# Scientific Report

| | |
|---|---|
| First name / Family name | Roberto Rigolin Ferreira Lopes |
| Nationality | Brazilian |
| Name of the *Host Organisation* | NTNU – Norwegian University of Science and Technology |
| First Name / family name of the *Scientific Coordinator* | Sverre Hendseth |
| Period of the fellowship | 01/11/2012 to 31/10/2013 |

# I – SCIENTIFIC ACTIVITY

The fellowship started discussing the viability of deploy web-based third party services using the broadband connection already available at the smart grid end users (e.g., ADSL, cable or fiber-to-the-home). With the meter/controller connected to the Internet, the web is the logical place to create the full-duplex links aimed in the smart grid vision, as illustrated in Figure 1. From a software engineering perspective, this scenario combined with open *application programming interfaces* (APIs) builds the basis to the development and deployment of third party services.

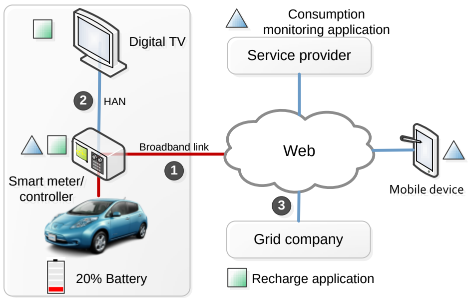


**Figure 1. Car monitoring scenario.**

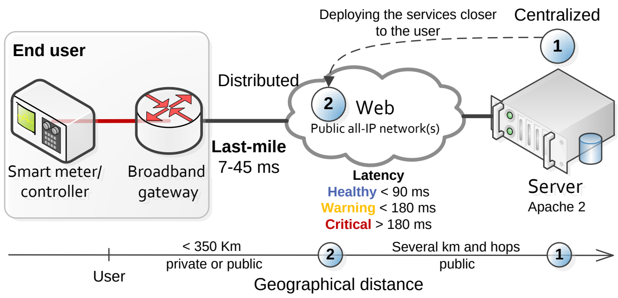


**Figure 2. Emulated IPv6 network environment.**

We started with the hypothesis that applications protocols, such as SPDY introduced by Google, can meet the *quality of service* (QoS) requirements from typical smart grid services. Our strategy to verify this hypothesis was composed by three steps. First, compile the smart grids QoS requirements, in the literature, composed by throughput, latency and reliability. Second, define and setup an IPv6 emulated network environment between the meter/controller and the service provider at the web, as illustrated in Figure 2. Third, perform and discuss a quantitative evaluation of HTTP, HTTPS and SPDY, with focus on meeting the QoS requirements compiled.

Motivation scenario: let's suppose that an electric car manufacturer wants to provide an application to clients monitor their cars autonomy. This application shows the cars power consumption summary and detailed history using digital TVs or through mobile devices, as illustrated in Figure 1. Moreover, the car manufacturer made a partnership with a grid company to offer low energy prices to shared users.

Three communication links are necessary to realize the scenario, also illustrated in Figure 1: (**1**) between the meter/controller and the grid company (e.g., using a broadband link); (**2**) between the devices inside the house and the meter/controller using a LAN or WLAN; and (**3**) over the web among the grid company, the service provider and the users devices (e.g., a mobile device or a digital TV). We performed quantitative experiments to delimit the connectivity available at the link (1).

Then, the investigation unfolded addressing the challenge of how to compile the user-centric data related to consumption, generation and storage. Figure 3 illustrates the continuous loop of data sensing which orchestrates the system to compile and share the microgrid status. This figure also highlights the components to (**1**) gather, (**2**) compile and (**3**) share the user-centric information. Empowered by graph-based data model, the loop is also able to track new users, generators/storages and consumption behaviours.

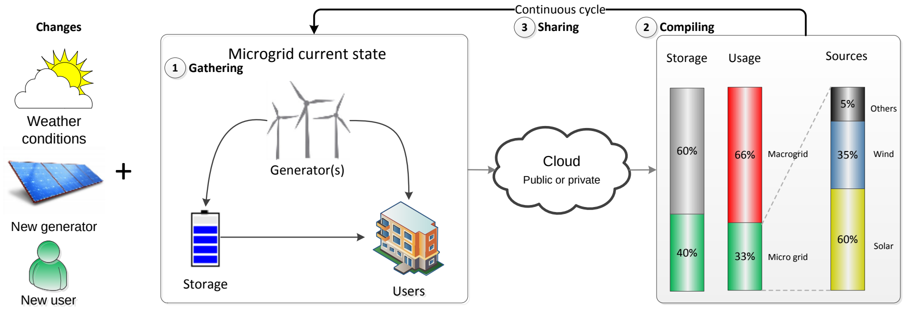


**Figure 3. Loop to compile the micro grid status: (1) gathering, (2) compiling and (3) sharing.**

The gathering component collects sensors data (e.g., current amount of energy stored in a battery at the user), and the compiling component extracts information from the data set (e.g., energy stored in the microgrid). Then, it is necessary do something useful with the information e.g., use the stored energy to avoid outages. Finally, this data set should be shared within the microgrid to collaboratively measure and map the current status.

The loop in Figure 3 also supports the necessity of continuously match supply and demand, because both can change over time. The aim was provide better quality electricity-related data in terms of freshness and accuracy. Moreover, consumers need to be informed about the current status of the microgrid in a comprehensible format and given incentives to reduce their consumption. The next step of the present investigation is use this loop to disseminate good consumption practices based on real users' experiences.

## II – PUBLICATIONS

Published in conferences:

1. LOPES, R. R. F. *Social networks adding community-scale to context-aware connectivity management*. In: IEEE Wireless Communications and Networking Conference (WCNC), 2013, Shanghai, p.1649 – 1654 (accepted).
2. LOPES, R. R. F., PLATOU, R. S., TORRISI, N. M., GREGERTSEN, K. N., MATHISEN, G., HENDSETH, S. *Deploying third party services at smart grids end users using broadband links*. In: IEEE Innovative Smart Grid Technologies Europe (IEEE ISGT Europe), 2013, Copenhagen, p.1-5 (accepted).

Submitted to conferences:

3. LOPES, R. R. F., PLATOU, R. S., CASTILLEJO, P., MARTÍNEZ, J. F., MATHISEN, G., HENDSETH, S. *Gathering, compiling and sharing the microgrid status from the end user perspective*. In: IEEE World Forum on Internet of Things (WF-IoT), 2014, Seoul – Korea (pending).
4. VATTEKAR, E., LOPES, R. R. F., CASTILLEJO, P., HENDSETH, S. *Security mechanisms for multi-homed smart grids end users*. In: IEEE World Forum on Internet of Things (WF-IoT), 2014, Seoul – Korea (pending).

# III – ATTENDED SEMINARS AND CONFERENCES

**IEEE Wireless Communications and Networking Conference** (WCNC)
April 7-10, 2013. Shanghai, P.R. China.

**ESEIA – International Summer School** *"Sustainable Smart Metropolitan Regions of Tomorrow"*. July 14-28, 2013. Brasov, Romania.

**Norwegian Research School in Renewable Energy**
August 12-16, 2013. Asker, Norway.

**Internet of Things and Smart Cities Ph.D. School**
September 16-20, 2013. Lerici, Italy

**IEEE 4th European Innovative Smart Grid Technologies Conference** (ISGT)
October 6 - 9, 2013. Copenhagen, Denmark.

**ABCDE Seminar III**
October 31$^{st}$ to November 1$^{st}$, 2013. Athens, Greece

# IV – RESEARCH EXCHANGE PROGRAMME (REP)

**Technical University of Madrid – UPM**
February 11-16, 2013. Madrid, Spain
Scientific coordinator: José Fernán Martínez

Collaboration was started to design a user-centric solution to track the microgrids status. The focus was on modelling consumption, generation and storage at the smart grids end users.

**Swedish ICT - SICS**
October 14-18, 2013. Stockholm, Sweden
Scientific coordinator: Joel Hoglund

Discussion about deploying third party services at smart grids end users was started. With focus on how guarantee QoS in multi-hop networks and how to push sensed data to public clouds.