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Concept for and Implementation of Wildlife Monitoring to Contribute Sustainable Development Goals

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***Abstract*—With the increasing use of the Internet of things (IoT), heterogeneous IoT services are offered to satisfy various needs. The Fed4IoT project aims to develop an IoT virtualization technology to realize a smart-city application that federates heterogeneous IoT services. In this project, wildlife monitoring was chosen as an example of the application. Wildlife damage is not only an agricultural problem but also is disturbing the daily lives of people who live in rural areas. It has been a universal problem for a long time. In this use 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 of an animal's approach, the condition of the cage, etc. through an information-centric network. The obtained data are used in other Fed4IoT services. In this work, the IoT platform and its application to wildlife monitoring are discussed. Moreover, this study and the project aim to help in the achievement of 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

I. Introduction

Since the Internet of things (IoT) has become widespread, heterogeneous IoT services have been offered. To meet various needs, the types of IoT service are wide-ranging. In addition, IoT technologies can solve social problems. Transport infrastructure [1], home security/automation [2], smart car parking [3], and manufacturing factories [4] are typical examples of IoT use cases.

The Fed4IoT project aims for federation of these IoT services and development of a smart-city application. As a part of the project, a wildlife-monitoring system in a rural and mountainous area was chosen as a use case. In this study, advantage is taken of IoT's characteristic of easily realizing a remote operation system through a network, and it is applied to a wildlife-monitoring IoT system for local cities that are behind the wildlife-monitoring management. Furthermore, this proposal can contribute to the Sustainable Development Goals (SDGs) that the United Nation established. The SDGs are 17 goals and 169 targets determined by the United Nations in order to make the world sustainable.

II. Summary of SDGs

Engineers must reconsider their accomplishments and how they influence society. As an expert in a particular field, one must develop society and examine the purpose of engineering. The guiding principles for an engineer's social responsibility are indicated by the SDGs.

SDGs are international goals adopted in 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 common problems between developed countries and developing countries, such as climate change [5]. The SDGs are universal and consist of 17 goals and 169 targets based on the ideal: "Leave no one behind." Fig. 1 shows the 17 SDGs

Fig.1. 17 goals of SDGs

The Fed4IoT project and this study are based on these goals, and the goals shown below are 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, and it leads to less motivation for farmers to work toward their objectives. If their concern about wildlife damage is lessened, farmers can work at their jobs without unnecessary care. This can be the foundation for innovation in agriculture. As Fig. 2 shows, introducing IoT technology into wildlife monitoring encourages innovation.

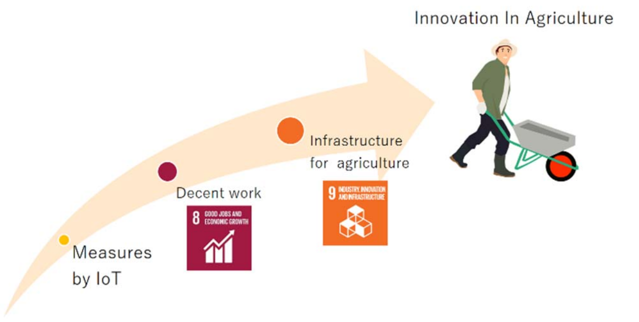

Fig.2. Taking IoT technology into a wildlife monitoring

Regarding the eleventh goal, a goal of this study and the project is to make senior citizens' lives more active. The proposed wildlife-monitoring system makes a senior citizen's outdoor life more active and helps cities where population aging is a serious problem. Therefore, it leads to a renewal of suburban cities.

Animal's lives are integrally related to wildlife monitoring, so it is not acceptable to be selfish and harm animals unnecessarily. Ethics and values of respect for the lives of others are essential for human beings. So, the fifteenth goal of the SDGs is an important factor for this study and the project.

III. SUMMARY OF FED4IOT PROJECT

Fed4IoT is a research and innovation project jointly funded by the European Commission and Japan's Ministry of Internal Affairs and Communications. This project aims at the development of a smart-city application using novel IoT virtualization technologies [6], [7]. As Fig. 3 shows, its goal is to solve social problems and promote social development, such as waste management and smart-car parking.

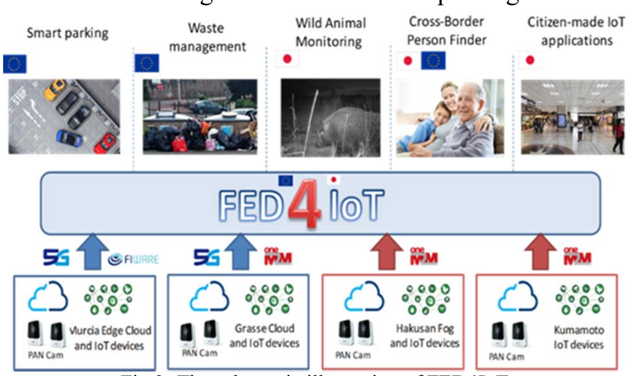

Fig.3. The schematic illustration of FED4IoT

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

This project has three goals.

1. Federate heterogeneous IoT systems to form a cross-domain shared dataset

2. Devise IoT virtualization technologies for providing IoT systems

3. Develop virtual device technologies

To achieve these goals, it is necessary to have a tangible use case, develop technology for it, trial it to verify the developed technology and its interoperability, and standardize it for popularization. Finally, the application service and collection of data are separated. As Fig. 4 shows, Kanazawa Institute of Technology has a campus called Hakusanroku Campus in Hakusan city, Ishikawa prefecture [8]. Wildlife monitoring was chosen 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 for other Fed4IoT services, such as smart-car parking and waste management.

Fig.4. Hakusanroku Campus

IV. THE PRESENT STATES OF WILDLIFE DAMAGE IN JAPAN

In Japan, although the amount of wildlife damage in agriculture has been decreasing, it still costs approximately 16.4 billion yen annually. Also, the damaged area is 5.3 million hectares, and the total quantity is 450,000 tons. Fig. 5 shows the amount of damage for each animal. Damage by deer and wild boar is the biggest part of the entire damage. It has been decreasing, but the damage by deer remains 34%, and the damage by wild boar remains 29%. Damage by crows is the biggest part of damage caused by birds and runs into approximately 1.5 billion yen [9]. Wildlife damage is not only an agricultural problem. Cases in which animals appear in residential areas have been increasing, because their habitats have been 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

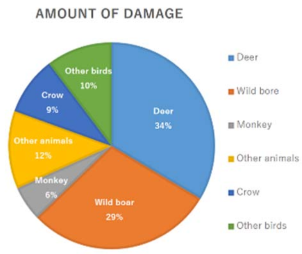

Fig.5. The amount damage of Wildlife attack in Japan

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 year by year [10]. Fig. 6 shows the amount of damage by wild boar in Ishikawa-ken and Hakusan city.

According to a report by the local government of Ishikawa prefecture, the amount of damage by monkeys is approximately 3 million yen in Ishikawa prefecture, and 2.7 million yen out of the total damage is the damage in Hakusan city, so most of the damage by monkeys is in that city. Also, the damage by monkeys is not only in agriculture. They also attack the people living there.

Wildlife damage leads to a greater lack of manpower in agriculture. Also, rural and mountainous areas where population aging is a big problem are not places where elderly people can live without worrying about animal attacks, and this diminishes the vitality of local cities. Therefore, wildlife damage is a big part of the reason why local cities do not show their charm.

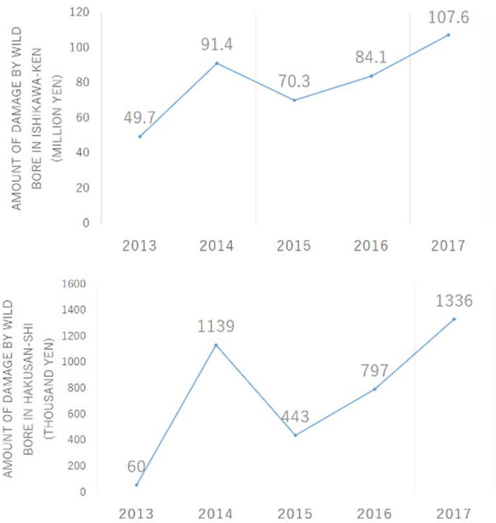

Fig.6. The amount of damage by wild boar in whole Ishikawa-ken and Hakusan city

V. PROPOSAL OF A WILDLIFE MONITORING SYSTEM USING IOT

In Japan, electric fences and other measures are currently adopted as a measure against wildlife damage, and also local hunters manage the number of wildlife, such as deer, wild boar, and bears [11]. In addition, habitat maintenance, such as buffer zone maintenance and removal of abandoned crops, is one of measures against wildlife damage. Recently, drones and other unmanned aerial vehicles have also been utilized for wildlife monitoring [12].

However, these methods are problematic, because they are heavy in human burden, and it is necessary to follow such laws as the Civil Aeronautics Act when using drones. In this study, to reduce this burden, a wildlife-monitoring system through a network is proposed.

As Fig. 7 shows, the system has a video collection server collecting information from cameras and cages, and the data are transformed into general file forms and sent to a local console for general users and government offices. Moreover, this information is transferred to a cloud server to use in other Fed4IoT services.

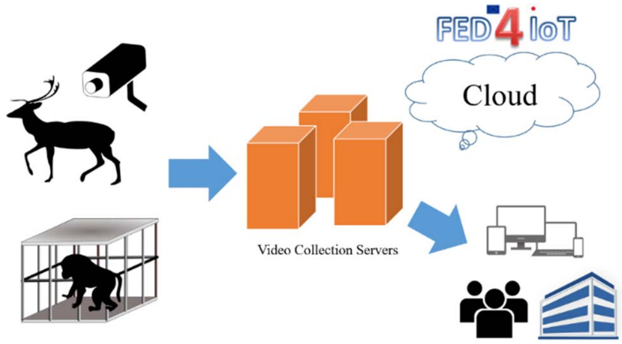

Fig.7. The schematic image of a system which we propose

VI. SYSTEM MODERL AND DETAILS

A. IoT system platform

Fig. 8 shows the IoT system introduced. In this study, an IoT system using Message Queuing Telemetry Transport (MQTT) [13] is proposed. It is a means of information-centric networking. There are three patterns of end device and also two different ways of transformation between an end device and an MQTT device. Patterns 1 and 2 are used at close range, and Wi-Fi is used to connect the end device and the MQTT device. In addition, Pattern 3 is used at a long range from residential areas, and it is assumed that it is difficult to secure enough electricity there. Therefore, LoRaWAN, which is specialized in low electricity usage, is used [14]. In addition, the programmable logic controller (PLC) in Patterns 2 and 3 is like the “if” in a programming language, and it makes the device turn on when under a certain condition. The information transferred to MQTT is sent to a data collection server and transformed into a general format, such as JPEG or MPEG. The transformed information is transferred to the cloud server for other Fed4IoT services.

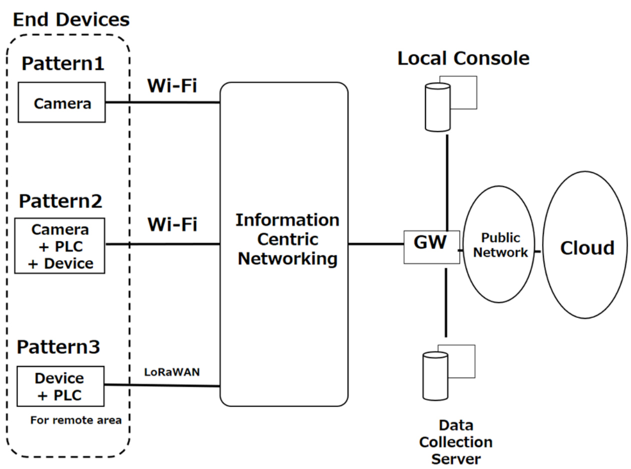

Fig.8. The schematic image of the IoT platform

B. Information-centric networking

Current addressing using an IP address makes it difficult to realize where the data came from when animals were detected. In this use case, it is considered that this system is for those who are not IT users, so, as Fig. 9 shows, information and communication technology (ICT) of the topic-addressing type makes data operations easier for those who do not use the IoT. 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. For the publisher, an optional topic name is related to transmit information, and the information is transferred to a broker. For subscribe, the protocol takes data by naming topic name where one wants.

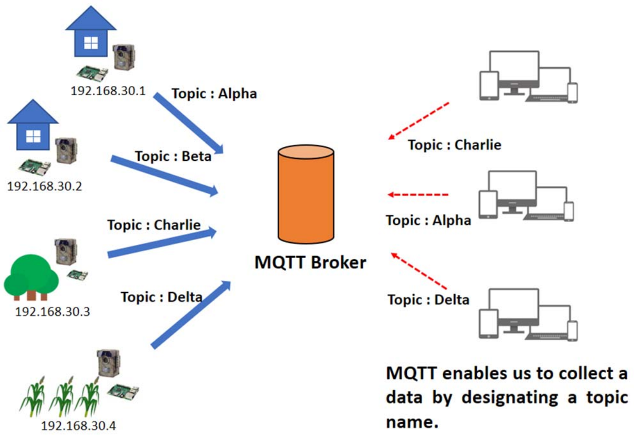

Fig.9. The image of information centric networking

C. Transformation to the wildlife-monitoring system

Fig. 10 shows a system in which is specialized into a wildlife-monitoring system. Detail is provided with video for local residents in Patterns 1 and 2, and they are notified of an animal's approach through the ICT network. Moreover, cages and sensors are provided to watch the cage's condition in Pattern 3 at a long range. Local residents are notified of its information through the ICT network.

There are two types of camera (trail and network cameras), so a video collection server needs to be provided to integrate different kinds of video format. It transforms transferred video with heterogeneous formats into a general format, such as JPEG or MPEG4, as animal recognition information. In addition, it is transferred to a local console and the cloud server for Fed4IoT.

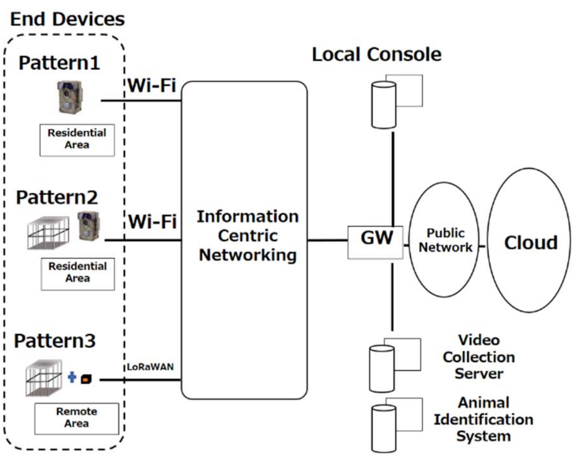

Fig.10. The schematic illustration of the wildlife monitoring system

1) Pattern 1

Fig. 11 shows a model of Pattern 1. In this system, pictures and videos that the trail and network cameras captured are transferred to the MQTT device through wireless communication. After that, local residents, local hunters, and the local office are notified of an animal's approach. Because of placing the trail camera and the network camera close to the residential area, Wi-Fi is adopted as a network between the MQTT device and the video camera. 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 transformed into a general format, such as JPEG or MPEG, there.

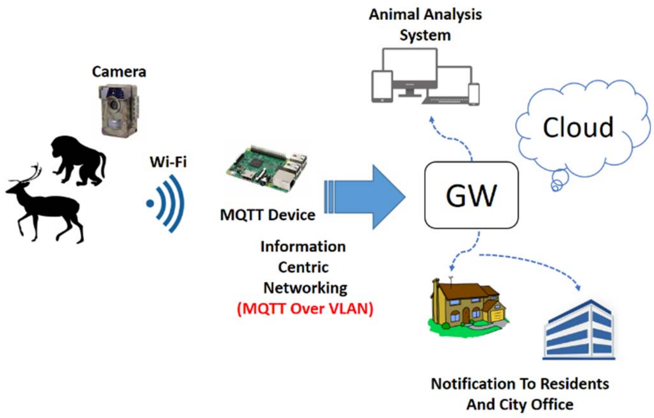

Fig.11. The image of Pattern1

2) Pattern 2

Fig. 12 shows a model of Pattern 2. In Pattern 2, there are a cage, target counter, and a network camera for overseeing a 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 close to the residential area, so Wi-Fi is used as the network between MQTT device and the end device.

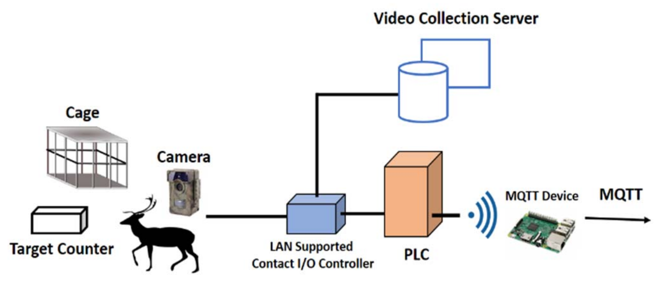

Fig.12. The image of Pattern 2

Fig. 13 shows the control flow of a recording process at the video collection server. There are a LAN-supported contact I/O controller and a target counter before the cage counting the number of animals coming into the cage. This is an on/off control section. When no animals are in the cage, data from the camera are transferred into only the MQTT device. 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 are transferred into the MQTT device; then, the video collection server and the video collection server start 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.

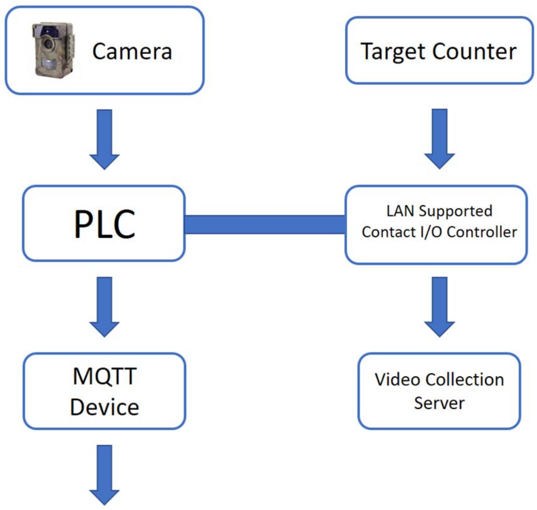

Fig.13. The recording process diagram

3) Pattern 3

Fig. 14 shows a model of Pattern 3. A passive sensor is mounted on a cage, and it senses an animal trapped in the cage. It is assumed that Pattern 3 is utilized far from the residential area, so the cage's condition is transferred through LoRaWAN for long-range network communication.

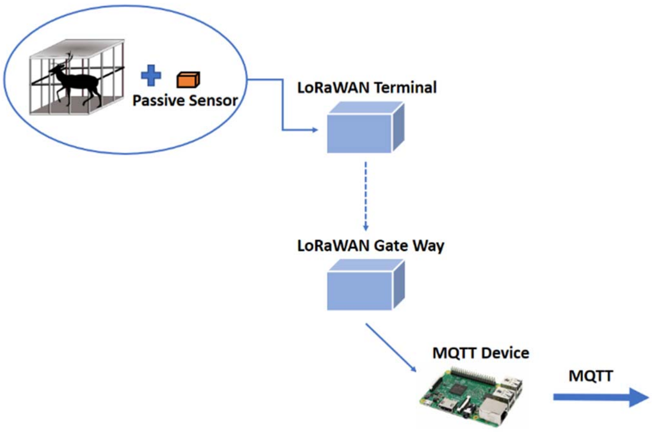

Fig.14. The image of Pattern 3

Fig. 15 shows the control flow of Pattern 3. The passive sensor outputs data with information about the animal that is trapped. The data are made into a data packet on a LoRaWAN device and transferred to a gateway. On the LoRaWAN gateway, the transferred data are collected into a single packet and transferred to an MQTT device. Because Pattern 3 is assumed to be used at long range and it will be difficult to secure enough and stable electricity, LoRaWAN, which has low power consumption [15], is used.

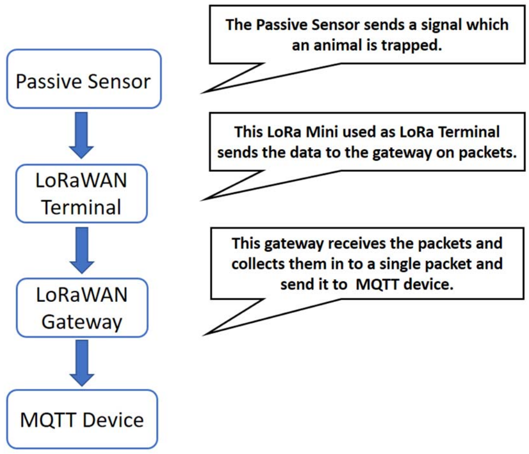

Fig.15. Operation process in Pattern 3

VII. Conclusion

A remote-controlled IoT system through a network was proposed as a part of the Fed4IoT project. Fed4IoT is a project that aims to develop an IoT smart-city application and to divide the IoT system from the IoT application. Currently, IoT technology is often used, and various services are offered to adapt to various cases. Therefore, it economically helps build the IoT smart city to integrate heterogeneous IoT systems in the cloud server. In this study, wildlife monitoring was chosen as a use case of the Fed4IoT project. In this system, two types of model were used at close range and one model at long range. The data transferred from them are sent to a data collection server through MQTT communication and transformed into a general format, such as JPEG and MPEG. Finally, the transformed data are transferred to a local console and a cloud server for Fed4IoT. Moreover, a wildlife-monitoring system using this platform was proposed. This study is one contribution to the SDGs that the United Nations established. As a future task, an on-site investigation of this system is planned.

Acknowledgments

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