

1.1 Publishable summary – Final Management Report

Trescimo improves Future Internet Research Experimentation testbed capabilities in Europe and in South Africa, demonstrated through experimental research linking smart and green technological and social innovation.

Smarter and greener cities are essential to address economic, social, and environmental challenges due to the increase in urbanization, requiring informed decisions based on Internet of Things generated data. A particular challenge is the unstable power supply of cities in developing countries (e.g. South Africa), thus requiring smart energy management. Future handling of grid overload in South Africa involves demand-response mechanisms, installing small devices at the end-user, communicating over different network technologies to a central controller, allowing loads to be measured and limited if necessary. Further challenges include the deployment of affordable smart sensors (e.g. air sensors) as well as gathering information from nodes with limited power access.

In scenarios from energy consumption to waste bin levels, data is either sent over IP networks (which delivers data immediately) or collected in a delay tolerant mode by mobile devices of individuals or crowds. In delay tolerant mode the data is stored locally, to be delivered when a suitable network is reached. In cases of open data collection the devices in this Future Internet realm are targets of security attacks and might be vendor-locked with proprietary software stacks.

Our approach to address these issues is to interweave sophisticated Smart City platforms (CSIR/I2CAT) and an ETSI/oneM2M compliant Machine-to-Machine (M2M) communication framework (TUB/FOKUS OpenMTC). We emphasize secure identification and authentication of sensors and users as well as store and forward functionality.

Figure 1 depicts components associated with the TRESCIMO reference architecture as on its final version. This version has evolved through regular updates according to the progress of the work, new requirements, and results achieved. The integration of several frameworks and associated applications involve two testbeds for smart cities M2M communication: one at the Technical University of Berlin (TUB), Germany, and another at the University of Cape Town (UCT), South Africa. A federated node of the testbed is hosted in Pretoria and accessible through the testbeds. An in-house Proof-of-Concept related to smart energy, at the CSIR premises in Pretoria, South Africa, enabling two trials: the Smart Energy System Trial in Gauteng, South Africa (CSIR/Eskom), and the Smart City Environmental Monitoring Trial in Sant Vicenç dels Horts, near Barcelona, Spain (I2CAT/ABS).

TRESCIMO is integrated into the Fed4FIRE SFA client, powered by FITeagle2, running under the following URL: <https://federation.trescimo.eu>

Short Description of the **Testbeds**:

- At Technical University of Berlin, Germany
 - Experimental Machine to Machine testbed
 - Providing Testbed management using the FITeagle Future Internet Testbed Management Framework
 - Based on OpenStack, a cloud computing software, and OpenSDNCore, an ETSI Network Function orchestrator developed by Fraunhofer FOKUS
 - Control flow: FITeagle → OpenSDNCore → OpenStack service images
 - Interconnection with other FIRE facilities through the Slice-based Federation Architecture (SFA)

- At University of Cape Town, South Africa
 - Experimental Machine to Machine testbed
 - Based on OpenStack, a cloud computing software and on the FOKUS OpenMTC middleware framework.
 - Connected via VPN to the TUB testbed and integrated in the control flow of FITeagle and OpenSDNCore
 - Hosts devices and gateways for aggregating and exchanging data.
 - Used for prototyping IoT applications in the areas of Smart Home, Smart Energy, eHealth
 - Expands on developed applications by making use of OpenStack virtualization to investigate scalability-driven evaluations
 - Allows for resources to be used as “Education Experiments” for students with access to the testbeds.

Short description of the **Trials**:

- **Smart Energy Trial**, in Gauteng, South Africa is currently running as component in TRESCIMO. The trial utilises a collection of ActiveGateways and smart energy management devices and links a number of households to the Smart City Platform. The aim of the trial is to establish means for energy demand-side management (i.e. data acquired, communicated, processed and the result communicated to a device or to a person). The interface to the person is of particular importance in the trial. A mobile application linking to the complete platform stack has been implemented and provides a view into a resident’s household. Eskom, as the leader of the Smart Energy Trial activity, is aimed at providing the energy consumer with the ability to monitor and control specific appliances in their homes, especially during peak demand periods using IoT and M2M technologies. The main aim of the trial is to test the impact on the consumer energy patterns when a customer is provided with comprehensive and timeous information about their energy usage.
- **Smart City Environmental Monitoring Trial**, in Sant Vicenç dels Horts, near Barcelona, Spain: The trial consists in the deployment of a Delay Tolerant Networks (DTN) based system for Environmental Monitoring in Smart Cities with no need of an on-purpose infrastructure for interacting with the sensors distributed through the city. It is an energy-efficient solution based on enhanced radio wake-up system mechanisms and bidirectional communication with the sensors (allowing monitoring and configuration).

Short Description of the **Proof of Concept**, in Pretoria, South Africa:

A proof-of-concept has been implemented at the CSIR premises (taking cognisance of the fact that the TRESCIMO solution is cloud based with components hosted elsewhere or in the CSIR Openstack instance). This proof-of-concept integrates all technology building blocks into an end-to-end future internet experimental platform. It integrates energy related sensors (Active devices) through gateways and interworking proxies with an instance of OpenMTC. Similarly, environmental sensors (e.g. air pollution) sensors are connected via a delay-tolerant network to the OpenMTC instance. The DTN gateway and wake-up sensors are located at I2CAT premises. The Smart City Platform provides a base for applications (i.e a visualization mobile application). The Smart City Platform is linked to the OpenMTC instance via another interworking proxy. This proof-of-concept links to the federated research facilities (via FitEagle) which allows for provisioning and control of the various building. The proof-of-concept provides a full-featured experimental facility for new research and development.

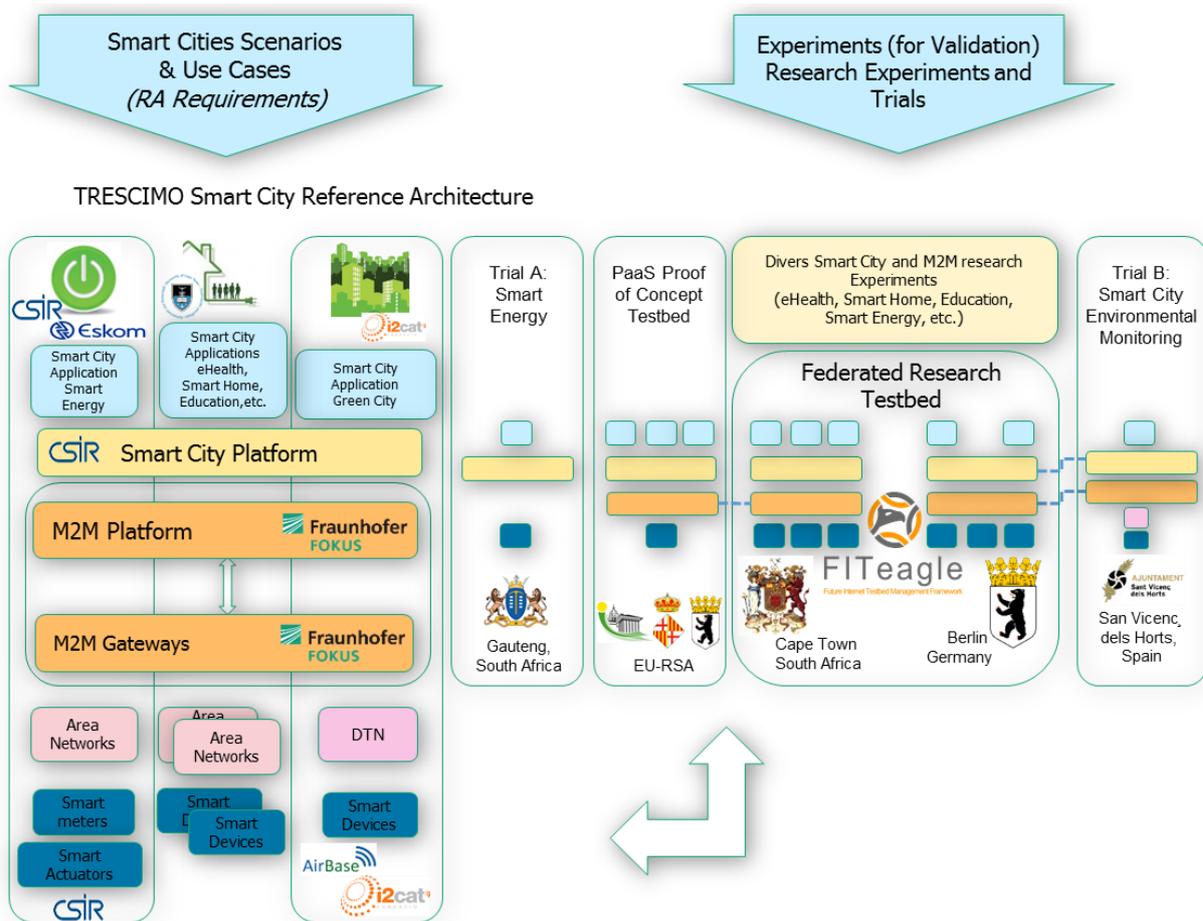


Figure 1 TRESCIMO Final Reference Architecture

TRESCIMO is a Future Internet Research Experimentation (FIRE) project, for EU-South Africa cooperation on future Internet experimental research and testbed interconnection. It started on January the 1st, 2014 and finished on December the 31st, 2015.

FIRE addresses the emerging expectations that are being put upon the Internet. TRESCIMO provides a research environment for investigating and experimentally validating highly innovative and revolutionary ideas. TRESCIMO offers Smart Infrastructures as a Service, and the project key achievement is a reliable and standard compliant Smart City Software Stack as a Service for evaluation purposes based on European and South African requirements of Smart Cities.

TRESCIMO has achieved all its main objectives:

- Strengthens the interconnection and extension of existing experimental facilities across continental boundaries with a specific focus on Smart Cities and Smart Energy;
- Integrates software-based cross-industry horizontal M2M frameworks with real world sensors and IoT device deployments;
- Uses autonomic communication methods for end-to-end M2M communication in Smart Cities focusing on smart energy management;
- Uses delay tolerant communication approach to support opportunistic information transmission;
- Leverages existing standards in the field of M2M and foster their global adoption;
- Deployed a federated testbed with sites across countries and continents, with a focus on developing countries and structurally challenged areas.

TRESCIMO reached all its main results, associated with the respective work performed on:

- **Scenarios and Requirements:** The work was completed in the first year of the project and reported in deliverables D2.1 (Scenario Specification), D2.2 (User and Technical Requirements) and D2.3 (Final Requirements and Scenarios). Based on the results reported an article including M2M/IoT domain and use case requirements analysis was accepted for publication at the 2nd IEEE WF-IoT 2015 conference.

- **Architecture and Implementation:** The architecture specification has been completed and published in D3.1, leading to the first version of the integrated prototype, which is described in D3.2. The second version of the integrated prototype was implemented, with a host of new features and improvements. These features include configurability, device management and on demand deployment of some of the backend services. The achievements are described in D3.3.

- **Experimentation:** The VPN environment was established and the Federation Environment was created and can deploy the whole architecture and also configure attached devices, as presented in D4.2. The definition of the Federated Environment and the selection of the evaluation criteria, in real world environments and in scalable testing facilities, for the assessment of the architecture and components were reported in D4.1. The experiments in the testbeds were executed and the results collected. The defined KPIs were checked. In addition, the long-term experiments were started in the trials and the results collected. The evaluation can be seen in D4.3.

TRESCIMO outcomes encourage the development of affordable technologies for future Internet, research activities on delay tolerant networks and opportunistic communications, as well as developments supporting innovative applications for social integration, improving the capabilities of testbeds on Future Internet technologies in Europe and in South Africa.

The development of the TRESCIMO technology (testbeds and platforms) can be used as best practice to guide the research, development and implementation of similar technologies for application in South Africa and Worldwide.

The execution of the validation trials provided insight and experience that is beneficial for human infrastructure development with regard to technologies needed for the M2M and Smart Cities platforms. Based on the TRESCIMO developed technology and insights through validation in the South African context, the South African partners are able to channel and contextualize European developed M2M technologies into the South African market for improved decision making in the context of energy utilization at both national, regional and city level.

With respect to future smart grid, both at national level as well as at municipality level TRESCIMO contributes to awareness rising at citizen level and encourages behavioural change leading to energy savings in public and private buildings and homes.

The developed technology of the TRESCIMO project can also be beneficial for supporting and enabling existing initiatives and foreseen programs in other domains, i.e. smart city programs dealing with water, waste, healthcare, education, transport, and logistics.

All the progress and project achievements are published on the project website under the European and the South African domains: <http://trecimo.eu/> and <http://www.trecimo.org.za/>.