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Role of Internet of Things in the Smart Grid Technology

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Abstract

The Internet of Things (IoT) has recently emerged as enabling technology for the smart gird, smart health, smart transportation, and smart environment as well as for smart cities. The major smart grid devices are smart home appliances, distributed renewable energy resources and power substations. The seven domains existing smart grid conceptual model was developed without the IoT concept in mind. As the smart grid evolved, many attempts started to introduce the IoT as enabling technology to the grid. Each device in the grid can be considered as an object. Utilizing the concept of IoT, each device can have a unique IP address that can upload its status and download control commands via the Internet. This paper proposes a conceptual model for the smart grid within the Internet of Things context. The proposed model is based on IPV6 as the backbone of the smart grid communications layer.

Keywords

Smart Grid, Smart Homes, Internet of Things, 6 Low PAN, Conceptual Model

1. Introduction

The smart gird is the integration of the 20th century traditional electrical power grid with the most recent 21st telecommunication and information technologies. Such integration enables efficient resource utilization to optimize energy consumption, install and manage distributed energy sources, as well as to exchange the generated power. In other words, the power flow and communications will be in two-ways [1]-[3]. Many utility companies around the globe started to install renewable energy sources such as solar and wind energy nearby the consumption sites. Also, residential home owners started to install smart home appliances and renewable energy resources in their premises to generate and consume electrical power efficiently [4] [5].

As the smart grid concepts emerged as a fast growing research and development topic in the last few years, the National Institute of Standards and Technology (NIST) developed a conceptual model for the smart grid to set the stage for a better understanding to the smart grid technology. The NIST conceptual model consists of seven domains [6], namely: bulk generations, transmissions, distributions, consumers, markets, operations and service providers. Smart grid users communicate in two-way directions by utilizing several wireless and wired communication protocols such as Zigbee, WiFi, Homeplug, power line carrier, GPRS, WiMax, LET, Lease line,

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and Fibers [7] [8]. Several software packages were updated and many are being developed to accommodate the new grid operation, maintenance and management such as, distribution management system (DMS), geographic information systems (GIS), outage management systems (OMS), customer information systems (CIS), and supervisory control and data acquisition system (SCADA).

As a result of the smart grid evolution, some recent enabling technologies have emerged to reduce the number of communication protocols and handle big amounts of data. The Internet of Things (IoT) is one the most recent enabler for the smart grid.

This paper proposes a conceptual model for the smart grid within the IoT context.

The rest of the paper is organized as follows: Section 2 explores the smart grid existing communication protocols, Section 3 introduces the proposed conceptual model for the smart grid within the IoT context and Section 4 concludes the paper major contribution.

2. Smart Grid Communication Protocols

Smart grid communications are based on wireless and wired networks technologies. Regardless of the technology, these networks can be classified based on their functionality within the smart grid. These classifications, as reported in the literature, are: home area network, neighborhood area network, access network, backhaul network, core and external networks [7]. These networks connect many smart grid objects suchas home appliances, smart meters, switches, reclosers, capacitors bank, integrated electronic devices (IEDs), transformer, relays, actuators, access points, concentrators, routers, computers, printers, scanners, cameras, field testing devices, and other devices. All these appliances and devices are geographically distributed throughout the grid, starting from residential units to substations and up to utility data and command centers.

As mentioned in the introduction, each device can access and exchange data via different communication protocols. **Figure 1** shows the smart grid communications protocols layers [7] [8]. The bandwidth and latency requirements for the smart grid appliances and devices vary from few msecs to several minutes and from few kbps to few hundreds kbps as shown in **Table 1** [9].

3. IoT Smart Grid Conceptual Model

As mentioned in the previous sections, smart homes have several appliances and some form of renewable energy resources. These appliances and resources can be considered as IoT technologies. Each can upload and download data and commands from utilities and home owners. In addition, the grid at large has many devices that can be considered as IoT objects such as reclosers, switches, capacitor banks, transformers, IEDs, smart sensors, and actuators in the substations. In general, smart grids for large cities or countries may have millions of home appliances and thousands of grid devices.

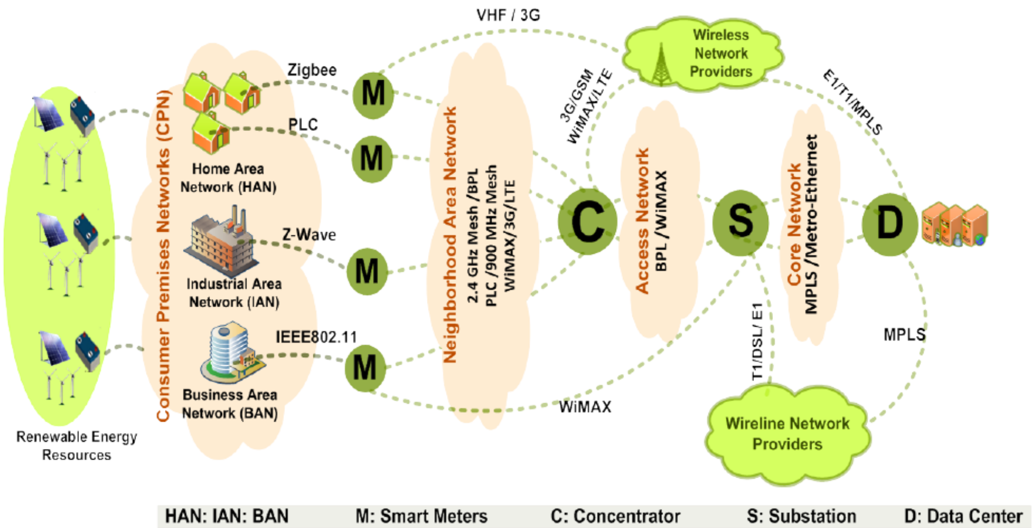

Figure 1. Smart grid communications protocols [7] [8].

Table 1. Smart gird applications bandwidth and latency requirements [9].

Smart Grid Application	Bandwidth	Latency
Substation Automation	9.6 -56 kbps	15-200 ms
WASA	600 - 1500 kbps	15-200 ms
Outage Management	56 kbps	2000 ms
Distribution Automation	9.6 -100 kbps	100 ms -2 sec
Distributed Energy Resources	9.6 -56 kbps	100 ms -2 sec
Smart Meter Reading	10-100 kbps/meter 500 kbps/concentrator	2000 ms
Demand Response	14 - 100 kbps	500 ms-min
Demand Side Management	14 - 100 kbps	500 ms-min
Assets Management	56 kbps	2000 ms

This research proposes that each one of the appliances and devices can have a unique IP address. For example, a dishwasher has a unique IP address a transformer's IP address. This requires the smart grid to have a large number of IP addresses. This is not an issue as the IPV4 is extending from 32-bits to 128-bits address size IP addresses. The IPV4 can address up to 2^{32} devices (4-billionunique addresses). Moreover, IPV6 can address up to 2^{128} (Trillions of unique addresses) [10] [11].

One outcome of such addressing schema is the 6LowPANcommunication protocol. It embarks on top of IPV6 and is designed to be used over the IEEE 802.15.4 standard [10] [11]. The 6LowPAN frame sized is limited to 127 bytes including a payload of 21 bytes for TCP and 33 bytes for UDP [10] [11]. With some techniques, the payload may increase to 65 - 75 bytes. This is adequate for the smart grid appliances and devices monitoring and controlling applications. This protocol is the backbone of the IoT communication media.

To model the smart grid within the IoT context, smart home appliances, renewable energy resources, substation devices and workforce tools will be assigned IPV6 address as follows:

1. Smart home appliances:

Recent smart homes are equipped with smart appliances and each appliance is considered as a thing (object). These things can be an air-conditioner, water-heater, dishwasher, refrigerator, smart energy/gas/water meters, in-home-display, automated lights, solar energy cell, wind mill, electrical rechargeable vehicle, and storage battery [9]-[11]. In the proposed model a unique IP address is assigned to each appliance and device. Each appliance or device can be accessed through the internet by an authorized personnel such as a utility's operator or homeowner. The appliance status can be transmitted (uploaded) or control command to be received (downloaded). The exchange data and control commands utilize the payload portion of the 6LowPAN frame as shown in **Figure 2**.

2. Substations devices:

The power substation has many devices (things) such as transformers, breakers, switches, reclosers, meters, relays, IEDs, capacitor banks, voltage regulators, cameras, and several other things. Similarly to smart homes, each device (thing) in the substation is considered as an object and is assigned a unique IP address. Each object (thing) can transmit its status and receive control commands from the utility authorized operator via the Internet. The payload is few bytes and can be accommodated using the 6LowPAN protocol as shown in **Figure 3**.

3. Distributed renewable energy resources:

The distributed renewable energy resources are one of the major smart grid enablers that can be installed around the residential neighborhoods, distributed transformers and substations. It supplements power sources that can be installed quickly to be used during the peak hours, as well as on other times of the day when is needed. Each one of these source can supply power to operate, monitor and control. An IP address can be assigned to each appliance and device. The payload size and other related 6LowPAN frames are shown in **Figure 2** [11].

4. Mobile workforce tools and devices:

To operate the grid efficiently, a mobile workforce should be on the move 24 hours a day, 7 days a week to fix issues related to residential power outages, feeders, transformers, meters, power lines, and other related issues. The workforce operators are equipped with ragged laptop, smart meters, mobile phone, and cameras. Each

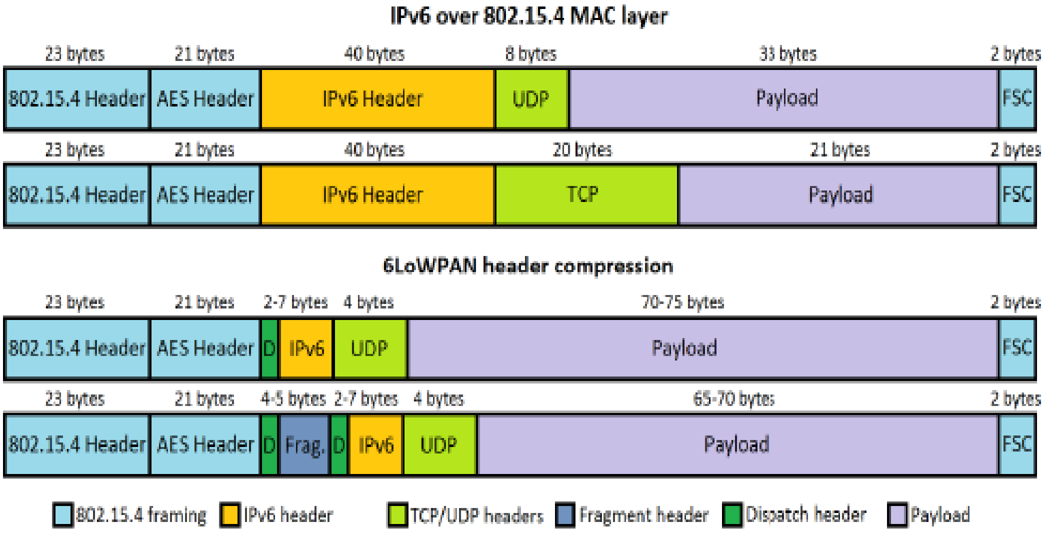

Figure 2. 6LowPAN frame structure for smart grid applications [11].

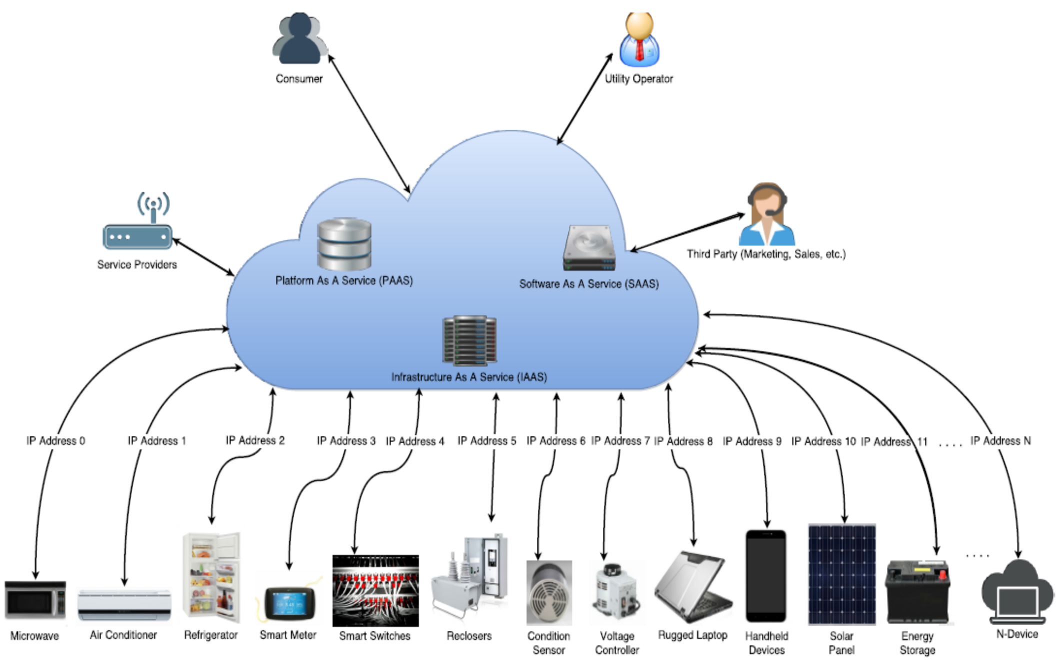

Figure 3. 6LowPAN frame structure for smart grid applications [11].

of these devices is assigned an IP address and can be accessed as in the above mentioned devices and appliances in Sections 1 - 3.

5. Utility data and control center infrastructure:

This center has many applications and database services such as, distribution management system (DMS), geographic information systems (GIS), outage management systems (OMS), customer information systems (CIS), and supervisory control and data acquisition system (SCADA). Each service has its own IP address.

6. Echo systems:

The echo systems could be external power server providers, marketing and third parties power providers. Each of which should have point of access through an IP address.

Figure 3 depicts the above mentioned proposed conceptual model for the smart grid within the Internet of Things contexts. It mimics and integrates the about appliances and devices in model that is scalable. The proposed conceptual model introduces other challenges in security and handling big data that are beyond the scope of this paper. It is worth mentioning that cloud computing is a paradigm that enables a solution to the smart grid environment requirements related to computational power, storage, and high availability of resources.

4. Conclusion

This paper presents a conceptual model for the smart grid within the IoT concept. Appliances and devices are considered objects. Each object is assigned an IP address based on the 6LowPAN communication protocol. The major contribution of this work is that one communication protocol is utilized rather than many other protocols such as Zigbee, WiFi, Bluetooth, WiMax, LTE, PLC and lease lines. This is a conceptual model and it is a work in progress. The authors are in the process of implementing this model in smart grid applications in residential area.

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