# Event-driven IPv6 Communication for the Smart Grid Infrastructure

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***Abstract*—There is a common understanding that we need to use energy in smarter and more efficient ways. In order to achieve increased energy efficiency for households there is a need to adjust energy consumption based on the dynamic needs of the people living there, and the available energy and costs at a specific time. Involved energy devices, such as electricity, gas and water meters, need to have a certain amount of "smartness"; however without a common way to integrate them we risk ending up with a multitude of heterogeneous smart devices that need to be manually controlled one by one via device-specific interfaces and protocols.**

**We believe that using IPv6 on every device is an important step towards creating a controllable and interoperable energy infrastructure. When every device can publish data and be directly addressed globally, real time monitoring and control becomes possible and more sophisticated as other parties can easily interact with it over Internet and integrate its functionality. Additionally the user is in control over which data to share, with whom and for what purpose (e.g. with the energy providers for billing), as well as which policy should be used when conditions change.**

**In this demo we show how a Smart Home with an IPv6-equipped electricity smart meter prototype can report meter readings to cloud hosted business services, which collect readings from a number of meters, and can detect deviations from expected usage. In case of unexpected power shortage or surplus, the tariff is accordingly adjusted and the smart meters are informed. In the case of a price increase, it is up to the user to either pay the higher price, or to reduce her consumption (automatically based on their predefined policy). Similarly for a price drop, the user can choose to execute energy-hungry tasks. By allowing a energy gateway to control not only electricity but also other devices in the household infrastructure such as heating, the energy management can be made more efficient.**

## I. Introduction

A key aspect of energy efficiency is its better management which can only be achieved with fine grained monitoring and control As we are shifting from having only a few number of large energy producers towards a distributed energy infrastructure where also a large number of smaller scale producers is attached to, we need a proper information infrastructure to manage the interactions among all actors. Additionally new services for energy management ought to be developed with optimization and control in mind adhering to large scale distributed system.

For any energy retailer there are benefits to be gained if fine grained consumption data can be accessed in real time, such as better detecting consumption patterns and allowing more accurate predictions of future energy consumption. For a retailer in a neighborhood with both consumers and producers there are further benefits in balancing production and consumption locally, to minimize transfer losses [1].

Fig. 1. Meter readings are sent to business services. The data is used for monitoring and control, including sending out tariff updates.

IPv6 allows every device to receive an unique address and be directly addressed. By having an all-IP infrastructure sensor data can be reported to and processed by standard servers, without the need for custom made gateways and proprietary solutions. Thus, IPv6 greatly simplifies operation and integration of smart energy devices in existing IT infrastructure. Using IPv6 is in line with the vision of the Internet of Things where all devices use Internet protocols [2] and provide their functionality as a service that can be integrated by other applications.

Since in the future the devices will be highly heterogeneous and with different capabilities, we use the $\mu$IP stack from the well known Contiki operating system [3], which is optimized for resource constrained devices and compliant with the newest standards for IP-communication. The stack has also been tested for interoperability with the other leading operating system for wireless sensor networks e.g. TinyOS [4].

To prevent unnecessarily network traffic, meters only report data when there is a service interested in receiving this data. The publish/subscribe type of communication allows grid operators to acquire data in an event based way and build more

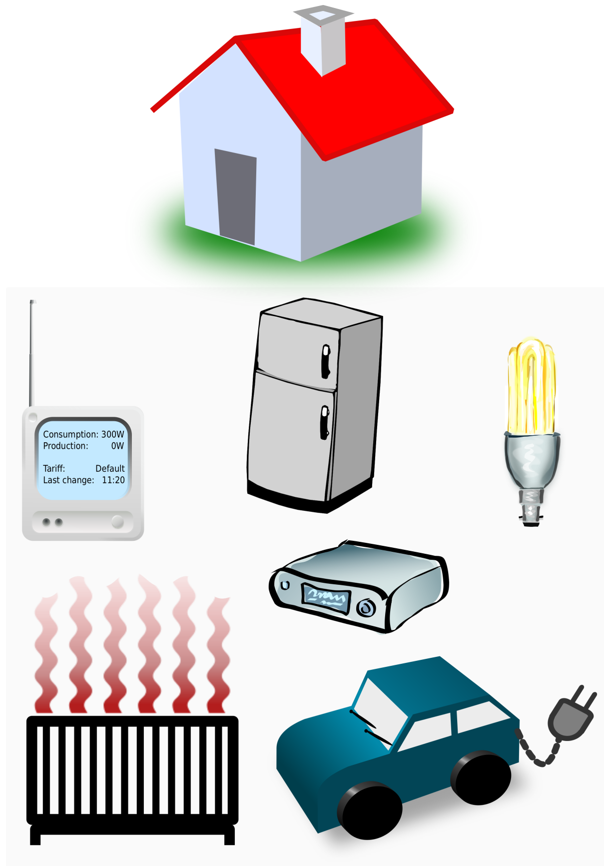


Fig. 2. Devices in the Smart household can report their consumption and be controlled through the respective interfaces.

intelligent approaches e.g. aggregate/process readings from multiple selected meters. For more fine grained control the meters also allow direct communication using the upcoming CoAP [5] standard designed for resource constrained and lossy networks. CoAP is lightweight, while still being easy to integrate with existing Internet services and applications.

## II. Demonstration Description

The demonstration shows how power meter data is forwarded to business services running in the cloud, and how a consumer chooses to adjust her energy consumption based on pricing signals from the provider. A neighborhood with consumers and producers is shown in Figure 1.

The demo setup consists of a household, in which important devices are equipped with sensors for monitoring and control. The heating system is illustrated by a small heater equipped with a small sensor/controller of its own. We demonstrate several networked embedded devices, each having an 802.15.4 radio and a low-power MCU (hence undisturbed access to one of the 802.15.4 radio channels, and a table for the hardware setup is needed).

The household reports the electricity consumption through its smart meter. An energy gateway connects all monitored and/or controllable household devices. The gateway is the information point which will receive pricing signals from the power provider, and where the user defined power policy will be executed, ensuring the consumption is regulated in line with the consumer's wishes. The Smart Home, as shown in Figure 2, contains controllable heating, lights and a charger for an electric car all of which cooperate with the energy gateway and adjust their behavior accordingly.

Depending on the gateway mode of operation – user at home-mode or user away-mode – the response to changed prices will vary. As an outcome the demo shows the resulting energy consumption and the cost of energy. Since the devices collaborate with the energy gateway, this can be located anywhere e.g. embedded in the smart meter, or the communication gateway (router), or even on the network (as a service).

## III. Conclusion and Future Works

The demonstration shows the feasibility of connecting energy devices using IPv6 and an event-driven infrastructure. By real time monitoring and localized control on the neighborhood level, the grid can quickly react to balance power locally, reducing the need for over-provisioning and minimizing losses due to transportation. By letting the end-user retain the final decision on how energy is consumed (stored as policy in the energy gateway), everyone can make their own trade-off between consumption and cost.

In the demo the business services are used to acquire the meter readings and provide the pricing signal back to the households. More complex services, such as creating local energy markets that will provide market-driven signals is under development [1]. Future work also includes utilizing recent results showing the feasibility of using IPSec for resource constrained networks to provide end-to-end security [6].

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