Demo Abstract: Holistic Energy Consumption Monitoring in Buildings with IP-based Wireless Sensor Networks

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Abstract

We present UBI-AMI v2 for holistic real-time monitoring of building energy consumption with two types of wireless sensors. A Mains sensor monitors the aggregate load at the root of the load tree and the individual loads of up to 30 circuit breakers using analog Hall sensors. A Socket sensor monitors the load of the connected individual appliances. The energy consumption is visualized in user interface in Web browser, through a proxy abstracting the wireless sensor network as a RESTful Web service. Data requests to the proxy are injected dynamically into the sensor network as computational tasks. These tasks can then be used as services for other tasks in the system and for the Web.

1 Introduction

The knowledge of the energy consumption can reduce energy usage up to 20% at homes and business premises without compromising any convenience [1]. We present the UBI-AMI v2, that introduces several improvements to traditional energy monitoring including real-time metering, separate measurement of the individual built-in components of the heating and cooling systems compared to an daily estimation, a Web user interface equipped with real-time electricity pricing information, alerts in case of malfunctions or other user configured situations, and curtailed possibility to remotely control appliances connected to the sensor nodes. As result, we have a holistic measurement system capable of monitoring energy consumption in a building and estimating costs, increasing awareness of energy consumption. This version is further enhanced of the system introduced by us [4]. The longitudinal evaluation in the wild revealed shortcomings, e.g. ignorance of the energy consumption of integrated or built-in elements such as heating and sauna. Traditionally, separate measurement systems are used for appliances with power chords and for built-in power branches such as heating or cooling [2]. Consequently, true energy consumption of the built-in elements has been difficult to monitor and gauge. As the impact of a particular energy saving action, e.g. decreasing the temperature of a room by one degree, under varying climate conditions. Visibility to the energy consumption of individual built-in elements gives the user better understanding of the effectiveness of each action.

The UBI-AMI v2 addresses this shortcoming by facilitating the monitoring of the energy consumption of individual built-in elements with analog Hall sensors attached to circuit breakers. Each built-in element can now be monitored separately, even when there are several appliances connected to the same branch as the level of energy used in appliances can be reduced from the energy usage of the branch. Further, the monitoring is coupled with the degree day, a measure for estimating energy costs for the building, giving more reliable information and allowing a more robust control of heating and cooling.

The monitoring is achieved by using continuations as computational tasks in the wireless sensor network (WSN) [3]. Each task, i.e. continuation, is described in a simple data structure containing the computation code, utilized resources and the state of the computation with local variables as the intermediate result [3]. Each continuation defines its own context: what information it uses, what it does, when and where. A continuation traverses in the WSN according to its resource list (here URLs). The computation advances step-by-step in the participating nodes for its part by running the task code. Now, we can dynamically inject any computational tasks into the WSN and distribute computational load [3].

When the location of the continuation is posted to a resource directory, other nodes can lookup the address of the node currently hosting the continuation and request its state. This way the continuation becomes a service in the WSN [3]. Each node is then both client and server simultaneously.

2 System Overview

The system architecture is distributed, contrary to the traditional client/server-based monitoring solutions, eliminating the need for single access point and centralized server. The system (Figure 1) has four logical components: 1) low-power resource-constrained wireless sensor nodes for the monitoring tasks, 2) proxy abstracting the WSN as RESTful Web service, 3) resource directory (RD) as repository for

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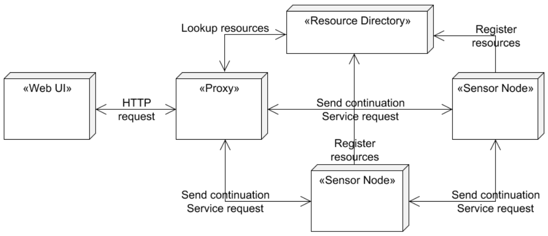

Figure 1. System Architecture in the demo.

the system resources, and 4) Web user interface (UI).

Sensor nodes communicate by CoAP messages with each other, the RD and the proxy, atop 6LoWPAN protocol stack with IEEE 802.15.4 radios on the 868 MHz band. The nodes register their resources, i.e. the data types, into the RD in start-up and when changes occur, allowing dynamic lookup for system resources. The proxy is implemented as a standalone Java library, allowing to run multiple instances in the system, even in the client devices. The Web UI issues HTTP requests to the proxy, i.e. GET to request data and POST to inject tasks or control the connected appliances in sensor nodes, operating also as a HTTP-CoAP proxy.

2.1 Sensors

A Socket sensor (Figure 2) is a plug, that is connected between a wall socket and the appliances to be measured and controlled. It measures energy consumption (Microchip MCP3909) and additionally local illumination and temperature. It also has a relay to disconnect attached appliance from the wall socket (grid) upon command.

A Mains sensor (Figure 2) is connected to the kilowatt-hour meter and/or to the circuit break panel. It calculates the electrical and/or optical pulses corresponding to the aggregate energy consumption. The sensor is also able to measure individual energy flow in up to 30 circuit breakers using analog Hall sensors (Honeywell CSLT6B100), being non-intrusive thanks to capability to measure current without galvanic connection. If clip type sensors are used, there is no need to disconnect electric wires from circuit breakers.

The sensor nodes have ATmega microcontrollers 1284P and 2560 with 8 or 16 Kb RAM. The task code in the CoAP messages is IntelHEX binary and is written to flash memory by an execution environment (EE) software. Then the code is run by the EE, which provides an interface to access local and remote resources. Lastly, the data structure is updated with the computation results and the message sent further.

2.2 User Interface

The user interface (Figure 3) has two views: Total and Graph. The Total view shows the current total energy consumption of connected appliances and built-in elements, estimated energy consumption based on the degree day for the building, estimated current total bill, and changes in comparison to historical consumption metrics. It pops up alert messages when user-defined consumption levels are exceeded. From the Graph view, user can see the current consumption of individual appliance or built-in element, and also issue alerts into the system.

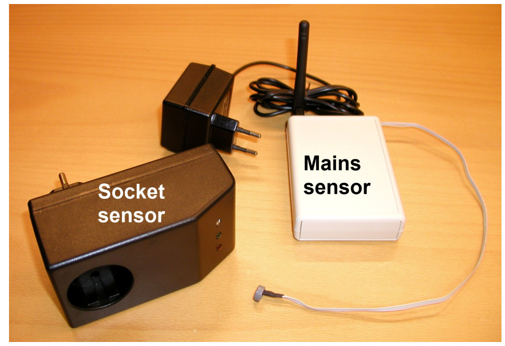

Figure 2. The Socket and Mains sensors.

Figure 3. Web user interface with Total view. Green colour indicates the degree day estimation.

3 Demo System Features

In this demo, we visualize in real-time the energy consumption of connected appliances and built-in elements. In the system services and tasks are described by continuations. One continuation provides the current total energy consumption and individual loads in each nodes. Using this as service, another continuation calculates the estimate of the bill and yet another provides comparison to collected historical data. We utilize external Web services from the WSN, which provide the pricing information and the degree day value. User-defined alerts, as continuations, monitor the energy consumption of an appliance and if meeting a threshold, the appliance is disconnected from the grid.

4 References

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