PROSUMER INTERACTIONS FOR EFFICIENT ENERGY MANAGEMENT IN SMARTGRID NEIGHBORHOODS

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ABSTRACT

The introduction of distributed energy generation has among other things the power to enable traditional consumers to also produce energy (called prosumers), which they subsequently may make available on the network. The emerging SmartGrid relies on the active participation of these prosumers, and their interactions may have a significant impact on its core operations. The NOBEL project investigates these interactions by considering the local context of the users and their behaviour in a neighbourhood within a smart city. The aim is to provide an information and communication driven infrastructure for the users to interact and e.g. buy and sell energy on online marketplaces. Such an envisioned infrastructure may pose significant opportunities as well as challenges for all involved actors, however it bears the potential to enable us to better manage the energy in the highly dynamic electricity network of the future.

Keywords: Energy efficiency, public lighting system, energy brokering, enterprise services.

1 MOTIVATION

Europe has set ambitious goals towards increasing energy efficiency and sustainability in order to tackle the emerging energy needs of its citizens. Additionally there is a strong movement towards distributed energy resources and decrease in dependence from traditional, environmental unfriendly ones. Distributed generation of energy coming from various vendors, even private homes, is a big challenge for tomorrow's power management systems that, unlike today, will not dispatch energy centrally or under central control. In the emerging infrastructure of SmatGrids the production, distribution and management of energy will be a reality, and taking into consideration local conditions and data one might better locally optimize its operation. The SmartGrid is a complex system of systems that will undergo a significant change in the next decades, and as any distributed system, it will be challenging to design, deploy and manage it in a traditional centralized way.

The NOBEL project (Marqués et al. 2010) envisions that market-driven interactions at local (neighbourhood) level may motivate energy to be traded locally by the producers and consumers and (i) better cover the local energy needs (increase efficiency), and (ii) assist the DSO to better assess the situation and plan its actions. Hence, via the local market, individual as well as groups of prosumers (Karnouskos 2010) can communicate their energy needs directly. The last brings market concepts to the business transactions among the users, which might introduce new opportunities as well as new revenue sources to the participants. A typical such example investigated within the NOBEL project is the ability to use public infrastructure (e.g. the public lighting system) as a flexible balancing market actor. This would enable the community to investigate an additional source of revenue by offering its flexibility to consume (e.g. by turning lights on) when too much production is available as well as to lower its consumption (e.g. by turning lights off) when it is needed.

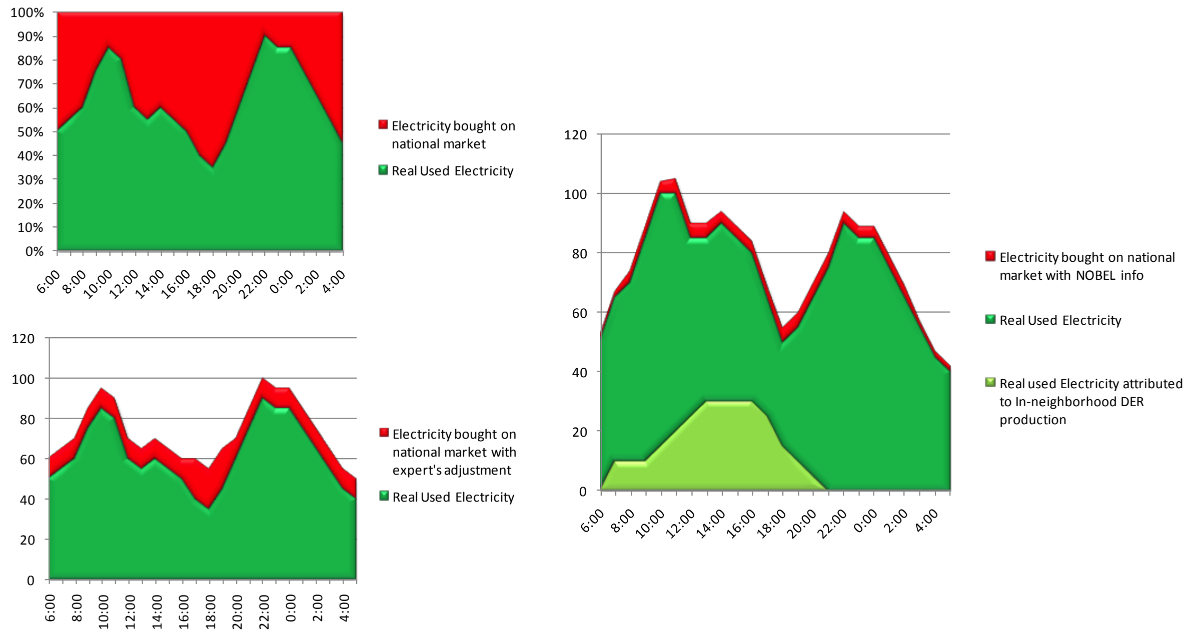

Figure 1: Towards Energy Efficiency in Neighborhoods

A significant problem is the balancing of energy production and consumption even at local level due to the highly nonlinear and very dynamic system. It is hard to predict disturbances and undertake counter measures on time. This is expected to get even worse with the introduction of Distributed Energy Resources (DER) such as Combined heat power (CHP), Fuel cells, Micro combined heat and power (MicroCHP), Microturbines, Photovoltaic Systems (PV), Small Wind power systems etc. As we can see in Figure 1, there are ongoing efforts to map production to consumption; however today this is mostly done by relying on static historical data and often to human intelligence (and many times feeling/expertise) to procure the envisioned energy from national energy market. However, the introduction of very dynamic energy resources such as DER may not be adequately tackled with these approaches.

As depicted in Figure 1, NOBEL aims at minimizing the electricity excess on the network while managing also DER. For neighbourhoods today the electricity is procured e.g. at a national market, however whatever is not really used is “wasted” (as depicted in the upper left part of Figure 1) although it was paid for (e.g. because the needs were falsely predicted). To minimize the losses, procurement of energy is done by experts who rely on historical data as well as prediction algorithms. They then buy the necessary energy in national markets in an optimized way (as depicted on the lower left part of Figure 1). However, the introduction of DER is hardly considered and difficult to be predicted. NOBEL aims at creating an infrastructure where the information among the users can be shared and where e.g. energy produced within the neighbourhood can also be used locally, resulting to more efficient internal management in the neighbourhood (as depicted on the right side of Figure 1). Our vision is to achieve this in a market-driven way by enabling interactions among the prosumers.

Hence NOBEL invests in realizing a cross-layer and open information flow among the different actors involved, so that they can transact and via these transactions to be able to make better tackle the system dynamics which may lead to better energy management and achieve better energy usage.

The ultimate objective is to achieve higher energy efficiency and optimise its usage. This can be achieved by analysing and continuously monitoring not only the components in the distribution network, but also the prosumer interactions, gathering the appropriate data and, finally, identifying on-the-fly situations where energy can be saved. This will allow NOBEL to create a highly dynamic system where the amount of electricity in the network follows more closely the current demand. Excess energy is monitored and managed to make the energy available in other parts of the network or to intelligently make use of it via demand side controlling. To achieve this goal, the energy that comes from the local network operator as well as the prosumers will have to be monitored, analysed, and decisions will need to be made in a timely manner. The objectives of the NOBEL project are in-line with the vision and the strategic deployment agenda set by the SmartGrids European Technology Platform (2010).

The key to NOBEL's efficiency improvement is that prosumers become sources of both energy and information that can be exchanged. The information allows the energy system to better adapt the amount of electricity in the network to the real time demand. The performance of the entire system is enhanced by exploiting the locality of the processes in monitoring and control that normally do not consider the detailed behaviour of the actual consumers.

2 THE NEIGHBORHOOD IN A SMART CITY

A neighborhood is a geographically localized community within a larger city, town or suburb sharing a common service infrastructure. In some countries, neighborhoods are often given official or semi-official status, serving to represent administrative division found immediately below the district level. In the context of NOBEL, a neighborhood is a group of households and public services served by a same electricity local Distribution System Operator (local DSO) and geographically localized in the same area. Thus, the neighborhood unit within the project refers to the capability to manage electricity related services. In this way, usually a local DSO will always manage at least one neighborhood, but there are also cases where a single local DSO manages several neighborhoods, as it happens nowadays in most cities. In this context, the NOBEL project proposes a way to bring together the various prosumers and the DSO in order to maximize energy efficiency; the approach is market-driven and interactions are facilitated in an online marketplace where brokering of electricity can take part.

While a universally agreed definition of a smart grid is not clearly stated and varies in focus in different countries; Hoang (2008) has already identified a number of typical components that should be considered:

- *Intelligent appliances* capable of deciding when to consume power based on preset customer preferences.
- *Smart power meters* empowering bidirectional communication between consumers and power providers for better data collection, maintenance, outage detection etc.
- *Smart substations* that include monitoring and control of critical and non-critical operational data such as power factor performance, breaker, transformer and battery status, security, etc.
- *Smart distribution* that depicts self-* features such as self-healing, self-balancing and self-optimization.
- *Smart generation* capable of "learning" the unique behavior of power generation resources to optimize energy production.
- *Universal access* to affordable, low-carbon electrical power generation (e.g., wind turbines, concentrating solar power systems, photovoltaic panels) and storage (e.g., in batteries, flywheels or super-capacitors or in plug-in hybrid electric vehicles).

In the context of NOBEL the relevant components for a neighborhood-oriented system include from the intelligent appliances to the smart distribution at a local level. The scope of the project, however, does not consider the intelligent appliances or the hardware developments as main topics of research, because other EU research projects and initiatives such as BeyWatch (www.beywatch.eu), OpenMeter (www.openmeter.com), AIM (www.ict-aim.eu), DEHEMS (www.dehems.eu), BeAware (www.energyawareness.eu), MIRABEL (www.mirabel-project.eu), ENERSip (www.enersip-project.eu) and SmartHouse/SmartGrid (www.smarthouse-SmartGrid.eu) already cover such topics. On the contrary, NOBEL tackles the use of information coming from Smart Meters (SM) and end users through proactive consuming/producing profiling to adapt the operational behavior of a local network, introducing brokerage capabilities and providing improved monitoring and control tools to distribute and move the decision making to a local level whenever it is possible.

Additionally the NOBEL project gives a significant focus on the business side and specifically on the enterprise services that would empower its concepts. Figure 2 depicts the overall project vision, where enterprise services integrate almost in real time information coming from highly distributed smart metering points, process it and take the necessary decisions. Data is collected from existing monitoring devices such as the smart meters are communicated via wired and wireless channels either directly to a service or via the usage of in-network intelligent data processors. The goal is to be better able to manage complexity and high distribution at the point of action and not at centralized systems. In our case the fully customized data capturing as well as processing is done by the respective NOBEL developed modules, while the integration of hardware and multiple communication channels is hidden.

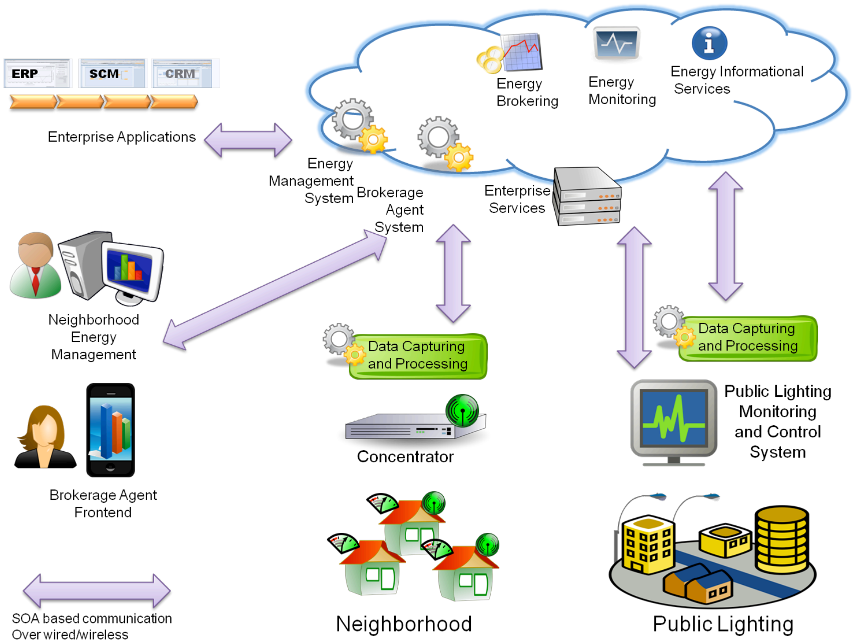

Figure 2: NOBEL Infrastructure Overview

The enterprise system is comprised of several Internet-accessible services, which in their turn can be used to create mash-up applications. Additionally, following a software-as-a-service (SaaS) model, we expect the rise of new applications (as well as feature enhancement) simply by rapidly combining cross-enterprise services to deliver customized functionality. This is the case for the energy management system portal (from which the DSO can get an overview of the network) as well as the mobile front-end (BAF), which is expected to be provided to the smartphone of the users and enable them to interact with the NOBEL infrastructure.

NOBEL aims at creating mash-up applications that use Internet services to create dynamically customized applications at the end user side, whether this is a simple user, a standard prosumer or a senior prosumer. This is a significant change for the energy domain, as we move away from heavyweight monolithic applications towards much more dynamic, up-to-date and interactive ones utilizing local capabilities. By increasing visibility via near real-time acquisition and assessment of the energy information, providing analytics on it and allowing selective management, NOBEL will provide a new generation of customized energy efficiency services. Typical Energy Enterprise Services envisioned include: Energy Brokering, Energy Monitoring, Energy Prediction, Energy Optimization, Energy Info Services, Energy Pricing, User/Profile Management, Energy Management, Energy Service Catalogue, Asset Management etc.

3 MARKET INTERACTION

In the future smart city, several of its neighborhoods will be supplied by different local Distribution System Operators (DSO) who coordinate with a few Transmission System Operators (TSO). The local DSOs are in charge of providing the last mile infrastructure, distributing the electricity to the end users according to the contracts they have with the different suppliers. Each local DSO is controlling and monitoring a number of neighborhoods (as depicted in Figure 4).

Each neighborhood is expected to have an Electricity Monitoring and Control System (NOEM) developed within NOBEL, assisting the DSO in having the overview by providing analytics as well as enabling the management of the energy (as depicted in Figure 2). The information that such services will process and depend upon, come from the network (smart meters, local distribution equipment, concentrators, network analyzers, etc.), the prosumers interacting with the network through a brokerage agent front-end (BAF), or the relevant local DSO. NOEM is a mash-up application composed by various enterprise services provided within the project and are expected to be cloud-hosted (as depicted in Figure 2).

Another mash-up application is the Brokerage Agent Front-end (BAF). This application is targeting mostly modern mobile devices, is again depending on a mash-up of several services to provide it with real-time data, and fosters direct interaction with the user who can not only receive info e.g. energy consumption, but also can connect e.g. to the online marketplace to buy and sell electricity. Of course similar functionality will be available via a web portal accessible also by normal desktop and laptop computers. The objective of BAF is the design and development of a tool for standard prosumers to interact with its brokerage agent. This tool provides to the STandard Prosumer (STP) a user-friendly and easy to use front-end to interact with the brokerage system managing the efficiency of its electrical demand. The front-end enables the active communication between the energy management system and its end users. In typical examples, the local Distribution System Operator Transmission System Operator may interact with the users and provide incentives in order to affect the behaviour of the consumers e.g. multiple tariffs. The Brokerage Agent Front-End is accessible from a wide variety of wired and wireless devices - PCs, smart phones and PDAs – in order to achieve access to the energy data anywhere, anytime, in any form easily and effectively.

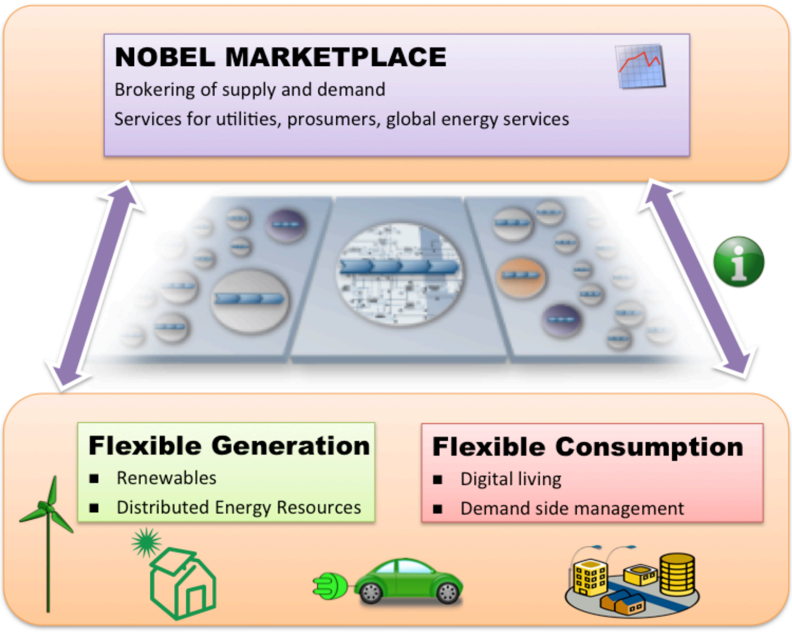

Figure 3: NOBEL Market

The Neighbourhood Oriented Public Lighting Monitoring and Control System (NOPL) is the example of a Senior Prosumer interacting with the NOEM. Senior Prosumers require internal energy management processes, which impose some constraints not necessarily observed by normal STPs, but also provides new capabilities to improve the energy efficiency of the target neighbourhood. In the case of a public lighting system as the one used in the NOBEL project, the main constraint would be the need to respect at any time the contractual obligation of providing a public service: major disruptions on the service could affect not only the well-being of citizens but also its security and safety. In this way the monitoring capabilities should be highly robust, which may limit the number of feasible energy-saving solutions. The NOPL will make available to the NOEM information related to consumed energy through the Data Capturing and Processing service, as an STP would do. Alarms on the behaviour of the lighting grid will be treated internally, and only the ones affecting the neighbourhood grid performance will be propagated to the NOEM – e.g. an unexpected demand due to heavy rain requiring more electricity than planned is an event of interest for the local DSO.

Market driven interactions lie in the heart of the emerging SmartGrid infrastructure. The bidirectional information exchange will put the basis for cooperation among the different entities, as they will be able to access and correlate information that up to now either was only available in a limited fashion (and thus unusable in large scale) or extremely costly to integrate. From the business side new, highly distributed business processes will need to be established to accommodate these market evolutions. The traditional static customer processes will increasingly be superseded by a very dynamic, decentralised and market-oriented process where a growing number of providers and consumers interact (as depicted in Figure 3). Such an infrastructure is expected to be pervasive, ubiquitous and service-oriented. However the biggest issue to be tackled for all of these to be made a reality would be the development of open interoperable approaches (NIST, 2010). Various roadmaps such as the one drafted by the SmartGrids European Technology Platform (2010) as well as the Federation of German Industries (2010) provide an insight on the challenges and directions.

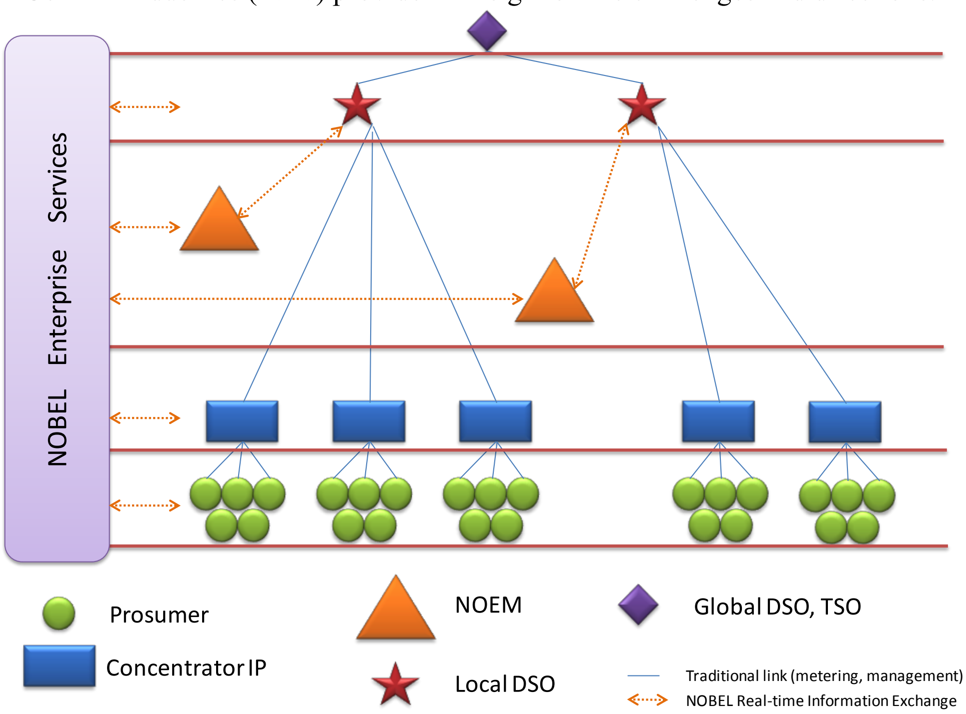

Figure 4: Market structure envisioned

NOBEL explores the importance of local energy markets to enable better energy management at neighborhood level; which implies the horizontal interactions among the prosumers (via a brokering system) and the ability to provide analytics at local DSO level. The concepts are expected to be trialed in 2012 in the city of Alginet in Spain. We plan a number of prosumers to be able to use the brokering capabilities provided and buy and sell electricity in the local marketplace (also provided by NOBEL). The interaction is expected to be mainly done via mobile devices i.e. smartphones and tablets. Besides the normal residential customers in the trial entities controlling the public infrastructure will be present. As such the public lighting system of the city will be used to act as a balancing partner twofold: (i) at the first stage by offering its flexibility to better balance the local energy needs, as a result of management from the NOEM, (ii) and later experiment by having it offering this functionality over the neighborhood market.

4 CONCLUSIONS

NOBEL uses state of the art technologies to dynamically obtain and process information from current available installed equipment. This is achieved by implementing bidirectional communication with all involved entities, process the information with respect to consumption and production and automate decisions to be made network-wide. The project also develops a service oriented framework that will allow easy flow of information among the prosumers and the enterprise systems in order to foster more energy efficient processes. This implies the development/extension of a middleware – i.e. a set of application independent services – that enable the distributed capturing, filtering and processing of the energy related data. The same services will ease enterprise wide inclusion and allow for better cross-layer collaboration which will lead to holistic optimization strategies. NOBEL fosters cooperation approaches for all entities involved. Once the basic infrastructure supporting real-time monitoring and management, as well as the respective brokering services, then scenarios demonstrating how energy efficiency can be achieved will be realized. NOBEL will try out these concepts in the city of Alginet in Spain in 2012 and assess the results from a real-world trial.

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