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Development of a Co-Creation Environment for an Open IoT Platform

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Abstract

Today, a "co-creation" culture for creating shared values plays an important role in our society. According to this cultural trend, co-creation is needed in developing smart objects. However, existing IoT (Internet of Things) platforms do not support a co-creation environment for users. Thus, this research aims to develop a co-creation environment that can allow users to create with others by sharing different ideas in the process of developing and testing smart objects. In this paper, we report our experience in the development of a co-creation environment for an open IoT platform. This paper contributes to the provision of developmental approaches to developers and researchers who develop IoT platforms that can support co-creation environments.

Keywords: *IoT, Open Platform, Co-creation*

1. Introduction

Today, everyday objects are equipped with computational power and Internet networks for diverse applications [1]. Everyday objects are transformed into smart objects through the combination of various technologies and the Internet [2]. It is becoming more and more important to bridge the gap between "the atoms of the physical" and "the bits of the digital" in order to utilize the advantages of both [3]. The "Internet of Things" (IoT) refers to the technology that connects objects embedded with sensors and communication functions to the Internet. This allows objects to exchange data with each other via network infrastructure [4-5]. Moreover, IoT platforms are rapidly being emerging for the purpose of managing and controlling diverse smart objects and creating new intelligent services based on IoT [6].

With the advance of these technologies, we are entering a new age in which we can realize our ideas by quick and easy prototyping of smart objects in open-source development environments. Moreover, by being globally networked, a "co-creation" culture is facilitated, one that is defined as "any act of collective creativity that is experienced jointly by two or more people" [7]. Co-creation is going beyond traditional collaboration in the process of creating something innovative that did not exist previously. According to this cultural trend, co-creation may be effective in developing innovative smart objects. However, IoT platforms that support a co-creative environment between users do not exist. Thus, this research aims to propose a co-creation environment for an open IoT platform that enables users to create with others, starting from the idea-generation for smart objects to the design, development, and testing process.

This study will start by exploring existing open IoT platforms in order to understand open IoT platforms and will analyze its limitations regarding co-creation. Also, existing collaborative platforms are investigated to extract the elements necessary for co-creation. Through these explorations, this research presents a framework for a co-creation environment in an open IoT platform. Based on the

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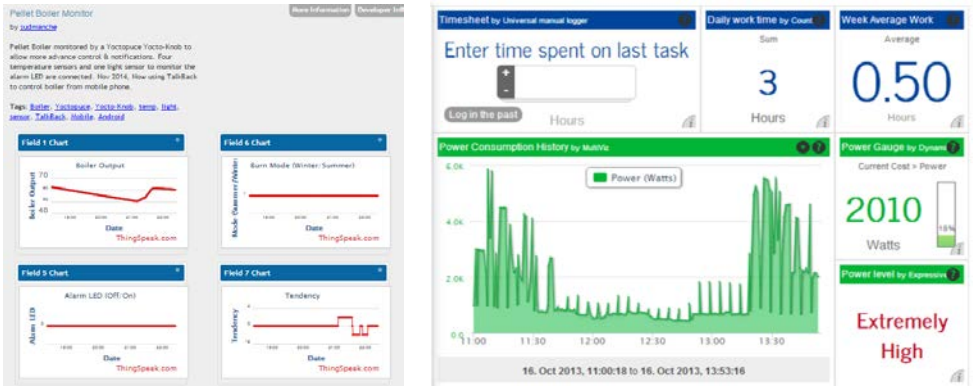
proposed framework, we developed a co-creation environment for an open IoT platform as a prototype.

This paper presents our experience with the development of a co-creation environment for an open IoT platform. In this environment, users can create smart objects with other users through mutual feedback in the process of developing and testing smart objects. Therefore, this study provides developmental methods to developers and researchers who develop open IoT platforms that can support co-creation environments.

2. Open IoT Platform

In open IoT platforms, users can connect different smart objects and devices regardless of the specific product and device. Open IoT platforms are generally composed of IoT-based web services that enable users to connect their smart objects and open-source APIs that enable users to build applications. The open IoT platforms supply “real time data collection”, “data processing”, and “data visualization” to its users. Thingspeak and Open.sen.se are representative open IoT platforms that allow people to connect any device for free. Thus, we investigate some issues with supporting co-creation environments in an open IoT platform by analyzing Thingspeak and Open.sen.se. Thingspeak and Open.sen.se provide a few options for co-creation through open dashboards by which people can check and monitor diverse IoT-based data as shown in Figure 1. Also, Open.sen.se enables people to share IoT-based data through its dashboards called sense board [8]. Thingspeak allows people to post comments and questions on open dashboards [9]. Both platforms lack full support for co-creation environments although they have some collaborative functions such as data sharing and monitoring by other users.



(a) Thingspeak (b) Open.sen.se

Figure 1. Open Dashboards

3. Process of Co-Creation

In order to extract the elements of a co-creation environment for an IoT platform, we analyzed the following representative web-based collaborative platforms: Github, Cage, and Mural.ly (Figure 2). Github is a web-based social repository platform that enables users to build software by collaboration and sharing of code with other users [10]. Cage is an online design collaboration service that allows users to easily present their work for feedback [11]. Mural.ly is a web-based creative collaboration platform that helps you or your team generate, organize, and discuss your/their ideas for creative work [12].

(a) Github (b) Cage (c) Mural.ly

Figure 2. Web-based Collaborative Platforms

We explored the basic structure of these collaborative platforms and the functions of its collaborative features. These collaborative platforms can basically manage and record the overall process of development, design or brainstorming. These processes can be broadly classified into three steps: (1) registration, (2) modification, and (3) renewal. All information generated in the process is recorded in detail and the collaborative platforms have functions that enable effective collaboration in each step. Although the detailed functions for collaboration features differ for each platform, the elements for collaboration can be categorized into idea-sharing, discussion, and decision.

In order to support co-creation during the development of smart objects, five guiding principles are needed: (1) “inspire participation”, (2) “select the very best”, (3) “connect creative minds, (4) “share results”, and (5) “continue development” [13]. The elements extracted through the analysis of collaborative platforms can satisfy these five principles in co-creation. Figure 3 illustrates the process of co-creation based on the basic structure and functions of collaborative platforms.

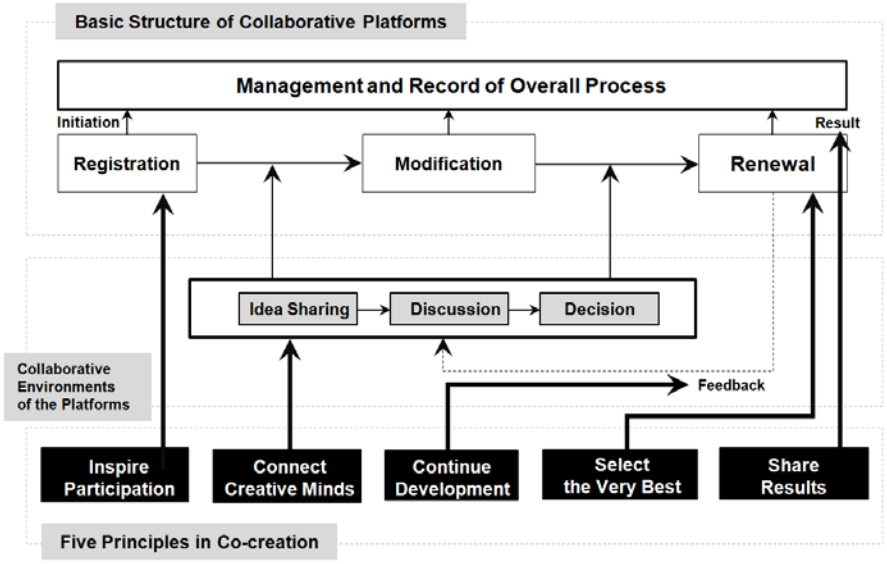


Figure 3. Process of Co-creation

4. Framework for a Co-Creation Environment in an Open IoT Platform

This project is our long-term project to develop a co-creation environment for an open IoT platform. During the pilot research phase of this long-term development project, a

framework for a collaborative environment in an Open IoT Platform was constructed [14]. Based on this pilot research, the framework for a co-creation environment was built.

Smart objects are created as a combination of hardware and software, and these smart objects work by being networked to an IoT platform [15]. Alternatives to Smart objects are generated within the cyclic development process comprising three steps: designing hardware, developing software, and configuring the IoT platform. Alternatives can be created anytime during this process, from the initial stage to the final stage. Therefore, each alternative in an open IoT platform includes a co-creation environment. Each alternative can be systematically recorded and managed. Thus, the framework in Figure 4 can dramatically increase feedback by applying modifications from diverse discussions and decisions.

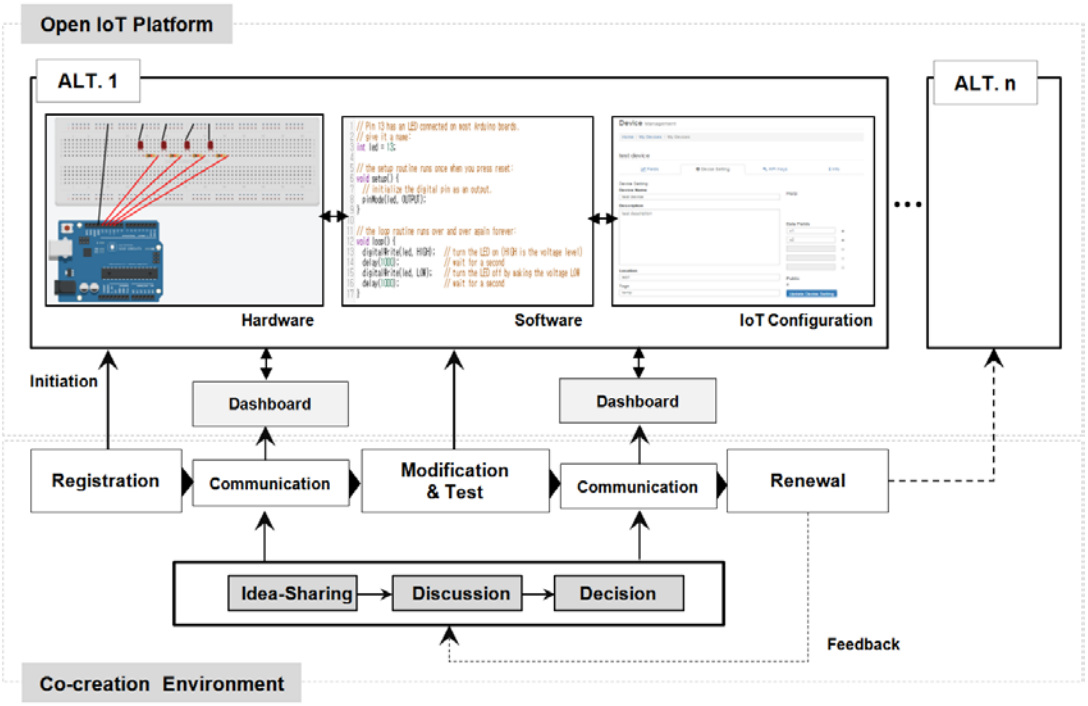


Figure 4. Framework of an IoT Platform with a Co-Creation Environment

5. Co-creation Environment for an Open IoT Platform

5.1. System Structure

The system structure for a co-creation-based IoT platform was designed based on the basic system structure of an open IoT platform. Generally, an open IoT platform consists of 5 modules: (1) web interface, (2) web controller, (3) data management, (4) data visualization, and (5) device management. First, the web interface module receives the user's requests which are transferred to the web controller modules. The web interface module also displays the results of the requests to users after processing it. Second, the web controller sends data to each module according to the user's requests. Third, the data management module stores the transmitted data from different sensors and transfers the data to smart objects when users request the data. Fourth, the data visualization module visualizes the raw data received from sensors with diverse diagrams. Lastly, the device management module manages the environmental information such as the name and type of smart objects and uploads the information to the data management module.

To develop an open IoT platform that supports a co-creation environment, a co-creation environment that consists of a version control module and a co-creation module

can be added to a general open IoT platform. The version control module manages the version number for projects in progress that can be considered alternatives. The co-creation module handles communication between users such as comments and replies. As shown in Figure 5, the co-creation environment was added to the system structure of an open IoT platform.

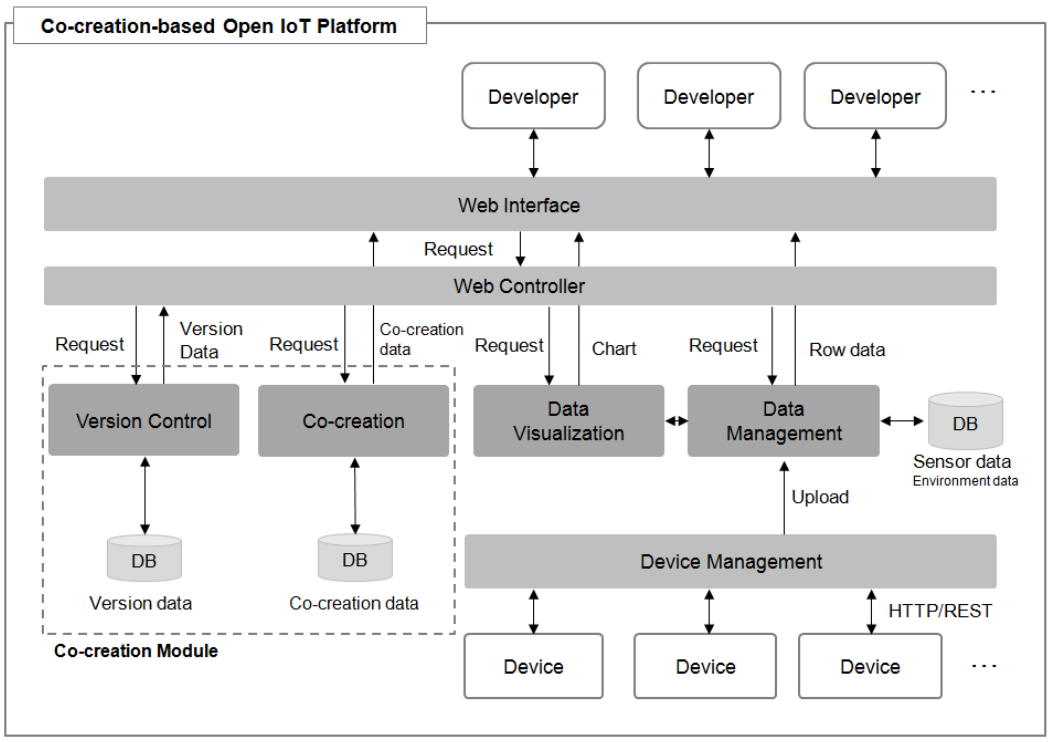


Figure 5. System Structure of a Co-Creation-Based IoT Platform

5.2. Data Structure for a Co-Creation Environment

Once a new project to develop a smart object is registered, the first version is automatically created by the version control module. A co-creation environment is subsequently implemented by the version control module. A single version consists of object information, object data, and collaboration data. The object information includes an IoT environment setting, hardware composition, and software code. Moreover, the object data is composed of sensor data sent to the hardware in addition to the environmental variables of surrounding sensors. The collaboration data includes data such as comments, replies, and pictures, which are generated by communications between users in the process of co-creating a project. When the object data of a project is updated through user communications, users can generate a new vision for the project. Figure 4 shows the data structure for a co-creation environment.

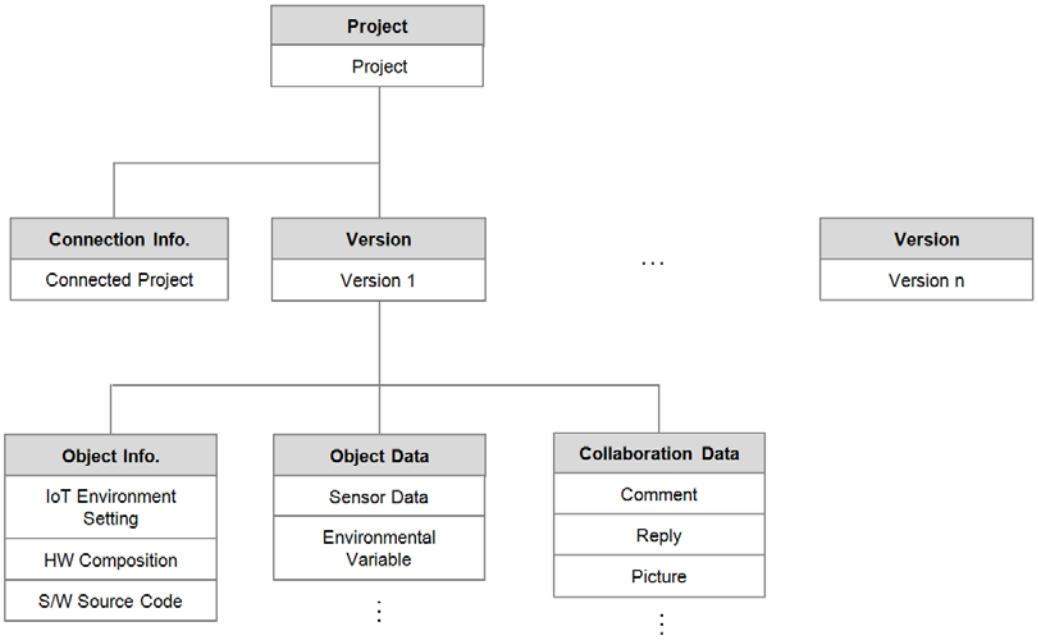


Figure 4. Data Structure for a Co-creation Environment

The data structure enables users to effectively record, manage, check, monitor, and test the development process. Each project is automatically connected to similar projects through connecting project information input by users. Through this, users can easily and quickly generate new, improved projects as new alternatives based on previous projects. Thus, this process will help users effectively generate and manage alternatives through diverse feedback.

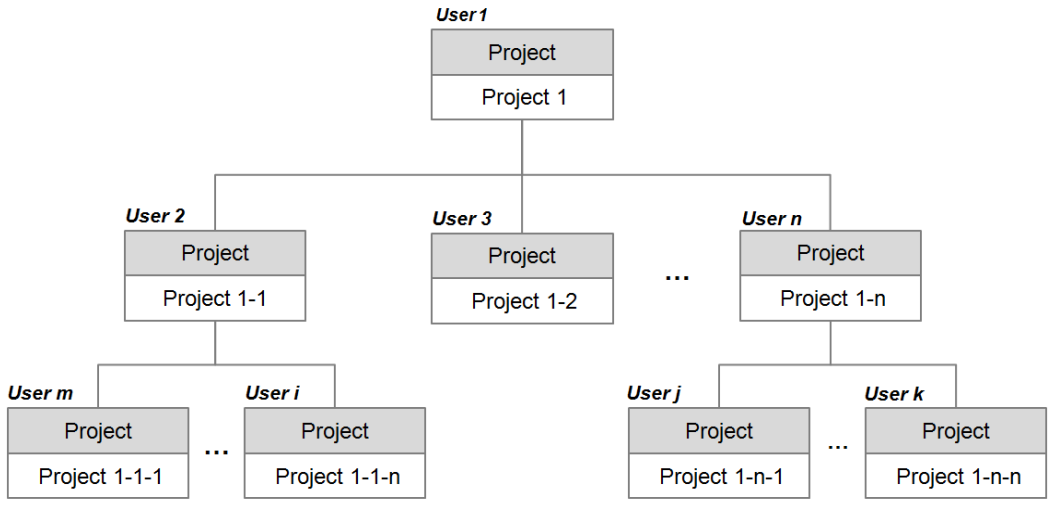


Figure 5. Structure of Connected Projects

5.3. Procedure of Data Processing

The platform proposed in this research automatically precedes the request for version information in a version control module before a web controller transmits requests to the relevant modules. The web controller, which receives version information from the version control module, sends the requests with version information to the relevant modules. Through this process, co-creation

environments that can utilize and control the diverse modules of an open IoT platform can be designed. Figure 6 illustrates the procedure of data processing in the open IoT platform proposed in this research.

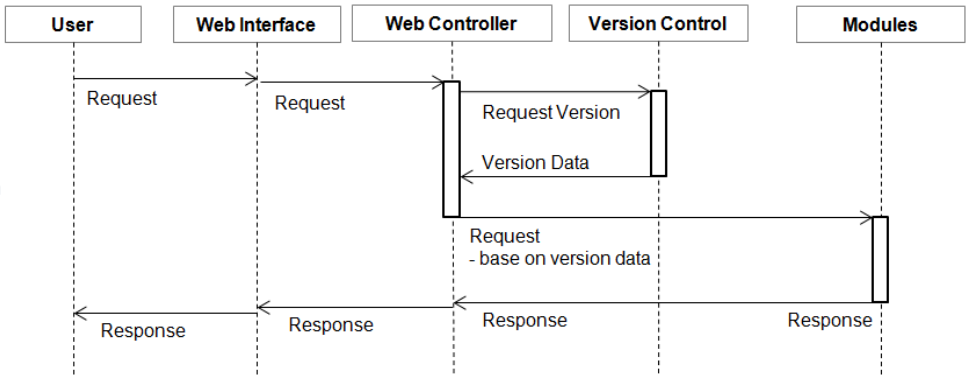


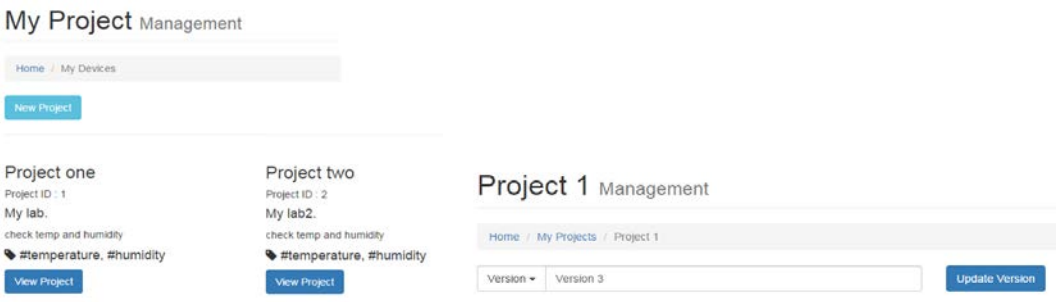
Figure 6. Procedure of Data Processing

6. Implementation

The co-creation environment for an open IoT platform was developed by the author based on the framework created [16]. In order to develop the co-creation environment, the Spring Framework was used as a developing environment because it is very useful for building dynamic web applications based on the Java platform. With this application framework, jQuery was used for the database and Bootstrap was used for the user interface as well as HTML5 and JavaScript. In addition to that, we used a Highchart library to visualize data and used the 123D Circuits of Autodesk™ to display H/W composition and S/W source codes. Data requests to each module by the web controller were processed by Json data through the Rest API.

6.1. Registration and Version Setting

In the basic view of our open IoT platform, users can register a new project and check the list of current ongoing projects. In the list of projects, users can see a simple description of projects and the information for the sensors used. When users register a new project, the first version is automatically generated. However, subsequent versions are generated by users in the version information view located at the top of each project. Users can easily and quickly check current versions and past versions in the version information view. Figure 7 shows the basic view with registration and version information.



(a) Registration (b) Version Information

Figure 7. Basic Views

6.2. Object Environment Setting

In the object environment setting, users can set up basic information about objects such as a name, description, location, tags, type of data, number of data, camera, and degree of openness. Afterwards, users connect their smart objects to our open IoT platform. Figure 8 shows the object environment setting view in our platform.

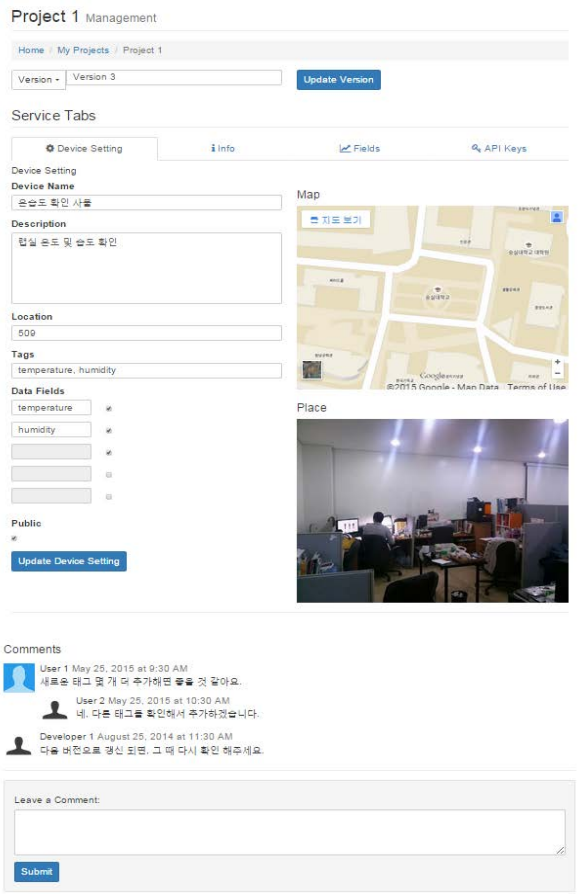


Figure 8. Object Environment Setting View

6.3. Object Composition

The object composition view provides information about the H/W composition and S/W source codes. Through this view, users can suggest new ideas, participate in tests, and contribute to improving the hardware or/and the software. In addition to that, users can obtain knowledge they lacked previously. Figure 9 illustrates the object composition view in our platform.

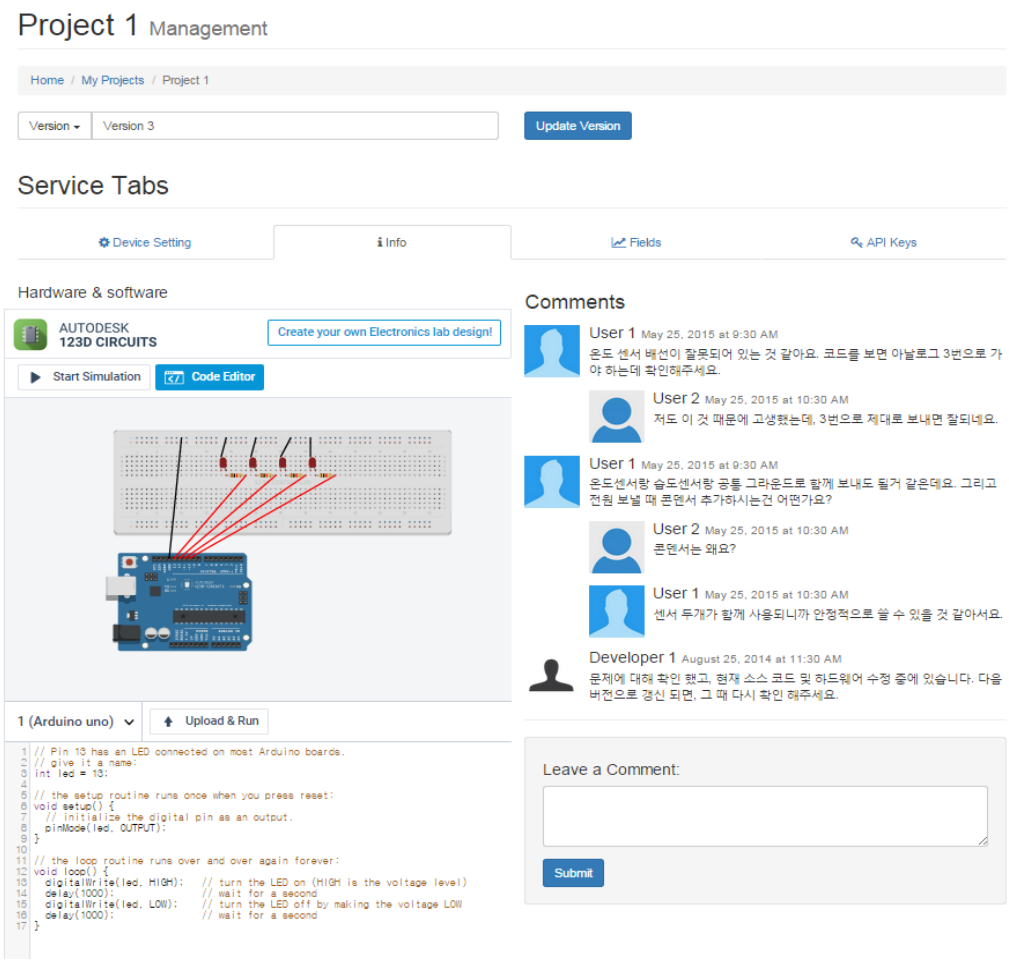


Figure 9. Object Composition View

6.4. Object Data

The object data view supports data visualization such as charts for smart objects connected to our platform. Through communicative functions, this view enables users to check data errors and to discuss with others to improve sensor data. Furthermore, it is possible for diverse users to test connected smart objects through sensors installed in different environments by others. Figure 9 shows the object data view in the platform.

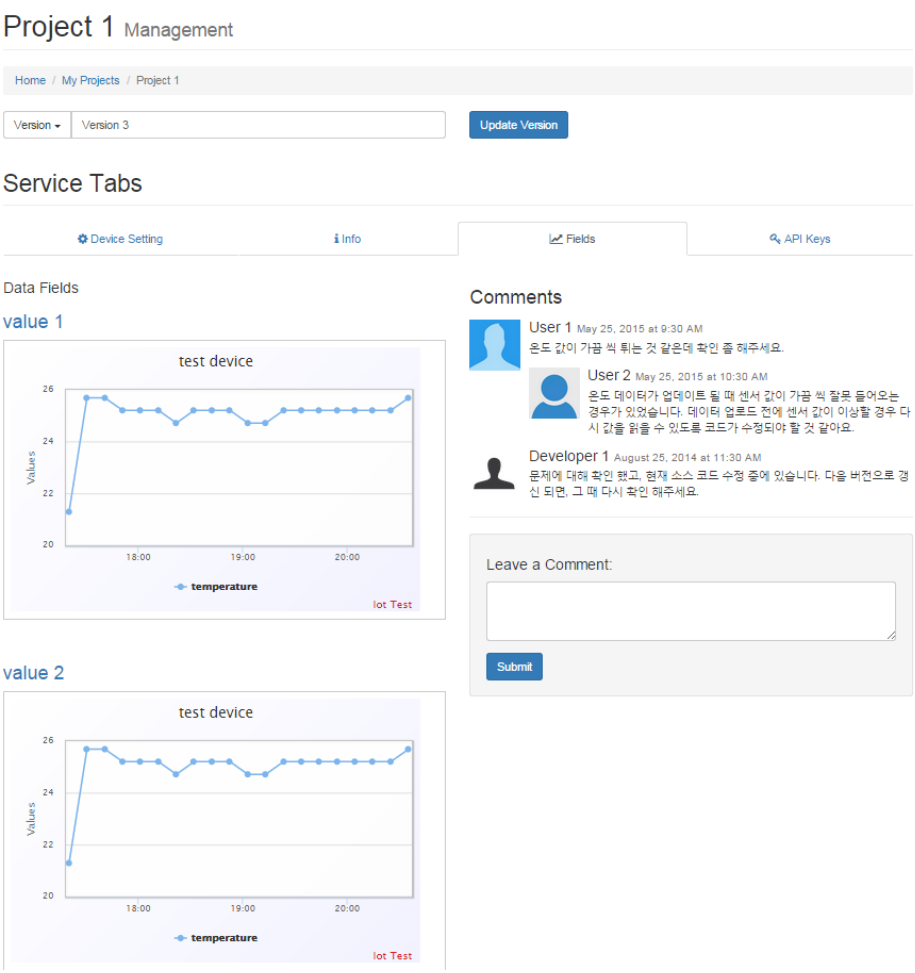


Figure 10. Object Data View

6.4. Open API

The data structure designed in this research can be connected with external systems through our open API. Consequently, all information from project information to the sensor data of smart objects and visualized charts can be openly shared based on the degree of openness set by users. It is possible for us to build a digital eco-system by connecting with other IoT platforms. Figure 10 presents an example of a chart connected to an external system.

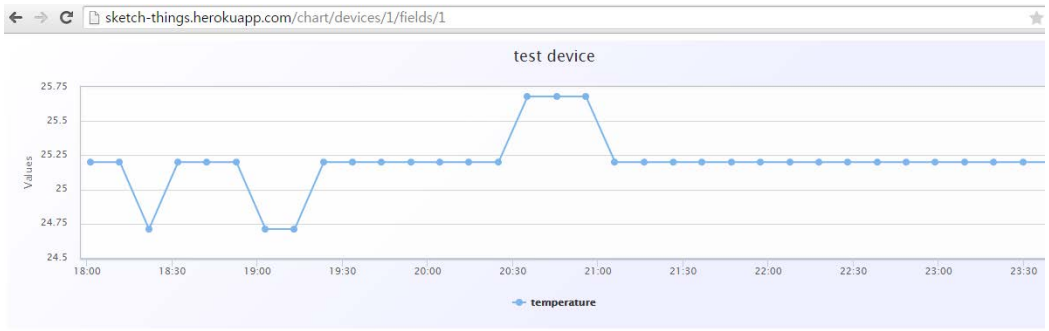


Figure 9. Example Connected to an External System

7. Conclusion and Future Research

In this paper, we propose a co-creation environment for an open IoT platform. We also present our experience with the development of a co-creation environment for an open IoT platform. The co-creation environment developed by the author enables users to effectively create smart objects with others, beginning from the early phase to the final phase through idea-generation, development, and testing.

From this research, our key findings are as follows: (1) a co-creation-based open IoT platform can be designed by adding a co-creation environment based on version control to a general open IoT platform and (2) each version in the co-creation environment for an open IoT platform requires a co-creation process that consists of idea-sharing, discussion, and decision in order to increase feedback between users. From these discoveries, the developmental directions of an open IoT platform that supports co-creation can be established.

In conclusion, the ultimate goal of the system developed in this research is to increase feedback between users with the purpose of enhancing co-creation. Thus, this research is expected to guide developers and researchers in developing a co-creation-based open IoT platform. The future research goal for this project is to examine its viability for practical use. For this purpose, we are preparing different experiments to prove the validity of our co-creation environments.

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