The concept of the internet of things framework for remote monitoring of solar home system

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Abstract. The application of a solar home system in remote areas is needed to be monitored by real time. The Internet of Things (IoT) system is capable of performing data management for monitoring and evaluating the solar home system performance in specific locations. The data are then collected and transmitted to a system monitoring through the internet which then can be stored in cloud for further analysis. The purpose of this paper is to develop the concept of IoT architecture by measuring the parameter of photovoltaic panels for the selected remote area.

1. Introduction

The characteristics of Indonesia is how it has a large population and geographical conditions which consist of various islands from large to small. These islands require special handling in terms of facing energy problems. Dependence on the supply of fossil fuels from island to island resulting in high transportation costs and greenhouse gases needs to be minimized. For this reason, the use of solar energy as an alternative energy source to support green energy programs on the small outermost islands need to be discussed and reviewed.

Solar energy which classifies as renewable energy and is available locally for island communities still needs to be developed. The eastern region of Indonesia, especially the outermost islands that have become the front borders require special attention in the case of energy problems. Dependence on the supply of fossil fuels from island to island resulting in high transportation costs and greenhouse gases needs to be minimized. For this reason, the utilization of renewable energy as an alternative energy source for energy generation needs to be studied [1].

In the previous works, Rumbayan et al. mapping the solar energy potential in Indonesia using artificial neural network and geographical information system [2]. These maps can provide useful information nationally as well as regionally for the local renewable energy planning on the islands of Indonesia.

The utilization of solar energy for the remote communities through solar home system application needs to be developed by monitoring the system using the IoT technology. This paper aims to develop the concept of IoT framework for remote monitoring of Solar Home System (SHS).

This paper is structured as follows. Section 2 provides a literature review on the concept of the IoT frameworks. Section 3 presents the proposed framework for remote monitoring of a solar system and finally Section 4 draws the conclusion.

2. Literature review

The Large-scale growth of IoT devices encourages the development of systems to monitor, control and analyse data generated from things. Some work shows an overview of the framework for monitoring IoT devices. Sadhukhan describes how the IoT-based frameworks are used to develop Smart City services. In general, the framework consists of the main components in the form of IoT network, Client Application and Control Server that provides data storage services [3]. IoT network is a collaboration between IoT nodes in the form of sensor nodes and actuators. Every IoT network has a Gateway as the main communication facility between end-devices.

Implementation of solar power plants in homes, is then called a solar home. Solar home is a part of smart city development in the context of using Green Energy. The development of solar home needs to be accompanied by the ability to monitor and control remotely. Soham et al. [4] and Wei et al. [5] provide examples of the implementation of a remote monitoring system for solar power plants. To distribute data from IoT nodes, the remote monitoring system in [4] use GSM/GPRS module connectivity installed on the microcontroller, while Wei et al. uses wi-fi on a raspberry pi to deliver data to the gateway in a Local Area Network (LAN) [5]. Data monitored on the monitoring system include: current and voltage from the battery as well as temperature and images that come from the camera. In addition to monitoring solar power infrastructure, IoT-based monitoring systems are also utilized for other fields, for example: aquaponics monitoring in the field of agriculture [6], monitoring healthcare equipment, monitoring in the field of health [7] and monitoring trash bin to optimize waste management [8]. Also, there is a framework developed by Crysdian to build a remote monitoring system based on visual data. The study is done by capturing images while being equipped with lenses to support observation for natural disasters [9].

The IoT infrastructure can differ from one infrastructure to another, especially in terms of the communication protocol used. Fernandez et al. built a remote-control system for things in a laboratory using the Web Socket protocol for educational purposes [10]. Alqinsi et al. built a remote monitoring system for Uninterruptible Power Supply (UPS) devices using the Message Queuing Telemetry Transport (MQTT) protocol [11]. This protocol is used because it can save energy and bandwidth from IoT devices. Kodali et al. monitored data from soil moisture sensors with the Constrained Application Protocol, also known as the CoAP protocol [12]. The use of various types of communication protocols is a difficult thing to avoid. The IoT application developers not only work on building software but also work to connect things to the Internet.

The growth and development of The IoT technology have expanded the pattern of utilization of web technology. The development of the Web paradigm as stated by Heuer starts with Connecting Content, Connecting People, Connecting Logic, Connecting Data and then the most recent paradigm, Connecting Things. Web technology has provided ways to develop applications on a variety of platforms and diverse infrastructures, for example by using the Web API [13]. Web technology is no longer only used to build interactions between humans and humans but has also been used to build interactions between humans and man-made physical infrastructures [13]. Optimal use of web technology for the development of an Internet of Things based system is known as the Web of Things, which is an extension of the Web. IoT applications built with the Web of Things architecture make the development process simpler. Guinard et al. [14,15], show the concrete implementation of the Web of Things. A resource-oriented architecture [15], uses the Representational State Transfer (REST) concept to provide resources from things to end-users. This creates a resource service that is independent of certain application platforms. Software developers can create an optimal collaboration between things in buildings with an IoT-based application.

3. The proposed framework

In this section we propose a framework for monitoring solar homes that are optimized using web technology. Sensor data on the solar home will be exposed to the internet and stored in the database. Then the client's application can be programmed to receive data from one or several remote solar home. We have seen a number of system implementation frameworks and models that have been developed to

monitor things from remote locations. There are various kinds of approaches and implementation techniques that have been utilized by previous studies. Figure 1 shows the framework that we are proposing. In this framework we explore the Web of Things architecture to be implemented in solar homes.
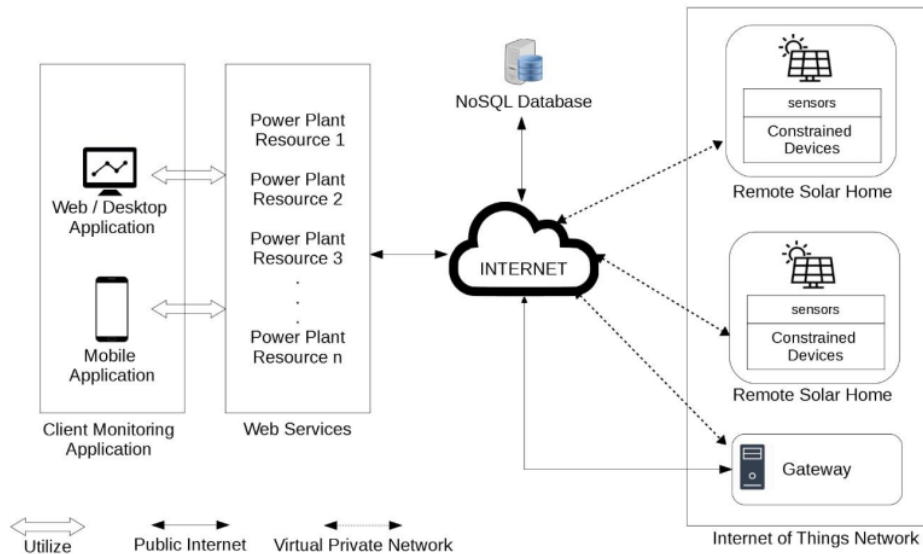

Figure 1. The proposed framework for monitoring solar home system.

The proposed framework for monitoring the solar home system encompasses the following aspects:

3.1. Client monitoring application

The monitoring application on the client side can be built using a variety of programming languages that can run on a computer or a smartphone device. Programs run by clients can utilize resource power plants that are available in the form of REST Application Programming Interface. When the client program executes a URI request, the REST server will respond by providing Javascript Object Notation (JSON) format content. JSON is a standard text format for the exchange of data between machines that is popular today in addition to eXstensible Markup Language (XML). The JSON's responses can be parsed by various types of programming languages such as C #, Java, PHP, Javascript and Python so that the development of various types of applications becomes flexible. Client's applications for personal use can be built to monitor electricity usage in one of the houses. In addition, by using exposed resources, a broader solar home monitoring system can be developed to monitor multiple solar homes at once.

3.2. Things as a service

Resources from solar power generation facilities exposed to the internet through a web service or Web API simplify the software development process for the purpose of monitoring, control and analysis. Abstraction of the IoT sensing infrastructure makes application developers more focused on the software development process. The things on a remote solar home are represented in the form of a Web Service called Power Plant resource in Figure 1, allowing it to be called from various types of applications. Therefore, it is not only accessible from a web-based application platform, The IoT resources can also be accessed from a mobile application. With this representation mechanism, The IoT resources are more flexible to be used through various platforms. By being modelled as a Web Service, things on the web

can have characteristics such as platform abstraction and infrastructure, resource reuse, flexibility and loosely coupled. This makes the term Things as a Service quite suitable to use besides the term that has been widely used, namely the Web of Things.

In this framework we use REST architecture style for our web service. With this architecture, the resources at the generator can be identified and called using a Uniform Resource Identifier (URI). In the REST mechanism, more universal interactions with solar homes can be possible. Not only between things and client's applications, but also between thing and another thing. A REST server can serve up-to-date data requests directly from sensing devices or based on historical data from databases that have been captured by sensors

A REST interface refers to certain resources generated by IoT devices. Behind the REST interface there are three infrastructure integration approaches described by Guinard, namely [14]: direct integration, gateway integration and cloud integration. Infrastructure integration is the way the client application on a laptop or smartphone can interact with IoT nodes on a remote solar home and vice versa. IoT node is a sensing infrastructure on a solar home. Direct integration is an approach where client applications access data directly to the IoT nodes without intermediaries. Gateway integration is an approach where client applications access IoT node resources through a gateway because the IoT network is limited to the CoAP communication protocol. Cloud integration Guinard and V. Trifa uses the MQTT communication protocol that requires a broker as an intermediary for communication between client applications and IoT resources. The MQTT broker runs on a cloud platform, named EVRTHNG [14].

3.3. Gateway

The concept of gateway in our framework is as the main communication infrastructure that establishes the interaction between client's applications and IoT nodes. Gateway allows client's applications to make data requests and IoT nodes can provide requested data to the clients. Our gateway also possible of acting as a REST server as well as WebSocket server to serve the client's application. REST servers can respond to a client's request with the latest data from solar home and also with the historical data stored in the database. Furthermore, a gateway can hold CoAP Proxy or a broker depending on what integration mechanism is selected to be use. Direct integration can use WebSocket protocol. CoAP Proxy will be used if the IoT networks utilizes the CoAP communication protocol while the broker using MQTT communication protocol.

3.4. NoSQL database

NoSQL Database is an implementation model of data storage used in this framework. NoSQL, which stands for Not only SQL, is also known as a non-relational database. Some studies done by Patil et al. [16], Rautmare and Bhalerao [17] and Ribeiro et al. [18], compare the performance of relational databases with non-relational databases. As described in many of these studies, the use of NoSQL generally gives positive results, especially in terms of faster response. Research by [16] and[17] used MongoDB as a non-relational database system where research Ribeiro et al. used HBase [18]. Data generated by IoT devices is individual data that is not directly related to other IoT devices. Besides that, our sensor works every few seconds as long as the IoT device is running so that it shows the potential of collecting a huge number of data records. MongoDB is a non-relational database system with a document-oriented model that offers a faster availability, scalability and data retrieval. Therefore, MongoDB is a database system that is suitable for use in the framework that we propose to store data from solar home facilities including historical data captured by sensors in each solar home.

3.5. Remote solar home

Solar home is a residential house equipped with solar power generation infrastructure. This solar home can be located far away from another solar home even on separate islands. Therefore, we establish the internet of things network by equipping each solar home with a constrained device and sensors which we called IoT node to support our monitoring system. Constrained devices are devices with limited

computing resources [19]. In general, it only has specific functions such as controlling sensors and actuators and delivering data to other nodes. Overall, the IoT node will provide the data for solar power generation infrastructure. Client's applications can use the data which are retrieved from a single as well as from multiple solar home through the gateway.

3.6. Securing the IoT Network using VPN
In our framework, IoT Network consists of Gateway and IoT nodes. The IoT nodes are located on solar homes. An alternative to secure IoT networks is to use a Virtual Private Network (VPN). With VPN we create private communication between devices in the IoT network through the public internet network. The gateway can act as a VPN Server and the IoT nodes as its clients. For this reason, we need constrained device specifications that are capable of running VPN client applications such as raspberry pi on each remote solar homes.

4. Conclusion
We have proposed a framework for building a solar home monitoring system. In this framework, client's applications for monitoring can be developed using resource power plants that have been in the form of web services. The data provided to the clients can come from the database as well as the latest data from the solar home infrastructure. Solar Home is a part of our IoT network and its resources can be accessed by client's applications through a Gateway. The entire interaction process from the client's application to the IoT node or vice versa is only possible through a gateway. Hereafter, securing IoT network with VPN is a part of our framework to increase security level.

The Internet of Things framework for remote monitoring on Solar Home System in this study can be a preliminary result for a further developed system of solar energy implementation in remote areas. The future of this research will be a system prototype for monitoring a photovoltaic plant that consists of voltage, current as well as energy generated based on the website on things. This monitoring will be used for knowing the performance of photovoltaic plants that are located in remote areas.

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