# NOBEL – A Neighborhood Oriented Brokerage ELectricity and Monitoring System

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**Abstract.** Distributed generation of energy coming from various vendors, even private homes, is a big challenge for tomorrows power management systems that, unlike today, will not dispatch energy centrally or under central control. On the contrary, the production, distribution and management of energy will be treated and optimized in a distributed manner using local data. Even today, parts of the power system are highly non-linear with fast changing dynamics. It is hard to predict disturbances and undertake countermeasures on time. In existing approaches electricity is distributed to the final users according to its expected estimated demand. Such non-dynamic approaches, are difficult to evolve and can not accommodate rapid changes in the system. By having a cross-layer and open information flow among the different actors involved we can make better and more timely predictions, and inject new dynamics in the system that will lead to better energy management and achieve better energy savings. The NOBEL project is building an energy brokerage system with which individual energy prosumers can communicate their energy needs directly to both large-scale and small-scale energy producers, thereby making energy use more efficient.

**Keywords:** smart grid, smart metering, prosumer, brokerage system, neighborhood management, smart city.

## 1 Motivation

Europe is striving towards saving of 20% of the European Union's primary energy consumption and greenhouse gas emissions, as well as the inclusion of 20% of renewable energies in energy consumption until 2020 (known as the "20-20-20" target). Energy efficiency is the most cost-effective way of reducing/optimizing energy consumption while maintaining an equivalent level of economic activity. Improving energy efficiency also addresses the key energy challenges of climate

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change, energy security and competitiveness. The main obstacles to energy efficiency improvements are the poor implementation of existing legislation, the lack of consumer awareness and the absence of adequate structures to trigger essential investments in and market uptake of energy efficient buildings, products and services.

Distributed generation of energy coming from various vendors, even private homes, is a big challenge and, additionally, a source for new business opportunities for tomorrows power management systems that, unlike today, will not dispatch energy centrally or under central control [2, 5]. On the contrary, the production, distribution and management of energy will be treated and optimized in a distributed manner using local data. Nowadays, 40% of all energy consumption in the world is electrical energy, with 41% of this energy consumed by households and services [1]. This will grow to 60% by 2040. Much of this energy is wasted by inefficient technologies, especially during its transport, but also in the last mile of distribution, where the management and control take place, most of the time, in a centralized way, as opposed to a more local driven monitoring and control. Information and Communication Technologies (ICT) are the key to enhance the monitoring and control of electrical energy from the source to the load, especially in cases where we have large scale distributed energy production [3].

In existing approaches electricity is distributed to the final users according to their expected estimated demand, usually precomputed yearly. Such non-dynamic approaches, are difficult to evolve and cannot accommodate rapid or unpredictable changes in the system e.g. on production side, on consumer side etc. By having a cross-layer and open information flow among the different actors involved we can make better and more timely estimations, and inject new dynamics in the system (e.g. locality of energy production, direct interaction of business processes with the energy management systems etc) that can eventually lead to better energy management and achieve better energy savings.

## 2 The NOBEL Approach

The NOBEL approach targets to develop, integrate and validate ICT enabling a reduction of the currently spent energy, by providing a more efficient distributed monitoring and control system for local network operators and prosumers (as depicted in Figure 1). NOBEL will focus its efforts in designing a new Neighborhood Oriented Energy Monitoring and Control System. This solution will help network operators to improve last mile energy distribution efficiency by integrating operators requirements and by enabling bidirectional interaction between them.

Two different prosumer (producer and consumer) profiles are considered for the proof of concept:

- A standard prosumer, represented via a Brokerage Agent. This Agent will be developed within the project to dynamically monitor the amount of energy that he has produced, and the amount that is not yet consumed. This energy

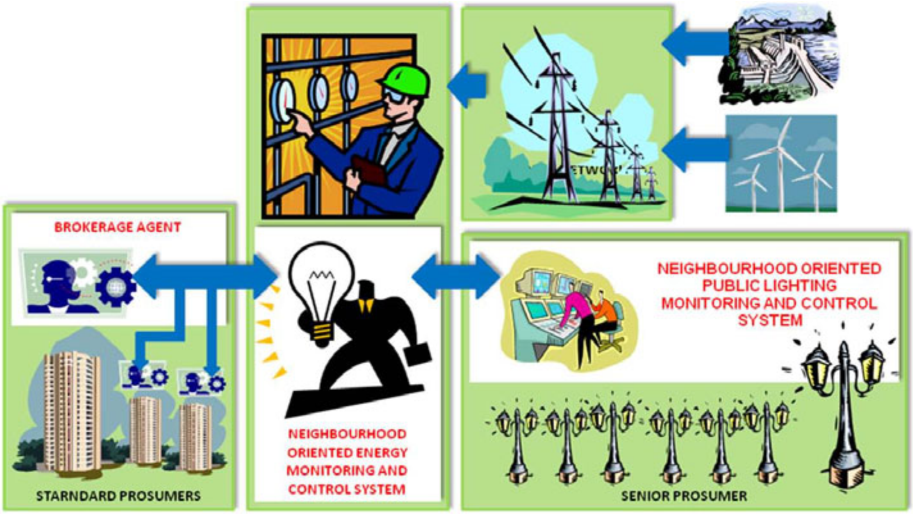


**Fig. 1.** NOBEL overview: Energy Efficiency for the Neighborhood

can be traded and therefore made available to other users, improving in this way the overall efficiency of the system.

– A senior prosumer, that extends the previous concept in the sense that that it requires additional internal processes to not only dynamically monitor but additionally control the energy produced or consumed in a largely distributed local area. Examples of senior prosumers are sport centers, industrial parks, shopping centers, etc. NOBEL will use a real-world testbed i.e. the Neighborhood Public Light System to validate and assess its concepts.

By improving monitoring efficiency, the NOBEL approach aims at reducing the required production of energy. In the short term, it is more important to improve the efficiency than trying to dramatically reduce the production, which would require a major social agreement and a major adjustment in the behavior of citizens. The key to NOBELs efficiency improvement is that prosumers become sources of both energy and information. 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 behavior of the actual consumers.

The ultimate objective is to achieve higher energy efficiency and optimize its usage. This will be achieved by analyzing and continuously monitoring the components in the distribution network, 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 the current demand. Excess energy already bought or created is monitored and managed to make the energy available in other parts of the network (see Figure 2) or to intelligently make use of it via demand side

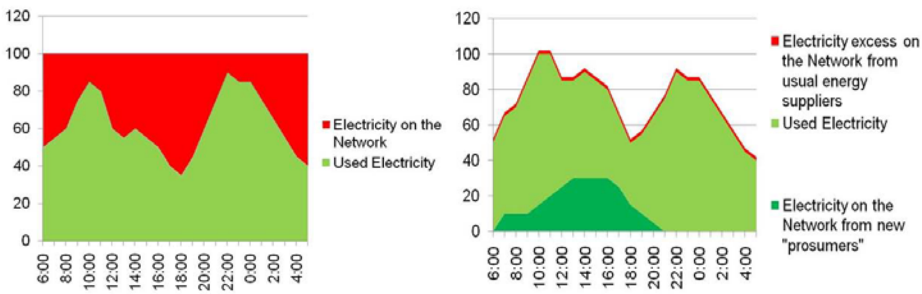


**Fig. 2.** NOBEL approach: demand-driven production/energy-purchase

controlling. To achieve this goal, the energy that comes from the local network operator as well as the prosumers will have to be monitored in a fine-grained way, analyzed, and decisions will need to be made in a timely manner.

In summary, the NOBEL project has set the following scientific and technical objectives:

- *Information retrieval:* NOBEL uses state of the art technologies to dynamically obtain and process information from current available installed equipment. This will be 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.
- *Information distribution:* NOBEL 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 and 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.
- *A cooperative system:* NOBEL develops cooperation approaches for all entities involved. This assumes cooperating objects at device level, at the energy brokerage system, at service level etc. Interoperability in heterogeneous environments will need to be tackled, while we focus on the use of the Internet Protocol for communication e.g. at smart meters, etc. The system includes a core platform to assist local network operators in the monitoring and control of energy, and a brokerage system and usage of brokerage agents that act on behalf of a prosumer, to distribute fine-grained knowledge and gather information through the network.
- *End-user applications:* A Neighborhood Oriented Energy Monitoring and Control System, a Brokerage Agent front-end, a Neighborhood Oriented Public Lighting Monitoring and Control System, and Applications are expected to be strongly integrated with the Enterprise Services and provide mash-up customized services to the users.

– *Real-world evaluation:* NOBEL validates and assesses the NOBEL approach in a real world Pilot Site, where customers reside and use it in their daily lives.

## 3 Challenges and Research Directions

Apart from the energy efficiency, the NOBEL project focuses on the technology side as well, including IP communication for low power networks, data capturing and on-device / in-network cooperative processing, enterprise integration and timely user interaction also with the usage of mobile devices.

### 3.1 IP Communication for Low-Power Networks

To support the large number of devices and communication patters in NOBEL, the underlying networking technology must be inherently scalable, interoperable, and have a solid standardization base to support future innovation as the application space grows. IP provides standardized, lightweight, and platform-independent network access embedded networked devices. The use of IP makes devices accessible from anywhere and from anything; general-purpose PC computers, cell phones, PDAs as well as database servers and other automated equipment such as a temperature sensor or a light bulb. NOBEL addresses three key issues in low-power IP networking:

– *Power-saving MAC protocols:* To provide a long lifetime of the power-constrained nodes, power-saving MAC protocols are crucial. Although IP packet transmission on Layer 3 has been standardized, there is a remaining need to develop low-power solutions for Layer 2. Several power-saving MAC protocols exist in the sensor network research community, but they are not developed with the traffic patterns of IP-based communication in mind. We will develop and evaluate low-power MAC protocols for IP-based sensor networks and embedded networked devices.
– *Application Programming Interface (API)*: General-purpose operating systems provide the so-called socket API to application programs, but the socket API was no designed to capture the specific requirements for multi-node communication patterns of sensor networks.
– *Routing-independent packet forwarding*: To support future innovation in routing protocols for cooperating objects, we provide a packet forwarding mechanism that is independent of the routing protocol running on top of the communication system. This allows for empirical evaluation of different routing protocols running in the same system, which is crucial for performance evaluation of future routing protocols for low-power networks.

### 3.2 Data Capturing and Cooperative Processing

The use of Cooperating Objects technologies [4] for the purpose pursued in NOBEL is a novel approach that involves the following challenges:

- The definition of relevant data to the application and its efficient capture within the network.
- The appropriate routing of this information to the critical parts of the system that requires it.
- The filtering of non-relevant information in order to minimize resource usage such as bandwidth and reduce the latency.
- The support of quality of service-type characteristics such as scalability with respect to the number of prosumer devices in the system and the timeliness of information to the appropriate devices.
- The cooperation of devices within the network to enable the emergence of large-scale properties that implement the application.

It is worth mentioning that the devices used for the metering and monitoring of the network are to be small and non-intrusive. Therefore, if there are no components in the network that are interested in the type of information a device is able to provide, the system should be able to recognize this and increase the level of efficiency in the data gathering. The transfer of relevant information to the appropriate devices includes not only the selection of the end-points for the routing of data, but also each intermediate node(s) that might be involved in the forwarding procedure. The use of an asynchronous event-based system using a publish/subscribe paradigm for this purpose seems to be the appropriate choice to disseminate information at the interested parties only. Routing is then selected based on the number and location of the subscribers in the network.

As with any kind of technology that makes use of small devices (such as sensor networks, ubiquitous devices or cooperating objects), the appropriate filtering of information plays a crucial role for the efficiency of the system. Even if data is produced by a device, if no other device in the system is interested in knowing what this information is all about, it does not need to be forwarded within the network. Similarly, if a piece of information is relevant to all of the devices, a flooding-like approach should be used. A publish/subscribe system is able to cope with the flexibility required by the system and hides the complexity of finding the appropriate routes and using the right techniques for data forwarding from the application.

An energy distribution network is very complex and contains many different elements. Depending on the state of the system and whether or not some of the components (nodes in the network) are able to produce and/or consume energy, their role in terms of the forwarding and data processing technology changes. Therefore, a publish/subscribe system that is able to adapt to these changes by the definition of additional subscribers and publishers can help in coping with the high application complexity. The challenge that still remains is the definition of the appropriate structures to cope with the requirements of timeliness and scalability.

### 3.3 Enterprise Integration and Energy Management

The aim is to effectively tackle the challenges of Enterprise Integration and Energy Management. To do this we will make the Enterprise systems and their services at first stage energy-aware, and then move towards optimization based on energy Key Performance Indicators (KPI).

To achieve this we need fine-grained energy monitoring (for the awareness) and subsequently management/control in order to close the loop and allow the system to optimize itself. To achieve the energy optimization, our system must be able to integrate and interact with a number of players. This includes the producers, the consumers as well as various service providers. The core of the approach is in the cooperative energy services that almost in real-time integrate the business and the real world, allowing bidirectional information flow and computation at device, network and enterprise level using the middleware developed within the project. The use of a publish/subscribe paradigm allows for the definition of data channels that can be used for the distribution of data gathered in all layers of the application. These need to be correlated and commonly evaluated in order to lead to energy efficient strategies by taking a holistic view on how energy efficiency can be achieved. This should include also cross-enterprise issues and in cooperation with external entities such as smart electricity grid and the increasing integration of alternative energy resources.

To ease cross-layer cooperation we need to tackle heterogeneity and allow interaction via open technologies. As such open cooperative services that can be used as basic blocks for creating more complex distributed energy-related applications should be designed and realized. Following the "software as a service" paradigm, dynamically scalable and often visualized resources are provided as a service over the Internet, including manifold auxiliary services for accessing, managing and using the infrastructure. As it can be expected, the advanced metering infrastructure (AMI) will pose new challenges to enterprise systems due to the high rate of communication with the metering devices and other interacting entities [3]. Also the way we design and implement enterprise applications will change, as now cooperation capabilities, direct end-to-end interactions with energy as KPI need to be built-in. Finally algorithms taking into consideration locality as well as global system dynamic requirements need to be investigated and applied.

## 4 Real-World Validation

Two real-world validation scenarios are envisioned and will be prototyped i.e. an electricity monitoring and management and a public lighting system management. The goal is to significantly raise energy efficiency.

### 4.1 Electricity Monitoring and Management System

The future energy monitoring and management systems are in close cooperation with the enterprise systems. As it is depicted in Figure 3, data available on enterprise systems is combined with data on the network (e.g. via personalized services), and both of them are mashed-up to create new user applications. NOBEL aims at creating dynamically applications that use the "software as a service" paradigm to create dynamically customized applications at the end user

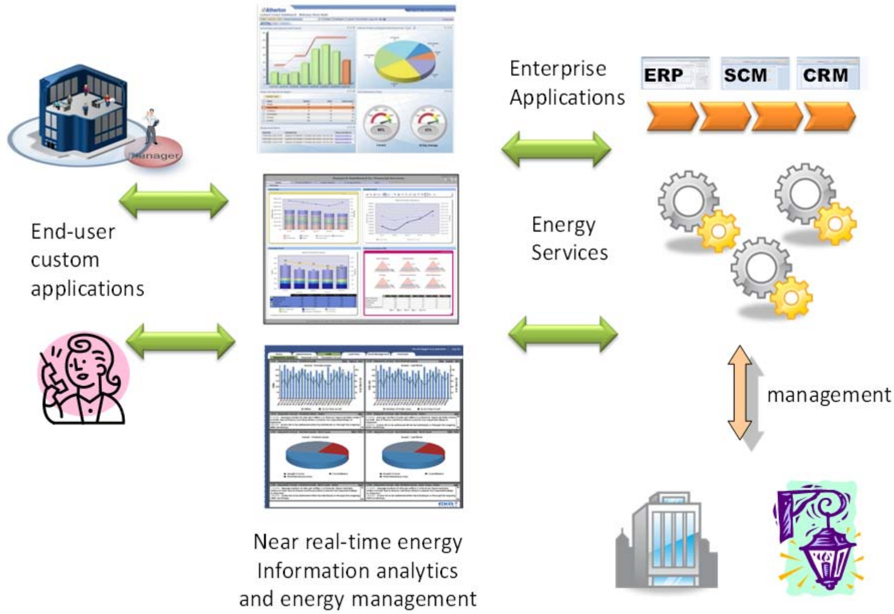


**Fig. 3.** End-user customized applications

side, whether this is a simple user, a standard prosumer or a senior prosumer (as defined in the project context). This is a significant change for the energy domain, as we move away from heavyweight monolithic applications towards much more dynamic, mobile, up-to-date and interactive ones.

To that extent close collaboration is needed. Applications for electricity monitoring and management are expected to be composed of services that are distributed and are brought dynamically together to realize a specific application (in the NOBEL case these will be service mash-ups). The envisioned applications will offer close coupling to existing energy monitoring infrastructure, to the information residing on enterprise systems, and the customized profiles of the users. Data will be mixed, processed and analyzed and near real-time analytics will be available.

The users will have access to their existing energy consumption, analysis of the situations and possible identification of energy wasting. They will be able to have a historical overview as well as a projection of their future energy and costs depending on their current consumption behavior. Further customized services will be available for them, and will be provided by wired and wireless means in order to achieve access to the energy data anywhere, anytime, in any form easily and effectively. Based on their capabilities the users will be able to not only have monitoring information but also manage their personal plans and their infrastructure. By increasing visibility via near real-time assessment of the energy information, providing analytics on it and allowing selective management, NOBEL will provide a new generation of customized energy efficiency services.

A real world trial will be realized in the town of Alginet, which is located 25 Km from Valencia, Spain. Alginet has 15000 inhabitants, the majority of whose lives in homes equipped with smart meters that can make fine-grained measurements. The Electrical Cooperative of Alginet is the local electricity provider with an approx. 6000 customer base where the neighborhood concepts of NOBEL can be tested. Additionally the coverage of the area via WiMax will enable us to test mobile applications.

### 4.2 Public Lighting Control System

Public lighting in urban areas represents a high cost to the municipalities in all Europe. Current modern public lighting control systems are based on the management of points of light which are controlled by a segment controller managed from a control center. We intent to demonstrate how the technologies realized in NOBEL, can provide better monitoring and managing of the electricity, and how better energy efficiency in public sector can be achieved. Therefore NOBEL will extend the capabilities of the control center to realize better visibility and increased performance.

In detail we will work towards providing:

- A higher level of granularity with respect to the control of lamps, thanks to the new developments in data capturing and processing.
- A real time capability to react to different situations implementing different policies (natural light conditions, meteorological conditions, different calendars, lamp conditions, effect of urban traffic on public lighting, etc).
- Real time monitoring of the amount of energy consumed, identifying geographically the different level of consumption in a neighborhood.

The energy efficiency can be improved by means of policies, adapting the light intensity to different situations. For instance, it is proposed to adapt the intensity of light, or even if necessary increase the number of lamps switched on, by taking into account the proximity of vehicles or pedestrians. This increases the life expectancy of lamps and equipment, generating significant economic and energy savings. Moreover, the powerline transmission of data to a GIS-database containing information on every single fixture enables the operator to easily identify lamps that have or soon will burn out therefore realizing better asset management.

## 5 Conclusion

NOBEL presents a new approach that focuses on the small and medium-sized communities, with the goal to better enable them to manage their resources and additionally achieve better energy efficiency. Towards this quest we will investigate and advance state of the art technologies by taking full advantage of the Internet technologies, the capabilities of modern networked embedded systems and the collaboration of different actors to achieve the common goals.

As we have presented there are several challenges that lie ahead, however the benefits for communities will be significant. We aim at validating our prototypes in real-world trials in the city of Alginet in Spain.

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