Methods for Communication and Power Supply
Provisioning over Physical Joints

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In the blink of an eye, the IoT (Internet of Things) has become a familiar concept in people's lives. We use not only RFID (Radio Frequency Identifier) technology for business and sensor technology but also technology such as smart houses on a daily basis. To put it simply, a smart house is one that automatically senses the environment and provides an environment that is optimal for people. IoT technologies are so ubiquitous that sometimes we live without being aware of them. Examples of such ubiquitous technology include Mitsubishi Electric's "Kirigamine" air conditioner, an air conditioner that can output different temperatures in the same space depending on where people live, an air purifier that operates in conjunction with Sharp's cloud service based on climate, washing machines that select the most optimal washing program depending on the amount of dirt on the clothes and cooking utensils that can automatically cook for us. IoT is not limited to home use; such technologies are bein used in a wide range of situations, with a recent example being that of "Wizarding World of Harry Potter", a new attraction at Universal Studios Japan.

Internet of Things technology faces a number of problems: achieving stable and widespread use, lowering power consumption, connecting things that are not yet connected to the internet, in addition to other security and global resource issues.

The author considers three things: IoT, earth resources, and objects that are not yet connected to the Internet, and assumes a system that has multiple functions and can be freely constructed and reconfigured. In order to realize this, we will introduce solid " parts " with various built-in functions in advance. By assembling parts like LEGO blocks, users can build what they need, or disassemble what they have built and rebuild something new. Since the parts do not become bulky, it is possible to reduce the possibility of being discarded due to space issues such as when moving. In addition, even if a part of the object constructed by parts is damaged, it can be easily repaired by replacing the damaged part. Parts have multiple functions, and can be part of any object by combining multiple parts. Since it can be used as a substitute for various electronic devices from home appliances, it can

be widely applied to home use, in-vehicle use, production, and robotics, and is expected to cause industrial reform. Another feature of the IoT is that it uses a large variety of objects in large quantities. If it is necessary to use a variety of things depending on the purpose, the user must prepare each of those things, which is complicated. If this system is realized, the convenience of the user will be improved by reducing the number of necessary items, and the value of the items will also increase. The idea that various things can be made by combining parts is not new, but the feasibility is enhanced by proposing a connection method that can realize power supply and communication between parts. Therefore, this research focuses on methods for physically joining parts and connecting objects.

The conventional method of connecting objects requires multiple wires to provide physical connection, power supply, and communication functionality. In addition, although the wire bonding method has high stability, the wiring capacity and the space used are limited. On the other hand, when power supply and communication are performed wirelessly, there are no restrictions compared to wired connection, but there is a problem that the efficiency is low and the system is easily affected by the environment and unstable. As described above, various issues remain regarding physical joints.

In recent years, single-pair Ethernet and power line communications (PLC) have been developed as communication systems that can simultaneously perform communication and provide electric power. These technologies have received a lot of attention due to their ability to provide both power and communication functionality in a flexible and cost efficient way. This study proposes a joint method that has flexibility at the junction between objects and can simultaneously provide high-efficiency communication and power supply with a single connection. After that, we will confirm the compatibility with each use case and clarify the technology of the joint that realizes the best joint according to the purpose of use.

In this research, first, the physical, communication, and power supply connection methods between existing objects are enumerated and described, as well as the connection methods for communication and supply power. Next, use cases are enumerated because the demand for the joining method differs depending on the object. Then, based on the enumerated use cases, we propose a joint method that can provide communication and power supply simultaneously over Physical Joints. Finally, we evaluate the proposed method and evaluate the adaptability of the listed use cases based on the result of averaging the evaluations performed multiple times.The evaluation content includes the electrical characteristics and physical characteristics of the bonding method. The electrical characteristics are divided into communication performance and power performance.Furthermore, communication

performance includes frequency characteristics and data quality, and power performance includes contact resistance and maximum allowable current.At the same time, the change in electrical characteristics with respect to the stress at the joint is also evaluated.

In more detail, in this study, we are studying the use of contact-based communication methods using a medium with very few physical connectors, such as Single Pair Ethernet (2 pins) and Power Line Communications (typical two-wire power line). Also, the connection between parts is divided into three types: physical connection, power supply connection, and communication connection. First, the physical connection method includes methods such as "mortise and tenon" structures, magnets and screws. We further consider the change in the angle of the joint between the parts. This is to evaluate the change of frequency characteristics etc. due to the change of angle. Next, there are various methods for power supply connection and communication connection. For wired connection, there is a conventional power supply and communication method using a "drawer" connector. On the other hand, in wireless connection, there are radiated and non-radiated power supply and communication methods. In proposing a connection method between parts, first, all the existing connection methods described above are enumerated, and each method is evaluated. In addition, we examine all combinations of each connection method and exclude invalid combinations. Next, we enumerate use cases of objects constructed by parts, and propose combinations of several types of connection methods that are considered optimal for each use case. Then, the physical connection strength, degree of freedom, power supply, communication efficiency, and changes in characteristics during use are measured for each combination, and the combinations of the proposed connection methods are evaluated for each use case. After that, the combination of each devised connection method and the consistency with the use case are confirmed, and the joint technology that achieves the best joint according to the purpose of use is proposed. During evaluation, a Vector Network Analyzer to measure the frequency characteristics, a Data Quality Analyzer to measure the data quality, a four-terminal measurement method to measure the contact resistance, and a thermographic camera were used to measure the maximum allowable current using.

As a result, this study reveals a joining method and technology that can simultaneously provide communication and power supply using the latest single pair Ethernet standard IEEE802.3cg for IoT according to the purpose of use of each use case of the thing.The features of the joining method that simultaneously performs physical, communication, and power supply were summarized.