TRESCIMO

Deliverable 4.1

Experiment Description

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Abstract

This document outlines experiments to be conducted in the TRESCIMO Virtual Private Network environment and the TRESCIMO Federated Environment, describing suitable evaluation criteria of the developed architecture and components in order to assess the communication platforms in both real world environments and in scalable testing facilities.

Based on the findings of WP2 (D2.2 document) and WP3 (D3.1 document) experiments are designed to validate use-cases and usage scenarios. Evaluation results of these experiments are to be delivered in WP2 and WP3 to provide feedback for the TRESCIMO architecture and prototype implementation.

Disclaimer

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Impressum

[Full project title] Testbeds for Reliable Smart City Machine-to-Machine Communication

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Executive Summary

The objective of the TRESCIMO project is to create an infrastructure for the experimental evaluation of different Smart City related use cases. This includes the operational domains for smart metering and energy management, environmental monitoring, health and education.

Experiments to be carried out, both on the VPN and the federated environments, are used to validate the prototypes and perform evaluations based on functionality, configuration and end-user testing. In addition, planned experiments are specified to extend the federated service to illustrate how the federated environment supports realistic usage scenarios in order to test for repeatability and scalability.

This document describes experiments that are needed to evaluate the development from WP3 that deal with the overall architecture based on the requirement defined in WP2.

List of Authors

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TUB	Ronald Steinke	Federated Experiments, Conclusions, Document Review
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Fraunhofer Fokus	Ancuta Corici	Federated Experiments
CSIR	Louis Coetzee	Smart City Platform Description and utilization for DTN experiments

Summary of changes addressing comments from the Review

Comment	How comment was addressed
Include a full description as to how the forthcoming trials will be evaluated taking into account real user expectation and experience.	***Section 2.4****- was added. This section focuses on the SA Trial (2.4.1) and the EU Trial (2.4.2).* ***Section 3.2.2-*** *User based KPIs relating to the Trial for Eskom Smart Energy customers were added.*
Reconsider the number of households taking part in the Eskom trial and to make every effort to increase the number of participants in order to enhance the statistical relevance of the trial and to include relevant incentives where necessary.	***Section 2.4.1****-Provides more details into the Eskom Trial:* *Number of Households: 20-30;* *Number of regions (4-6);* *Possible incentives for participating in the trial.*
It is not clear how the testbeds can and will be used by the FIRE community and can contribute to the further evolution of Fed4FIRE.	***Section 2.2.2-*** *The federated Testbed architecture diagram has been updated in order to include experimenters using the FITeagle-SFA client*
Justifies the use of the combined features of the underlying testbeds	***Section 2.2-*** *Added text that explains the benefits of the combined testbed infrastructure***.**
The energy experiments provide a good description of KPIs related to the technical performance and impact of the proposed interventions, however KPIs about user experience are currently lacking	***Section 3.2.2-*** *User based KPIs relating to the Trial for Eskom Smart Energy customers were added.*
The role of the simplistic health care scenario is pretty unclear	***Section 4.4-*** *The basic health care experiment has been merged with the federated one in this section.*
Demonstrating the benefits of a combined integrated infrastructure (Smart City platform, M2M platform, DTN forwarding) and develop an adequate set of experiments for it.	***Section 2.4.2-*** *The Smart city Platform will now be used in the Spanish (EU) Trial* ***Section 4.1 and 4.2-*** *Infrastructure experiments have been added.*

Additional changes	
Add information on previous trial done by ESKOM as means to provide background to the SA Trial.	***Annex 1 –*** *was added to provide information on the Eskom AMI Pilot Project*
Provide information on the proof of concept testbed in Pretoria	***Section 2.3 –*** *This section was added to provide details on the proof of concept in Pretoria.*

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Abbreviations

ABS	Airbase Systems
AEC	Appliance Energy Consumption
AMI	Advanced Metering Infrastructure
CSIR	Council for Scientific and Industrial and Research
DR	Demand Response
FI	Future Internet
FIRE	Future Internet Research and Experimentation
I2CAT	Internet Innovacio Digital a Catalunya
IoT	Internet of Things
KPI	Key Performance Indicator
M2M	Machine-to-machine
PT	Total Power consumption per residence
SFA	Slice-based Federated Architecture
TC	Total consumption
TRESCIMO	Testbeds for Reliable Smart City Machine to Machine Communication
TSP	Total Suspended Particles
TUB	Technical University of Berlin
UCT	University of Cape Town
VLAN	Virtual Local Area Network
VOC	Volatile organic compound
VPN	Virtual Private Network

Definitions

Actors	Anything with behaviour, including the system under discussion itself, when it calls upon the services of another system.
Use-cases	Provide a description of the possible sequence of interactions between the system under discussion and its external actors related to a particular goal.
Usage scenarios	Specific manifestations of use-cases as experimenters (actors) conduct their experiment using slices from the federated virtualized infrastructures. It provides a path through a use-case or through a portion of a use-case.
Domain	Coherent field of activity.
Horizontal Scalability	Addition of extra infrastructures into the federated environment.
Vertical Scalability	Addition of extra resources into the existing infrastructure.

1 Introduction

The need for large-scale testbeds for Smart Cities has been recognized by industry and academia, in order to develop a prospect model for the Smart City implementation [7]. In TRESCIMO, we are building a federation of testbeds that allows experimentation with enabling technologies, standardized platforms and applications for Smart Cities with different configurations. Experimental tools provide an effective option to study the behaviour of integrated software and hardware before implementing real deployments.

The TRESCIMO testbed is based on a virtualized standardized M2M platform (OpenMTC within OpenStack) and an open-source, SFA-compatible framework for managing and federating testbeds (FITeagle). The testbed consists of three interconnected sites located in Berlin-Germany, Cape Town-South Africa and Pretoria-South Africa. Additionally, the federation with other testbeds will allow the sharing of resources (i.e. sensors, actuators and data) among different services and users regardless of their location. The integrated resources include sensors and devices used in different test environments as well as applications.

In D2.1 (Scenario Specification) [4] various Smart City scenarios associated with energy, transportation, safety, health, education and water have been highlighted. The experimentations described in this document are based on a selected set of these scenarios. However, the available experimental sites are extendable to cover a selected set of smart city's usage scenarios. The experiments will consider different environmental settings for research and testing of software and hardware related with physical aspects, medium access control, networking, communication issues or standards in a controlled way.

1.1 Objective of this document

This primary objective is to describe the experiments that are needed to evaluate the developments from WP3 based on the requirements defined in WP2. The remaining sections of this document describes the experimentation scenarios and objectives; the Key Performance Indicators (KPIs) linked to use-cases or usage-scenarios are identified. The goal of this task is to act as an experimenter willing to evaluate a smart city service on the experimental research facility.

The deliverable is organized as follows:

Section 2 provides a compact overview of the service experimenter environment. In Section 3 experiments on basic usage scenarios in the VPN environment are presented for configuration, functionality and end-user tests, while Section 4 extends the experimentation into a federated environment with additional tests for repeatability and scalability. Section 5 concludes the document and provides direction for future work.

2 Experimenter Environment

2.1 Types of Planned Experiments

As further described in D3.1 [5], the following types of tests will be conducted:

- Configuration: to validate the performance of the implemented service under various environments, by conducting different measurements with configurable conditions.
- Functionality: to validate the specified functionality of utilized infrastructure, components and technologies of the system.
- End-user testing: to gain insight into the effect of status communication back to the end-user (e.g. the user's current energy consumption).
- Repeatability: or test–retest reliability is the variation in measurements taken by a single person or instrument on the same item and under the same conditions. A measurement may be said to be repeatable when this variation is smaller than some agreed limit [10].
- Scalability: to test the infrastructure based on its ability to cope with increasing number of users while satisfying individual user's metrics.

2.2 Testbeds

The testbeds at TUB, UCT and CSIR are interconnected via a Virtual Private Network (VPN) connection. The three testbeds are realized as a mix of virtual services (as OpenStack-based virtual machines) and physical components [9].

The M2M Middleware core is using the OpenMTC platform and the CSIR Smart City Platform. Within the complete federated technology stack OpenMTC provides functionality related to store and forward, connectivity management (profiles and priority), security, access rights and seamless "http/coap proxying". On the other hand, the Smart City Platform adds complementary functionality to further enrich the environment. The SCP functionality is related to the modelling of the real world, and the integration between the digital (sensed world) and physical worlds. The SCP also provides a "thin" and easy to use API for applications (i.e. for analytics or visualization), thus providing capabilities for the development of the "final" building block, to build "use-full" applications for a specific user.

As an example of this functionality (for instance in the energy experimental domain) the urban world is modelled: a suburb has several streets, each street has houses, within a house there is a collection of sensors. Furthermore, the sensors are associated with devices with a specific profile. This implies that interaction with the sensors can occur via a meta-information description (the type of sensor, the capabilities of the sensor). Additionally interaction can occur via a physical model approach: which device, in which house with what profile has the highest consumption of energy and which device can be switched, taking into account the device and context (is the device a respirator for a patient?).

It is this combination and integration of complementary building blocks that creates an opportunity for a rich set of experiments (e.g. the impact and effect of progression from a subset of building blocks to a fully interconnected set of building blocks).

Within the two trials and proof-of-concept it is the combination of building blocks that creates a rich experimental environment. The introduction of "real-world" modelling in the Spanish trial allows for a geo-spatial view of the physical environment. For example, where are the sensors physically deployed (i.e. street and building)? Thus, when visualizing the collected data a better understanding of the real-world context becomes possible.

The aim of the interconnected Testbeds is to allow researchers access to resources that are available within the individual testbeds at TUB, UCT and CSIR. This will lead to advantages such as:

- A more diverse range of devices to be available, as sharing access to sensors, physical servers and services reduces the need for these resources to be recreated in each of the locations.
- Increased redundancy, as when one of the individual testbeds is unavailable, researches will still be able to use resources from other connected testbeds via the same portal. It is particularly useful as currently in South Africa, power outages occur occasionally.
- Better connectivity for local experimenters, as they will be able to use the virtualised TRESCIMO middleware hosted on any of the three testbeds depending on their location.

The setup of the testbed interconnection is planned in two stages. In the first stage, which is the VPN environment, experiments will be conducted to allow for configuration, functionality and end-user testing. This stage is necessary to commence experimentation while the integration of FITeagle into the architecture is being carried out. On completion of the latter, experiments will be carried out to allow for repeatability and scalability tests.

2.2.1 Stage 1: VPN Setup Testbeds

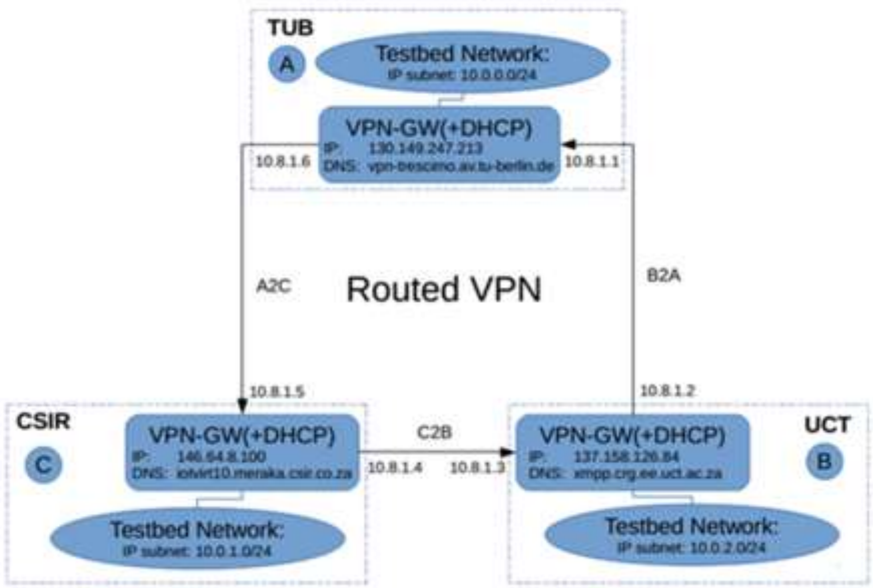

Figure 1 VPN Environment

2.2.2 Stage 2: Federated Testbeds

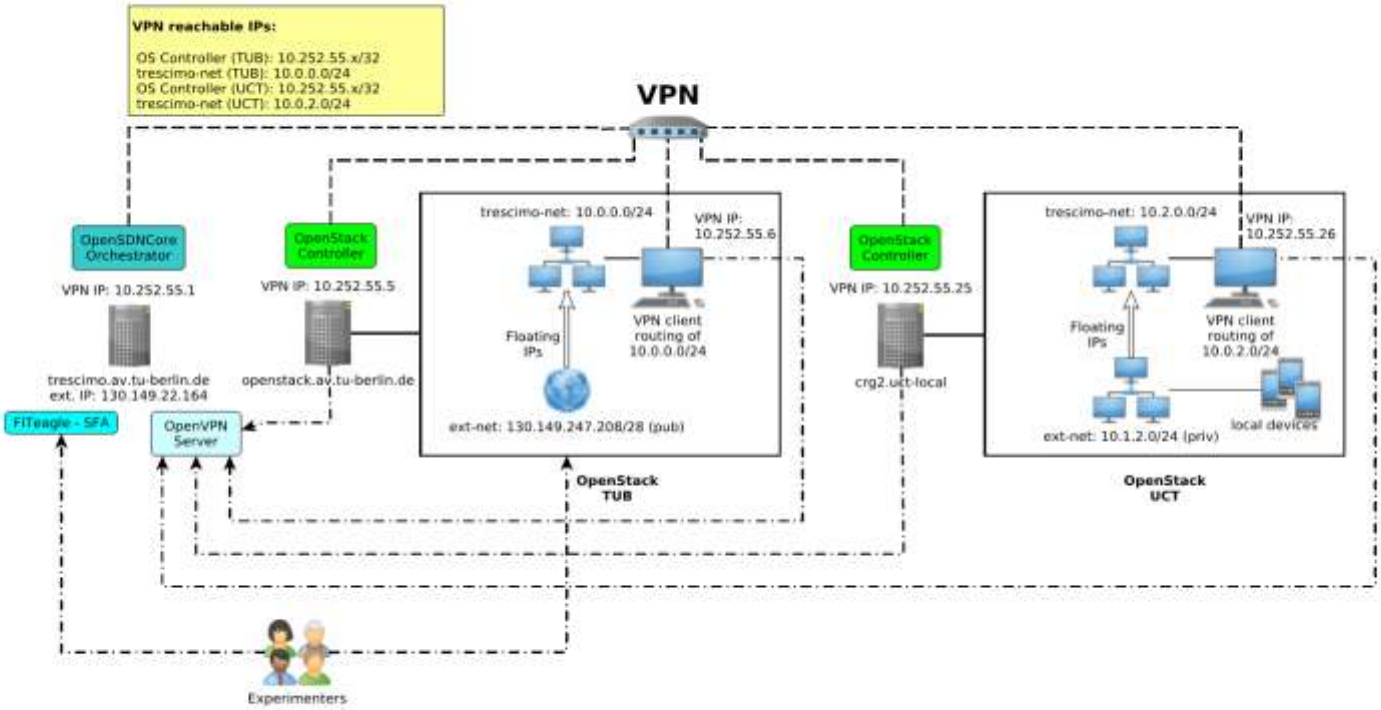

Figure 2 Federated Environment

2.3 Proof of Concept

The combination of heterogeneous technologies as applied to vast differences in context (i.e. European vs. African context [4]) creates a number of challenges. Most prominent of these are to be able to select the most appropriate technologies for the context. There are a multitude of building blocks available, many different devices and applications.

The selection and verification of the most appropriate combination blocks for a context requires an architecture which allows for a “build-your-own-platform” methodology. This methodology enables rapid configuration of suitable technology elements that provide a suitable solution for a particular context, and allows for linkage to legacy systems that are used in that context. The architecture as presented in D3.1 as built around D4.1 and D2.1, D2.2 and D2.3 holds the promise of supporting a “build-your-own-platform” methodology. Through the use of interworking proxies and support for different protocols, building blocks can potentially be removed. But it does raise the question “what functionality would be lost if not all the building blocks of a specified solution are used?”

The proposed Proof of Concept is positioned to investigate the aspects mentioned above:

- Does the proposed architecture support the “plug-and-play” nature that is required for a contextual end-to-end solution? And if so how easy is it?
- What functionality would be sacrificed / gained if such an approach (i.e. where additional building blocks are used) is followed?
- Would an implementation with minimal building blocks be sufficient for a contextual solution?

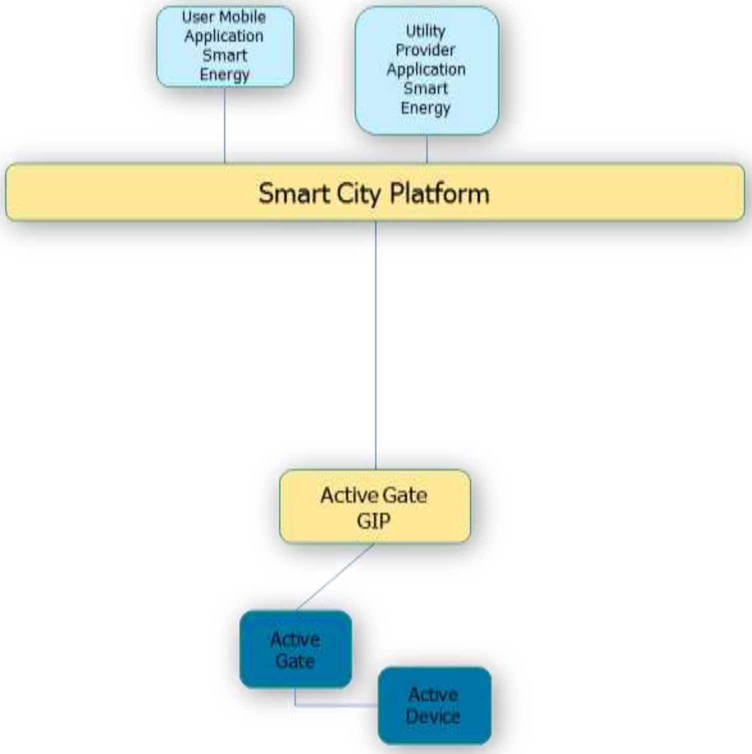

Figure 3 Proof-of-concept: Minimal Implementation

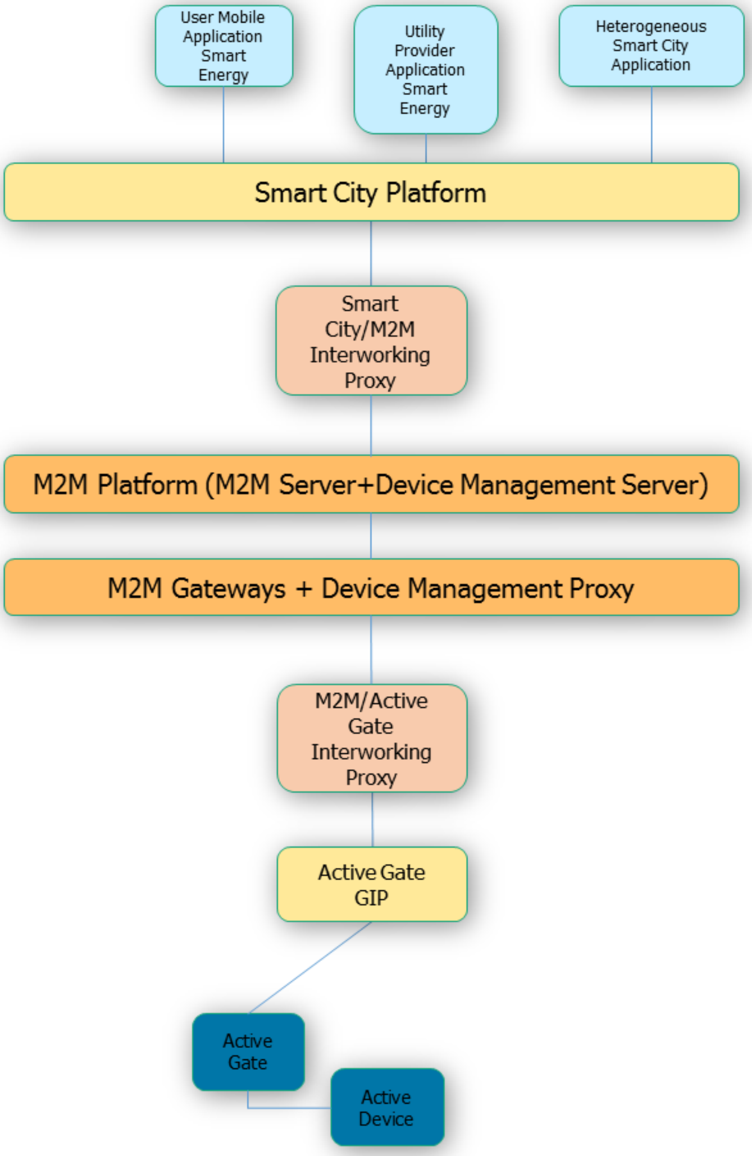

Figure 4 Proof-of-Concept: Full implementation

Figure 3 presents an envisioned minimal implementation. Figure 4 presents the envisioned full implementation for the Proof-of-Concept.

The proposed Proof-of-Concept with a progression from functionality as presented in Figure 3 to Figure 4 will be implemented at the CSIR. The installation will be physical (in the sense that none of the components will be virtualized). For the larger testbed federation, these components are virtualized and are running on distributed cloud infrastructure. Contrasting the two implementations full vs. minimal allows for a comparison with regards with suitability for wider implementation (e.g. does the cost associated with a M2M platform justify the added value? Will a minimal installation be sufficient in the local developing world context, if not, what are the most important components to add?).

2.4 Trials

2.4.1 SA Trial

The South African trial will be based on the architecture as presented in Figure 3 (a thin installation adapted to the South African context) and based on the learning from the Proof-of-Concept substantiated in the real-world trial implementation.

Within the trial, relevant questions related to the effect and impact of more timely information delivered to the consumer is measured. Some of the key questions to be addressed for the trial as a measurement of success include the following:

- Is IoT suitable technology option to implement Demand Management in the South African context?
- What are the best feedback methodologies or tools which could be realised through an IoT infrastructure?
- Can IoT provide real time feedback to customers and does it have an impact in energy consumption behaviour?
- How can energy bills be communicated to customers using IoT?
- What is the best method of communicating with customers?
- Do incentives drive behavioural change?
- What software applications need to be developed to empower customers to change energy usage patterns?
- How can IoT be integrated as part of Smart Grid implementation strategy?

Eskom is continually in the process of researching and investigating innovating ways to modernize the use of energy. For this purpose, Eskom set out to test and pilot Smart-Metering technologies as discussed in Annex 1. The company is planning on furthering this initiative in the future. Due to the fact that Smart-Metering and Home-Energy Management technologies are so closely related in function (and the fact that there is a possible cooperative relationship to be created between the two), there is a focussed effort to narrow the boundary between the two technology groups.

The following implementation plan is to be followed for the South-African Trial:

- A total of **20 to 30 residential customers in 4 to 6 locations in the Gauteng Province (South Africa)** will be considered and installed with a number of Smart Devices.
- It is intended that each trial participant's house will be fitted with **one ActiveGate device, one ActiveDIN device and two ActivePlug devices at minimum**. The system will be setup similar to what is depicted in figure 3.
- It is intended to make use of an Eskom contracted high-speed cellular APN to connect to the individual ActiveGate devices. While installed inside the residence, the various Smart Devices will be able to communicate with one-another by means of creating an IEEE 802.15.4 wireless network and making use of CoAP and 6LowPAN as supporting M2M technologies.
- All data generated by the Active Devices will continuously be stored by making use of the CSIR Smart City Platform. This platform will also be used to send control instructions through to the Active Devices. With this system in place, a smart-phone application will be developed to allow the customer to interface with the data held by the platform and to control the operation of appliances connected to the Smart Devices remotely.

- In order to accurately gauge the impact of the trail and the impact of Smart technologies on the customer, a number of customer interaction processes are intended.
    - Initially, customers will be selected based on their response to an **acceptability questionnaire**. The questionnaire will intend to gauge if a particular customer is able and willing to accommodate the technical and time-related limitations of the trial.
    - During the course of the trial, **a customer query/complaint email address will be made available to provide the customers with a permanently open line of communication**.
    - Finally, a **survey will be held at the end of the trial to determine the customers' general thoughts** and feelings about the trial, the way it was done, the technology used and the functionality provided by the hardware and mobile application. This will ultimately influence the degree to which the learnings will be made and used of in the future.
- A number of potential risks and obstacles to take note of in terms of dealing with Eskom customers are highlighted below:
    - The way in which customer interactions and engagement is undertaken is very important due to the fact that the customers used are **actual/real Eskom customers**; and negatively influencing their view towards the business could have adverse effects on the business.
    - In order to ensure sufficient customer participation and buy-in, a number of **customer interaction engagements, forums and direct meetings** are to be held.
    - Due to the fact that this project requires the entrance of the customers' residence, it is very important that they be made fully aware of what is intended and that they state clearly what they will be comfortable with before signing up to be a part of the trial.
    - Due to the fact that some of the devices will have to be wired into the customers' electrical system (distribution board), it is important to note that the trial is to make use of qualified electricians and that **Electrical Compliance Certificates (COC) be issued** after the Smart Devices are installed; and also when they are subsequently removed during the decommissioning process.

2.4.2 EU Trial

The EU trial will deploy an enhanced system consisting on the following elements:

- Sensor devices
  - 40 nodes build on wake-up enabled IEEE802.15.4 devices, to measure temperature, relative humidity, barometric pressure, light or trash container occupancy.
  - 2 GPRS and 4 WLAN AirBase CanarIT mini air quality monitoring station with advanced Nano-Tech sensors technology to measure concentration of Ozone, NO2, Total VOC, TSP (Total Suspended Particles), noise level, relative humidity and temperature.
- 4 enhanced gateways to be installed on buses. They will have WLAN and IEEE802.15.4 interfaces for the communication with sensors and a cellular interface to access the remote platform. The gateway integrates the following features:
  - Radio triggered wake-up system to interact with the deployed low-power consumption sensors
  - OpenMTC gateway middleware
- OpenMTC server middleware, which provides standardized M2M platform facilities
- CSIR Smart City Platform, aimed to provide enhanced smart city platform capabilities and to facilitate the deployment of services and end-user applications on top of it. This includes the introduction of a “real-world” model related to the deployment of sensors, and the utilization of the “thin” API for the development of applications.
- Environmental monitoring application, which will allow the municipality of Sant Vicenç dels Horts, as end user, to be more conscious about environmental parameters (e.g. air pollution) in the city, which might affect the quality of life of citizens. They are especially aware of the air monitoring since they have a cement factory close to the village.

Figure 5 Image of Sant Vicenç dels Horts in the foreground and the cement factory in the background, in the same municipality.

Note that the system proposed in the trial has been possible thanks to cooperation. Different elements used came from other partner in the consortium. For example the environmental station has been developed by Airbase, the M2M platform handling the data captured has been offered by Fokus and the Smart City platform has been developed by CSIR.

The municipality of Sant Vicenç dels Horts is not part of the project consortium, but, as final user, has been involved in the definition of the use case that will be deployed in the trial and has provided feedback about the kind of sensors that would be interesting for the city. Furthermore, the municipality is also engaged in the trial providing the necessary facilities/permissions to install the sensor and gateway devices in the city premises/public transportation vehicles. In this respect, the municipality expects the project to provide them the data collected by the deployed system.

As air quality is one of the main worries of the citizens of Sant Vicenç dels Horts, it is expected that they will be anxious to have better information about the environment of the city. Opening the data is good since it is a way to provide information, but it should be precise in order to avoid any false alarm to the population that results in complains. This is probably the most relevant obstacle for the deployment of the system.

The feedback mechanism can be based on common tools such as web traffic analytics and email address to receive suggestions and complains. Also a simple like/dislike button can be useful to get a fast feedback.

On the other hand, the trial can be considered as a proof of concept of the feasibility of deploying infrastructure-less data acquisition systems for Smart Cities, which might be applicable to other usage scenarios. In order to evaluate this feasibility, the following performance indicators will be taken into account in the evaluation of

the trial: range and efficiency of the wake-up system, amount of data that can be transmitted during the wake-up progress, quantity of data collected by each of the gateways, end-to-end delay and packet losses in the DTN network. Further details about the experiment KPIs are provided in section 3.3.

3 Current Experiments and Goals

The experiments in this section will be conducted using the VPN environment given in Figure 1.

3.1 Smart Energy

3.1.1 Utility Provider - Possible Outages

Usage Scenario

This experiment will involve a potential power outage scenario where the utility provider has priority over the user in disabling certain devices in the Smart Home. This will be done by the provider in order to avoid load shedding; this experiment is based on a subset of the Johnie use case [3].

The Utility provider will be able to send the consumer warnings related to the state of the national power grid, prior to taking action in disabling his/her device [8]

Activity Diagrams

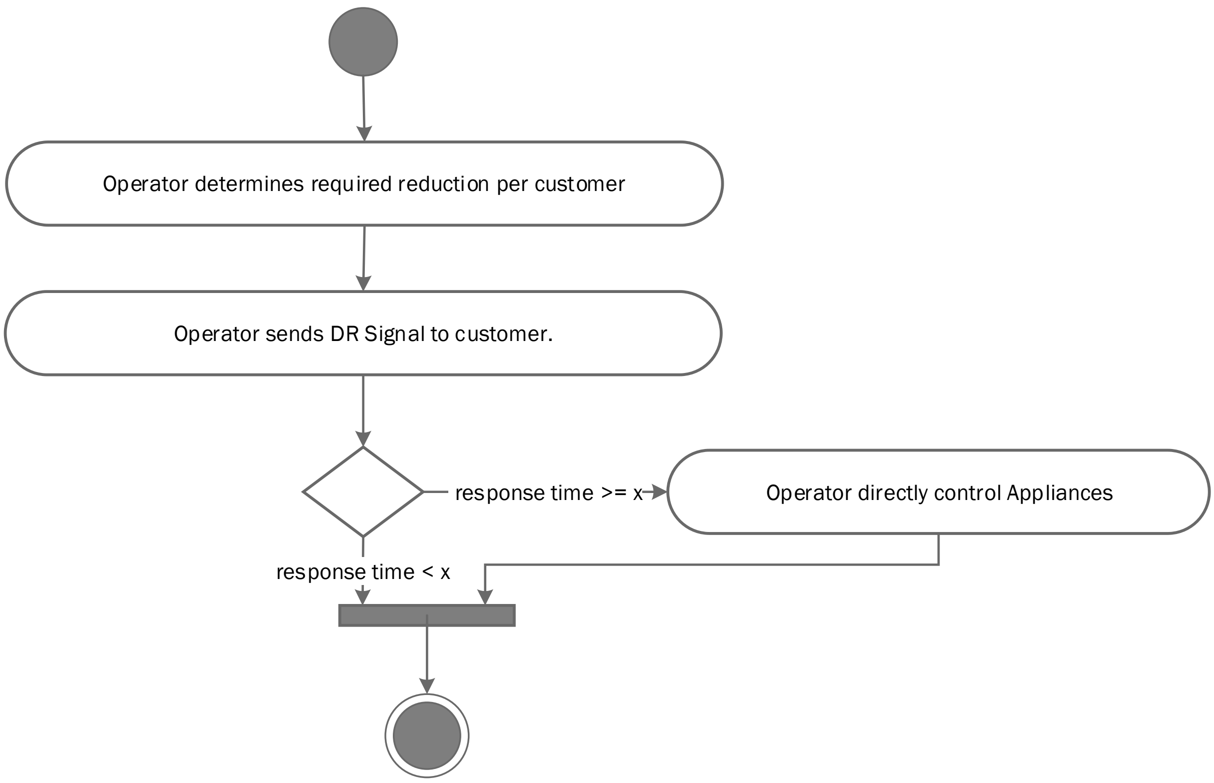

Figure 6 Activity Diagram - Delivery of power alerts

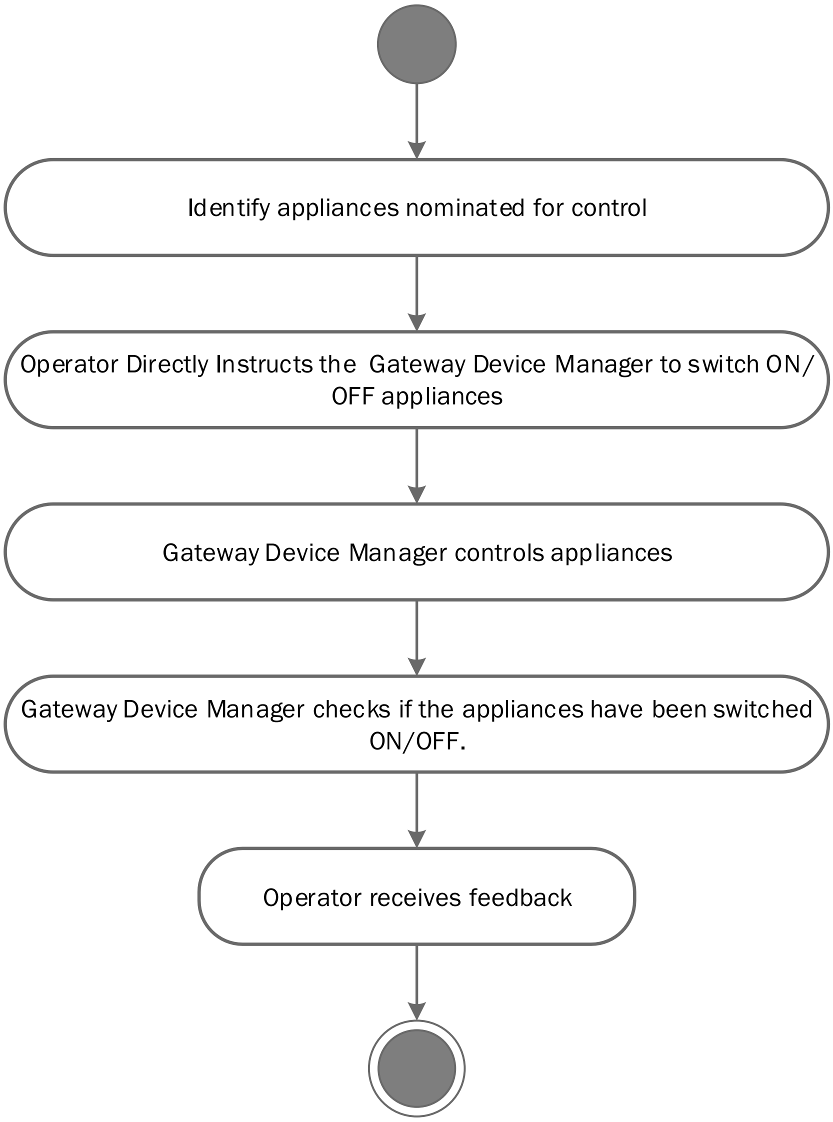

Figure 7 Activity Diagram - Forcibly disable appliances.

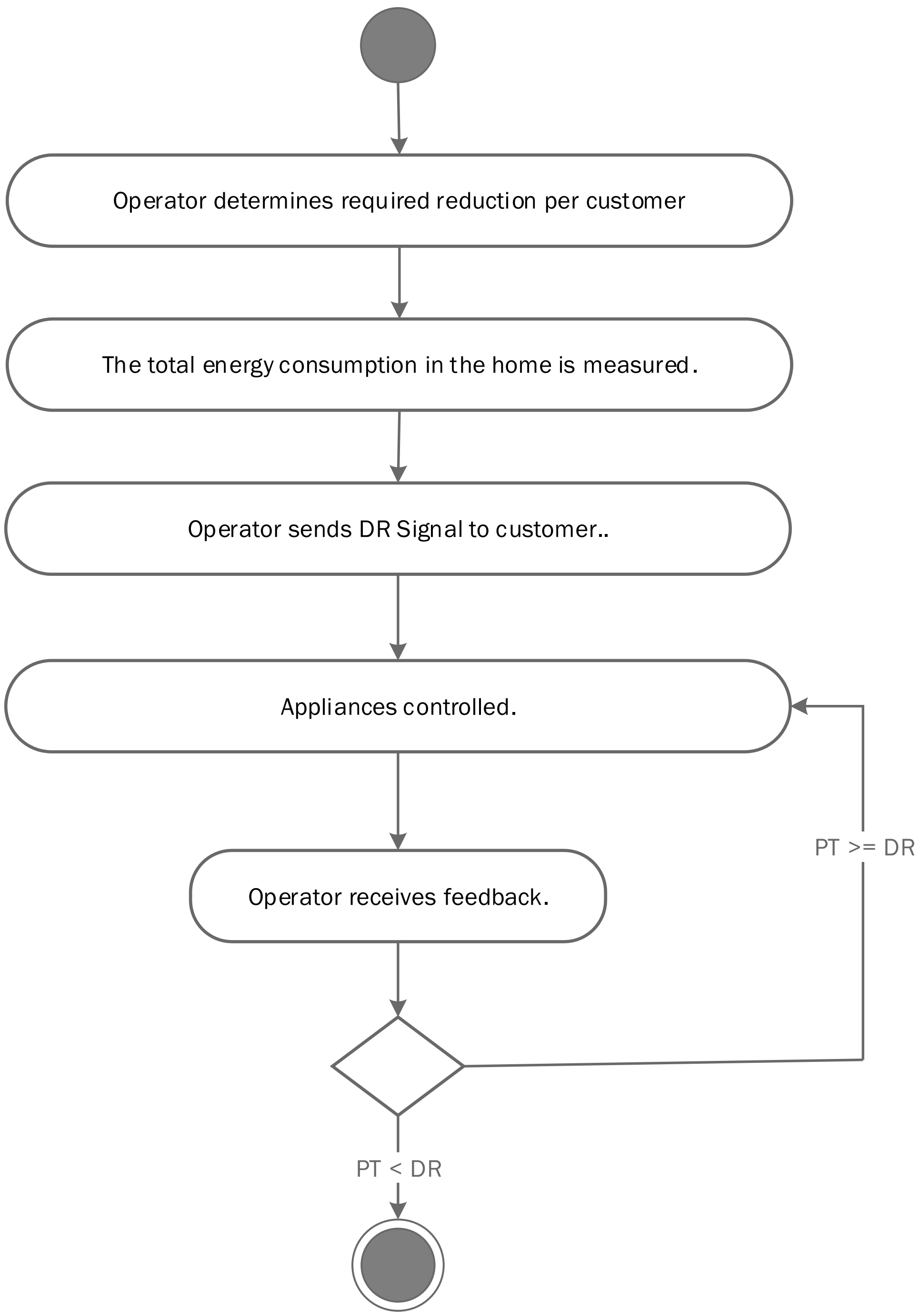

Figure 8 Activity Diagram - Energy Consumption in the home

Potential KPIs

KPI Name:	Delivery of power alerts.
Description	Residents will be alerted of actions to be taken by the utility provider if the former do not reduce consumption in x minutes.
Relevance	This would allow the utility provider to inform residents when their devices will be shut down, if the latter do not reduce their energy consumption.
Classification	Functionality Test; End-User Test.

KPI Name:	Forcibly disable appliances.
Description	Device manager initiates shutting down of appliances resulting from a command issued by the utility provider.
Relevance	The user has not reduced their energy consumption within x minutes.
Classification	Functionality Test; Configuration Test.

KPI Name:	Energy Consumption in the home.
Description	The total energy consumption is measured in the home before and after the service provider has forcibly disabled some devices.
Relevance	This KPI may provide an insight on the amount of energy that has be saved by forcibly disabling some devices in the home.
Classification	Functionality Test; End-User Test.

3.1.2 Energy Measurement in the Smart Home

Usage Scenarios

This experiment will involve measuring the energy consumed by specific devices in a Smart Home, Amal and Maggie use cases [4].

We need to estimate the energy consumption of the appliances and their overall consumption in the smart home. All information provided back to the user may positively influence their future behaviour.

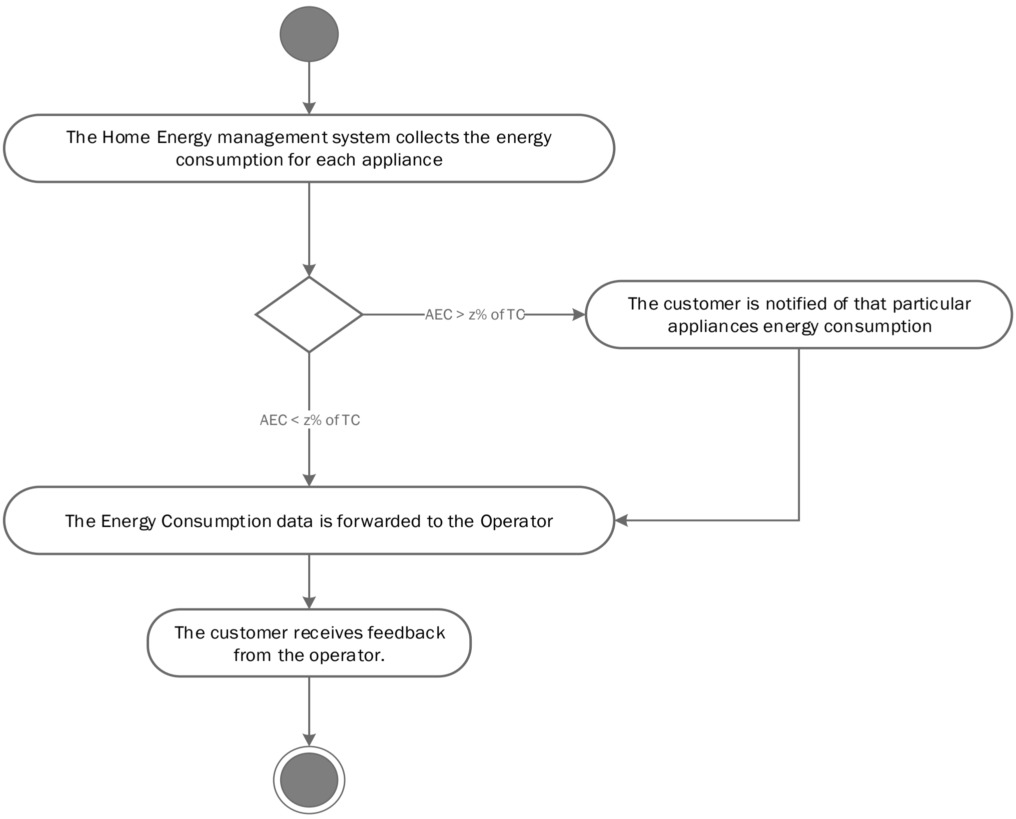

Figure 9 Activity Diagram - Device Energy Consumption

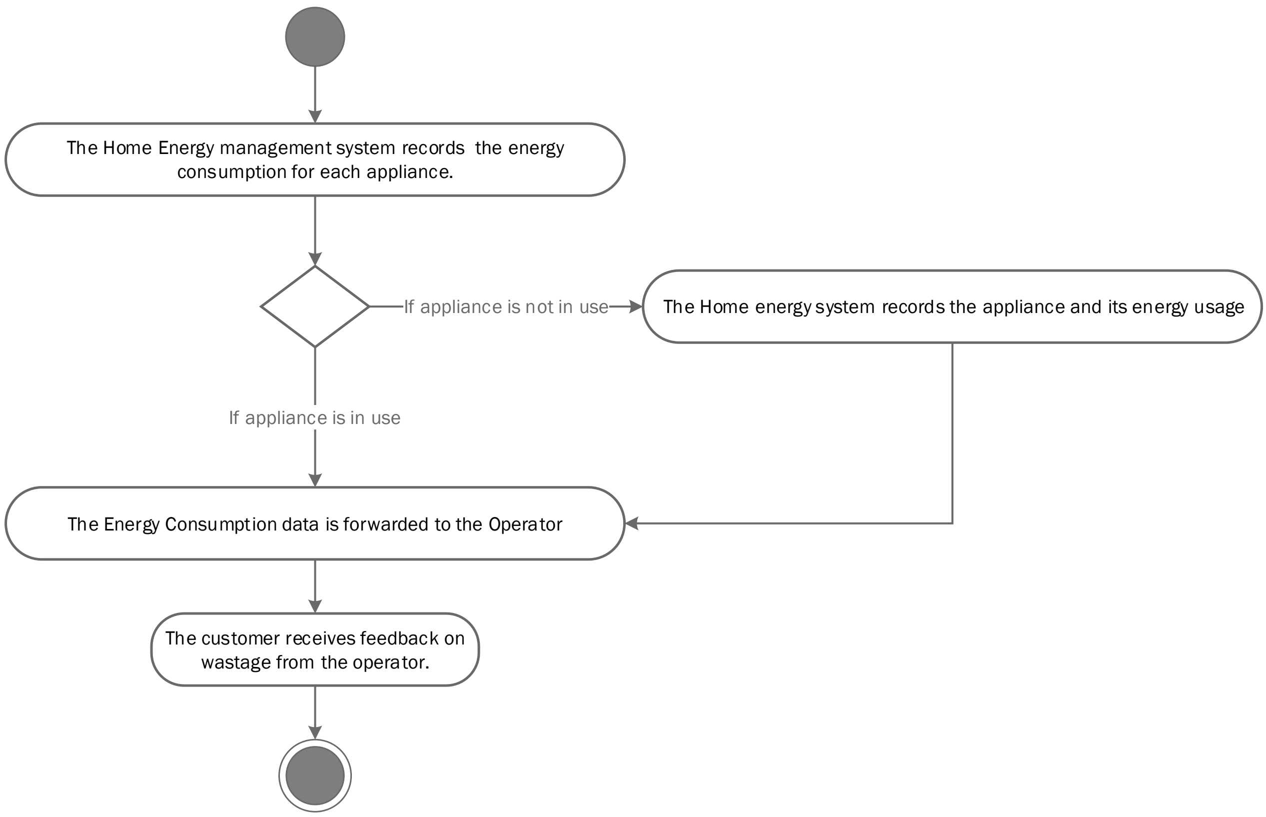

Figure 10 Activity Diagram - User Energy Wasted

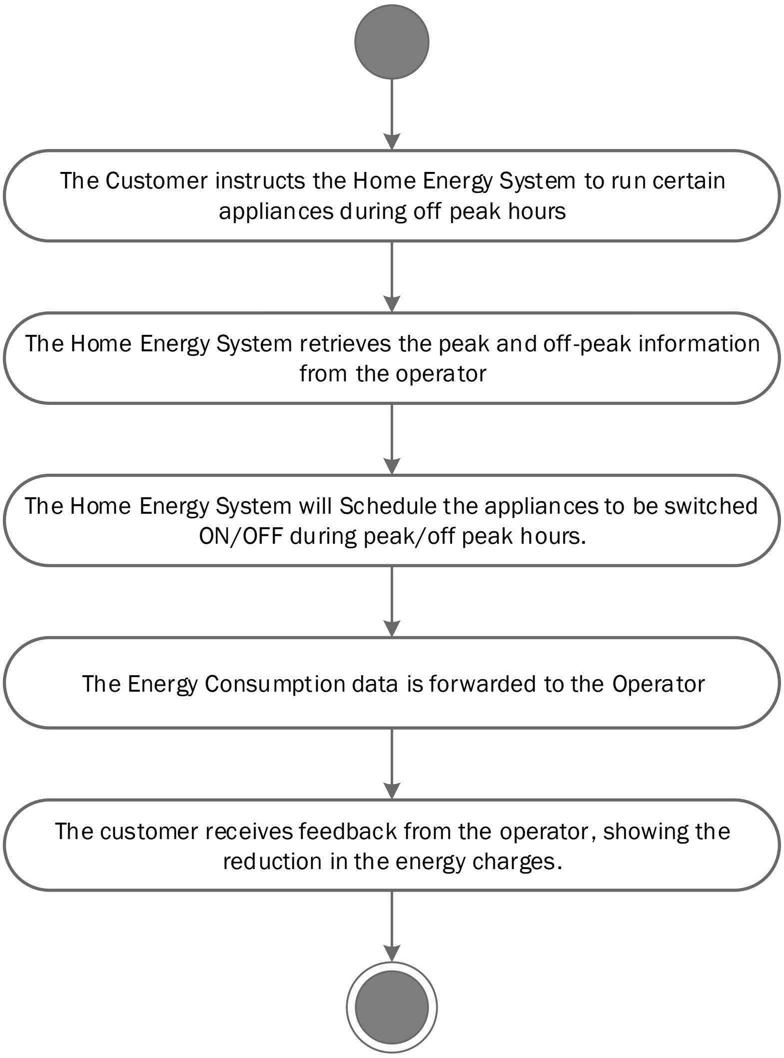

Figure 11 Activity Diagram - Peak Consumption Reduction

Potential KPIs

KPI Name:	Device Energy Consumption.
Description	This KPI measures the energy consumption by the devices connected in a home and its proportion (z) with respect to the total home consumption.
Relevance	This KPI may provide an insight of the energy consumption per device across various households.
Classification	Functionality Test.

KPI Name:	User Energy Wasted.
Description	This KPI measures the energy wasted by the household, i.e., appliances that are left on when not in use.
Relevance	This KPI may provide an insight on areas of potential energy savings.
Classification	Configuration Test.

KPI Name:	Peak Consumption Reduction.
Description	This allows the consumer to schedule the use of specific device to reduce their peak consumption.
Relevance	This KPI allows the consumer to reduce electricity charges.
Classification	Configuration Test; Functionality Test.

3.2 Smart Metering

3.2.1 Proof-of-Concept

This laboratory experiment will involve a utility–consumer interaction through a mobile application as described in the Grant use case [3].

Usage Scenarios

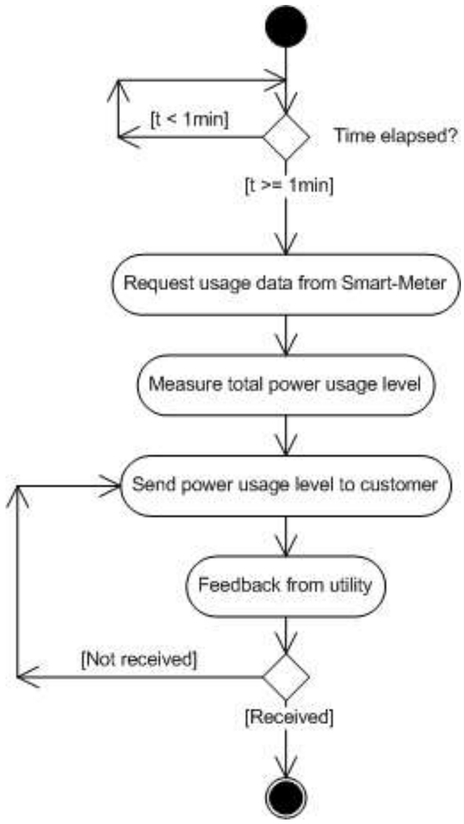

Figure 12 Activity Diagram - Total Energy Consumption

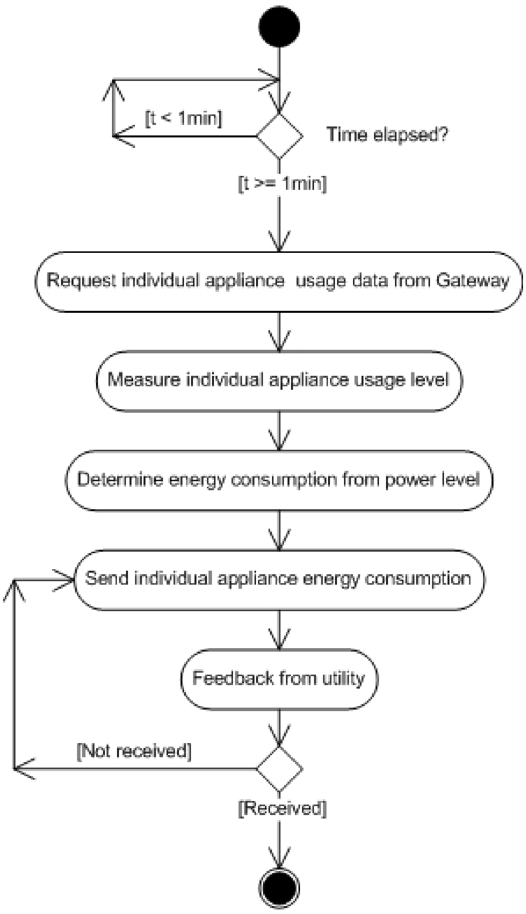

Figure 13 Activity Diagram - Individual Appliance Consumption

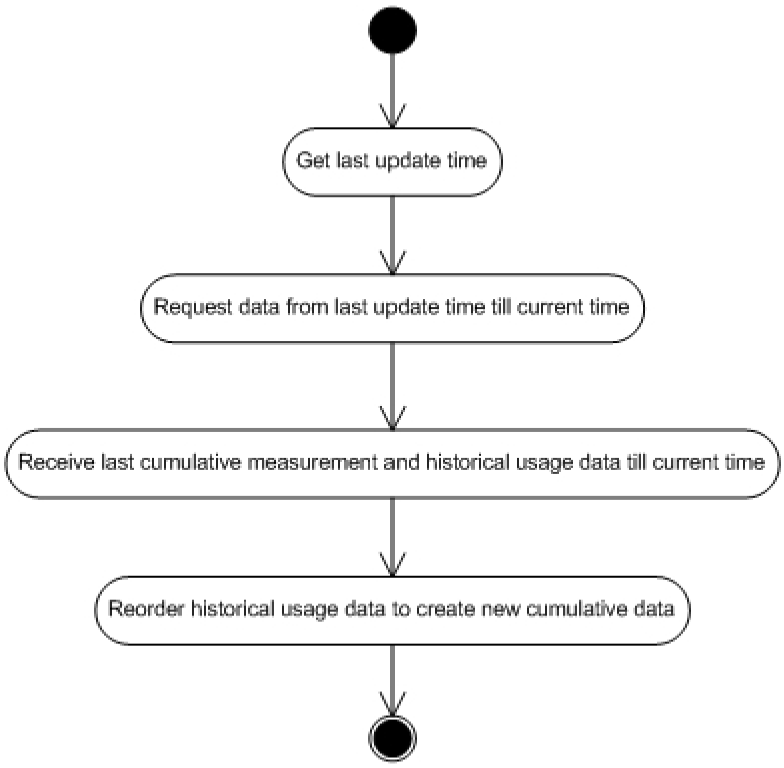

Figure 14 Activity Diagram - Historic Total and Individual Appliance Consumption

Potential KPIs

KPI Name:	Total Energy Consumption
Description	This KPI measures and displays the total energy consumption on a mobile application at less than “x” measurements per minute at a specific moment in time.
Relevance	The consumer will be made aware of their total energy consumption.
Classification	Functionality Test

KPI Name:	Individual Appliance Consumption
Description	This KPI measures and displays the individual appliance’s consumption.
Relevance	The consumer will be made aware of their individual appliance’s consumption.
Classification	Functionality Test

KPI Name:	Historic Total and Individual Appliance Consumption
Description	This KPI tests the degree to which the customer can view and compare his historic total and individual consumption.
Relevance	This KPI will provide insights into the consumer’s historical energy consumption patterns.
Classification	Functionality Test

As described in Section **Error! Reference source not found.** the validity of the proposed architecture is tested in a “build-your-own-platform” methodology, i.e. moving from a minimal implementation as in Figure 3 to a full implementation (Figure 4).

The Grant use-case will be used as basis, but the experimental focus will be on the validity and utility of the various components and the associated opportunity costs of including, or not including them. Most specifically investigating the impact of progressing to a “full stack” M2M platform.

Potential KPI

KPI Name:	Building block utility
Description	This KPI tests if the use-case can still be fulfilled when comparing a minimal implementation against a full implementation under different simulated operating conditions

	(always on connectivity -- WiFi, intermittent via mobile networks). One specific aspect in this experiment is when connectivity is lost between the edge and the middleware and how the stack (from minimal to full) copes with the loss of connectivity.
Relevance	This KPI will provide insights into the utility of building-blocks
Classification	Functionality Test

3.2.2 Trial for Eskom Smart Energy Customers (ESKOM, CSIR)

This field experiment will involve a utility–consumer interaction through a mobile application as described in the Grant use case [3].

Usage Scenarios

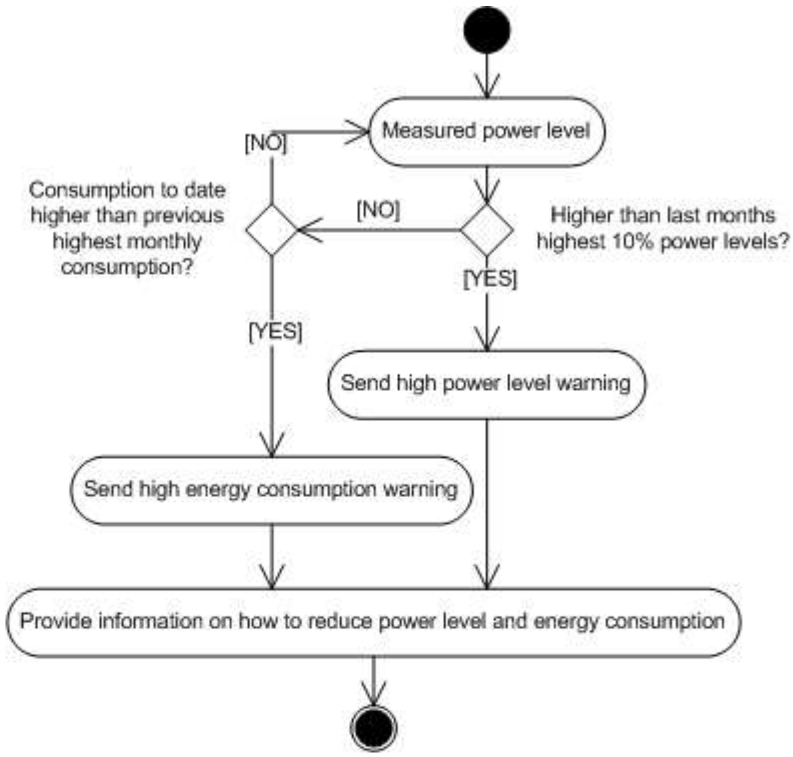

Figure 15 Activity Diagram - Consumer Consumption Awareness

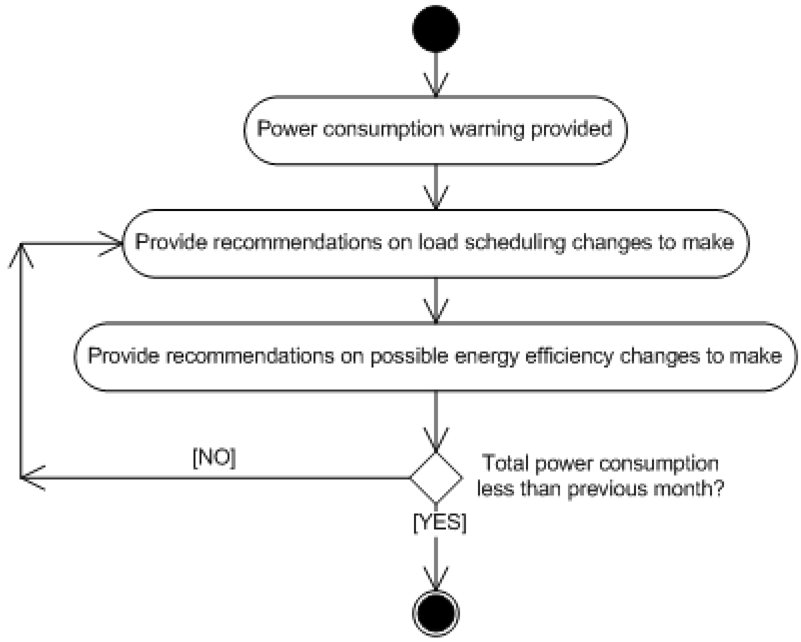

Figure 16 Activity Diagram - Consumer Behavioural Change

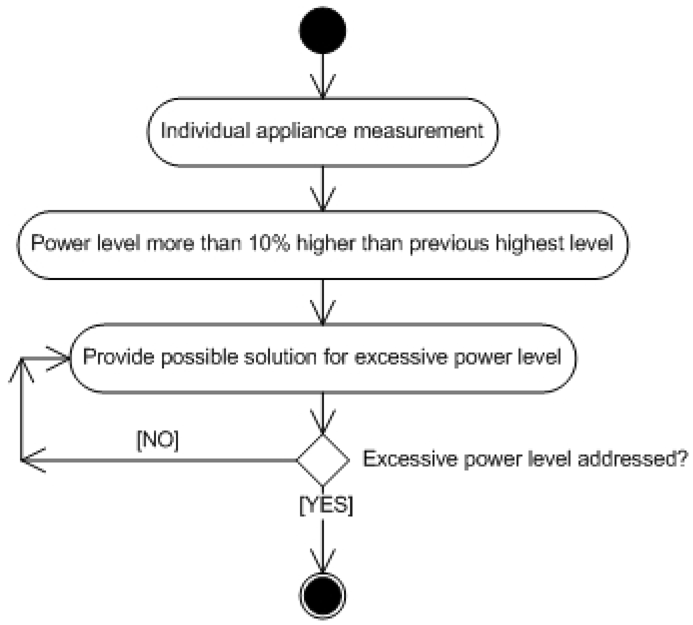

Figure 17 Activity Diagram - Excessive Consumption Alert

Potential KPIs

KPI Name:	Consumer Consumption Awareness
Description	This KPI measures the extent to which the consumer is provided with comprehensive and timeous information about his energy consumption patterns.
Relevance	This KPI would determine if the consumer is provided with adequate information such as energy consumption, costs and projected costs.
Classification	End User Test.

KPI Name:	Consumer Behavioural Change
Description	This KPI measures if a consumer is able to alter his power consumption behaviour, to reduce his total consumption, based on the continuous information provided.
Relevance	This KPI will demonstrate that the provision of continuous information will result in consumer behavioural change
Classification	End User Test.

KPI Name:	Excessive Consumption Alert
Description	This KPI measures the ability of the utility to warn to consumer of excessive consumption detected and possible solutions to address this.
Relevance	This provides insights into how the consumer may respond to home energy management system alerts.
Classification	End User Test.

KPI Name:	Mobile Application – Ease of Navigation
Description	This KPI measures the ease with which a user is able to navigate the various tabs and functions available in the application.
Relevance	This KPI would test whether a user is able to make full use of the functionality provided and if they are able to effectively navigate between the various screens.
Classification	User Experience Test

KPI Name:	Mobile Application – Ease of Use
Description	This KPI measures whether an average user is able to fully utilize the functionality offered in the application, and if they are able to instinctively view and interpret the information presented.
Relevance	This KPI would test if an adult is able to interpret and make full use of the functionality provided in the application, without the need for any explicit technical background or the explicit need for a user manual or training.
Classification	End User Test.

KPI Name:	Benefit from system
Description	This KPI measures the extent to which the addition of the hardware and functional capabilities would be intrusive on the customer.
Relevance	This KPI would test whether the addition of the IoT hardware would aid the customer in the ways that were intended or, if the addition of the hardware would impede the customer from optimizing their energy usage.
Classification	User Experience Test

KPI Name:	User Involvement
Description	This KPI measures whether the system had been developed with the customer needs in mind.
Relevance	This KPI would test if a customer feels that their particular needs have been taken into account and to what extent the user was given the chance to comment on and improve on the usability of the application, throughout the course of the trial.
Classification	User Experience Test

KPI Name:	Hardware Performance Metrics
Description	This KPI measures the operational performance of the system during initial testing and throughout the lifetime of the trial.
Relevance	This KPI would test whether the hardware functions as intended by its design-to-criteria. The test would specifically take into account physical rigidity, software stability, protection against moisture and ingress, RF performance, etc.
Classification	Hardware Performance Test

3.3 Smart Environmental Monitoring in EU trials

3.3.1 Environmental Sensor Experiments

The experiment is based on the deployment of a set of stations with different characteristics in the village of Sant Vicenç dels Horts and the usage of the public bus system as a mechanism to collect the data captured by the stations. This approach will facilitate the deployment as no communication facility has to be set up.

The experiment will provide two types of data. One type corresponds to environmental related parameters such as temperature, atmospheric pressure, relative humidity of the air, level of illumination or air quality to mention some. The other type of data comes from the performance of the system itself. It includes the power consumed by a station, the connection time and the range of the full system.

There will be two types of stations deployed in the city. The ones from ABS that connect with the bus using WiFi and the ones from I2CAT that are polled by the bus and rely on the use of IEEE802.15.4 frames.

The first experiment will be focused on retrieving information from the station to the bus, once the former is wakened up by the latter. The experiments carried out are of two types, those intending to offer the Delay Tolerant Network as an experiment and others relate to data collection and device actuation.

The following tables show the description of the key performance indicator parameters proposed to evaluate the performance of the Delay Tolerant Network and the radio wake-up system in relation to the capabilities to capture Smart City data.

Potential KPIs

KPI Name:	Device Energy Consumption.
Description	This KPI measures the energy consumption of the devices deployed along the city that work under the principle of radio wake-up
Relevance	This KPI may provide an insight on the energy savings that the radio wake-up principle may offer in front of other approaches such as being all the time listening for a transmission from the collector or using a duty cycle approach.
Classification	Functionality Test.

KPI Name:	Connectivity duration.
Description	This KPI measures the connectivity time between the bus and the stations, so that they are able to exchange information. This time is measured as the interval from the moment a station replies to the wake-up until the last message from the station is received by the collector (located in the bus). This measurement is done with a special functionality that requires the station to keep transferring and waiting for acknowledgments.
Relevance	This KPI may provide an insight on the amount of data that can be transferred from the device to the collector. This will give a hint on the type of data that can be reported; one single information item or a bunch of registers measured since the last time the station has been prompted.
Classification	Functionality Test.

KPI Name:	Communication range.
Description	This KPI measures the range of the system between the collector and the station. The parameter can be measured thanks to the fact that the location of the station is known and that the location of the collector is provided thanks to the on-board GPS.

Relevance	This KPI may provide an insight about the coverage that a radio wake-up solution can reach.
Classification	Functionality Test.

In relation to the acquisition of environmental data from the sensors involved in the Spanish trial, the following KPIs can be defined.

KPI Name:	Air pollution measurements
Description	The KPI provides data related to air quality and pollution measured by the sensors deployed in the Smart City. Data is collected in a delay-tolerant manner; thus, real-time measurements are not available.
Relevance	This KPI would allow end users to get an overall view of the pollution in the city. This information can be useful to take statistics and monitor air quality evolution. Furthermore, it can be used as input for the deployment/evaluation of new algorithms useful for air quality analysis.
Classification	End User Test, Functionality Test

KPI Name:	Environmental parameters measurements
Description	The KPI provides data related to other environmental, such as noise, temperature, humidity, atmospheric pressure and light, measured by the sensors deployed in the Smart City. Data is collected in a delay-tolerant manner; thus, real-time measurements are not available.
Relevance	This KPI would allow end users to get an overall view of the environmental status of the city. This information can be useful to take statistics and get more consciousness of environmental parameters. Furthermore, this information can be used as input for the deployment/evaluation of new algorithms useful for environmental analysis and the deployment of new services in the city.
Classification	End User Test, Functionality Test

3.3.2 Collector to Station experiments

The second experiment extends the first one in the sense that it studies the capability of the proposed solution to send information from the collector to the station. This capability is useful for changing the configuration of the station or even modifying its firmware. The volume of information that can be sent from the collector is related with the connectivity duration that has been measured in the first experiment. This parameter is very relevant since it will limit the capability to modify the behaviour of the station and will help in defining the approach on how to transfer these modifications. Common approaches assume one single file transfer with the new firmware or configuration file, but from the results obtained, a fragmented approach can be envisage where every time the collector and the station are in range a fragment of the file can be transferred.

Potential KPIs

KPI Name:	Amount of bytes transferred from collector to station
Description	This KPI measures the amount of bytes that can be transferred from the collector to the station when both are in range. This measurement is done using a special functionality that requires the collector to keep transferring data and waiting for acknowledgments.
Relevance	This KPI may provide an insight of the amount of data that can be transferred from the collector to the station. This amount of data will help to define the approach to transfer fragments of a file with a new firmware or a configuration file.
Classification	Functionality Test.

4 Planned Federated Experiments

One goal of the TRESCIMO project is to offer a Smart Infrastructure Software Stack as a Service for remote experimenters. Here the Smart City context acts as an important field of application that provides specific requirements for such a service. The software stack is composed of

a) Smart City Platform: ideally offering standard APIs for this domain (CSIR)
b) Smart Communication Platform: offering standard APIs (e.g. OneM2M or ETSI M2M) for secure and reliable information exchange (OpenMTC)
c) Devices: physical or virtual (e.g. AirBase sensors)

An experimenter should be able to provision (parts of) this stack and access the APIs to conduct his experiment (e.g. developing a Smart City or OneM2M compliant client). The user should make use of FIRE tools (such as jFed or MySlice) in order to provision the needed resources. The TRESCIMO federation offers an according SFA interface by deploying the FITeagle framework. Internally, the different sites are interconnected via a VPN, offer the virtualized services within OpenStack environments that are orchestrated by the OpenSDNCore.

4.1 Infrastructure

4.1.1 Resource Experiments

The concept in TRESCIMO is centred on the federation of testbeds over continents and using localised infrastructures. Scenarios, defined use-cases, and experiments have focused on the application space using the provided federated infrastructure, mostly per installation and not over the integrated infrastructure as presented in Figures 1 and 2. With this in mind, experiments related to the infrastructure are presented. These experiments will validate the utility of the infrastructure for domain related experiments with associated societal impacts.

Potential KPIs

KPI Name:	Federated Infrastructure bootstrap
Description	Measure the ability to start, configure and link all components in the federated architecture.
Relevance	Demonstrates that a federated infrastructure has been implemented.
Classification	Functionality Test.

KPI Name:	Resource identification
Description	Identify a subset of resources as available throughout the federated infrastructure from multiple test beds.
Relevance	Ensure that minimal resources can be identified for experimentation.
Classification	Functionality Test.

KPI Name:	Immediate Resource Reservation / Provisioning
Description	Provision a subset of resources for experimentation as available throughout the federated infrastructure from multiple test beds.
Relevance	Ensure that resources are available to a specific scientist as per request and need.
Classification	Functionality Test.

KPI Name:	Resource control signals and dataflow
Description	As per reserved resources, access and control resources as to provide dataflow and control signals through the stack
Relevance	Ensure that devices and associated resources can be controlled and that data can be retrieved and made available for potential applications.
Classification	Functionality Test.

4.2 OpenMTC/M2M Middleware Experiments

In this section we describe general experiments that can be carried out with only OpenMTC components for functionality, interoperability, scalability testing.

Potential KPIs

KPI Name:	LWM2M Client Registration
Description	A LWM2M client registers to a configured LWM2M server with its endpoint and IP. Can be done with OpenMTC Gateway Device management client plugin or other implementations of LWM2M client available (e.g. add-on for LWM2M for Mozilla as client, Leshan server as Server, experiments can have 4 mixing possibilities at least)
Relevance	Ensure the LWM2M client and server registration operation is interoperable.
Classification	Interoperability Test.

KPI Name:	LWM2M triggered Client Registration
Description	LWM2M Client Registration triggered by manipulating the Resource tree of the M2M gateway – M2M Gateway adapter for LWM2M
Relevance	Ensure the M2M Gateway adapter for LWM2M is functional.
Classification	Functionality Test.

KPI Name:	Reboot command
Description	Request the reboot operation on a registered M2M Gateway or on attached device to the M2M Gateway. An application on the M2M gateway subscribes to the location of the Device

	management object in the M2M Gateway resource tree and restarts a device, e.g. a webcam.
Relevance	Ensure the M2M server, M2M Server Adapter, M2M Gateway Adapter, LWM2M client and server interaction is correct for sending reboot command on Device management object.
Classification	Functionality Test.

KPI Name:	Provision of the M2M service/server cloud/federation instance IP to M2M Gateway
Description	The M2M Gateway announces the M2M server via LWM2M that is interested in the IP of a M2M service/server in the cloud/federation by registering a TransportPolicyMangement management object. When OpenSDNCore creates a new instance of the service, a connectivity application, running on the M2M server hosting the Device Management server, will forward the trigger containing the new instance IP to the M2M Gateway by updating the TransportPolicyMangement management object.
Relevance	Ensure the flexibility of the setups in a Smart City and Federation environment.
Classification	Functionality Test.

KPI Name:	M2M Reply delay in the case of massive number of M2M devices
Description	Using the OpenMTC emulator that can send every 3 seconds data for 500 devices, instantiate it a couple of times to see how the curve of the delay is evolving.
Relevance	Ensure the scalability of the M2M server.
Classification	Scalability Test.

KPI Name:	M2M Gateway connectivity awareness involving Store and Forward
Description	On a M2M gateway machine disable all the network interfaces. Then send a request to be retargeted to a M2M server running in the cloud. See that the request is stored. Enable the interface towards that M2M server. See that the request is sent.
Relevance	Ensure the connectivity awareness and Store and Forward capability of the M2M Gateway.
Classification	Functionality Test.

4.3 Smart Energy

4.3.1 Energy Measurement in Smart Home

The experiment in Section 3.1.2 of this document will be extended to focus on Configuration testing, Scalability testing, Repeatability testing, Functionality testing and End-user testing.

Scalability testing will involve adding more households to the system, while maintaining an acceptable level of service. Real and emulated variants of the devices will be used to increase the number of devices.

4.3.1.1 Functionality and Configuration Testing

The functionality and the configuration of the interface for the FIRE tools shall be tested in this experiment.

Potential KPIs

KPI Name:	Experiment Setup.
Description	This allows the experimenter to setup to investigate the energy consumption of multiple homes.
Relevance	This KPI allows the experimenter to test the provisioning of the needed infrastructure for an experiment.
Classification	Functionality Test.

KPI Name:	Experiment Configuration.
Description	The experimenter shall setup an experiment and configure it to have multiple homes each having its own gateway.
Relevance	This KPI allows the experimenter to test the configuration of a complex experiment.
Classification	Configuration Test

4.3.1.2 Scalability Testing

The experiment 3.1.2 will be extended to test for Horizontal scalability. This will involve an increase in the number of homes being monitored until the system is unable to meet the required performance metric for each of the individual homes. To achieve this, a combination of real and emulated variants of the devices will be used to easily increase the number of devices.

Potential KPI

KPI Name:	Peak data emergence handling.
Description	The experiment shall use multiple gateways and a single Network service capabilities layer. As more and more devices sending data are spawned, the effects on the system are observed
Relevance	This KPI allows the experimenter to test the scalability of the system.
Classification	Scalability Test

4.4 Health

4.4.1 Single Patient Monitoring

Usage Scenario

This experiment will be based on the use case involving the fragile Mrs. Kabahuma [4]. It will be limited to a single domain, where Dr Dlodlo will remotely monitor Mrs. Kabahuma's health status. We propose to look initially at blood pressure monitoring. This experiment will test the end-user functionality and configuration.

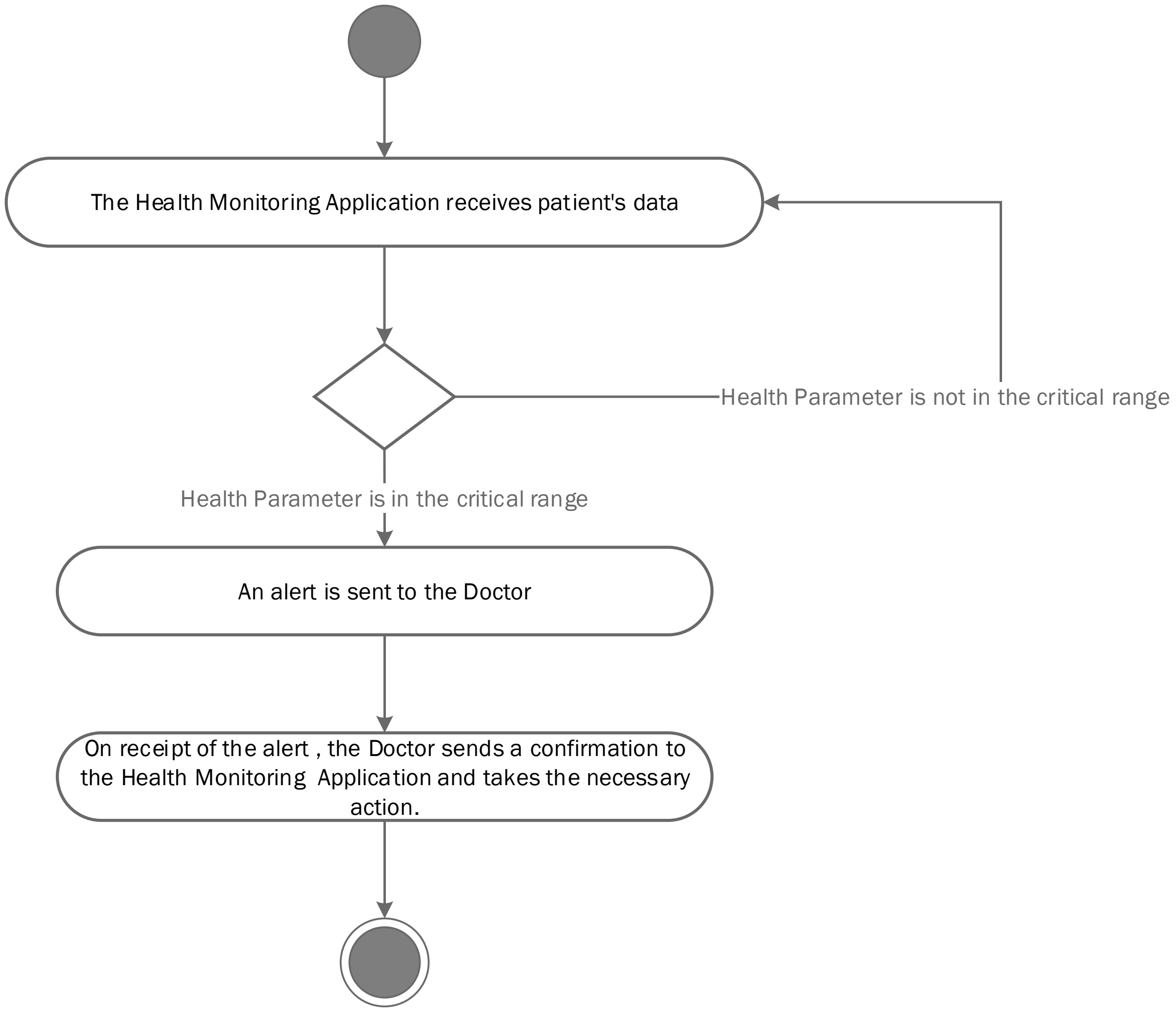

Figure 18 Activity Diagram - Remote Health Monitoring

Potential KPI

KPI Name:	Doctor emergency notification
Description	System picks up on irregularity with a patient and alerts the doctor. The time taken by the doctor to confirm receiving this alert is noted.
Relevance	The doctor is alerted to a life threatening situation with the patient.
Classification	Configuration Test; Functionality Test.

4.4.2 Health Monitoring Experiment

For eHealth experimenting specific devices available at TUB shall be used. These devices are pulse oximeter and blood-pressure meter. The pulse oximeters can measure the saturation for oxygen in the blood. These devices can be integrated with the M2M system using an already existing protocol adapter. In the experiments the experimenter can test a specific application or the different handling of specific data.

4.4.2.1 Functionality and Configuration Testing

The functionality and the configuration of the interface for the FIRE tools shall be tested in this experiment.

Potential KPIs

KPI Name:	Experiment Setup.
Description	This allows the experimenter to setup a small experiment environment.
Relevance	This KPI allows the experimenter to test the provisioning of the needed infrastructure for an experiment.
Classification	Functionality Test.

KPI Name:	Experiment Configuration.
Description	The experimenter shall setup an experiment and configure it to have a complex infrastructure with at least two gateways connected to a server and more than one device per gateway. One gateway should be located at another testbed.
Relevance	This KPI allows the experimenter to test the configuration of a complex experiment.
Classification	Configuration Test

4.4.2.2 Scalability Testing

The experiment 3.3.1 will be extended to test for vertical scalability. This will involve an increase in the number of patients being monitored until the system is unable to meet the required performance metric for each of the patients. For this an emulated variant of the devices will be used to easily increase the number of devices.

Potential KPI

KPI Name:	Peak data emergence handling.
Description	The experiment shall use a gateway and more and more devices sending data should be spawned. The load of the gateway should be measured and when a specific threshold is reached, another gateway handling the new devices shall be instantiated.
Relevance	This KPI allows the experimenter to test the scalability of the system.
Classification	Scalability Test

4.5 Education

4.5.1 Education Experiment

This experimentation will involve usage of the education portal from DAAD-Unifi project [6]. The DAAD-Unifi portal enables the federation of educational resources and testbed infrastructure provisioned by participant universities.

The target scenario, will consider a student watching a lecture from distance and afterwards provisioning some service or components over the federated testbeds in order to perform a practical task related to the registered class. For example a student form TUB can perform a practical task using the M2M gateway instantiation to control a specific device located at UCT.

The experiments shall be set up with the LabWiki tool (see Figure 19), which is an OMF client for setting up and running experiments. This can be used in lectures where the instructor will create an experimentation plan to be done by the students. In the end the results may be presented in a common format so that the instructor can easily check them.

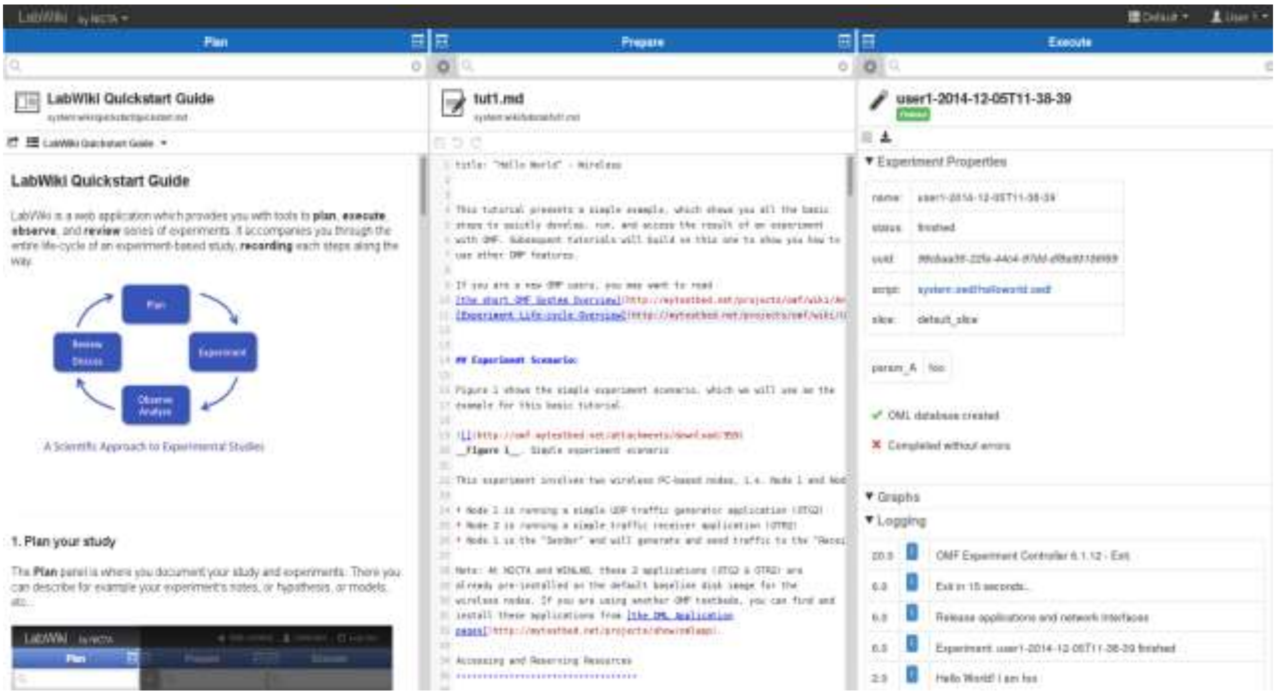

Figure 19 LabWiki tool

4.5.1.1 Functionality and Configuration Testing

The experiments will be set up and executed with the help of the LabWiki tool.

Usage Scenario

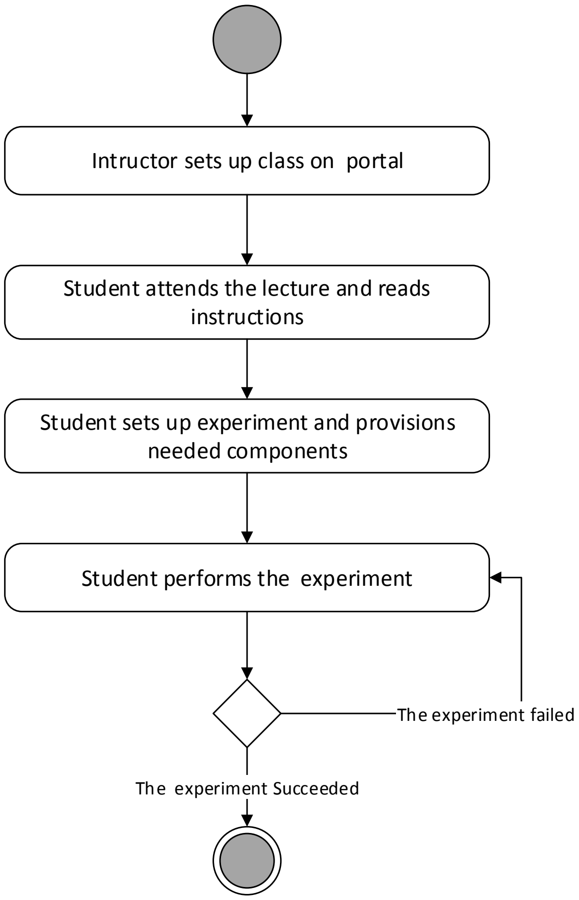

Figure 20 Activity Diagram - Education

Potential KPIs

KPI Name:	Lecture and experiment setup.
Description	The instructor shall setup a lecture and two students shall setup an experiment with one gateway where the students tests an application against the gateway.
Relevance	This KPI allows the experimenter to check the workflow of a lecture experiment.
Classification	Configuration Test; Functionality Test.

KPI Name:	Delivery of multimedia material
Description	The ability to deliver educational material of an acceptable quality.
Relevance	This KPI will allow the experimenter to check the extent to which the infrastructure can support
Classification	End User Test; Repeatability Test.

KPI Name:	Using resources from different testbeds in one experiment.
Description	An experiment shall be created where resources from different testbeds shall be connected and used.
Relevance	This KPI allows the experimenter to check the provisioning of resources of different testbeds but use it in one interconnected infrastructure.
Classification	Horizontal Scalability Test.

5 Conclusions and further Directions

This deliverable presents the TRESCIMO experimental testbeds and experiments to be conducted, based on TRESCIMO use cases and usage scenarios previously identified. The specification of the TRESCIMO testbeds addresses technical and functional requirements highlighted in D2.2. Additionally, suitable evaluation criteria of the developed architecture and components are identified in order to assess the communication platforms. After formulating these experiments, functional requirements relating to the experiments were fed back into work packages 2 and 3.

The described experimental environment would be able to provision required resources form the testbeds software stack and access the APIs to conduct different experiments related to Smart City. FIRE tools (such as jFed or MySlice) are used here to provision the resources, and insure the extensibility of the experimental testbeds. During the experimentally driven software development cycle, users of the federation are drawn from the TRESCIMO consortium.

The next step is the completion of the testbed and trial setup phases of the project. This activity will result in the production of document D4.2 “Evaluation Environment” which documents the evaluation environment that is going to be used to conduct the experiments described here. Once experiments have been carried out, with evaluations and results collected, D4.3 “Experiment Results” will be produced. This document will detail the results obtained during the evaluation task.

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Annex 1 – Eskom AMI Pilot Project

Overview

In 2008, Eskom embarked on an Advanced Metering Infrastructure (AMI) project. The project aims to install AMI meters to 120 000 qualifying Eskom residential suburban customers.

The programme implementation was divided into Phases (Phase 1 and Phase 2) as a risk mitigation strategy.

- The Phase 1 scope was a 10 000 customer pilot implementation with the key objective to develop internal capacity and experience on AMI technology and implementations. It also aimed to rollout and test the residential time-of-use tariff, Homeflex.
- The Phase 2 scope targets approximately 120 000 customers and implements the required systems, processes and support infrastructure based on the lessons learnt in Phase 1.

Project Objectives

The Eskom AMI programme is a specific intervention to assist with addressing the current electricity constraints, as required by the Electricity Regulations in Government Notice 773 of 2008. Regulation 773 requires distributors to ensure that all customers consuming over 1000kWh per month are on time-of-use tariffs and that non-essential electricity loads are managed by smart systems by 1 January 2012. The AMI programme also supports the Eskom 49M initiative by empowering customers with information on their energy usage patterns and encouraging energy efficient customer behaviour.

Besides regulatory driver, the AMI programme also has the following business drivers:

- **Shift Residential Peak Load** – to reduce the morning and evening peaks
- **Promote Customer Behaviour Change** - Incentivise the efficient use of electricity, promoting energy conscience lifestyle changes and empowering customers with usage information.
- **Improve Customer Service & Maximize Operational efficiencies** – Reduce meter reading costs and the need for estimations through automated meter readings. Reduce non-technical losses through tamper detection and usage monitoring. Reduce call-outs through remote meter disconnects and reconnects and supports proactive maintenance through low voltage (LV) network visualisation monitoring.
- **Develop a Standardised Solution** – Design, develop, implement, test and refine a standardised solution that should become the base standard for all residential metering, including prepaid metering.

Solution Architecture

AMI infrastructure is illustrated in Figure 21below (AMI Solution Architecture)

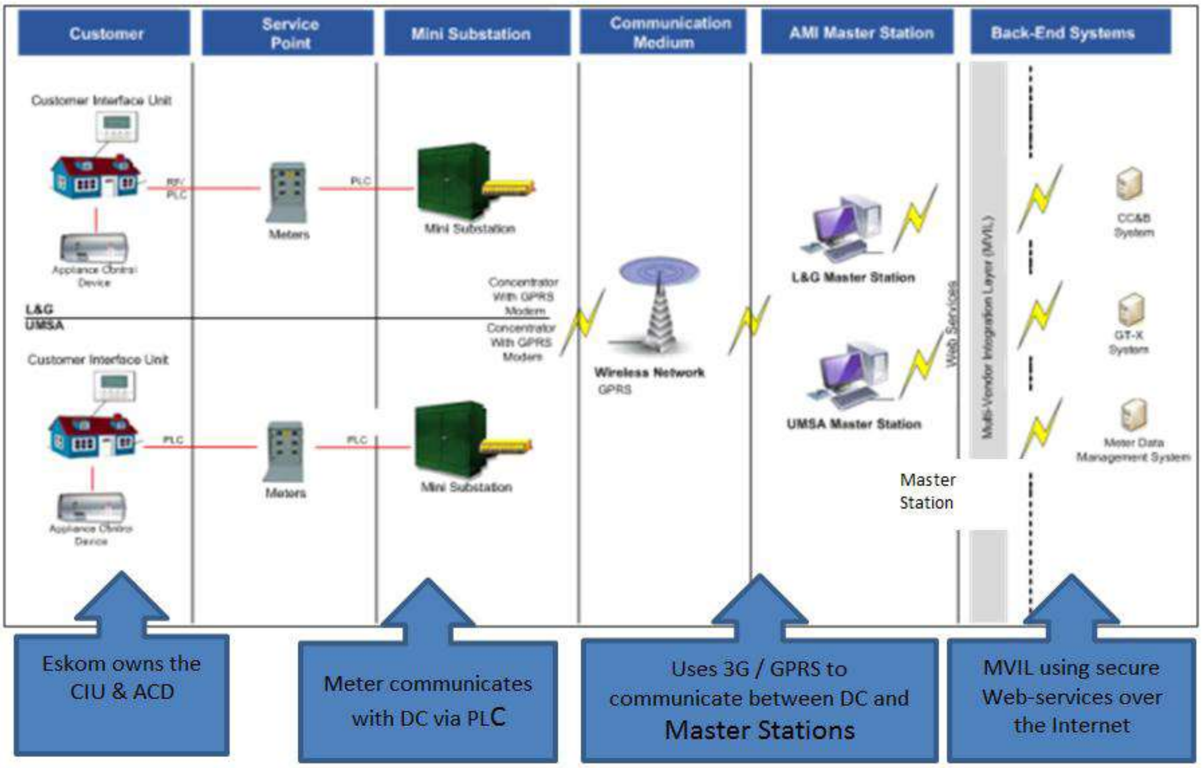

Figure 21 AMI Solution Architecture

Key Challenges and Lessons Learnt

The following were some of the key Phase 1 challenges:

- Significant delays were experienced due to a legal challenge of the AMI solution tender process.
- Several AMI solution technical performance issues were encountered, such as:
  - Meters disconnecting customers randomly.
  - Communication problems; between meter and Customer Interface Unit (CIU); meter and Data Concentrator (DC); DC and head-end system.
- Eskom's project personnel had limited experience with AMI implementations.
- The solution specification was based on the first version of national standard for Advanced Metering Infrastructure (AMI) - NRS049:2008. Being, version 1, the specification was still immature and untested. It was therefore expected that this specification would have to undergo revisions.

Key Accomplishments

Eskom has realised the following benefits:

- Reduction of "Non-Technical Losses"
- Automated Meter Reading (AMR) cost savings
- Avoided "Peak Generation" cost due to "Load Shifted"
- Avoided "Generation" due to "Customer Energy Efficiency"
- Reduction in Field Costs (Remote disconnect/reconnect)
- Customers are now actively moving towards being Energy Efficient