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A secure home automation prototype built on raspberry-pi

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KEYWORD

Ethernet, WSN, Raspberry-pi, Relay, Spoofing, Edon80, SNR, Cloud Computing, API

ABSTRACT

With the development of sensor, wireless mobilecommunication, embedded system, the technologies of Internet Of Things have been widely used in SmartMeter, public security, intelligent building and so on. Because of its huge marketprospects, Internet of Things has been paid close attention byseveral governments all over the world. IOT facilitates theseamless integration of wireless sensor networks.In this paper, we present an IOT prototype which is built onRaspberry Pi and uses SMTP (simple mail transfer protocol) forcommunication. Through this device, we have proposed thecommunication system which is less complex and more secure. Itintegrates with any "thing" and makes it electronically communicable. We give an implementation of prototyping systemand system validation.

1. Introduction

IOT is regarded as the third wave of Information Technology after the Internet and mobile communication network, which is characterized by more thorough sense and measure, more comprehensive interoperability and intelligence. Technologies of IoT can effectively facilitate the integration of material production and service management, the integration of physical and digital world.

Things are increasingly equipped with a large amount of sensors, actuators, and communication devices (mobile devices, GPS devices and embedded computers). In particular, numerous things have possessed powerful sensing, networking, communication and data processing capabilities, and can communicate with other things or exchange info with external environments over various protocols.

The increasing demand and use of the IOT technology has evolved various communication and security issues. The explosive growth of the requirement of the communication for information between machines raised concerns, such as, the optimization of the human environment, the management of urban security, the improvement of living quality, and the effective management of production, [1] the "Internet of Things" (loT) is in great demand.

The advances in IoT have provided a promising opportunity which is Convenience. As more connected devices can handle more operations (lighting, switching, temperature etc.).

In 1999, MIT Auto-ID Labs first proposed the concept of the Internet of Things, which investigates to realize object localization and state recognition using wireless sensor networks(WSN's)and radio frequency identification technologies(RFID's) [9], [24]. In 2005, International Telecommunication Union (ITU) released 'ITU Internet Report 2005: Internet of Things', formally proposed the concept of the Internet of Things, which noted that ubiquitous Internet of Things communication era dawned, in which all objects in the world can exchange information via the networks actively [9], [25]. In 2009, IBM presented the "Smart-Planet" concept which aims to embed sensors in several physical objects such as power grid, railway, buildings, and make them smart by intelligent processing technologies [9], [26].

XaolinJia et al (2012) have discussed RFID Technology and its applications in IoT. They have described various applications and advantages of RFID and WSN. Various machines and prototypes like iMedBox [5], Opportunistic Large Array (OLA) [4], Complex Programmable Logic Device (CPLD) [6], and many others. They have used radio signals to establish communication between nodes or from nodes to a centralized system. [4] has studied SNR received by the nodes in Radio Communication. If we do communication directly in such a way, communication-related issues are potential.

Sachin Babar et al (2010) have presented the security requirements and security & threat taxonomy for IOT. They have insisted on going for a Trusted Platform Module which offers facilities for the secure generation of cryptographic keys, and limitation of their use, in addition to a hardware pseudo-random number generator.

We have objected in eliminating these issues, fulfilling the security requirements and improvising and simplifying the technological approaches being used till date.

We have built a prototype which works on Internet Protocol (IP) technology. It uses the IPV4 or IPV6 address, whichever the network supports, and communicates using the same network address. We have tried to keep the prototype's idea free from any special hardware requirements, other than it must get an IP address to start communication. This machine shows an idea of such a machine which is capable of being integrated with any "thing" which is trying to connect to the internet or any network to communicate and function through signals transferred through the same network. We call it Unitor. The communication that we present is secure and less sophisticated. The system overview of our prototype is given as figure 1.

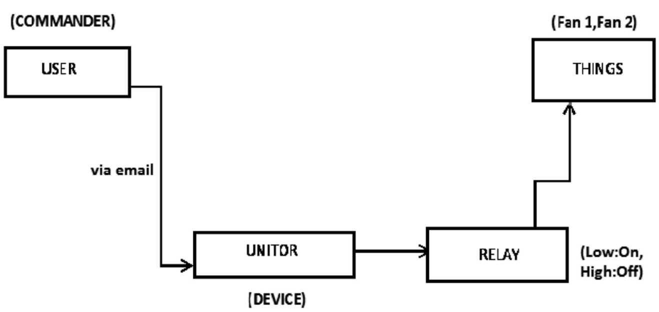


Figure 1. System overview.

2. Prior work and comparision

IOT Gateway was used with smart home by [9]. Smart home is a new type of house which is embedded with sensors, information home appliances, network communications and automation equipment, etc. in order to provide a comfortable, safe, green, convenient living environment. On one side, the inhome IOT Gateways play a very important role in interconnecting multiple smart devices together to form an inhome network and share resources and information among various home appliances. On the other side, in-home IOT Gateway also plays another role to connect the external networks to the in-home network and provide the access interface to the external networks.

Geng Yang et al have developed a health-IOT platform based on the integration of Intelligent Packaging, Unobtrusive Bio-Sensor, and Intelligent Medicine Box was built. It is an intelligent home based health care system in which an intelligent medicine box (iMedBox) serves as a home healthcare gateway. It can deliver a variety of services such as on-site analysis, health social network, telemedicine, emergency and medication management services. In order to solve the medicine misuse problem, improve the pharmaceutical non-compliance situation, and make the daily task as easy and smart as possible, an intelligent medicine packaging (iMedPack) is built. IOT devices (e.g. wearable sensors, iMedPack, etc.) are connected to iMedBox.

[2] have discussed that RFID uses electromagnetic induction or electromagnetic propagation for the purpose of non-contact automatic identification of objects or human. In wireless conditions, the affiliated EEPROM in the electronic label can be written and read by professional read-write equipment, RFID has the features against reproduction, combined encryption, and items, for the purpose of anticounterfeiting.

[27] have developed Vehicular data cloud services in the IOT environment by integrating various devices such as sensors, actuators, controllers, GPS devices, mobile phones, and other internet access equipment and employing networking technologies, cloud computing, IOT, and middleware. This platform supports communication mechanism and is able to collect and exchange data among drivers, vehicles, and roadside infrastructures such as cameras and street light.

M-health things (m-IOT) has been introduced recently and defined as the new concept that matches the functionalities of m-health and mainly used for diabetes management. This device is based on IPV6 and 6LoWPAN protocols architectures [3], [15]. The non-invasive diabetes sensors from the patient are linked via IPV6 connectivity to a relevant healthcare provider. This device senses the glucose level of the patient and send the data to the respective clinic. Thereby, physicians and nurses are able to check remotely patient's health status.

The prototype which we will develop will be easy to handle w.r.t networks. While WSN can realize the short distance communication among the objects by constructing wireless networks in ad-hoc manners. However, it is difficult to connect WSN and mobile communication networks or the internet with each other because it lacks uniform standardization in communication protocols and sensing technologies and the data from WNS cannot be transmitted in long distance with the limitation of WNS's Transmission protocols. Therefore the goal is to handle heterogeneity between various sensor networks and mobile communication networks or internet. Hence the prototype which we will develop will be able to handle the diversity of protocols in WNS and traditional telecommunication networks.

High level security requirements in IOT are (1) resilience to attacks, (2) data authentication, (3) access control, (4) client privacy, (5) user identification, (6) secure storage, (7) identity management, (8) secure data communication, (9) availability, (10) secure network access, (11) secure content, (12) secure execution environment and (13) tamper resistance as suggested by Sachin Babar et al (2010).

Other communication requirements are (1) Ruggedized Communication Devices and Physical Media, (2) network topology, (3) resiliency and redundancy (4) network management (5) transportability (6) availability and reliability (7) time synchronization and accuracy (8) cyber security (9) maintenance. [23]

If we successfully fulfill these requirements, IOT can be implemented will any machine (or "thing") which can be communicated, controlled or monitored electronically. The prototype that we have developed fulfils these requirements.

3. Methodology

3.1. Basic Idea

The basic idea behind our prototype is to make any machine (or "thing") communicable, controllable or monitorable electronically.

We have tried to make the communication more secure and less sophisticated, both for the engineers and target users. Each thing will get an IP address which can be further used by it for node to node or node to user communication.

3.2. The Architecture

Figure 2 shows the network architecture used in our prototype. This model is based on 4 layers: Physical & data link, network and application layers. We use SMTP at the application layer, IP at the network layer, and Ethernet at the physical and data-link layers.

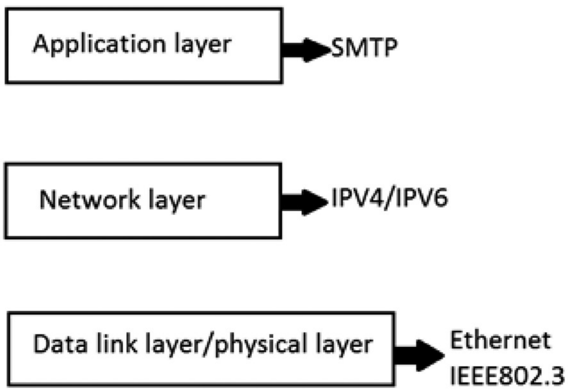


Figure 2. Network architecture.

To reduce the complexity of storage management, secure storage, and secure data communication we prefer not to establish communication directly. Instead of this, we have used the e-mail technology. We will, in this case, have a server to store data, and all the security to the e-mail accounts. This model is shown in figure 3.

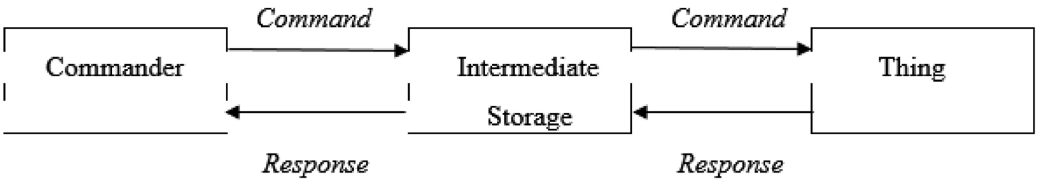


Figure 3. The communication model.

A better communication system will be made when we have various nodes working in coordination with each other, resulting in a smart system (for instance, a smart home or hospital), rather than having each node functioning independently. Internet of things is a collection of person-tomachine and machine-to-machine communication systems [16], [18], [19].

Dong Chen et al (2011) have shown the random distribution of malicious and misbehavior nodes in the simulations. This is shown in figure 6. If we establish communication between the nodes directly, the communication structure will be too complicated, as shown in figure 4.

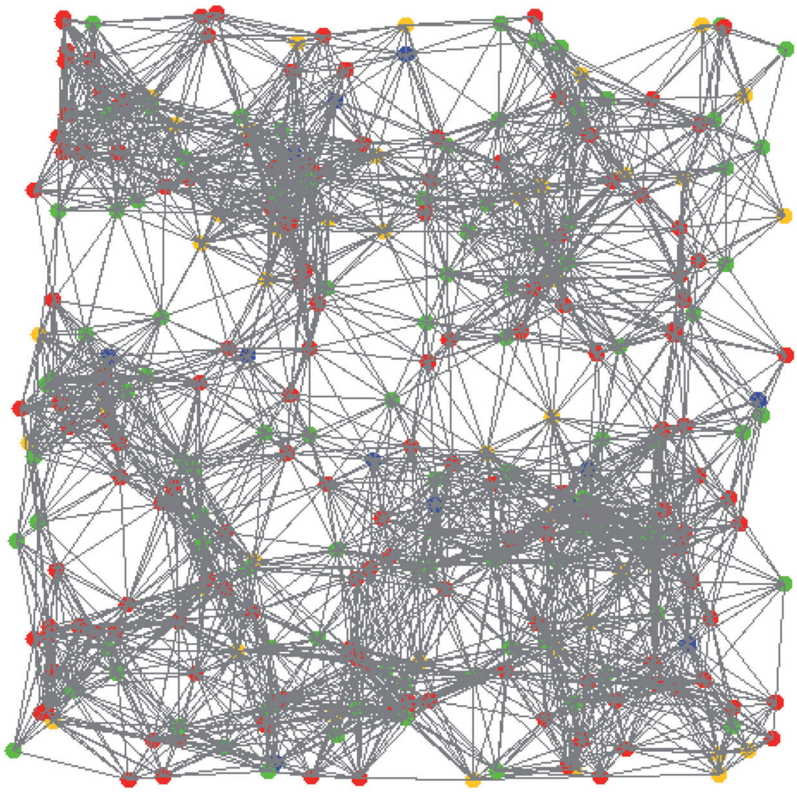


Figure 4. The random distribution of malicious and misbehavior nodes in the simulations.

Email communication introduces an intermediate storage facility which will make the communication simpler, as the graph shown in figure 7. A similar architecture was implemented by [27] and [9] as in figure 5.

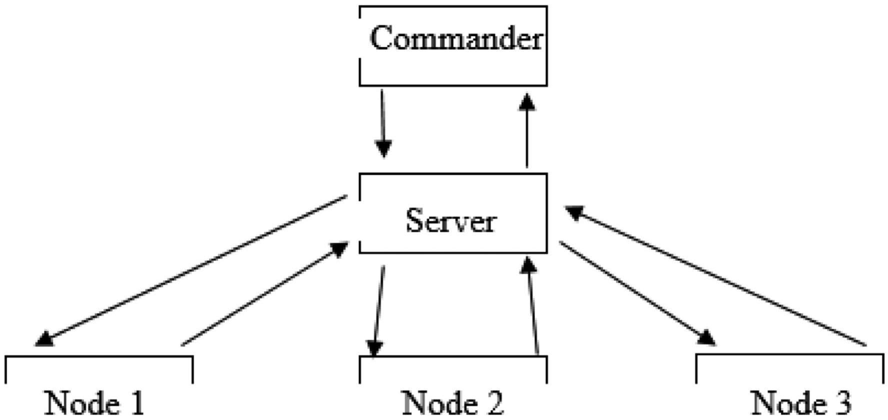


Figure 5. The structure of data transfer.

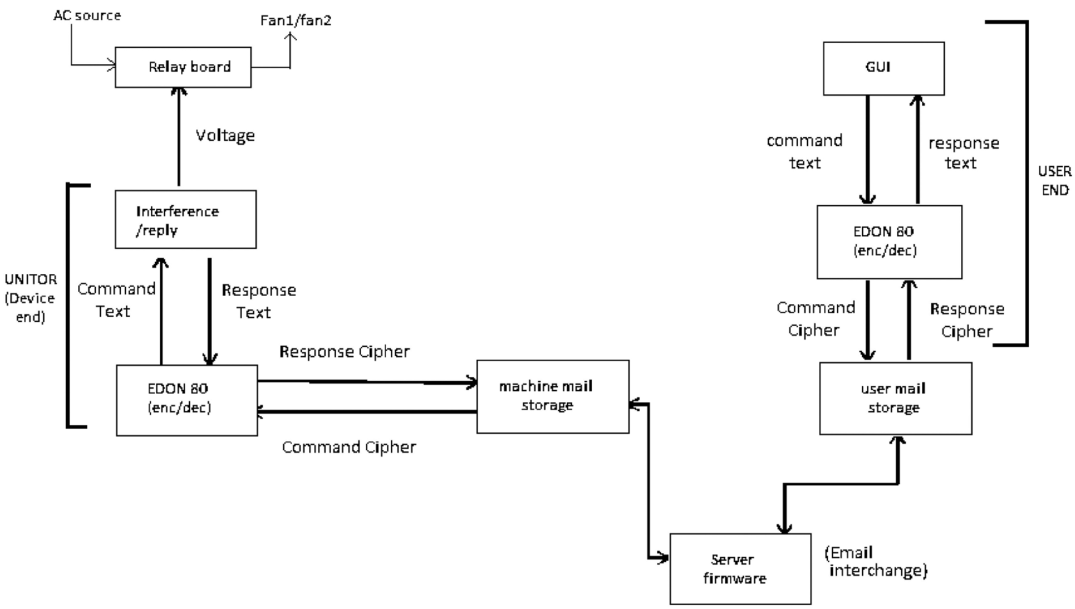


Figure 6. Communication architecture.

3.3. Implementation

For demonstration, we have built Unitor. Unitor is built using Raspberry Pi Model B+. It connects to the network through Ethernet (IEEE 802.1). The working program on Unitor is built in python. Raspberry pi model 3 has 40 usable pins. So 40 “things” can be connected to Unitor.

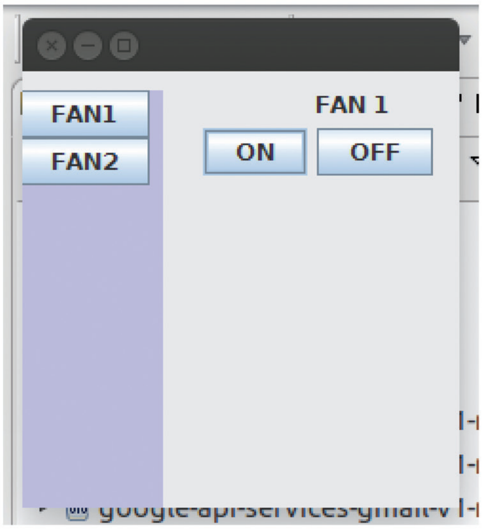
We developed a GUI which takes commands from the user and sends to the “thing (s)”. This software also contains the information of (1) the e-mail IDs of all the devices, (2) the “things” that the devices are integrated with, and (3) details about the list of commands related to the devices. It is built on Java Platform.

The user and the node(s) communicate in the method described in figure 6.

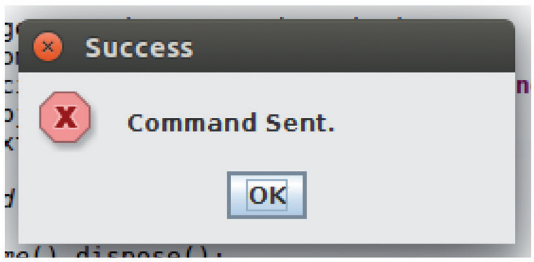
Both Unitor and the GUI use respective e-mail addresses to communicate to each other. Unitor ignores all the emails that are sent from some e-mail id, other than it is registered. It also keeps a check on the subject of e-mails sent to it.

The user clicks on one of the objects (or one of the “things” he wants to communicate with) and send commands or receive status(es) from Unitor about the object(s) it is connected with. Figure 7 shows the GUI and its possibilities of functions.

To overcome the issues of information to be hacked or cracked, we have used the keystream generated by Edon80 [21] algorithm (section 2.7) to encrypt data. Edon80 has passed the NIST (National Institute of Standards and Technology [28]) test [22]. [20] This will make the data that we use in communication more secure. Unitor ignores any e-mail which is decrypted to form an unknown string, not resembling any string from the protocol set.



(a)



(b)

Figure 7. (a) The main window of the GUI. An example to command 2 fans. The left pane contains 2 options – “on” and “off” – available with “fan1”. (b) On success of the e-mail sent, the user is notified with “command sent” notice.

4. Conclusion

This paper describes a prototypic implementation of embedded system which connects any "thing" to network through Ethernet. It communicates via e-mail. We have used the raspberry pi to build Unitor. We have developed a GUI which takes command from a user and sends to the Unitor.

We have combined all the best available approaches for security, communication, cost effectiveness and develop a unified platform for a node to user and node to node communication for the best possible automated systems by giving independence of hardware and software to the users. We have successfully implemented and tested this system.

Some key benefits that Unitor renders are as follows:

- The time complexity of communication is precisely constant irrespective of the physical distance between the user and the device.
- It is a three layer secure system as (a) It ignores all the e-mails sent by any other email-ids except the one(s) which are authenticated by Unitor, (b) if a hacker spoofs, it checks for the subject of the mail and ignore the unregistered one(s), and (c) we have encrypted the data that is being transferred during communication.
- We have presented a prototype that can connect with any number of devices as Raspberry Pi B+ has 26 GPIO pins which can be used to integrate with 26 devices.
- This design provides hardware and software platformindependence using email technology so the user can use cheaper microcontroller other than Raspberry Pi.

By making minor changes in the design Unitor,phenomenal benefits can be rendered to the user.

Using Wi-Fi instead of Ethernet, we can get independence of motion.

Using GSM technology instead of Ethernet, we can get the geo-location of the device using a separate GPS module.

If there is some error in connectivity we will not be able to communicate. In this situation, we can add a switch which will decide whether to use the thing by direct power or through Unitor, shown in figure 8.

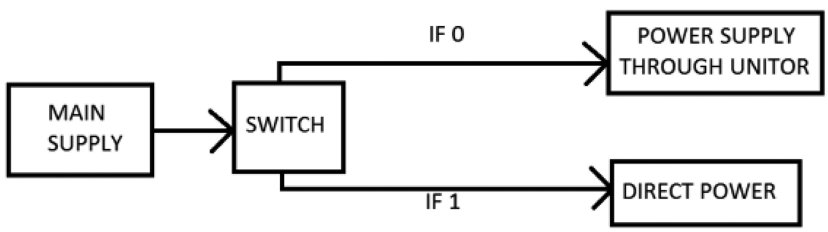


Figure 8. A design of electrical connections to handle connectivity faults.

Proposing this model, we insist on making the machine obtain an IP address first and not do the communication directly through ZigBee or RFIDs. We insist on making it compulsory to use the Internet Protocol at the network layer. If we target for the IP, we have a wide range of protocols above and below network layer, for example, Wi-Fi at the physical layer, or GPRS of GSM and the SMB protocol at the application layer. We can even use the IP address directly for communication.

Hence, we increase the dimensions of independence of protocols and devices and enable the machine to access the functionalities that can be obtained only through the Internet Protocol, and make our "thing" actually use the Internet, as the name IOT suggests, for communication.

This is expected to make the lives of people better by providing more reliable, secure and less complex communication. It can be used with any devices or appliances from those at a scientific laboratory to a home for controlling and monitoring purposes. It can not only just turn a machine on or off, but by the functionalities that microcontrollers provide, we can read or generate pulses too. So it can be used with any electronic device.

Using this prototype, various devices can communicate with each other, providing more intelligent systems free from any human intervention as suggested by [16], [18], [19].

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