Research on Building an Internet-of-Things Oriented Large Scale Experiment Environment

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"Internet of Things" (IoT) is getting feasible with advances in development of microcontrollers and low-power wireless communication technologies. Various "things" which are different from ordinary computers such as servers or desktop computers are used in IoT network systems. Typical usage of "things" is to collect information from environments, or to control devices which interact with physical space. In IoT network systems, computers which have limited computation resources to provides limited functions such as sensors or actuators are utilized. In this research project, I call them IoT-devices which are distinct from ordinary computers. IoT network systems may widely distribute IoT-devices; for example, wireless sensor network. In such network systems, it is hard to renew systems with retrieving distributed IoT-devices after deployment with distribution of IoT-devices. Thus, it is important to examine the network systems before deployment of the systems.

There are several requirements for an experiment of IoT: flexible experiment network structure; mixture of different computer architectures; mixture of communication media; control of physical elements. In case of a large-scale experiment, scalability is a requirement as well. There are two typical way to examine IoT network systems. One is to utilize a testbed which provides experimenters real IoT-devices. In this way, there is a spatial restriction that sets limits to the total amount of IoT-devices

and to the space used for wireless communication. The other is to simulate an IoT network system with emulating IoT-devices. In this way, ther is a restriction caused by the capacity of the computer which is processing the simulation. In addition, there are few ways to communicate across the simulation. Both of the two ways are not enoughly suitable for the requirements. Especially, to perform large scale experiments, it is hard to extend the scale of experiments.

Network testbeds are facility to perform experiment of network systems. There are two kinds of testbeds; one is to use the Internet, and the other is independent from the Internet. Condition of wireless communication is an important parameter for IoT network systems. To control the parameter, it is necessary to remove noise. Thus, testbeds which are independent from the Internet are suitable for IoT network systems because they aren't affected by the unpredictable communication condition in the Internet. A StarBED-style testbed has experiment network independent from the Internet. It provides experimenters experiment networks independent from the Internet and other experiment networks. This ensure experimenters that condition of the communication is not affected by the noise. However, a StarBED-style testbed is a computer cluster which consists with experimental nodes of oridnary computers and wired networks. Hence experimenters cannot run IoT-device applications implemented with architectures which are different from ordinary computers. In addition, it is not able to use wireless network technologies in a wired network.

In this research project, I proposed a framework called "Generic Utilization of Assorted Networking" (GUAN). In design of GUAN, there is necessity to adopt two components. One is a component to enable experimenters to perform experiments of IoT-device applications in a StarBED-style testbed. Hence I defined "virtual IoT-device" that executes IoT-device applications on an ordinary computers, with ensuring consistency with IoT-devices, and I treated them as the main components of GUAN. Virtual IoT-devices enables experimenters to perform experiments of IoT-device applications in a StarBED-style testbed. The other is a component to handle communications of wireless network protocol in a wired network environment. GUAN is a framework to adjust interfaces of the virtual IoT-devices and to relay communications among the virtual IoT-devices — i.e.

to relay frames which are outputted by the virtual IoT-devices. Thus, GUAN is able to handle frames of wireless communication protocols in a wired network environment. Furthermore, emulating the condition of wireless communications at relaying the communication, IoT-devices can communicate in an emulated wireless network. For StarBED-style testbeds, researchers are developing methods to emulate conditions of wireless communication. Meteor is a wireless network emulator which performs in the data link layer. It is efficient for IoT experiments which requires mixture of communication media. Therefore, designing to adopt these components, I realized the framework which enable experimenters to perform network experiment with emulating the condition of communications.

To perform an experiment based on GUAN, I have implemented following applications: a virtual IoT-device and application running on it; mechanism to generate many virtual IoT-devices with unique ID; machanism to control virtual IoT-devices simultaneously; machanism to relay communications among virtual IoT-devices. I performed an experiment with these implementations in StarBED. As a result, I proved the fundamental concept of this research project; it is able to extend the scale of the experiment with utilizing multi computers. Thus, I concluded that GUAN is an efficient framework for large-scale experiment of IoT.

It is hard for existing methods of IoT experiments to extend the scale of the experiment to perform a large scale experiment. In this research project, I proposed a framework for larger scale IoT experiments with utilizing multi computers, and I performed an experiment to prove efficiency of the framework. I concluded that GUAN that it is suitable for the requirements: on flexible experiment network structure; on mixture of different computer architectures; on mixture of communication media; and on scalability. For existing methods, it is hard to extend the scale of experiments. This research result facilitates the extension of the experiment scale. It became able to perform experiments of the network system in which many IoT-devices and multi network systems take coordinated actions. This contributes to research and development of IoT.