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Integrated Sensor Network Platform Implementation based on Fog Computing

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Abstract: Products that utilizing Wireless Sensors are rapidly advancing. Including personal and public facilities usage, a huge amount of data is being processed through the Internet to client ends. It is intelligent to manage sensor nodes and those data by a united Cloud System. However, as scale and factors increasing, issues such as latency, bandwidth, heterogeneity will prevent the implementation and application usage. In this paper, an Integrated Sensor Network platform based on Fog Computing was proposed. By distributed sensor management and data processing at the local layer, it enables more possibility for Real-time interaction both between cloud services and end users.

1. Introduction

Over the past few years, the technology of Internet of Things (IoT) has been advancing greatly. Thanks to its contribution, various sensors and actuators were able to be deployed around people's daily life, in home, office, or even outdoors. A lot of services and applications have risen up to monitor and support users' activity. Wireless sensor networks (WSNs) played a very important role among those platforms. Although there are different approaches to constructing the platform, common issues such as data processing, sensor heterogeneity is required to be considered carefully.

Cloud Computing, Edge Computing, Fog Computing are providing paradigms for the concept architecture from a different focus. From centralized to distributed structure, each of them is providing many benefits, but the same time facing its limitations. In this paper, it discusses mainly Fog Computing and proposed an architecture for environment sensing platform. WSNs were divided into groups based on area and the wireless communication interface. Each group has several sensor nodes and one gateway, which is responsible for the data processing and transfer tasks as a local computing center. Platforms utilizing this architecture can improve features of Fog Computing characteristics like less latency real-time data accessing, support for heterogeneous sensor and wireless interfaces, location awareness of different nodes.

To test and prove the proposed architecture implementations were set up in a practical situation for environment sensing. Integrated sensors were used in the implementation, which has a built-in wireless module and sensor modules of temperature, noise, air pressure, light, etc. This can make the platform more efficient by reducing the work on sensor connection and data processing. Sensors with different wireless communication interfaces were deployed in different remote places. Through the gateway application, clients can easily access and visualize the sensor data in real-time. The application can show sensors data with their location, it helps users to understand the data more intuitively. The deployed platform and result show the possibilities of proposed architecture, but the implementation was still on a relatively small scale, along with other issues required effort to solve in the future study.

This paper is organized as follows. In the second section, it introduces the background of Fog Computing, differences from other diagram and issues of them. The third section describes the design and architecture of proposed platform that helps to improve factors like latency, heterogeneity, etc. In the following section, to prove the proposed platform several experiments were conducted, the detail and result of implementation are discussed. As a conclusion, the last section describes the current state of the work in this paper, with a discussion of future work.

2. Background

2.1 Fog Computing

The term of Fog Computing was introduced by Cisco Systems [1] as an IoT network paradigm to extend Cloud Computing. Cloud Computing itself has been widely known over past decade. Michael defines it as:

> `Cloud computing refers to both the applications delivered as services over the Internet and the hardware and systems software in in the data centersthat provide those services` [2].

Since Cloud Computing is holding and managing its resources and data within the Internet, it is very convenient and efficient for clients to reduce their computing tasks and storage requirement. It has been utilized by many big companies in their services, such

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Table 1: Summary of Cloud, Fog, Edge Computing

	Cloud	Fog	Edge
Unit Size	Large	Small Group	Single Node
Structure	Centralized	Distributed	Distributed
Data Process	Data Center	Gateway	End Devices
Response Time	Long	Short	Immediately
Deployent	Unified	Local Based	Ad-hoc
Network Scale	Device	Local	Global

as Google, Facebook, etc. However, features for those services also brought issues that hinder the coming IoT revolution [3]. For example, the huge amount of data take corresponding bandwidth and time for data transmission to user requests. The latency caused will not meet IoT systems requirements for real-time applications with users direct interaction. Another problem is Cloud Computing frees the client from the specifications of so many details, therefore it is difficult to provide location awareness for IoT systems.

An information technology research company Gartner, Inc. forecasts that 6.4 billion connected things will be in use worldwide in 2016, and will reach 20.8 billion by 2020 [4]. Therefore, a new platform to meet these IoT system requirements like Fog Computing is required. In Chiang's paper Fog Computing was the defined as:

> `Fog is an architecture that distributes computation, communication, control and storage closer to the end users along the cloud-to-things continuum` [3].

As it describes, by distributing the resources closer to client user, the structure can be more flexible to carry IoT systems. Especially the feature characteristics of less latency real-time interaction, hterogeneous compatibility, location awareness.

There is another term Edge Computing which is similar to Fog Computing. The definition is as below:

> `Edge Computing refers to the enabling technologies allowing computation to be performed at the edge of the network, on downstream data on behalf of cloud services and upstream on behalf of IoT services` [5].

Compare to Fog Computing which is using a gateway, "edge" represents any computing and network resources along the path between data sources and cloud data centers. This makes every edge devices can have capability of computation and data transmission through network. Different from P2P approaches, Edge Computing is a decentralized paradigm that allow heterogeneous resources to be connected and controled [6].

2.2 Related Works

Table 1 shows the the differences summary of the three diagrams. Compare to Cloud Computing, though the other two paradigms are difficult to organize, they are easier for IoT systems such as sensors and actuators. Edge provide more possibilities for the end devices, but for environment sensing usage, it is better to manage sensors in each area as one group rather than one by one. IBM Research describes their work in Smart Grid utilizing Fog Architecture [7]. To maintain low power consumption, sensors using Bluetooth or ZigBee were connected to gateway which conduct the computation and transmission tasks. Cirani is proposing a hub architecture which Fog gateway is managing the lower layers and providing organized information to client users, so that users can avoid the complex manipulations of end nodes [8].

The authors of this paper have been working on environment sensing and applications before [9] [10] [11]. Integrated Environment Sensor was used which have sensor modules of temperature, noise level, air pressure, light, etc. It can reduced nodes of environment sensors into one. In the past works sensor network with only one node of Integrated Sensor was implemented. In this paper Fog Computing structure was proposed for larger scale environment sensing platform, to provide features of real-time data access, heterogeneous support, location awareness.

3. Architecture

As describes in the section above, the proposed platform is focusing on environment sensing using Integrated Sensor as end nodes. **Fig. 1** describes the construction local sensor group as one Fog Node. With one unique gateway, all data will be collected and organized for transmission. The gateway itself can connected to the Internet, and by providing RESTful API, both end users and cloud services can access the data directly. Because of the gateway is the only one layer between sensor group and data requests, the real-time access latency could be reduced to the minimum. The sensors may use different wireless communication method depends on different group, gateway should provide the interfaces to meet the sensors' heterogeneity, such as Bluetooth, Mesh Wireless, etc. And for each gateway is set up one specific area, in that area sensors are located in different corners, it is easy to track the location information while accessing the sensor data.

With the same structure of Fog Nodes, different local sensor groups can be connected together as a flexible scale sensor network. No matter what communication method the end sensor is using, on the gateway layer all data will be converted to a unified format. Applications can directly access one Fog Node for the environment data in that specific area, or it can access the cloud service which collecting all the Fog Nodes data together and store them for long term usage, like data analysis and other application. The whole architecture of all Fog Nodes is described as **Fig. 2**.

4. Implementation

For implementation, Raspberry Pi was used as the gateway of Fog Nodes, because it is based on Linux OS and easily to configure different wireless communication methods on its interfaces. It can also provide web server as for the data requests. Web socket was utilized for real-time communication. The Integrated Sensors are using 3 different wireless interfaces, Bluetooth, Mesh Network, Long range wireless's communication. Wireless modules were add to the gateway, with WiFi connection the gateway

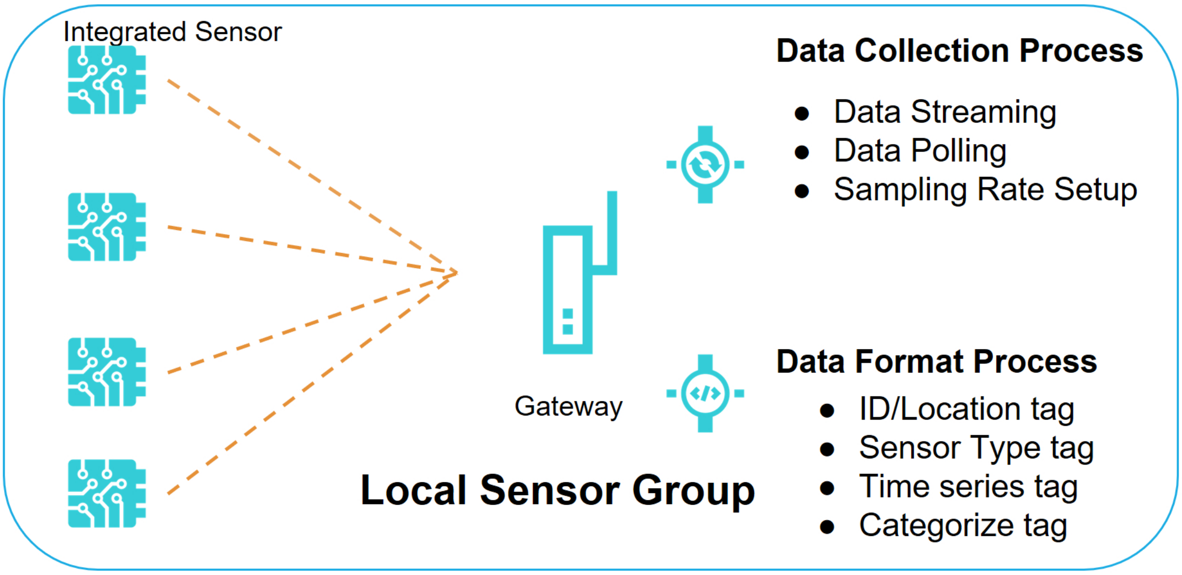

Fig. 1: A Fog Node: Local Sensor Group with Gateway

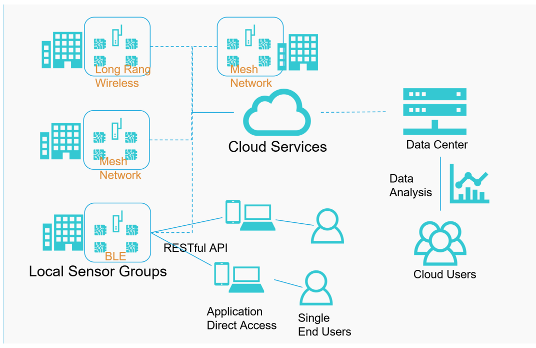

Fig. 2: Architecture for all Fog Nodes

Fig. 4: Indoor view for local sensor group

can get data input through the wireless modules and send data output through WiFi.

The experiment was conducted in a university campus. Sensor groups using different wireless communication methods were separated into three remote buildings. As application, a location based visualizing interface was developed. **Fig. 3** shows real-time data visualization of diffirent sensor groups, **Fig. 4** shows one local sensor group.

Fig. 3: Outdoor view for remote sensor groups

5. Conclusion

As a result the implementation works well for the real-time visualization from different type of sensor groups, and by using location based interface, it is easier for users to see the influence people activity will made to the environment. In the next step, bigger scale experiment need to be conducted to testify the proposed platform in more scenarios.

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Erratum to "Integrated Sensor Network Platform Implementation based on Fog Computing"

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Erratum: The paper published in 2017-DPS-170(20),1-4 (2017-02-23) , 2188-8906 with the title of "Integrated Sensor Network Platform Implementation based on Fog Computing" and authors Dongyu Wang, Ruowei Xiao, Naohisa Ohta, Kazunori Sugiura would like to have the following completion to the above article

Author Name

The fourth author named with "**Kazunori Uhyo Sugiura**" should be **Kazunori Sugiura**.

Missing part in section 3 Architecture

Add this paragragh in th beginning: In Fog Computing concept, the computation and other processing tasks are distributed to each gateway. A minimum unit of the proposed platform is a Local Sensor Group, which consists of two main elements: 1) Gateway; 2) sensor devices. With connecting sensors connected to the gateway, the Local Sensor Group can work alone to provide data and services. Or it can join with other groups together to build up a wider scale network. Thus, the Local Sensor Group is very important. It must provide the basic functions of data collections and transmission. In addition, it should have capabilities to enable the features of Fog Computing that have been discussed in the 2 Section.

Add this paragragh in the end: As use cases, in homes, schools, offices and other environments, local sensor networks can be set up individually. There might be different types of sensors and communication methods inside of each network, but on the Fog Nodes layer, all data will be processed in a common way. With a uniform interface, applications can directly access any Fog Node for the environment data in that specific area. On the other hand, services that utilizing wider scale of environment data can access nodes from different locations at the same time. By recording and analyzing the data for a long term, the services will be able to provide more variety of applications.

Missing part in section 4 Implementation

Add these paragraphs in the beginning: To prove and test the proposed architecture, the platform was implemented from the Local Sensor Group to distributed Fog Networks based on campus experiments. Results and issues are discussed after the experiments.

As described in the section above, the platform is focusing on environment sensing. Integrated Environmental Sensor has been used in the previous works. Each Integrated Sensor consists of a variety of environment sensing module, Temperature, Humidity, Light, Pressure, Noise, Acceleration.

The sensors are all built with same integrated modules, but for different occasions and distances, there are three wireless communication methods installed: Bluetooth low energy(BLE), Mesh Network, Long Range Wireless. Basically, the usage of each module is from short to long distance. BLE was used in small and open spaces, Mesh Network can be used in a large and complicated environment inside one floor, the Long Range Wireless can be used between buildings. The data formats are different too with the communication methods. Gateways are divided into three groups, that configured with separated wireless modules and data conversion functions. As a result, all the groups will prepare a set of JSON data ready for application use.

To stream the data in real-time, normal HTTP requests are not efficient enough. Therefore, WebSocket protocol*2 was utilized in the proposed platform. It was layered over TCP, enables two-way communication between clients and servers that not rely on opening multiple HTTP connections. Every Gateway with an independent IP address can be used as a WebSocket server for real-time data streaming. The latency could be reduced as the Gateway sending data right after the conversion process.

For location information, the platform intends to separate indoor location and outdoor location. Outdoor location can be traced based on network or GPS. The indoor location could be preset with specific sensor identification. At the current stage of implementation, the location information process was done on the application side.

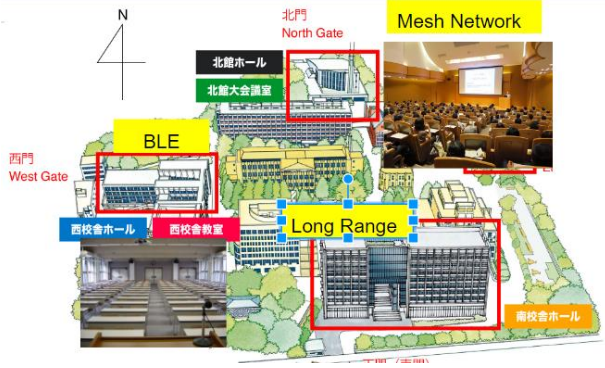

Fig. 3: Experiment Layouts in Keio University Mita Campus

The experiment was conducted on a university campus. The layout of the whole network was shown in Fig. 3. Three Local Sensor Groups were deployed in three remote buildings. BLE type was in a classroom of West Building; Mesh Network type was in the hall of North Building; and Long Range Wireless sensors are located in South, North and West Building. Gateways for those nodes were given independent IP address through WiFi connection.

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