Demo Abstract: Energy Management as a Service over Fog Computing Platform

Korosh Vatanparvar and Mohammad Abdullah Al Faruque
Department of Electrical Engineering and Computer Science
University of California, Irvine, Irvine, California, USA
{kvatanpa, alfaruqu}@uci.edu

ABSTRACT

Cyber-Physical Energy System (CPES) has been seen as the new paradigm of tight integration of power systems, embedded systems, control, and communication. CPES is capable of improving power grid reliability, efficiency, and performance by managing the supply and demand functionalities of the power systems effectively and intelligently. In this demo, we present an energy management system prototype for home and microgrid levels (both from residential domain), implemented over a fog computing platform. The prototype is capable of supporting interoperability, scalability, ease of deployment, cost effectiveness, open architecture, plug-n-play, and local and remote monitoring in a single package to fulfill the mandates by US Department of Energy (DOE) [1].

1. INTRODUCTION

Recent improvements of technology, cost, and feature size have enabled us to build low-power and high performance embedded computing devices cheaper than before. Hence, the introduction of the advanced controlling devices (actuators) and monitoring devices (sensors) have transformed the traditional, manually controlled power grid into more efficient, smarter, and cyber-integrated power grid. This new paradigm is called Cyber-Physical Energy System (CPES), where the demand side of the power grid, may comprise of multiple distributed generators, energy storage, and loads [2]. Moreover, various sophisticated cyber-physical energy management systems need to be implemented in order to efficiently monitor and manage the loads [3] in a CPES. Energy management system may be implemented for any type of buildings and microgrids[1], e.g. residential, commercial, and industry. In this demo, we mainly focus on the residential microgrids and buildings - homes - to manage their energy consumption.

The platform to implement the energy management system on, requires interactivity, interoperability, flexibility, and scalability [1]. One of the most important properties to consider while designing the platform is the capability of penetrating into the consumer market and affordability for an ordinary consumer. Major requirements, besides the above-mentioned features, for the platform which influence the penetration and affordability are: 1) ease of deployment; 2) open source software; 3) open architecture; 4) plug-n-play capability; 5) customizable services; and 6) local and remote connectivity [1]. These requirements should be met in a single-package and should be cost-effective.

[1]A microgrid is comprised of distributed generators, energy storage, and loads which may connect to the power grid or operate autonomously [4].

ICCPS '15 Apr 14-16, 2015, Seattle, WA, USA
ACM 978-1-4503-3455-6/15/04.
http://dx.doi.org/10.1145/2735960.2735986.

CPES allows connecting intelligent and self-controlled devices in a dynamic and global network platform [2, 5]. It overcomes the gap between the physical world and their representation in information systems. Recently, to provide further features for CPES, such as the computation capability, open source software and hardware, data privacy, low-latency connection, and plug-n-play capability, **fog computing** platform has been introduced. ***Fog computing*** *moves the paradigm of cloud computing further to the edge of network [5]. This platform may provide CPES with the capability of pre-processing the data while meeting the data privacy and low latency requirement.*

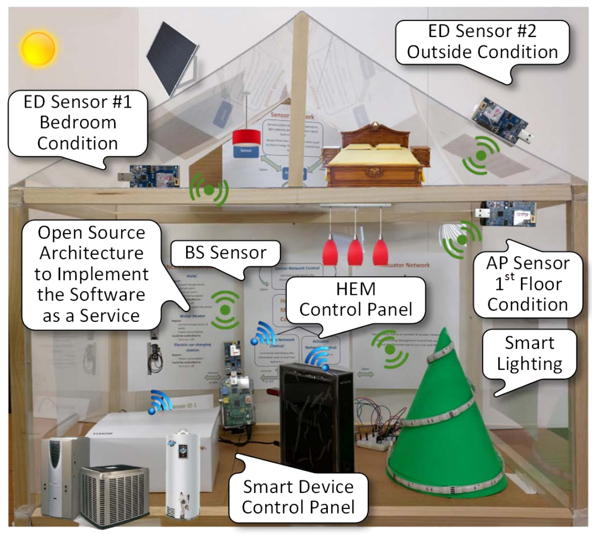

Figure 1: Prototype Demonstrating HEM-as-a-Service over Fog Computing Platform.

2. ENERGY MANAGEMENT PLATFORM

A home energy management (HEM) and a microgrid-level energy management have been implemented over a fog computing platform. These two prototypes, which will be explained further, are adequate examples of using the fog computing for energy management systems. The hardware architecture of the fog computing platform (e.g. HEM or microgrid-level platform) consists of the following devices:

1. **Connecting:** these devices provide the connectivity among the existing and compatible devices. The wires, sockets, and antennas are considered as this category.
2. **Gateway:** various devices may have different connectivity standards and protocols, e.g. ZigBee, Bluetooth, Ethernet, etc. The gateway devices establish a compatible connectivity between multiple devices if required.
3. **Sensor:** the energy management system needs to monitor the environment for timely changes, e.g. weather, light, energy price, etc. The sensors may digitize the analog signal generated by the environment.
4. **Actuator:** the energy management system may decide to configure multiple devices according to environment changes, in order to optimize a variable, e.g. energy

consumption. These configurable devices are considered as actuators which may be locally or remotely controlled.

5. **Computing:** devices that store, process, and analyze the data in the system. They may also implement sophisticated controllers to configure the actuating devices.

Open source and user-configurable NETGEAR routers have been used as computation and connecting devices. These routers feature a distribution of Linux on a MIPS processor, which helps the developers easily program, compile, and run their algorithms. Also, they provide multiple network adapters and interfaces to establish connections between different devices.

TelosB mote modules are compatible with TinyOS which is an open source operating system. They also feature multiple sensors, e.g. humidity, temperature, and lighting. Having the open source OS, multiple sensors, and on-board connections, they are used as sensor and actuator devices in the platform. TelosB motes use ZigBee standard for communication. However, the routers have USB, Wi-Fi, and Ethernet connections. Also, there might be other devices with incompatible connections. Hence, gateway devices have to be used in order to solve this problem. A Raspberry Pi has been used to establish a relay connection between Ethernet and ZigBee network. This would be eliminated if the router had the right driver for ZigBee adapter.

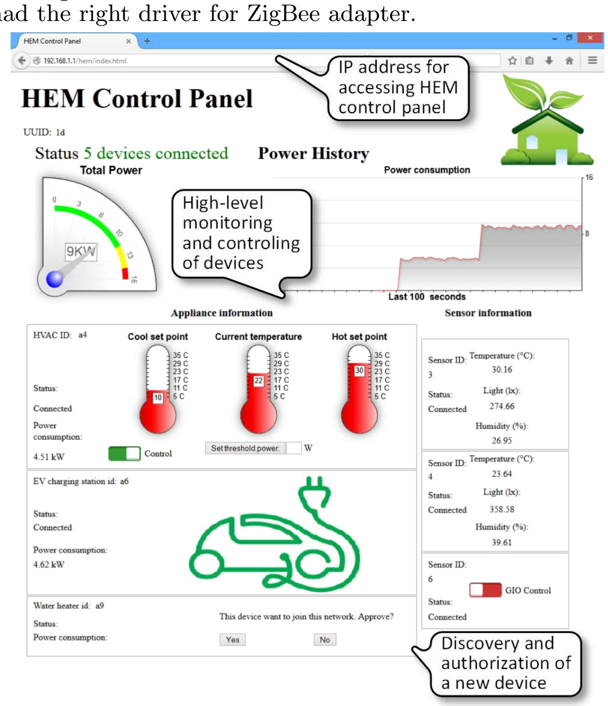

Figure 2: HEM Control Panel for High-Level Monitoring and Controlling Smart Devices in Home.

3. PROTOTYPE DEMONSTRATION

To test the energy management platform, a HEM and a microgrid-level prototypes have been implemented to demonstrate different operating domains of the platform.

HEM Prototype: the HEM platform is implemented for one home as shown in Fig. 1. In the home, multiple smart devices such as: HVAC, water heater, EV charger, and smart lighting are implemented. The home is being monitored by a network of four sensor devices (TelosB mote modules). They sample the temperature, humidity, and lighting inside and outside of the home. Each device is monitored and controlled by the HEM control panel (the main computing and controlling device in home prototype). The HEM control panel views the current devices connected to the platform (see Fig. 2). Through this, the user may discover and authorize new devices, turn on/off each device individually, monitor the device power consumption, monitor temperature and humidity measured by the sensors, and control the lighting. Also, the devices have their own control panels (see Fig. 3 for HVAC control panel) to monitor their status and set their configurations. In this prototype, all the devices are software modeled, however, in the real-world implementation, the control panels of the devices will be provided by their vendors.

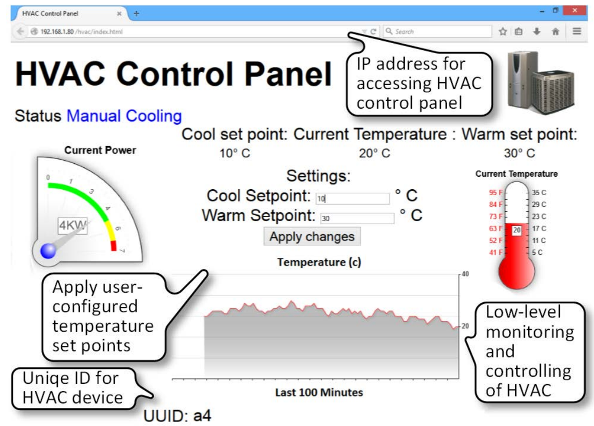

Figure 3: HVAC Control Panel as an Example for Low-Level Device Monitoring and Controlling.

Microgrid-Level Prototype: the energy management platform in the microgrid-level comprises three homes connected to a transformer. A control panel is implemented in the transformer-level to monitor and manage the power consumption of each home. The transformer-level control panel monitors the load of each home and the current condition of the transformer. Based on this information and the controller, the control panel may decide to send commands to the HEM for each home, in order to reduce their power consumption by a specific value. The transformer control panel is implemented in one router and other homes with their emulated smart devices are implemented in other routers.

More web-based user interfaces have been implemented, however due to the limited space, just the main HEM control panel and HVAC control panel have been shown in this demo abstract.

4. REFERENCES

[1] U.S. Department of Energy Energy Efficiency and Renewable Energy Golden Service Center. Financial Assistant Funding Oppurtunity Announcement. 28 March 2013. "DE-FOA-0000822: "Turn Key" Open Source Software Solutions for Energy Management of Small to Medium Sized Buildings"., 2014.

[2] Mohammad Abdullah Al Faruque and Fereidoun Ahourai. A Model-Based Design of Cyber-Physical Energy Systems. *19th Asia and South Pacific Design Automation Conference (ASP-DAC)*, pages 97–104, 2014.

[3] Korosh Vatanparvar, Quan Chau, and Mohammad Abdullah Al Faruque. Home Energy Management as a Service over Networking Platforms. *IEEE PES Conference on Innovative Smart Grid Technologies (ISGT)*, 2015.

[4] Korosh Vatanparvar and Mohammad Abdullah Al Faruque. Design Space Exploration for the Profitability of a Rule-Based Aggregator Business Model Within a Residential Microgrid. *IEEE Transactions on Smart Grid*, 2014.

[5] Flavio Bonomi, Rodolfo Milito, Jiang Zhu, and Sateesh Addepalli. Fog Computing and Its Role in the Internet of Things. *Proceedings of the 1st Mobile Cloud Computing Workshop*, pages 13–16, 2012.