IIJ's Efforts to Promote LoRaWAN® in Agricultural IoT

2.1 Introductions

IoT initiatives are expanding rapidly across a whole range of fields. As the use cases multiply in manufacturing, healthcare, automobiles, and other areas, IIJ has turned its eye to agriculture. Agriculture is a core industry and backbone of the nation, yet it is plagued by issues including serious workforce aging and a lack of successors as well as poor profitability. To address these issues, Japan's Ministry of Agriculture, Forestry and Fisheries has made "smart agriculture" a keyword and is actively engaged in demonstration testing nationwide.

Against this backdrop, IIJ is looking at whether it can lend a hand to ease the burden on Japanese agriculture and help make it more economically viable. Our track record so far includes developing paddy field sensors that use LoRaWAN®, a new wireless communications technology that IIJ is focused on.

The biggest issue facing IoT for agriculture is enabling data communications. Here, we take a deep dive into the know-how we have amassed through experience and trial-and-error in the field, which has involved installing base stations, evaluating data link performance, and the like.

2.2 Testing IoT-based Paddy Field Water Management

With support from the National Agriculture and Food Research Organization's special scheme project on vitalizing management entities of agriculture, forestry and fisheries, IIJ has been developing and testing a low-cost ICT water-management system that facilitates labor saving in the area of paddy field water management. This year, we launched Mizukanri Pack S [Water Management Pack S], which packages together the results of these efforts as a set of paddy field sensors that measure water levels and temperature, a wireless base station, a smartphone water management app, and cloud services (Figure 1). The paddy field sensors and wireless base station use LoRaWAN® to communicate. A package that automates water management is also available, comprising the Mizukanri Pack S paddy field sensors and base station as well as a valve that automatically controls water volume based on water levels measured by the sensors.

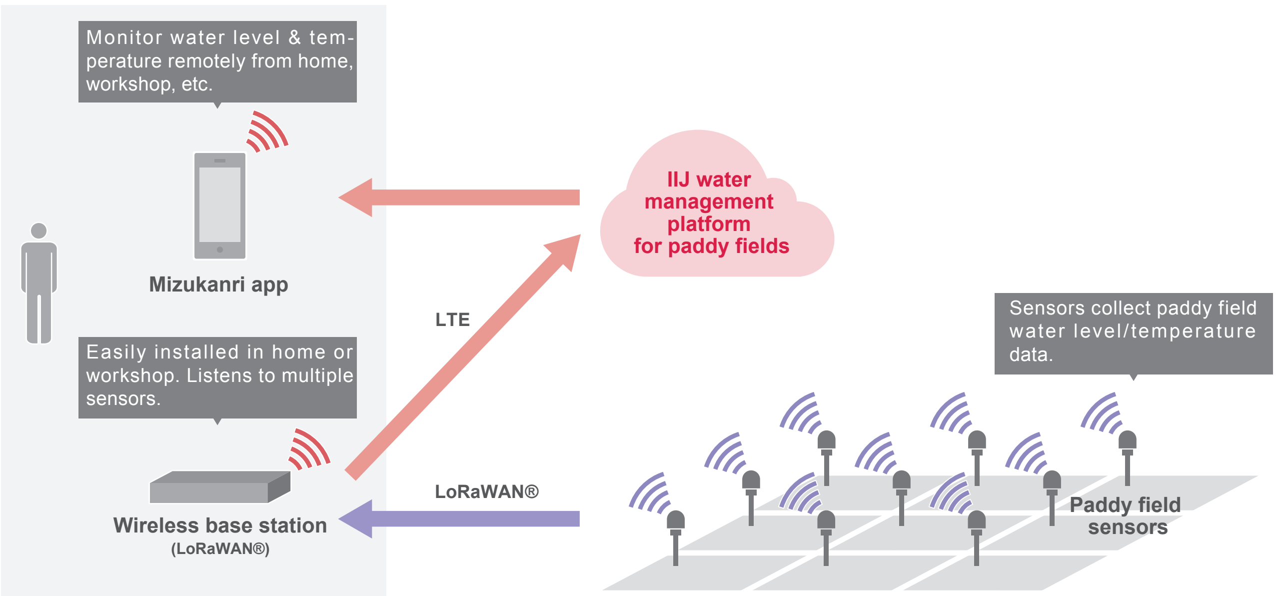

Figure 1: Mizukanri Pack S Saves Labor in Paddy Field Water Management

IIJ is a communications carrier, so working in an unfamiliar area like agricultural IoT and venturing outside of our area of expertise to develop new devices like paddy field sensors was challenging and a constant struggle. We detail these efforts in "The IIJ Stories"*1.

In this report, we focus on the wireless base stations, part of IIJ's business domain, and describe efforts to promote use of LoRaWAN® in agricultural IoT. Although it is part of our business domain, we were inexperienced in many respects and faced a range of challenges. In particular, we travelled frequently to measure data link status, from Hokkaido in the north down to Kyushu in the south. Before delving into the knowhow those efforts produced, we first provide some background knowledge on LoRaWAN® and how it is distinct from other LPWA standards.

2.3 A Single Base Station Can Cover Several km with LoRaWAN®

2.3.1 About LoRaWAN®

LoRaWAN® is a wireless networking specification that uses a spread spectrum modulation technique called LoRa®, developed by Semtech. Although LoRa® communication speeds are slower than Wi-Fi and BLE, it can cover an even wider range than LTE, as illustrated in Figure 2. It also makes it possible to create low-power devices that can communicate for several years on battery power alone. Mizukanri Pack S paddy field sensors take advantage of these characteristics to cover an area of several kilometers with a single base station and operate throughout an entire growing season on two AA batteries, with no need for the batteries to be replaced.

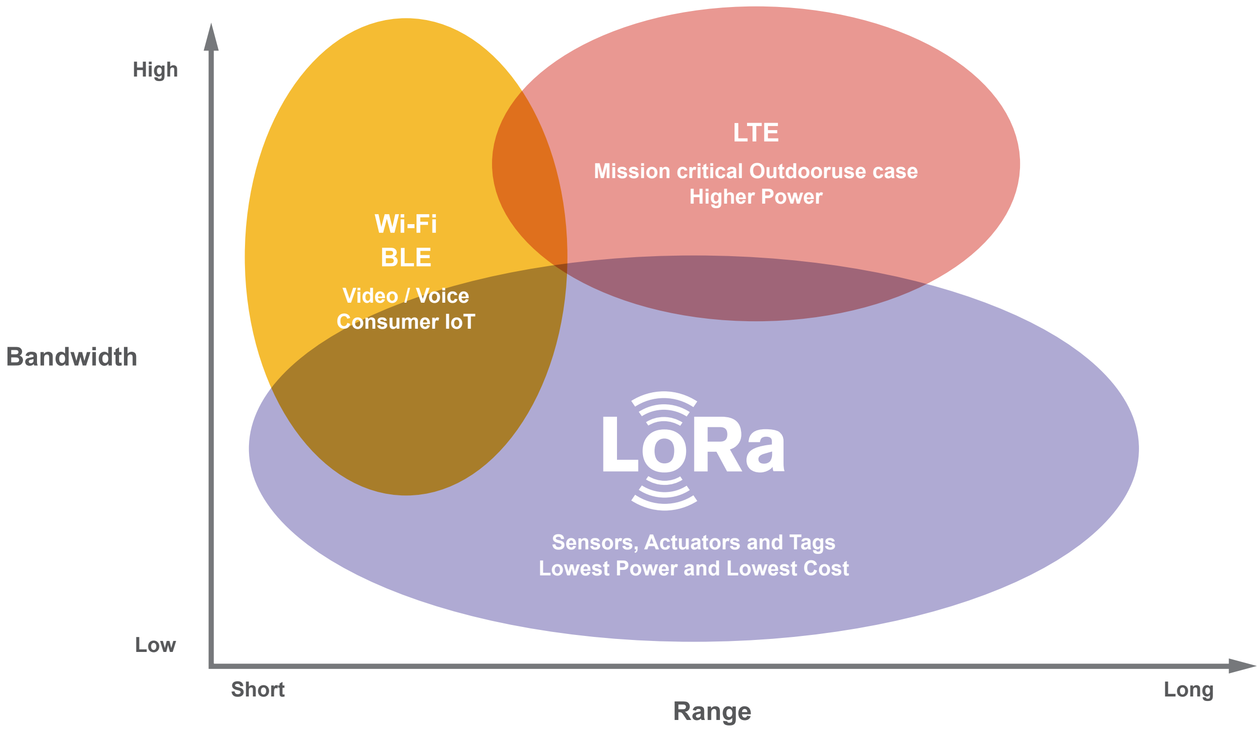

Figure 2: LoRa® Relative to Other Standards

*1 The IIJ Stories | IoT is changing the future of Japanese agriculture by supporting rice farmer work-style reforms (https://www.iij.ad.jp/interview/03.html, in Japanese).

Some LoRa® wireless networks use proprietary protocols, but the standard is LoRaWAN®, specified by the LoRa Alliance®, comprising over 400 member companies including IIJ. LoRaWAN® certificated devices are interconnectable, opening up a wide range of choice with respect to sensors and other connected devices from different manufacturers.

Figure 3 shows the structure of a LoRaWAN® system. The devices communicate via gateways and LoRaWAN®. The gateways connect to a network management server, called a network server, via LTE, Wi-Fi, or wired Ethernet. The network server provides management capabilities, including device activation, elimination of duplicate data received from the same device via multiple gateways, control of communication routes to the application server for each data payload, and variable data rate control. The application server communicates with the network server via a REST API or the like, and stores data received from end-devices, provides application-based visualizations, and controls devices according to user command or automatically according to preset criteria.

2.3.2 Features Compared with Other LPWA Standards

LoRaWAN® is a type of LPWA (low-power wide-area) network. These networks are characterized by low power consumption, low bit rates, and wide area coverage. Many other LPWA wireless networks exist, including Sigfox and LTE-M. Communications carriers operate base stations nationwide for Sigfox and LTE-M, and the networks can be used within the coverage areas without the need to install your own base station.

Sigfox is very inexpensive, with usage fees as low as 100 yen per device per year (depending on the number of devices under contract), and covers 95% of the population as of January 2020. In basic terms, it allows for uplink only with payloads limited to 12 bytes and the number of messages per day limited to 14. Yet it is the leader in Japan in terms of number of devices deployed, with, for example, 850,000 compatible devices that use these features for taking gas meter readings already slated for installation.

The LTE-M standard is developed by 3GPP, and three mobile carriers provide LTE-M services in Japan: NTT Docomo, KDDI, and SoftBank. Using a bandwidth of 1.4MHz allows bidirectional communication of up to 1Mbps, and it also supports FOTA (Firmware Over-The-Air) remote device firmware updates. It also supports handover switching of base stations when on the move, so it can be used in much the same way as regular LTE. However, if used only on carrier networks, the data charges are 100–150 yen per device up to 10,000 devices, which is far more expensive than Sigfox.

Some carriers provide their own LoRaWAN® base stations and base stations shared among users, but generally you need to install your own base station. Low-price LoRaWAN® gateways are available that are similar to mass-market LTE-capable IoT gateways, like the Kiwi Technology TLG3901BLV2 included in Mizukanri Pack S.

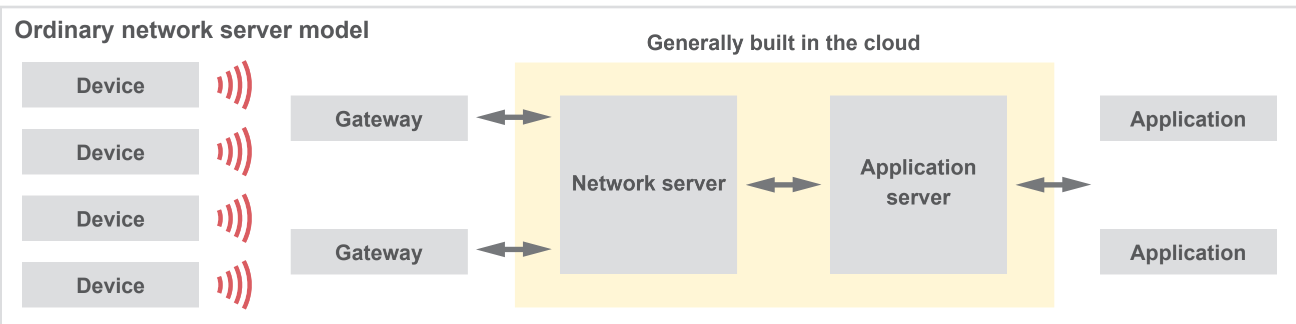

Figure 3: Overview of a LoRaWAN®-based System

2.3.3 Applications Suited to LoRaWAN®

Having to install your own base station puts LoRaWAN® at a disadvantage to Sigfox and LTE-M in terms of equipment and installation costs. But an advantage is the ability to add base stations to reach areas not covered by outdoor base stations, such as basements and inside buildings. And because there are no data charges for communications between devices and the gateway, the cost benefits are considerable if only a few base stations are used to serve a large number of devices. LoRaWAN® is particularly suitable for low-cost applications that involve multiple battery-powered devices installed in large buildings, such as factories, shopping centers, and offices.

With no downlink restrictions, LoRaWAN® is also effective in agricultural IoT, including paddy field water management, when there is a need to control devices like water supply valves. Ensuring profitability in agricultural IoT can be difficult if expensive devices and services are used, so the advantages of LoRaWAN® and inexpensive equipment come into play here to enable low-cost services even when using multiple devices of different types. A range of LoRaWAN®-compatible devices from different manufacturers are already available for agricultural IoT, including paddy field sensors and water supply valves for paddy field water management, weather sensors for measuring rainfall and temperature, and soil sensors for measuring soil temperature and moisture. These can all be accommodated by a single LoRaWAN® base station. Another advantage is the ability to set up your own base stations to provide coverage in areas where carrier-operated base stations can struggle, such as mountainous terrain.

Figure 4: Kiwi Technology's TLG3901BLV2

2.4 Challenges in Promoting LoRaWAN® for Agricultural IoT

So far we have discussed:

- Features of LoRaWAN® and suitable applications
- Advantages of LoRaWAN® in agricultural IoT

So what challenges do we face in popularizing LoRaWAN® for agricultural IoT?

2.4.1 Installing Inexpensive Outdoor Base Stations

I was involved mainly in base station design as part of the three-year paddy field water management IoT demonstration testing project, and based on my experience, the biggest issues are finding places to install base stations and obtaining a power supply.

The TLG7921M is a waterproof outdoor LoRaWAN® gateway with strong wireless performance, so a single unit can cover a wide area if installed in an elevated spot, such as a rooftop or mountain. But it is more expensive than indoor LoRaWAN® gateways, and the cost of installation, including wiring, is also high, so it is an expensive option unless installed on a decent scale (e.g., rolled out across an entire region).

Kiwi Technology's TLG3901BLV2 is a very cheap LoRaWAN® gateway included in the Mizukanri Pack S. It is an indoor device intended for installation in homes or offices of agricultural businesses, but offices and homes are often far from the paddy fields where the sensors are installed, and the data links can be unstable. Installing them in private homes with a power source near the fields would work, but this is not all that realistic since users themselves would have to negotiate with property owners about how much to pay for the electricity used by the LoRaWAN® gateway and so forth.

2.4.2 Simple Pre-installation Data Link Tests

Even if you are able to install inexpensive base stations outdoors, you may need to relocate them or add additional units if you are unable to easily determine beforehand that they can link to devices without any issues.

Several companies offer commercial wireless simulators that let you enter base station latitude, longitude, and installation height to simulate data links with peripheral devices. We actually tried one of these, but while the simulator included topographical data, it did not include data on buildings and trees, so we were unable to determine the effect of such objects on data links. When we compared the results of the wireless simulator with real-world measurements taken in the vicinity of the paddy field water management IoT test site, the simulation tended to match the real world in places with few buildings, but even then, when testing close to a building, we found that small changes in device position can greatly affect data transfer success rates. Even if data on buildings and trees is incorporated into the simulator in the future, covering all buildings and trees is likely to be difficult, as is keeping the data up to date, so disparities between simulation and real-world testing seem inevitable. In the real-world tests, the data links were also sometimes unstable near busy roads. Assessing such time-based changes in data link status is also likely to be difficult in wireless simulators, even in the future.

So simulation-based pre-installation checks of connectivity do have their limitations, and you need to do real-world tests to say anything with certainty. However, there are limits to the extent to which we, or a contractor, can measure connectivity every time a base station or device is installed, and this would also be costly.

2.5 Solutions to the Issues

So far, we have explained that promoting the use of LoRaWAN® for agricultural IoT will be difficult unless we can achieve either of the following:

- Install inexpensive base stations outdoors
- Easily assess data link performance before installation

To solve these issues, our aim was to make the system as DIY-friendly as possible for agricultural businesses. I describe our solutions below.

2.5.1 DIY Solar-powered Base Stations to Expand Installation Options and Cut Installation Costs

If the TLG3901BLV2 indoor LoRaWAN® gateway included in Mizukanri Pack S could be waterproofed and made to run on a cheap solar panel and battery, obviating the need for a power supply, then it could be installed on the edge of paddy fields where it was previously not possible to do so and thereby provide stable data links. So we decided to make available a DIY solar-powered base station package that agricultural businesses can easily set up themselves, consisting of a cheap solar panel and battery and materials readily available online or at home centers. Agricultural business owners are used to DIY, with many building their own greenhouses for instance, and they often have a decent set of tools, so we believe they will be able to install the DIY solution themselves as long as we provide a clear set of instructions. Finding an installation spot along the side of a field should also be easy, and the cheap price means that the system can easily be restored if it is, say, damaged by natural events or stolen.

We expect the package we are putting together to provide a solar-powered base station that runs year round at an additional cost of about 70,000 yen on top of the TLG3901BLV2. To evaluate the package, we have already obtained materials and built a DIY solar-powered base station ourselves (Figure 5), and I blogged about the process. See my posts for more details[*2].

*2 IIJ Engineers Blog, "We set up a solar-powered LoRaWAN® base station for smart agriculture (Parts 1 & 2)" (https://eng-blog.iij.ad.jp/ archives/5567, in Japanese) (https://eng-blog.iij.ad.jp/archives/5599, in Japanese).

Four of us installed the first solar-powered base station, but we believe we need to make improvements as we develop the package so that two people or fewer can install it in a shorter amount of time. So we recently arranged to use a location relatively close to our workplace for a day, and undeterred by rain, ten of us tested out a number of installation patterns using various tools and materials. I hope to write the experience up in a blog post soon. And we look forward to launching a package that embodies what we learned.

2.5.2 Simple Data Link Tests via a Wireless Survey Tool

To enable agricultural businesses to easily measure data link performance themselves, we decided to develop a wireless survey tool, a device that measures data link performance. We started out with the following development requirements.

1. We will not create a smartphone testing app. The system will consist of only the TLG3901BLV2 and a wireless survey tool. Both will run on a mobile battery or dry-cell battery.
2. The measurement process will take 5 minutes and consist of 30 individual measurements taken at 10-second intervals.
3. The wireless survey tool will have an LCD screen to display measurements in real time.
4. The TLG3901BLV2 will be usable without a SIM.

We decided on Requirement 1 to make it easy to conduct testing anywhere. If we created a smartphone app, users would need to learn how to operate it, but some agricultural businesses are not all that familiar with smartphones. Mizukanri Pack S includes a smartphone app, so users need to acquaint themselves with its use once they decide to install the system, but we wanted to make the bar as low as possible in the initial pre-installation survey stage. Making the devices battery powered not only eliminated the need to be near a power source, it also made it possible to eschew a power button and have tests start automatically when the battery is connected.

Figure 5: DIY Solar-powered Base Station

Requirement 2 is in line with devices we have used for testing so far. Although the LoRaWAN® specification allows for shorter intervals, we selected our interval in light of potential interference in the case of multiple devices using the same 920MHz band being nearby as well as the potentially strong effect of environmental noise from, for example, moving vehicles.

We decided on 3 instead of a smartphone app. The wireless survey tool sends an ACK request via uplink to the Kiwi Technology LoRaWAN® gateway. If an ACK is returned, it is counted as a success; if no ACK is returned, this is a failure. Successes and failures are displayed as O and X on screen. Once the data link test is complete, the screen shows the number of successes over the total number of tries (Figure 6). Displaying the test results in real time was also a good idea because the user can disconnect the battery and stop the test if no data is being received at all.

Figure 6: The Wireless Survey Tool's LCD Screen

Requirement 4 is there because otherwise, if we were to create several sets of the TLG3901BLV2 and wireless survey tool to lend out to people, we would need the same number of SIMs. As Figure 3 shows, LoRaWAN® systems normally need to connect to a network server in the cloud and thus need a mobile line accessed via a SIM or the like. Fortunately, Kiwi Technology LoRaWAN® gateways feature their own built-in network server. Figure 7 illustrates a LoRaWAN® system using the built-in network server.

The built-in network server enables the gateway alone to provide almost the same level of functionality as network servers usually available in the cloud. The gateway can store data received from devices in internal storage for a period, allowing for its retrieval externally at any time via a REST API. You can also request control of devices via the REST API. When an ACK is received from a device, you can return an ACK from the unit. This allows for bidirectional communication with devices even if the application server cannot be reached. The built-in server was originally intended to facilitate PoC in the absence of a network server contract, but we were also able to make effective use of this feature in the wireless survey tool.

Figure 8 shows the prototype wireless survey tool that we developed. We have actually already lent it to a number of people to use, and in addition to the expected outcome of users being able to perform a preliminary survey of wireless performance, some also expressed surprise at the system's range: "It picks it up from this far away?!" So the tool also

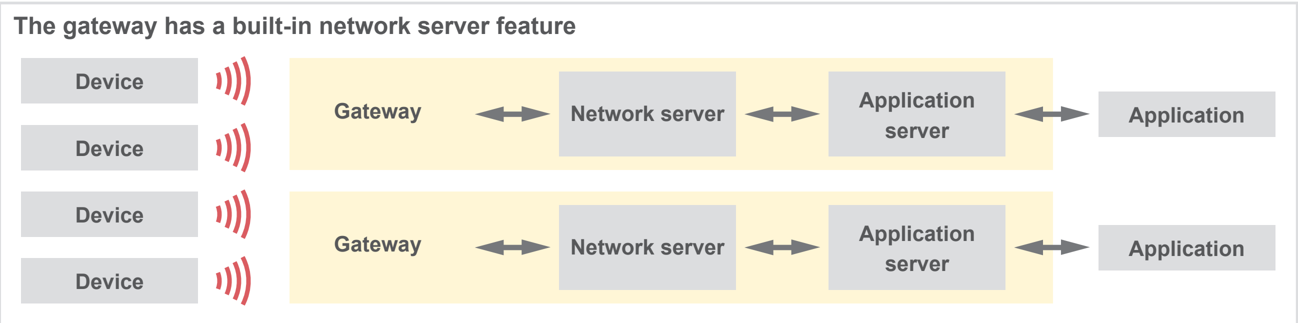

Figure 7: Overview of a LoRaWAN® System Using the Built-in Network Server

turns out to be an effective way for people to experience the long range LoRaWAN® offers before installing a system. It is also an effective way of collecting real-world test data from a whole range of locations, something we could not do alone, so we hope to continue utilizing the wireless survey tool while making additional improvements going forward.

2.6 Conclusion

We have discussed the features and suitable applications of LoRaWAN® compared with other LPWA wireless networks and the advantages of LoRaWAN® in agricultural IoT. We also looked at challenges to promoting the use of LoRaWAN® in agricultural IoT along with solutions.

However, solving the issues we discussed merely means we have done the minimum groundwork necessary to put Mizukanri Pack S on the market. If sales volumes rise, we will have to address issues including simplifying pre-shipment kitting and making it easy to diagnose the situation when problems arise after a product is shipped. To that end, IIJ is working with Kiwi Technology to extend the features of the LoRaWAN® gateway by adding SACM zero-config support, for instance.

SACM is a next-generation management system service for routers and IoT gateways, developed by IIJ based on SMF technology, which enables the automatic connection and centralized management of devices, and offered on an OEM basis. With zero-config support, a device will automatically connect to SACM when powered on, acquire its settings, and start running. This eliminates any need to operate a device directly. The user interface allows SACM administrators to centrally configure, monitor, and manage a large number of devices. See our Focused Research report in IIR Vol. 36 for details of SACM[*3].

The features we have developed for agricultural IoT and the sales and operating knowhow we have built will also be effective in deploying LoRaWAN® solutions for other applications. By continuing to develop this technology and build a knowledge base, IIJ aims to lower the bar to implementing LoRaWAN® and see it deployed in a range of different fields.

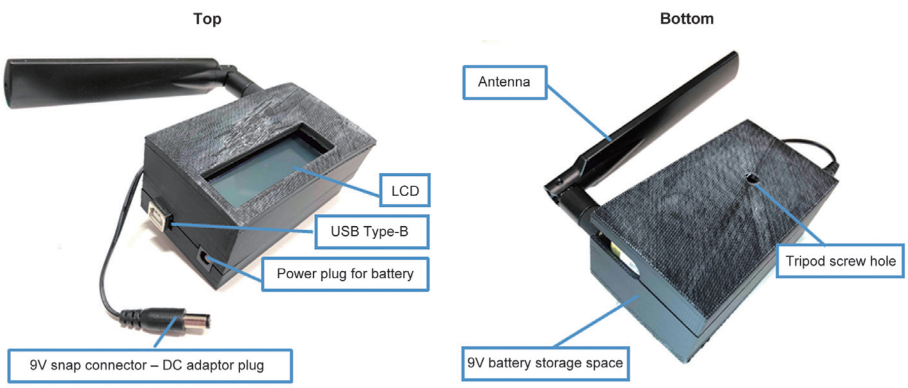

Figure 8: Wireless Survey Tool Prototype

Moto Onishi
Product Manager, New Business Promotion, IoT Business Division, IIJ
Mr. Onishi joined IIJ in June 2016. He handles project planning for IoT and camera solutions.

*3 Internet Infrastructure Review (IIR) Vol.36 (https://www.iij.ad.jp/en/dev/iir/036.html).