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Lo-Ra Based Framework for Smart Green House Monitoring Systems

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Greenhouses in agriculture have their own pace of revolution by sensors, actuators, monitoring and control systems. As many greenhouses nowadays have standalone monitoring applications, this project proposed an integrated real time monitoring application framework for a smart greenhouse in order to create an autonomous, self-regulating system that can be remotely controlled by the user through the internet. The solution for this integration consists of sub nodes for Green Energy House, Green Garden Management with the humidity parameter, and Aquaponic Management. The Aquaponic Management comprises of hydroponics management for ambient temperature and humidity, turbidity and electric conductivity. These systems were also integrated with fishpond management that is capable to monitor the pH value, water turbidity and water temperature. All sub nodes will send and receive signals based on data access networks with cloud computing and the development of web-based interfacing for control and monitoring. The design methodology using the Arduino as the controller device and the data communication using the Long-Range Radio (LoRa) Network technology. Beyond this framework development, investigation in depth has been done regarding the data collision analysis for the network performance. The framework designed was evaluated and materialized in good impact for the smart green house at Politeknik Port Dickson with efficient network performance.

Key words: *Green House, Internet of Things, Long Range Radio (LoRa), Monitoring System.*

Introduction

Greenhouse technology is a part of agriculture, providing promising environment situation to the plants. To protect plants from the harmful climatic conditions such as wind, cold, extreme temperature and disease, assembling a greenhouse will protect the plants by providing suitable environmental conditions. Greenhouses have their own place in the agriculture sector and the awareness to keep the sustainability of the greenhouse is important. There are activities in adopting sustainable agriculture through greenhouse technology itself which includes several considerations (Shamshiri et al., 2018) ;(Garcia et al., 2018). Vertical farming nurtures plants within a rooftop greenhouse or on vertically inclined surfaces. Advantages for vertical farming include less weather-related crop failures due to threads. Additionally, aquaponics is a sustainable food construction system that combines conventional aquaculture with modern methods of raising aquatic animals such as fish in tanks. In aquaculture, waste accumulates in the water and increases toxicity for the fish. Therefore, the waste accumulated water is led to a hydroponic system which is then filtered by the plants as nutrients and circulated back to the aquaculture system. On other hand, the smart sprinkler system is an approach to reduce production cost whereas smart systems use water only when needed. The systems also save production time as they are designed to acquire location data into the smart system, where the controller adjusts the watering schedule based upon local conditions or soil moisture.

Integrated farming increases crop yields, nutrient recycling leads to strengthened environmental sustainability. An integrated farming system consists of a range of resource-saving practices that aims to achieve acceptable high profits and sustained production levels, while minimizing the negative effects of intensive farming and preserving the environment. In line to these conditions, an integration needs data centralization for the monitoring purpose. The implementation of a wireless data network for monitoring of production output achievement can transform the data process and help the agriculture sector to meet the demands (Zulkifli, 2015), (Hashem et al., 2016). The needs of developing a management system for agriculture will increase the production in this industry (Dan et al., 2015; Rahman, Bindu & Islam 2018).

Related Work

A web-based monitoring system has been developed in agriculture for precision in real time data acquisition and can improve the efficiency of environment room management. There are also implementations of web-based monitoring in the manufacturing industry where a wireless mesh network for real-time monitoring of production output achievement in an industrial context was developed using radio-frequency identification (RFID) and IEEE 02.15.4/ZigBee technology (Zulkifli, 2015). Other applications using wireless mesh network are applied for helping aging population with technology using the *Giraffplus* system (Barsocchi, 2016). This system comprised four units of sensors networks in home, data management infrastructure using Global System for Mobile communication (GSM), tele-presence robot (the *Giraff*), and interaction front-end that allows to visualize data coming from the house as well as to remotely call the robot.

In China, Liu Dan et al developed a monitoring system based on ZigBee technology for the agriculture industry. The wireless sensor and control nodes takes CC2530F256 as core to control the environment data. The system is made up of front-end data acquisition, data processing, data transmission and data reception. The gathered data is sent to the intermediate node through a wireless network (Dan et al., 2015). From a Malaysian perspective of agricultural development, it is the development of using RFID and Wireless Mesh Sensor Network (WMSN) which is important (Zulkifli and Noor, 2017). The ZigBee technology platform is applied in 2.45 GHz and active RFID to sustain the Wireless Sensor Network (WSN) by developing a fully automated Internet of Things (IoT) solution in agriculture for irrigation systems. The system proposed wireless automated irrigation system for efficient water use and production.

From all the developed systems, most of the recent system are using ZigBee technology as the wireless sensor network platform. Other than ZigBee technology, a study using Long range radio transmission (LoRa) networks in IoT technology in an agricultural environment has been conducted between a LoRa gateway and multiple sensor nodes (Park et al., 2018). Based on forestry radio propagation, the study uses a small drone with a gateway mounted on its fuselage that collects sensor data from nodes on the ground to test the feasibility of this communication method. Furthermore, recent papers present a solution for the precise monitoring of essential parameters for fruit growing in a walnut orchard with LoRa technology (Sacaleanu and Kiss, 2018). It also performed a characterization of the network lifetime and coverage.

In developing the Internet of Things platform, the wireless sensor network has a role of being a group of autonomous devices using sensors to monitor physical or environmental conditions. The sensor node is attached with sensors which detect and receive the required information. Recent studies and developments show that ZigBee and LoRa technology are well-known networks in implementing the monitor to the environmental parameters. In conjunction , this paper proposes a LoRa framework in monitoring environmental parameters for smart greenhouses that includes smart garden and aquaponics management. This system instructs LoRa in the smart greenhouse due to very low power usage and significant cost advantage (Dan et al., 2015).

This paper is structured as follows. Section 2 describes the technologies used in the system for physical layer, communication layer and application layer. Section 3 discusses results and discussions. Finally, Section 4 gives the conclusion.

Technology Used

Wireless sensor network refers to a network of devices that can communicate the information gathered from a monitored field through wireless links (Garcia et al., 2018). Wireless sensor network permits communication between sensors that measure environmental conditions like temperature, sound, pollution levels, humidity, wind speed and direction and pressure. The data is forwarded through multiple nodes, and with a gateway, the data is connected to other networks. For this research, long range radio transmission was used for the wireless sensor network.

Real time monitoring of the physical variables which apply the internet of things, presents an interesting technological challenge (Garcia et al., 2018). An environmental monitoring system for precision in real time data centralized on a smart green house was developed in Politeknik Port Dickson. The long range radio transmission (LoRa) is a spread spectrum modulation, low powered wireless standard meant for providing a cellular style low on data rate communication networks. This framework provides the intermittent low data rate connectivity over significant distances (Poonam et al., 2016). The radio interface has been designed to enable very low signal levels to be obtained, and as a result even lower power transmissions can be accepted at significant ranges.

A. Smart Greenhouse Monitoring System

The main distinctive of the wireless sensor network used for this smart greenhouse is the data collision intended for the network performance. This research incorporates LoRa which was formed to standardize LPWAN (Low Power Wide Area Networks) for IoT, in 433MHz with Arduino to develop an embedded system for monitoring and data acquisition. The endpoints are the elements of the LoRa network where the sensing or control is undertaken (Roselliet, 2015). The smart garden embedded an analogue soil moisture sensor to measure volumetric water content in soil. Measuring soil moisture is vital for agricultural applications to help farmers in their irrigation systems management. For the aquaponic management the sub nodes were divided into two main section which is fishpond and the hydroponic section. Fishpond was developed to measure water turbidity (NTU) based on the ISO water quality. It reflects the amount of total suspended solid (TSS) in the water. TSS can include a wide variety of material, such as silt and decaying plant and animal matter. High concentrations of suspended solids will lead to many difficulties for stream health and aquatic life. The fish pond also measures pH water using pH electrode probe and water temperature measurement with waterproof temperature sensor. The hydroponics section uses a capacitive humidity sensor and a thermistor to measure the ambient. It also perceives pH and the turbidity also electrical conductivity (EC). EC is the total dissolved salts in a solution, the factor that affects a plant's capability to absorb water.

All sub nodes described are the slave devices that initiate communication with LoRa gateway. The gateway receives the communication from the LoRa sub nodes and then transfers them into the cloud computing system. It forms the bridge between the devices and the Things network that can be in the form of Ethernet, cellular or any other telecommunications link wired or wireless. The smart greenhouse developed uses wireless network Wi-Fi 802.11ac technology which is ideal for long-range deployment of high-performance wireless networks.

The data centralization through the Internet of Things (IoT) then were located in the cloud computer where the network of distant servers is hosted in the Internet to store, manage, and process data, rather than a local server or a personal computer. This refers to the communication layer in IoT architecture (Jesús, 2017), (Cor et al., 2019), (Lee and Ke, 2018). A middleware using Laravel was developed including the database server which primarily stores and retrieves data requested by other applications. The client requests and responses activity which were developed in this smart greenhouse system on web-based applications. As current system is not a web-based system, the framework proposed web-based monitoring system.

B. The IoT Framework

In designing the IoT for communications, there are four main layers of architecture (Portocarrero et al., 2017), (Yue and He, 2018), (Weyrich and Ebert, 2016). Table I shows the IoT architecture layer information.

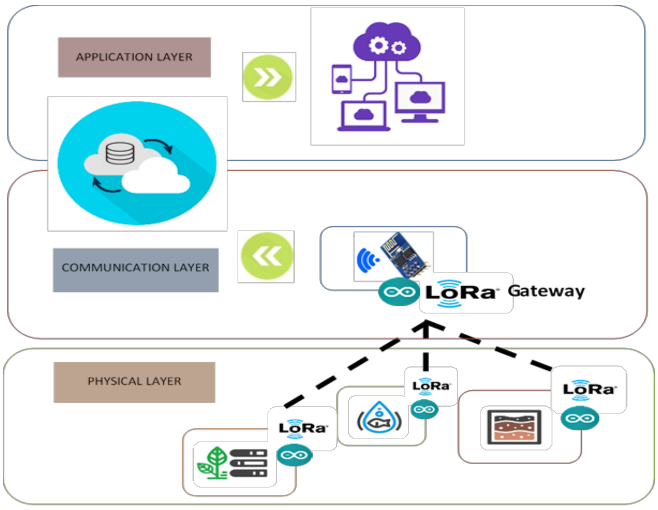
Table 1: IoT Architecture layer information.

Layer	**Characteristics**		
	Associate Layer & Functions		***Tools/ Technology***
Physical	Percept ion	Produce valuable data sensing field variables using a WSN	Sensors
	Control	Receiving information from a communicati on layer or a perception layer in the simplest case	Actuators
Communi cation	Shift the information from the physical layer to the Internet. field gateways acting as interfaces between IoT gateways and transceivers (ZigBee, Bluetooth, NFC, WiFi, LoRa, or Sigfox)		Ethernet or mobile networks (GPRS/3G/4 G/NB-IoT and eventually 5G)
Service	Data incorporation from the communication layer, as well as their storage, analytics, visualization, and security		Middleware
Applicatio n	Utilizes services from the previous layer in the architecture and allows user for monitoring, controlling, prediction and logistics.		Mobile Apps, Web-based Application

The broad concept framework of the smart greenhouse system shown in Figure 1 are divided into three main layers of architecture involving the physical layer, communication layer, and the application layer. In this framework, the communication layer comprises the integration of communication layer with the service layer. The physical layer consists of the sub nodes that are embedded with the LoRa wireless sensor network. Specific, the devices embedded with the sub nodes should have the device capability including sleeping and waking up devices that can reduce the energy consumption. Another crucial capability is the possibility of sensors to gather and upload information directly to the communication network (Cor et al., 2019), (Meda et al., 2017). As for the system, the integrated sub nodes were developed supported by the 9V batteries and the data collision were analysed to check the network performance.

The communication layer will then be integrated with the application layer to complete the monitoring system. At this layer, the gateway must be able to support devices that are connected through the wireless sensor network technologies and protocol conversion. A gateway is the mount in the greenhouse Politeknik Port Dickson. The gateway is embedded with a Wi-Fi module to ensure the bridge construction with the cloud using wireless technology. The cloud computing is the IoT communication platform that was developed with the web server, database and PHP as the server-side programming language. The application layer is a human interfacing layer. The user can monitor their farm anywhere using the internet connectivity to retrieve the real time data using tools in this layer. The technology can be from the web-based application or from the mobile application. For the smart greenhouse in this layer, a web-based dashboard was developed to envision the collected IoT data.

Figure 1. The broad concept framework of the Politeknik Port Dickson smart greenhouse.



Result and Discussion

There are numerous analysis activities that had been carried out for this framework research. This included read range analysis, power consumption, database performance and network performance. For this paper, the network performance analysis through the data collision percentage were highlighted. Several considerations for data collision were considered to check whether the LoRa sub nodes can transmit data to the LoRa gateway at any time without significant packet collision (Lee and Ke, 2018). This will offer the appropriate wireless network operation with good probability of frame collision (Garcia-Sanchez, et al., 2011). It is crucial to check the ability of the sub nodes to send data with considerable amount of data without collision (Zorbas and O'Flynn, 2018).

The proposed framework models a condition of network configuration. The network sets up with lower distance with point to point configuration. The model simulates 2 samples of LoRa sub nodes devices and 2 samples of integrated LoRa with sensors communicate with 1 LoRa gateway. In the experiment, the distance is in 2m, 5m, 10m, 15m and 20m with the reader respectively. There is a data co1lision when the data from all the LoRa sub nodes were transmitting 100 times for each ID sub nodes. The same thing happened with the experiment using integrated LoRa with sensors.

Figure 2. Data collision analysis between LoRa sub nodes and Integrated LoRa

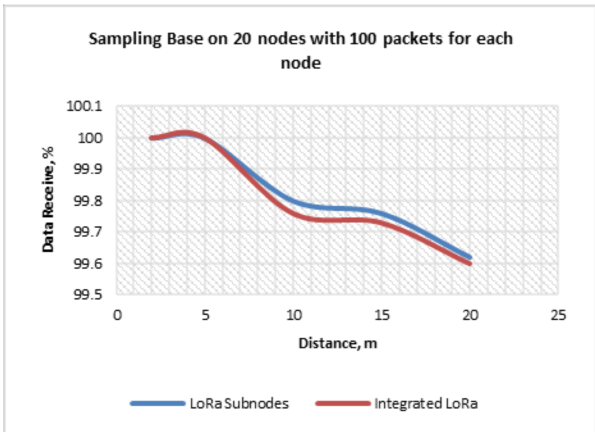


Figure 2 shows the percentages of data transmitted from 100 times for each type of sub nodes to the gateway simultaneously. The result shows that data collision have been occurred for each sub nodes. When the distance increases the percentage of reading data for each node will decrease. With point to point communication, in distance 20 m 0.026% data collide for standalone sub nodes and 0.03% data collide for integrated devices. From the analysis carried out, the average percentage collide data was 0.03% for the distance range tested. This reading is considerable in monitoring the smart greenhouse data. The average data collision shows that the network performance is efficient.

Conclusion

This research proposed a monitoring system that senses data such from 2 sections of management: smart garden and aquaponic management. The parameters senses are ambient humidity and temperature, water turbidity, pH level, electric conductivity and soil moisture for a smart greenhouse. From the framework proposed, the sensors are embedded with LoRa subnodes at the physical layer. This information data was transmited from the LoRa subnodes to the LoRa gateway as the wireless sensor network. This will integrate to the communication layer. The information then will be stored at the IoT platform and can be visualized from the web-based application dashboard which lays at the application layer. As many parameters were analysed for this research, this paper focuses on the network performance analysis using data collision parameter to offer appropriate wireless network operation. An experiment for data collision was set up using 2 samples of LoRa sub nodes devices and 2 samples of integrated LoRa with sensors to communicate with 1 LoRa gateway. The tests showed how the setup of LoRa communication works as well as the data collision for the network. The data collision analysis shows that LoRa wireless network is efficient for the Politeknik Port Dickson smart greenhouse framework.

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