenStack controller.
R.NL.3/ R.BC.3	Controller Node Requirement: Linux OS.	Section 4	The controller nodes at the NFV MANO context, e.g. the OpenStack controller, require Linux OS.
R.NL.5/ R.BC.5/ R.BC.6/ R.BC.7	Hypervisor Nodes Requirement: At least 4 CPU cores and 8 GB RAM, at least 2, 1Gbps Network interfaces.	Section 4	This is fulfilled or in line with the requirements for the compute nodes of the NFVI, see section 4.4.
R.NL.6/ R.BC.8/ R.BC.9	Hypervisor Nodes: KVM and Linux Containers (LXD) must be supported by the Hypervisor Linux OS.	Section 4	This is supported in the compute nodes that form the NFVI, e.g. at the cloud level.
R.S.1	The confidentiality of all network communication MUST be protected using state-of-the-art mechanisms.	Section 3 and D3.7	The requirement was achieved in SDN connection with ovs switches by enabling SSL, and the Communication between Pattern Orchestrator and Pattern Engines with SSL.
R.S.2	Authentication and authorization of the stakeholders MUST be enforced by the Network controller, e.g. through access and role-based lists for different levels of function granularities (overlay, customized access to service, QoS manipulation, etc.)	Section 3 and D3.2	The Security Manager can provide authorization to the users entering the controller.
R.P.4	A short data retention period MUST be enforced and maintaining data for longer than necessary avoided	Section 5	Attribute-Based Encryption can be used for enforcing a maximum access-time to stored data.
R.P.8	Data MUST be stored in encrypted form.	Section 5	ABE achieve this requirement since it is used for encrypting user-specific data.
R.P.9	Repeated querying for specific data by applications, services, or users that are not intent to act in this manner SHALL be blocked.	Section 5	The Policy Enforcement Points (PEP) will be seeing all requests and can thus detect and mitigate such attempts.

R.P.13	The user SHALL be able to control the privacy mechanisms (i.e. redemption period, data granularity and dissemination, and anonymization technique)	Section 5	This can be enforced by using Attribute-Based Encryption as described in Sub-use case 3. The user is then able to enforce his/her privacy-concerns and wishes by encrypting the user specific data with the help of ABE.
R.GSP.9	The SARA system SHALL provide robust mechanisms to protect Patient-related data.	Section 5	This is fulfilled with the use of Security Manager as described in Sub-Use Case 3
R.GSP.10	The SARA system MUST fully comply with all relevant Italian laws governing the privacy, security and storage of sensitive Patient health-related data.	Section 5.3.4	SEMIoTICS Pattern Engines and Security Manager allows to implement patterns that implement GDPR-compliant behaviour.
R.UC2.1	The SEMIoTICS platform SHOULD support time- and safety-critical requirements by allowing SARA application logic to be deployed on resource-constrained edge gateways (e.g. smartphones, vehicles, mobile robots). SEMIoTICS platform functionalities SHOULD be locally available even in case of failure of communication with the SEMIoTICS cloud nodes.	Section 3 Section 6	SEMIoTICS TS Encoder is available locally on the Robotic Rollator Hub. SEMIoTICS Local Thing Directory and IoT Gateway is available locally on the Robotic Rollator Hub.
R.UC2.2	The SEMIoTICS platform SHOULD support the SARA solution to manage the trade-off between different requirements (e.g. reliability, power consumption, latency, fault-tolerance) by allowing both SARA application logic and platform features to be distributed over a cluster of gateways (SARA Hubs).	Section 4	This requirement is fulfilled with the use of SFCs and NFV.
R.UC2.3	The SEMIoTICS platform SHOULD guarantee proper connectivity between the various components of the SARA distributed application. The SARA solution is a distributed application not only because it uses different cloud services (e.g. AREAS Cloud services, AI services) from different remote computational nodes, but also because the SARA application logic itself is distributed across various edge nodes (SARA Hubs).	Section 3 Section 4	This requirement is fulfilled with the use of SFCs and NFV.
R.UC2.5	The SEMIoTICS platform should allow the SARA solution to discover the IoT devices that are registered in the system. IoT devices deployed by the SARA solution are expected to register themselves into the system using various standard protocols (e.g. LwM2M, MQTT, Bluetooth LE, ZigBee, etc.).	Section 6	All the sensors onboard of the RR, are exposed through the CoAP protocol and combined with a node-wot servient.

R.UC2.6	The SEMIoTICS platform SHOULD allow the SARA solution to retrieve the resources exposed by registered devices via their object model (i.e. a data structure wherein each element represents a resource, or a group of resources, belonging to a device). The SEMIoTICS platform SHOULD support at least the OMA LWM2M object model.	Section 6	The semantic descriptions for all the types of smart objects are based on W3C Web of Things (WoT) standard Each sensor, actuator or thing from all SEMIoTICS use cases were identified and for each smart object one Thing Description (TD) was provided.
R.UC2.11	The SEMIoTICS platform SHOULD allow a SARA component to request a group of devices to take/initiate an action (e.g. turn on/off a light bulb).	Section 6	The SARA ZigBee Servient creates an http binding for the Hue hence it is possible to control the light bulb using standard REST call over http for turning the light on.
R.UC2.12	The SEMIoTICS platform SHOULD allow SARA components to delegate to the platform the computation of complex functions over the data received by field devices. These computations may result either in the generation of higher-level observation events (e.g. significant Patient events abstracted form sensor data) towards the ACS or in sensors configuration parameters (including actuators command). The SARA components MAY specify computations either as Dataflow or as Finite State Machine.	Section 7	This requirement is fulfilled with the interaction of Human Task Manager, Human Robot Interaction Manager, Robotic Assistant Agent, Coordination Server and Monitoring Component.
R.UC2.14	The SEMIoTICS platform MAY allow the SARA solution to access information concerning the location of mobile robotic nodes and to maintain SARA specific location information (e.g. collected map data). This would allow the SARA hub or cloud to send to robotic devices high level navigation related commands (e.g. “go to location”).	Section 7	This requirement is fulfilled with the use of the MDP queries.
R.UC2.15	The SEMIoTICS platform SHOULD provide low latency connectivity between the SARA hubs and cloud services (i.e. AREAS cloud services and AI services) to allow offloading of near real-time computation intensive tasks to the cloud.	Section 1, Section 4	This is related to the network management sub use case.
R.UC2.16	The SEMIoTICS platform SHOULD support secure bootstrap, configuration and diagnostic of SARA hubs and devices.	Section 5	In order to monitor that the system correctly enforces the intended behaviour, for this we describe how SEMIoTICS monitoring is used as a solution for periodical self-audit capabilities by monitoring for pattern-compliance.

9. ETHICS GUIDELINES

Although the health care use case (SARA) of SEMIoTICS referred to safety of patient, security and privacy of patient data, in the validation of this use case no personal data were used. However, this section provides details on the procedures & criteria to deal and to process personal information that could be used or collected during the project demonstration if real data were required. Based on the above, the Ethics information related to the SARA use case can be assumed as a part of task "Task 5.5 – Demonstration and validation of SARA-Health scenario".

9.1. Details on the procedure and criteria to identify/recruit research participants

The SEMIoTICS healthcare aimed to conduct two types of tests (i) Lab tests and (ii) Controlled trials supervised by medical staff and/or caregivers. Of the two only the latter would entail patient recruitment since the Lab tests were aimed to assess the technological properties (e.g. availability, reliability) of the SARA system to be conducted by ENG researchers. On the contrary the controlled trials, although not occurred, would require the involvement of patients to assess how the patients would deal with the SARA technology and whether such a kind of technology is accepted by the envisaged target patients population. However, due to the pandemic situation no trials were conducted, therefore the below presentation on the criteria could be taken as guidelines for conducting similar experimental trials.

9.2. Target group definition

Given its nature of acceptance test the controlled trials could be conducted on a small group (around 6) of elderly participants living at home or in residential care. The participants could be recruited in Italy in a pilot site run by an institution from the ENG network of AREAS customers. End users would present probable poly-pathology (according with Tinetti ≤ 20) such as: cardiovascular disease, pulmonary disease, diabetes, and neurological diseases.

Criteria	Description
Inclusion criteria:	• Age ≥ 65 y.o. (Elderly users) • Tinetti ≤ 20 (high risk of falls) and /or ≥ 1 fall within the last year • MMSE ≥ 20 (minimum cognitive level needed to be able to co-operate in this part of the study) • Stable patients (>1 month from last acute event) • Presence of Caregiver (formal or informal) if user has MMSE ≤ 26 during 24h for 7 days per week, otherwise caregiver or family member available to be contacted.
Exclusion criteria:	• Presence of aphasia and/or neglect (clinical evaluation) • Presence of major behavioural disturbances (clinical evaluation). • Rehabilitative training • The previous and current use of assistive device is not an exclusion criterion.

9.3. General Guidelines for Recruitment

Participation of Humans in SEMIoTICS in SARA use case should be only on a volunteer basis. Contact with participants should be established initially email and at later stage by telephone. During these initial steps, potential participants should be informed them about the aims of the project (informative flyer) and, for those interested, the possibility of having a further meeting in which the full details of the trials and the research undertaken and how any data collected from them should be used and provided. The same details should be provided in writing. In any period of this voluntary participation, a participant may acquire additional information. In addition, participants may withdraw at any time without any consequence and any data collected from them up to the point of their withdrawal will be destroyed.

The user selection process could be performed on-site by the medical experts comprising the clinical staff (e.g. neurologists, geriatricians, physiotherapists, psychologists, social workers, nurses). It is important to highlight the fact that the process described below is a generic guideline that the ENG partner institution might adapt depending on its circumstances.

In order to identify users, the pilot site could use database of local health care or social services (e.g. hospitals, home care services, municipalities). In the case that the selected pilot site would not be a medical institution (e.g. municipality), it could be supported by professionals working in the care services in relation to this municipality. When the users would be selected, a contact should be established with a family member or a caregiver with an offer to participate in the study.

Although the details of the user selection methodology could be defined by a medical staff once the SARA functionalities could be established in a concrete implementation, the following key characteristics should be anticipated:

- The user selection methodology could include a set of inclusion criteria and exclusion criteria to be applied in the scope the selection/recruitment process.
- The initial visit would require approximately 1-1 1⁄2 hour to complete, aimed to confirm the satisfaction of the inclusion and exclusion criteria. At this visit, thorough history-taking would be performed - including medical, behavioural and social background information - along with a routine physical examination. A medical expert, on the basis of an overall look of the available information could decide if the user fulfils the inclusion criteria.
- When a user fulfils the inclusion criteria, details about the SARA solution should be described to the user and his/her caregiver (rational behind the project, procedures, anticipated results and benefits, confidentiality, rights and obligations). This should be performed with the help of special dissemination material prepared for this end.
- The user and the caregiver should be given ample time to completely read the ‘Informed Consent Form’ and to raise any project related questions. Before signing the forms, the clinician would establish that they fully understand the study and agree with the study related procedures. A copy of the signed Informed Consent Form will be given to the user and his/her caregiver and another would be retained by the Pilot site.

9.4. Participation Informed Consent Procedures

Extraordinary care should be taken to receive appropriate and legally valid informed consent from the participants. This will only be carried out with the prior, free, informed and expressed consent of the participating individuals. This should be done in accordance with all applicable international laws and ethical guidelines related to the protection of personal data as well as internationally accepted rules on ethics and human rights. Each participant should be informed what is done with his or her data according to the principle that autonomy needs consent. All decisions and/or interventions to be made should be made with respect to the privacy of the persons concerned and the confidentiality of such personal data subject to applicable national and international data protection laws. Templates of informed consents should be provided in the respective deliverables. A potential participant interested in being involved in SEMIoTICS activities, should be given a written informed consent form and if participant agrees, both sides should sign this informed consent.

9.5. Collection and/or Processing of Personal Sensitive Data

Collecting and sharing personal data can be a threat to personal integrity, and such threat should be minimised. The SEMIoTICS ethics committee should be responsible for the personal data protection. The details on this the data protection plan should be defined by this committee. In general, collected data should be anonymized before they are stored. Collected data should be stored throughout the project execution time and should be deleted after the project ends. All personal data should be stored encrypted and should be accessible only to specific individuals authorized by the ethics committee. The data repository should be decided by the project consortium adopting appropriate physical and IT security measures.

The SARA integrated platform had two key objectives: (a) to provide end-users with a tailored and effective ICT based fall management solution, (b) to offer to medical experts and health professionals a wide range of configuration, deployment, management and decision support tools, enabling them to tailor ICT solution to the end-users' profiles and target needs.

In order to enable SARA to achieve its key objective there would be the need to collect and process personal sensitive data of end-users. In particular the end user would visit the pilot site and perform his/her SARA training sessions. During the sessions, the end user would perform his/her exercises according to the SARA rehabilitation programme. After each session, the health record of the end user should be updated with the data collected during the training session and the medical expert would be able to assess the progress of the end user.

Table 6 contains evaluation criteria that should be followed as guidelines throughout the project. Fulfilment of these criteria should be supervised, deviations from it will be minimized and appropriately justified. A brief report, describing criteria fulfilment, eventual conflicts and how these have been solved, should be produced.

TABLE 6 EVALUATION CRITERIA GUIDELINES

Criteria	Yes	No	N/A
The participants have been informed about the goals of the project.			
The participants have given their consent to their participation.			
All the data collected are necessary (but also are the minimum) for the work undertaken.			
For any data not initially expected or specified in the consent form, additional consent forms have been provided to the participants.			
Personal identification information has been dissociated from the rest of information about the participants.			
Personal identification information has been encrypted on a separate database.			
PCs storing personal identification information are password protected.			
Risk of identifying participants from dissociated data analyzed has been minimized.			
Any transfer of data within consortium members has been encrypted.			
For trial scenarios showing conflict with legislations about privacy and security, necessary adaptations to fulfil these legislations have been carried out.			
Dissemination activities performed do not allow in any circumstance's identification of the participants.			

10. CONCLUSION

10.1. Observed Obstacles

The most observed challenges for the implementation of this use case were related to the multi-domain deployment of the different components of the SEMIoTICS architecture that participated in SARA use case. There were constraints related to the private and public networking aspects realizing the implementation of this use cases closer to the reality of assistive living. Especially the current pandemic situation, which the project faced during the last year, pushed the use case 2 participants to work efficiently to overpass any constraint and achieve the overall scope and objectives of this use case.

10.2. Concluding Remarks

This deliverable presented the results of the validation of the SEMIoTICS technologies in the context of the development of SARA a solution in the domain of Ambient assisted living.

This document also identified the challenges subsumed by the implementation of two of the SARA assistive tasks (*Falls Management Assistive Task* and *Gait Analysis Assistive Task*).

The document presented the SEMIoTICS-based implementation of SARA by five points of view (sub use cases) each focusing one of main areas addressed by the SEMIoTICS project: (a) security, privacy, dependability and safety: (b) IoT semantic interoperability; (c) embedded intelligence and (d) automated trustworthy network management.

The results of UC2 demo were shown to the advisory committee and ACTIVAGE project where there were external stakeholders representing healthcare domain. In this way the consortium plan to involve stakeholders around UC2 pilot has been put in place beyond the project duration.

Finally, although due to COVID-19 situation, there was no possibility for trial experimentation and collection of personal data by the users, the ethics guidelines included in this report gives the necessary importance on this aspect of this use case.

11. REFERENCES

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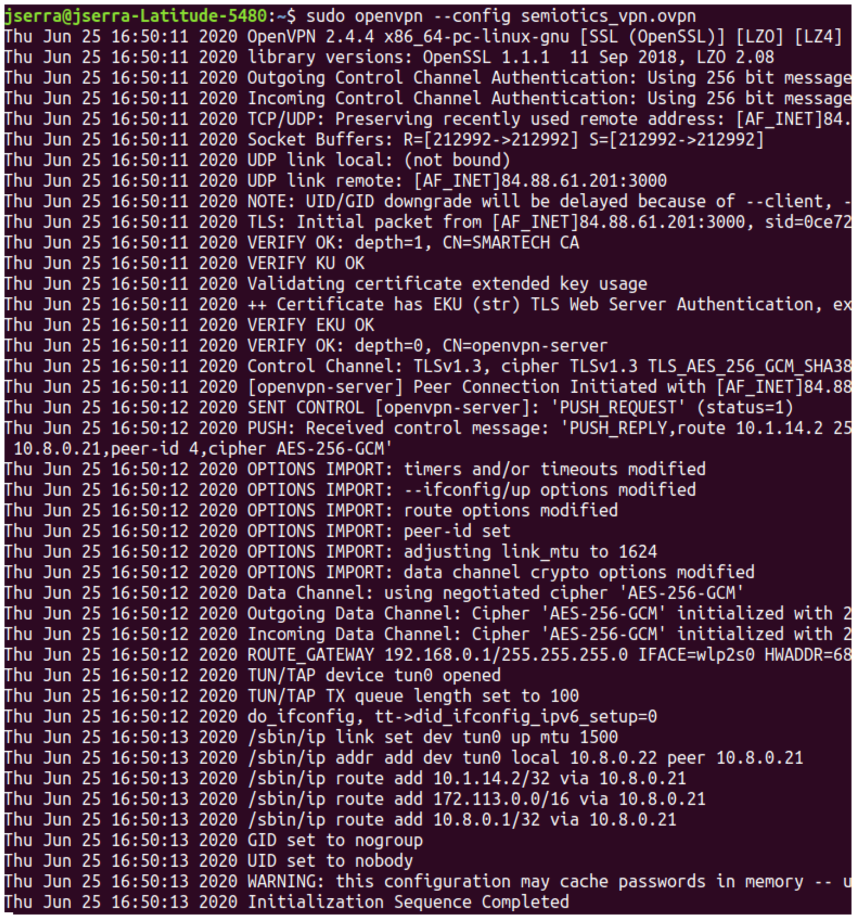
APPENDIX A - NETWORK INFRASTRUCTURE VALIDATION

It is worth mentioning that a VPN has been configured at CTTC to let external users to access the NFV testbed described above. In Figure B.1, we show that the execution of the VPN connection instruction, based on a configuration file, is successful. Then, in Figure B.2 and Figure B.3, it is shown that the VPN allows to access the OSM and OpenStack GUIs, respectively. Moreover, below it will be shown, that the external VPN users can use properly the OSM and OpenStack services. To this end, a generic VNF and they corresponding Network Service (NS) will be created, onboarded to OSM and instantiated on top the NFVI, which is managed by the OpenStack. Observe that in OSM a VNF is always within the context of NS, which can be interpreted as a higher layer entity. In fact, a NS can contain multiple VNFs.



```
jserra@jserra-Latitude-5480:~$ sudo openvpn --config semiotics_vpn.ovpn
Thu Jun 25 16:50:11 2020 OpenVPN 2.4.4 x86_64-pc-linux-gnu [SSL (OpenSSL)] [LZO] [LZ4]
Thu Jun 25 16:50:11 2020 library versions: OpenSSL 1.1.1  11 Sep 2018, LZO 2.08
Thu Jun 25 16:50:11 2020 Outgoing Control Channel Authentication: Using 256 bit message
Thu Jun 25 16:50:11 2020 Incoming Control Channel Authentication: Using 256 bit message
Thu Jun 25 16:50:11 2020 TCP/UDP: Preserving recently used remote address: [AF_INET]84.
Thu Jun 25 16:50:11 2020 Socket Buffers: R=[212992->212992] S=[212992->212992]
Thu Jun 25 16:50:11 2020 UDP link local: (not bound)
Thu Jun 25 16:50:11 2020 UDP link remote: [AF_INET]84.88.61.201:3000
Thu Jun 25 16:50:11 2020 NOTE: UID/GID downgrade will be delayed because of --client, -
Thu Jun 25 16:50:11 2020 TLS: Initial packet from [AF_INET]84.88.61.201:3000, sid=0ce72
Thu Jun 25 16:50:11 2020 VERIFY OK: depth=1, CN=SMARTECH CA
Thu Jun 25 16:50:11 2020 VERIFY KU OK
Thu Jun 25 16:50:11 2020 Validating certificate extended key usage
Thu Jun 25 16:50:11 2020 ++ Certificate has EKU (str) TLS Web Server Authentication, ex
Thu Jun 25 16:50:11 2020 VERIFY EKU OK
Thu Jun 25 16:50:11 2020 VERIFY OK: depth=0, CN=openvpn-server
Thu Jun 25 16:50:11 2020 Control Channel: TLSv1.3, cipher TLSv1.3 TLS_AES_256_GCM_SHA38
Thu Jun 25 16:50:11 2020 [openvpn-server] Peer Connection Initiated with [AF_INET]84.88
Thu Jun 25 16:50:12 2020 SENT CONTROL [openvpn-server]: 'PUSH_REQUEST' (status=1)
Thu Jun 25 16:50:12 2020 PUSH: Received control message: 'PUSH_REPLY,route 10.1.14.2 25
 10.8.0.21,peer-id 4,cipher AES-256-GCM'
Thu Jun 25 16:50:12 2020 OPTIONS IMPORT: timers and/or timeouts modified
Thu Jun 25 16:50:12 2020 OPTIONS IMPORT: --ifconfig/up options modified
Thu Jun 25 16:50:12 2020 OPTIONS IMPORT: route options modified
Thu Jun 25 16:50:12 2020 OPTIONS IMPORT: peer-id set
Thu Jun 25 16:50:12 2020 OPTIONS IMPORT: adjusting link_mtu to 1624
Thu Jun 25 16:50:12 2020 OPTIONS IMPORT: data channel crypto options modified
Thu Jun 25 16:50:12 2020 Data Channel: using negotiated cipher 'AES-256-GCM'
Thu Jun 25 16:50:12 2020 Outgoing Data Channel: Cipher 'AES-256-GCM' initialized with 2
Thu Jun 25 16:50:12 2020 Incoming Data Channel: Cipher 'AES-256-GCM' initialized with 2
Thu Jun 25 16:50:12 2020 ROUTE_GATEWAY 192.168.0.1/255.255.255.0 IFACE=wlp2s0 HWADDR=68
Thu Jun 25 16:50:12 2020 TUN/TAP device tun0 opened
Thu Jun 25 16:50:12 2020 TUN/TAP TX queue length set to 100
Thu Jun 25 16:50:12 2020 do_ifconfig, tt->did_ifconfig_ipv6_setup=0
Thu Jun 25 16:50:13 2020 /sbin/ip link set dev tun0 up mtu 1500
Thu Jun 25 16:50:13 2020 /sbin/ip addr add dev tun0 local 10.8.0.22 peer 10.8.0.21
Thu Jun 25 16:50:13 2020 /sbin/ip route add 10.1.14.2/32 via 10.8.0.21
Thu Jun 25 16:50:13 2020 /sbin/ip route add 172.113.0.0/16 via 10.8.0.21
Thu Jun 25 16:50:13 2020 /sbin/ip route add 10.8.0.1/32 via 10.8.0.21
Thu Jun 25 16:50:13 2020 GID set to nogroup
Thu Jun 25 16:50:13 2020 UID set to nobody
Thu Jun 25 16:50:13 2020 WARNING: this configuration may cache passwords in memory -- u
Thu Jun 25 16:50:13 2020 Initialization Sequence Completed
```

FIGURE B.1 VPN THAT ENABLES EXTERNAL USERS TO ACCESS THE CTTC's NFV TESTBED.

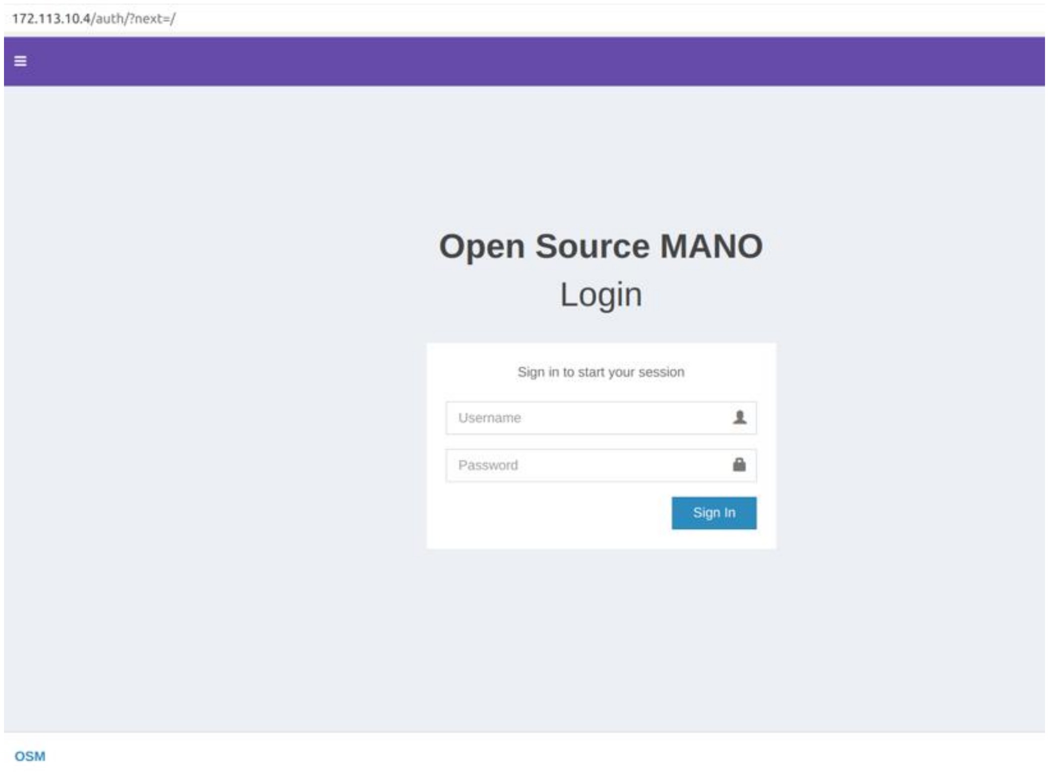


FIGURE B.2 VPN ALLOWS ACCESS TO OSM AT CTTC's NFV TESTBED.

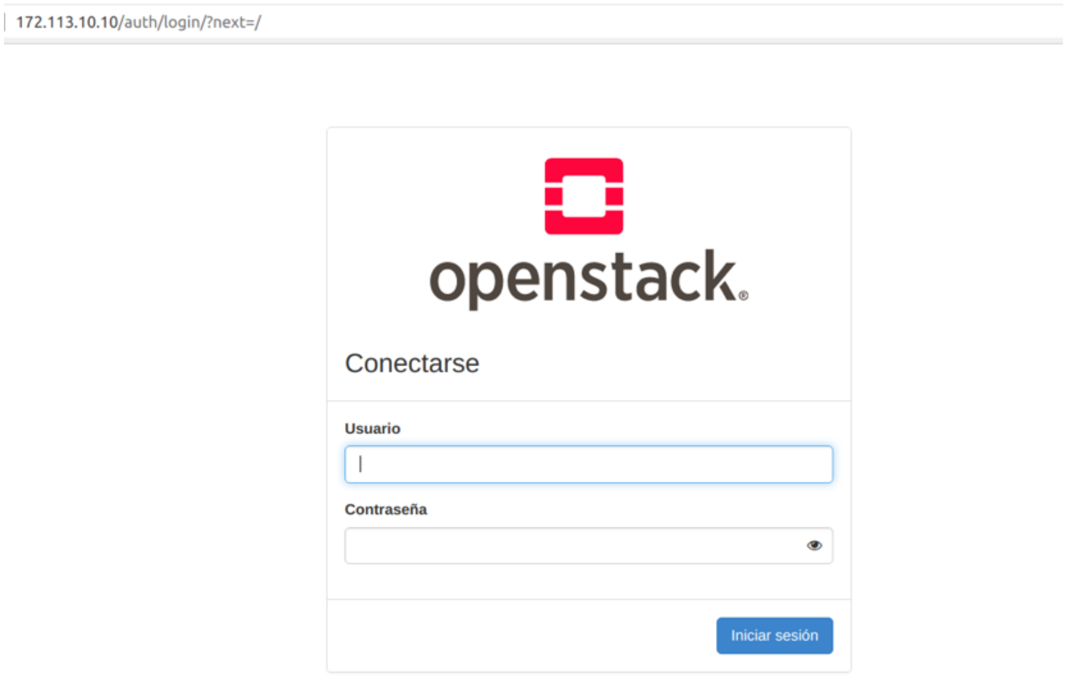
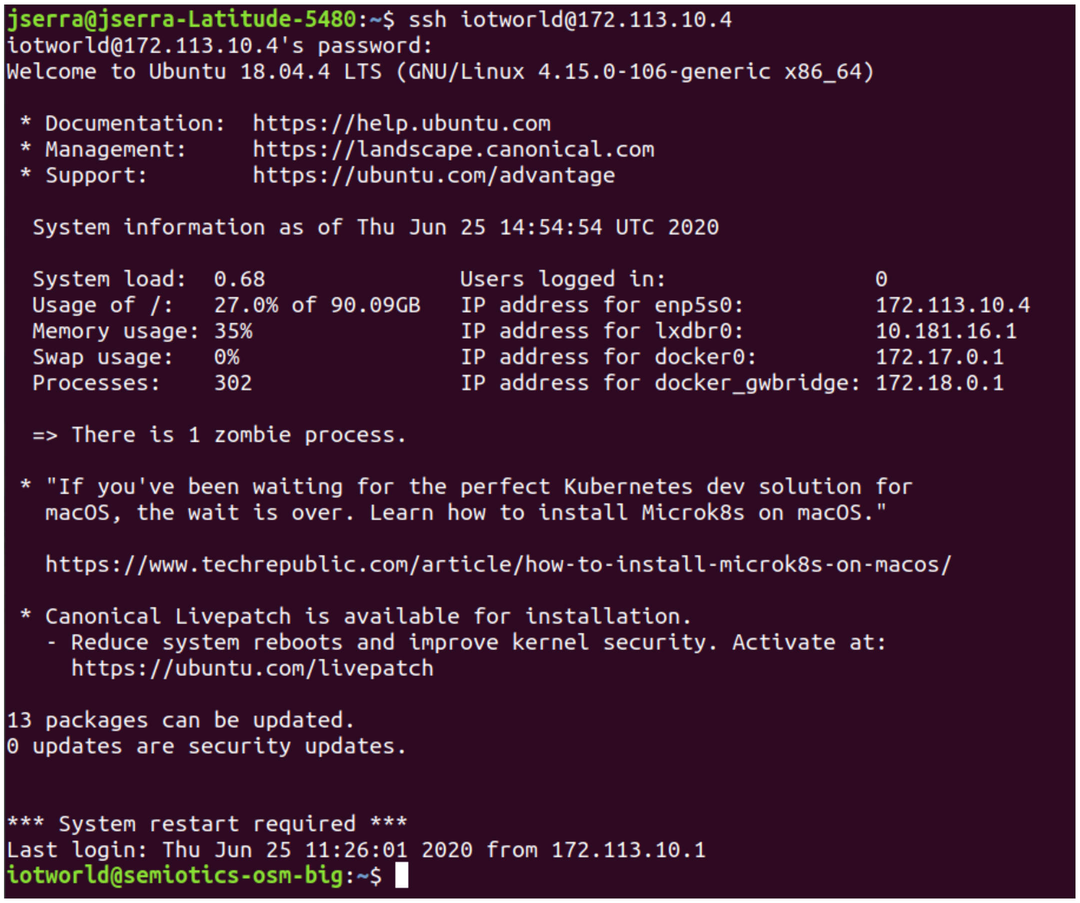


FIGURE A.3 VPN ALLOWS ACCESS TO OPENSTACK AT CTTC's NFV TESTBED.

Next, as it was mentioned above, a generic VNF and its corresponding NS are created, onboarded to OSM and instantiated on top of the NFVI. This shows that the external VPN users can access properly the NFV testbed and use its NFV services, i.e. OSM and OpenStack. To this end, we use the OSM command line interface (cli). Thereby, first it is shown in Figure 6 that the external users can enter via ssh to the VM that contains the OSM.



```
jserra@jserra-Latitude-5480:~$ ssh iotworld@172.113.10.4
iotworld@172.113.10.4's password:
Welcome to Ubuntu 18.04.4 LTS (GNU/Linux 4.15.0-106-generic x86_64)

 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/advantage

  System information as of Thu Jun 25 14:54:54 UTC 2020

  System load:  0.68               Users logged in:                0
  Usage of /:   27.0% of 90.09GB   IP address for enp5s0:          172.113.10.4
  Memory usage: 35%                IP address for lxdbr0:          10.181.16.1
  Swap usage:   0%                 IP address for docker0:         172.17.0.1
  Processes:    302                IP address for docker_gwbridge: 172.18.0.1

  => There is 1 zombie process.

 * "If you've been waiting for the perfect Kubernetes dev solution for
   macOS, the wait is over. Learn how to install Microk8s on macOS."

   https://www.techrepublic.com/article/how-to-install-microk8s-on-macos/

 * Canonical Livepatch is available for installation.
   - Reduce system reboots and improve kernel security. Activate at:
     https://ubuntu.com/livepatch

13 packages can be updated.
0 updates are security updates.


*** System restart required ***
Last login: Thu Jun 25 11:26:01 2020 from 172.113.10.1
iotworld@semiotics-osm-big:~$
```

FIGURE B.4 SSH TO THE VM THAT CONTAINS THE OSM.

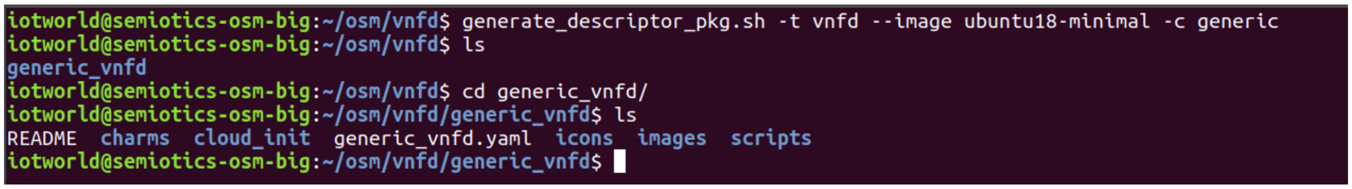
After entering to the VM that hosts the OSM, we will follow a set of steps to create, instantiate and terminate the generic VNF and the generic NS. Note that, the end user only needs to interact with the OSM, which communicates internally with the OpenStack. Moreover, the interaction with the OSM is through a set of configuration files that define the computing, storage and networking features of the VNF and the NS. These configuration files are so-called VNF descriptor (VNFd) and Network Service descriptor (NSd), respectively. Thereby, the next steps will be followed below to create, instantiate and terminate the VNF and NS.

- Create generic NSd and VNFd.
- Generate VNF/NS packages.
- Onboard the VNF/NS packages to OSM library.
- Instantiate the NS (and the VNF).
- Check that we can access the VM created for the VNF instantiation.
- Terminate the NS.

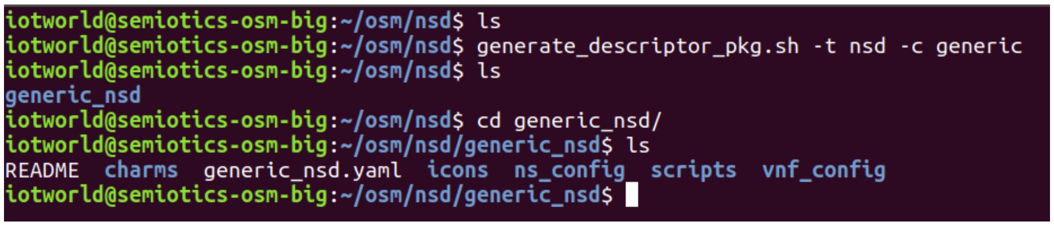
Create generic NSd (and VNFd).

- Create VNFd, NSd folder structure

First, OSM needs to create a folder structure for the NSd, VNFd and its related files, such as the cloud init, which defines the initial configuration of the VM that will hold the VNF. This is accomplished by using a shell script provided by OSM, it is called “generate_descriptor_pkg”. In Figure 7, we show how that folder structure is created correctly.



```
iotworld@semiotics-osm-big:~/osm/vnfd$ generate_descriptor_pkg.sh -t vnfd --image ubuntu18-minimal -c generic
iotworld@semiotics-osm-big:~/osm/vnfd$ ls
generic_vnfd
iotworld@semiotics-osm-big:~/osm/vnfd$ cd generic_vnfd/
iotworld@semiotics-osm-big:~/osm/vnfd/generic_vnfd$ ls
README  charms  cloud_init  generic_vnfd.yaml  icons  images  scripts
iotworld@semiotics-osm-big:~/osm/vnfd/generic_vnfd$ 
```



```
iotworld@semiotics-osm-big:~/osm/nsd$ ls
iotworld@semiotics-osm-big:~/osm/nsd$ generate_descriptor_pkg.sh -t nsd -c generic
iotworld@semiotics-osm-big:~/osm/nsd$ ls
generic_nsd
iotworld@semiotics-osm-big:~/osm/nsd$ cd generic_nsd/
iotworld@semiotics-osm-big:~/osm/nsd/generic_nsd$ ls
README  charms  generic_nsd.yaml  icons  ns_config  scripts  vnf_config
iotworld@semiotics-osm-big:~/osm/nsd/generic_nsd$ 
```

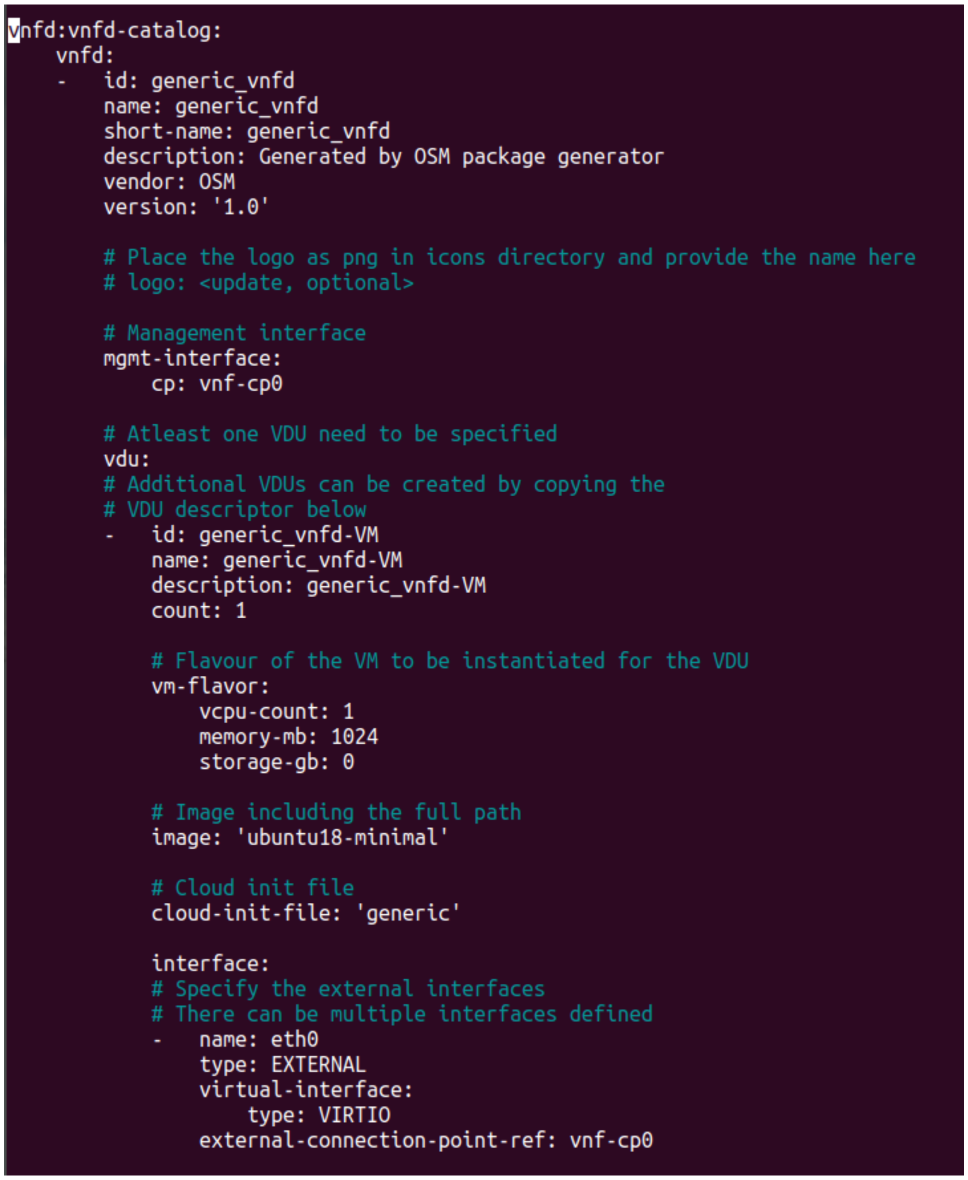
FIGURE B.5 CREATION OF THE FOLDER STRUCTURE NEEDED TO CREATE VNFd and NSd.

- Edit VNFd

After creating the folder structure for the VNFd and NSd, we can edit the VNFd, which is a yaml configuration file. In Figure A.6 we present the snapshot of the yaml file that we have used to specify the VNFd. In the sequel, the important parts of this file are discussed. The tag “id” is the unique identifier for the VNF and it is important to recall it, as it is used in the NSd. The tag “mgmt-interface” is the interface over which the VNF is managed. Moreover, the “cp” within it just specifies the type of management endpoint, in our case “cp” means that we will use a connection point. Another important tag is the “vdu”, which stands for virtual description unit, and it specifies the features of the VM that will host the VNF. The “vm-flavor” indicates the computing, memory and storage features of the VM that will host the VNF. Thereby, note that we define a VM with 1 virtual CPU, 1 GB of RAM and no persistent storage, as the “image” that we discuss next defines enough storage for this test. The tag “image” indicates the image that will be used to create the VM, in our case we will have an Ubuntu OS. The “cloud-init-file” indicates the cloud init file that will be used by the VM. The snapshot for this cloud init file is actually described below. The “interface” tag within the “vdu” tag specifies the interfaces for the vdu.

- Cloud init file specification

This file is the one that specifies the initial configuration that we aim for the VM that will host the generic VNF. Note that its name is specified in the vnfd, as commented above. In Figure A.7, we provide the snapshot of this cloud init file and describe its functionalities. First, note that we have a field called “users”. This allows to add users to the system. Note that we have added a user called “generic”. Finally, within this user, there is an important field to be added, the “ssh_authorized_keys”. This is important, because here we add the public ssh keys of the users that will access the VM that hosts the VNF.

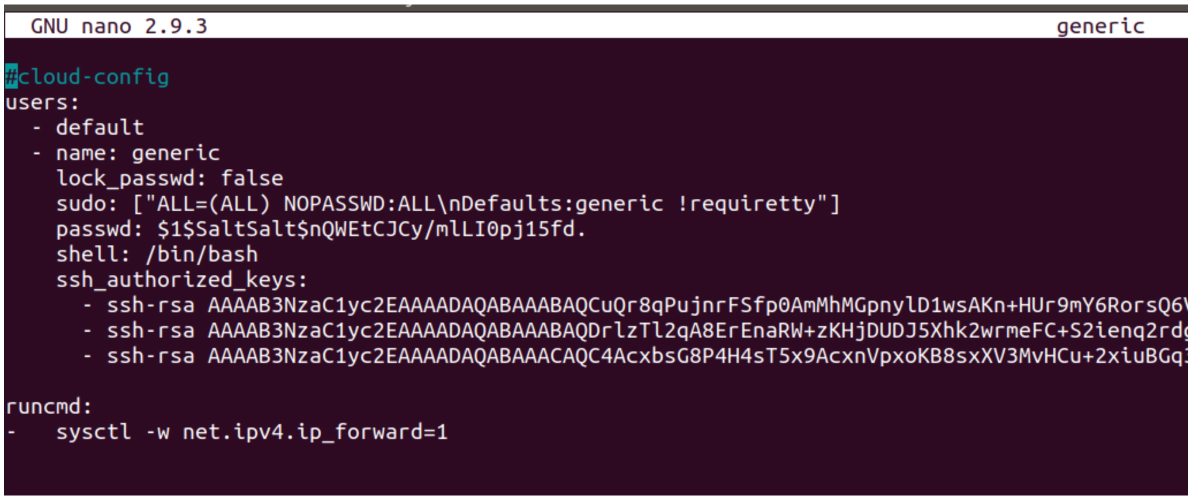


```
vnfd:vnfd-catalog:
    vnfd:
    -   id: generic_vnfd
        name: generic_vnfd
        short-name: generic_vnfd
        description: Generated by OSM package generator
        vendor: OSM
        version: '1.0'

        # Place the logo as png in icons directory and provide the name here
        # logo: <update, optional>

        # Management interface
        mgmt-interface:
            cp: vnf-cp0

        # Atleast one VDU need to be specified
        vdu:
        # Additional VDUs can be created by copying the
        # VDU descriptor below
        -   id: generic_vnfd-VM
            name: generic_vnfd-VM
            description: generic_vnfd-VM
            count: 1

            # Flavour of the VM to be instantiated for the VDU
            vm-flavor:
                vcpu-count: 1
                memory-mb: 1024
                storage-gb: 0

            # Image including the full path
            image: 'ubuntu18-minimal'

            # Cloud init file
            cloud-init-file: 'generic'

            interface:
            # Specify the external interfaces
            # There can be multiple interfaces defined
            -   name: eth0
                type: EXTERNAL
                virtual-interface:
                    type: VIRTIO
                external-connection-point-ref: vnf-cp0
```

FIGURE B.6 VNFd THAT DESCRIBES A GENERIC VNF.

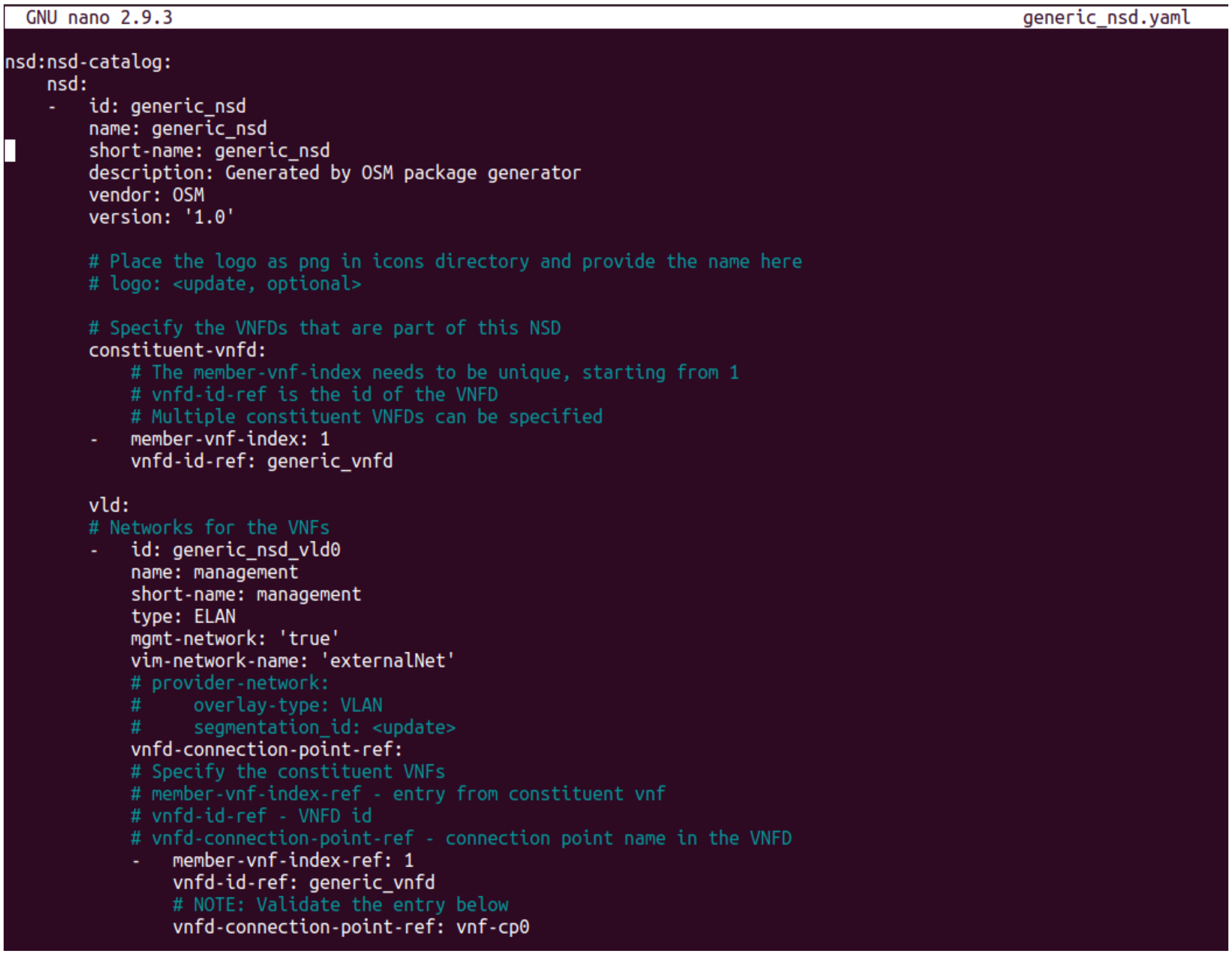
- Edit NSd

Next, in Figure B.8 we display a snapshot of the yaml file that we edited to specify the NSd. The relevant tags are described in the sequel. First, note that the tag “id” determines the unique identifier for the NS. The tag “constituent-vnfd” indicates which VNFs are part of the NS. In our case we have just the generic VNF, whose identification is “generic_vnfd” and is specified through the tag “vnfd-id-ref”. Note that, in the vnfd the “id” tag has to correspond with that value. Then, we have the tag “vld”, which is a description of the virtual links used by the NS for networking connections. In our case, note that the tag “type” is set to “ELAN”. This indicates that the virtual link is a service to connect VNFs. The tag “mgmt.-network” set to “true” means that this is a VIM management network. The tag “vim-network-name” describes the name of the network in the VIM account, in our case “externalNet” is the name that was given such network in the OpenStack framework. Finally, the tag “vnfd-connection-point-ref” describes the connection points for the virtual links towards a vnf. We can see that this is a connection towards our generic VNF as the tag “vnd-id-ref” is set to “generic_vnfd”.



```
  GNU nano 2.9.3                                                                          generic

#cloud-config
users:
  - default
  - name: generic
    lock_passwd: false
    sudo: ["ALL=(ALL) NOPASSWD:ALL\nDefaults:generic !requiretty"]
    passwd: $1$SaltSalt$nQWEtCJCy/mlLI0pj15fd.
    shell: /bin/bash
    ssh_authorized_keys:
      - ssh-rsa AAAAB3NzaC1yc2EAAAADAQABAAABAQCuQr8qPujnrFSfp0AmMhMGpnylD1wsAKn+HUr9mY6RorsQ6
      - ssh-rsa AAAAB3NzaC1yc2EAAAADAQABAAABAQDrlzTl2qA8ErEnaRW+zKHjDUDJ5Xhk2wrmeFC+S2ienq2rd
      - ssh-rsa AAAAB3NzaC1yc2EAAAADAQABAAACAQC4AcxbsG8P4H4sT5x9AcxnVpxoKB8sxXV3MvHCu+2xiuBGq

runcmd:
-   sysctl -w net.ipv4.ip_forward=1
```

FIGURE B.7 CLOUD INIT FILE ASSOCIATED TO THE GENERIC VNF.

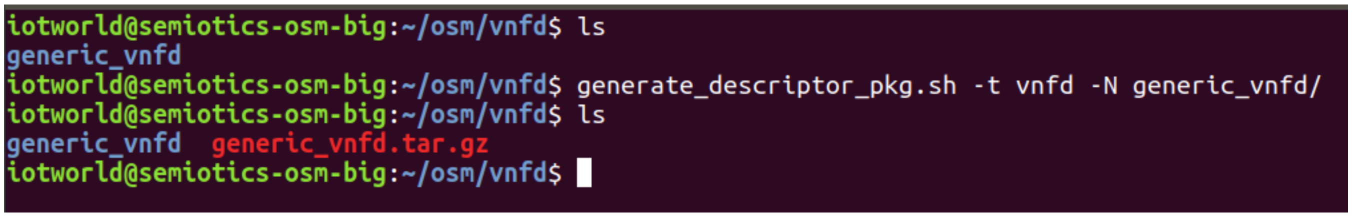


```
  GNU nano 2.9.3                                                                     generic_nsd.yaml

nsd:nsd-catalog:
    nsd:
    -   id: generic_nsd
        name: generic_nsd
        short-name: generic_nsd
        description: Generated by OSM package generator
        vendor: OSM
        version: '1.0'

        # Place the logo as png in icons directory and provide the name here
        # logo: <update, optional>

        # Specify the VNFDs that are part of this NSD
        constituent-vnfd:
            # The member-vnf-index needs to be unique, starting from 1
            # vnfd-id-ref is the id of the VNFD
            # Multiple constituent VNFDs can be specified
        -   member-vnf-index: 1
            vnfd-id-ref: generic_vnfd

        vld:
        # Networks for the VNFs
        -   id: generic_nsd_vld0
            name: management
            short-name: management
            type: ELAN
            mgmt-network: 'true'
            vim-network-name: 'externalNet'
            # provider-network:
            #     overlay-type: VLAN
            #     segmentation_id: <update>
            vnfd-connection-point-ref:
            # Specify the constituent VNFs
            # member-vnf-index-ref - entry from constituent vnf
            # vnfd-id-ref - VNFD id
            # vnfd-connection-point-ref - connection point name in the VNFD
            -   member-vnf-index-ref: 1
                vnfd-id-ref: generic_vnfd
                # NOTE: Validate the entry below
                vnfd-connection-point-ref: vnf-cp0
```

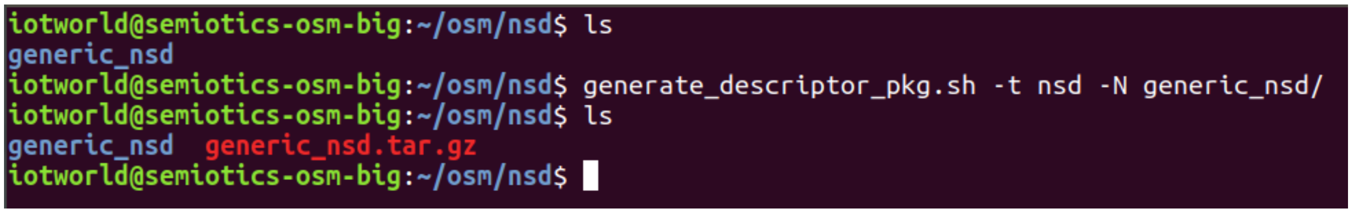
FIGURE B.8 NSd ASSOCIATED TO THE GENERIC VNF.

- Generate VNFd/NSd packages.

At this point, the VNFd and NSd are already edited. Thereby, we can generate the NSd, and VNFd packages, which are required in the onboarding process of the OSM. This means, the process of having our NS and VNF packages available in the OSM library. To generate those packages we only need to execute the shell script "generate_descriptor_pkg" provided by the OSM, which needs the NS and VNF folder structure that we created above in Figure 7.



```
iotworld@semiotics-osm-big:~/osm/vnfd$ ls
generic_vnfd
iotworld@semiotics-osm-big:~/osm/vnfd$ generate_descriptor_pkg.sh -t vnfd -N generic_vnfd/
iotworld@semiotics-osm-big:~/osm/vnfd$ ls
generic_vnfd  generic_vnfd.tar.gz
iotworld@semiotics-osm-big:~/osm/vnfd$
```



```
iotworld@semiotics-osm-big:~/osm/nsd$ ls
generic_nsd
iotworld@semiotics-osm-big:~/osm/nsd$ generate_descriptor_pkg.sh -t nsd -N generic_nsd/
iotworld@semiotics-osm-big:~/osm/nsd$ ls
generic_nsd  generic_nsd.tar.gz
iotworld@semiotics-osm-big:~/osm/nsd$
```

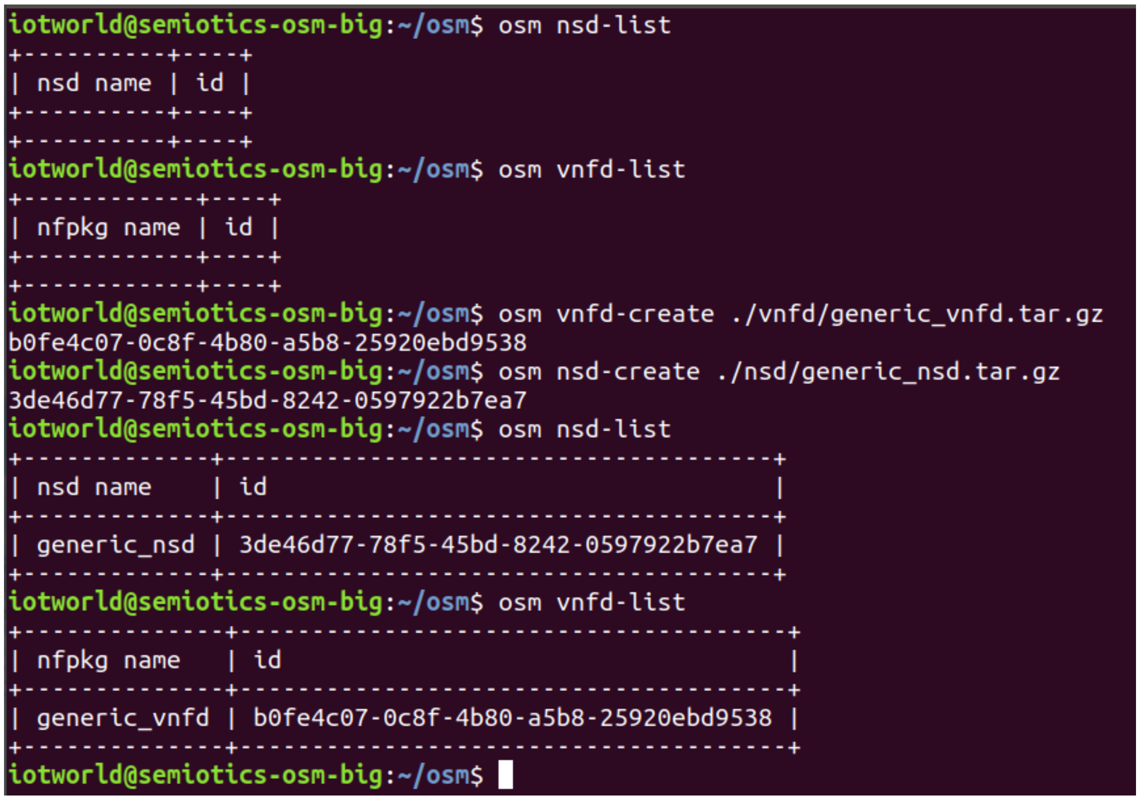
FIGURE B.9 GENERATION OF VNFd AND NSd PACKAGES.

- Onboard the VNF/NS packages to OSM library.

Next, in Figure B.10 it is demonstrated that we are able to onboard properly the NSd and VNFd packages into the library of OSM. Recall that these are a set of configuration files that describe the properties of our VNF and the requirements in terms of computing and networking that it has. Also, they describe the features of the VM that will host the VNF and the initial configuration and software packages installations that we need in the VM. We have called the NSd and VNFd as generic_nsd and generic_vnfd, respectively. It can be observed that OSM has onboarded properly the NSd and VNFd, as they appear on the list of available packages in the OSM library. Note that the osm instruction "osm nsd-list" and "osm vnfd-list" were used.

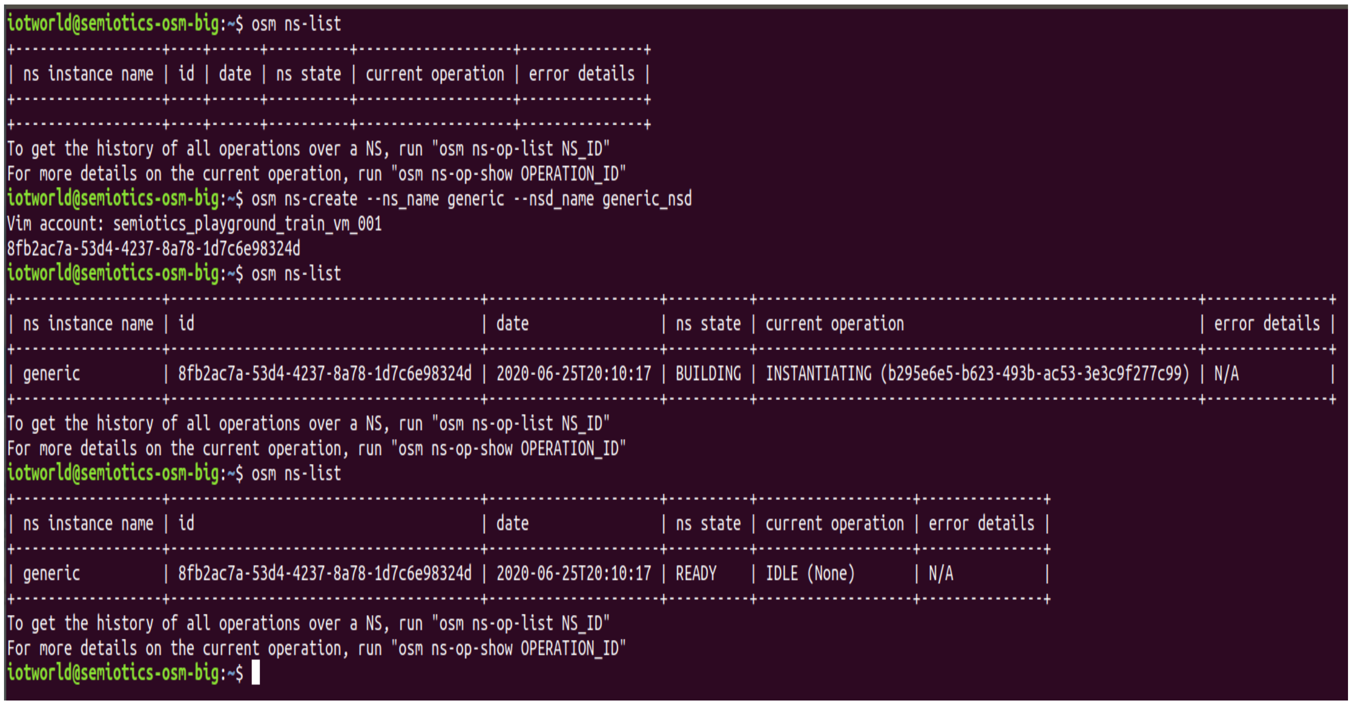
- Instantiate the NS.

Then, in Figure B.11 we trigger the instantiation of the NS that we have onboarded in OSM for our generic VNF. This means that OSM will communicate with the OpenStack controller, which creates the VM that will host our VNF on top of the virtual resources exposed by the OpenStack compute node. For that, obviously, the OSM takes into account the information embedded within the NSd and VNFd. Note that to trigger the NS instantiation we used the OSM command "osm ns-create –ns_name generic –nsd_name generic_nsd". Observe that you must specify for the nsd_name option the name of the NSd that you want to instantiate, otherwise the NS will not be instantiated.



```
iotworld@semiotics-osm-big:~/osm$ osm nsd-list
+----------+----+
| nsd name | id |
+----------+----+
+----------+----+
iotworld@semiotics-osm-big:~/osm$ osm vnfd-list
+------------+----+
| nfpkg name | id |
+------------+----+
+------------+----+
iotworld@semiotics-osm-big:~/osm$ osm vnfd-create ./vnfd/generic_vnfd.tar.gz
b0fe4c07-0c8f-4b80-a5b8-25920ebd9538
iotworld@semiotics-osm-big:~/osm$ osm nsd-create ./nsd/generic_nsd.tar.gz
3de46d77-78f5-45bd-8242-0597922b7ea7
iotworld@semiotics-osm-big:~/osm$ osm nsd-list
+-------------+--------------------------------------+
| nsd name    | id                                   |
+-------------+--------------------------------------+
| generic_nsd | 3de46d77-78f5-45bd-8242-0597922b7ea7 |
+-------------+--------------------------------------+
iotworld@semiotics-osm-big:~/osm$ osm vnfd-list
+--------------+--------------------------------------+
| nfpkg name   | id                                   |
+--------------+--------------------------------------+
| generic_vnfd | b0fe4c07-0c8f-4b80-a5b8-25920ebd9538 |
+--------------+--------------------------------------+
iotworld@semiotics-osm-big:~/osm$
```

FIGURE B.10 ONBOARD VNFd AND NSd PACKAGES TO OSM.

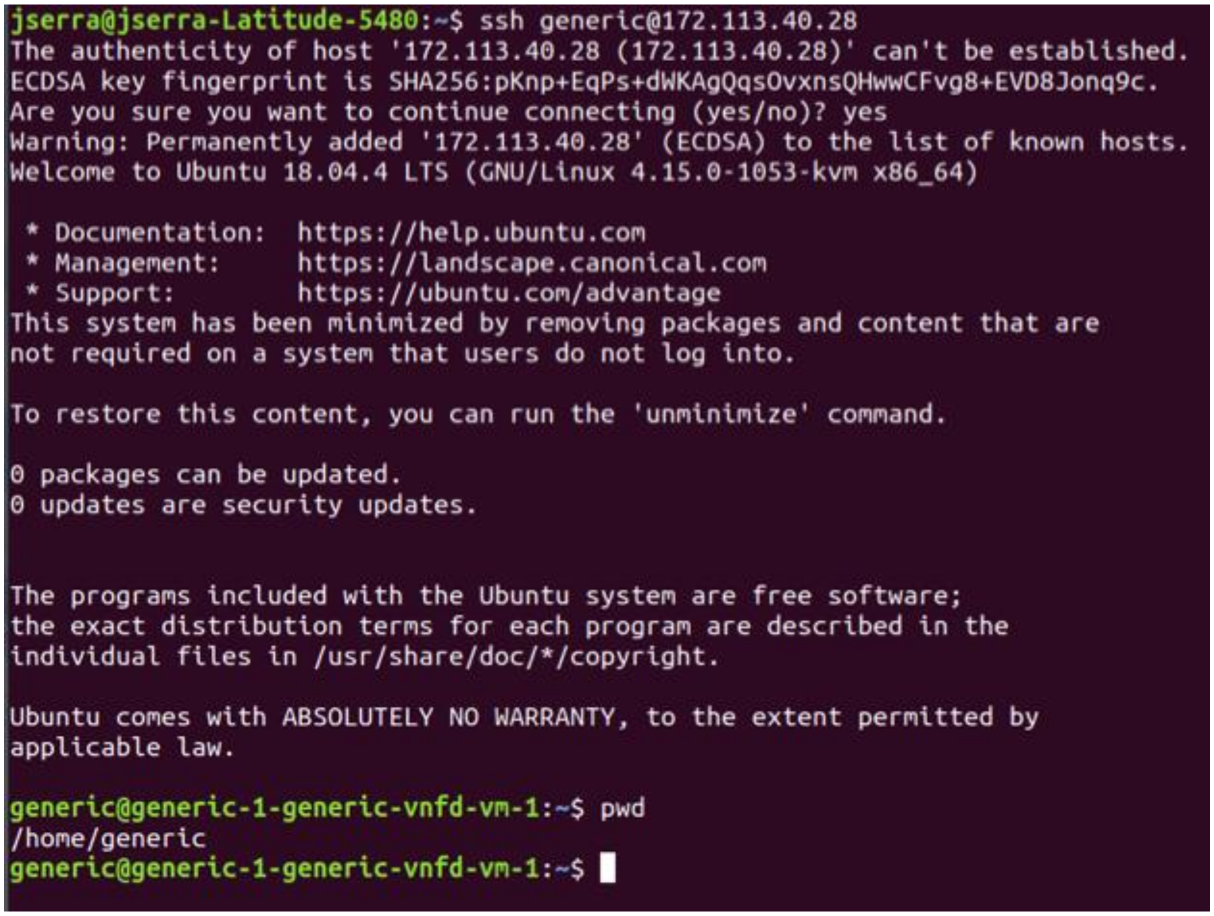


```
iotworld@semiotics-osm-big:~$ osm ns-list
+------------------+----+------+----------+-------------------+---------------+
| ns instance name | id | date | ns state | current operation | error details |
+------------------+----+------+----------+-------------------+---------------+
+------------------+----+------+----------+-------------------+---------------+
To get the history of all operations over a NS, run "osm ns-op-list NS_ID"
For more details on the current operation, run "osm ns-op-show OPERATION_ID"
iotworld@semiotics-osm-big:~$ osm ns-create --ns_name generic --nsd_name generic_nsd
Vim account: semiotics_playground_train_vm_001
8fb2ac7a-53d4-4237-8a78-1d7c6e98324d
iotworld@semiotics-osm-big:~$ osm ns-list
+------------------+--------------------------------------+---------------------+----------+------------------------------------------------------+---------------+
| ns instance name | id                                   | date                | ns state | current operation                                    | error details |
+------------------+--------------------------------------+---------------------+----------+------------------------------------------------------+---------------+
| generic          | 8fb2ac7a-53d4-4237-8a78-1d7c6e98324d | 2020-06-25T20:10:17 | BUILDING | INSTANTIATING (b295e6e5-b623-493b-ac53-3e3c9f277c99) | N/A           |
+------------------+--------------------------------------+---------------------+----------+------------------------------------------------------+---------------+
To get the history of all operations over a NS, run "osm ns-op-list NS_ID"
For more details on the current operation, run "osm ns-op-show OPERATION_ID"
iotworld@semiotics-osm-big:~$ osm ns-list
+------------------+--------------------------------------+---------------------+----------+-------------------+---------------+
| ns instance name | id                                   | date                | ns state | current operation | error details |
+------------------+--------------------------------------+---------------------+----------+-------------------+---------------+
| generic          | 8fb2ac7a-53d4-4237-8a78-1d7c6e98324d | 2020-06-25T20:10:17 | READY    | IDLE (None)       | N/A           |
+------------------+--------------------------------------+---------------------+----------+-------------------+---------------+
To get the history of all operations over a NS, run "osm ns-op-list NS_ID"
For more details on the current operation, run "osm ns-op-show OPERATION_ID"
iotworld@semiotics-osm-big:~$
```

FIGURE B.11 INSTANTIATE THE NS RELATED TO THE GENERIC VNF.

- Check that the we can access the VM created for the VNF instantiation.

The NS instantiation creates the VM that holds the VNF, on top of the NFVI. Thereby, it is important to check if we have access to such VM. In order to obtain the IP of the VM we can just execute the openstack command ”openstack server list”. OSM also provides this IP in the information of the NS instance. In Figure B.12 we show that we can access the VM that holds the generic VNF.

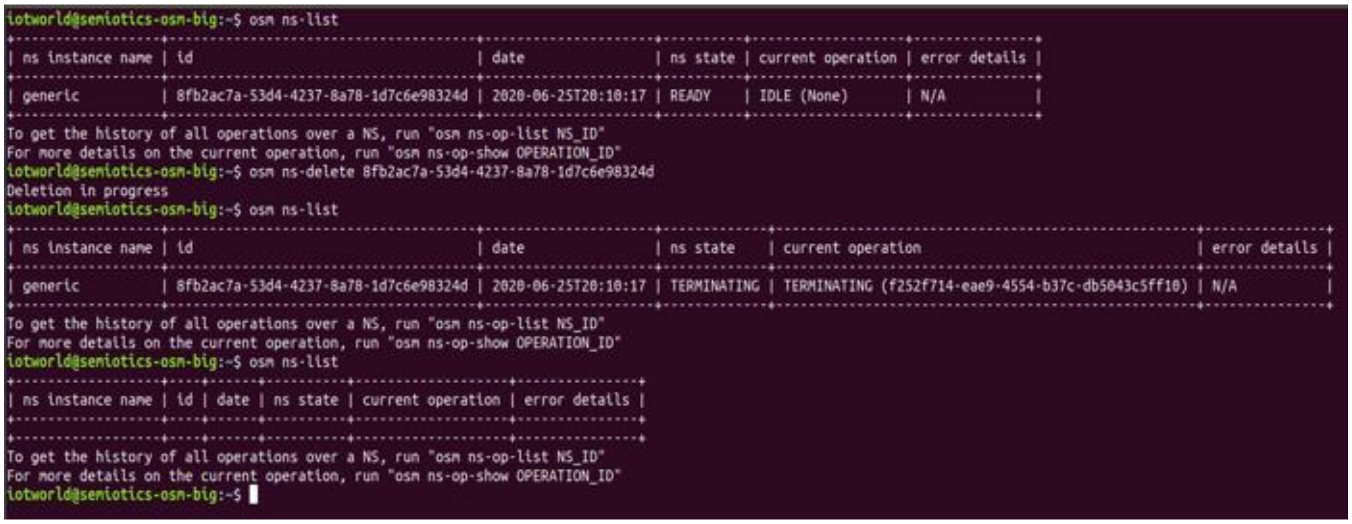


```
jserra@jserra-Latitude-5480:~$ ssh generic@172.113.40.28
The authenticity of host '172.113.40.28 (172.113.40.28)' can't be established.
ECDSA key fingerprint is SHA256:pKnp+EqPs+dWKAgQqsOvxnsQHwwCFvg8+EVD8Jonq9c.
Are you sure you want to continue connecting (yes/no)? yes
Warning: Permanently added '172.113.40.28' (ECDSA) to the list of known hosts.
Welcome to Ubuntu 18.04.4 LTS (GNU/Linux 4.15.0-1053-kvm x86_64)

 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/advantage
This system has been minimized by removing packages and content that are
not required on a system that users do not log into.

To restore this content, you can run the 'unminimize' command.

0 packages can be updated.
0 updates are security updates.


The programs included with the Ubuntu system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Ubuntu comes with ABSOLUTELY NO WARRANTY, to the extent permitted by
applicable law.

generic@generic-1-generic-vnfd-vm-1:~$ pwd
/home/generic
generic@generic-1-generic-vnfd-vm-1:~$ 
```

FIGURE B.12 CHECK THE ACCESS TO THE VM CREATED TO HOLD THE GENERIC VNF.

- Terminate the NS

Finally, we show that we can terminate the NS, which shows the overall lifecycle of a NS and its associated VNFs. To this end, we use the OSM command “osm ns-delete” and its argument must specify the id of the NS instance that we want to terminate. In Figure B.13 we show that we can terminate the NS instance associated to the generic VNF.



```
iotworld@semiotics-osm-big:~$ osm ns-list
+------------------+--------------------------------------+---------------------+----------+-------------------+---------------+
| ns instance name | id                                   | date                | ns state | current operation | error details |
+------------------+--------------------------------------+---------------------+----------+-------------------+---------------+
| generic          | 8fb2ac7a-53d4-4237-8a78-1d7c6e98324d | 2020-06-25T20:10:17 | READY    | IDLE (None)       | N/A           |
+------------------+--------------------------------------+---------------------+----------+-------------------+---------------+
To get the history of all operations over a NS, run "osm ns-op-list NS_ID"
For more details on the current operation, run "osm ns-op-show OPERATION_ID"
iotworld@semiotics-osm-big:~$ osm ns-delete 8fb2ac7a-53d4-4237-8a78-1d7c6e98324d
Deletion in progress
iotworld@semiotics-osm-big:~$ osm ns-list
+------------------+--------------------------------------+---------------------+-------------+-------------------------------------------------------+---------------+
| ns instance name | id                                   | date                | ns state    | current operation                                     | error details |
+------------------+--------------------------------------+---------------------+-------------+-------------------------------------------------------+---------------+
| generic          | 8fb2ac7a-53d4-4237-8a78-1d7c6e98324d | 2020-06-25T20:10:17 | TERMINATING | TERMINATING (f252f714-eae9-4554-b37c-db5043c5ff10) | N/A           |
+------------------+--------------------------------------+---------------------+-------------+-------------------------------------------------------+---------------+
To get the history of all operations over a NS, run "osm ns-op-list NS_ID"
For more details on the current operation, run "osm ns-op-show OPERATION_ID"
iotworld@semiotics-osm-big:~$ osm ns-list
+------------------+----+------+----------+-------------------+---------------+
| ns instance name | id | date | ns state | current operation | error details |
+------------------+----+------+----------+-------------------+---------------+
+------------------+----+------+----------+-------------------+---------------+
To get the history of all operations over a NS, run "osm ns-op-list NS_ID"
For more details on the current operation, run "osm ns-op-show OPERATION_ID"
iotworld@semiotics-osm-big:~$ 
```

FIGURE B.13 TERMINATE THE NS RELATED TO THE GENERIC VNF.

Validation of the NBI between NFV and OSS

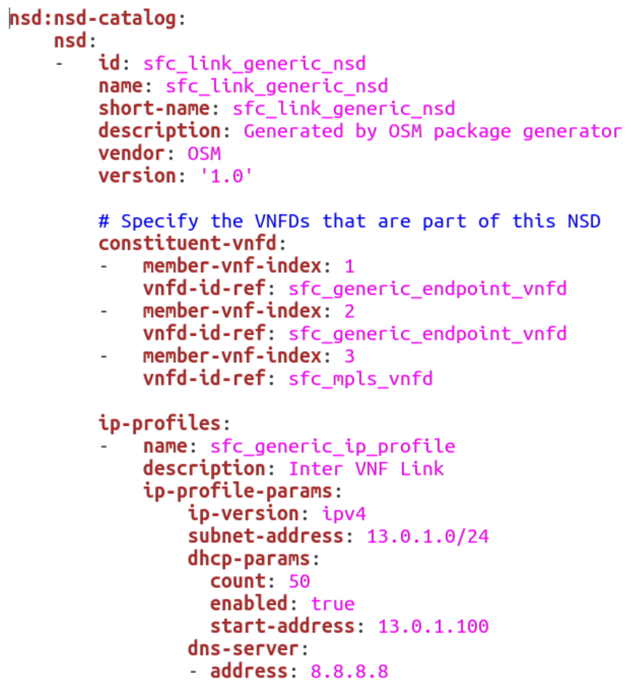
The experiments that validate the NBI interface, which allows the connection between the NFV and external OSS, have been carried out thoroughly in SEMIoTICS' deliverable D3.8. Thereby, we refer the reader to D3.8 for full details on that validation.

Validation of the SFC capability in NFV

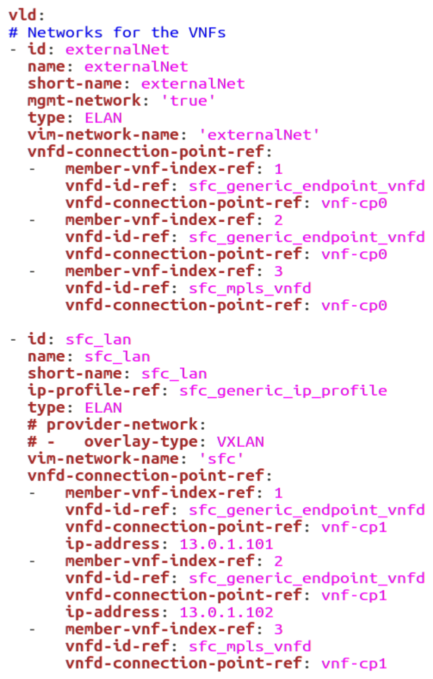
Next, we provide the experiments that validate the configuration of the SFC capability in the NFV testbed. Recall that SFC is enabled in OpenStack by installing and configuring the "networking-SFC" plugin for the OpenStack Neutron sub-block, see section 4.3.1.

First, in Figure B.14 we present the NSd that is used to carry out the SFC tests that validate the SFC capability in the NFV testbed. The NSd is presented in three segments to fit the figure in one page. The first segment is the top left figure, the second one is the top right and the last segment is the bottom one. The relevant tags of the .yaml file for the SFC purposes are described next.

- constituent-vnfd: Lists the VNF identifiers of the VNFs that belong to the SFC.
- ip-profiles: This is used to define an inner sub-network for the SFC. This means that the VNFs that belong to the SFC will communicate through this network. Their IPs are only visible to VM that belong to the network, i.e. they are not visible to other VM in the CTTC's NFV testbed.
- vld: Here the networks' link of the VNF's that belong to the SFC are defined. Note that there are two networks. One inner network, which is the one commented in the previous point. The other is an external network, i.e. it allows the connectivity to other VMs within the CTTC's NFV premises. It also allows the connectivity with other computers that are within the VPN context, though outside CTTC's premises.
- vnffgd: This is the tag that defines the behaviour of the SFC. The "classifier" tag defines which traffic is captured by the SFC and the ingress link, which is associated to a given VNF. In our case, the ingress is through the "sfc_generic_endpoint_vnfd" and we capture IP traffic whose source is 13.0.1.101 at port 2 and destination 13.0.1.102 at port 80. The "rsp" tag defines the order, in terms of the VNFs, that the traffic will follow to traverse the inner part of the SFC. In our case, we just consider one inner VNF, sfc_mpls_vnfd.

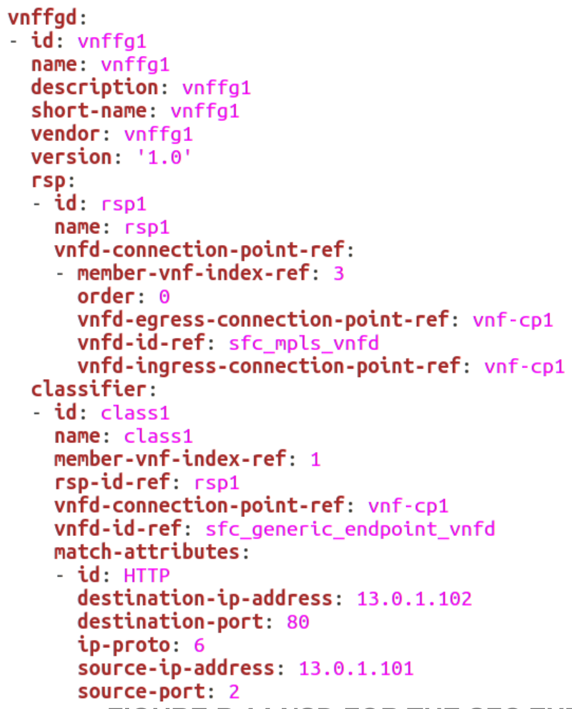


```
nsd:nsd-catalog:
    nsd:
    -   id: sfc_link_generic_nsd
        name: sfc_link_generic_nsd
        short-name: sfc_link_generic_nsd
        description: Generated by OSM package generator
        vendor: OSM
        version: '1.0'

        # Specify the VNFDs that are part of this NSD
        constituent-vnfd:
        -   member-vnf-index: 1
            vnfd-id-ref: sfc_generic_endpoint_vnfd
        -   member-vnf-index: 2
            vnfd-id-ref: sfc_generic_endpoint_vnfd
        -   member-vnf-index: 3
            vnfd-id-ref: sfc_mpls_vnfd

        ip-profiles:
        -   name: sfc_generic_ip_profile
            description: Inter VNF Link
            ip-profile-params:
                ip-version: ipv4
                subnet-address: 13.0.1.0/24
                dhcp-params:
                  count: 50
                  enabled: true
                  start-address: 13.0.1.100
                dns-server:
                - address: 8.8.8.8
```



```
vld:
# Networks for the VNFs
- id: externalNet
  name: externalNet
  short-name: externalNet
  mgmt-network: 'true'
  type: ELAN
  vim-network-name: 'externalNet'
  vnfd-connection-point-ref:
  -   member-vnf-index-ref: 1
      vnfd-id-ref: sfc_generic_endpoint_vnfd
      vnfd-connection-point-ref: vnf-cp0
  -   member-vnf-index-ref: 2
      vnfd-id-ref: sfc_generic_endpoint_vnfd
      vnfd-connection-point-ref: vnf-cp0
  -   member-vnf-index-ref: 3
      vnfd-id-ref: sfc_mpls_vnfd
      vnfd-connection-point-ref: vnf-cp0

- id: sfc_lan
  name: sfc_lan
  short-name: sfc_lan
  ip-profile-ref: sfc_generic_ip_profile
  type: ELAN
  # provider-network:
  # -   overlay-type: VXLAN
  vim-network-name: 'sfc'
  vnfd-connection-point-ref:
  -   member-vnf-index-ref: 1
      vnfd-id-ref: sfc_generic_endpoint_vnfd
      vnfd-connection-point-ref: vnf-cp1
      ip-address: 13.0.1.101
  -   member-vnf-index-ref: 2
      vnfd-id-ref: sfc_generic_endpoint_vnfd
      vnfd-connection-point-ref: vnf-cp1
      ip-address: 13.0.1.102
  -   member-vnf-index-ref: 3
      vnfd-id-ref: sfc_mpls_vnfd
      vnfd-connection-point-ref: vnf-cp1
```

1.

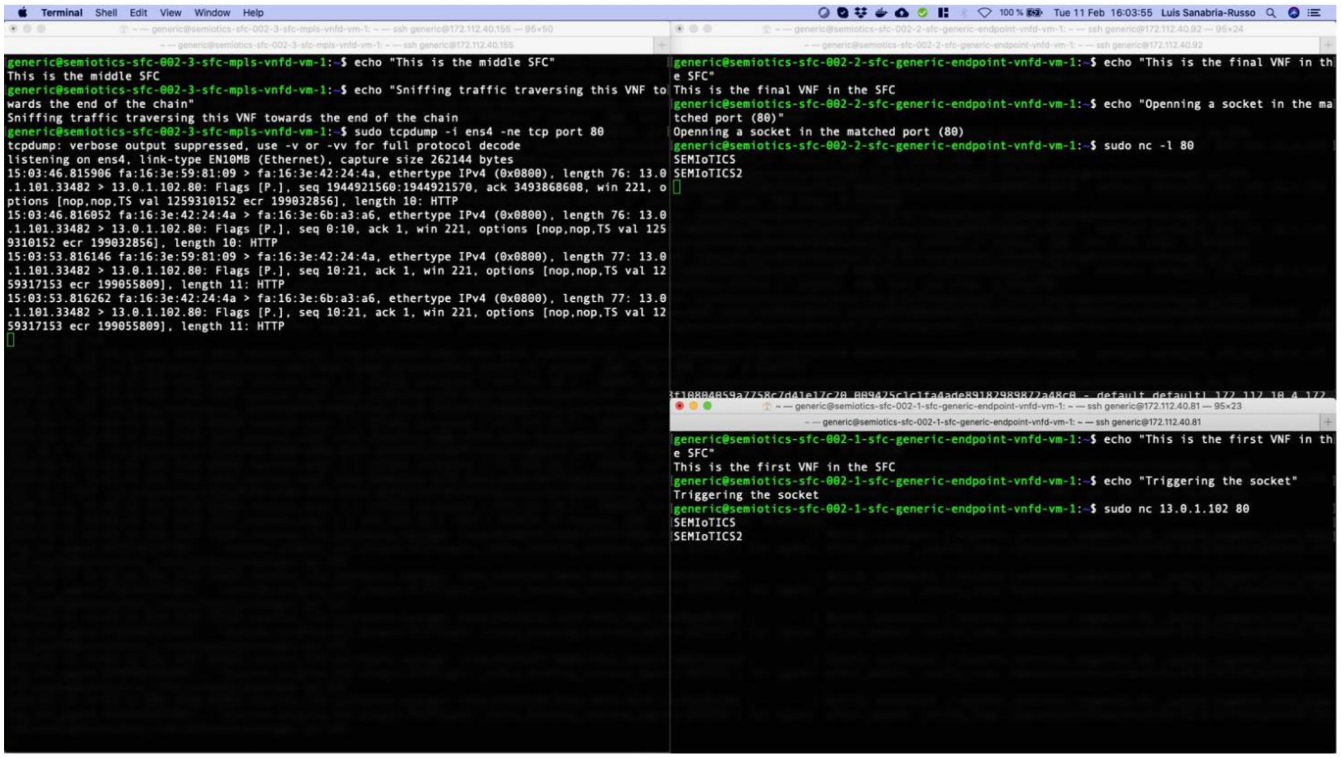


```
vnffgd:
- id: vnffg1
  name: vnffg1
  description: vnffg1
  short-name: vnffg1
  vendor: vnffg1
  version: '1.0'
  rsp:
  - id: rsp1
    name: rsp1
    vnfd-connection-point-ref:
    - member-vnf-index-ref: 3
      order: 0
      vnfd-egress-connection-point-ref: vnf-cp1
      vnfd-id-ref: sfc_mpls_vnfd
      vnfd-ingress-connection-point-ref: vnf-cp1
  classifier:
  - id: class1
    name: class1
    member-vnf-index-ref: 1
    rsp-id-ref: rsp1
    vnfd-connection-point-ref: vnf-cp1
    vnfd-id-ref: sfc_generic_endpoint_vnfd
    match-attributes:
    - id: HTTP
      destination-ip-address: 13.0.1.102
      destination-port: 80
      ip-proto: 6
      source-ip-address: 13.0.1.101
      source-port: 2
```

FIGURE B.14 NSD FOR THE SFC EXPERIMENTS IN THE NFV TESTBED.

In Figure B.15 we present the first experiment to validate the SFC capability in the NFV testbed. In this case, all the VMs are within the CTTC's NFV testbed. Namely, the source of traffic is considered to be the first VNF of the SFC, i.e. the one whose IP is 13.0.1.101 and the destination the last VNF i.e. the one whose IP is 13.0.1.102.

We generated the traffic using the netcat utility[17], which allows to write and read from network connections using TCP. Thereby, at the destination we also use netcat to receive the transmitted TCP message. Moreover, we use the tcpdump utility[18] to analyse the network traffic and see whether the traffic is captured by the middle VNF of the SFC. Figure B.15 shows how the TCP packet sent by the source is received at the destination. We can also see that the SFC captures the packet and it traverses the middle VNF.



```
generic@semiotics-sfc-002-3-sfc-mpls-vnfd-vm-1:~$ echo "This is the middle SFC"
This is the middle SFC
generic@semiotics-sfc-002-3-sfc-mpls-vnfd-vm-1:~$ echo "Sniffing traffic traversing this VNF to
wards the end of the chain"
Sniffing traffic traversing this VNF towards the end of the chain
generic@semiotics-sfc-002-3-sfc-mpls-vnfd-vm-1:~$ sudo tcpdump -i ens4 -ne tcp port 80
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on ens4, link-type EN10MB (Ethernet), capture size 262144 bytes
15:03:46.815906 fa:16:3e:59:81:09 > fa:16:3e:42:24:4a, ethertype IPv4 (0x0800), length 76: 13.0
.1.101.33482 > 13.0.1.102.80: Flags [P.], seq 1944921560:1944921570, ack 3493868608, win 221, o
ptions [nop,nop,TS val 1259310152 ecr 199032856], length 10: HTTP
15:03:46.816052 fa:16:3e:42:24:4a > fa:16:3e:6b:a3:a6, ethertype IPv4 (0x0800), length 76: 13.0
.1.101.33482 > 13.0.1.102.80: Flags [P.], seq 0:10, ack 1, win 221, options [nop,nop,TS val 125
9310152 ecr 199032856], length 10: HTTP
15:03:53.816146 fa:16:3e:59:81:09 > fa:16:3e:42:24:4a, ethertype IPv4 (0x0800), length 77: 13.0
.1.101.33482 > 13.0.1.102.80: Flags [P.], seq 10:21, ack 1, win 221, options [nop,nop,TS val 12
59317153 ecr 199055809], length 11: HTTP
15:03:53.816262 fa:16:3e:42:24:4a > fa:16:3e:6b:a3:a6, ethertype IPv4 (0x0800), length 77: 13.0
.1.101.33482 > 13.0.1.102.80: Flags [P.], seq 10:21, ack 1, win 221, options [nop,nop,TS val 12
59317153 ecr 199055809], length 11: HTTP
```

```
generic@semiotics-sfc-002-2-sfc-generic-endpoint-vnfd-vm-1:~$ echo "This is the final VNF in th
e SFC"
This is the final VNF in the SFC
generic@semiotics-sfc-002-2-sfc-generic-endpoint-vnfd-vm-1:~$ echo "Openning a socket in the ma
tched port (80)"
Openning a socket in the matched port (80)
generic@semiotics-sfc-002-2-sfc-generic-endpoint-vnfd-vm-1:~$ sudo nc -l 80
SEMIoTICS
SEMIoTICS2
```

```
3f10804059a7758c7d41e17c20 089425c1c1fa4ade89182989872a48c0 - default default1 172.112.10.4 172
```

```
generic@semiotics-sfc-002-1-sfc-generic-endpoint-vnfd-vm-1:~$ echo "This is the first VNF in th
e SFC"
This is the first VNF in the SFC
generic@semiotics-sfc-002-1-sfc-generic-endpoint-vnfd-vm-1:~$ echo "Triggering the socket"
Triggering the socket
generic@semiotics-sfc-002-1-sfc-generic-endpoint-vnfd-vm-1:~$ sudo nc 13.0.1.102 80
SEMIoTICS
SEMIoTICS2
```

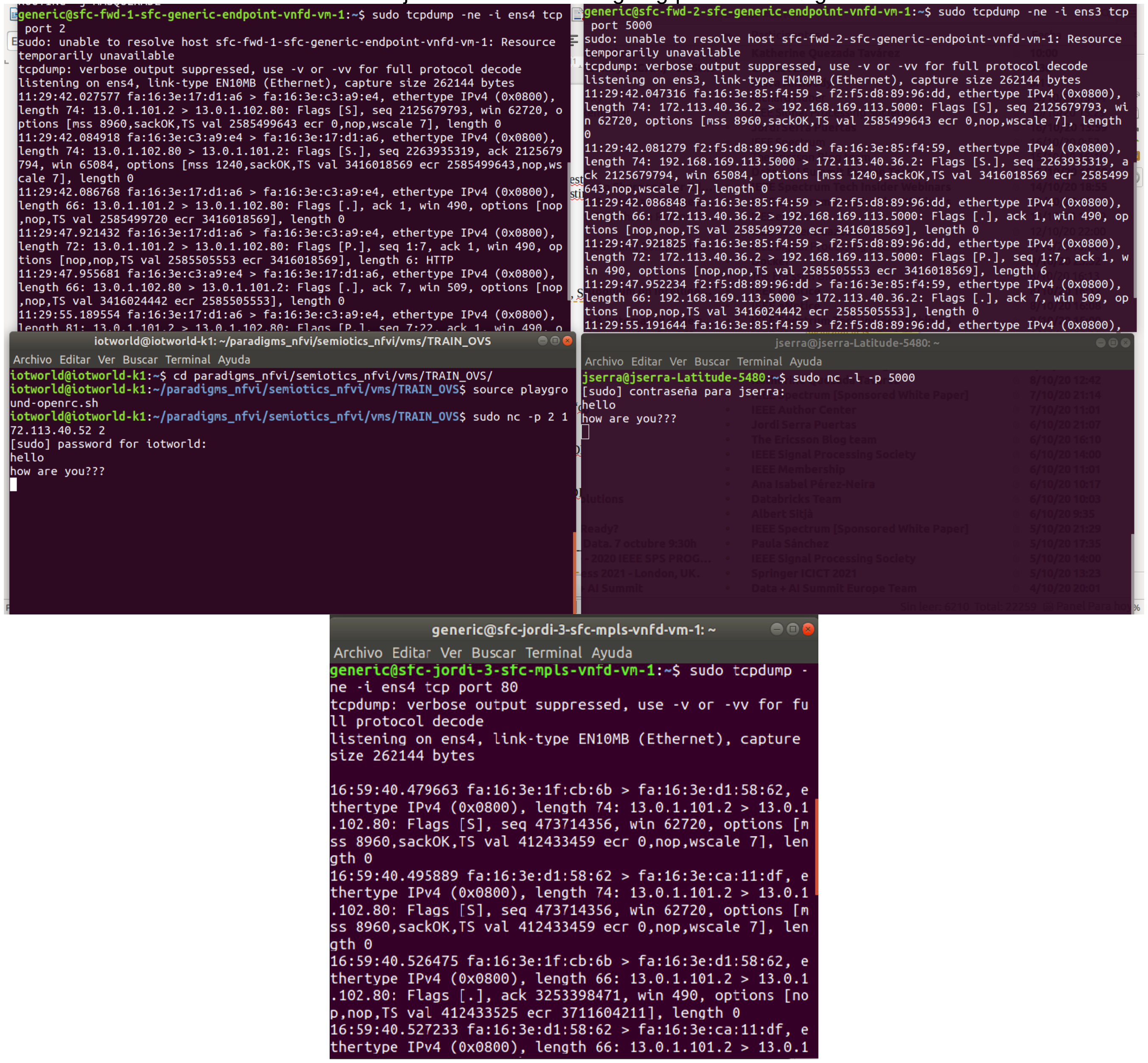
FIGURE B.15 SFC EXPERIMENT IN THE NFV TESTBED, WHEN THE TRAFFIC SOURCE AND DESTINATION ARE WITHIN THE NFV TESTBED.

In Figure B.16, we did an experiment that is similar to the one of Figure B.15. However, in this case, the source of traffic and the destination are VMs that are within the NFV testbed but that do not belong to the SFC. The aim is to assess whether the SFC can receive and forward traffic that is generated outside the SFC. Note that scenario is closer to a real scenario where the NFV testbed is integrated with other SEMIoTICS' components. In order to forward the traffic that arrives to the SFC to a given destination we make use of the linux iptables[19] utility. Namely, the next two shell command instructions are leveraged, which have been included in the cloud-init associated to the first VNF of the SFC for its automation, i.e. the one with IP 13.0.1.101.

- sudo iptables -t nat -A PREROUTING -p tcp --dport 2 -j DNAT --to-destination 13.0.1.102:80
- sudo iptables -t nat -A POSTROUTING -o ens4 -j MASQUERADE

[17] https://linuxize.com/post/netcat-nc-command-with-examples/
[18] https://www.tcpdump.org/manpages/tcpdump.1.html
[19] https://help.ubuntu.com/community/IptablesHowTo

4. Note that these two instructions refer to the nat table, as iptables defines tables containing chains of rules for the treatment of packets and nat is the one that allows to change the source and/or target ip-address in packets. Also, observe that the nat table works by using two chain of rules, PREROUTING and POSTROUTING. The former is the chain where the packets enter before a routing decision is made. The latter is the chain where packets enter after the routing decision is made and before they are released to the hardware. In the PREROUTING command we say that all the TCP packets that arrive associated to port 2 we want to forward them to the IP 13.0.1.102 at port 80. Note that this is the last VNF of the SFC. The POSTROUTING command just forwards the outgoing packets through the network interface ens4.


iotworld@iotworld-k1: ~/paradigms_nfvi/semiotics_nfvi/vms/TRAIN_OVS
Archivo Editar Ver Buscar Terminal Ayuda
jserra@jserra-Latitude-5480: ~
Archivo Editar Ver Buscar Terminal Ayuda
generic@sfc-jordi-3-sfc-mpls-vnfd-vm-1: ~
Archivo Editar Ver Buscar Terminal Ayuda

```
generic@sfc-fwd-1-sfc-generic-endpoint-vnfd-vm-1:~$ sudo tcpdump -ne -i ens4 tcp
 port 2
sudo: unable to resolve host sfc-fwd-1-sfc-generic-endpoint-vnfd-vm-1: Resource
temporarily unavailable
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on ens4, link-type EN10MB (Ethernet), capture size 262144 bytes
11:29:42.027577 fa:16:3e:17:d1:a6 > fa:16:3e:c3:a9:e4, ethertype IPv4 (0x0800),
length 74: 13.0.1.101.2 > 13.0.1.102.80: Flags [S], seq 2125679793, win 62720, o
ptions [mss 8960,sackOK,TS val 2585499643 ecr 0,nop,wscale 7], length 0
11:29:42.084918 fa:16:3e:c3:a9:e4 > fa:16:3e:17:d1:a6, ethertype IPv4 (0x0800),
length 74: 13.0.1.102.80 > 13.0.1.101.2: Flags [S.], seq 2263935319, ack 2125679
794, win 65084, options [mss 1240,sackOK,TS val 3416018569 ecr 2585499643,nop,ws
cale 7], length 0
11:29:42.086768 fa:16:3e:17:d1:a6 > fa:16:3e:c3:a9:e4, ethertype IPv4 (0x0800),
length 66: 13.0.1.101.2 > 13.0.1.102.80: Flags [.], ack 1, win 490, options [nop
,nop,TS val 2585499720 ecr 3416018569], length 0
11:29:47.921432 fa:16:3e:17:d1:a6 > fa:16:3e:c3:a9:e4, ethertype IPv4 (0x0800),
length 72: 13.0.1.101.2 > 13.0.1.102.80: Flags [P.], seq 1:7, ack 1, win 490, op
tions [nop,nop,TS val 2585505553 ecr 3416018569], length 6: HTTP
11:29:47.955681 fa:16:3e:c3:a9:e4 > fa:16:3e:17:d1:a6, ethertype IPv4 (0x0800),
length 66: 13.0.1.102.80 > 13.0.1.101.2: Flags [.], ack 7, win 509, options [nop
,nop,TS val 3416024442 ecr 2585505553], length 0
11:29:55.189554 fa:16:3e:17:d1:a6 > fa:16:3e:c3:a9:e4, ethertype IPv4 (0x0800),
length 81: 13.0.1.101.2 > 13.0.1.102.80: Flags [P.], seq 7:22, ack 1, win 490, o
```

```
generic@sfc-fwd-2-sfc-generic-endpoint-vnfd-vm-1:~$ sudo tcpdump -ne -i ens3 tcp
 port 5000
sudo: unable to resolve host sfc-fwd-2-sfc-generic-endpoint-vnfd-vm-1: Resource
temporarily unavailable
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on ens3, link-type EN10MB (Ethernet), capture size 262144 bytes
11:29:42.047316 fa:16:3e:85:f4:59 > f2:f5:d8:89:96:dd, ethertype IPv4 (0x0800),
length 74: 172.113.40.36.2 > 192.168.169.113.5000: Flags [S], seq 2125679793, wi
n 62720, options [mss 8960,sackOK,TS val 2585499643 ecr 0,nop,wscale 7], length
0
11:29:42.081279 f2:f5:d8:89:96:dd > fa:16:3e:85:f4:59, ethertype IPv4 (0x0800),
length 74: 192.168.169.113.5000 > 172.113.40.36.2: Flags [S.], seq 2263935319, a
ck 2125679794, win 65084, options [mss 1240,sackOK,TS val 3416018569 ecr 2585499
643,nop,wscale 7], length 0
11:29:42.086848 fa:16:3e:85:f4:59 > f2:f5:d8:89:96:dd, ethertype IPv4 (0x0800),
length 66: 172.113.40.36.2 > 192.168.169.113.5000: Flags [.], ack 1, win 490, op
tions [nop,nop,TS val 2585499720 ecr 3416018569], length 0
11:29:47.921825 fa:16:3e:85:f4:59 > f2:f5:d8:89:96:dd, ethertype IPv4 (0x0800),
length 72: 172.113.40.36.2 > 192.168.169.113.5000: Flags [P.], seq 1:7, ack 1, w
in 490, options [nop,nop,TS val 2585505553 ecr 3416018569], length 6
11:29:47.952234 f2:f5:d8:89:96:dd > fa:16:3e:85:f4:59, ethertype IPv4 (0x0800),
length 66: 192.168.169.113.5000 > 172.113.40.36.2: Flags [.], ack 7, win 509, op
tions [nop,nop,TS val 3416024442 ecr 2585505553], length 0
11:29:55.191644 fa:16:3e:85:f4:59 > f2:f5:d8:89:96:dd, ethertype IPv4 (0x0800),
```

```
iotworld@iotworld-k1:~$ cd paradigms_nfvi/semiotics_nfvi/vms/TRAIN_OVS/
iotworld@iotworld-k1:~/paradigms_nfvi/semiotics_nfvi/vms/TRAIN_OVS$ source playgro
und-openrc.sh
iotworld@iotworld-k1:~/paradigms_nfvi/semiotics_nfvi/vms/TRAIN_OVS$ sudo nc -p 2 1
72.113.40.52 2
[sudo] password for iotworld:
hello
how are you???
```

```
jserra@jserra-Latitude-5480:~$ sudo nc -l -p 5000
[sudo] contraseña para jserra:
hello
how are you???
```

```
generic@sfc-jordi-3-sfc-mpls-vnfd-vm-1:~$ sudo tcpdump -
ne -i ens4 tcp port 80
tcpdump: verbose output suppressed, use -v or -vv for fu
ll protocol decode
listening on ens4, link-type EN10MB (Ethernet), capture
size 262144 bytes

16:59:40.479663 fa:16:3e:1f:cb:6b > fa:16:3e:d1:58:62, e
thertype IPv4 (0x0800), length 74: 13.0.1.101.2 > 13.0.1
.102.80: Flags [S], seq 473714356, win 62720, options [m
ss 8960,sackOK,TS val 412433459 ecr 0,nop,wscale 7], len
gth 0
16:59:40.495889 fa:16:3e:d1:58:62 > fa:16:3e:ca:11:df, e
thertype IPv4 (0x0800), length 74: 13.0.1.101.2 > 13.0.1
.102.80: Flags [S], seq 473714356, win 62720, options [m
ss 8960,sackOK,TS val 412433459 ecr 0,nop,wscale 7], len
gth 0
16:59:40.526475 fa:16:3e:1f:cb:6b > fa:16:3e:d1:58:62, e
thertype IPv4 (0x0800), length 66: 13.0.1.101.2 > 13.0.1
.102.80: Flags [.], ack 3253398471, win 490, options [no
p,nop,TS val 412433525 ecr 3711604211], length 0
16:59:40.527233 fa:16:3e:d1:58:62 > fa:16:3e:ca:11:df, e
thertype IPv4 (0x0800), length 66: 13.0.1.101.2 > 13.0.1
```

FIGURE B.16 SFC EXPERIMENT IN THE NFV TESTBED, WHEN THE TRAFFIC SOURCE IS ANOTHER NS OF THE NFV TESTBED AND DESTINATION IS OUTSIDE CTTC NFV TESTBED.

The same rationale is applied at the last VNF of the SFC to forward the traffic to an external machine, a local PC in the VPN, whose IP is 192.168.169.100:

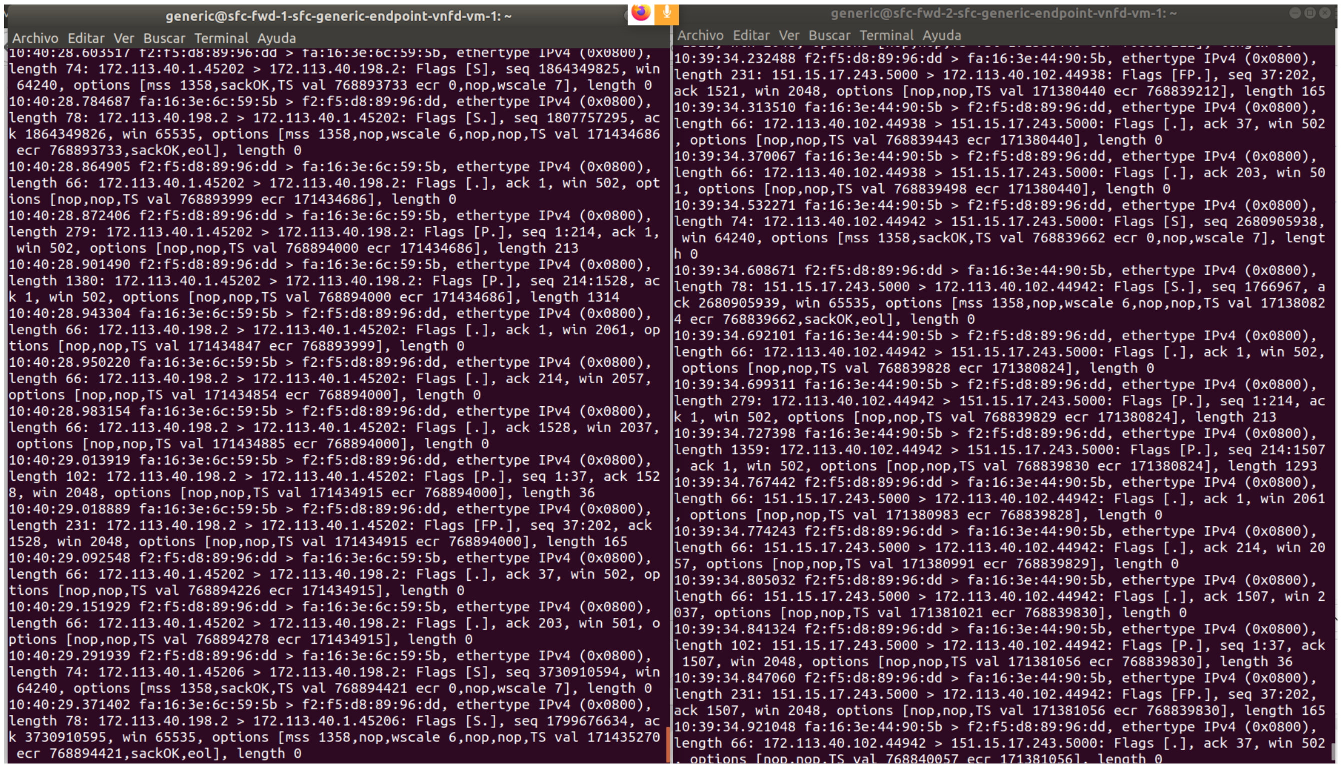
- sudo iptables -t nat -A PREROUTING -p tcp --dport 80 -j DNAT --to-destination 192.168.169.100:5000
- sudo iptables -t nat -A POSTROUTING -o ens3 -j MASQUERADE

In Figure B.16, we see how the traffic generated in the middle left figure passes through the first VNF of the SFC, on the top left. Then, it passes through the middle VNF of the SFC at the bottom, and finally leaves the SFC by traversing the last VNF of the SFC at the top right figure. Finally, it arrives to the external machine, as the middle right figure shows.

Finally, in Figure B.17 we have done a similar experiment than in Figure B.16. However, in this case the source of traffic is located at the IoT GW in the Engineering premises, i.e. outside CTTC premises. Similarly, the destination is a backend server located in the Engineering premises as well. This validates the end-to-end connectivity. In terms of the iptable commands, we used in the first VNF of the SFC the same commands than for Figure B.16, as we want to route the incoming traffic until the last VNF of the SFC. The iptable commands of the last VNF of the SFC are also similar to the ones of Figure B.16, we just changed the destination IP address where we want to route the traffic:

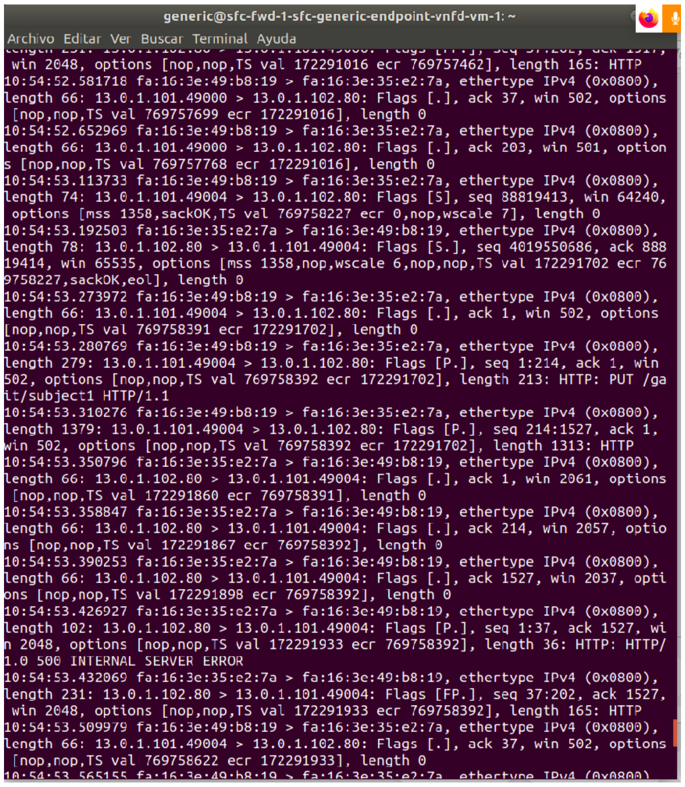
- sudo iptables -t nat -A PREROUTING -p tcp --dport 80 -j DNAT --to-destination 151.15.17.243:5000
- sudo iptables -t nat -A POSTROUTING -o ens3 -j MASQUERADE

In Figure B.17, on the top left, we show how the external traffic generated at Engineering arrives to the first VNF of the SFC, note that the traffic displays the external IPs of the SFC, i.e. 172.x.x.x. Namely, 172.113.40.1 is the IP of the external router of the NFV testbed. And 172.113.40.198 is the external IP of the first VNF of the SFC. Also, note in the bottom figure that the first VNF of the SFC chain forwards the traffic to the last VNF of the SFC. To show this situation we display the IP of the internal network of the SFC, i.e. 13.x.x.x. Finally, on the top right figure we show how the last VNF of the SFC routes the traffic to the backend server located at Engineering, whose IP and port are 151.15.17.243 and 5000, respectively. This figure also shows that the server at Engineering sends an ACK message, so it receives the traffic.


generic@sfc-fwd-1-sfc-generic-endpoint-vnfd-vm-1: ~
Archivo Editar Ver Buscar Terminal Ayuda
generic@sfc-fwd-2-sfc-generic-endpoint-vnfd-vm-1: ~
Archivo Editar Ver Buscar Terminal Ayuda

```
10:40:28.603517 f2:f5:d8:89:96:dd > fa:16:3e:6c:59:5b, ethertype IPv4 (0x0800),
length 74: 172.113.40.1.45202 > 172.113.40.198.2: Flags [S], seq 1864349825, win
 64240, options [mss 1358,sackOK,TS val 768893733 ecr 0,nop,wscale 7], length 0
10:40:28.784687 fa:16:3e:6c:59:5b > f2:f5:d8:89:96:dd, ethertype IPv4 (0x0800),
length 78: 172.113.40.198.2 > 172.113.40.1.45202: Flags [S.], seq 1807757295, ac
k 1864349826, win 65535, options [mss 1358,nop,wscale 6,nop,nop,TS val 171434686
 ecr 768893733,sackOK,eol], length 0
10:40:28.864905 f2:f5:d8:89:96:dd > fa:16:3e:6c:59:5b, ethertype IPv4 (0x0800),
length 66: 172.113.40.1.45202 > 172.113.40.198.2: Flags [.], ack 1, win 502, opt
ions [nop,nop,TS val 768893999 ecr 171434686], length 0
10:40:28.872406 f2:f5:d8:89:96:dd > fa:16:3e:6c:59:5b, ethertype IPv4 (0x0800),
length 279: 172.113.40.1.45202 > 172.113.40.198.2: Flags [P.], seq 1:214, ack 1,
 win 502, options [nop,nop,TS val 768894000 ecr 171434686], length 213
10:40:28.901490 f2:f5:d8:89:96:dd > fa:16:3e:6c:59:5b, ethertype IPv4 (0x0800),
length 1380: 172.113.40.1.45202 > 172.113.40.198.2: Flags [P.], seq 214:1528, ac
k 1, win 502, options [nop,nop,TS val 768894000 ecr 171434686], length 1314
10:40:28.943304 fa:16:3e:6c:59:5b > f2:f5:d8:89:96:dd, ethertype IPv4 (0x0800),
length 66: 172.113.40.198.2 > 172.113.40.1.45202: Flags [.], ack 1, win 2061, op
tions [nop,nop,TS val 171434847 ecr 768893999], length 0
10:40:28.950220 fa:16:3e:6c:59:5b > f2:f5:d8:89:96:dd, ethertype IPv4 (0x0800),
length 66: 172.113.40.198.2 > 172.113.40.1.45202: Flags [.], ack 214, win 2057,
options [nop,nop,TS val 171434854 ecr 768894000], length 0
10:40:28.983154 fa:16:3e:6c:59:5b > f2:f5:d8:89:96:dd, ethertype IPv4 (0x0800),
length 66: 172.113.40.198.2 > 172.113.40.1.45202: Flags [.], ack 1528, win 2037,
 options [nop,nop,TS val 171434885 ecr 768894000], length 0
10:40:29.013919 fa:16:3e:6c:59:5b > f2:f5:d8:89:96:dd, ethertype IPv4 (0x0800),
length 102: 172.113.40.198.2 > 172.113.40.1.45202: Flags [P.], seq 1:37, ack 152
8, win 2048, options [nop,nop,TS val 171434915 ecr 768894000], length 36
10:40:29.018889 fa:16:3e:6c:59:5b > f2:f5:d8:89:96:dd, ethertype IPv4 (0x0800),
length 231: 172.113.40.198.2 > 172.113.40.1.45202: Flags [FP.], seq 37:202, ack
1528, win 2048, options [nop,nop,TS val 171434915 ecr 768894000], length 165
10:40:29.092548 f2:f5:d8:89:96:dd > fa:16:3e:6c:59:5b, ethertype IPv4 (0x0800),
length 66: 172.113.40.1.45202 > 172.113.40.198.2: Flags [.], ack 37, win 502, op
tions [nop,nop,TS val 768894226 ecr 171434915], length 0
10:40:29.151929 f2:f5:d8:89:96:dd > fa:16:3e:6c:59:5b, ethertype IPv4 (0x0800),
length 66: 172.113.40.1.45202 > 172.113.40.198.2: Flags [.], ack 203, win 501, o
ptions [nop,nop,TS val 768894278 ecr 171434915], length 0
10:40:29.291939 f2:f5:d8:89:96:dd > fa:16:3e:6c:59:5b, ethertype IPv4 (0x0800),
length 74: 172.113.40.1.45206 > 172.113.40.198.2: Flags [S], seq 3730910594, win
 64240, options [mss 1358,sackOK,TS val 768894421 ecr 0,nop,wscale 7], length 0
10:40:29.371402 fa:16:3e:6c:59:5b > f2:f5:d8:89:96:dd, ethertype IPv4 (0x0800),
length 78: 172.113.40.198.2 > 172.113.40.1.45206: Flags [S.], seq 1799676634, ac
k 3730910595, win 65535, options [mss 1358,nop,wscale 6,nop,nop,TS val 171435270
 ecr 768894421,sackOK,eol], length 0
```

```
10:39:34.232488 f2:f5:d8:89:96:dd > fa:16:3e:44:90:5b, ethertype IPv4 (0x0800),
length 231: 151.15.17.243.5000 > 172.113.40.102.44938: Flags [FP.], seq 37:202,
ack 1521, win 2048, options [nop,nop,TS val 171380440 ecr 768839212], length 165
10:39:34.313510 fa:16:3e:44:90:5b > f2:f5:d8:89:96:dd, ethertype IPv4 (0x0800),
length 66: 172.113.40.102.44938 > 151.15.17.243.5000: Flags [.], ack 37, win 502
, options [nop,nop,TS val 768839443 ecr 171380440], length 0
10:39:34.370067 fa:16:3e:44:90:5b > f2:f5:d8:89:96:dd, ethertype IPv4 (0x0800),
length 66: 172.113.40.102.44938 > 151.15.17.243.5000: Flags [.], ack 203, win 50
1, options [nop,nop,TS val 768839498 ecr 171380440], length 0
10:39:34.532271 fa:16:3e:44:90:5b > f2:f5:d8:89:96:dd, ethertype IPv4 (0x0800),
length 74: 172.113.40.102.44942 > 151.15.17.243.5000: Flags [S], seq 2680905938,
 win 64240, options [mss 1358,sackOK,TS val 768839662 ecr 0,nop,wscale 7], lengt
h 0
10:39:34.608671 f2:f5:d8:89:96:dd > fa:16:3e:44:90:5b, ethertype IPv4 (0x0800),
length 78: 151.15.17.243.5000 > 172.113.40.102.44942: Flags [S.], seq 1766967, a
ck 2680905939, win 65535, options [mss 1358,nop,wscale 6,nop,nop,TS val 17138082
4 ecr 768839662,sackOK,eol], length 0
10:39:34.692101 fa:16:3e:44:90:5b > f2:f5:d8:89:96:dd, ethertype IPv4 (0x0800),
length 66: 172.113.40.102.44942 > 151.15.17.243.5000: Flags [.], ack 1, win 502,
 options [nop,nop,TS val 768839828 ecr 171380824], length 0
10:39:34.699311 fa:16:3e:44:90:5b > f2:f5:d8:89:96:dd, ethertype IPv4 (0x0800),
length 279: 172.113.40.102.44942 > 151.15.17.243.5000: Flags [P.], seq 1:214, ac
k 1, win 502, options [nop,nop,TS val 768839829 ecr 171380824], length 213
10:39:34.727398 fa:16:3e:44:90:5b > f2:f5:d8:89:96:dd, ethertype IPv4 (0x0800),
length 1359: 172.113.40.102.44942 > 151.15.17.243.5000: Flags [P.], seq 214:1507
, ack 1, win 502, options [nop,nop,TS val 768839830 ecr 171380824], length 1293
10:39:34.767442 f2:f5:d8:89:96:dd > fa:16:3e:44:90:5b, ethertype IPv4 (0x0800),
length 66: 151.15.17.243.5000 > 172.113.40.102.44942: Flags [.], ack 1, win 2061
, options [nop,nop,TS val 171380983 ecr 768839828], length 0
10:39:34.774243 f2:f5:d8:89:96:dd > fa:16:3e:44:90:5b, ethertype IPv4 (0x0800),
length 66: 151.15.17.243.5000 > 172.113.40.102.44942: Flags [.], ack 214, win 20
57, options [nop,nop,TS val 171380991 ecr 768839829], length 0
10:39:34.805032 f2:f5:d8:89:96:dd > fa:16:3e:44:90:5b, ethertype IPv4 (0x0800),
length 66: 151.15.17.243.5000 > 172.113.40.102.44942: Flags [.], ack 1507, win 2
037, options [nop,nop,TS val 171381021 ecr 768839830], length 0
10:39:34.841324 f2:f5:d8:89:96:dd > fa:16:3e:44:90:5b, ethertype IPv4 (0x0800),
length 102: 151.15.17.243.5000 > 172.113.40.102.44942: Flags [P.], seq 1:37, ack
 1507, win 2048, options [nop,nop,TS val 171381056 ecr 768839830], length 36
10:39:34.847060 f2:f5:d8:89:96:dd > fa:16:3e:44:90:5b, ethertype IPv4 (0x0800),
length 231: 151.15.17.243.5000 > 172.113.40.102.44942: Flags [FP.], seq 37:202,
ack 1507, win 2048, options [nop,nop,TS val 171381056 ecr 768839830], length 165
10:39:34.921048 fa:16:3e:44:90:5b > f2:f5:d8:89:96:dd, ethertype IPv4 (0x0800),
length 66: 172.113.40.102.44942 > 151.15.17.243.5000: Flags [.], ack 37, win 502
, options [nop,nop,TS val 768840057 ecr 171381056], length 0
```


generic@sfc-fwd-1-sfc-generic-endpoint-vnfd-vm-1: ~
Archivo Editar Ver Buscar Terminal Ayuda

```
 win 2048, options [nop,nop,TS val 172291016 ecr 769757462], length 165: HTTP
10:54:52.581718 fa:16:3e:49:b8:19 > fa:16:3e:35:e2:7a, ethertype IPv4 (0x0800),
length 66: 13.0.1.101.49000 > 13.0.1.102.80: Flags [.], ack 37, win 502, options
 [nop,nop,TS val 769757699 ecr 172291016], length 0
10:54:52.652969 fa:16:3e:49:b8:19 > fa:16:3e:35:e2:7a, ethertype IPv4 (0x0800),
length 66: 13.0.1.101.49000 > 13.0.1.102.80: Flags [.], ack 203, win 501, option
s [nop,nop,TS val 769757768 ecr 172291016], length 0
10:54:53.113733 fa:16:3e:49:b8:19 > fa:16:3e:35:e2:7a, ethertype IPv4 (0x0800),
length 74: 13.0.1.101.49004 > 13.0.1.102.80: Flags [S], seq 88819413, win 64240,
 options [mss 1358,sackOK,TS val 769758227 ecr 0,nop,wscale 7], length 0
10:54:53.192503 fa:16:3e:35:e2:7a > fa:16:3e:49:b8:19, ethertype IPv4 (0x0800),
length 78: 13.0.1.102.80 > 13.0.1.101.49004: Flags [S.], seq 4019550686, ack 888
19414, win 65535, options [mss 1358,nop,wscale 6,nop,nop,TS val 172291702 ecr 76
9758227,sackOK,eol], length 0
10:54:53.273972 fa:16:3e:49:b8:19 > fa:16:3e:35:e2:7a, ethertype IPv4 (0x0800),
length 66: 13.0.1.101.49004 > 13.0.1.102.80: Flags [.], ack 1, win 502, options
[nop,nop,TS val 769758391 ecr 172291702], length 0
10:54:53.280769 fa:16:3e:49:b8:19 > fa:16:3e:35:e2:7a, ethertype IPv4 (0x0800),
length 279: 13.0.1.101.49004 > 13.0.1.102.80: Flags [P.], seq 1:214, ack 1, win
502, options [nop,nop,TS val 769758392 ecr 172291702], length 213: HTTP: PUT /ga
it/subject1 HTTP/1.1
10:54:53.310276 fa:16:3e:49:b8:19 > fa:16:3e:35:e2:7a, ethertype IPv4 (0x0800),
length 1379: 13.0.1.101.49004 > 13.0.1.102.80: Flags [P.], seq 214:1527, ack 1,
win 502, options [nop,nop,TS val 769758392 ecr 172291702], length 1313: HTTP
10:54:53.350796 fa:16:3e:35:e2:7a > fa:16:3e:49:b8:19, ethertype IPv4 (0x0800),
length 66: 13.0.1.102.80 > 13.0.1.101.49004: Flags [.], ack 1, win 2061, options
 [nop,nop,TS val 172291860 ecr 769758391], length 0
10:54:53.358847 fa:16:3e:35:e2:7a > fa:16:3e:49:b8:19, ethertype IPv4 (0x0800),
length 66: 13.0.1.102.80 > 13.0.1.101.49004: Flags [.], ack 214, win 2057, optio
ns [nop,nop,TS val 172291867 ecr 769758392], length 0
10:54:53.390253 fa:16:3e:35:e2:7a > fa:16:3e:49:b8:19, ethertype IPv4 (0x0800),
length 66: 13.0.1.102.80 > 13.0.1.101.49004: Flags [.], ack 1527, win 2037, opti
ons [nop,nop,TS val 172291898 ecr 769758392], length 0
10:54:53.426927 fa:16:3e:35:e2:7a > fa:16:3e:49:b8:19, ethertype IPv4 (0x0800),
length 102: 13.0.1.102.80 > 13.0.1.101.49004: Flags [P.], seq 1:37, ack 1527, wi
n 2048, options [nop,nop,TS val 172291933 ecr 769758392], length 36: HTTP: HTTP/
1.0 500 INTERNAL SERVER ERROR
10:54:53.432069 fa:16:3e:35:e2:7a > fa:16:3e:49:b8:19, ethertype IPv4 (0x0800),
length 231: 13.0.1.102.80 > 13.0.1.101.49004: Flags [FP.], seq 37:202, ack 1527,
 win 2048, options [nop,nop,TS val 172291933 ecr 769758392], length 165: HTTP
10:54:53.509979 fa:16:3e:49:b8:19 > fa:16:3e:35:e2:7a, ethertype IPv4 (0x0800),
length 66: 13.0.1.101.49004 > 13.0.1.102.80: Flags [.], ack 37, win 502, options
 [nop,nop,TS val 769758622 ecr 172291933], length 0
10:54:53.565155 fa:16:3e:49:b8:19 > fa:16:3e:35:e2:7a, ethertype IPv4 (0x0800)
```

FIGURE B.17 SFC EXPERIMENT IN THE NFV TESTBED, WHEN THE TRAFFIC SOURCE AND DESTINATION ARE THE IOT GW AND BACKEND SERVER AT ENG PREMISES.