# OpenIoT: An Open Service Framework for the Internet of Things

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***Abstract*—The Internet of Things (IoT) has been a hot topic for the future of computing and communication. It will not only have a broad impact on our everyday life in the near future, but also create a new ecosystem involving a wide array of players such as device developers, service providers, software developers, network operators, and service users. In this paper, we present an open service framework for the Internet of Things, facilitating entrance into the IoT-related mass market, and establishing a global IoT ecosystem with the worldwide use of IoT devices and softwares. We expect that the open IoT service framework we proposed will play an important role in the widespread adoption of the Internet of Things in our everyday life, enhancing our quality of life with a large number of innovative applications and services, but also offering endless opportunities to all of the stakeholders in the world of information and communication technologies.**

***Keywords*-Internet of Things; open service framework; software platform; OpenIoT;**

## I. Introduction

With the advent of ubiquitous computing and communication technology, the world's people could use information access and communication technologies at anytime and from anywhere through smartphones or tablet computers. Indeed, by embedding ultra-small short-range mobile transceiver such ZigBee into our everyday devices and things, the world's things could also be connected each other with smart characteristics and capabilities–the Internet of Things [1].

The Internet of Things is not only a technological revolution that influences our daily lives, but also a great opportunity for a large number of players in industrial domains. However, in order to realize the vision and goal of the Internet of Things into our daily life and encourage the key players in industrial domains including consumers to participate and establish an ecosystem from which they will benefit, an *open service framework* for the Internet of Things is a must. Within a global ecosystem based on the open service framework for the Internet of Things, the key players, including device developers, service providers, software developers, and network operators will be able to make a profit, and consumers will enhance their quality of life and personal performance in the future.

We propose an open service framework for the Internet of Things, which facilitates entrance into the IoT-related mass market, establishing a new ecosystem for the Internet of Things with the widespread adoption of IoT-related devices and softwares: 1) device developers produce IoT devices and register its APIs (application programmable interface) to an Open API portal, 2) with the APIs registered, software developers develop App or Web programs for mobile devices, tablet, or desktop computers, which can connect and control IoT devices through networks, and finally register them on an App store site like Apple, 3) service providers purchase IoT devices and register them on the open service framework, where the large and fast growing number of IoT devices could be monitored and managed efficiently, 4) network operator could capitalize on their mobile and wireless communication technologies, 5) consumers could easily find, connect, and control them using IoT device searching and browsing service.

One of the advantages of the open service framework for the Internet of Things we proposed is support for B2C (business-to-consumer) and C2C (consumer-to-consumer) business model as well as B2B (business-to-business) and B2G (business-to-government) business model. In the modern world of information and communication technologies, services or applications based on a large number of physical sensors and actuators have been developed by a big player such as a government or company, e.g., weather monitoring sensor network. These are typically based on B2B or B2G business model. However, in the upcoming future of the Internet of Things, for an individual's innovative thought to grow from an idea to an specific application or service, an open service framework is required, and we believe our proposed open IoT service framework will be a key to unlocking the potential for dissemination of IoT-related devices, softwares, applications, and services.

## II. Related Work

The best-known example of open service platforms for the Internet of Things is Cosm (formerly, it was Pachube) [2], which was originally created by Usman Haque. Cosm is a platform that allows developers and companies to connect IoT devices and Apps to securely store and exchange data. Its functionality includes support for connecting an open-source electronics prototyping platform such as Arduino [3], real-time data handling by pushing and pulling XML, JSON and CSV data to REST-

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ful API and socket-server, user-customized console (e.g., real-time graphs and widgets) to control, monitor, and analyze data sets collected from IoT devices, and large-scale deployments through Web-based registration service. It also provide the feature to search for devices and sensors by querying location or tag, helping users find interesting data such as Fukushima radiation levels in Japan. This style of open service platforms provided the motivation for this research into an open service framework for connecting between people and IoT devices and between IoT devices themselves, establishing a global ecosystem for the Internet of Things with benefits for all sides: device developers, network operators, grassroots software developers, small service providers, and consumers.

Another example is EVRYTHNG, which gives every physical thing an Active Digital Identity (ADI), connecting and organizing the world's object [4]. EVRYTHNG's software engine for ADI provides all of tools and services to create unique online profiles for everyday items and devices, helping device developers and software developers create brilliant new services and applications by connecting the world's things with people. For example, smart meters will know the cheapest time, so turn on wash machines to cut costs. This vision of stimulating the creation of brilliant products and entirely new services through IoT-related service frameworks also echoes our motivation in this paper.

Many literatures have been published to emphasize the need for providing globally-accepted, large-scale, open, and secure infrastructure for the Internet of Things to realize the vision of future Internet [5], [6].

## III. Open Service Framework for IoT

In order to facilitate entrance to an IoT-related ecosystem, we consider two important functionalities which would be offered by the open IoT service framework we proposed. First, the open IoT service framework is designed with the developer-oriented structure based on open software architecture, encouraging them to develop and realize their innovative services swiftly with Open IoT platforms, and stimulating rapid growth of the IoT-related mass market involving devices, App/Web softwares, and services. Second, by providing users with quick search for IoT services they want, a large number of users take advantage of the IoT services shortly, resulting in the rapid proliferation of IoT-related products, applications, and services. Without user participation, the IoT ecosystem could not be well driven even though a service framework involving IoT-related stakeholders would be established for their efforts. Therefore, we design the open IoT service framework, which provide support for location-based search services for a plethora of IoT devices worldwide. When users want to connect to the searched IoT device, the softwares (e.g., smartphone App or Web) related to the searched device would be unobtrusively downloaded to their smart devices like smartphones or tablet computers, and ready to serve the IoT service. Because most IoT devices have their own geographical coordinates, a map- and location-based device search will play a pivotal role in interactively and unobtrusively connecting people to IoT devices.

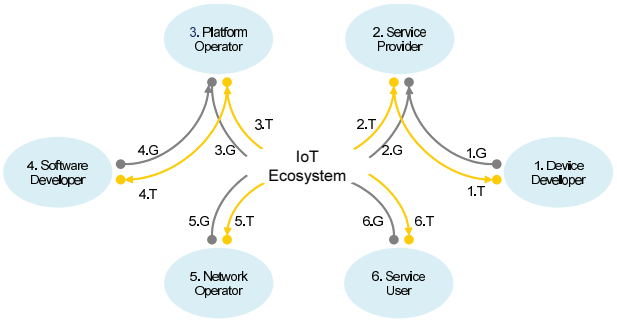



Figure 1. Ecosystem of IoT services

### A. Stakeholders and Ecosystem of IoT services

Because the open service framework for the Internet of Things (OpenIoT) is designed for sustainable growth of stakeholders within an IoT-related ecosystem, we first need to define the stakeholders. We chose the six key stakeholders, which are device developer, service provider, platform operator, software developer, network operator and service user respectively. Each stakeholders are defined as follows:

- Device developer: an individual or company who produces and distributes things for providing particular services in the IoT environment;
- Service provider: an individual or company who purchases and installs things in the IoT environment to provide particular service;
- Platform operator: a company operating software platforms to build the IoT environment, network operators can substitute for platform operators;
- Software developer: an individual or company who develops and releases softwares such as App and Web application for providing particular services using things in the IoT environment;
- Network operator: a company providing network and communication solutions for composing the IoT environment;
- Service users: an individual or company who utilize services in the IoT environment.

Fig. 1 shows a glance of the IoT ecosystem and role of stakeholders. The contribution (Give) and benefit (Take) between stakeholders is described in Table I.

### B. Architecture of OpenIoT Framework

We proposed open IoT service framework (OpenIoT) to facilitate the stakeholders joining IoT ecosystems for themselves. The OpenIoT basically consists of three server side platform, which are Planet Platform, Mashup Platform, and Store Platform respectively and one device side platform named by Device Platform. The all platforms have open APIs based on RESTful interface, which is a style of software architecture for developers to make their own software easily using the APIs. Once we know the API of the platform, we can develop a new software

Table I
GIVE AND TAKE BETWEEN STAKEHOLDERS

| Stakeholder | Give | | Take | |
|---|---|---|---|---|
| 1.Device developer | 1.G | IoT Devices | 1.T | Sales profit |
| 2.Service provider | 2.G | Information and services related to IoT devices | 2.T | Service fee |
| 3.Platform operator | 3.G | IoT software platforms | 3.T | Platform access fee |
| 4.Software developer | 4.G | IoT Service Apps and Webs | 4.T | Sales profit |
| 5.Network operator | 5.G | Network services | 5.T | Network access fee |
| 6.Service user | 6.G | Service charge | 6.T | Usage of IoT services |

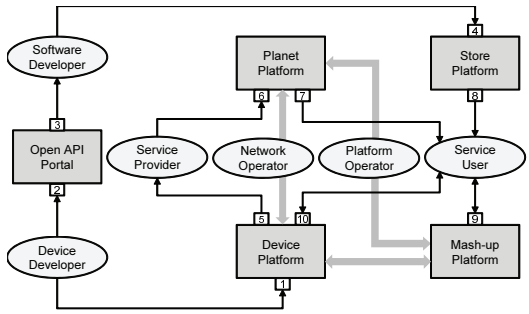



Figure 2. Open service framework of IoT services

interacting with the platforms. Therefore open API portal is required in addition to the OpenIoT platforms to support that service developers easily search APIs which they want to use. The platforms for OpenIoT are defined as follows:

- Device Platform: a well-designed, embedded SW platform to help connecting and cooperating things to Open IoT platforms and application software. It has commonly light weighted tiny web server;
- Planet Platform: a server platform for IoT device registration, management, monitoring, and search in the global IoT environment;
- Mashup Platform: a service platform for providing new integrated services based on data sets collected from IoT devices and its mashup of information over the Internet;
- Store Platform: an App/Web store containing applications or links to Web address that provide user services through interaction between IoT devices or Mashup Platforms.

Fig. 2 shows the service flows of OpenIoT Platform related with stakeholders. we are describing the flows related with each stakeholder to help you understand.

1) Service flow for device developers
This stage includes flow#1 to flow#2 as the process of producing new IoT device products. First, device developers develop and produce a IoT device using a offered reference HW and SW system of Device Platform (flow#1). After that they should register its APIs to the Open API portal (flow#2).

2) Service flow for software developers
This stage includes flow#3 to flow#4 as the process of developing new IoT service softwares such as App and Web softwares to use IoT devices for mobile devices, tablet, or desktop computers. First, service developers search the APIs of the IoT devices or mashup services at the open IoT portal which they want to use (flow#3). After that, they make softwares using the APIs. Finally, The developed softwares should be registered to Store Platform (flow#4).

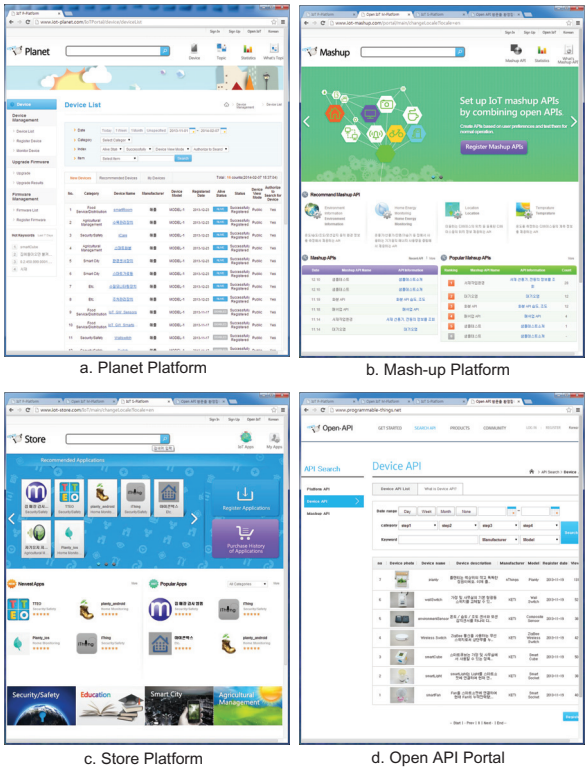
3) Service flow for service providers
In this stage, service providers purchase IoT devices from device developers (flow#5) and register the profiles of them on the Planet Platform (flow#6). The profile is consisted of deviceID, locationInfo, serviceCategory, tags and description. Here, deviceID is global unique identifier of the device. locationInfo is the coordinations on the map selected by service provider. Later, service users use it to search the device on the map. serviceCategory and tags are the service type of device and the related keywords respectively, also they are used to search the device by service users. Lastly, description is the brief information of the device.

4) Service flow for service users
This service flow includes flow#7 through flow#10 as the process for service users. First, service user downloads and installs the IoT browser software which is a dedicated application to search IoT devices worldwide. After that, the user will search and browse IoT devices using the IoT browser. Such search and browse services are performed in the IoT browser using RESTful Open APIs provided by the Planet Platform, and a combination of all the information about IoT devices registered, including deviceID, locationInfo, serviceCategory, and tags.

In case of connecting IoT devices around users, they can directly choose the IoT devices with QRcode or NFC (near field communication). In case of connecting IoT devices geographically far from users, users move the map view of IoT browser to a new location they want to explore, or search IoT devices by querying tag information and serviceCategory (flow#7).

If users select a searched IoT device in the IoT browser, the IoT browser again searches application softwares related to the IoT device by querying the Store Platform with the IoT deviceID through Store Platform Open APIs. The way of showing search results depends on the type of user smart devices. In case of Android OS-based smartphones, for example, basic information about the IoT device and a list of Android Apps and links to Web applications related to the device will be displayed on users' smartphones. Once users select a specific App, it will be downloaded and installed on user's smartphones or immediately run if already installed. In case of selecting a specific link to Web application, the Web page will be loaded (flow#8).

Through the process of Flow#8, users can build a connection directly to the IoT device they chose or the




a. Planet Platform b. Mash-up Platform

c. Store Platform d. Open API Portal

Figure 3. Service platforms of OpenIoT

Mashup Platform with App or Web applications. For such connections, the point of contacts to IoT devices and Mashup Platforms (e.g., IP address and MSISDN) will be provided by the Planet Platform.

There are two ways for connecting and controlling IoT devices, which will be autonomously decided according to the App and Web application downloaded. One way is a service through the connection to Mashup Platforms (flow#9). With Mashup Platforms, user can collect data sets from the IoT device in real-time but also historical and statistical data sets, even control the IoT devices. The other way is a service through direct connections to IoT devices (flow#10). Users can directly control or collect information from the IoT devices they chose. A combination of these two method for providing IoT services will be possible depending on the types of IoT service developed.

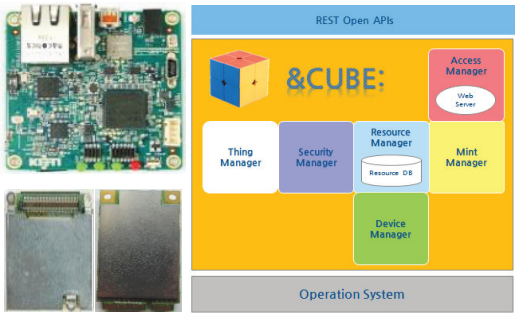
5) Infrastructure services

Network operators provide the network connection service such as 3G networks and LTE networks for Device Platforms and service users, and platform operators (as mentioned previously, platform operators can be substituted by network operators) are responsible for operating Planet Platforms, Mashup Platforms, and Store Platforms.

## IV. Implementation

In this section, we briefly describe our implementation of the open service framework for the Internet of Things.

Fig 3. shows our implementation regarding service platform consists of Planet Platform, Mash-up Platform, Store Platform, and Open API portal. Planet Platform




a. hardware b. software

Figure 4. Device platform of OpenIoT

supports IoT device's registration, management and discovery. When an IoT device is registered with Planet Platform, device profiles including device's ID, name, keyword, location, and network address are delivered to Planet Platform. These device profiles are stored and indexed in Planet Platform and afterwards Planet Platform can process a discovery request and respond it. Mashup Platform plays a role as data repository and also provides mash-up service. IoT devices registered with Planet Platform send their generated data such as sensing data to their corresponding Mashup Platform. The data in Mashup Platform can be accessed through open APIs by App and Web applications. In addition, Mashup Platform sets up mash-up APIs and provides them by combining open APIs. IoT device's applications can be registered with Store Platform and users can download applications from Store Platform and install the applications to their smart devices or IoT devices. Open API portal provides the Open API list of IoT devices registered by device developers. Application developers can refer to this site and develop their IoT applications by using referred open APIs.

Fig 4. shows Device Platform implementation including both hardware part and software part. Device Platform consists of the hardware part including communication modules and the software part supporting interaction with Planet Platform and Mashup Platform. Device Platform's software part is composed of 6 components which are Access Manager, Thing Manager, Resource Manager, Device Manager, Security Manager, and Mint Manager. The Access Manager component takes responsibility of communication with Planet Platform and Mashup Platform and exchanges data or control messages. The other components are used to manage resources, sensors, actuators and attached devices related to the device. Device Platform also provides REST based Open APIs, and through these APIs, user can access the resources managed by Device Platform. Hardware part supports various communication modules such as ZigBee, 3G, LTE, and WiFi/Ethernet.

## V. A Practical Use Case

Proposed OpenIoT Platforms could be applied in wide service areas such as home monitoring and control, healthcare, agriculture management, energy monitoring and control, smart education, smart city, and security.

Here, we provide a public bicycle rental service named by *iBike* service as a practical use case of many IoT services. The iBike system consists of a iBike station for managing bicycles, iBike tags attached to bicycles and iBike Apps for rental service users and managers. The iBike station has Open APIs to support reservation, rental and management functions and iBike tags have functions to inform the states of bikes.

To explain the process of the iBike service, we describe the behaviors of each stakeholder in iBike service focused on smartphone users. In iBike service, device developers develop their own iBike stations and iBike tag and register those APIs at Open API portal. Also, they develop a basic iBike Apps to use the iBike system. iBike service providers purchase iBike systems and install them. Software developers develop various smart phones Apps and mashup service Apps for iBike services. For example, they can make a new mashup App by combining forecast service, train information service and iBike service.

Now, we like to look at iBike service from service user's perspective. First, a service user on the train who want to make reservation a bike searches iBike station closest to the destination station using IoT browser. After that, the user selects an appropriate station then Apps associated with the selected station are listed. Next, the user selects and downloads a App want to use. After installing the App on user's smart phone, the user makes reservation a bike using the App. After get off the train, the user run the downloaded iBike App immediately by contacting his or her smartphone to iBike station. This procedure is performed through user's smart phone get the station's ID by short range communication such as NFC. Finally, the user can rent the reserved bike on the iBike station. Also, service providers can remotely manage iBike stations by manager Apps.

As we can see above, OpenIoT platform provides not only considerable convenience for service users, but also variety business opportunities for device developers, service developers and service providers.

## VI. Conclusion and Future Works

We have presented an open service framework for the Internet of Things, OpenIoT, which is proposed to facilitate entrance into the IoT-related mass market, and establishing a global IoT ecosystem with the worldwide use of IoT devices and softwares. The service framework is composed of four open software platforms including Device Platform, which is a sort of tiny, lightweight web server, Planet Platform, a server for device registration, management, and search, Mashup Platform, a service platform for providing IoT-related services, Store Platform, an App/Web store containing applications or links to Web address, and Open API portal where device developers register open APIs of devices and software developers download them to develop App or Web applications. We believe that the open IoT service framework will play an important role in disseminating the Internet of Things into our daily lives, but also giving great opportunities for a large number of enterprising business. We are constructing the Open API portal and developing each software platform in cooperation with SK Telecom Co., a wireless telecommunication operator in S. Korea, but also investigating pilot services in order to show the practical feasibility of the proposed open service framework.

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