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An IoT Approach for Developing a Smart Campus

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ABSTRACT: A Smart Campus can be seen as asmaller version of a Smart City. Although, the requirements of a university campus are slightly different from that of a smart city, most of the smart systems that are installed in a smart city, can be installed in a smart campus. In this paper, we will discuss about smart systems that can be integrated in a university campus. This paper covers a broad category of technologies due to heterogeneous end systems and protocols. Developing our smart campus will include one smart card approach, smart lighting, environment analysis, smart waste management, campus security systems and automation of various systems in a university. This paper aims at providing a suitablearchitecture for a smart campus despite heterogeneous protocols and systems. We have tweaked and proposed smart home and smart city concepts for our smart campus.

KEYWORDS: Smart Campus; Sensors; Internet of things (IoTs); Raspberry pi; Protocols; Modules; ESP8266

I. INTRODUCTION

A Smart Campus is similar to a miniaturized Smart City, which foresees connecting the wide-reaching educational resources to the faculty and the students while contributing in their overall intellectual and social development [2]. Although, the requirements of a university campus are slightly different from that of a smart city such as installing smart traffic congestion reducing systems are of little to no use in a smart campus but on the other hand a university campus may benefit from Smart Waste Management System and Centralized Information System.

The Bharati Vidyapeeth Unviresity Smart Campus project involves developing an open, integrated and scalable Internet of Things technology for Smart Management of various campus utilities [1]. This brings together One Smart Card Approach, Smart Microgrid, Smart Lighting, Smart Environment Analysis for pollution check, Smart Waste Management, Smart Campus Security, Automation of various systems of the University. The initial sphere is smart waste management and smart environment analysis for a sustainable campus environment, and can be extended to other spheres such as energy by implementing smart microgrids. Along with one smart card approach, Smart Lighting, Smart Security and Automation of various university utilities. Information from all the sensor nodes can be collected and sent to the cloud for further processing and analysis.

A fully functional Smart Campus can be achieved with the help of Internet of Things [1]. A Smart Campus includes multiple type of sensors nodes, gateways, actuators, various end systems, servers, database management systems and web interfaces.

The future increments will also include integration of electric vehicle charging stations, smart laboratories, smart structural health systems and data-analysis of the data generated from the sensor nodes. Some of the problems that are going to be addressed through the introduction of a smart campus and its various utilities are: Lack of Convenience, Lack of interest in studies, Lack of an interactive campus, Lack of proper security, Lack of a healthy environment. Also on the way of developing the smart campus some of the difficulties that could arise are Heterogeneous field of application, Lack of established practices, Complex Scenarios, Huge investment, Technological leaps and many more could come up as we may proceed with the development.

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This initiative came forward as a contribution to the Smart Cities Mission by Government of India.The main aim of proposing this system is to have a smart campus solution which is not only scalable but which can be implemented to any other campus with the slenderest modification or alternation so as to create smart people, "As a smart campus creates smart people".

Section II of this paper consist all the services that can be implemented in a Smart Campus. Section III covers the architecture of Smart Campus which includes data format, protocols, devices and hardware resources that are required for the development of a smart campus.

II. RELATED WORK

In [1], the authors have proposed some services that can be provided via a smart campus. We looked into those services and found out the way to implement those services. In [2], authors are developing a smart campus that implements an e-card for various purposes such as access control and payments and the data generated is analysed for the human behaviour. Our smart campus also generates a lot of data due to smart cards and we can implement the same data analysis system to understand human behaviour at our campus. In [3], authors have developed the architecture of a smart campus mirogrid. We will be using the same architecture with different technologies. Authors have used Zigbee but we will be using the Wi-Fi and so on. In [4], authors have developed a smart waste management system but the exact technologies weren't disclosed. We will be using a raspberry pi, Wi-Fi and distance sensors. In [5], authors have discussed all the type of smart cards that can be implemented in a smart campus. We will be using microprocessor chip based cards delivered by MIFARE. In [6], authors have used Arduino mega board, ESP8266 modules and sensors to collect and analyse environment data. We will be using Raspberry pi, ESP8266 modules and similar sensors to collect the environment data which can later be processed. Our raspberry pi's will be working as local sensors which will process data locally and send them to the database over Wi-Fi routers. In [7], authors have developed a sensor node using a raspberry pi and various sensors. But this will be very expensive, therefore we are using multiple ESP8266 modules with a single Raspberry pi in an area in a campus. This will reduce the costs as well as the power consumption. In [8], authors have designed a home automation system using MQTT and ESP8266 modules. We will be using this research to develop a smart campus using MQTT, Raspberry pi and ESP8266 modules. In [9], authors have compared HTTP with MQTT and gave us the reason to use MQTT instead of HTTP.

III. PROPOSED SERVICES

Internet of things can be seen as the building blocks for the Smart Campuses. In this section, we overview some of the services that can be implemented in a Smart campus. The major issue that we came across while considering all the services that can be integrated into our smart campus was heterogeneity of systems and the technologies that they use. But we finally developed an IOT approach that can resolve the issue of heterogeneity. These services aim at increasing productivity in a campus, saving a lot of time and make life easy for all those people present on the campus. These services are:

A. *One Smart-card approach:*

Smart card is a mini-computer capable of storing and processing data [5]. This is the main service that will be integrated into our existing university system. A single smart card will be responsible for various functions. It will be used for identification, access control, cafeteria payments and access to various computers in the campus [5]. There are various types of smart cards. Smart cards with microprocessors have data processing capabilities, a card operating system and use encryption which make them secure and suitable for a smart campus [5]. Bharati Vidyapeeth University has already installed MIFARE smart card systems and MIFARE smart cards are already in use. Those smart cards can be used to their full potential.

B. *Smart Waste Management System [4]*:

A campus generates a lot of waste that should be handled properly at regular intervals so that a campus can be clean and hygienic. Dustbins are equipped with sensors and when they are about to be full, a notification is sent to the garbage trucks or waste disposal unit [4]. A request is automatically generated for waste collection. Hence, the location and status of each dustbin can be monitored. This helps in easy disposalof waste and a healthy environment.

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C. *Smart Microgrids [3]*:
Microgrids are modern, small-scale versions of the centralized electricity system [3]. They achieve specific local goals, such as reliability, carbon emission reduction, diversification of energy sources, and cost reduction, established by the community being served. Like the bulk power grid, smart microgrids generate, distribute, and regulate the flow of electricity to consumers, but do so locally. Smart microgrids are an ideal way to integrate renewable resources on the community level and allow for customer participation in the electricity enterprise. We will use renewable energy sources that will help in reducing carbon footprint as well as it can power various systems in our university. A centralized control centre can control those smart microgrids. We will use wind turbines and solar photovoltaics to produce energy. That energy can be stored in advanced energy storage systems. Then, that energy can be distributed over the campus.

D. *Smart lighting*:
Lighting in a university campus consume a lot of energy. So, we will build smart lighting systems that will work on motion sensors as well as light detection sensors. Motion sensors can be controlled by a system-on-chip computer or a microcontroller such as Arduino. Light detection sensors will detect the intensity of lighting in the environment and will switch on/off the lights accordingly.

E. *Environment analysis*:
Air quality and pollution sensors can be installed in the lamp posts, corridors and classrooms around the campus so that they can detect the quality of environment and can report the same. In paper [6], ESP8266 module has been used with Arduino microcontroller and various sensor nodes. We will use various sensor nodes along with ESP8266 modules and Raspberry pi single board computer [7]. Raspberry pi will work as a local gateway for multiple ESP8266 modules in the vicinity and will provide instant actions after taking inputs from the sensors.

F. *Security and Safety*:
Security and safety are two of the main concerns for university authorities. A smart security and system can tackle that issue with the help of various systems. IP-based cameras, smart smoke monitoring systems, motion detection systems and door monitoring systems can be used for that case. IP-based cameras can be controlled from the control centre and live feed can be accessed remotely and wirelessly. Smoke monitoring systems can detect smoke, automatically turn on water sprinklers and alarm the authorities. Door monitoring systems can instantly report the open/close status of a door, if armed. These systems can make a campus safe and secure.

G. *Automation*:
University campuses can be automated for more efficient uses of resources as well as for easing the life of students, professors and staff. For example, some sensors that can detect humidity and temperature can be installed in a classroom so that those sensors can automatically switch on/off the fans and air-conditioners. Lighting can also be automated. Entry points of various colleges can be automated for automatic identification. All the equipment can be turned off/on remotely and wirelessly through some dedicated controllers. Doors can be remotely opened and closed with the help of wirelessly-controlled actuators. A single remote can control all the automated systems. It can tremendously reduce costs associated with electricity and increase productivity for staff, professors and students.

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Fig.1. Smart Campus Services

IV. SMART CAMPUS ARCHITECTURE – BHARATI VIDYAPEETH UNIVERSITY

A Smart Campus has a centralised architecture with various types of sensors, relay modules and actuators. There are hundreds and thousands of peripheral devices that remain active at a time in a smart campus. One necessary characteristics of this architecture is that it can be used with existing technologies. Because it is a centralised architecture, a control centre is located on the campus where all the servers are located. These servers can process the data as well as store huge amount of data.

In this section, we will discuss about the protocol architecture of a smart campus, link layer technologies that are required by our systems to communicate with each other and devices involved in our smart campus.

A. *Protocol Stack*

There are many protocols that may be used in IoT domain. Each protocol has different standard. But because IoT has limited processing capability and require quick response for proper functionality, we need to use protocols that don’t have excessive overheads. Data format should be lightweight so that it can be transferred instantaneously. In Fig. 2., we have lightweight protocol stack and standard protocol stack. Lightweight protocol stack can be used over TCP/IP protocol suite. JSON and MQTT can be mirrored to regular HTML/XML and HTTP protocol at the gateway. In the protocol architecture, we can easily distinguish between three layers: 1) Data, 2) Application and 3) Network. Lightweight and standard protocols can be mapped at these functional layers. In this section, we will talk about the operations of these protocols and their mapping.

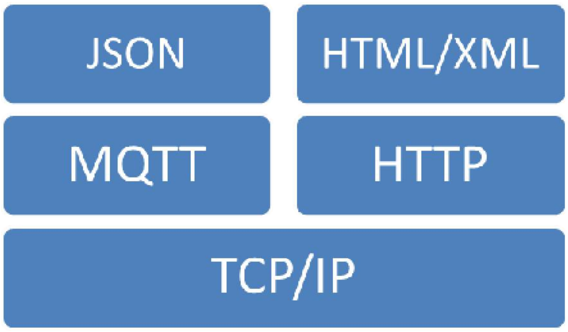

Fig.2.Lightweight Protocol Stack (left) and Standard Protocol Stack (right)

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1) Data Format: Traditionally, HTML and XML are used as the standard formats for data exchange. But the size of XML messages is often too large that may bypass the capacity of devices with limited resources. Furthermore, structure of XML makes parsing XML messages very complex for the devices with limited CPU power. JSON grew up because there was a need of lightweight real-time server-to-browser communication protocol. But as technology has advanced, JSON can now be used in machine to machine communication. RFC 7159 of IETF defines the syntax of JSON [10]. JSON is built on two structures which are universal data structures i.e. 1) a collection of name/value pairs such as an object, record, struct, dictionary, hash table, keyed list, or associative array; 2) an ordered list of values such as an array, vector, list, or sequence [11]. In our smart campus, raspberry pi works as a local gateway as well as MQTT broker. Therefore, a raspberry pi can convert standard data formats such as XML to JSON and vice-versa. Messages between sensor node and gateways can be exchanged in JSON format. When those messages reach the gateway, they get converted to standard data format. Any controller device that is accessing the gateway and the sensor node, will be able to access the sensor data and control the sensors, actuators and relays wirelessly because of XML/JSON conversion.

2) Application Layer: Most of the data flowing across the Internet is carried at the application layerby HTTP over TCP. But the complexity ofHTTP protocol makes it unsuitable for use in IoT devices. In such an environment, HTTP performs poor because of associated overheads. MQTT overcomes these difficulties [9]. MQTT stands for Message Queuing Telemetry Transport. MQTT is a machine-to-machine connectivity protocol which is an extremely lightweight publish/subscribe messaging transport protocol and useful for connections with remote locations where a small code segment is required or network bandwidth is limited [12]. MQTT can easily interoperate with HTTP because it supports the ReST methods of HTTP (GET, PUT, POST and DELETE). A gateway can help in one-to-one correspondence between the response codes. This makes it possible for HTTP devices to interoperate with IoTs.

3) Network and Transport Layer: IPv4 addressing technique can easily work with MQTT and IoTs. Although, it is recommended to use IPv6 in smart cities due to huge numbers of nodes. We will still use IPv4 because a smart campus will have limited number of nodes and they are only required to be accessed from the internal network. IPv4 has 32-bit address field. Each Raspberry pi will be assigned a different IP address and all of the ESP8266 modules connected to a particular raspberry pi can be accessed via that particular IP address. On transport layer, our smart campus uses TCP protocol. Advantages of using IPv4 is that there is no need of Port Address Translation because there are no devices that are assigned the IPv6.

B. Link Layer Technologies

A university campus is spread across a wide area and it produces a huge amount of traffic. There are two types of link layer technologies – Traditional link layer technologies and lightweight link layer technologies. Traditional technologies include communication technologies which are highly reliable, have low latency, and have high transfer rates, high complexity and high energy consumption such as Ethernet, Wi-Fi andfiber optic. Lightweight technologies include technologies with low energy consumption and low transfer rates such as RFID, IEEE 802.11 Low Power and NFC. For a university, a Wi-Fi network is very suitable due to low cost and high range. Bharati Vidyapeeth University has Wi-Fi all over its campus and hence it can be used to connect all the sensor nodes to ESP8266, ESP8266 to Raspberry Pi and Raspberry pi to the router. It also allows students to remotely connect to the Wi-Fi for learning. RFID access control units can be used for gaining access to various facilities according to the authorization.

C. Software Platforms

In the first phase of this smart campus project, a particular software platform is used. Home Assistant is an open-source home automation platform running on Python 3 which can track and control all devices and automate control. It was developed to be used for a home [13]. But this platform can be configured for a smart campus. We have tweaked it to suit our needs. It provides an operating system called Hassbian, which is a Raspbian spin-off. This operating system can be installed on all the raspberry pi. One of the most famous MQTT broker, mosquito, is an open source message

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broker that implements the MQTT protocol versions 3.1 and 3.1.1. MQTT provides a lightweight method of carrying out messaging using a publish/subscribe model which makes it suitable for "Internet of Things" messaging [14]. Home assistant provides a wonderful user interface to control various systems and check real-time status of various systems such as temperature, alarms etc. Arduino IDE is required to program the required functionalities in ESP8266. MQTT will also work on ESP8266 module [8].

D. Devices

This section will cover all the devices that are going to play a role in our smart campus and are classied by the position they take in our smart campus.

1) Servers (backend): Backend servers are located in the control center. They are the power horse behind the whole smart campus. They collect, store, analyze and process the data. They are not necessary for the actual functioning of IoT system. But they have become an integral part of any IoT system because they provide added features and can analyze behavioral data generated from various sensor nodes round the campus. These servers may include:
Database Management Systems: They store huge amount of data that has been generated from sensor nodes. That data can further be retrieved and processed.
Websites: These servers may need to host the websites that may be necessary for a campus such as university website. They may also contain study resources for the students.
Sensor Data Management System (SDMS): Sensors produce a lot of data. Some of that data is relevant and some is irrelevant. SDMS can refine relevant data, process it and produce necessary analytics that can be used to understand the behavior of people in the campus, increase productivity and reduce campus operating costs.
2) Gateways: Gateways are the devices that interconnect end devices with each other and with the systems on other side of the network. They are also responsible for protocol translation and mapping. For example, JSON data format can be converted to XML and vice-versa, at a gateway. MQTT can be bridged to HTTP at the gateway. In our smart campus, raspberry pi and wireless routers are used as gateways. Raspberry pi does all the mapping and routers connect all the raspberry pi to the controllers and servers.
3) Nodes: They are the devices that produce the data which is sent to the control center. These nodes consist sensors, actuators, Radio Frequency Tags, Smart Cards, Mobile devices, Laptops, Tablets. Portable computers can interact with system through Wi-Fi and NFC etc.

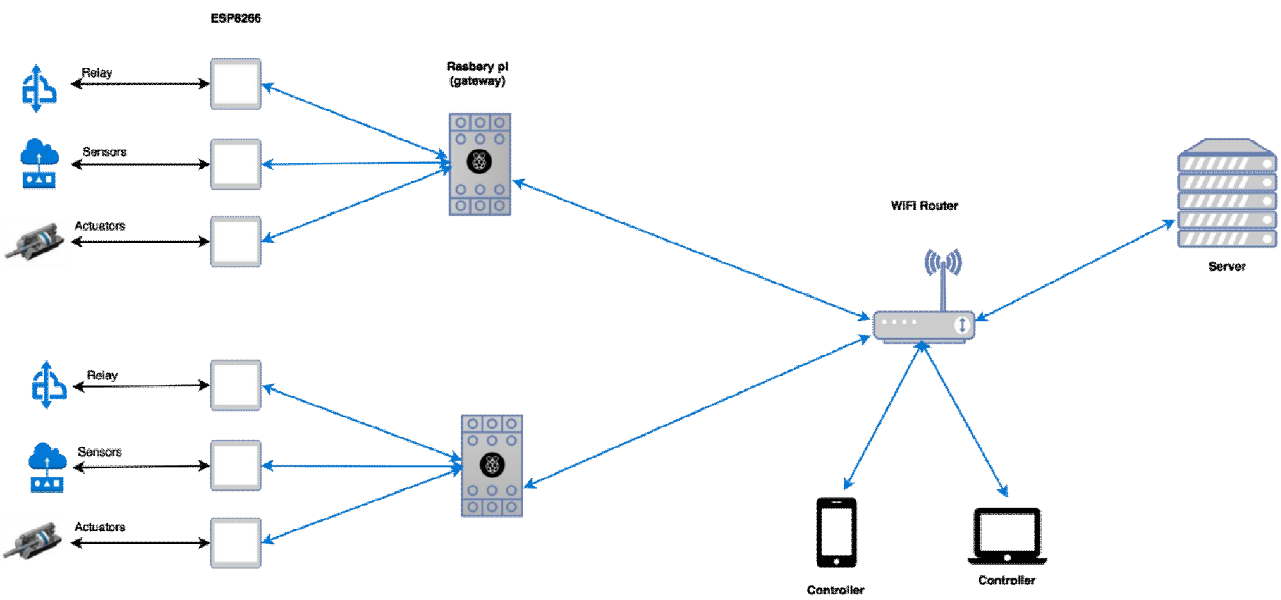

Fig. 3. General Architecture of Smart Campus (sensors, relays and actuators)

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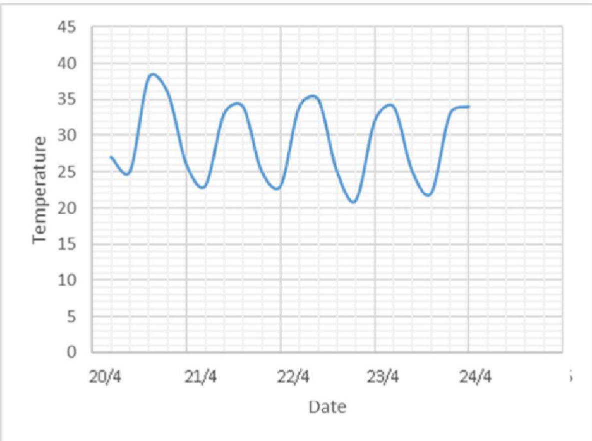
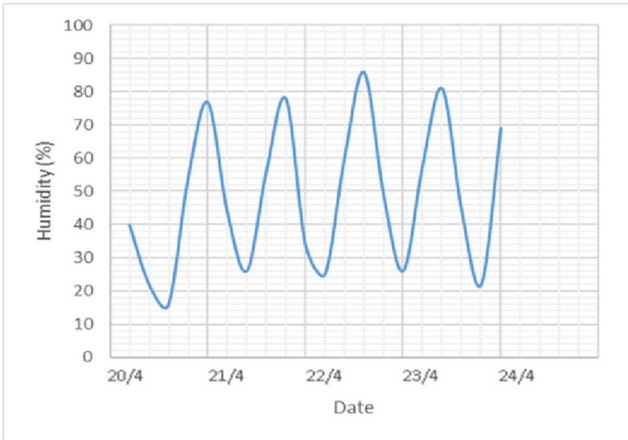
V. RESULTS

This smart campus project is still in its development phase. We have implemented some of the services. But due to financial constraints, other services will be integrated later on. The services that we have made prototypes for, are environment analysis, smart lighting, automation and security systems. We have implemented security system for doors which tells us if a door open/close at any particular moment. If the alarm for doors is armed, then the alarm can go off if someone will open the door and the authorities will be able to find out the same remotely on their controllers. Security systems can be controlled from a touch screen controller. Lights, fans and other equipment can also be controlled from the same controller with the help of relays and ESP8266. Full-fledged integration of services is under review by the authorities. We have some temperature and humidity readings from our sensor.



a)



b)

Fig. 4 Data from Sensors a) Temperature b) Humidity

VI. CONCLUSION AND FUTURE WORK

A Smart Campus is scaled-down version of a Smart city and an extended version of a Smart home/office. Bharati Vidyapeeth Smart Campus project is a scalable project which can be extended to other university campuses. In this paper, we analyzed technologies that can be implemented to develop a smart campus. There are many standard technologies that can be used in a smart campus. We have analyzed many of those standard technologies and came across very few of them that suit our purpose. In Section II, we have listed and explained all the services that may be implemented in a smart campus, which includes smart lighting, automation, smart waste management system, smart card systems, environment analysis, smart microgrids and advanced safety and security measures. Section III covered a general architecture of a smart campus. This includes the protocol stacks, underlying linked-layer technologies and peripheral nodes that exist on a smart campus. The future additions to our smart campus will also include integration of electric vehicle charging stations, smart laboratories, smart structural health systems and data-analysis of the data generated from the sensor nodes.

REFERENCES

1. A. Alghamdi and S. Shetty, "Survey Toward a Smart Campus Using the Internet of Things", 2016 IEEE 4th International Conference on Future Internet of Things and Cloud (FiCloud), Vol.3, pp. 235-239, 2016.
2. G. Sun, Y. Zhou and J. Li, "Build Smart Campus Using Human Behavioral Data", 2016 Intl IEEE Conferences on Ubiquitous Intelligence & Computing, Advanced and Trusted Computing, Scalable Computing and Communications, Cloud and Big Data Computing, Internet of People, and Smart World Congress (UIC/ATC/ScalCom/CBDCom/IoP/SmartWorld), Vol.13, pp. 133-136, 2016.

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(An ISO 3297: 2007 Certified Organization)

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3. H. Talei, B. Zizi, M. Abid, M. Essaaidi, D. Benhaddou and N. Khalil, "Smart campus microgrid: Advantages and the main architectural components", 2015 3rd International Renewable and Sustainable Energy Conference (IRSEC), Vol.3, pp. 1-6, 2015.
4. F. Folianto, Y. Low and W. Yeow, "Smartbin: Smart waste management system", 2015 IEEE Tenth International Conference on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP), Vol.10, pp. 1-2, 2015.
5. T. Halawani and M. Mohandes, "Smart card for smart campus: KFUPM case study", 10th IEEE International Conference on Electronics, Circuits and Systems,Vol.3, pp. 1252-1255, 2003. ICECS 2003. Proceedings of the 2003.
6. N. Sastra and D. Wiharta, "Environmental monitoring as an IoT application in building smart campus of Universitas Udayana", 2016 International Conference on Smart Green Technology in Electrical and Information Systems (ICSGTEIS), Vol.3, pp. 85-88, 2016.
7. K. Hentschel, D. Jacob, J. Singer and M. Chalmers, "Supersensors: Raspberry Pi Devices for Smart Campus Infrastructure", 2016 IEEE 4th International Conference on Future Internet of Things and Cloud (FiCloud), Vol.4, pp. 58-62, 2016.
8. R. Kodali and S. Soratkal, "MQTT based home automation system using ESP8266", 2016 IEEE Region 10 Humanitarian Technology Conference (R10-HTC), Vol.5, pp. 1-5, 2016.
9. T. Yokotani and Y. Sasaki, "Comparison with HTTP and MQTT on required network resources for IoT", 2016 International Conference on Control, Electronics, Renewable Energy and Communications (ICCEREC), Vol.2, pp. 1-6, 2016.
10. "RFC 7159", Ietf.org, 2014. [Online]. Available: https://www.ietf.org/rfc/rfc7159. [Accessed: 12- Jan- 2017].
11. D. Crockford, "JSON", Json.org. [Online]. Available: http://www.json.org/. [Accessed: 11- Jan- 2017].
12. "MQTT", Mqtt.org. [Online]. Available: http://mqtt.org. [Accessed: 18- Feb- 2017].
13. H. Assistant, "Home Assistant", Home Assistant. [Online]. Available: https://home-assistant.io/. [Accessed: 17- Mar- 2017].
14. "An Open Source MQTT v3.1 Broker", Mosquitto.org. [Online]. Available: https://mosquitto.org/. [Accessed: 20- Mar- 2017].