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Wildlife Monitoring to Contribute Sustainable Development Goals - Concept, Requirement and Implementation -

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Abstract: With the increasing use of the Internet of things (IoT), heterogeneous IoT services are being offered to satisfy various needs. The Fed4IoT project aims to develop an IoT virtualization technology that could realize the possibility of a smart-city application that federates heterogeneous IoT services. In this project, wildlife monitoring was chosen as an example of this application. Wildlife damage is not only a problem in agriculture but also a problem for people who live in rural areas as it disturbs their daily lives. It is a universal problem that has existed for a significant amount of time. In this case, an IoT platform with end devices that consist of a cage, camera, target counter, etc. is employed, and local offices and residents are informed about the approach of an animal, the condition of the cage, etc. through an information-centric network. The obtained data is subsequently used in other Fed4IoT services. In this study, the IoT platform and its application to wildlife monitoring are discussed after its implementation, which would help achieve the United Nations Sustainable Development Goals© (17 goals and 169 targets to eradicate poverty and realize a sustainable world).

Keywords: Smart City, IoT, SDGs, Wildlife Monitoring, Data Federation

1. INTRODUCTION

The use of the Internet of things (IoT) has become widespread, and therefore there has been a rise in heterogeneous IoT services[1]. The different types of IoT services are wide-ranging in order to meet various needs. This includes using IoT technologies to solve social problems or its application to transport infrastructure [2], home security/automation [3], smart car parking [4], healthcare [5] and manufacturing factories [6].

The Fed4IoT project aims to federate these IoT services and develop a smart-city application. As part of the project, a wildlife-monitoring system in a rural and mountainous area was chosen as the use case. In this study, the characteristic of the IoT to easily realize a remote operation system through the network, was utilized. It was applied to a wildlife-monitoring IoT system for local cities. Additionally, the implementation of the proposed system would contribute to the sustainable development goals (SDGs) established by the United Nations. The SDGs are 17 goals and 169 targets that were determined by the United Nations in a bid to make the world sustainable[7].

This paper is organized as follows. In section 2, a summary of the SDGs is provided. In section 3, we summarize the Fed4IoT project. In section 4, wildlife damage in Japan is discussed. In section 5, a wildlife monitoring system is proposed to solve the wildlife damage problem. In section 6, more details about the system and its implementation are discussed. Finally, it should be noted that this paper is an extension of the paper that was submitted in 3ICT 2019 (2019 International Conference on Innovation and Intelligence for Informatics, Computing, and Technologies)[8].

2. SUMMARY OF THE SDGS

Engineers must reconsider their accomplishments, and how they influence society[9]. As an expert in a particular field, one must contribute to the development of society and examine the purpose of engineering. The guiding principles of the social responsibility of an engineer are indicated by the SDGs.

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SDGs are international goals that have been adopted by the United Nations Summit and written in "The 2030 Agenda for Sustainable Development." To eradicate poverty and realize a sustainable world, the goals aim to address not only social problems, such as poverty but also problems that are common in both developed countries and developing countries, such as climate change [10]. The SDGs are universal, and consist of 17 goals and 169 targets based on the ideal: "Leave no one behind.". In Figure 1, the 17 goals of the SDGs are shown.

Figure 1. 17 goals of SDGs

The Fed4IoT project and this study are based on these goals, and the goals shown below are the most important to the project and the study.

8. Decent work and economic growth
9. Industry, innovation, and infrastructure
11. Sustainable cities and communities
15. Life on land

The eighth and ninth goals are related to each other. In Japan, the amount of wildlife damage in agriculture is approximately 15 billion yen, which leads to farmers being less motivated to work toward their objectives. Nevertheless, if their concerns about wildlife damage are addressed, farmers could do their jobs without unnecessary burdens. This could be the foundation for innovation in agriculture. As shown in Figure 2, introducing IoT technology into wildlife monitoring encourages innovation.

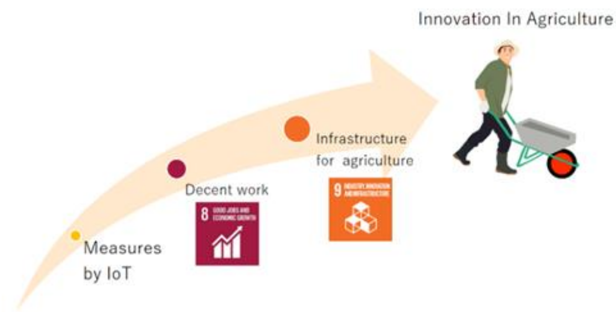

Figure 2. Taking IoT technology into a wildlife monitoring

Regarding the eleventh goal, this study and the project aims to make the lives of senior citizens more active. The proposed wildlife-monitoring system could aid in that regard and make the outdoor life of a senior citizen more active, which would help cities with an aging population; this would lead to a regeneration of suburban cities.

The lives of animals are strongly related to wildlife monitoring and therefore it is not acceptable for humans to be selfish and aid in the unnecessary harm of animals. Ethics and values in respecting the lives of others are essential for human beings. Thus, the fifteenth goal of the SDGs is an important factor in this study and the project.

3. SUMMARY OF THE FED4IOT PROJECT

Fed4IoT is a research and innovation project that is jointly funded by the European Commission and Japan's Ministry of Internal Affairs and Communications. This project aims to develop a smart-city application by using novel IoT virtualization technologies [11], [12]. As shown in Figure 3, this project has 4 locations (Murucia in Spain, Grasse in France, Hakusan and Kumamoto in Japan) and IoT services are provided at each location. The goal of the project is to solve social problems and promote social development, such as waste management and smart-car parking.

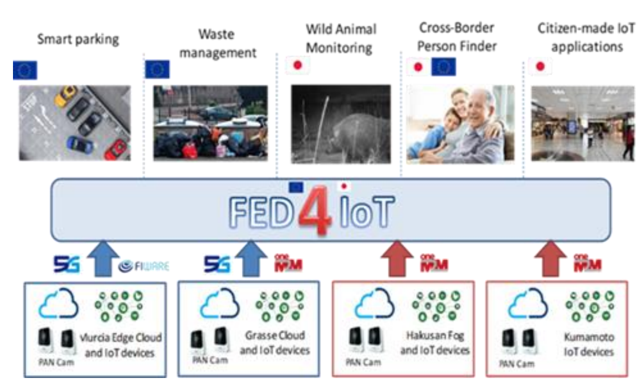

Figure 3. The schematic illustration of FED4IoT.

Smart-city applications require the use of a large-scale heterogeneous IoT system and hence may be too expensive. Thus, an IoT virtualization platform is required to cope with the expenditure problem and simplification. In this project, the focus was on the development of the IoT virtualization system through a cloud server that integrates heterogeneous IoT information.

This project has the following goals.

1. Federate heterogeneous IoT systems to form a cross-domain shared dataset
2. Devise IoT virtualization technologies for IoT systems
3. Develop virtual device technologies

To achieve these goals, it is necessary to have a tangible use case, develop the technology for it, and conduct a trial for it in order to verify the developed technology and its interoperability before standardizing it for popularization. Finally, the application service and collection of data are separated. As shown in Figure 4, the Kanazawa Institute of Technology has a campus called the Hakusanroku Campus in Hakusan city, Ishikawa prefecture [13]. Wildlife monitoring was chosen here as one of the use cases of the project and an attempt was made to verify the wildlife-monitoring IoT system at the Hakusanroku Campus. The goal is to make the network system a platform and send its data to the cloud for data collection of other Fed4IoT services, such as smart-car parking and waste management.

Figure 4. Hakusanroku Campus

4. THE PRESENT STATE OF WILDLIFE DAMAGE IN JAPAN

In this section, Japan's case is discussed as an example of wildlife damage. Despite the decrease in the amount of wildlife damage in agriculture[14], wildlife damage still costs Japan approximately 16.4 billion yen annually. The damaged area is approximately 5.3 million hectares and the total quantity amounts to 450,000 tons. The amount of damage done by each animal is shown in Figure 5; damages done by deer and wild boars seem to be the highest. Despite its decrease, damages done by deer and wild boars remain at 34% and 29%, respectively. Damage done by crows seems to be the most frequent among the damages caused by birds; these damages amount to approximately 1.5 billion yen [15]. Wildlife damage is not only an agricultural problem but also a residential one. Cases in which animals appear in residential areas have been increasing as a consequence of their habitats spreading.

Kind of animal	Amount of damage in 2016 (billion yen)	Amount of damage in 2017 (billion yen)
Deer	5.6	5.5
Wild boar	5.1	4.8
Monkey	1.0	0.9
Other animals	1.9	2.0
Crow	1.6	1.5
Other birds	1.9	1.7

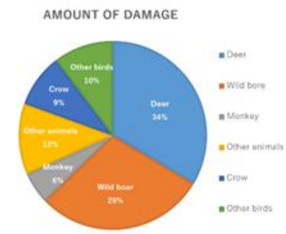

Figure 5. The amount damage of Wildlife attack in Japan

A. *The present states of wildlife damage in Hakusan-shi*

The amount of wildlife damage in Hakusan city, Ishikawa-ken, which is the location for this research, has been increasing annually[16]. In Figure 6, the amount of damage done by wild boars in Ishikawa-ken and Hakusan city is shown. The Figure 6 is referred from [16].

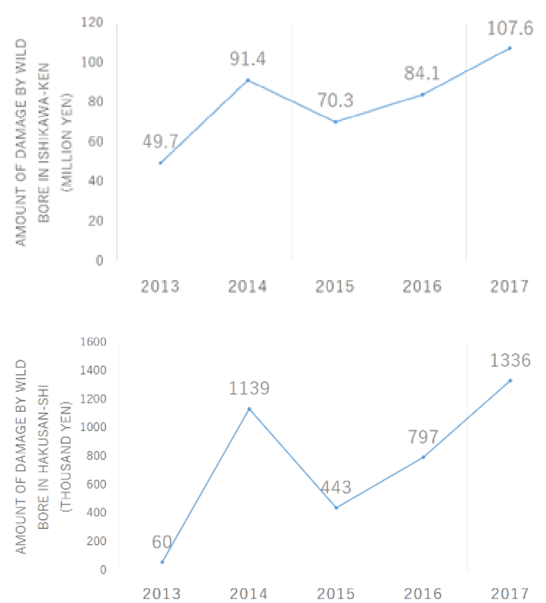

Figure 6. The amount of damage by wild boar in whole Ishikawa-ken and Hakusan city

According to a report by the local government of the Ishikawa prefecture, the amount of damage done by monkeys amounts to approximately 3 million yen in the Ishikawa prefecture. Furthermore, 2.7 million yen out of the total damage is damage that has taken place in Hakusan city. Therefore, most of the damage by monkeys happens in that city; these damages do not only occur in agriculture but also in the daily lives of people as they are also attacked by monkeys.

Wildlife damage leads to a greater lack of manpower in agriculture. Moreover, rural and mountainous areas, where an aging population is a big concern, are not ideal places for elderly people to live in without worrying about animal attacks; this diminishes the vitality of local cities. Thus, wildlife damage plays an important role in the decline of local cities.

5. PROPOSAL FOR A WILDLIFE MONITORING SYSTEM USING IOT

Electric fences and other measures are currently being adopted to combat wildlife damages[17]. An example of these measures is local hunters who manage the number of wildlife, such as deer, wild boar, and bears [18]. Another measure, habitat maintenance, such as buffer zone maintenance and removal of abandoned crops, has also been used against wildlife damages. Recently, drones and other unmanned aerial vehicles have also been utilized for wildlife monitoring [19].

However, these methods are problematic as they can be heavy burdens on humans, and concerning drones, it is necessary to follow laws such as the Civil Aeronautics Act when they are being used. In this study, a wildlife-monitoring system through a network is proposed, which would reduce the burdens on humans.

The schematic image of the proposed system is shown in Figure 7. As shown in the figure, the system has a video collection server that collects information from cameras and cages. The collected data is subsequently transformed into a general file form and sent to a local console for general users and government offices. Subsequently, this information is transferred to a cloud server to be made readily available for other Fed4IoT services.

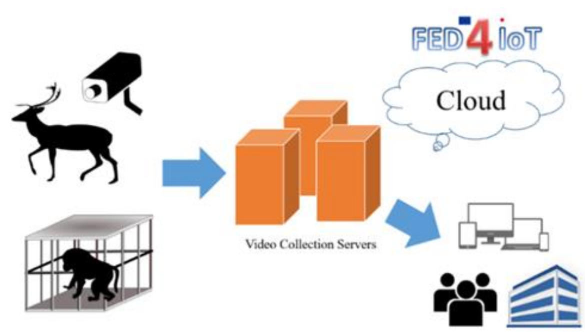

Figure 7. The schematic image of a system which we propose

6. SYSTEM MODEL AND DETAILS

In this section, more details regarding the IoT platform proposed in section V and its communication system are discussed. Moreover, the configurations of each end device and implementation are also discussed.

A. IoT system platform

The IoT system that is being introduced is shown in Figure 8. More technical details on the IoT platform which is shown in the Figure 7 is shown in the Figure 8. In this study, an IoT system using the Message Queuing Telemetry Transport (MQTT) [20] is proposed. This will serve as a means of information-centric networking. There are three patterns of end-devices and two different ways of transforming between an end device and an MQTT device. Patterns 1 and 2 are used in close ranges, where Wi-Fi is used to connect the end device and MQTT device. However, Pattern 3 is used in long ranges from residential areas, where it is assumed that there are difficulties in securing enough electricity. Therefore, LoRaWAN, which is specialized in low electricity usage, is used [21]. In addition, the programmable logic controller (PLC) in Patterns 2 and 3 behaves similarly to the "if" in a programming language; it turns the device on under a certain condition. The information transferred to the MQTT is sent to a data collection server and transformed into a general format, such as the JPEG or MPEG. The transformed information is then transferred to the cloud server for other Fed4IoT services.

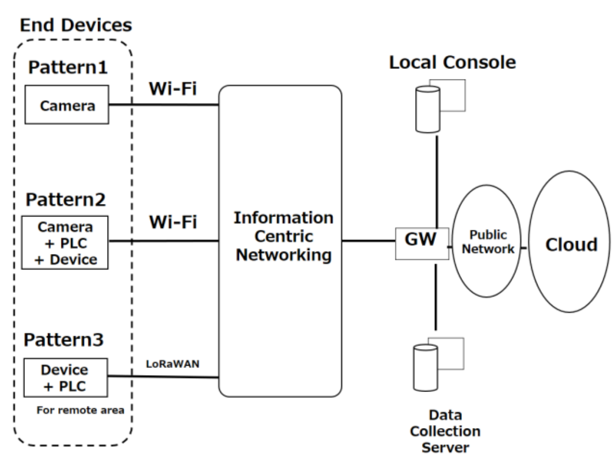

Figure 8. The schematic image of the IoT platform

B. MQ Telemetry Transport (MQTT) Protocol

Current addressing using an IP address makes it difficult to track where the data comes from when animals are being detected. In this use case, it is considered that this system is for those who are not IT users; thus, as shown in Figure 9, information and communication technology (ICT) of the topic-addressing type makes data operations easier for those who do not use IoT[22]. To use each end device flexibly, the IoT platform is built using an MQTT network. MQTT is a communication protocol of the publish/subscribe type[23]. For the publisher, an optional topic name is related to transmit the information before the information is transferred to a broker. For subscribe, the protocol takes data by naming each topic according to the request of the user.

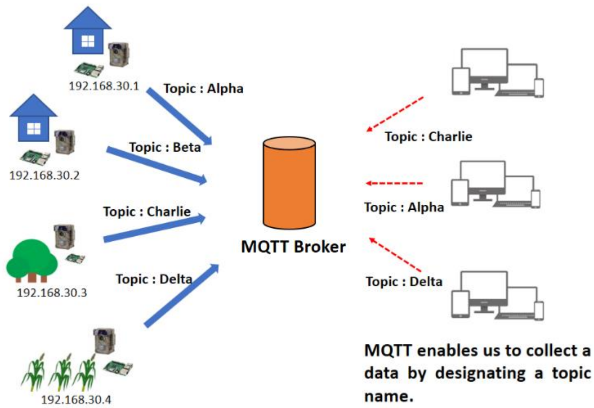

Figure 9. The image of the MQTT network

C. Classification to the wildlife-monitoring system

In Figure 10, a system introduced in the Figure 8 that is transformed into a wildlife-monitoring system is shown. Details are provided with videos for local residents in Patterns 1 and 2; they are notified of an animal's approach through the ICT network. Moreover, cages and sensors are provided to observe the conditions of the cage in Pattern 3 from a long-range. Local residents are notified of the information collected by the sensors through the ICT network.

There are two types of cameras, trail and network cameras, which means a video collection server needs to be provided to integrate the different kinds of video formats. The video collection server will transform the transferred video with heterogeneous formats into a general format, such as the JPEG or MPEG4, as animal recognition information before being transferred to a local console and the cloud server for Fed4IoT.

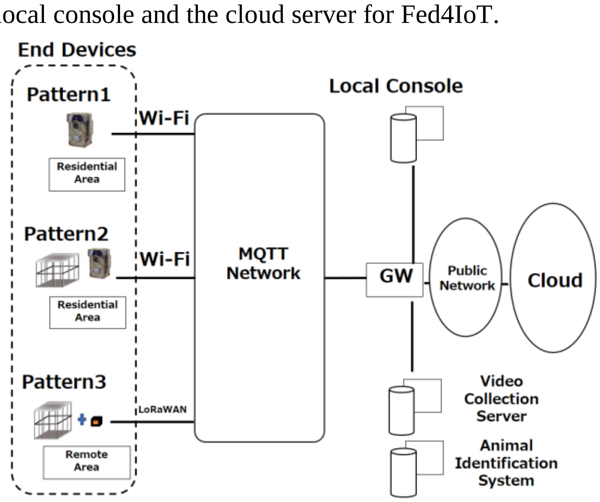

Figure 10. The schematic illustration of the wildlife monitoring system

D. Configuration of Pattern 1 and implementation

In Figure 11, a model of Pattern 1 is shown. In this system, pictures and videos that are captured by the trail and network cameras are transferred to the MQTT device through wireless communication. Subsequently, local residents, hunters, and the local office are notified of an animal's approach. Wi-Fi is adopted as the network of choice between the MQTT device and video camera because of the proximity between the trail and network cameras and the residential area. The MQTT device gets data from each MQTT device and transfers them to a video collection server through the MQTT network. The received data with heterogeneous formats are then transformed into general formats, such as the JPEG or MPEG.

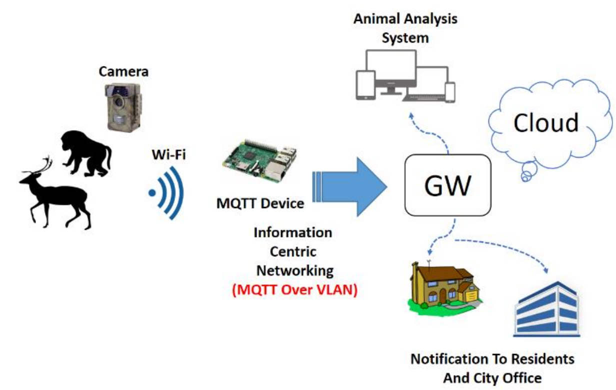

Figure 11. The image of Pattern 1

E. Configuration of Pattern 2 and implementation

1) End device configuretion

In Fig. 12, the model of Pattern 2 is shown. Pattern 2 comprises a cage, a target counter, and a network camera for overseeing the cage's condition. The network camera observes animals, and if the target counter senses a set number of animals, the video collection server starts recording. This pattern is also used in areas that are close to the residential area. Similar to Pattern 2, Wi-Fi is used as the network between the MQTT device and the end device.

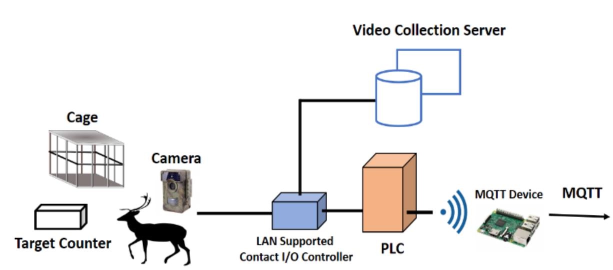

Figure 12. The image of the Pattern 2

The control flow of a recording process at the video collection server is illustrated in Figure 13. There is a LAN-supported contact I/O controller and a target counter before the cage counts the number of animals that approach it. This is an on/off control section. When no animals are in the cage, data from the camera is transferred into the MQTT device only. Nevertheless, when the target counter senses a set number of animals, the LAN-supported contact I/O controller transforms the contact signal into an IP address, and data from the network camera is then transferred into the MQTT device before the video collection server and the video collection server starts recording. To realize this system, a PLC is used. The PLC receives the number of the target counter as a contact signal and commands the video collection server to record based on the received signal.

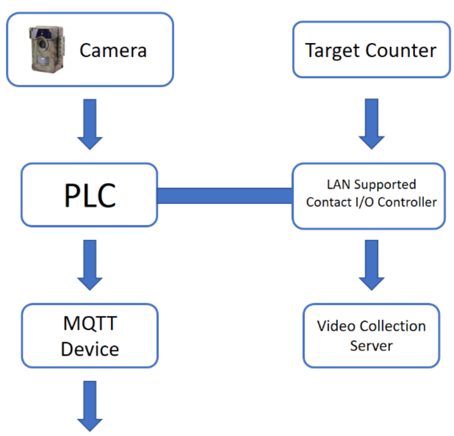

Figure 13. The recording process diagram

2) Implementation of the Pattern 2 end device

As shown in Figure 14, the Pattern 2 end device consists of sensors and cameras. All data from the sensors are collected at the PLC and sent to the MQTT device. The PLC decides whether to send data from the camera to the network interface or not when it detects a signal from the sensors.

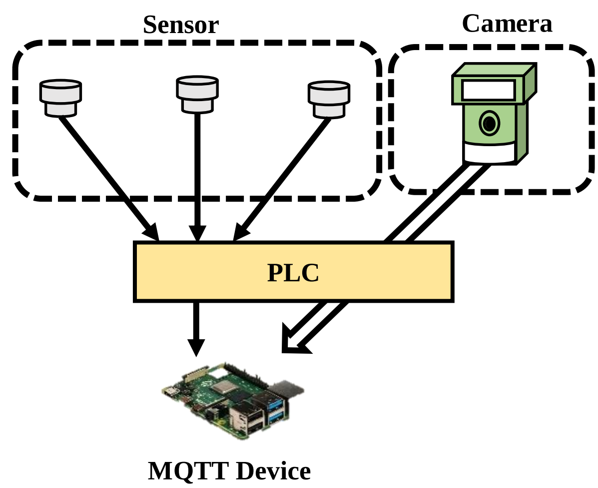

Figure 14. Image of the end device with PLC

The structure of a record-processing system in the end device of pattern 2 is shown in Figure 15. When the PLC receives signals from the infrared sensor (passive sensor) and the target counter, it gives instructions to the camera to start recording and send its information to the video collection server. Videos from the trail camera are analog yet the video collection server only supports digital videos, hence, a video encoder is set up to convert the analog video into a digital one.

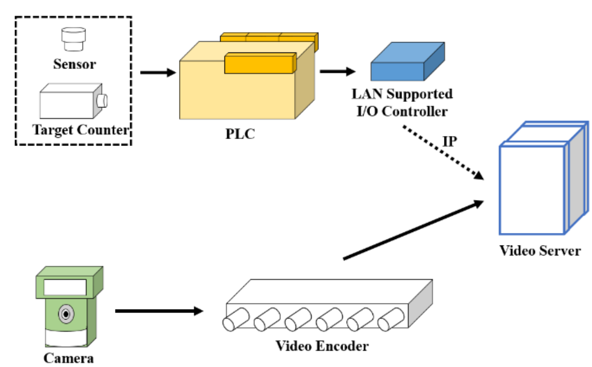

Figure 15. Composition of the record processing system

In Figure 16, the appearance of the pattern 2 end device is depicted.

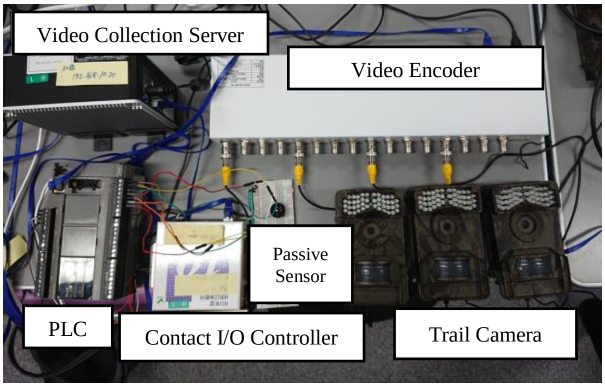

Figure 16. Composition of the record processing system

3) Detail of the flow chart of the record processing system

The PLC works on a ladder logic that a relay circuit is encoded into, which is shown in Figure 17. In this ladder logic, the camera will start recording when a signal from sensor 1 (contact point) is provided as the input. After that, the PLC will start counting and record with another camera if another contact point is provided as the input.

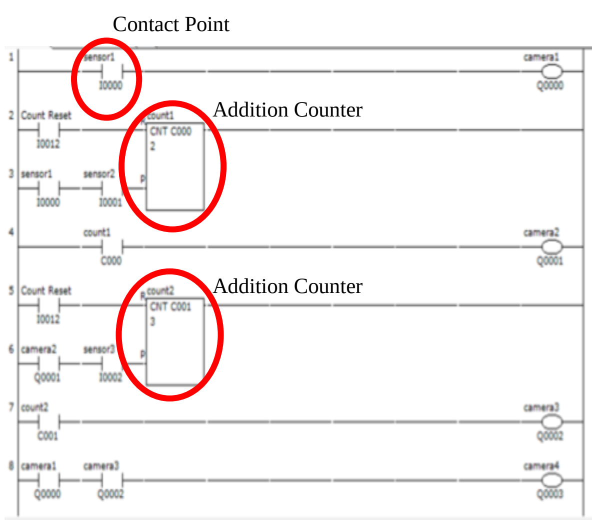

Figure 17. Ladder logic of the PLC

Figure 18 shows a flow chart of the ladder logic.

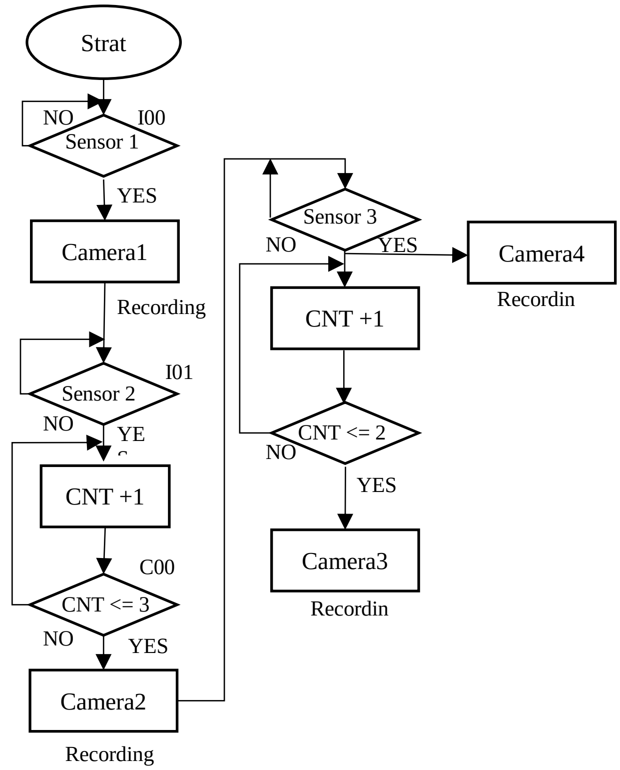

Figure 18. Flow chart of the ladder logic

(1) If sensor 1 (contact point) is detected, the PLC will start recording with camera 1 and the signal will be sent to the sensor 2.

(2) If sensor 2 is detected, the PLC will start counting with the addition counter and start recording with camera 2. Subsequently, the signal will be sent to sensor 3.

(3) If sensor 3 is detected, the PLC will start recording with camera 4, start counting with the addition counter, and start recording with camera 3.

F. *Configuration of Pattern 3 and implementation*

1) Detail of the pattern 3 end device

In Figure 19, the model of Pattern 3 is shown. A passive sensor is mounted on a cage and it senses an animal gets trapped in the cage. It is assumed that Pattern 3 is utilized far from the residential area; therefore, the cage's condition is transferred through the LoRaWAN for long-range network communication.

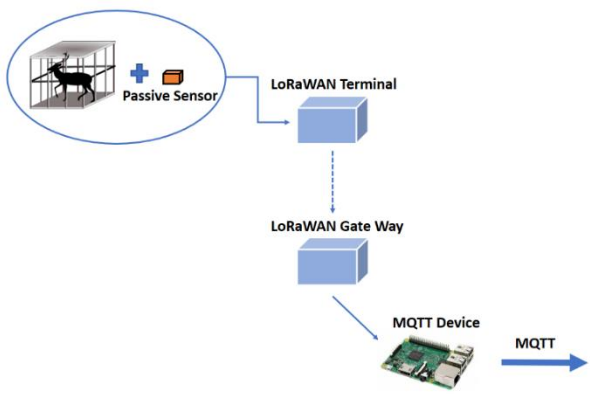

Figure 19. The image of Pattern 3

The control flow of Pattern 3 is shown in Figure 20. The passive sensor outputs data that contains information about the animal that is trapped. The data is then made into a data packet on a LoRaWAN device and transferred to a gateway. On the LoRaWAN gateway, the transferred data is then assembled into a single packet and transferred to an MQTT device. Because Pattern 3 is assumed to be used at long range, and difficulties in securing the required, stable electricity, the LoRaWAN, which has low power consumption [24], is used.

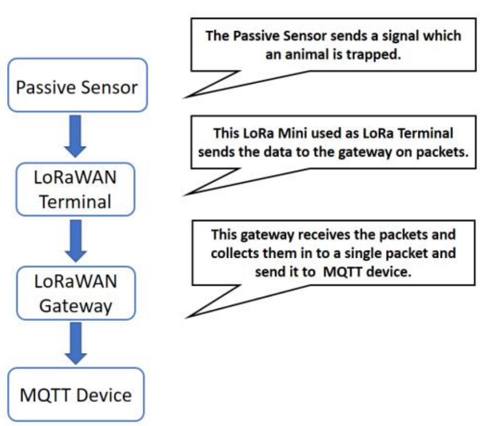

Figure 20. Operation process in the Pattern 3

2) Implementation of the Pattern 3 end device

The Pattern 3 end device was designed to monitor a cage in a remote area from the residential area because the LoRaWAN supports limited resources. Therefore, the end device has a simple structure that contains a few sensors. As shown in Figure 21, all data from sensors are collected and integrated at the network interface prior to being sent to the gateway. In order to reduce packets between the network interface and gateway, [25] was applied.

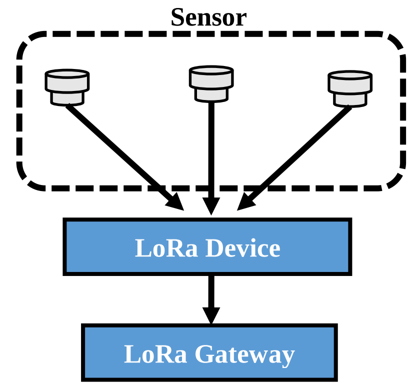

Figure 21. Outline of the Pattern 3 end device

In Figure 22, the structure of the Pattern 3 end device that is applied to a wildlife monitoring system is shown. The end device consists of 4 sensors; a luminance sensor, temperature/ humidity sensor, acceleration sensor, and pressure sensor. Data from the temperature/humidity sensor and the luminance sensor are treated as weather data. On the other hand, data from the acceleration sensor and the pressure sensor are handled as data regarding the condition of the cage.

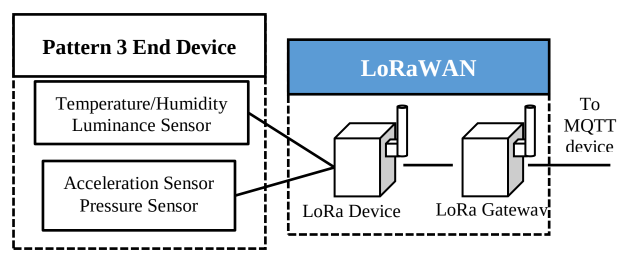

Figure 22. The structure of the Pattern 3

The Pattern 3 end device that generates weather data is shown in Figure 23. This end device consists of a temperature/humidity sensor, luminance sensor, LoRaWAN device and battery. The LoRaWAN device connects LoRaWAN gateway with Wi-Fi.

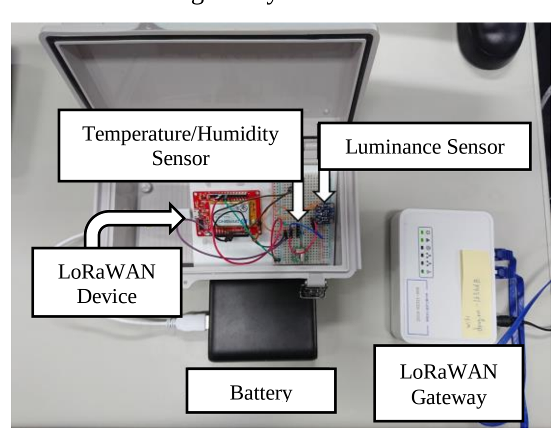

Figure 23. Appearance of the Pattern 3 end device for common data

The animal capture system with the acceleration sensor and pressure sensor is shown in Figure 24. The acceleration sensor monitors the movement of the door and the pressure sensor monitors the pressure the moment an animal gets trapped.

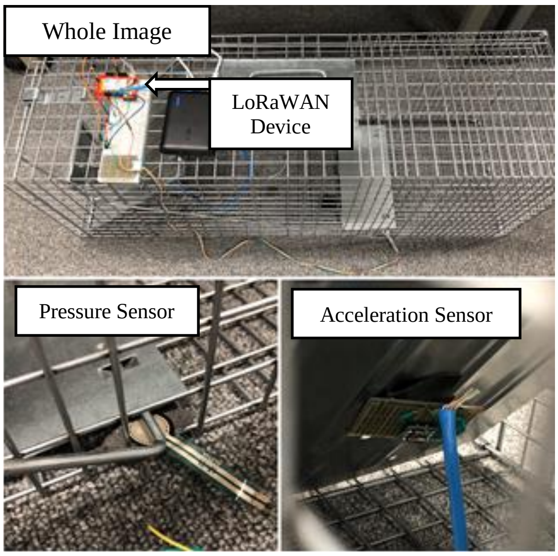

Figure 24. Appearance of the animal capture system for the Pattern 3

3) Communication format of LoRaWAN

In Pattern 3, data from the sensors are sent to the LoRaWAN gateway based on a data format that is determined in advance. In Figure 25, the data format is shown, which consists of 18 bytes with “Start Delimiter”, “Header”, “Sensor Data” and “Cyclic Redundancy Check (CRC)”.

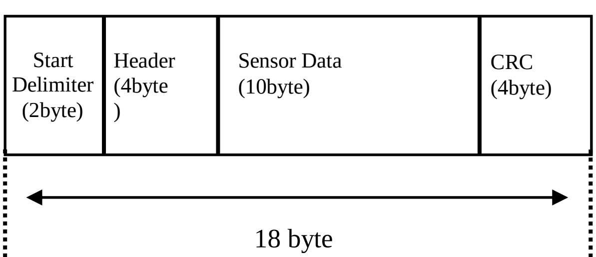

Figure 25. The communication format of LoRaWAN

Received data at the LoRaWAN gateway is shown in Figure 26. The programming code of the LoRaWAN gateway and the LoRaWAN device is able to be edited with the Arduino IDE, so the Figure 26 was captured in the serial monitor of the LoRaWAN gateway through the Arduino IDE.

```
[2019-11-26 10:41:43.048] got flame: 10 ID = 111 .temperature . 24.C humdity . 37.% Lux . 206. lux Rain . 255.%
[2019-11-26 10:41:54.082] got flame: 10 ID = 111 .temperature . 24.C humdity . 37.% Lux . 206. lux Rain . 255.%
[2019-11-26 10:42:05.111] got flame: 10 ID = 111 .temperature . 24.C humdity . 36.% Lux . 207. lux Rain . 255.%
[2019-11-26 10:42:16.125] got flame: 10 ID = 111 .temperature . 24.C humdity . 36.% Lux . 206. lux Rain . 255.%
[2019-11-26 10:42:18.278] got flame: 10 ID = 112 .Cage ON! :  kanatsu . 20 kasokudo_x . 180 kasokudo_y . 185
[2019-11-26 10:42:27.154] got flame: 10 ID = 111 .temperature . 24.C humdity . 36.% Lux . 201. lux Rain . 255.%
[2019-11-26 10:42:38.183] got flame: 10 ID = 111 .temperature . 24.C humdity . 36.% Lux . 202. lux Rain . 255.%
[2019-11-26 10:42:49.212] got flame: 10 ID = 111 .temperature . 24.C humdity . 37.% Lux . 216. lux Rain . 255.%
[2019-11-26 10:43:00.226] got flame: 10 ID = 111 .temperature . 24.C humdity . 36.% Lux . 204. lux Rain . 255.%
[2019-11-26 10:43:11.255] got flame: 10 ID = 111 .temperature . 24.C humdity . 36.% Lux . 200. lux Rain . 255.%
[2019-11-26 10:43:17.417] got flame: 10 ID = 112 .Cage ON! :  kanatsu . 20 kasokudo_x . 181 kasokudo_y . 185
[2019-11-26 10:43:22.284] got flame: 10 ID = 111 .temperature . 24.C humdity . 36.% Lux . 197. lux Rain . 255.%
[2019-11-26 10:43:33.298] got flame: 10 ID = 111 .temperature . 24.C humdity . 36.% Lux . 197. lux Rain . 255.%
[2019-11-26 10:43:44.327] got flame: 10 ID = 111 .temperature . 24.C humdity . 37.% Lux . 198. lux Rain . 255.%
[2019-11-26 10:43:55.356] got flame: 10 ID = 111 .temperature . 24.C humdity . 37.% Lux . 198. lux Rain . 255.%
[2019-11-26 10:44:06.386] got flame: 10 ID = 111 .temperature . 24.C humdity . 37.% Lux . 198. lux Rain . 255.%
[2019-11-26 10:44:17.430] got flame: 10 ID = 112 .Cage ON! :  kanatsu . 20 kasokudo_x . 180 kasokudo_y . 185
[2019-11-26 10:44:18.554] got flame: 10 ID = 111 .temperature . 24.C humdity . 37.% Lux . 196. lux Rain . 255.%
[2019-11-26 10:44:28.428] got flame: 10 ID = 111 .temperature . 24.C humdity . 37.% Lux . 193. lux Rain . 255.%
[2019-11-26 10:44:39.458] got flame: 10 ID = 111 .temperature . 24.C humdity . 37.% Lux . 199. lux Rain . 255.%
[2019-11-26 10:44:50.487] got flame: 10 ID = 111 .temperature . 24.C humdity . 37.% Lux . 199. lux Rain . 254.%
[2019-11-26 10:45:01.500] got flame: 10 ID = 111 .temperature . 24.C humdity . 36.% Lux . 194. lux Rain . 255.%
[2019-11-26 10:45:12.530] got flame: 10 ID = 111 .temperature . 24.C humdity . 36.% Lux . 201. lux Rain . 255.%
[2019-11-26 10:45:17.459] got flame: 10 ID = 112 .Cage ON! :  kanatsu . 20 kasokudo_x . 181 kasokudo_y . 185
[2019-11-26 10:45:23.559] got flame: 10 ID = 111 .temperature . 24.C humdity . 37.% Lux . 198. lux Rain . 255.%
[2019-11-26 10:45:34.572] got flame: 10 ID = 111 .temperature . 24.C humdity . 37.% Lux . 198. lux Rain . 255.%
[2019-11-26 10:45:45.603] got flame: 10 ID = 111 .temperature . 24.C humdity . 37.% Lux . 198. lux Rain . 255.%
[2019-11-26 10:45:56.632] got flame: 10 ID = 111 .temperature . 24.C humdity . 37.% Lux . 198. lux Rain . 255.%
[2019-11-26 10:46:07.662] got flame: 10 ID = 111 .temperature . 24.C humdity . 36.% Lux . 199. lux Rain . 255.%
[2019-11-26 10:46:17.490] got flame: 10 ID = 112 .Cage ON! :  kanatsu . 21 kasokudo_x . 181 kasokudo_y . 185
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Figure 26. Result of the received data

As shown in the Figure 26, 2 types of data were shown. The line with ID = 111 is data sent from the end device shown in the Figure 23, and it is updated every 11 seconds. Another line with ID = 112 is data sent from the animal capture system shown in the Figure 24, and it is updated every 60 seconds.

7. CONCLUSION

A remote-controlled IoT system through a network was proposed as part of the Fed4IoT project. Fed4IoT is a project that aims to develop an IoT smart-city application and divide the IoT system from the IoT application. Currently, IoT technology is often used to offer various services. Therefore, it is economically beneficial to build an IoT smart city to integrate heterogeneous IoT systems into the cloud server. In this study, wildlife monitoring was chosen as a use case of the Fed4IoT project. In this system, two types of models were used; one model at close range and another at long range. The data transferred from them were sent to a data collection server through the MQTT communication and transformed into general formats, such as the JPEG and MPEG. Finally, the transformed data were transferred to a local console and cloud server for Fed4IoT. Moreover, a wildlife-monitoring system, which used this platform, was proposed. There are 3 patterns of end devices in the system. The end devices of Pattern 2 and Pattern 3 were implemented in practice. In Pattern 2, the PLC was mounted for the record processing. In addition, the capture system with the LoRaWAN in the Pattern 3 end device was verified. To conclude, this study serves as a contribution to the SDGs that were established by the United Nations. Future works could be done to verify the Pattern 1 end device and plan an on-site investigation.

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