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Power Transmission and Distribution Monitoring using Internet of Things (IoT) for Smart Grid

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Power Transmission and Distribution Monitoring using Internet of Things (IoT) for Smart Grid

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Abstract. In the last decade, much of the attention is made towards introducing the smart systems and appliances to meet the requirement of the century and make life comfortable. During the same period, electric power sector also made the necessary innovation to compensate the demand of today's electric supply and to make use of electric resources effectively by introducing "Smart-Grid". The smart grid is a part of transformation and reformation in the power industry sectors. The smart grid is a future modern power system that utilizes internet of thing to monitor, control and create various intelligent communications in the electrical system. In this paper, the author first presents the fundamental architecture of Internet of Things (IoT). They then outline the key technologies of IoT for Smart Grid. Finally, the ideas of applied communication and framework of transmission and distribution monitoring based IoT for Smart Grid is discussed. The deployment of IoT technologies in Power System infrastructures would accelerate the smart grid development and enhance the electricity delivery services becoming more robust, attractive, responsive and communicative.

1. Introduction

Electric power transmission and distribution is an integral part of electric power system. It mainly focuses on delivering the electric power to the end user. Most of them on a radial topology with generation located in a remote area far from the end user. The transmission and distribution system mostly fails to provide real-time data monitoring to the service provider, operator and end user. Smart grid system allows the utilities to control the electric usage. It is the intelligent process by which supplier can increase the overall efficiency, stability and make the electric power transmission and distribution in more appropriate way. In recent years, researchers are making efforts to work in order to make electrical power system more intelligent by means of power transmission and distribution monitoring using the Internet of Things (IoT) for the smart grid. IoT is a communication network with the objective for connecting, exchanging and communicating all kind of sensing information devices with the internet which use radio frequency identification (RFID), global positioning system (GPS), infrared sensors and laser scanner through secure gateway protocol. By using IoT one can achieve intelligent monitoring, managing, tracking, positioning, identification and tracking some particular system [1].

Smart grid is a new technology paradigm for electricity supply to answer the afore-mentioned challenges. The term Smart Grid is widely used with different meanings and diverse definitions. Basically, the definition of a smart grid is the integration of information technology (IT), IoT, intelligent devices and advanced control method with the existing power system networks to enable power generation, transmission and distribution making it more robust, attractive, responsive and communicative. The main advantages of smart grid implementation in terms of utility benefits include lower maintenance and operational cost; increased large-scale renewable energy utilization; reduced outage and perturbation; minimal power loss; enabled energy management system; and real-time power flow monitoring. Correspondingly, the advantages of smart grid implementation in terms of customer benefit include enabled electricity consumption monitoring and customer energy management systems.

One of the key successes of the smart grid is all-in-one integration and communication between power system infrastructures as hardware and information sensing, processing, analyzing and controlling it as intelligent systems [2]. To integrate these systems needs an emerging information one processing and data acquisition method, which is known as Internet of Things (IoT) technology. IoT is the right response to address the all-in-one integration and communication in the smart grid. Nowadays, most of the current studies in Indonesia only emphasize the broad theoretical concept of a smart grid, and there are very few detailed studies on power transmission and distribution monitoring system using IoT. This paper zooms in the technical aspect of IoT for transmission and distribution monitoring that could be implemented in Indonesia. Implementing IoT in the current existing power grid is an important approach to speed up the smart grid development.

In this paper, Section 2 describes the fundamental architecture of IoT technology. The key technology of IoT for Smart grid is discussed in Section 3. The ideas of applied communication and framework of transmission and distribution monitoring based on IoT in smart grid is proposed in Section 4. Finally, Section 5 concludes the paper.

2. Internet of Things (IoT) architecture in smart grid

In recent years, IoT gaining significant interest from researchers due to its potential for information processing and data exchange in various aspects of our everyday life. In order to form complete smart grid system, it needs various IoT elements as shown in figure 1. The IoT system architecture consists of four layers, including the application layer, cloud management layer, network layer, and device layer as described in Figure 1 [3].

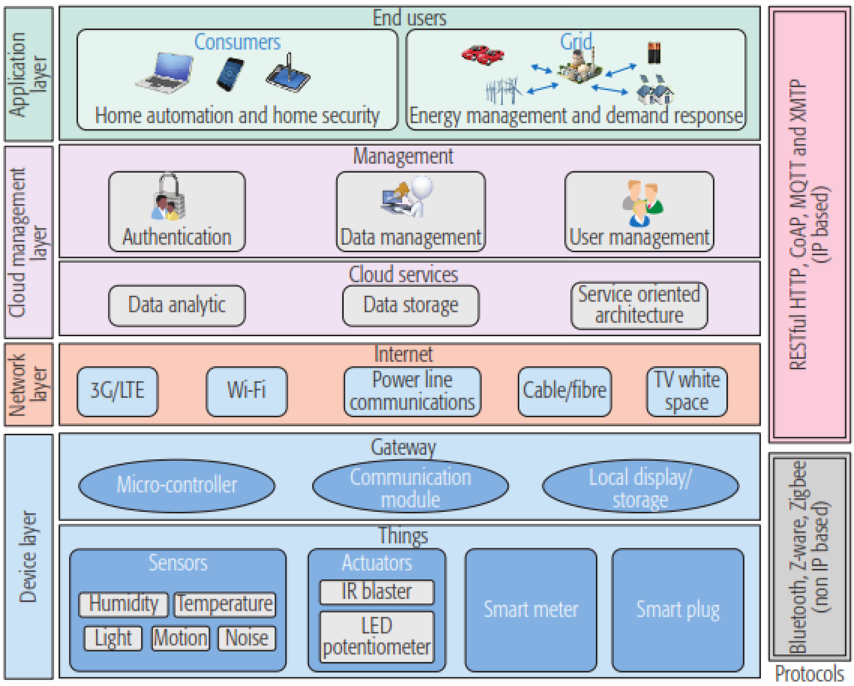

Figure 1. The system architecture of IoT [3].

The top layer is the "application layer", which is responsible for collecting, processing and calculating information from end users. The application layer provides services to consumers through broad of intelligent application infrastructures such as real-time energy management, demand response management, visual monitoring platform and other basic services solution. The application layer also enables the end user to interact with smart grid through the user interface and responds to the information provided by the application devices and software features.

The second layer is "cloud management layer". The cloud service layer is cloud storage in which digital data is managed, maintained, processed and backed-up remotely. This cloud layer is available and accessible for the user to retrieve the data over internet services anytime. On the other hand, the management layer is an application where the digital database is managed. It enables users to create, control and manage their authentication and account. The key point of the cloud management layer is data storage, data management, data processing and computing.

The third layer is "network layer". The network layer integrates all kinds of devices between the application layer and device layer within the smart grid. The network layer consists of communication networks such as the Internet, fiber optic cable, power line communication, wireless broadband and 3G/4G mobile communication network.

The fourth layer is "device layer" which contains things sub-layer and gateway sub-layer. The things layer is responsible for collecting raw information which is acquired from sensing equipment, smart meter, smart plug-in devices and actuators. Meanwhile, the gateway sub-layer connects all the things layer devices and mediates multiple accesses to the things layer through a microcontroller, communication module and local storage. The main tasks of device layer are gathering, identifying, processing and analyzing all necessary information data using a variety of smart equipment and transmitting the information to the cloud management layer.

3. Key technologies of IoT for smart grid

In order to utilize IoT for Smart grid, there are several key technologies which must be used in transmission and distribution monitoring system. It can be described as follows:

3.1. Smart Sensor Technology (SST)

The smart sensor can be considered as one of the most important devices of IoT for the smart grid. Smart sensor is a device that informs the control system about certain parameters and what is actually occurring in the physical object that is monitored. Smart Sensor provides raw data for information processing, analyzing and feedback. Currently, several numbers of advanced sensors technology have been applied in various fields. The major objectives are to provide a technical solution, achieve a high level of precision, enhance system quality and reliability [4].

In transmission and distribution monitoring system, smart sensors can be used at multiple places and spread over the grids such as on the transmission tower, transmission and distribution lines, distribution transformer and sub-stations. They are two types of smart sensors that can be utilized. The first type is used to measure weather condition around the assets such as wind direction sensors, temperature sensors, wind speed sensors, humidity sensors and rain sensors [5]. These sensors are responsible for natural disaster mitigation and prevention that is not available on the current grid. The other sensor type is used for asset and power quality monitoring such as GPS, strain sensors, accelerometer sensor for vibration and line monitoring, conductor temperature sensor and magnetic field sensor [5]. These sensors are mainly responsible for monitoring states of the towers, lines, and sub-stations. For power quality monitoring the sensors including voltage sensor, a current sensor, temperature and fault sensor. By installing these sensors in the distribution line, the quality of distribution line can be monitored in real time basis. In addition, the sensor also can be used to monitor or identify particular information in substation transformers such as temperature, primary voltage, and secondary voltage.

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3.2. Information and Communication Technology (ICT)

To enable the IoT on smart grid, information and communication technologies are required in order to create end-to-end coordination and perform bi-directional communication for all IoT layer elements. According to data transmission coverage area, ICT can be classified into two types: short-range communication and wide range communication technologies [6]. The short range ICTs including Bluetooth, Ultra Wide Band (UWB) and Zigbee. Zigbee is the latest wireless communication technology based on IEEE 802.15.4 standard and was developed for transmission line monitoring [5]. The wide range of ICTs includes General Packet Radio Service (GPRS), IP based Internet/Wireless Sensor Network, 2G/3G/4G mobile communication network, satellite communication network and Fiber Optic Cable. In the smart grid system, ICT is important and essential to assist wireless sensor network in delivering and forwarding data.

4. System design

In designing the transmission and distribution based IoT one can consider using Wireless Sensor Network (WSN) and General Packet Radio Services (GPRS). A WSN is a wireless network formed by large numbers of sensor nodes where each node equipped with sensors to monitor physical conditions. GPRS is a GSM-based wireless communication packet network that provides wide-range IP protocol connection from point to point node. GPRS is a high-speed data processing, for which allows multiple packet data transmission, extensive signal coverage, fast installation feature and low maintenance cost [7]. GPRS technology seems out of date if compared to the 3G/4G technologies. However it's still reliable and good alternative for data processing and communication. Moreover, several transmission and distribution networks in Indonesia are located in a remote area where the 3G/4G network is not available.

Figure 2 illustrates the typical system architecture of IoT for the power transmission and distribution monitoring system. On the left side, one can deploy sensors node where physical events are measured. By using single-hop or multi-hop, the data measured by individual sensors are collected and aggregated which subsequently is transmitted through GPRS network to the database or server for further analysis, making decisions and taking appropriate actions. The server part of cloud management layer in which all the data is stored and it is a place for data retrieval.

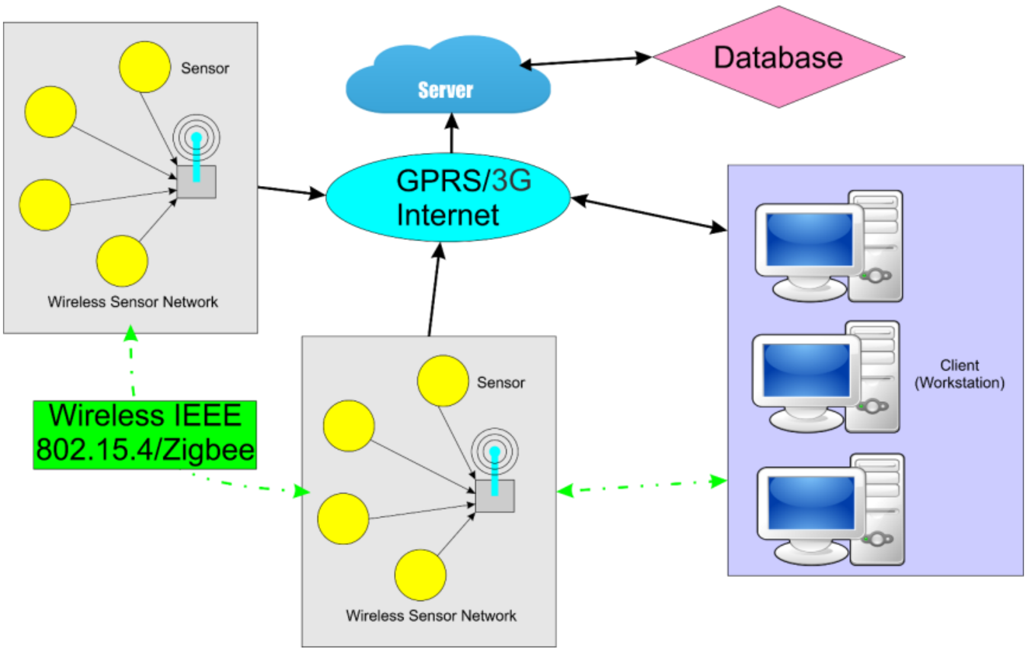

Figure 2. IoT system architecture.

To transmit data from the sensors, the system uses a combination of GPRS technology and Zigbee module. In this framework, one can adopt a two-layer wireless network to give more freedom and flexibility. The first level uses IEEE 802.15.4 or Zigbee wireless which is low cost, low energy consumption and has a communication range between 100 up to 1000 meters in each node [8]. With regard to Zigbee networking capability, mesh topology is proposed in this system. The main benefit of the mesh topology is that every single node is able to communicate with any other node directly within the coverage area range. Furthermore, it increases network reliability and sustains wireless connection if one of the nodes has a fail, loss signal or disabled. The second level uses GPRS module to assist the network in sending or forwarding data. The GPRS technology can improve network performance for real-time data as well as it is more efficient and robust [5]. GPRS module also supports TCP or IP protocol that enables to send data directly to the server using particular node's address. By using the two-layer wireless sensor networks, collecting and forwarding data to server or cloud management layer become more reliable.

4.1. Transmission hardware design

Figure 3 depicts deployment of the equipment in the transmission system based on IoT. It consists of four parts, namely wireless sensor network, data transmitter, the server (cloud management) and workstation. The WSN is capable of sensing the physical world in the transmission line and towers such as temperature, humidity, conductor temperature, tension sensor, wind velocity and leakage current etc. Sensors collect sensing data and deliver them through data transmitter IEEE 802.15.4 / Zigbee module between node to node or node to node server. Then the merged data is transmitted to GPRS to achieve long-distance and high-speed information transmission between WSN and server. Through GPRS communication module the server collects, processes, analyzes and stores all sensing data. The cloud management is connected to the internet and has a specified IP address to receive and forward information data to the workstation. The workstation is a real-time monitoring center that monitors transmission parameter obtained from the WSN. It is connected with the internet enables access from a remote area by the operating personnel.

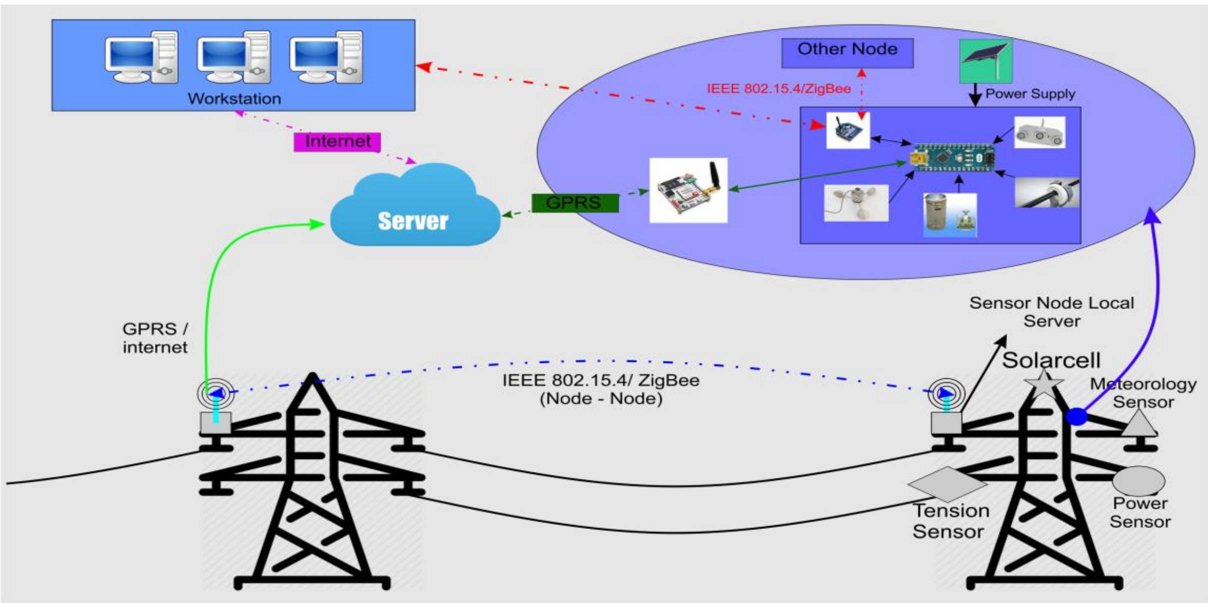

Figure 3. Transmission system based IoT.

4.2. Distribution hardware design

Figure 4 depicts the deployment schematic of the equipment in the distribution system based IoT. The WSN device, network model, communication topology and data processing are similar to the

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transmission system. However, monitoring status of sub-station is of the main concern in the distribution system. Therefore, sub-station should be well equipped with a smart sensor and smart meter, through which important parameter such as current and voltage profile, transformer temperature, oil level, load profile, fault and outage can be monitored. Monitoring on transmission and distribution system based IoT is a powerful tool to increase system reliability, realizes early warning and real-time monitoring through the cloud information management. The status of power transmission and distribution system can be displayed visually on PC, laptop and smartphone.

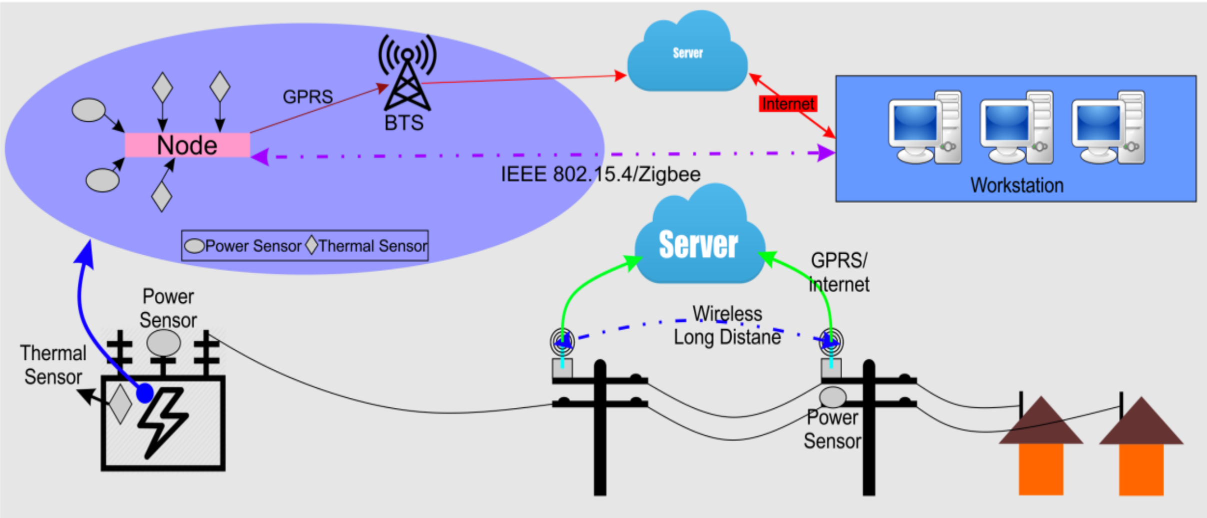
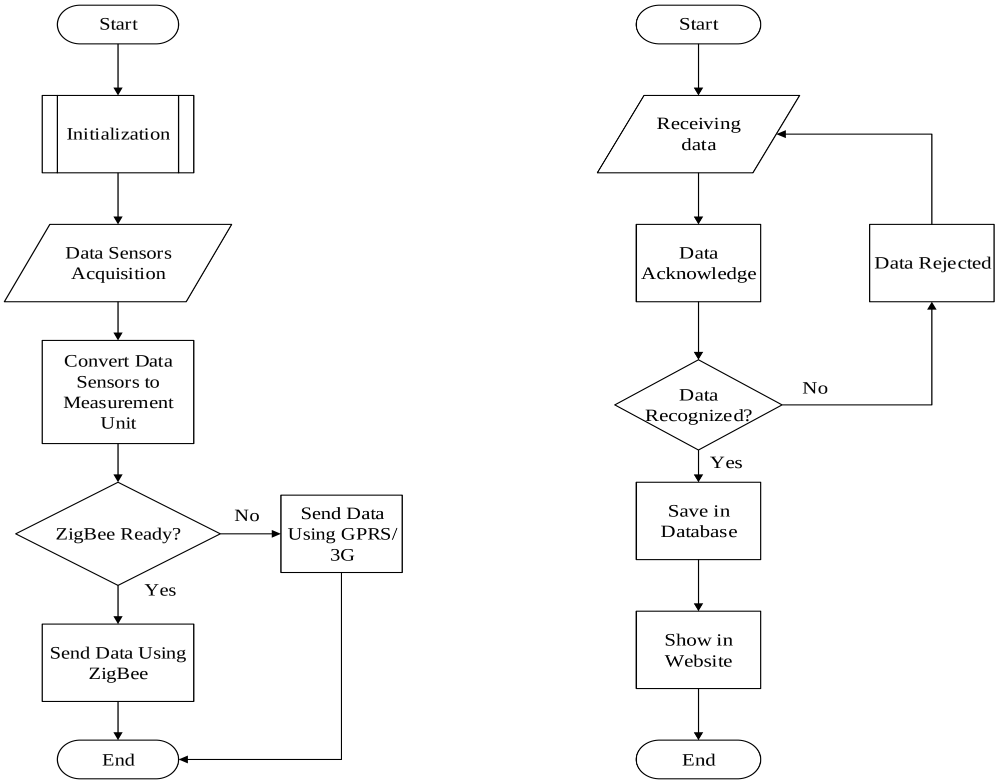


Figure 4. Distribution system based IoT.

4.3. *Software design*

In general, the software of this system is composed of WSN software and IoT software. Both of them are customized software developed and installed in the sensor nodes, coordinator nodes, embedded operating system, applications and server. Figure 5 shows flowcharts of the software.



(a) (b)

Figure 5. (a) Flowchart of WSN, (b) Flowchart of IoT.

The WSN software is mainly responsible for system initialization, sensors data acquisition, and data processing from analog to digital. Then the data are sent to the server through Zigbee network or GPRS. On the other hand, the IoT software is management software that connected to the internet and has a particular IP address. This software is responsible for data verification, data reception, data processing and data storage. All of these data are stored in the database and accessible through a web server.

5. Conclusions

This paper introduces fundamental Internet of Things architecture for power transmission and distribution monitoring system. The system and its hardware design are analyzed and discussed. In designing WSN based IoT one must consider the sensor requirement as well as system architecture suitable for specific local power transmission and distribution system. Therefore for archipelagos and developing countries like Indonesia, a combination of wireless transmission with Zigbee and GPRS is suggested to meet the basic requirement in terms of communication data, real-time and long distance monitoring system. Through IoT technology, the power transmission and distribution parameters can be visually displayed on PC and even smartphone. In future work, the authors will focus on developing the design to experiment devices for power distribution system, which could be beneficial to Indonesia.

Acknowledgements

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