Development of IoTcloudServe@TEIN Smart-Energy@Chula Service Gateway : Case Study of Secured On-Demand Building Energy Management System Data Platform Using NETPIE

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***Abstract*—This paper proposes a framework for implementing Smart-Energy@Chula system of IoTcloudServe@TEIN by using NETPIE security mechanisms. IoTcloudServe@TEIN project aims to integrate networked collaborative efforts of research and educational communities in the Trans-Eurasia Information Network (TEIN). Smart-Energy@Chula service has been developed on the earlier completed so-called CU-BEMS (Chulalongkorn University's Building Energy Management System) testbed with the technical support of CUBEMS IEEE1888 protocol server engine which aims not only to show on-site energy management automation but also raise people awareness. In practice, building automation system can use CU-BEMS cloud, which allows the sharing of function or micro-service resources, for real-time decision-making algorithm. For cloud enhancement, we also require a new channel means to enable the secured on-demand sharing of CU-BEMS OpenData repository via a herein so-called interworking service gateway. The development of the interworking service gateway in this research thus enhances the building energy management to be compliant with different communication protocols, which could be useful for researchers and manufacturers in the future.**

***Index Terms*—IoTcloudServe@TEIN, building energy management systems (BEMS), IEEE1888, open data, gateway**

I. Introduction

"Data-centric IoT-cloud service platform for smart communities" or IoTcloudServe@TEIN project has been established since 20 June 2018. The main purpose of this project is to integrate networked collaborative efforts of research and educational communities from developed-countries (Korea, Japan), from another developing country (Malaysia), and from a least developed country (Laos) [1]. In the project, we should like to achieve a framework design and a proof-of-concept implementation for a data-centric IoT-cloud platform that can help enable IoT-domain service diversification. As an example for IoT-domain service demonstration, herein, the focus is concerned with the IoTcloudServe@TEIN's Smart-Energy@Chula service based on the earlier completed so-called CU-BEMS (Chulalongkorn University's Building Energy Management System) testbed.

CU-BEMS, with the technical support of CU-BEMS IEEE1888 protocol server engine from the University of Tokyo [2] [3], is readily available with more than 250 energy-related sensors [4] [5] and smart meters [6] that send the real-time energy and room ambient readings to CU-BEMS storage. With the total data generation rate up to 800 data points in every second, the design of CU-BEMS is to monitor, control and analyze actual energy consumption profiles as well as relevant building's ambient environments. The main goal is not only to show site energy management automation in engineering department buildings but also to raise people awareness [7]; for example; a smart meter records energy usage of air-conditioning systems inside a room and motion sensors in that area check the people movement. If no motion is detected in that room, then the CU-BEMS will alarm the waste energy usage of the air-conditioning system for energy saving. For information-pushing model design in CU-BEMS, the testbed provides Interactive Display as a Service (IDaaS) to notify to building users the real-time energy-related information to create awareness to staffs and students inside campus [8].

Accumulation, dissemination, and analysis of CU-BEMS data to all related partners, therefore, form the basic foundation of how current and future Smart-Energy@Chula system functions and evolves. In this paper, we report our implementation of an interworking service gateway to provide a secured means of interacting with CU-BEMS OpenData repository. The gateway is designed by using the well-established security mechanisms available in the NETPIE capability which can be facilitated within the IoTcloudServe@TEIN framework.

The paper is organized as follows: Design of CU-BEMS OpenData repositry in Smart-Energy@Chula System in Section II, and particularly focus on Interworking service gateway and proof-of-concept secured on-demand data fetching functonality test in Section III. Following that, The Gateway Performance Testing in Section IV. We conclude the paper in Section V.

II. Design of CU-BEMS OpenData repositry in Smart-Energy@Chula System

In CU-BEMS cloud, there are two types of resources to be shared. Firstly, we apply the concept of application virtualization using an open-source network function virtualization (NFV) framework, together with OpenStack cloud operating system [9], to allow the sharing of function or micro-service resources. As the second resource type, within the scope of this paper, sensor and control data must be shared and made securely accessible by involved researchers and developers. Practically, if one needs data for a big analytics purpose, a large archival of past data can be exported manually and forwarded to the data users on preplanned requests. However, the archival is performed only daily after midnight in order to avoid CU-BEMS storage server overload risks during the normal working hours when the system must be immediately responsive to all user interactivity via IDaaS or a normal CU-BEMS web portal. The historical storage archives must be periodically scheduled when the server utilization is not too high, and hence, not exactly *real-time* data accessibility.

In practice, a building automation system needs on-demand real-time data sharing from the sensor cloud storage system, like CU-BEMS, to monitor and control building facilities in an energy efficient manner. Significantly, there are instantaneous data requests from various type of sensors used for decision-making algorithm for building automation. To achieve that, we require a new channel means to enable the secured on-demand sharing of CU-BEMS OpenData repository via a herein so-called interworking service gateway.

III. Interworking service gateway and proof-of-concept secured on-demand data fetching functonality test

The mechanism and functionality of interworking service gateway or Fetching Gateway are illustrated in Fig. 1 and explained as follows.

At first, an administrator creates Application ID, later called APPID, in a NETPIE account [10] and gets two generated key-secret pairs, namely, kGW-sGW and kFetch_html-sFetch_html for Fetching Gateway and Fetch html client, respectively. These key-secret pairs of NETPIE security mechanism [11] allow the interworking service gateway to identify users' authentication and authorization in requesting for CU-BEMS data. During the service initialization phase, the administrator also sets Topics T1 and T2 to announce where data requesters can send their requested data PointIDs as well as where the requested data values will be published subsequently.

Upon its instantiation, the gateway authenticates to NETPIE by using kGW-sGW key and remains to be in its server-listening mode waiting for any data exchange requests that would be published and notified in its subscribed NETPIE Topics.

Whenever a user wants to request for a CU-BEMS data by specifying data PointIDs, the user's request after passing all NETPIE security checks will be sent automatically to Topic T1. The gateway, which already subscribes to Topic T1, gets the published PointID and performs any accessory IEEE1888 FETCH to CU-BEMS storage. CU-BEMS storage replies back with PointID's data to the gateway, which in turn publishes the responded data values at NETPIE Topic T2. Finally, the Fetch_html of requesting user is notified of the requested data.

Fetch request's result of one PointID example from CU-BEMS storage is shown in Fig. 2. The requested sensor's data at the latest stored timestamp has been successfully fetched upon with no errors. For next session, the gateway will be tested to support concurrent requests from multiple users and to verify how the developed mechanism can properly handle possible errors in practice.

IV. The Gateway Performance Testing

In this section, we present a performance of our gateway to support concurrent requests from multiple users. The fetching result of multiple-PointID requests from Smart-Energy@Chula is shown in Fig. 3. These requested sensor data at the latest stored timestamp also are successfully fetched with no errors which confirm that the gateway can support concurrent multiple-PointID requests.

A. Experimental Setup

We have conducted a series of testings to show the performance of the gateway in terms of time delay and CPU usage. The experiments were carried out on Intel® Core™ i7-8550U Processor, 1.8 GHz CPU, 8 cores and 16 GB RAM running on Microsoft Windows 10 platform (64 bits) for 30 minutes continuously. Our experiments consist of 33 test cases for both time delay and CPU usage testing: 3 main cases with 11 subcases. Therefore, we set fetching requests at 5, 25, and 125 PointIDs per request with 11 different fetching rate for each request to retrieve information from gateway at 1, 5, 10, 15, 20, 25, 30, 35, 40, 45, and 50 requests per second (req/s) respectively. In addition, the whole test has been repeated for 25 times on 20 Mbps internet package and the 95% confidence interval has been computed.

B. Results and Discussion

We first have evaluated our gateway performance on the time delay as illustrated in Fig. 4, which is measured from the instance when a request is fetched to the instance when the corresponding response is correctly returned, and CPU utilization as illustrated in Fig. 5, which is measured at the computer running our developed gateway function. Note also, in term of hardware, this computer running gateway has the lower computational capability than the server of CU-BEMS and NETPIE, so any performance degradation herein observed would be contributed mainly from this gateway.

In Fig. 4, the results show that the total loading is proportional to the increase of request rate as well as the number of PointIDs being fetched per each request. At 125 PointIDs per request and towards the fetch rate of 50 requests per second, the time responsiveness becomes acceleratingly worsen with the time delay increases aggressively. Such performance degradation is understandable as seen in Fig. 5. Particularly,

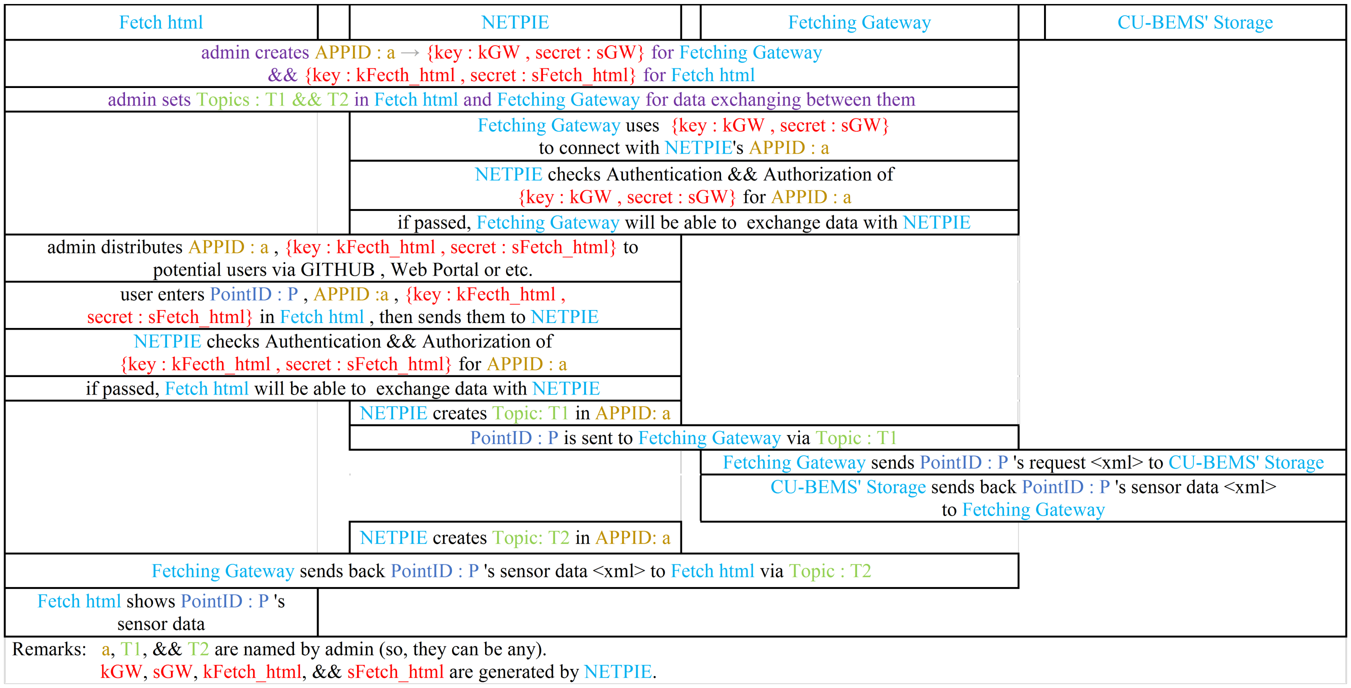

Fig. 1. Fetch procedure

Fetched result:


```
<?xml version='1.0' encoding='UTF-8'?><soapenv:Envelope
xmlns:soapenv="http://schemas.xmlsoap.org/soap/envelope/"><soapenv:Header/><soapenv:Body><ns2:queryRS
xmlns:ns2="http://soap.fiap.org/"><transport xmlns="http://gutp.jp/fiap/2009/11/"><header><OK/><query
id="12ed9de4-1c48-4b08-a41d-dac067fc1c0d" type="storage" acceptableSize="1000"><key
id="bems.ee.eng.chula.ac.th/energy_consumption/department" attrName="time" select="maximum"/></query>
</header><body><point id="bems.ee.eng.chula.ac.th/energy_consumption/department"><value time="2019-
02-20T01:55:00.000+07:00">23279.572643</value></point></body></transport></ns2:queryRS>
</soapenv:Body></soapenv:Envelope>
```

sensor's value

Fig. 2. Fetching result for CU-BEMS sensor's value

Fetched result:


```
xmlns:ns2="http://soap.fiap.org/"><transport xmlns="http://gutp.jp/fiap/2009/11/"><header><OK />
<query id="12ed9de4-1c48-4b08-a41d-dac067fc1c0d" type="storage" acceptableSize="1000"><key
id="www.dr100.com/north/cmi/cmi2/meter/1/monitor/power_all_1m" attrName="time" select="maximum" />
<key id="www.dr100.com/northeast/nma/nma9/meter/1/monitor/power_all_1m" attrName="time"
select="maximum" /></query></header><body><point
id="www.dr100.com/north/cmi/cmi2/meter/1/monitor/power_all_1m"><value time="2017-11-
22T01:10:08.000+07:00">319.2</value></point><point
id="www.dr100.com/northeast/nma/nma9/meter/1/monitor/power_all_1m"><value time="2017-03-
27T10:59:14.000+07:00">496.2</value></point></body></transport></ns2:queryRS></soapenv:Body>
</soapenv:Envelope>
```


Fig. 3. Fetching result of multiple PointIDs for Smart-Energy@Chula sensors' values

the CPU utilization of the computer running the gateway function becomes saturated over that increased loading range. In contrast, with lower fetch rates or fewer number of PointIDs per request, the time delay does not grow radically. This observation on the low range of time delay in Fig. 4 is therefore consistent with the non-saturated CPU utilization in Fig. 5.

In practice, when virtual or physical computing hardware responsible for running the gateway becomes overloaded, in the Smart-Energy@Chula of IoTcloudServe@TEIN testbed, a cloud orchestrator can be configured to automatically scale-

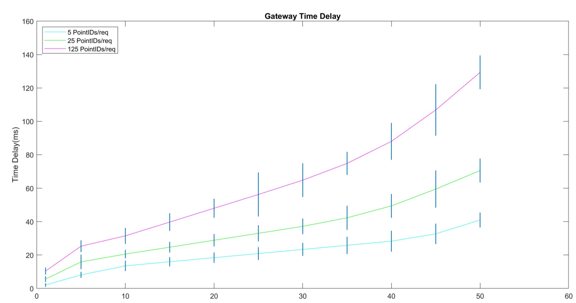

Fig. 4. Gateway time delay

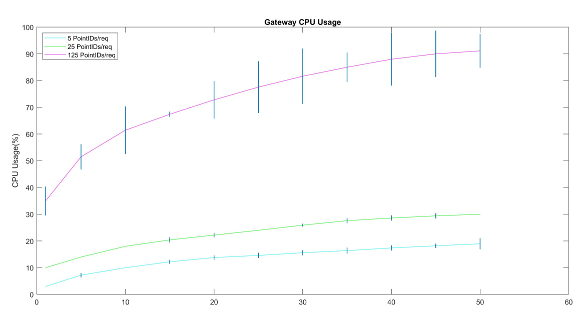

Fig. 5. Gateway CPU usage

out the gateway function. This automatic scaling-out operation upon immediate load increases, as well as an automatic scaling-in operation upon load surge disappearance, would be a major advantage that one should like to test further once our virtualized international cloud testbed infrastructure is completed and the results will be reported in a sequel.

V. Conclusion

In this paper, we present an interworking service gateway and proof-of-concept secured on-demand data fetching functionality. Users can use the gateway to fetch Smart-Energy@Chula's sensor values from the html webpage with NETPIE security mechanisms. The development of the interworking service gateway in this research thus enhances the building energy management to be compliant with different communication protocols, which could be useful for researchers and manufacturers in the future.

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