Performance Enhancement and IoT Based Monitoring for Smart Home

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Abstract— **In recent years, home automation has become so popular due to its numerous advantages. The home environment has witnessed a rapid introduction of network enabled digital technology. This technology comes with new and exciting opportunities to increase the connectivity of different devices within the home for the purpose of home automation. This paper aims at designing a basic home automation system of controlling multiple appliances which can be monitored and accessed from anywhere in the world with very low cost. The technology incorporates Raspberry Pi and the web server. The Raspberry Pi and Arduino integrated with Nrf modules are used to monitor the home environment appliances, and the readings are passed to the web server designed. The parameters or commands sent through web page are monitored frequently and if any threats found the mobile connected to this web server is alerted through an alarm or message. The user can access this application from anywhere in the world. The result produced is low cost advantageous and absolute. Performance Analysis of different protocols (MQTT, HTTP and CoAP) is estimated using visualizations.**

Keywords— Home Automation, Raspberry Pi, Web Server, MQTT, cost effective.

I. INTRODUCTION

Smart home technologies have developed rapidly from home networks and multimedia to various home automation systems. Particularly, these technologies are used extensively in home energy management, although their applications are mainly limited to individual households. Because of the Internet of things (IoT), smart home technologies have begun to integrate various smart devices, ranging from conventional sensors and remote controllers to smart home appliances and robot systems. Consequently, many innovative applications have been developed. Recently, smart home technologies have been integrated with cloud-based services to provide value-added services, operations, and management.

The popularity of network enabled home automation system has been increasing greatly in recent years due to simplicity and much higher affordability rate. Moreover, with the rapid expansion of the Internet services, there is the potential for the monitoring and remote control of such network enabled appliances. However, the new and exciting opportunities to increase the connectivity of devices within the home environment for the purpose of home automation through internet are yet to be explored. Several definitions are available in the literature for Home Automation. There has been significant research into the field of home automation with many other communication protocols like blue tooth, hand gestures, DTMF etc.

In addition to energy management, home safety and health care have been explored in smart house studies. Smart home systems typically integrate various sensors and surveillance cameras to identify and assess abnormal events regarding home safety. In home health care, smart home systems not only employ body condition-specific sensors but also combine resources from remote cloud platforms with professional medical and healthcare services.

Features of the proposed System

This paper presents a novel, low-cost, stand alone and flexible Raspberry Pi based home automation system. The proposed architecture is designed to reduce the system's complexity and lower fiscal costs. Hence, the system endeavors not to incorporate expensive and complex components, such as a high end personal computer (PC), where possible, as it uses only one Raspberry Pi as primary controller and Arduinos as clients for control. The system is scalable and flexible, allowing other home appliances designed by multiple vendors, to be securely and safely added to the existing home network with the minimum amount of effort. The system allows home owners to monitor and control connected devices in their home network, through a variety of controls, including a Raspberry Pi based remote control, and any Wi-Fi enabled device with Java support. Additionally, users may remotely monitor and control their home devices using any Internet enabled device which supports Java. A home gateway is implemented to facilitate interoperability between heterogeneous networks and provide a consistent interface, regardless of the accessing device. A virtual home network pre-processes all communications before they are realized on the real home automation system. All communications are checked for security and safety before being allowed to continue to their respective destinations.

This paper is organized as follows: Section 2 discusses the related work on smart home systems. Section 3 discusses the developed home automation architecture, including a review

of the technology used. Section 4 describes the implementation of the proposed system. Section 5 provides a conclusion.

II. RELATED WORK

A literature review showed that studies on smart home systems have primarily emphasized three areas: smart devices, multiple displays, and cloud-based services.

There are many definitions of home automation technology available in the literature. [1] Describes home automation as the technology within the home to enhance the quality of life of its occupants, through the provision of different services such as telehealth, energy conservation and multimedia entertainment.

There has been significant research into the field of home automation. The X10 industry standard, developed in 1975 for communication between electronic devices, is the oldest standard identified from the author's review, providing limited control over household devices through the home's power lines. Recently, research into the field of home automation technology has continued to receive much attention in academia. [2] developed a Java technology based home automation system. An embedded board physically connected all the home automating devices and, through integration with a personal computer based web server, provided remote access to the system. The use of Java technology, which incorporates built-in network security features can produce a secure solution. However, the system requires an invasive and expensive wired installation and the use of a high end computer system. [3] Introduced a Bluetooth technology based home automation system, which consists of a primary controller and a number of Bluetooth sub-controllers. Each home device (appliance) is physically connected to a local Bluetooth sub-controller. The home devices communicate with their respective Bluetooth sub-controller using wired communications. From the sub-controller all communications are sent to the primary controller using wireless communications. It is most desirable for each home device to have a dedicated Bluetooth module. However, due to the fiscal expense of Bluetooth technology, a single module is shared amongst several devices. This architecture basically reduces the amount of physical wiring required and hence the invasiveness of the installation, through the use of wireless technology. However, the architecture does not completely reduce the invasiveness of the installation due to the incorporation of some wired communications. Moreover the sharing of a single Bluetooth module between numerous devices has the disadvantage of suffering an access delay. [4] introduced a telephone based remote controller for home and office automation. The system differs in that all communications occur over a fixed telephone line and not over the Internet. The system can be accessed using any telephone that supports dual tone multiple frequency (DTMF). The disadvantages of this system are threefold: users are not provided with a graphical user interface (GUI), users have to remember an access code for access, and they have to remember which buttons to press for the control of connected devices to it. [5] Proposed a novel control network, using hand gestures. The controller uses a hand glove to relay hand gestures to the system. The problem with the system lies in the inaccuracy of hand gestures, with the potential for normal arm movements being inaccurately interpreted as commands. Mainly, there is the risk of user exhaustion if repetitive hand gestures are required. [6] Defined a home gateway as the point of access between a public access network and a personal area network. They developed a web server based home gateway to interconnect IEEE1394, with a power line based home automation system, and the Internet service. To make the system more attractive to home owners, a real time AV transcoding capability was also included. The system offers an insightful look into the development of a home gateway; however, the use of power lines as the communication media limits the positioning of devices within the home in close proximity to power sockets. [7] Proposed a home energy management focused home gateway, which connects the home network with the Internet. The system was installed in twenty houses in the Tokyo area. [8] Implements the initial provisioning function for home gateway based on open service gateway initiative platform. [9] Implemented the Home Gateway and GUI for Control the Home Appliance. [10] Cloud-Based Services Regarding Household Living: To achieve high-level home automation, third-party servers and configured smart home systems are recommended to address data privacy and authentication concerns in inter-home, multiple-device smart environments. Smart home systems have been extended to intelligent building systems, with both indoor and outdoor scenarios being involved. In addition, regional environment information is used in the dynamic intermediate layers of the architecture.

III. PROPOSED SYSTEM ARCHITECTURE

*A. **Proposed System Architecture***

The paper proposes a Raspberry Pi based home automation system through web server and smart phones. This model uses a simple user friendly interface for the access of the raspberry pi. This model aims at designing a basic home automation application on Raspberry Pi through commands sent through web page and the algorithm for the same has been developed in python environment which is the default programming environment provided by Raspberry Pi. Thus user can access any number of device from anywhere in the world. But using Raspberry Pi for controlling each component needs many Raspberry Pi modules which is not at all cost effective. For this, it uses Arduino with Nrf module integrated to every appliance to communicate with Raspberry Pi controller integrated with Nrf module to control multiple appliances (shown in figure 1) which make this model more cost effective. LEDs were used to indicate the switching action. Results show the efficient implementation of proposed algorithm for home automation.

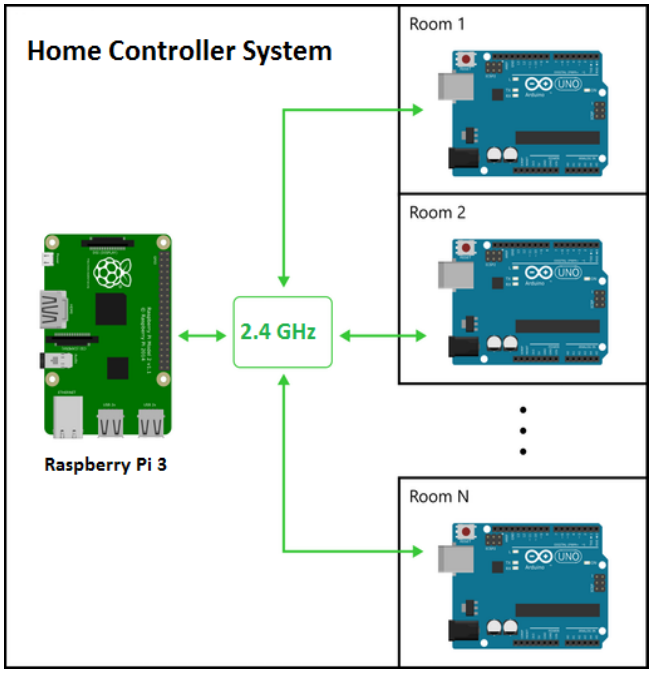

Figure 1.Raspberry Pi integrated with Nrf modules

In addition, integrating cloud-based services with community services can provide location-based services [11]. Moreover, to achieve multiple in-home displays, standard interface devices can be employed to separate the logic and user interfaces (UIs). The aforementioned features were the major contributions of this study. On the basis of the implementation results, hypertext transfer protocol (HTTP) and message queuing telemetry transport (MQTT) protocol were compared. In summary, consistent with IoT characteristics, the MQTT protocol can be used to provide home control services in smart home systems, while HTTP can be used to deliver location-based information integration services

B. Predefined Interfaces and Device Settings at Home

In this study, the predefined interfaces of the home controller system were designed to comprise a local area network (LAN), DIO lines, RS485 wiring systems, and USB cables. The LAN was used to connect the home network with the internet. The DIO lines were used to connect wired physical devices (e.g., emergency buttons, magnetic switches, and gas detectors and valves) and integrate power lines and motor devices through relay devices, thereby enabling the smart home system to conduct light control with on/off and dimmer options as well as curtain control with open/close options. Using RS485 wiring systems enables connecting RS485-related devices or an analog I/O converter with RS485-related devices, which include power meters, water meters, infrared (IR) controllers, and environmental sensors (e.g., temperature, humidity, and CO2 sensors). Furthermore, in the smart home controller system, the USB slots can extend to wireless devices, such as devices compliant with the Raspberry Pi protocol, including power plugs and PIR motion sensors. Various devices can be easily connected to the home controller system for many smart home functionalities as shown in figure 2 (e.g., energy management, security, and scenario controls).

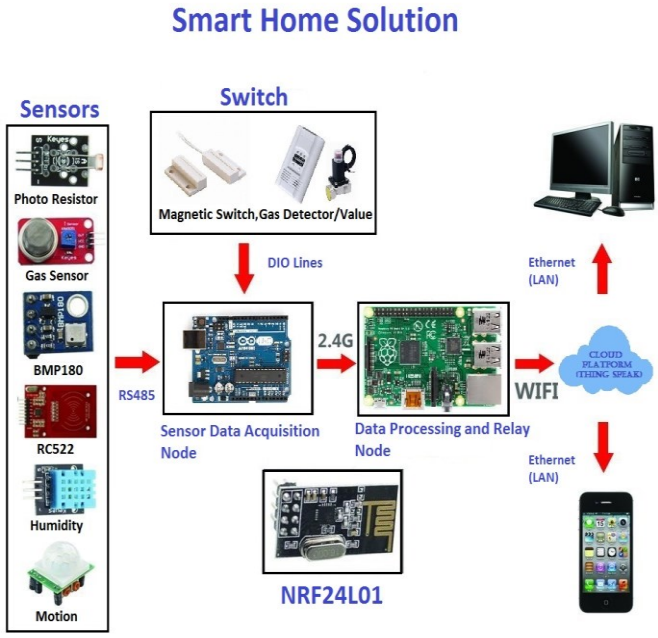

Figure 2.Integrated Home Automation System

After the devices are matched and the connection is configured, the registration of services and reporting processes are established. Separating the configuration logic from the UI enables the various display devices to follow the arrangement for the menu and UI controls, thus creating similar UIs by selecting the managed devices and obtaining and setting the function values through the communication interfaces. Such devices manipulations are not limited to proprietary apps issued for particular devices.

C. Intrusion Detection and Security Management

Security is one of the main concerns of the society. Every society has to be equipped with guards who do surveillance of a certain marked area by taking rounds, in some specific time intervals. This job is not only tedious for the guard but also has many chances of human error, for example lets say person on surveillance has just taken a round of any area and will return in the same after some time‘t’, so for that‘t’ time that area remains vulnerable to intrusion and anyone with little clever approach can easily beat the system.

The modules involved in the system include a broker service module (i.e., gateway for service and content), and a home management module. The home management module provides administrative tools for a security guard unit to manage residential affairs and affairs regarding condo status and alerts. Through the use of a graphic user interface, the management system can perform emergency management and create a history log. Therefore, daily operations (e.g., notices regarding registered mail, parcels, and fees; announcements regarding water and power service interruptions and residential council meetings; and gas meter readings) become paperless, thereby

enhancing operational efficiency and saving resources. In addition, to achieve integrated and comprehensive community services, the surrounding-facility-system integrated module focuses on integrating security systems and building automation systems (e.g., central monitor and control system as well as a vehicle-charging system).

We have used some algorithms and techniques of Digital Image Processing.

Threshold: It is the way to convert gray scale images to binary images. Intensity a every pixel is compared with a threshold value and that pixel is assigned either 0 or 1.

Frame Differencing: Frame differencing is a technique in which a computer checks the difference between two video frames. Any change in the pixels indicates a change in the image.

Background Subtraction: Background subtraction is a type of frame differencing in which the one frame (that does not contain object of interest) is saved and is subtracted from all subsequent video frames. The difference between them indicates any change in the frame.

Background Adaption algorithm: This is an algorithm used for keeping he background image updated.

We assumed that there are three doors and made a graphical interface so that one can set trip wire automatically, If any intrusion is greater than particular size and noticed for particular amount of time then an alarm is generated. (Figure 4)

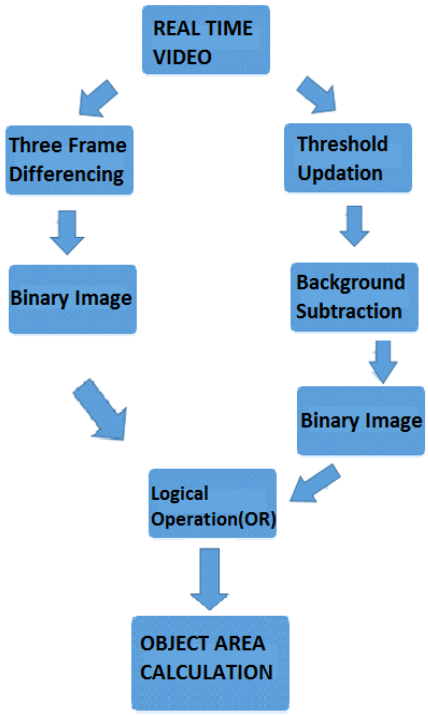

Figure 3.Flowchart of Intrusion Detection

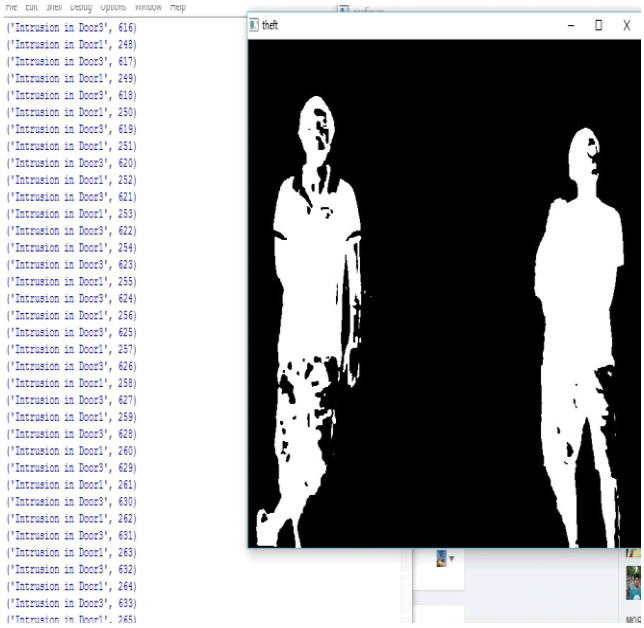

Figure 4.Alert showing Intrusion

In summary, this study proposes a community broker that uses system integration (e.g., a schedule for door access control based on local time and weather) to provide value-added solutions such as a pop-up camera window on a local surveillance system triggered by detecting abnormal door access or security alerts reported to a guardian when residents press a home-level emergency button. Moreover, regarding long-term operations and maintenance, these integrated systems can proactively detect cross-system failures (e.g., a mail notice at the network level, a central monitor at the device level, and an alert log at the user level), thus reducing repair times.

D. Platform Services and Modules on the Cloud

In this study we considered an open data cloud-platform for the Internet of Things, ThingSpeak. ThingSpeak enables real-time data collection with an Open API provided and sophisticated data processing and analysis capabilities. With plug-ins, data visualizations and the ability to integrate your data with a variety of third-party platforms, technologies and systems including other leading IoT platforms such as ioBridge and Arduino. ThingSpeak is the perfect complement to an existing enterprise system to crack into the Internet of Things.

IV. IMPLEMENTATION RESULTS & DISCUSSION

A summary of the configuration and device deployment in the various layers of the proposed architecture is explained here. At the home end, a home intranet was formed by integrating a fixed touch panel with a home controller system as well as various sensors and devices to deliver energy, scenario, information, and security functions. The cloud platform that can be connected through the internet comprises a core management server farm and global solution server

farm, and is used to connect third party servers. According to the proposed architecture, consumers can access smart home services and multiple display services over the Internet through various fixed and mobile carriers.

A. Screenshots of Implemented Results

The screenshots exhibit the various functions of the proposed fixed touch panel of the home controller. The Homepage mainly displays the function menu, calendar, time, weather information, and temperature. It enables single-touch control of the curtains and lights, and presents an integrative scenario control. The Security page presents statuses of the aforementioned magnetic switches and emergency buttons; this page can be used to enable a security mode when no resident is at home, which activates a real-time alarm upon detecting an intruder. Weather information is presented in the Weather page, which aids residents in deciding what clothes match the weather conditions and whether rain gears are necessary.

The proposed smart home system allows users in offices to access home and community information through remote web pages. Moreover, employing the smart home system enables users to check home security and control scenarios on their smart phones when they are not at home. Therefore, the discussed scenarios are implemented in ThingSpeak platform. For example temperature feature of the proposed smart home system shown in figure 5.

Figure 5.Monitoring of Temperature alert systems

B. Service Protocol and Performance Evaluation

The proposed system architecture can use conventional HTTP and the IoT influenced MQTT protocol. Previous studies have compared the power consumption, latency, and data traffic of the two protocols. For example, regarding maintaining connection operations, a connection established using the MQTT protocol consumed less energy than an HTTP connection did. Moreover, when the MQTT protocol and HTTP were applied to proxy servers separately, the MQTT-based proxy servers produced lower latency compared with that of the HTTP-based proxy servers. In addition, when tested in a global-positioning-system environment, the MQTT-based proxy servers resulted in lower data traffic than the HTTP-based proxy servers did.

MQTT is fast and lightweight. It takes very few bytes of data to connect to the server and connection can be kept open all the time. Communication consumes less data and time than the HTTP protocol, which is a great advantage. The MQTT system consists of many clients and one broker. Our devices act as clients. Clients can be our laptops or cell phones too. Each client communicates with a broker only, clients don't communicate among themselves. The whole system is based on publish and subscribe method of communication. Each client can be a publisher which publishes (sending) messages, subscriber which listens to incoming (receiving) messages, or both at the same time. Broker is a kind of server whose task is to accept published messages from publishers and forward them to respective subscribers.

To efficiently evaluate the feasibility of the proposed architecture for use in different scenarios, this study compared the data traffic and latency generated by the MQTT (Mosquitto) and HTTP (REST) based architectures. Overall, in contrast with the HTTP-based architecture, the MQTT-based architecture produced lower data traffic and lower latency in the command mode.

In addition, MQTT is characterized by the concept of topics and focuses on devices. Therefore, the number of and home IDs in the architecture depends on the scale of services provided. However, the number of home devices can vary by time, which may incrementally affect the number of topics and the subsequent efficiency of the servers. Therefore, this study focused on one service scenario and proposed two types of abstract MQTT process to reduce the number of topics in the processes.

Performance Indicators

- t_{http}**:** execution time of the HTTP Protocol
- t_{mqtt}**:** execution time of the MQTT Protocol
- t_{coAP}**:** execution time of the CoAP Protocol

Speedup of MQTT over HTTP:

$$S = t_{mqtt} / t_{http}$$

Speedup of CoAP over HTTP:

$$S = t_{coAP} / t_{http}$$

The energy usages of the MQTT, CoAP and HTTP processes were investigated. The battery used in each process were calculated, as shown in figure 6 & 7.

- Energy consumed by HTTP is much larger than MQTT protocol.
- We can send 100 times more messages with MQTT than HTTP by using same battery percentage in both.

The MQTT protocol only provides guidelines for connection security but does not stipulate imperative methods. Therefore, this study examined the bandwidth of the backbone networks and the processing capacity of the cloud platform by combining the MQTT protocol and the one time password (OTP) function of HTTP to enhance the safety of the proposed service architecture. The evaluation results of the consumption

of the core resources indicated that, in contrast with conventional client-server architectures, the proposed architecture integrated and saved energy by managing the bandwidth of the backbone networks and the processing capacity of the cloud platform.

	HTTP	CoAP	MQTT
Messages /Hour	3628	134235	263314
% of Battery/Hour	18.43%	6.58%	3.45%

Table 1. Performance Analysis of different protocols

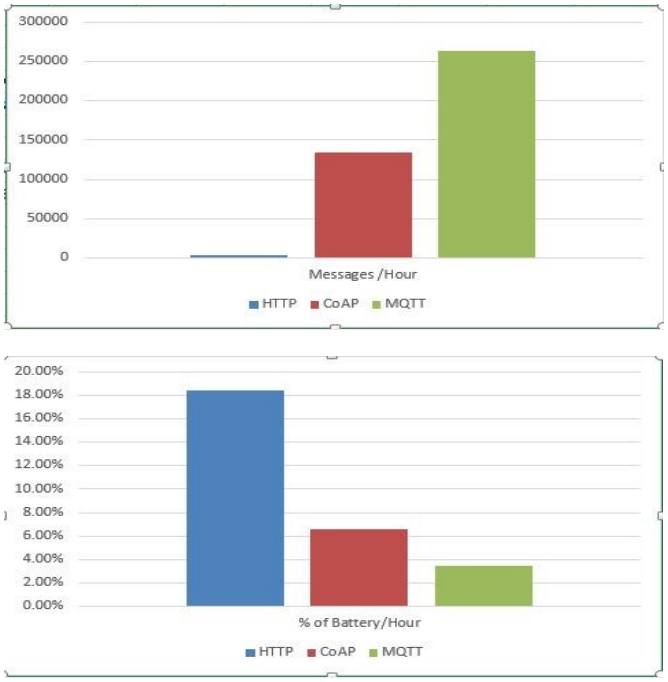

Figure 6 &7.Performance Analysis of different protocols

This study had limitations and could be improved by implementing follow-up measures. For example, when the data traffic and latency generated by the MQTT- and HTTP-based architectures were compared, the difference in the MQTT and HTTP mechanisms resulted in the implemented architectures functioning differently. The comparison may not have been fair because different benchmarks were employed. In follow-up studies, a high level of consistency in the comparisons could be achieved by planning and comparing implementation scenarios (e.g., command-based scenario versus information-based scenario). Moreover, this study could be extended by including an examination of data analysis applications.

V. CONCLUSION

This study first proposed a hierarchical, smart home-service architecture, which employed standard interface devices at the home end to separate the logic and user interfaces, and achieving multiple in-home displays. Therefore, a complete and integrated smart home system can be achieved. In addition, integrating cloud-based services with community services provided location-based services. Subsequently, to investigate the effects of two application protocols (i.e., typical HTTP and the IoT-influenced MQTT protocol) on the proposed architecture, the data traffic and latency generated by the HTTP- and MQTT-based architectures were compared. The consumption of core resources by relevant architecture components (i.e., backbone networks and the cloud platform) was evaluated and indicated that, in contrast with conventional client-server architectures, the proposed hierarchical architecture can save resources by managing the bandwidth of backbone networks and the processing capacity of the cloud platform. This study recommends that follow-up studies employ data analysis applications and user perspectives in designing UX based interfaces. This proposed hierarchical architecture is expected to transform high-tech smart home systems into simple and easy-to-operate home automation solutions.

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