Smart energy monitoring based on IoT Lora-Wan on the campus buildings: Case study Indonesian Defence University (Unhan), Sentul, Bogor

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Abstract. Smart building constructions such as Campus Buildings have been designed for use, where the physical structure and system components are interrelated and can maximize functionality for operation and maintenance. So that the Campus building can be used with a longer age. One of the sub-systems that can monitor and notify the range of energy usage on a campus building is a smart electrical energy meter (kWh meter), which is connected to all devices that consume electrical energy in campus buildings. These interconnected smart devices use IoT (Internet of Things) interconnection networks and low power wireless technology (Lora). In a case study of the use of this system at the Indonesian Defense University, Unhan, Sentul, Bogor, West Java, it can be seen how the maximum efficiency in the use of electrical energy can be obtained in the smart campus building construction, which runs automatically.

1. Introduction
In the current state, advances in technological developments, information and communication are transforming so fast. Major innovations occur in the capabilities of software systems and hardware, as well as other supporting infrastructure in industries. Computing system hardware capabilities and capacities become powerful, with the physical size getting smaller. This has impact on the human way of life, as well as the fundamental work process. The development of information technology has turned a system into an automation trend and occurs in all fields. All human activities and machines are transformed into a digital system, includes cyber-physical systems, internet of things (IoT), cloud computing, and cognitive computing, which can be connected to the global Internet network. This is changing as a new approach that can combine real, digital, fundamentally and is called the era of the Industrial Revolution 4.0.

We recently entered and struggled in the era of the industrial revolution 4.0 with all the challenges of change and its positive impacts. Scientists have examined changes in human behavior and roles, not being completely replaced by robots but will remain at the center of management for making various policies and decisions. The Japanese state also took the initiative with a modern way of life to be more positively adapted, creating a new life for the Society 5.0 era where all community activities will be human-centered (human-centered).

A modern building construction in the Industrial 4.0 and society 5.0, will be designed and established by utilizing an automation system whose goal is to provide a sense of comfort, be environmentally friendly and also prioritize efficiency in various aspects, including automation of the use of electrical energy, water, and all the resources used to serve users of a building. The objective of this study is to
show how an IoT system solution that utilizes a low-power wireless network platform (Lora-Wan) with wide coverage capabilities can be used as part of a new way to easily monitor the use of electrical energy consumption with high efficiency. The concept of smart energy monitoring here will discuss the kWh energy meter system which is packaged as a node device, and is controlled by the application at the Head Office, functioning as a master on premises and cloud server that covers a large campus building area.

2. Campus as smart buildings
A physical construction of modern buildings today, all construction designs will prioritize usage functions with great efficiency, but still consider comfort and interaction to the beauty of the environment.

A modern building construction is designed and is called a smart building if it is integrated with building and installation technology that allows the entire facilities of the building can be designed and programmed according to user’s needs, desires and centralized automatic control.

2.1. Smart building definition
When discussing the definition of smart building in the industrial era 4.0, the definition of smart objects only states a work process, which can take and set devices automatically, and actively performs various calculations and provides relatively fast, precise and accurate information for decision makers, henceforth make a choice.

Indeed, there is no general definition of smart building [2]. The existing definition only focus on three main features, including: Reduction of building operation and maintenance costs, improve health, satisfaction and welfare of building users, Minimizing the environmental impact of buildings (not only by consuming energy / water or waste, but also sustainable architecture).

In this study, we will introduce IoT-Lora-wan technology as a function of: Reduction of building operations and maintenance costs.

3. IoT technology
The Internet of Things, or IoT, refers to the billions of physical devices around the world that are now connected to the internet, all collecting and sharing data.

IoT is like super-cheap computer chips and the ubiquity of wireless networks, it's possible to turn anything, from something as small as a pill to something as big as an aeroplane, into a part of the IoT [3].

The IoT segment is quite broad, involving various network technologies as part of its support. Network technologies are interchangeable, from standards and established ones such as Bluetooth Wireless LAN and Wi-Fi. Or for Long Distance with Power Cellular Network as used in traditional M2M communication standard 3G / 4G Cellular service. Now, the trend is starting to switch and use Low Power (Lora) WAN networking technology which provides more efficiency.

There are two topologies used for IoT implementation. The first is the mesh topology and the second is the star topology. In mesh topology, the data can be exchanged with any neighbor. If the receiver is not within the range, the data is passed from node to node until it reaches the destination. Meanwhile, in star topology, the data is passed from sender through the central hub node then to destination node.

3.1. IoT with wireless LAN
IoT is simple and can be implemented as a wireless networking device, using well-established network technology such as LAN.

Nir-cable technology for short distance Local Area Networks, which we know earlier, are common, widely used, and well-established. It is good for mobile devices, in -home, and short range, but it has issue with battery life and is not good for long range. The devices including Bluetooth and Wireless Fidelity (Wi-Fi). Bluetooth technology is a short-range wireless communications technology to replace the cables connecting electronic devices, allowing a person to have a phone conversation via a headset,
use a wireless mouse and synchronize information from a mobile phone to a PC, all using the same core system [4]. The Bluetooth RF transceiver (or physical layer) operates in the unlicensed ISM band centered at 2.4 gigahertz (the same range of frequencies used by microwaves and Wi-Fi). The core system employs a frequency-hopping transceiver to combat interference and fading. Wi-Fi has its origins in a 1985 ruling by the U.S. Federal Communications Commission that released the bands of the radio spectrum at 900 megahertz (MHz), 2.4 gigahertz (GHz), and 5.8 GHz for unlicensed use by anyone. Wi-Fi standard is 802.11, which was approved by the Institute of Electrical and Electronics Engineers (IEEE) in 1997.

3.2. IoT with Low power WAN (Lora-Wan)
IoT Lora-Wan is remote power without battery network technology which is currently as IoT of objects. With the Lora-Wan based IoT emerging as a physical solution layer of OSI layers, it is currently the most appropriate for IoT manifestations in actual practice.

Because it has been tested and is suitable and good for fulfilling the role of the IoT as a device that has characteristics: long-range, long-battery, low cost, as a positioning. Lora-wan IoT solutions, however, are not great for services that require high-speed data rate. IoT Lora-wan Radio Frequency in Indonesia using frequency 920 – 923 Mhz. IoT Lora-Wan can provide long range access for 1-5 km in City area, and +/- 15 km for open space area. With IoT Lora-wan compliance with low powered can operates up to 5 years. And it can be low cost, because one gateway can accommodate a maximum of 5000 nodes. In practice, for 200-300 nodes with 1 gateway it is still OK and safe. Lora-wan IoT, has high interoperability and can be used for various use-cases. This journal will explain IoT Lora-Wan's use case for use as energy monitoring and can be categorized as smart energy monitoring, although the definition of smart here is for efficiency. Where is IoT Lora-Wan with the node as kWh meter which is worth more. Because it is programmed, as a scheduling relay for campus operational hours, it is turned on between 07.00 and 21.00 hours, apart from that electrical energy cannot be used. With the application on the premises, the dashboard can be monitored how much efficiency and savings can be achieved.

4. Case study: Implementation
The Indonesian Defense University campus, which belongs to the Indonesian Defense Department and located in the IPSC area, Sentul, Bogor, West Java, was used as a case study for implementing Smart energy monitoring with Lora-wan-based IoT solutions.

4.1. IoT-Lora-Wan device specifications for smart energy meter kWh
The use of IoT Lora-wan as a Smart Energy Monitoring is basically not designed as a full smart automatic energy monitoring, but only functions as a recording unit of time unit and totalizer, as well as scheduling meter usage at certain hours. It can be programmed on demand or continuously with the embedded IoT-Lora-Wan energy meter unit [5].

The emergence of the idea of using IoT as Smart Energy Monitoring is due to the demand for the needs of end-users to solve big problems by reducing the operational costs of using electrical energy in classrooms and administration at the Indonesia Defense University. End users want efficiency for all the energy (kWh) meter which cannot be controlled according to usage needs only and has caused large operational cost in classrooms in the campus building every month and every year. Unit metering kWh IoT Lora-Wan and IoT Lora-Wan networks diagram can be seen in Figure 1.
Figure 1. (a, left) Unit metering kWh IoT Lora-Wan and IoT Lora-Wan networks diagram (b, right).

Figure 2. +/- 261 hectares wide area of the Defense University Campus, in the IPSC area, Sentul Bogor, West Java.

Figure 3. Electrical panel display and PC dashboard with SmartMeter kWh with IoT-Lora-Wan controller at the Defense University Campus, Sentul, Bogor.
Figure 3 is electrical panel display and PC dashboard with Smart Meter kWh with IoT-Lora-Wan controller at the Defense University Campus, Sentul, Bogor. The Lora-wan IoT is used as a node pre-post electrical kWh meter. All nodes will broadcast hardware ID and other data values to the gateway or concentrator.

4.1.1. Smart energy kWh integrated with IoT Lora-Wan. A unit of energy meter, or kWh meter which is designed as an integrated IoT-Lora + wan node device, its hardware type has been certified to the standard as MID / DLSM / COSEM. It can be demonstrated to have shown excellent device performance, and stable accuracy as an energy meter. Certificated with MID and DLMS/COSEM, ready use for single phase, three phase and the phase connected with CT Meter. All operations done remotely from the central server, including meter billing, configuration, credit purchase, alarm events report. Supports exchangeable payment between prepayment and post-paid, and able records of different tampers can be configured to switch off the load supply when the tamper occurs. Also, it provides neutral current and maximum demand measurement.

4.2. Lora-Wan gateway device
IoT LoRa-WAN® network architecture is usually implemented in a star topology, where IoT-Lora-Wan devices, exist that function as gateways, which convey messages between the end device and the central network server.

The Gateway device will connect to the network server via a standard IP connection and act as a transparent bridge, simply by converting RF packets into IP packets and vice versa.

IoT-Lora-Wan communications exist a single hopping link between the end device and one or more gateways. All modes are capable of bidirectional communication, and there is support for multicast addressing groups to use spectrum efficiently during tasks such as Firmware Over-The-Air (FOTA) upgrades or other mass distribution messages.

4.3. Basic features of the device
- Can be functioned as indoor or outdoor depending on the material and its resistance standards in various environments.
- For use in industrial environments, the standard casing used is IP67 compliant.
- Supports RF band, with unlicensed band: 863-874.4Mhz (EMEA, India), 902-28Mhz (North America), 915-928 Mhz (APAC, Latin America), for frequency usage at the Indonesian Defense University, by the Ministry of Information
- 8ch Rx (125 kHz, multi spreading factor), + 1ch Rx (250 kHz or 500 kHz mono spreading factor), + 1 ch RX (FSK) to get 10 ch Rx + 1 ch TX.
- Backhaul connectivity with 4G / 3G Worldwide module with 3G / 2G fallback and Ethernet (RJ45).

5. Analysis and discussion
The Indonesian Defense University campus area is +/- 261 hectares at Sentul - Bogor consisting of 9 (nine) main lecture buildings including the Rector's office (see Figure 2).

In the case study here, the observations were carried out during the implementation of Smart Energy Monitoring kWh meter, replacing the existing passive kWh meter, for pre-paid and some postpaid types of PLN electricity subscriptions. It can be simulated as follows:

A lecture room in building A, room area 100x600 m². Energy consumption during active lecture hours is only from 07.00 to 21.00, outside of this time, electricity is not used. In room A, there are 5 units of AC @ 1.5 PK, which are only turned-on during lectures. There are 35 TL lamps with energy saving power @ 35 watts. Alternative AC backup, there are 5 large fans @ 350 watts. And 1 (one) projector with a capacity of 500 lumens @ 750 watts, used only during lectures. The cost of electricity consumption for lecture activities in building A, which must be incurred according to the kWh meter measurement is as in the following Figure 4.
Appreciation to Wira Energi who has supported the implementation of the observation and is directly involved in implementing the IoT-Lora-Wan Smart Energy Monitoring at the Indonesian Defense University (Unhan) at Sentul, Bogor, West Java.

![Image](image.png)

Figure 4. Details of electrical energy consumption in building A, before the installation of smart monitoring negeri IoT-Lora-Wan.

With a system of limiting electrical energy for one month in building A, with IoT-Lora-Wan, which functions only as a Scheduling System, there is a record of decline as in Figure 5 below.

![Image](image.png)

Figure 5. After installed smart energy kWh monitoring based IoT based Lora-Wan.

And can save costs of IDR 781,440, with the support of a smart energy monitoring kWh system based on IoT-Lora-Wan. Subsequent observations can be observed from the trending dashboard application mode per day, week, month to year including the real status, which includes all areas of the campus and can be easily seen from a desktop PC or smartphone, at any time, to check conditions at the location. From the dashboard and IoT-Lora-Wan trending data, it will be stored as a Bigdata feed, for various needs between correlation with other data.

6. Conclusion

Consuming energy such as electricity will increase awareness of safety security and efficiency are driving the need for more information and better working process and automation.

Internet of Things (IoT) can connect and manage advanced sensors to build a smarter world, and gradually but sure change people live in future with behaviours society 5.0. With advanced technology, IoT become more efficient connectivity and wide reach, and uses very low power. It has been proved with advance features Lora-wan open protocol, to be the most preferred choice for building smart
systems for industry and building management including smart campus functions, as pioneered in this case study with implementation at the Indonesia Defence University (Unhan).

Wide application, had proven IoT-Lora-wan technology, can be implemented with growth with scalability. And functional utilization must be designed in usage, so that it becomes the right advanced system solution.

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