Design and Implementation of Water Monitoring Using LoRa and NB-IoT

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Abstract. Array of Things in smart city initiatives can add tremendous value to the life of citizens and public servants alike by constructing apps that make use of disparate information streams. Data integration and visualization platforms can generate real situational awareness, measurable smart city a better quality of life for urban inhabitants by interpreting and reorganizing information from networks of devices integrated across towns. In this study, the implementation of Array of Things is demonstrated in water quality monitoring and analysis as the experimental study using LoRa and NB-IoT.

Keywords: AIOT · IoT · Water monitoring · NB-IoT

1 Introduction

The use of the right technologies in planning and working is one of the main ways to achieve a smart city. The harmony of the fundamental intelligent city objectives and goals must be linked to best digital technology and intelligent technology. Intelligent information must be used to transform a campus or town and use the finest technology. The maxims, analytics and heuristic algorithms behind the efficient use of intelligent information remain critical to any effort to build a better, safer and smarter city, where people and neighborhoods thrive, technology is deployed and people are employed in a profitable manner. In effectively analyzing and addressing technology, efficient planning, and intelligent details, it can lead to a sense of real society. This means that social cohesion is nurtured and smart procedures and efficient techniques can flourish all over the areas.

The Internet of Things (IoT) and Array of Things (AoT) provides cities with new opportunities to use the information to handle traffic, reduce pollution, make better use of infrastructure and maintain people secure. A fully integrated

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modular and scalable framework to effectively deliver and handle smart city services to assist towns make the most of digital opportunities. The completely integrated strategy fulfills the essential necessity of a shared, secure, and scalable linked environment where every "thing" can communicate to each other to make the towns of tomorrow smart, secure, and viable.

In this paper, the implementation of IoT and AoT for smart city is demonstrated in water monitoring and analysis. The design system is deployed in the campus as a living labs.

2 Background Review and Related Study

In this section, we review some background knowledges for later use of system design and implementation. Several components are applied as the methods in this paper: IoT, Big Data, Cloud Computing, and OpenStack. The next parts discuss each component in more detail.

2.1 The Internet of Things (IoT)

The IoT is a network of physical machines, cars, home appliances, and other products integrated with electronics, software, sensors, actuators, and connectivity to the network that allows these objects to communicate and exchange information. Through its embedded computing scheme, each thing is uniquely recognizable but can interoperate within the current Internet infrastructure. Experts estimate that around 30 billion objects will consist of IoT by 2020.

The IoT enables objects to be sensed or remotely monitored across current network infrastructure, creating possibilities for more direct integration of the physical globe into computer-based systems, and resulting in enhanced effectiveness, precision, and financial benefits in relation to decreased human interference. When IoT is enhanced with sensors and actuators, the technology becomes an example of the more general class of cyber-physical devices, including technologies such as smart grids, virtual energy plants, smart homes, smart transportation and smart towns.

2.2 The Array of Things (AoT)

The Array of Things (AoT) is an urban sensing network of programmable and modular nodes to collect data on the city's climate, facilities, science and public use in real time in cities. AoT will primarily serve the community, as measurement of the living conditions in cities like the weather, air quality and noise.

AoT will provide researchers and the public with real-time location data on the urban environment, infrastructure and activity This initiative was structured so that scientists, policy-makers, developers and residents can collaborate and take specific measures to improve the security, productivity and well-being of cities. The data will help communities operate more efficiently and save on costs by predicting problems like air quality status and health.

2.3 NB-IoT

Narrow-band Internet of Things (NB-IoT) is a wide-area network communication system that uses a narrow band radio frequency. It operates inside the permitted spectrum. The licensing frequency band is used by 3GPP's 2/3/4G cellular communication technologies. Different from the existing networks, three deployment options such as in-band, guardband or independent carrier coexist, and NB-IoT is also supported by telecom firms throughout the world. A key LPWAN technology, as well as a leading solution for large-scale connectivity in all three of 5G's core use cases, is LoRA [6]. There is a 20 dB improvement in coverage capacity compared to LTE, which is comparable to a 100-fold increase in coverage area. Because of its deep coverage capabilities, it can also be used in industrial settings like factories, underground garages, and manhole covers. NB-IoT can enable 50–100 times more accesses than current wireless technologies on the same base station. It is possible for a sector to accommodate up to 100,000 connections while also providing low latency sensitivity, ultra-low equipment costs, low equipment power consumption, and a well-designed network architecture. NB-IoT network does not need to be rebuilt, and it saves money over LoRa because the radio frequency and antenna may be reused multiple times [7].

2.4 Related Study

The network architecture based on LoRaWAN is facing the problem of environmental limitations, and its harsh propagation environment greatly limits the coverage of the LoRaWAN network in the city. Dias and Grilo [2] designed and implemented a multi-hop uplink solution compatible with the LoRaWAN specification, which can be used as an extension to the deployed gateway. The terminal node transmits the data message to the intermediate node, and the intermediate node selects a route based on a simplified version of the target sequence distance vector (DSDV) routing and relays them to the gateway.

Celesti and Fazio [3] proposed an IoT system monitoring and management framework, which integrates the AllJoyn function, used to interconnect IoT devices, MongoDB, used to achieve big data storage, and Storm, used to run real-time data analysis. In the experiment, the author studied three different data modes, namely normal, event-based and automation. The experimental results show that the delay of monitoring and service depends largely on the type of management application running in the system, and is not affected by the data pattern.

Chen and Ran [1] proposed a smart city smart manhole cover management system based on edge computing in 2017; Wang et al. [4] designed a smart manhole cover management system based on multi-layer distributed structure and NB-IoT network in 2018. Smart street light management system for solar street lights; Zhang et al. [5] completed the long-range (LoRa) communication technology and the least recently used (LRU) algorithm to design a low-power information monitoring system in 2018; Anand and Regi [8] used NB-IoT to remotely monitor the water tank in 2018 The water level.

3 System Architecture

The overall architecture of this research is shown in Fig. 1. It is mainly composed of two parts. The first part is the hardware which includes Arduino deployment, water sensors, and combined with LoRa and NB-IoT modules, assembled into high-quality airboxes. The second part is the data source, collecting information of the water sensory data of Tunghai University. MySQL was used as the database system for sensory data. Grafana was applied to visualize the water monitoring system. The communication system uses MQTT transmissions. Figure 1 describes the system architecture of this research.

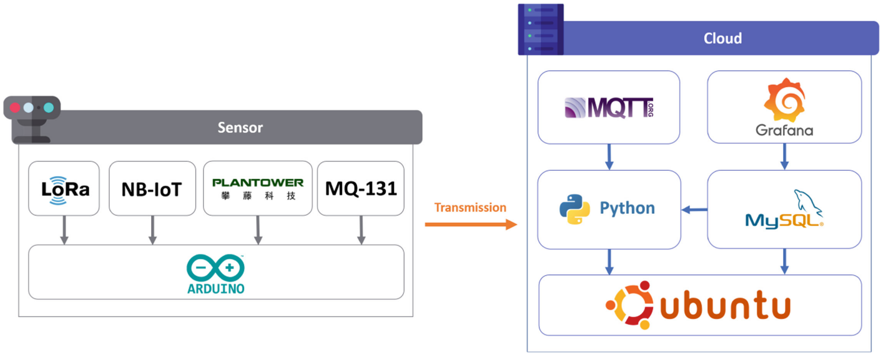

Fig. 1. Water monitoring system architecture

There are four layers in NB-IoT system, Perception, Transport, Platform, and Application layers. The architecture diagram of NB-IoT is shown in Fig. 2.

Transmit data quickly and save energy is also a major issue, therefore this system uses Message Queuing Telemetry Transport (MQTT) as a bridge of communication between machines. Figure 3 shows the scheme of overall data transmissions and System runtime process.

4 Experimental Results

4.1 Device Installation

The device is equipped with several sensors, including temperature sensor DS18b20, pH sensor, conductive sensor, and dissolved oxygen sensor. The sensing range of temperature is −55 °C–125 °C, the sensing range of pH is 0–14, the sensing range of conductivity is 1 ms/cm–20 ms/cm, and the sensing range of DO is 0–20 mg/L. A total of four values are obtained for LoRaWAN and MQTT transmission, which can operate normally regardless of indoor aquariums and outdoor lakes. Figure 4 presents the water sensor component.

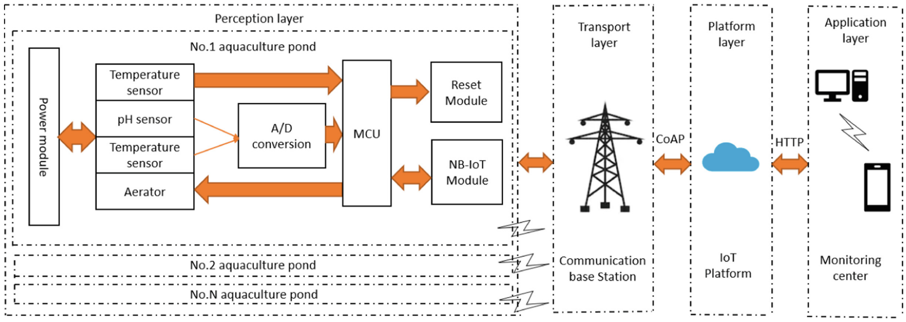

Fig. 2. NB-IoT architecture diagram

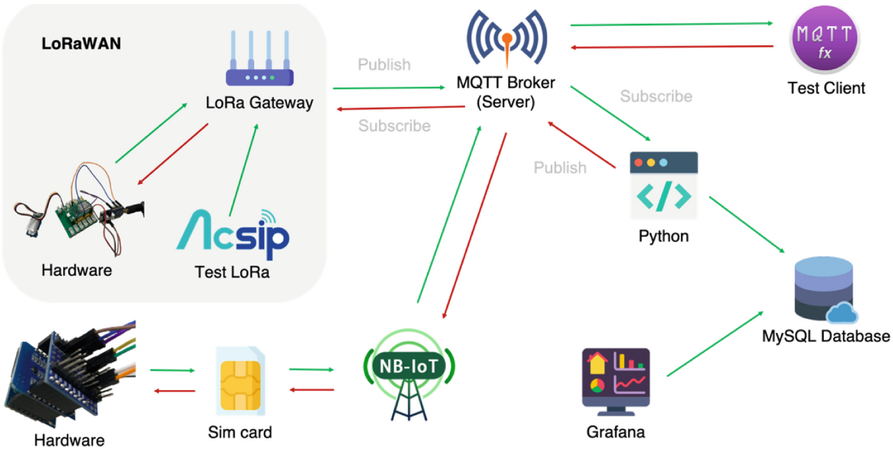

Fig. 3. System runtime process

4.2 Water Monitoring System

Grafana and WordPress were built to complete the tasks of data access and visualization. It is expected to present the real-time water status. WordPress was used to manage data access permissions and Web API interface to communicate with other sub-projects. The reason using Grafana because Grafana has the following six main features:

– Convenient display: Convenient and flexible graphical operations, and rich visual charts are available use.
– Multiple data sources: Many different data sources are supported.
– Early warning notification: Visually define the early warning rules for important indicators in the data.
– Mixed display: Different data sources can be mixed in the same chart, and combined display according to custom queries.

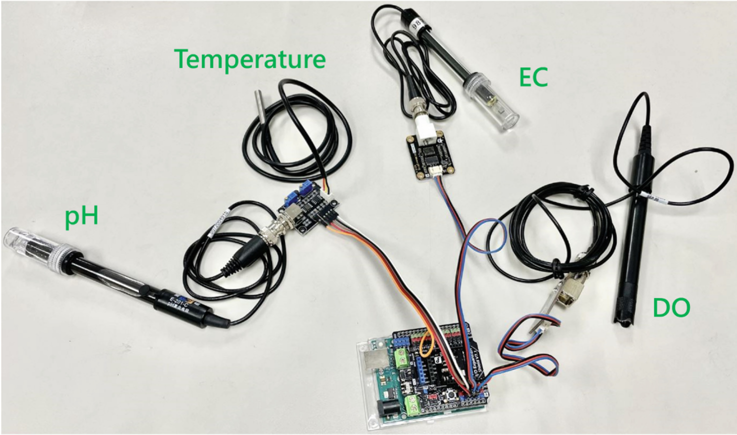

Fig. 4. Water sensor components

– Monitoring template: the old monitoring can be stored as a template, so that different hosts with the same data source can be quickly imported and applied.
– Permission control: You can control the access permissions of the underlying users by establishing different role permissions.

Figure 5 demonstrates the result of Water monitoring system in Grafana visualization.

Fig. 5. Water monitoring in Grafana visualization

5 Conclusion

This study implemented a water monitoring system by integrating water sensors, LoRa, NB-IoT, and MQTT as AIOT architecture. The monitoring results then visualize in Grafana. Based on the experiment, the combination of LoRa and NB-IoT is feasible. In the future, further evaluations can be conducted in detail. Also, this system might be equipped with AI model.

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