

UNIVERSITY OF VAASA

FACULTY OF TECHNOLOGY

COMMUNICATION AND SYSTEMS ENGINEERING

Wu Mengdi

**WIRELESS COMMUNICATION TECHNOLOGIES IN INTERNET
OF THINGS (IOT)**

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Supervisor Mohammed Elmusrati

Instructor Mohammed Elmusrati

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LIST OF ABBREVIATIONS

IoT	Internet of Things
ICT	Information and communications technology
CS	Communications Satellite
WLAN	Wireless Local Area Network
SSID	Service set identifier
MAC	Media Access Control
WEP	Wired Equivalent Privacy
WPA	Wi-Fi Protected Access
M2M	Machine to Machine
UHF	Ultra high frequency
ISM	Industrial, Scientific and Medical
BR	Basic Rate
EDR	Enhanced Data Rate
BLE	Bluetooth-Low Energy
RFID	Radio frequency identification
NFC	Near Field Communication
POS	Point of Sale

PAN	Personal Area Network
LAN	Local Area Network
NAN	Neighborhood Area Network
WAN	Wide Area Network
IaaS	Infrastructure as a service
PaaS	Platform as a Service
SaaS	Software as a Service
HCI	Human-Computer Interaction

University of Vaasa
Faculty of Technology
Author:

Mengdi Wu

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Mohammed Elmusrati

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Mohammed Elmusrati

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ABSTRACT

Internet platform is developing fast, and new concepts are coming out all the time. The internet backbone is the tie for connecting Things-to-Thing (T2T), Human-to-Thing (H2T) and Human-to-Human (H2H) connection network. Hence, the more general term of the Internet of Things has been presented.

In this thesis, the general concept of the Internet of Things has been presented. Moreover, some important protocols inherited from the Internet are given. Furthermore, some major communication technologies that are strong candidate to be used in the Internet of Things have been discussed. In addition, cognitive IoT system has been revealed to organize the whole concept of the Internet of Things and the final goal to achieve in Internet of Things.

As case study, there will be a sample application for the Internet of Things. In this application, it presents us how this IoT technology would interact with our life. The sensor simulator will generate all the data for the temperature and humidity. Later on, the data would be transmitting to the IBM Watson IoT platform through the wireless communication. The platform will allow us to create a standard to judge the data. When the data reach the limits, then the platform will send a tweet to warn the user.

In the end, this thesis would give you a general understanding of the Internet of Things. The interaction between human and machine will be revealed. Moreover, the cognitive IoT should also give reader a general understanding with the development of IoT.

KEYWORDS: Internet of Things, Protocols, Internet of Things' Structure, Cognitive IoT, Cloud Computing, Bluemix, Node-RED, RFID

1 INTRODUCTION

1.1 Purpose of Thesis

The Internet is developing rapidly. Human is not only user in the whole network chains. Machine-to-Machine communication should be considered as well. Therefore, a new concept of Internet of Thing has been created.

The main goal of the Internet of things is trying to achieve the three “A” goal. As shown in Figure 1, the new dimension of ICT is trying to get things work at any time, any place and anything.

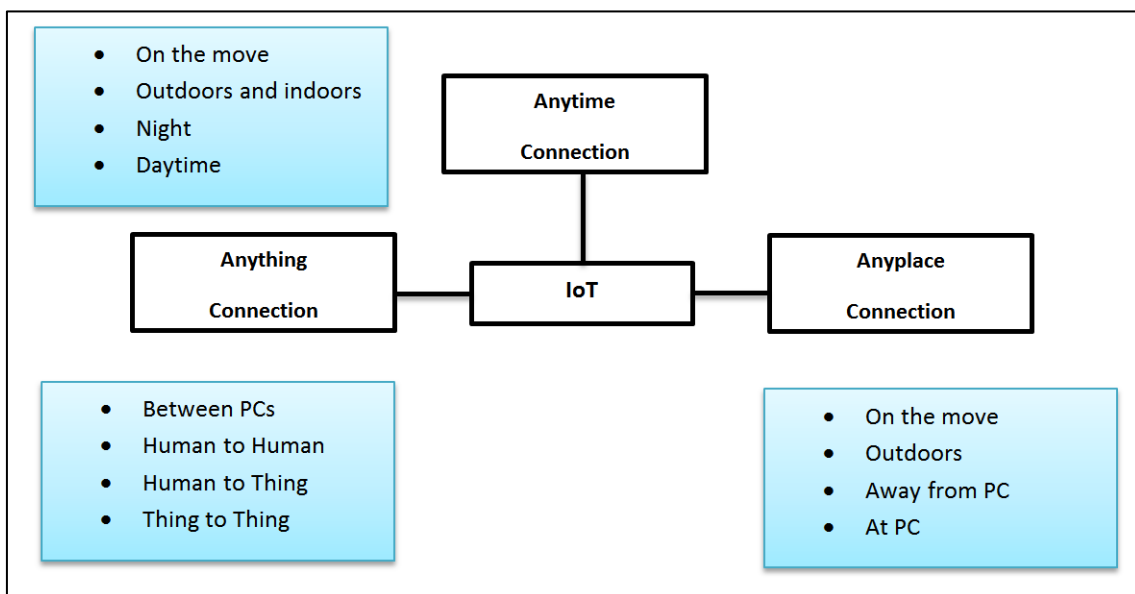


Figure 1 ICT's New Dimension [International Telecommunication Union 2005]

Nevertheless, how to get this concept working is another challenge. As a part of the Internet of Things, there are still some myth have not been discovered.

This thesis is mainly focus on the concept of the Internet of Things. The important technology in IoT and application that is using the Internet of Things will be discussed.

1.2 Overview Structure of Thesis

The basic structure of this thesis is shown in Figure 2. In Chapter 2, the Internet of Things and the important protocols that have been used in the Internet of Things will be discussed.

Chapter 3 is the structure of the Internet of Things. The explanation of the three-layer structure and the function ability will be discussed.

Moreover, the Chapter 4 presents the technology that plays an important role in nowadays' Internet of Things. A real application in Internet of Things will be introduced in Chapter 5. Finally, Chapter 6 concludes the thesis.

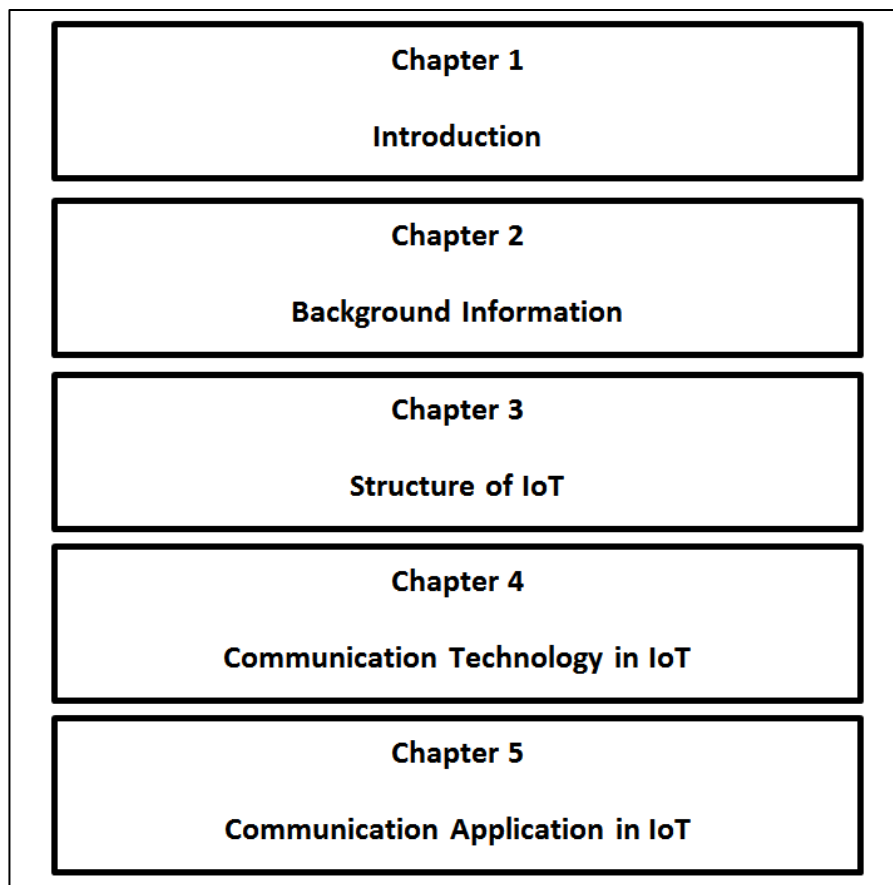


Figure 2 Overview structure of the Thesis

1.3 Methodology

Through the whole project, we used the following tools and methods:

- 1) IBM Bluemix, it is a cloud platform for Internet of Things that helps user to create application.
- 2) Node-RED, it is a web service that helps user to create the application flow.
- 3) IoT sensor simulator, it is acting like a sensor node information collector. It simulates the data that we need in order to complete the application in IoT.

2 BACKGROUND INFORMATION

2.1 Introduction

In this chapter, It is mainly focus on the background of wireless communication technologies and the general view of IoT. First, the wireless communication protocols will be introduced. Then, the structure of IoT and some important features that relate to the wireless communication applications in IoT is also included.

In section 2.1, the definition of the Internet of Things and its main purpose will be talked. In addition, section 2.3, it is about wireless communication protocols that have been use in IoT.

The Internet of Things is based on the traditional telecommunication networks and other information carriers. IoT is an extension of the normal Internet. The Internet terminal is the computer (PC, server); they run all kinds of programs. Internet is nothing more like a data processing and transmission between computer and network. There is no other terminal (hardware) involved in the Internet.

The main idea for IoT is still the Internet. Unlike the Internet, there are not only PC and servers, but also there are embedded computer systems and its supporting sensors can be treating as terminals. It can connect all kind of independent objects and form them to function together, in order to achieve a functional interconnection network.

This is the inevitable result in our computer science and technology development. The computer has to serve human in variety of forms, such as environmental monitoring equipment, virtual reality equipment and so on. As long as there is hardware or products connect to the Internet, or the occurrence of data exchange, we call it “Internet of Things”.

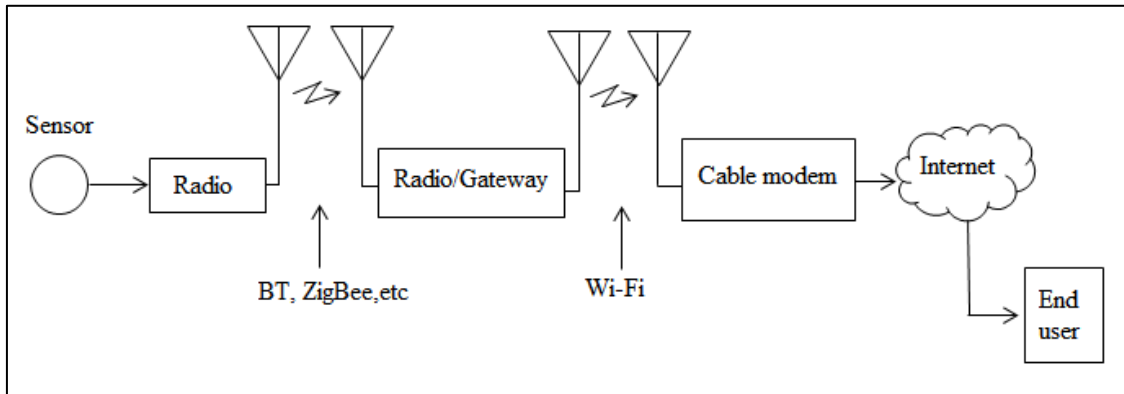


Figure 3 Wireless-connection scenarios for IoT

Figure 3 shows how the IoT looks like in the wireless connection. Moreover, there are six important wireless communication protocol standards are used in IoT in order to face different requirements in building up the IoT.

2.2 Important Communication Protocols in IoT

2.2.1 Mobile

In wireless communication, it uses electromagnetic waves to carry signals, but these waves require line-of-sight. Due to the earth shape, it is hard to achieve a long-distance communication.

In order to solve this problem, various antennas or stations is built on Earth. The signal is sent from earth straight up to space, so Communications Satellites (CSs) can relay and amplifies the signals, which extend the strength of the signal. Then the signal will be sent to different location on Earth that is intended to be. Those signals can be telephone calls, Internet data, radio and even TV broadcasts (Chris Woodford, 2016).

In cell phone communication, CSs enable the communication in a larger range, for example, the communication distance in GSM can be up to 35km. Moreover, based on the speed of the connectivity, there are also different communications such as GSM/GPRS/ EDGE (2G), UMTS/HSPA (3G), LTE (4G) and so on.

Everything has its good side and bad side, although the stable connection and universal compatibility is known as benefits, but CSs also require high monthly cost to keep them up and the high power consumption. All these advantages and disadvantages should be considered while evolving the IoT, so satellite is mainly use in industrial purposes.

2.2.2 WiFi

WLAN is also known as Wi-Fi, an IEEE802.11-base technology. It is a wireless local area network (WLAN), which allows two or more mobile devices use Internet via the wireless connection. This connection is based on an access point, which allows the users to move around within a certain coverage area. Nowadays, WiFi has been commonly use in our daily life. It is easy to get access and affordable.

802.11 Protocol	Release date	Frequency (GHz)	Data rate per stream (Average)	Data rate per stream (Maximum)	Approximate indoor Range (m)	Approximate outdoor range (m)
Legacy	1997	2.4	1Mbit/s	2 Mbit/s	20	100
802.11a	1999	5	25 Mbit/s	54 Mbit/s	35	120
802.11b	1999	2.4	6.5 Mbit/s	11 Mbit/s	35	140
802.11g	2003	2.4	25 Mbit/s	54 Mbit/s	38	140
802.11n	2009	2.4 or 5	300Mbit/s (20MHz* 4MIMO)	600Mbit/s (40MHz* 4MIMO)	70	250

Table 1 802.11 Standards

In IEEE 802.11 standards, device usually communicate in the 2.4, 3.6, 5 and 60 GHz frequency bands. The Table 1 shows the basic information such as data rate and communication range in the 802.11 standards. From the table's data, it is not hard to find out which one is the best so far. Nowadays, IEEE802.11n is most commonly used according to the high-end performance. In order to achieve the high quality performance, it also need higher power consumption. According to the power consumption problem, WiFi is not recommended for low-powered supplied devices.

Most of the IEEE 802.11 networks use 2.4 GHz frequency, there are 14 channels have been separated from total 5GHz in 2.4GHz range. It is shown in Figure1, each channel has around 22MHz band and they are overlapping. It is shown in Figure 4, among all the channels, channel 1, 6 and 11 have the least interrupting problem. Many modem manufactures are using these three channels as their default WiFi channel. This set up will cuase the channle can be way too crowd, if there are many WiFi routers and users in the area. The reliability has also been considered as an important problem in WiFi.

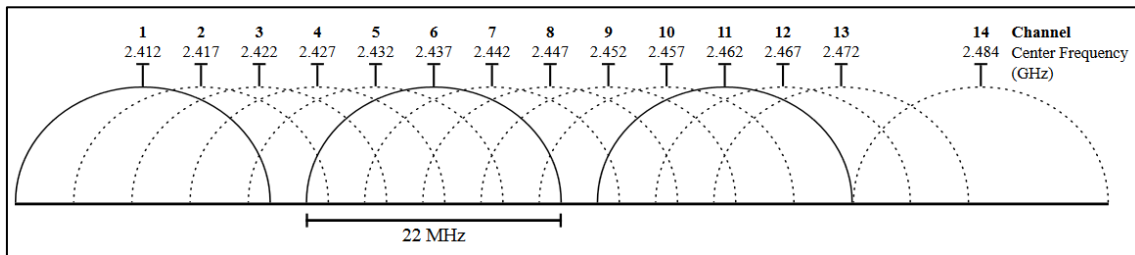


Figure 4 Graphical Representation of 2.4 GHz Band Channels Overlapping

WiFi is not as secured as wired networks, so wireless security is also another important aspect we should consider. It can be an open network to all the users in the area if we do not secure our WiFi with security measures. The measurements can be SSID hiding, MAC ID filtering, Wired Equivalent Privacy (WEP), Wi-Fi Protected Access (WAP) and so on.

2.2.3 Bluetooth

Bluetooth is a wireless technology that enables short-range data exchange among fixed equipment, mobile devices and personal area networks. It is using short-wavelength UHF radio waved in ISM bands between 2.4 and 2.485GHz (Bluetooth 2010).

Bluetooth products (such as headphones and watches) contain a small computer chip, a radio and software that support for connecting Bluetooth. When two Bluetooth devices want to communicate, they need to be paired first. The communication between Bluetooth devices is carried in a temporary short-range network, also known

as piconet. The network can let two to eight devices to connect. When the network environment is created, one device acts as the master device and others act as the slave devices.

Bluetooth Core Specification Working Group (CSWG) develops Bluetooth; it has more than one version. Currently, there are two main type of Bluetooth. They are the Bluetooth Basic Rate (BR)/ Enhanced Data Rate (EDR) and Bluetooth-Low Energy (BLE). BR/EDR is mainly used for speakers and headphones, but BLE is used for the newest products such like smart home.

In Bluetooth 4.2, there are few improvements:

- 1) Support flexible Internet connection options (IPv6/6LoWPAN or Bluetooth Smart Gateway). This feature will help IoT's implementation.
- 2) Improve the Privacy Rights, Energy Efficiency and Security Performance to make Bluetooth Smart smarter.
- 3) Boost the Throughput Speed and Packet Capacity to make Bluetooth Smart faster.

2.2.4 ZigBee

The name of Zigbee comes from the bee's waggle dance. Bees make "zig" sound to communicate the pollen's location while flying, so they form the communication networks in this way.

ZigBee is another IoT data link protocol, which based on IEEE802.15.4 standard. A low-power local area network protocol operates at 2.4GHz.

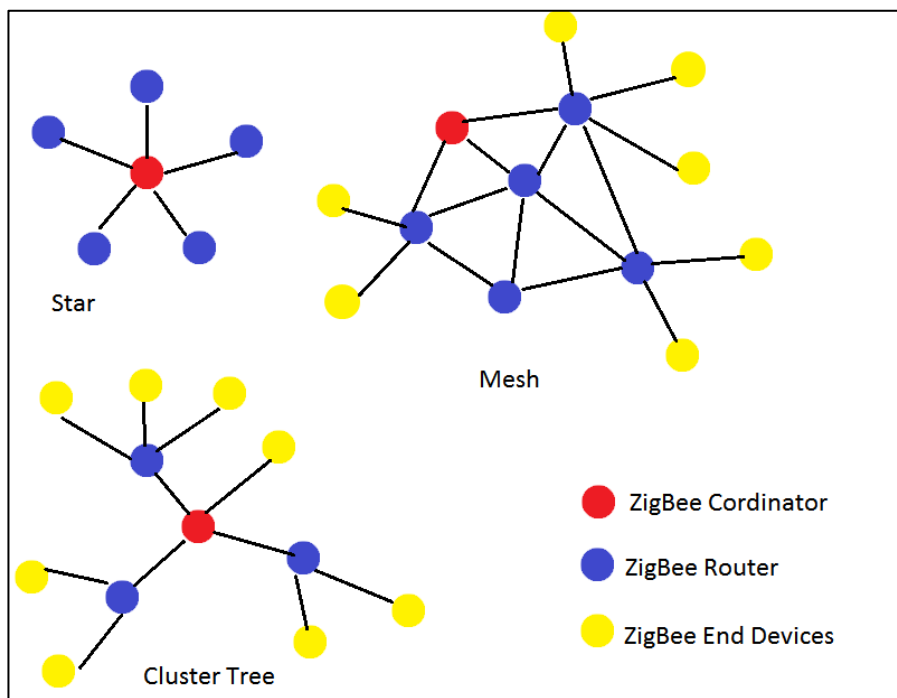


Figure 5 Star, Cluster Tree and Mesh Topology

There are a few advantages of ZigBee.

- 1) Low power consumption; in low power standby mode, two double A batteries can support a node to work for 6 to 24 months. It saves large power to operate, compared to WiFi and Bluetooth.
- 2) Low data rate; ZigBee operates at 250kbps data rates in 2.4GHz frequency.
- 3) Short data transmission range; the transmission range is generally between 10 to 100 meters. We can increase the range up to one to 3km, if we increase the transmit power.
- 4) Short delay; it takes only 15ms for ZigBee to respond from sleep into working state and 30ms for a node to connect into the network.
- 5) High capacity; it is shown in Figure 5. ZigBee has star, cluster tree and mesh network structures. A master node can manage up to 254 child nodes; meanwhile a layer of network nodes can also manage a master node. ZigBee can form a large network that can contain up to 65,000 nodes.

Nowadays, ZigBee is mainly used in sensor and wireless control networks in M2M and IoT due to its properties.

2.2.5 RFID

Radio Frequency Identification (RFID) is a wireless communication technology that allows radio signals to identify specific target, read and write related data without establishing a mechanical or optical contact between the system and a specific target. In RFID, two main devices are Tag and Reader.

Radio signals are using radio frequency electromagnetic fields to attach the data on the Tag and transmit it out, in order to automatically identify and track item. Tags will gain energy from the reader's electromagnetic fields, so they do not need battery. Moreover, some Tags also have power, they can send radio frequency by themselves. The Tag contains the information stored electronically; we can identify it within a few meters.

Radio frequency identification system mainly has the following several advantages:

- 1) Easy to read; in RFID there is no light resource needed, people can read from outside of the package. If the tag has its own battery, the effective recognition distance can be up to 30 meters.
- 2) Fast reaction time; when the tag is into the electromagnetic field, the reader can immediately read the information. Moreover, reader can deal with multiple tags.
- 3) Large data capacity; RFID tags can store numbers up to 10K.
- 4) Long lasting life; it has a sealed packaging and it can be used in bad environments.
- 5) Real time communication; the tag and reader can communicate at a 50 to 100 times per second frequency.

Due to all these facts, a variety of industry areas is already using RFID technology.

2.2.6 NFC

NFC stands for “Near Field Communication”. It is another form of RFID. However, unlike RFID, NFC is a short-range, high-frequency wireless communication technology that allows non-contact point-to-point data transfer between electronic devices in a range of 10 cm distance (GSMArena, 2016). It can choose one of 106kbps, 212kbps or 424kbps transmission speed. The difference between NFC and Bluetooth is that there are no pair devices in NFC. The difference cause the connection set up procedure become easier.

In nowadays, NFC is normally implemented in cell phones. There are five main applications with NFC technology:

- 1) Touch and go; Cell phone becomes as a key.
- 2) Touch and Pay; user put the NFC part to the POS machine to complete a payment, such like “Apple Pay”
- 3) Touch and connect; user can connect two phones by using peer-to-peer data transmission. For example, with this application user could download music, exchange pictures or contacts and so on.
- 4) Touch and explore; user can access traffic information by scanning a NFC-enabled smart public telephone or posters on the street.
- 5) Load and touch; user can download the information and get access to a payment.

2.2.7 Summary of Wireless Technology Parameters

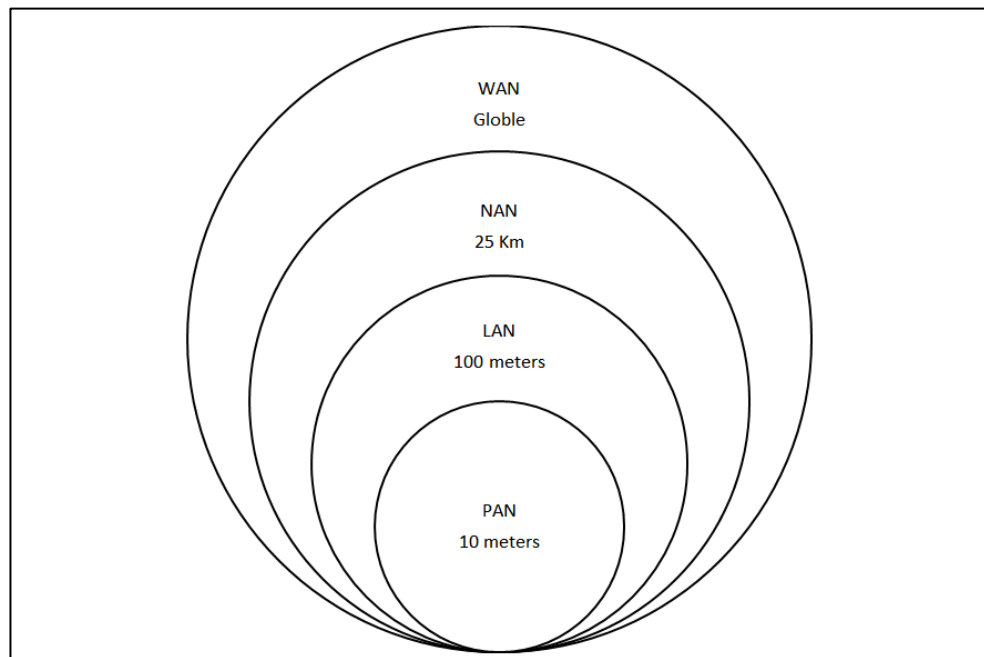


Figure 6 Network Range [Gil Reiter, 2014]

In Figure 6, it shows a clear range of Personal Area Network (PAN), Local Area Network (LAN), Neighborhood Area Network (NAN) and Wide Area Network (WAN). In order to face the different situation, different networks types will be chosen.

In order to have a better view of six wireless communication protocols in IoT, it is shown in Table 2. We could see that WiFi, Bluetooth, NFC, NFID and ZigBee are short-range wireless protocols. However, the data rates are quite different. According to the transmission rate, they are separated in different use and networks.

There is no standard to define which protocol is better, but there is always a protocol to fit in IoT.

Protocol	Standard	Frequency	Range	Data Rates
Mobile	GSM/GPRS/EDGE (2G), UMTS/HSPA (3G), LTE (4G)	900/1800/1900/2100MHz	35km max for GSM; 200km max for HSPA	35-170kps (GPRS), 120-384kbps (EDGE), 384Kbps-2Mbps (UMTS), 600kbps-10Mbps (HSPA), 3-10Mbps (LTE)
WiFi	802.11n	2.4GHz and 5GHz bands	50m	600 Mbps(max) 50-200Mbps
Bluetooth	Bluetooth 4.2 core specification	2.4GHz	50-150m	1Mbps
ZigBee	IEEE802.15.4	2.4GHz	10-100m	250kbps
RFID	ISO 18000	120–150 kHz (10cm), 3.56 MHz (10cm-1m), 433 MHz (1-100m), 865-868 MHz (Europe), 902-928 MHz (North America) (1-12m)	10cm(short)	LF - 125-134 kHz HF - 13.56 MHz UHF - 850-960 MHz
NFC	ISO/IEC 18000-3	13.56MHz (ISM)	10cm	100–420kbps

Table 2 Communication Protocols Comparison

3 STRUCTURE OF INTERNET OF THINGS

3.1 Introduction

In IoT, there are three things will be focused on, which are comprehensive sensing, reliable transmission and intelligent processing. Therefore, IoT is divided into three layers. They are the sensing, network/transport and application layer. It is shown in the Figure 7.

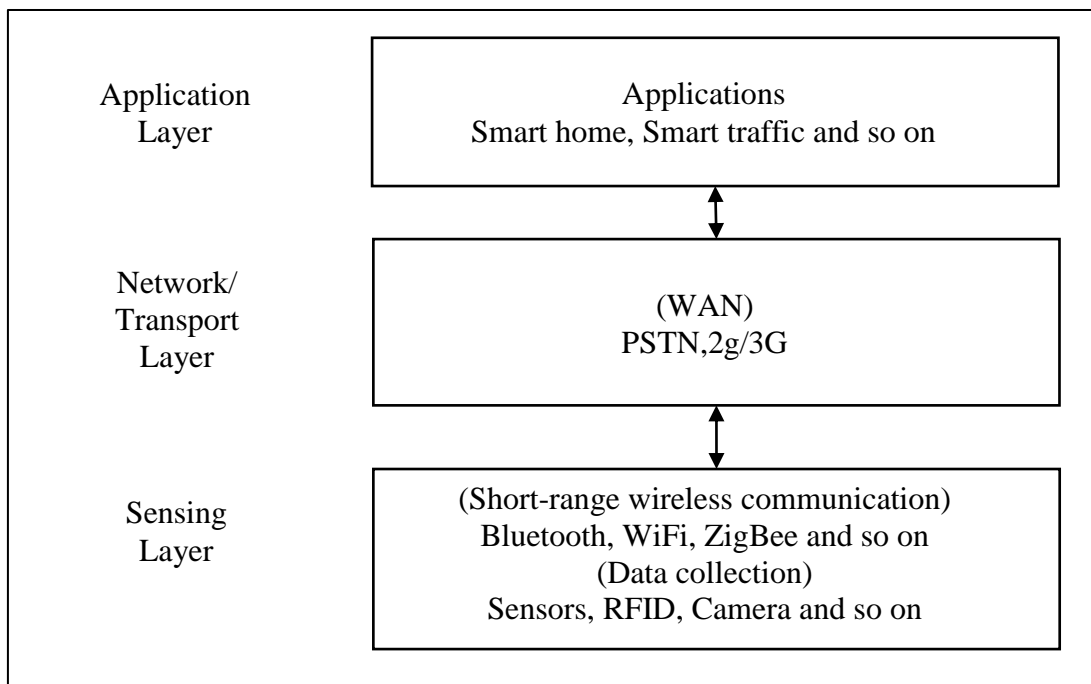


Figure 7 Structure of IoT

3.2 The Sensing Layer

The sensing layer mainly solves the data collection problem from devices. In this layer, there are two main parts. One is the basic sensors, such like RFID tags and readers, various sensors, cameras, GPS, two-dimensional code labels and readers and other basic identification and sensor components). The other one is the sensor network. Both networks could be used to recognize the mark on the item and collect information intelligently. Therefore, this layer is the most basic and core layer in IoT.

Sensor nodes are tiny devices; they are self-organizing wireless communications. They use wireless communication technology for data forwarding. Each node has both data acquisition and data fusion forwarding functions.

Due to different manufacturing features, there are different types of sensor. Most of them have the function of detecting temperature, light, sound and vibration. There are also some components for the wireless sensors, which are processor, memory, RF transceiver, power source and sensor.

As shown in Figure 8, the basic building blocks of sensor node include a sensing unit, processing unit, a communication unit and a power supply section. The processor module is the core of the sensor nodes. It is in charge of the entire node device control, task allocation and scheduling, data integration and transmission and so on.

The goal of the sensor node is to collect all the data and transform the data into an electrical signal. In the end, we can send the signal to the sink or the base node.

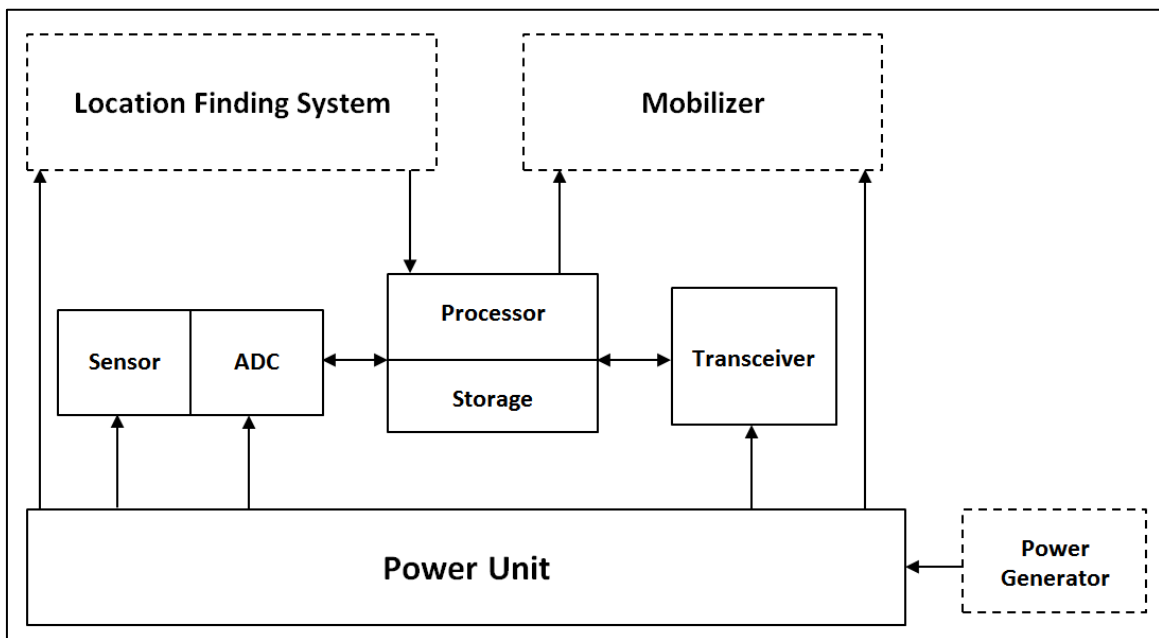


Figure 8 Sensor Node Architecture

RFID technology, sensing and control technology, short-range wireless communication technology is the main technology involved in this layer. In addition, the core products include sensors, electronic tags, sensor nodes, wireless router and wireless gateways.

3.3 The Network/ Transport Layer

It is also called transport layer. This layer mainly solved the problem about data sensing and data transmission in a certain range. It builds on the existing mobile communication network and the Internet. Therefore, IoT will connect to the mobile communication network and the Internet by using different access equipment. Moreover, this layer also has information storage, network management and other functions.

The cloud-computing platform will be an important part of the network layer of the Internet of Things since it could storage and analysis massive data. This is also the foundation of many applications in application layer.

In the industrial chain, communication network operators will play an important position in the network layer of IoT. Cloud computing is also developing rapidly, who could give a hand to IoT's development.

The most involving things in this layer are Short-range wireless communications, self-organizing network, simplify IPv6 agreement and Enhanced Machine to Machine (M2M) wireless access and core network standards and so on.

3.4 The Application Layer

The application layer is also known as “The processing layer”. The main function is to solve the problem in the information processing and the interface between man and machine. This layer is the final function implement layer.

In the layer, it processes the data from the network layer and then sends the data into all kinds of information system. In the end, the data will be interacted with people through the certain device.

The application layer contains different platforms, such as service support platform, network management platform (such as M2M management platform), information processing platform, information security platform. The platforms accomplish the function such as data management; calculation, storage, analysis and service deliver for the industry and massive users.

The core technology in this layer is automation and virtualization. The automation technology can deal with the user request and organize the resource automatically. Moreover, the virtualization technology can improve the usage of the resource efficiently, in order to reduce the cost.

3.5 Summary

The communication among all the layers, they are not transmitting in one way. They can communicate in both directions. For example, they can identify both static and dynamic information for the product in specific application system.

Although the IoT has different application features in the intelligent industry, intelligent transportation, health care and other different fields. There is one thing in common that they all base in this three-layer structure.

In general, there are five key features should be introduced, in order to build up an IoT platform. They are:

- 1) Sensor or controllers
- 2) A gateway device
- 3) A communication network
- 4) Software for processing data
- 5) The end application service

4 WIRELESS COMMUNICATION TECHNOLOGIES IN IOT

4.1 Introduction

Internet of Thing is a new trend. In order to achieve the goal of ubiquitous computing system, several technologies work effectively in Internet of Things. They are RFID, wireless sensor network and cloud computing. Among all the technologies, these three are playing an important role in the Internet of Things topic.

4.2 RFID Technology

NFC and RFID technologies are introduced in previous chapter, but it is not mentioned as the most implement technology in the very early stage. This technology is usually applied in the sensing layer.

Although these two technologies are similar, but in nowadays the products made of RFID technology is more than NFC in Internet of Thing. It is acting like an information carrier and helping user collect certain data in an efficient way. In another word, RFID offers user better options; such longer identify distance, faster data transmission speed, large capacity and more wearable.

In Figure 9, it shows a general look in RFID technology in Internet of Things. There are several parts in this system. As shown in the figure, they are electronic tags, reader, middleware, internet and numerous databases. First, reader will identify the information in electronic tag and then send them to the middleware part. In the middleware part, the main function is processing and managing the information. Then through the gateway, all the information will update to the network databases, in order to store all the information.

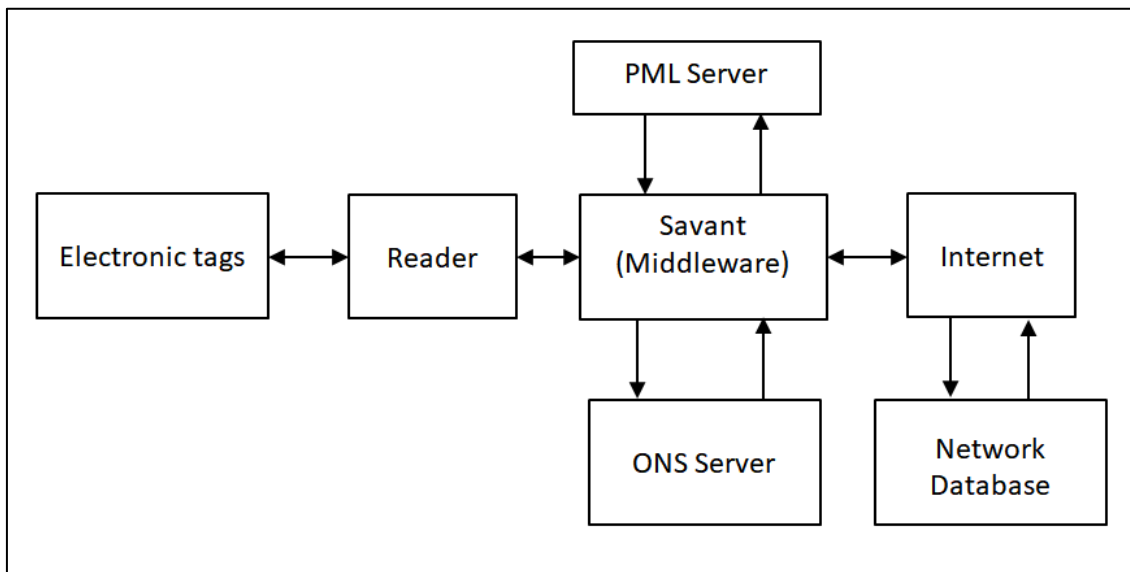


Figure 9 RFID Working Principle of Internet of Thing

In the daily life, things are generating so fast. The RFID technology has already been implemented everywhere. In Figure 10, it shows the size of RFID chip in 2016. It can exist in anything, such like the passport, library cards or even some advanced business application (Himadri Nath Saha, 2016). Moreover, RFID is commonly applied in the asset tracking industry to manage the huge information that is happening around the world. This technology helps user to improve the efficiency and transparency in the supply chain among all the aspects.



Figure 10 Global RFID Chip Market 2016 Industry Size

For example, the RFID technology that has been used in passports and visas. The immigration and migration laws are changing all the time in many governments around the world (Workpermit, 2006). The paper-only method is not working economically and efficiently. Therefore, the RFID technology has been taking into the market. Users only need to deploy a small in size, rewritable and long-life lasting chip into the passports and visas.

Nevertheless, everything has its two sides; there is security problem that should be considered. RFID is a less secured technology. The information could be easily skimmed without getting the RFID owner's attention. More and more countries have noticed the risks and safety measures in RFID. They have accepted RFID chips are supposed to be encrypted. Even more, the reading distance is also required in some countries.

Unlike RFID, NFC is normally applied in short distance one-way communication. With the range, it is easier to monitor the information security than RFID. Both NFC and RFID technologies help users to solve the "Any THING connection".

4.3 Wireless Sensor Network Technology

In the beginning phase of Internet of Things, it is all about wireless sensor networks. WSN is the most important area in Internet of Things. The main purpose for Internet of Things is to build a worldwide network among all the possible objects. Moreover, WSN is a truly helping technology that let user to achieve the real meaning of IoT. The main idea of WSN is to connect the sensing layer and network layer in the IoT.

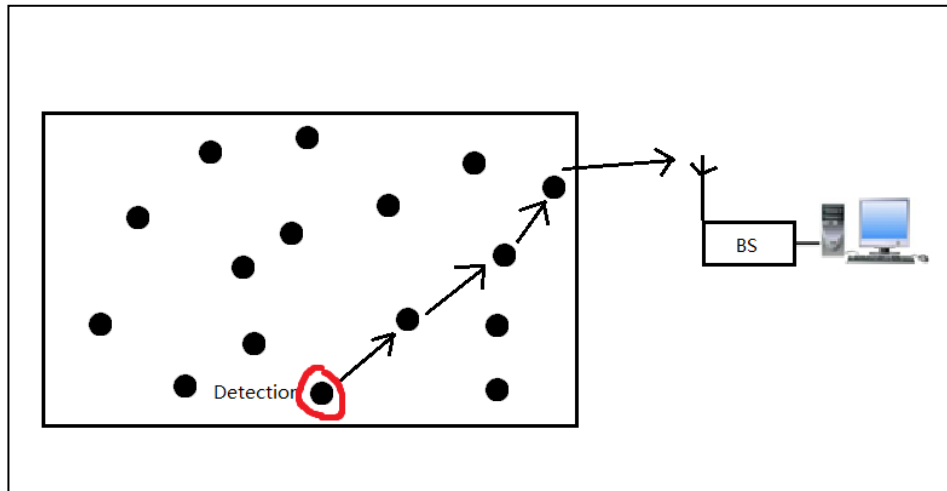


Figure 11 Wireless Sensor Network (Independent Network)

The Figure 11 is an example of wireless sensor network. The sensor node will detect an even and collect data. Then each node will communicate to another wirelessly in a direction. In the end, the base station will get the data from the closest node. This is the basic structure of Independent network in WSN. We only send data through a single gateway.

There are two different approaches and they are Hybrid Network and Access Point network. The structure of them is showing in Figure 12 and 13.

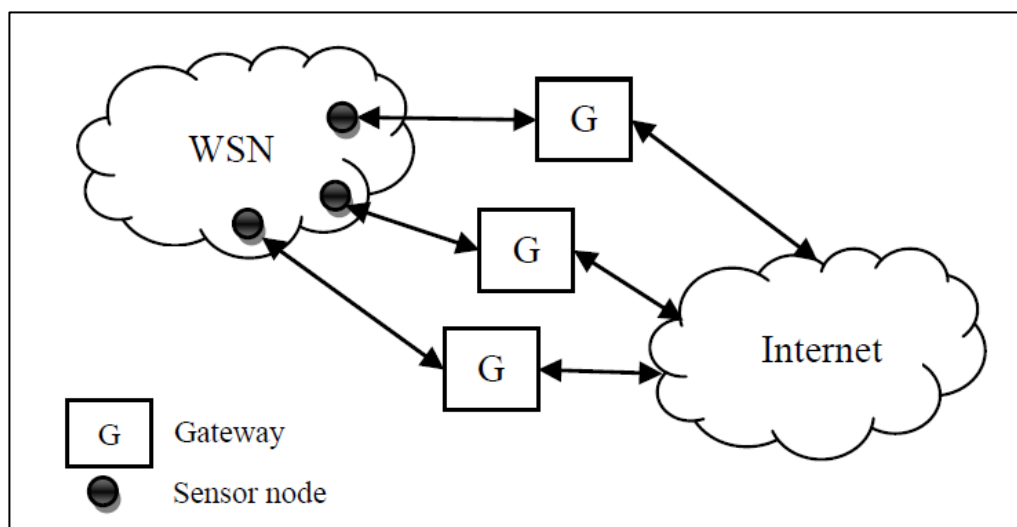


Figure 12 Hybrid Network

Hybrid Network is a developed version of Independent Network. The multiple sensor nodes can connect to multiple gateways, in order to transmit data faster. This network type will make WSN working more efficient.

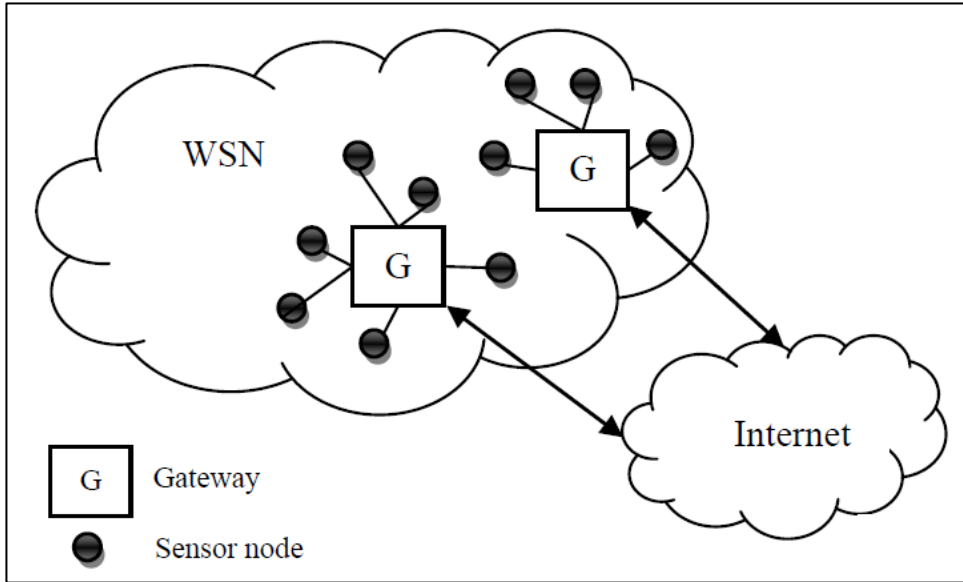


Figure 13 Access Point Network

The access point network is different from other two. This network is inspired from WLAN structure (Delphine Christin, Andreas Reinhardt, Parag S. Mogre, Ralf Steinmetz, 2009). As we can see in Figure 13, all the nodes in the WSN all organize first, then they will connect to the internet in on hop.

The Independent Network is only connecting WSN and Internet through one gateway. Once the gateway broke down, there is no other way to connect both networks. However, Hybrid Network fixes this lacking of backup problem. It is stronger than the Independent Network. Unlike the previous method, Access point network works as a self-organized application in WSN. It is requiring low latency and direct connections in this network.

4.4 Cloud Computing Technology

Cloud computing is usually mentioned in the network layer; since the cloud could help users store more information. However, Cloud Computing is connecting both the Network layer and Application layer. It is a combination of tradition computing and internet technology. In another way, it is more like a service over the internet and it help users analyse and store the data from the sensor node. It is solving the “Any PLACE connection” and “Any TIME connection” problem.

Unlike most of the computing, cloud computing is making the distribution of computing in a large number of distributed computers. The processing data speed is faster due to the massive size of the Cloud. However, it does not take any space in the local PC or any servers. For example, Google use millions servers to form the cloud.

The location for the cloud is not needed. It is a virtualized concept. Clients can access the service in any location. The only thing we need is a laptop or a smartphone and then the user will get the requested data deliver by the “Cloud” eventually.

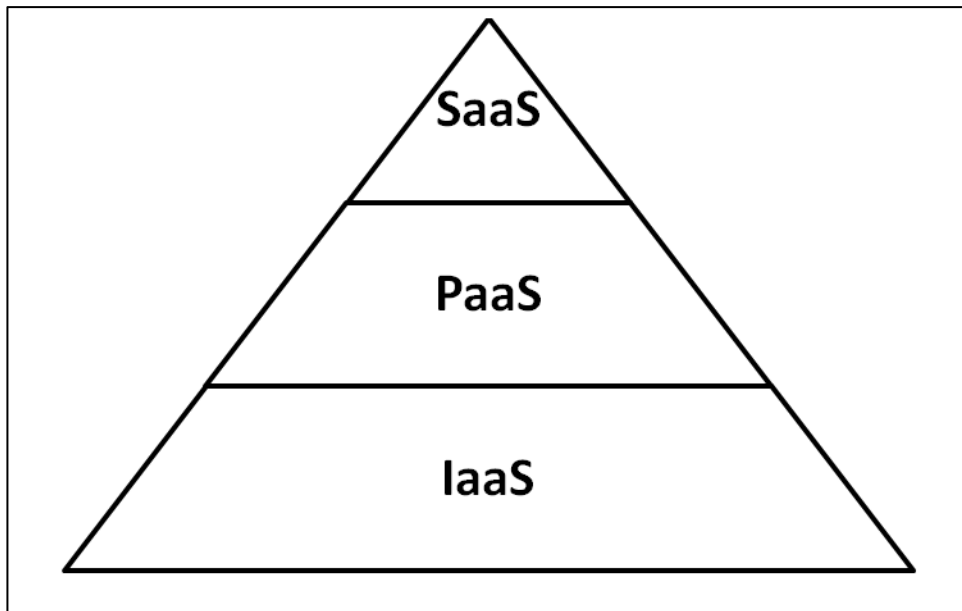


Figure 14 Architectural Layers of Cloud Computing

In practical, the cloud offers three kinds of services. In Figure 14, we could see the architecture layers in cloud computing.

- 1) Infrastructure as a Service (IaaS), it offers basic storage and compute capabilities as standardized services to the end user.
- 2) Platform as a Service (PaaS), it refers services as in the SaaS model to the software development platform. It opens to the application owners.
- 3) Software as a Service (SaaS), it is a model for providing software over the Internet without purchasing software.

The growing amount of user for IoT would not let us only use PCs or servers to deal with massive data. The cloud computing helps the IoT could spread in a steady speed.

4.5 Summary

In this chapter, three technologies in the Internet of Things have been reviewed. They are playing an important role in the general structure of the Internet of Things. Not only they presenting the layers, but also they are the main technologies that connect all the layers.

As the IoT is developing rapidly, we may have more issue to deal with. However, there is always a challenge in the future.

5 CONGNITIVE SYSTEM IN IOT

5.1 Introduction

In this chapter, it is mainly focus on cognitive system for IoT. As the technology has developed rapidly, intelligent computer technology has been implemented into all aspects in Computer Science. Cognitive System is one of the most new concepts, which has been introduced in Computer Science. In a general understanding that artificial intelligence is the final goal, those scientists try to accomplish. The basic connection between artificial intelligence and cognitive system is highly related. Moreover, the method has also been implemented in Internet of Things, in order to fully control the machine that could work perfectly for human being. The most talked topic in IoT is the smart engine; it will be introduced in the following chapter.

5.2 Cognitive System Definition

In general, cognition is the processing procedures and activates between human brain and the nerve system, which create the mind in human body. It contains learning, memory, thinking, understanding and other behaviours that occur in the cognitive process.

Cognitive science is a scientific study that tries to find out the processing rules for the cognitive behaviour. Therefore, language and psychology, brain and nerve is an important research content for cognitive science. According to human minds, computer science also becomes the object in cognitive science research. Moreover, there is no such pattern in cognitive science. Since cognition is not a certain concept could be described in one or two words, the only thing that has been concluded is from the experience.

5.3 Cognitive Development

In the psychology area, there is a theory called Jean Piaget's Theory. It is described the development in cognition. The theory explained the mental processes that have been formed during a child's growing. As it mentioned before, computer science is also an object could be developed in cognitive science. They all share the same patterns. In this case, it is similar to understand a known theory and relate it to the cognitive system in IoT.

There are three basic components to Piaget's cognitive theory. They are schemas, adaption processes and stages of cognitive development.

5.3.1 Schemas

It is a mental template with our own mind, which establishes the basic aspect of the world. Human brain will generate the schemas for all kinds of items and activities. In another way, it is the basic knowledge that children will have during the time they grow up. Schemas are more like building blocks of knowledge.

In IoT, schemas are also played an important role. In computer science, individuals are machine that they do not have their own mind. According to this fact, developers need to give machine or program a basic knowledge module to react with all kinds of basic activities. Not only basic module, but also all the used data or activities should be stored for the further analysis in order to generate the system more intelligent. The reaction in the last section in IoT should be the schemas, which are generated by the developers and from the collected data.

5.3.2 Adaptation Processes

According Piaget's theory, the schemas are not a settled concept. As the time pass by, new schema will be generated all the time. It is more like a steady process, which develop by an adaptation processes. There are three main concepts in the adaptation processes, which are assimilation, accommodation and equilibration.

1) Assimilation

It deals with new object or situation by using the existing schema (McLeod, S. A., 2015). For example, a child knows how a chair looks like. When he faces a sofa, he will generate a thought that this is a chair to sit, but when parent tell him this is a sofa that share the same function as chair. He will generate a new schema that the sofa is not a chair, but it has the same function as chair.

Therefore, in IoT the program will also have this process. The changing situation will be stored, developer will analyses it and give the program a more developed schema.

2) Accommodation

When the existing schema does not fit for the new object or situation, the new schema should be generated to face the new object or situation.

3) Equilibration

It fits between the process of assimilation and accommodation. When there is a disequilibrium accrued, equilibration will be participate in the whole process to force the child to learn something new in order to generate a new schema that fits the situation or object. It works as a catalyst to develop the whole adaption process.

In Figure15, it shows the general process for the adaption process. When event happens, first it will go through the assimilation process. Child will go through the existing schemas. He will equilibrate the object or situation with the schemas he has. When there are no existing schemas fit for it, new situation will be created. The child will feel unsatisfied. Then new schema will be generated to fit through the new situation by learning new knowledge. This cycle will go through again when a new event happens.

In IoT, there is also similar situation. As machine does not have mind, the developer should go through the same adaption process as it shows in Piaget's theory to fit through the whole data process.

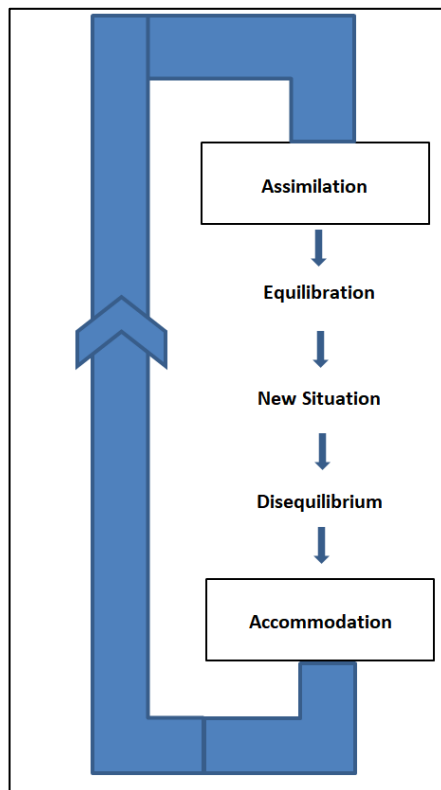


Figure 15 Adaptation Processes

5.3.3 Stages of Cognitive Development

There are four main stages in the cognitive development. In Piaget's theory, each stage present differently.

They are:

1) Sensorimotor Stage

It is the beginning of everything; child will interact with the environment from start. The basic knowledge and intelligence for objects will be formed in this stage.

2) Preoperational Stage

In this stage, things will be symbolized. It is not only an object, but also it represent by a own word for it.

3) Concrete Operational Stage

The major schemas have been formed in this stage. Child can work things out by go through the adaption process. There is a major mental phase has been created.

4) Formal Operational Stage

This final stage will last to the end. According to the previous stages, child will have the ability to sort and order all the schemas that have been formed earlier. Moreover, they also have been through the adaption process for a long time. The processing procedure is more practical than other stages. It is more skillful with all kinds of similar and unfamiliar situation.

Among these four stages, each stage derives from the previous stage. There is no reverse for the previous stage. Child will go through each stage by its order. Therefore, no stage will be skipped.

These four stages are also fit for IoT. In IoT, the base is human-computer interaction (HCI). From both human and computer sides, cognition is the key word that will be developed when time pass by. It is a long journey for IoT, which it is similar to a growth period for the children. From nothing to another artificial intelligence level, the cognitive system should be applied into the development of Internet of Things.

5.4 Cognitive System Structure in IoT and Development

The key for cognitive IoT and artificial intelligence is about advanced machine learning. Two drivers matter in this case, which is algorithms and unlimited data processing capabilities and storage. (Romeo Kienzler, 2017) The goal for cognitive system is trying to mimic the way the human brain works.

In cognitive IoT, the concept of edge computing is involved in. Due to the enormous data that IoT will deal with, edge computing will force the computing into small section and push them toward to the sensor end. In this structure, it helps to solve the massive computing loading problem for IoT. Moreover, there are two main concerns for the cognitive IoT, which are latency and transfer cost. The edge computing

architecture could solve the problem easily. For latency, edge computing pushes the data toward the sensor. This cause the data could travel faster and save the reaction time. Due to nowadays technology, it is also impossible to send enormous data through the communication protocols. The transfer cost will be countless. The need for the real-time stream processing is emergently, the combination of edge computing and cloud computing will fit right through the whole cognitive IoT to solve the latency and transfer cost problem.

In Figure 16, it is the flow char for cognitive IoT. First, the data will be collected from the sensor end. Through the communication process, all the data will be sent through different protocols in order to reach the IoT application. Moreover, the application will deal with all the data through the cloud computing services then react to human or machine.

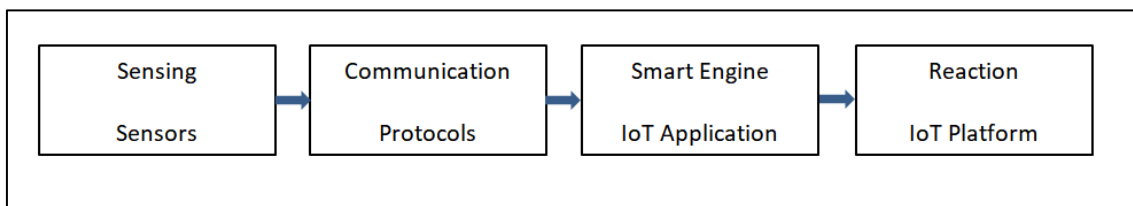


Figure 16 Flow Char for Cognitive IoT

As mentioned before, cognitive IoT is trying to mimic the way the human brain works. It involves self-learning system. The cognitive IoT does not have a certain module, but it should start with certain basic knowledge block. With the IoT application implement, all the data that have been collected to the IoT platform should be stored and personalised in order to fit the different need in real life acquirement.

In Figure 17, it shows the IoT cognitive system architecture. This is a higher level view of an IoT Cognitive System Architecture. It is always an evolving process for cognitive IoT. Old data or value will stay in the cloud service, but there is always new data will be added to the cloud services. As it mentioned before, it is similar to Jean Piaget's Theory. The development for cognitive IoT will be from basic information blocks to personalized service.

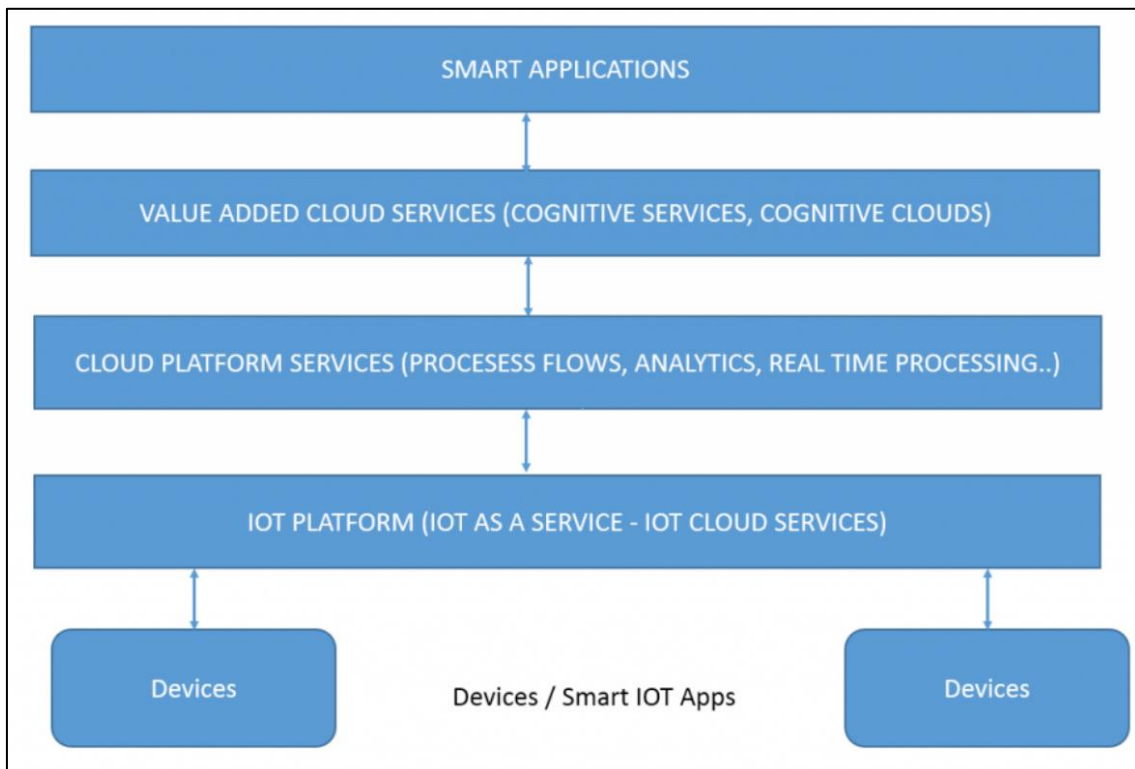


Figure 17 IoT Cognitive System Architecture [Naveen Balani, 2015]

For example, a smart home project should be discussed to gain a better understanding for Figure 17. User build a smart automation system at home, which lead to the smart application in Figure 17. It has basic function to start with, such like control the humidity and temperature at home. The sensors first collect the basic daily data and send it to the cloud services. In the cloud platform, all data will be real time processed and analyzed. Moreover, there will be some changes made due to different users and during the different time of the year in the IoT platform to face the different need for the users. It is developing in real time processing. Machine will learn from the data that have been collected during the time. For longer time, the cognitive IoT system have been arranged, the more personalized the system will be in order to face the acquirement from the user. In the end, the system will be highly artificial intelligent. There is no pattern to follow that how this system has been involved, but we could say that the past data and machine self-learning processes made the cognitive IoT more intelligent.

5.5 Summary

The cognitive IoT system is the heat topic in IoT aspect. The cognition process is like human brain. There is no such pattern to follow how cognitive systems really develop cognitive system; it is more like a self-learning and evolving process at the same time.

It is truly interesting to develop this cognitive system in IoT aspect. The final goal in IoT is that machine could work as a servant for human being, which also called artificial intelligent machine. The machine evolving process should be like human brain. It is from nothing to truly deep thoughts. Imagine one day, u walk in your own home everything is prepared for you to arrive. It proves human intelligent could make machine mimic like human and work for human.

6 WIRELESS COMMUNICATION APPLICATION IN IOT

6.1 Introduction

In this chapter, a communication application in IoT sample will be introduced. The application is based on the structure and technology in the Internet of Things that have been discussed above. In this application, the main function is about to sense the temperature and humidity. First, the sensor data will be collect and send to the cloud. Later on, the data will be analysed by a certain rule. When the data have reached the limits, the alert information will be send through tweeter to warn the user.

6.2 Methodology

In this application, Node-RED, IBM Bluemix and their IoT sensor simulator will be used.

IBM Bluemix is a PaaS cloud platform developed by IBM. In the Bluemix, there are hundreds of services to choose. In this application, the service is name as Internet of Things Platform Starter. With this service, all the data will be easily analysed and managed by the program. It is easy way to create an application and even easier to deploy an application with Bluemix. This is the base of the application.

Node-RED is a web service to write the Internet of Things. User can run node-red in any open platform. It is visualized and easy to use. The build in functioned nodes help user to create the flow and connect them together without difficult programming. It comes with a large library of complementary modules.

In addition, user should have some data from the sensor. In this application, the already made IoT sensor simulator is showing in Figure 15 down blow (Edward Prosser, 2015). This simulator is from IBM Watson IoT platform. In this case, no a physical device is needed. It is possible to finish the test with simulated data. In the simulator, user could choose the numbers by our own need. There is a random

generated mac address in the simulator. In the later process, this unique code will be needed to set up our application.

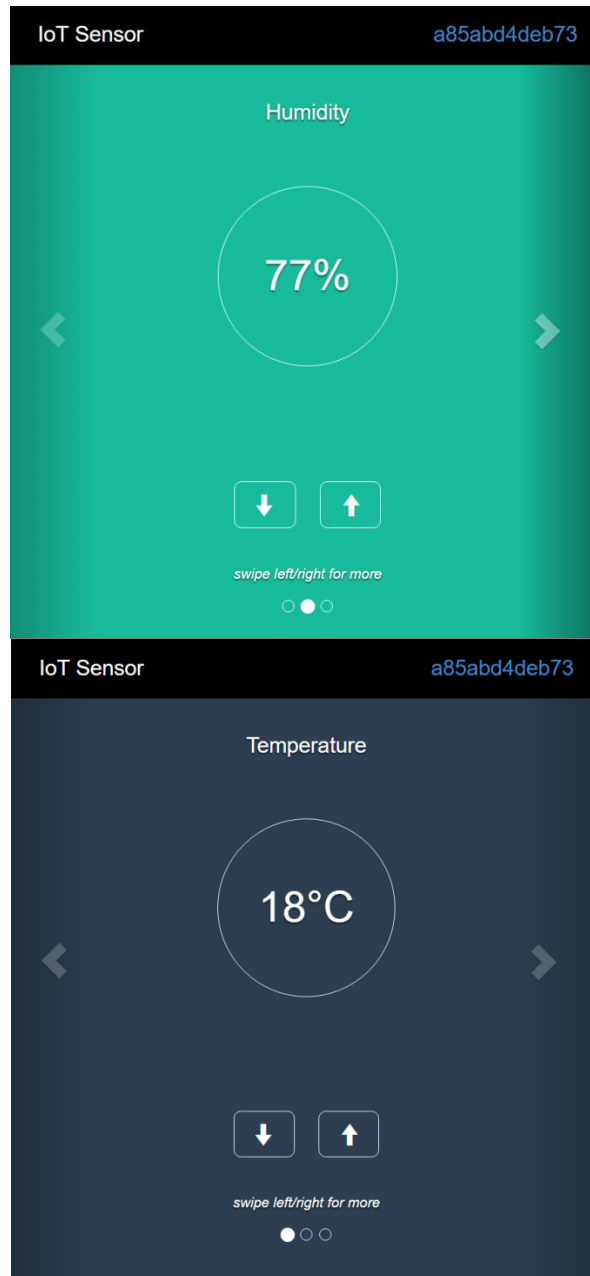


Figure 18 IoT Temperature and Humidity sensor simulator.

6.3 Configuration

In Figure 16, it shows the procedure in setting application in Bluemix platform. In the Bluemix catalogue, we choose the service called Internet of Things Platform Starter.

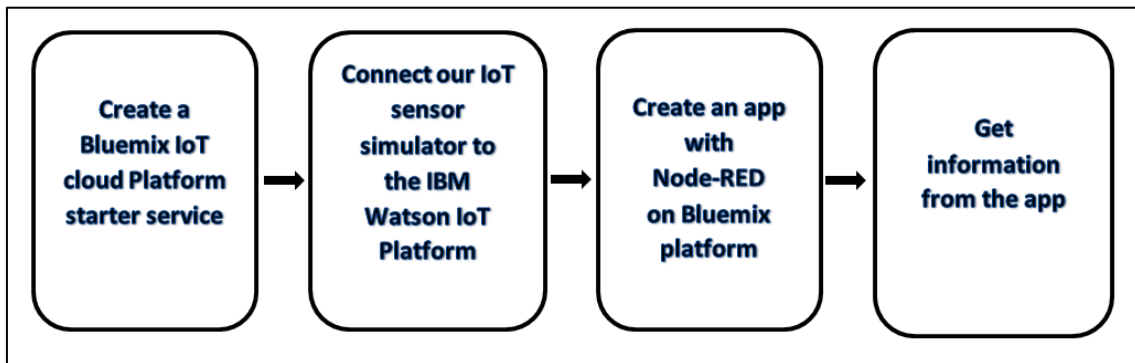


Figure 19 Flow Chart for Setting up the Application

User will be able to set our App and host name. The IBM Bluemix will generate user's own domain while creating the application. Then user could see application's statue and memory usage which is showing in Figure 17.

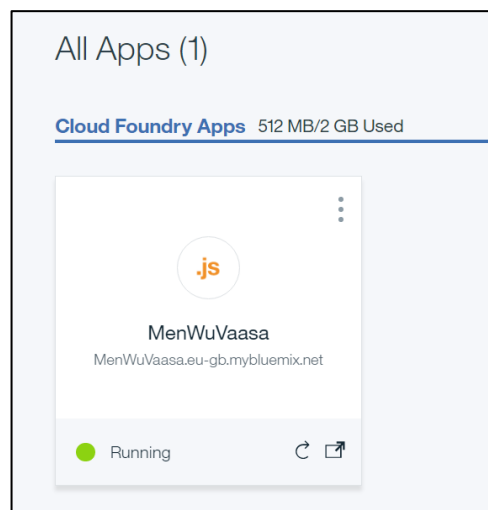


Figure 20 Application Statues

As it mentioned before, user is using an IoT sensor simulator. The unique MAC address of the simulated device will be given. Therefore, user simply goes to the IBM Watson IoT platform and type the MAC address in the quick start and then the live data will be shown from user's device. It displays in Figure 18, the value of different data point and the time will be seen. They are generating the data every two seconds.

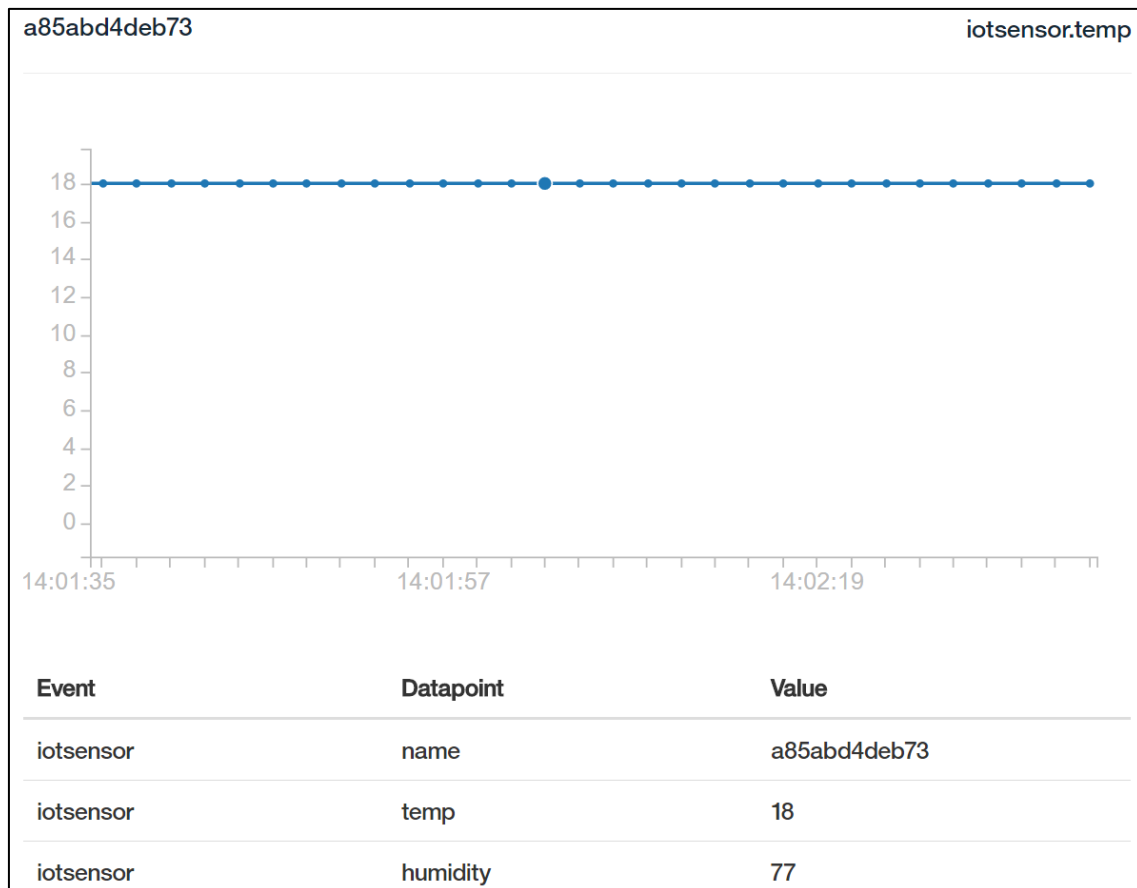


Figure 21 Device Live Data

Then user should jump to the Node-RED part to draw the flow of the application, which is showing in Figure19. User will also configure each node.

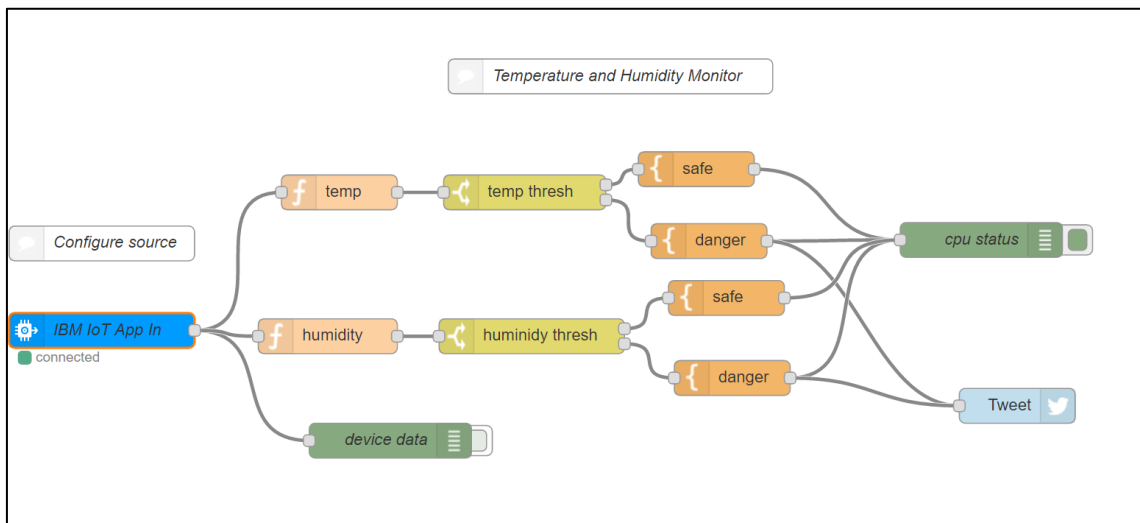


Figure 22 Application Flow

First, user should connect device to the application in order to get all the data from the sensor. It is showing in Figure 20. For the authentication, user should choose “Quick start” option, since it is done in IBM Watson Platform. Moreover, user should also put the MAC address in the device ID option.

Edit ibmiot in node

Cancel
Done

Authentication
Quickstart

Input Type
Device Event

Device Id
a85abd4deb73

Name
IBM IoT App In

Quickstart: Use the Input Type property to configure this node to receive Events sent by IoT Devices, Status Messages referring to IoT Devices, or Status Messages referring to IoT Applications

Check the info tab, to get more information about each of the fields

Figure 23 Configuration of the IBM IoT App in Node

Second, user starts to configure the function node, which are “temp”, and “humidity” node that is showing in Figure 18. In the function field, user will type the code as down blow in order to get the certain data from the IoT platform.

```
return {payload:msg.payload.d.temp};
```

```
return {payload:msg.payload.d.humidity};
```

Furthermore, user will configure the switch node and template node. There is a set up rule for the collected data. Therefore, user should set it as the way that shows in Figure 20.

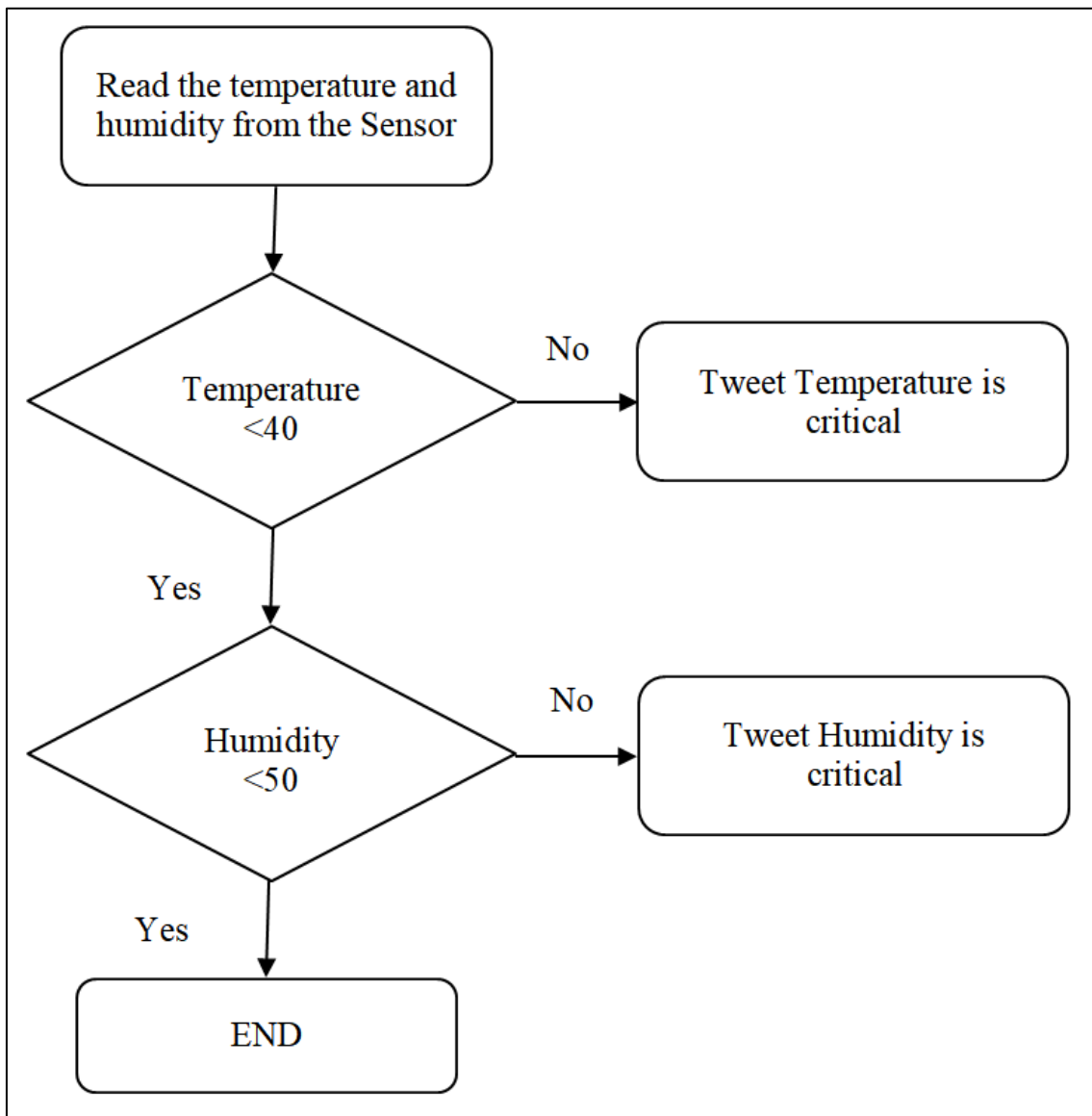


Figure 24 Flow Chart of Temperature and Humidity Sensor application

In order to complete the main purpose of IoT, which is to achieve the goal that user could get connection anywhere, anytime and anything. We first get the data from the sensor and then we will process the data. If the temperature is higher than 40 or the humidity is higher than 50%, then we will tweet a message on twitter. Therefore, we do not need to stay with PC all the time. When there is an event, we could get information from our social network in order to build a network that we could get access anytime and anywhere.

The figure displays two screenshots of the 'Edit switch node' configuration window, showing the setup for two different switch nodes.

Top Screenshot: humidity thresh

- Name:** humidity thresh
- Property:** msg. payload
- Rules:**
 - Rule 1: \leq 50 → 1
 - Rule 2: $>$ 50 → 2
- Status:** checking all rules

Bottom Screenshot: temp thresh

- Name:** temp thresh
- Property:** msg. payload
- Rules:**
 - Rule 1: \leq 40 → 1
 - Rule 2: $>$ 40 → 2
- Status:** checking all rules

Figure 25 Configuration for Switch Node

6.4 Result and Analyse

We could see the results in all the Figures down below. When there is one of the feature is over the limit, the application will tweet a report in the twitter. It is a live report, as we can see all the time stamps are almost at the same time. After the test, we could have a better understand in the Internet of Things. Not only IoT could help us

live more efficiently, but also we could do more with the Internet. As the technology is developing, more and more application will be created in order to achieve the real Internet of Things that helps not only us but also the machine to be smarter.

In this application, we only peak a part of the IoT. Nevertheless, we can use this application in lots of the field that need attention on temperature and humidity.

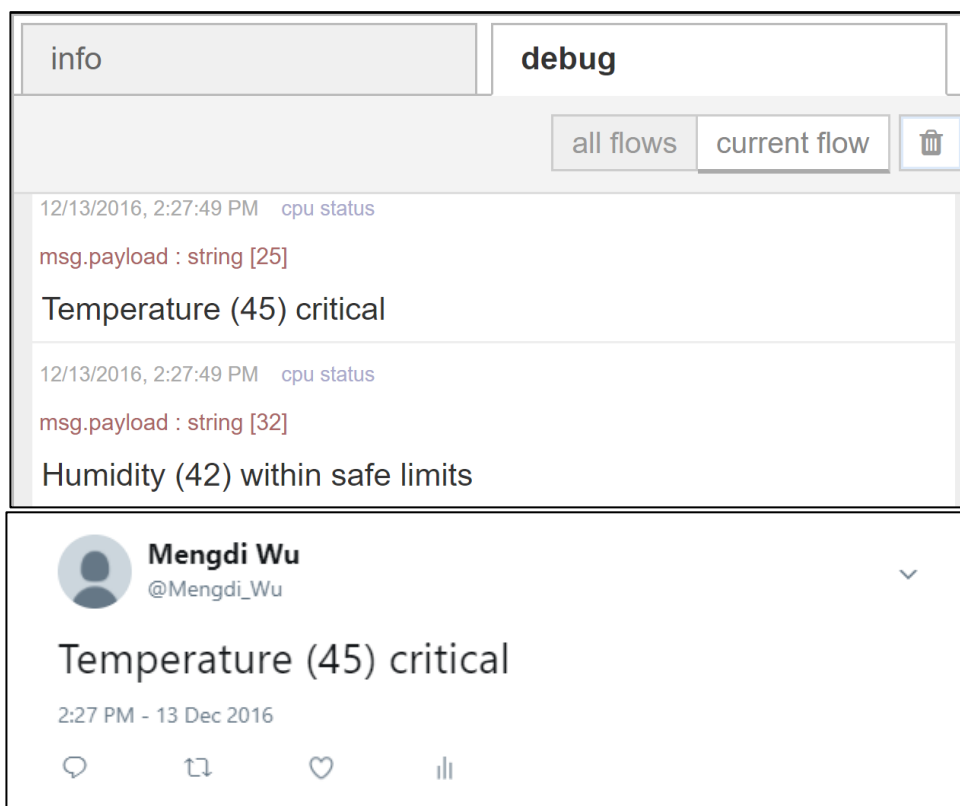


Figure 26 Result of When Temperature is higher than Limit

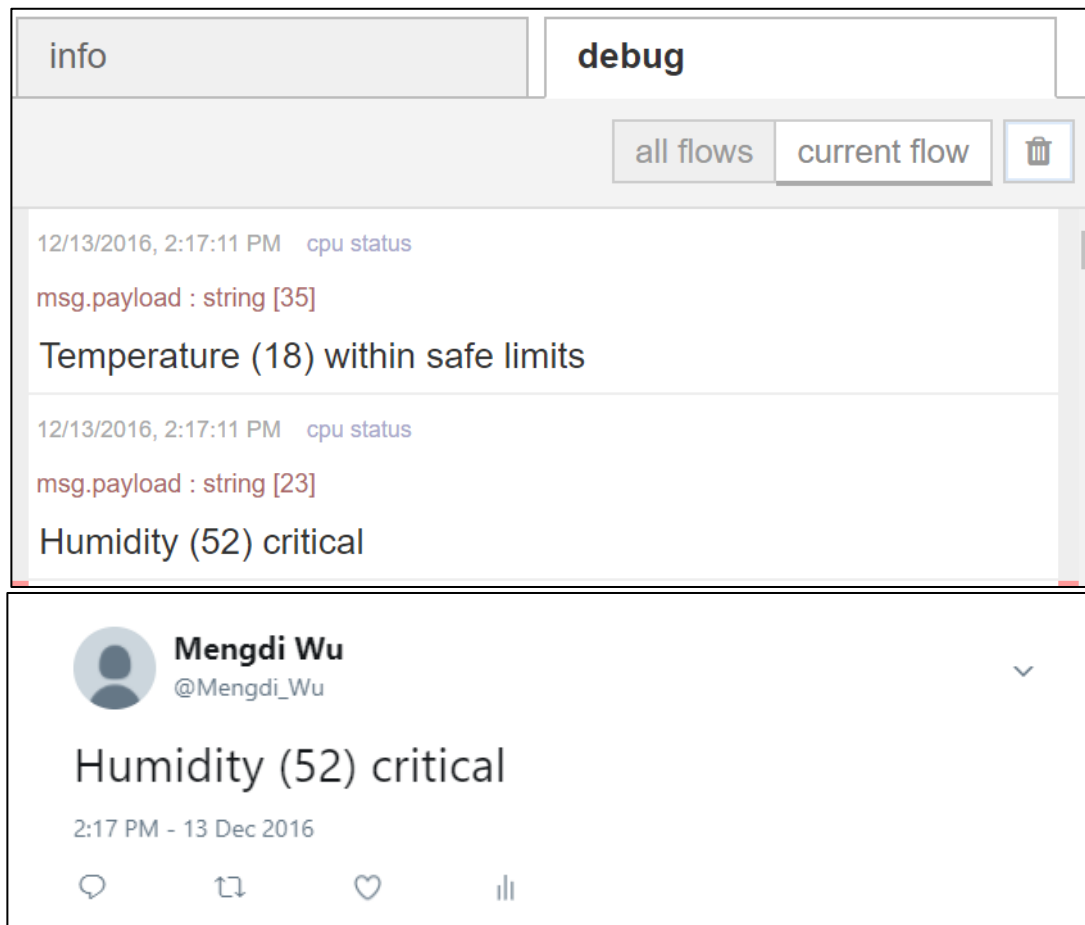


Figure 27 Result of When Humidity is higher than Limit

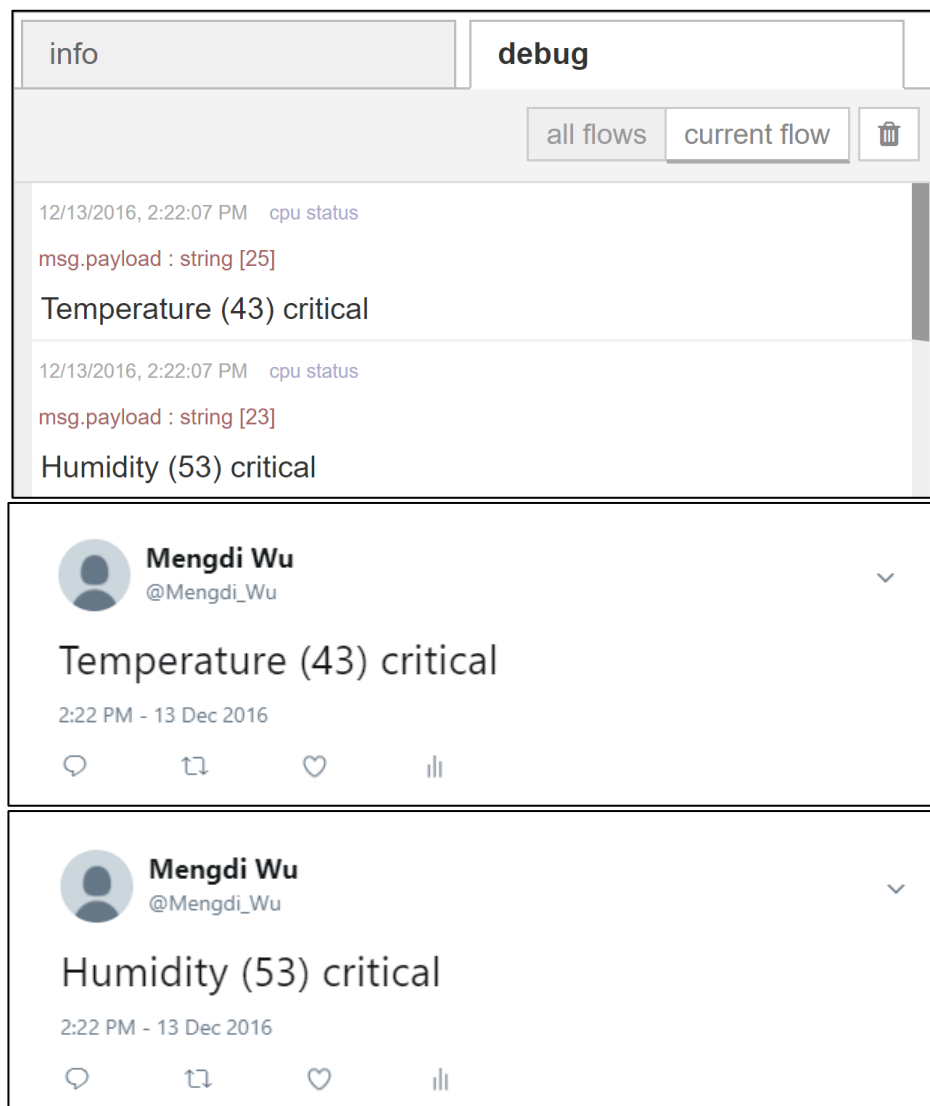


Figure 28 Result of Temperature and Humidity is higher than Limit

7 CONCLUSION AND FUTURE WORK

In this thesis, the important communication protocols, communication technologies in Internet of Things and cognitive system were introduced. In order to explain the concept of Internet of Things, the structure was revealed. Therefore, a general understanding of Internet of Things was done.

In addition, the concept of cognitive IoT was mention as well. It is the most popular topic that has been discussed in the recent decade. In order to achieve the final goal for artificial intelligence machine system, cognition is the key concept to be discussed. Therefore, the basic knowledge of cognitive system and development should be introduced. The cognitive IoT system is a real life changing technology to improve human life and work quality. As longer as the cognitive IoT system is developed, the more convenient human life would be. The growth of the system helps user personalize different acquirement in all aspects in life.

Just imagine that the thing people interact every day could manage themselves with various functions and serve for people. Moreover, the anytime, anywhere and anything connection concept in Internet of Things will help people to live a more efficient life. The live-stream report from all kind of application would improve the quality of our life with a huge step.

This topic is still developing rapidly. Intern of Things is the main direction that people should focus on. Some big companies start offering different kind of services into our daily life, such as Smart Home, Health Monitor and so on to develop human's life quality by using Internet of Things. It is a huge step for the whole computer science technology.

Nevertheless, everything has its two sides. There are some issues should draw our attention. As we all know, IoT is a next generation of Internet, but it is still based on Internet. The security problem should always be an import point that should be looking into. The technology in telecommunication also limited the development

speed for Internet of Things. In addition, there are more issues should draw us an attention such as latency, transfer cost and so on.

The example IoT application that has been mentioned in the paper. It explained how a basic IoT could affect people's life already. However, there is future work should be considered. The cognitive IoT system is more complicated, but it is more effective to see how IoT could reach the final goal of Internet of Things. The design for a real cognitive IoT system should be considered as a future work.

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