A Comparative study of Operating System for Internet of Things

Shivam Thakur, Ms. Ruchika Rani
Department of Computer Applications
Chandigarh School of Business
Chandigarh Group of Colleges,
Jhanjeri, Mohali, India
shivamthakur45558@gmail.com, ruchika.j2758@cgc.ac.in

Abstract- Internet Of Things is nowadays one of the most advanced and in trend technology. Internet Of Things basically means the network which internally connects all hardware and software devices. All these devices connected through Internet Of Things can be controlled by the user. One of the core components of Internet Of Things is Operating System which is a kind of software written through which the use of punch cards and magnetic tapes were replaced and programs can be run by a single user with less efforts and less time consumption.

Review paper is basically about how the Internet Of Things and Operating System operates, there pros and cons, features, core components, their cause of origin and how the Operating System is crucial component of Internet Of Things. The most renowned companies serving Internet Of Things as well as Operating System services are also listed, when and how they started, their products which were made specifically for the Internet Of Things purpose or were afterwards made to be used for Internet Of Things purpose.

Not only the information about Internet Of Things and Operating System technologies are listed but also how these two are related to each other is also mentioned review paper. What was the past and present of the Internet Of Things and Operating System technology is listed here but what can be the future of the Internet Of Things and Operating System is also tried to be predicted on the basis of facts and figures. As a conclusion Operating System itself is a powerful technology but Internet Of Things needs Operating System to be implemented otherwise without Operating System Internet Of Things is just some hardware machines which needs to be operated in same old way though knobs and switches or Operating System can be said as a core of Internet Of Things world to some extent.

Keywords- Internet Of Things, Operating System, Kernel, UI, GUI, NLI, CLI, API, Blockchain.

1. INTRODUCTION TO EMERGING INTERNET OF THINGS AND OPERATING SYSTEM TECHNOLOGY

Nowadays the world is experiencing the fourth wave of Internet of Things or we can say it the era of Internet Of Things. Let us first get a close picture of what Internet Of Things is, Internet Of Things can be referred to as the things which can be controlled through microprocessors or microchips. Internet Of Things is not just a magic wand which spins and make the gadgets work as the user direct it to. This whole process has a full-fledge electronic science behind it. The base of science behind the working of Internet Of Things relies on the Operating System .

These devices may be made smartly controllable while their manufacturing before the origin of the term Internet Of Things or they were made controllable by installing the micro-processors in them under the effect of Internet Of Things wave. At the present moment almost each and every device or we can say each and every device which needs electricity as an input to operate can be controlled with the help of a smart assistants like Alexa, Google Assistant, Siri or by some other apps which we may find easier to use. These smart assistants are these days considered the one of the best ones at work in their fields.

Now we all know what the Internet Of Things can upbeat, but it all does not ends here the core of Internet Of Things is Operating System. The Operating System is the core of almost all gadgets which contains a single board pc or a motherboard to control the device by just giving commands to the machine by a keyboard, mouse, voice assistants or by gesture control. All these devices are not just some hardware containing chips, processors and other basic things to perform all fundamental functions, it also contains a valuable software which is termed as Operating System. This Operating System is a software developed to control each and every port and function of a particular hardware device. Through Operating System we can control the device by the means of CLI (Command Line Interface) or by GUI (Graphical user Interface).

Operating System was the First revolution after the time when people user to assemble in front of computer with punch cards and magnetic tapes having the programs loaded in them, and after that physically inserting them in the computer and waiting till execution turn by turn. After that term Operating System arrived. Operating System took the job of computer operators an all that time consuming process was minimized and can be simply done by a single person with much less efforts, As the other components began to be included and being upgraded the technology also innovated with great speed.

When the Operating System were first developed the storage size of the Operating System were about few kilobytes as that time was the start of the computer era whereas today's Operating System are about few gigabytes as the expectation and functionalities of the computers have increased way more than before. As the storage size of the Operating System have increased the size of hardware to run them have also increased.

The Operating System which are in use in these times requires space consuming and costly hardware which may increase the cost of smart devices and the size of mini smart devices which are designed to be portable. So, to solve this problem Operating System were made for the only purpose of controlling the electronic devices and gadgets and doing other basic functions. These Operating System cannot perform having tasks which other Operating System like Microsoft, Mac and Ubuntu can do but are best for performing Internet Of Things functions like controlling machines.

These Operating System do not require large and expensive motherboards. They can run on the single board PCs which are less

expensive and smaller in size than motherboard and other components of a desktop or any type of computer. So, this reduces the size as well as cost of the Internet Of Things device manufacturing.

2. OPERATING SYSTEM , ITS'S COMPINENTS AND WORKFLOW

Operating system is one of the most useful and famous upgrades happened so far in the area of computers and any other device which runs on 0,1 binary language. Before the rise of Operating System, operating of computers was a way difficult task. Bunch of well-trained computer operators were hired. Each one of them wrote their own part of codes on the magnetic tapes and punch cards after that each computer operator have to line up in front of the mainframe computers and each one have to wait for their turn and insert their magnetic tapes and punch cards turn by turn in computer and wait for the code to run and compile.

To resolve this issue the first operating system came in with the name GMOS. Almost all the problems which were previously faced while operating computers were solved. The main function of the Operating System was storing the pre-written codes stored in the form of files. All these files containing the pre-defined codes when executed using the default compiler do the particular functions which they are programmed for.

Contribution of Operating System to the computer world not only saved time but also the human labour as we do not need highly skilled workers to write and store codes on magnetic tapes and punch cards instead users can directly interact with the systems with the help of GUI interface or CLI Interface as per preference. Operating System not only brought ease in operating computers but also introduced a new input device known mouse for hovering over screen and selecting different files, folders and running, executing different set of programs (nowadays are known as applications).

Apart from the predefined programs written in Operating System, customised codes can also be written in any programming language supported by Operating System which can be further executed to perform any task. Parts of Operating System are as follows.

2.1 HARDWARE DEVICES: It is most outer layer of the Operating System. Here lies the tangible parts of the computer naming monitor, mouse, keyboard, ports, switches and hubs etc.

2.2 DEVICE DRIVERS: Device Driver is a piece of software code used to control and interact with the hardware devices like speakers, screen and camera etc.

2.3 FILE SYSTEM: File System is a kind of treelike structure. Which needs to be present in any Operating System. The motive of file system is to store and display the data or information stored in the Operating System so that the functions like accessing, updating, deleting, searching and filtering data with less resource consumption in effective and efficient manner.
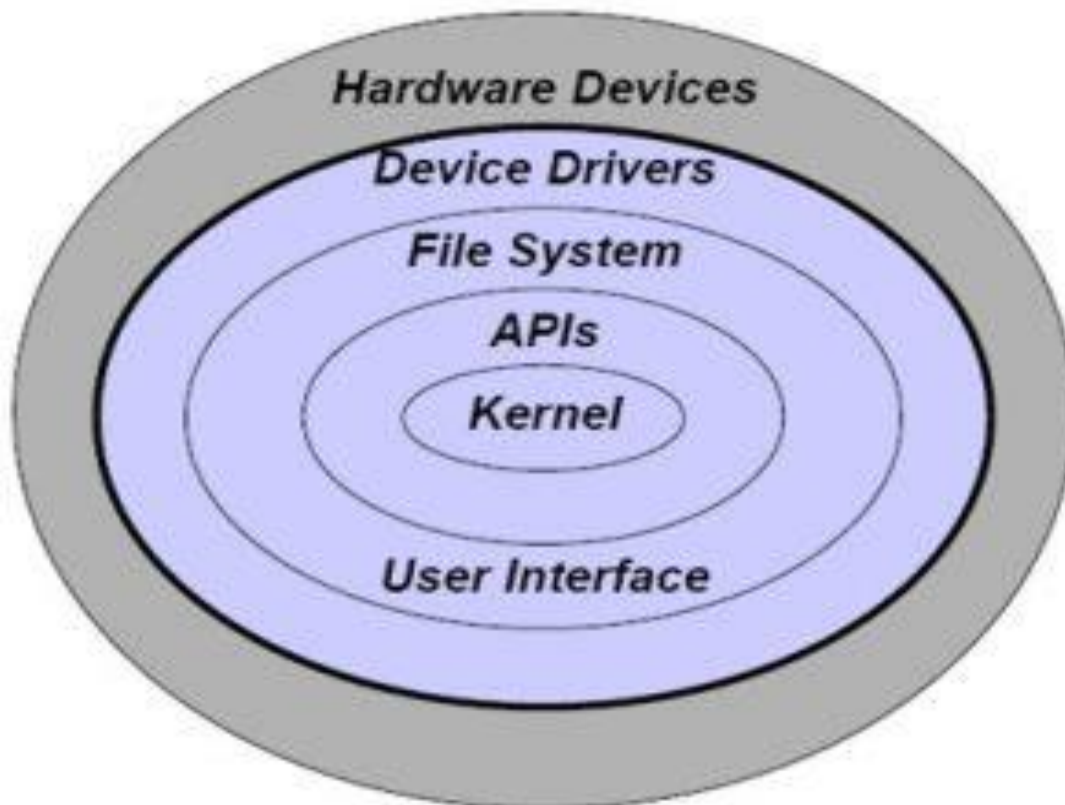

Fig 1 : component structure of OS(Operating System)

2.4   USER INTERFACE: user interface is a visual representation to control each and every device connected to Operating System.
Motive of user interface is to make human and computer interaction easy for users. Types of user interface are as follows.

2.4.1   GUI (GRAPHICAL USER INTERFACE): This type of user interface gives control to the user in form of icons and menu bars. All the services can be accessed by the mouse, keyboard, touchpad or any other input device which can be used to select menu bars or icons present on the screen.

2.4.2   CLI (COMMAND LINE INTERFACE): This type of User Interface interacts with the devices by typing commands in a command shell. In this type of UI, the only input device allowed is keyboard.

2.4.3   NLI (NATURAL LANGUAGE INTERFACE): Nature Language interface is a type of User Interface in which user don't have to give commands by sitting in front of screen through keyboard or mouse like in GUI or CLI instead we control the devices by giving voice commands. This type of UI can be considered as most user-friendly UI among all the UIs mentioned above. This type of UI is mainly used in providing INTERNET OF THINGS services. Some of the devices that used NLI UI to operate are Alexa, Siri, Google Assistant etc.

2.5   API: The term API means Application Programming Interface. The main function of API is used to make two software capable of communicating with each while staying, following the protocols, standards made for communication between the software. Working architecture of API contains a client a software who send request to a software which receives the request known as server.

2.6   KERNEL: Kernel can be said as a core component of the Operating System. When the system starts the kernel gets loaded in memory and remains until the computers shuts down. Some of the functions for which kernel is responsible are task management, disk management, memory management etc.

3.   INTERNET OF THINGS AND ITS COMPONENTS

The term Internet Of Things can be described as a web of interconnected nodes (electronic devices) through medium of internet. Motive of creating this web of electronic devices is to control them in easier and more efficient way by giving voice commands or visual gestures instead of accessing them physically through switches or knobs. There is a whole cycle which is to be followed to provide an Internet Of Things service anyone. Some of components necessary to provide Internet Of Things services are as follows.

3.1 HARDWARE DEVICE: It is node or electronic device in the interconnected web of internet which is to be controlled through Internet Of Things technology.

3.2 GATEWAY: Gateway in terms of Internet Of Things meant a connection hub used to connect hardware to the cloud for accessing, transferring and perform other function data stored or to be stored in cloud services being used.

3.3 CLOUD: Cloud is next component after the gateway it is used to store the data being transferred through the gateway from hardware devices and let the authorised users to fetch, insert or update the data according to the needs.
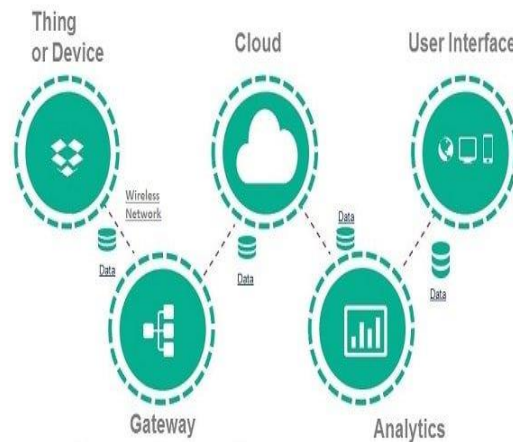
Fig 2 : major components of Internet Of Things

3.4 ANALYTICS: Internet Of Things technology is spread across a huge region and humongous number of users. So, data collected is also quite big. Analysing this amount of data cannot be done manually so analytical algorithms and software are implemented. Even a minute decision creates a

great effect on the organization and quality of service so each decision must be perfected calculated before being taken. That is why analytics is also important in Internet Of Things process.

3.5 USER INTERFACE: User interface is a software or application generated with the motive of becoming of as user friendly as it can

be and at the same time it can effectively and efficiently have all the control over hardware device of which user have access to.

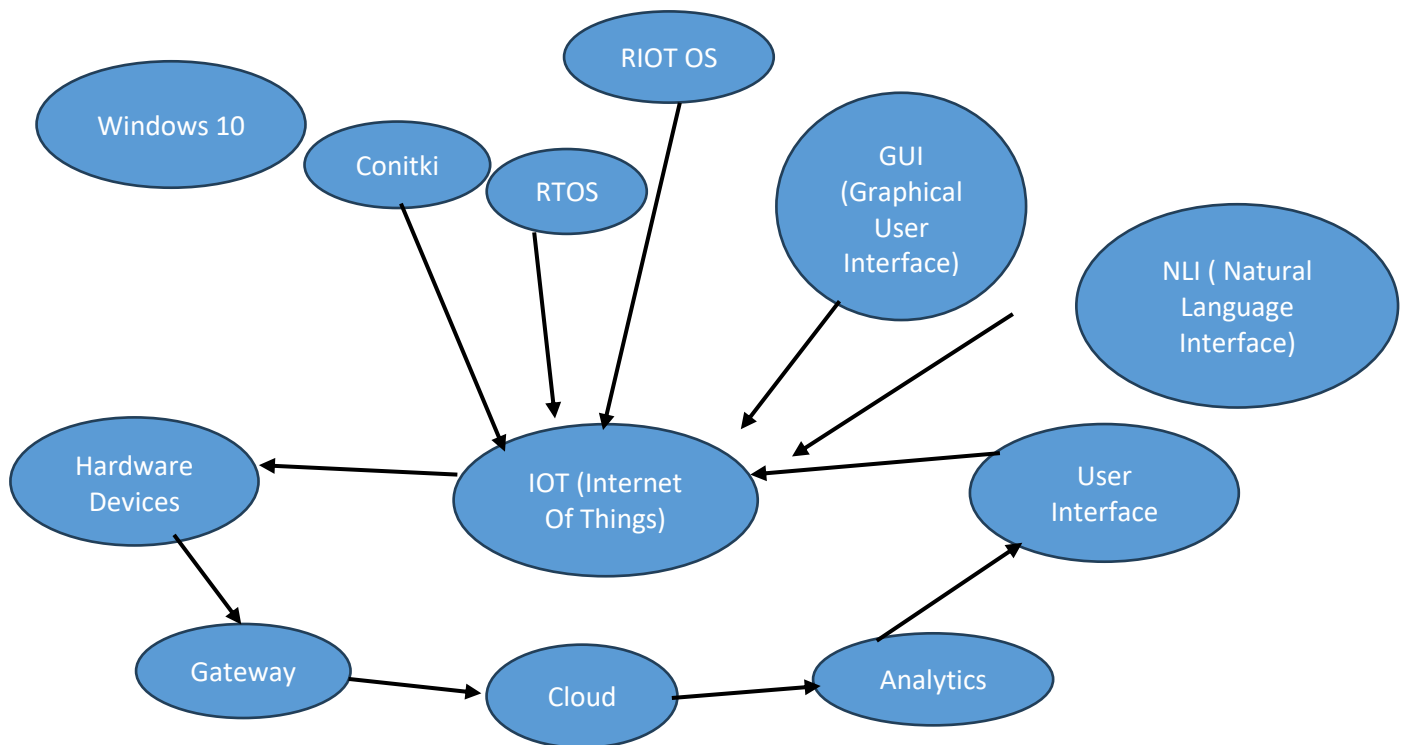Flow chart of how Operating System is linked to Internet Of Things
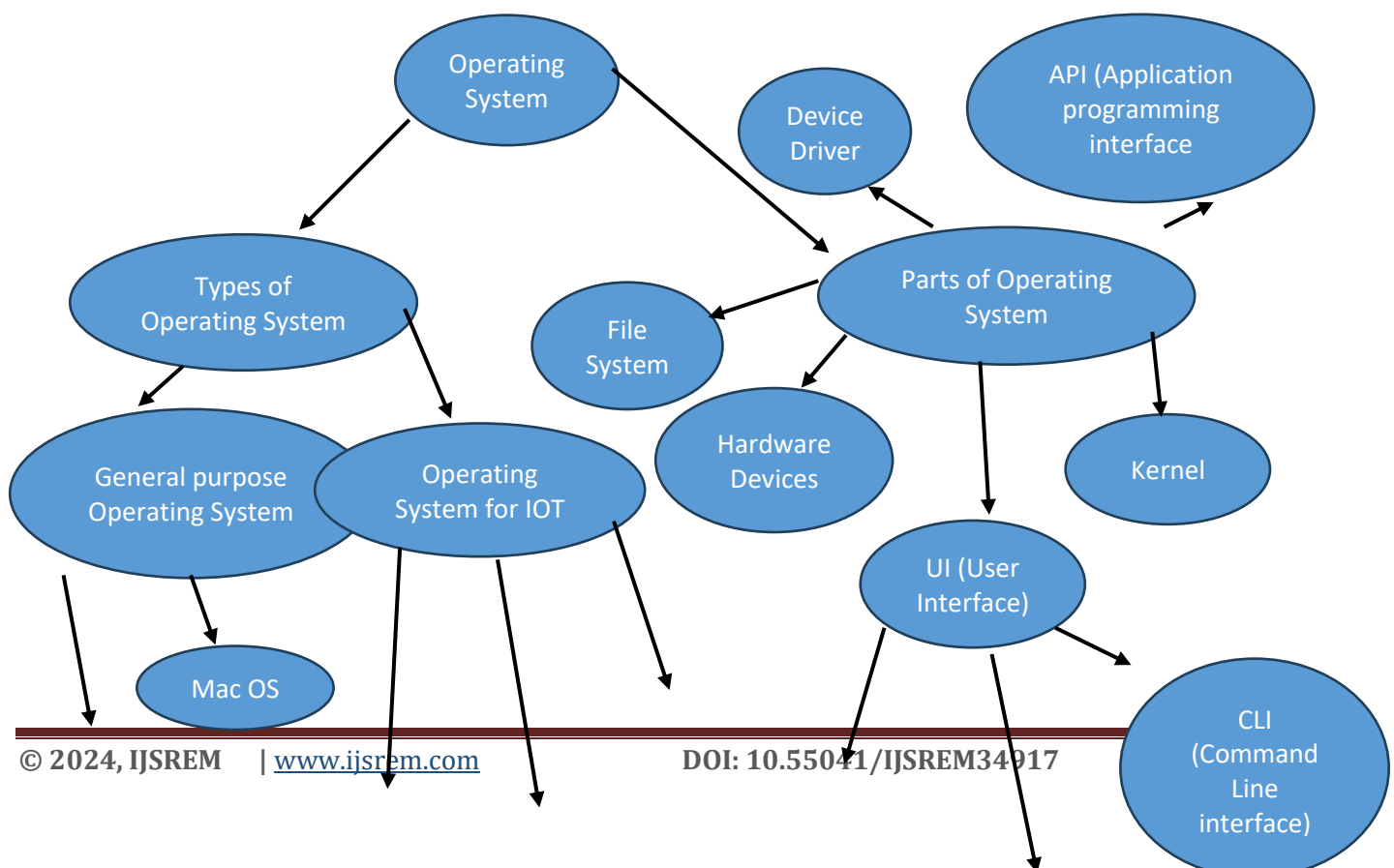
Fig 3 : flow chart of OS and INTERNET OF THINGS connectivity.

4.   ROLE OF OPERATING SYSTEM IN INTERNET OF THINGS

Operating System and Internet Of Things are two technologies which are very useful in real life but together they walk hand in hand with each other to act as booster in the growth of each other. Operating System were developed to perform heavy as well as light weight tasks so the resource required to run these Operating System were quite large. In Internet Of Things devices we cannot afford to include high level resources and huge power supplies to power up the Operating System as it will increase the cost of the device and flaws in its design.

To resolve this problem all not so necessary features for Internet Of Things are removed while developing the Operating System. In return Operating System require less resources as compared to the normal general-purpose Operating System. Apart from less resource consumption and increase in sustainability the cost of development and maintenance.

It is not that the none of the above two technologies cannot work without the help of each other. Operating System can be used on any computer, Pc, Desktop, Mobile or any other device. Internet Of Things unlike Operating System cannot run without the help of Operating System as we can gather actuators, sensors and other devices but to interact with them we must have an Operating System either a general-purpose Operating System or an Operating System specifically made for Internet Of Things.

5.   TYPES OF OPERATING SYSTEM IN INTERNET OF THINGS

Various types of Operating Systems are being developed and used nowadays in order to meet the needs of large variety of Internet Of Things services. Some of the types of the Operating Systems used for Internet Of Things services which are in trend are as follows:

5.1   REAL-TIME OPERATING SYSTEMS (RTOS): RTOS is an Operating System designed with the purpose of providing the real time updates in the information and data of the Internet Of Things devices and services and using that data to make the Internet Of Things services or device nearer to demands of the Internet Of Things device/ service user. Examples includes Zephyr, RIOT Operating System, Contiki and Free RTOS.

5.2   EMBEDDED LINUX: Some of the Operating Systems which are used for Internet Of Things devices and services are the customized version of Linux Operating System and have numerous amounts of features specially designed for Internet Of Things. As these Operating Systems are made on the base of Linux so it also offers the security and other features of the Linux Operating System.

5.3   CONTIKI: Contiki is an Operating System developed in order to works in an environment in which the memory and the power provided in a hardware are very limited. The performance of the Operating System in these minimal requirements is maintained by using the up-to-date advancements in the Operating System. It is an open-

source Operating System. All these features of Contiki Operating System make it suitable to some extent for the Internet Of Things devices and services.

5.4 RIOT OPERATING SYSTEM: RIOT Operating System is another Real Time Operating System (RTOS) it focuses on providing the Internet Of Things services within the limits set up by the hardware device whether it is power consumption, processing power or any other resource apart from these features the RIOT Operating System also focus on scaling of the Internet Of Things service after once be deployed. RIOT Operating System is an open-source Operating System.

5.5 GENERAL-PURPOSE OPERATING SYSTEMS**:** These types of operating systems are not particularly for Internet Of Things services or we can say not for the purpose of providing the Internet Of Things services within the nominal resource requirements provided. In some of the scenarios the focus is not only on providing the Internet Of Things services within the limited requirements of the hardware device but the main goal is to provide the best services with a good experience. Here comes the quite heavy Operating System like windows 10 which needs high power and processing requirement but provides the services accordingly. Heavy Operating Systems like windows 10 are used instead of the light Operating Systems like RIOT Operating System and Contiki Operating System where the high-level computations and processing are required. In such conditions the focus is on performance-oriented tasks without considering the parameter that how many resources are available.

6. EMERGING CHALLENGES IN OPERATING SYSTEM AND INTERNET OF THINGS TECHNOLOGY

Operating systems acting as the core of Internet Of Things technology have to deal with large number of confrontations due to the heterogeneous Internet Of Things environments. some of the issues that the Operating System developers have to deal while developing an Operating System with the motive of providing Internet Of Things services are as follows:

6.1 LIMITED RESOURCE UTILIZATION: Internet Of Things devices often have limited supply of resources like power, Storage, and battery in order to make Internet Of Things devices look similar to the normal devices in the area of size and weight as well as make them capable of providing Internet Of Things services. Operating systems developed specifically for Internet Of Things must be able to handle all the tasks of an Internet Of Things service while staying within the boundaries of the minimal specification of an Internet Of Things device or a service. The Internet Of Things device cannot exceed the weight or size limit need to be lightweight and should be able to perform all the unction of an Internet Of Things service b using the minimum number of resources.

6.2 CROSS-PLATFORM COMPATIBILITY: Different Internet Of Things companies have their own different environment that means each company can have its own protocols, mechanisms limitation, advantages and all other features of an Internet Of Things service or device which may or may not differ from device to device or service to service,

developing a different Operating System by each and every company. So, in order to save he cost of the Operating System development, for the ease of Internet Of Things developers there must be cluster of Operating Systems which can be used in all Internet Of Things devices and must adapt in future according to the conditions.

6.3 CONTINUOUS DATA UPDATES: Some of the Internet Of Things devices or services are not programmed to work only on the basis of data programmed previously but are programmed to keep on collecting the data by some means and then using that data for Internet Of Things functioning. To achieve these goals the concepts of using the Real Time Operating Systems arises. Achieving the timely updates continuously and using that data for further functions looks like near to impossible task and Real Time Operating Systems guarantees this services to some extent.

6.4 DATA VULNERABILITY: In order to provide Internet Of Things services first priority to be considered is to reduce or eliminate the latency to its best. To fulfill the purpose of least or no latency security of the data which needs to be carried to different devices the security of the data is compromised up to some extent. Insecurity of the data is not truly eliminated till date but in order to make data transfers secure up to some point in Internet Of Things some steps are taken like security protocols are created and followed while transferring the data.

6.5 ECOSYSTEM FRIENDLY OPERATING SYSTEM: Operating System which is to be used for Internet Of Things services must be following the global standards as we cannot write a different Operating System each and every time for a different Internet Of Things device. So, the Operating System which is used to run Internet Of Things services must be applicable around each and every Internet Of Things device present in the ecosystem of a company or an organization. Operating System should be able to transfer data from one Internet Of Things device to another and make the interaction between the two devices complete and successful while fulfilling requirements of an Internet Of Things user.

6.6 LESS RESOURCE CONSUMPTION: While developing an Operating System for the motive of providing the Internet Of Things services the Operating System developer must keep in mind that the Operating System should be able to control the Internet Of Things while keeping in control the consumption of the power, storage and other performance related components like CPU, RAM etc. To meet the listed requirement the Operating System developer must make the Operating System as light and simple as possible having only important features which are necessary for performing basic services through Internet Of Thing devices

6.7 EXTENSIBLE: Internet Of Things is not only about creating Internet Of Things devices and making them ready-to-use for providing Internet Of Things services but these Internet Of Things services should also be made available across the globe. All these Internet Of Things services must be connected to each other though the medium of internet, so that the service of the particular organization can be

propagated on a large scale. All this can be done by providing accurate number of resources, using different network topologies as required and other measures required.

6.8 MAINTENANCE: Keeping a check and resolving each and every issue on an Internet Of Things service which is deployed on a large scale is quite challenging task. Operating System must be developed in away that in future troubleshooting an error, updates in Operating System or any other changes can be done in easiest manner. To achieve these goals on the Operating System developer's end the code must be written in a way that it should be easy to manipulate in future and on the organization's end some services like cloud services must be utilized in order to make Operating System maintenance more quick, accurate, effective and efficient.

7. FUTURE SCOPE OF OPERATING SYSTEM IN INTERNET OF THINGS

What the Operating System and Internet Of Things together can do today cannot be declared as the full might of Operating System and Internet Of Things but it is just a scratch on the shell that contains all what Internet Of Things and Operating System together can do. Some of the expectations that can be done from the Operating System and Internet Of Things technology in future are as follows:

7.1 DECENTRALIZED DISTRIBUTION OF OPERATING SYSTEM: The era of Internet Of Things will be moving towards distribution of the processes like data processing among different places rather than at a particular single place. This approach will revolutionise the Internet Of Things industry by making the services capable of managing themselves in a modular architecture or we can say in a decentralised architecture.

7.2 ENHANCING INTERNET OF THINGS THROUGH ARTIFICIAL INTELLIGENCE (AI): Those were the days when the Internet Of Things was just about giving commands and controlling the Internet Of Things service enabled machines through a user interface. But from recent times AI have started to engage in Internet Of Things services nowadays the Operating System itself learns what functions should be performed by Internet Of Things devices to give the best experience to the Internet Of Things operator.

7.3 INCREASE IN SAFETY: Increase in Internet Of Things services have undoubtedly made the life easier but with pros of Internet Of Things this technology also has some cons like information breach, data loss etc. So, keeping these threats in mind the safety should be considered as one of the most important improvements. In future many precautionary measures like security protocols must be used while data transfers, global standards must be followed, intrusion detection system must be implemented and other security measures should be taken.

7.4 IMPLEMENTING GLOBAL STANDARDS: In future the a common standard or group of standards must be decided. Which needs to be followed if the Internet Of Things service provider wants to make his or her Internet Of Things services applicable to each and every Internet Of Things device it doesn't matter whether they are of different companies, ecosystems or from varying geographical conditions. If the particular Internet Of

Things service provider have been approved by the global standards than it can interact with any Internet Of Things device approved by the global standards.

7.5 EFFICIENT RESOURCE CONSUMPTION AND SUSTAINABILITY: Internet Of Things devices may sound to be good in the Internet Of Things services which they were designed to do. But the resources that they require to provide those Internet Of Things services are available in very limited amount on that Internet Of Things device like batteries needed to power up device and processor needed to process the commands given and perform those commands efficiently. To resolve this problem on the organization's end design of the Internet Of Things device can be improved in way so that it can carry more power supply and processing components can sustain for longer time without recharge in case of rechargeable devices and without replacing batteries in case of non-rechargeable batteries.

7.6 CONTRIBUTION OF BLOCKCHAIN TECHNOLOGY: Blockchain technology is one of the emerging technologies nowadays in the data transportation. Blockchain technology transfers the data from one place to another by storing data in the form of blocks which are joined in the form of chains and the data gets transported through these chains of blocks. In present INTERNET OF THINGS technology is deployed world-wide and a lot of data is recorded daily about how why and where the data is used. Transferring and rotating the data in organisation providing Internet Of Things services is kind of difficult task with the old technology.

7.7 USER FRIENDLY AND INTERACTIVE INTERFACE: Internet Of Things was made for the ease of controlling and operating the electronic devices by human beings but being a high level technology it is quite confusing and difficult for a portion of Internet Of Things users. Because of its not so simple user interface and other components on the client user end. This problem must be solved in future by simplifying user interface of Internet Of Things services and making it more interactive and user friendly for the users. Internet Of Things services should not only stay for the personal use of individual but should also be contributed towards other sectors which includes medical sector, transportation and lot more other industries .

8. CONCLUSION

After doing all the research work and summarizing the whole research in the form of review paper this all study concludes that without Operating System the Internet Of Things technology is merely nothing or little bit more than some hardware machines which need to be controlled in old ways with the help of knobs and switches. Operating System plays a vital role in the success of the Internet Of Things technology and is also crucial component of working architecture of the Internet Of Things devices and services. Operating System acts as an essential aid in limiting overutilization of resources therefor preventing resource scarcity, making Internet Of Things services capable of working in perfect manner independent of platform on which services are availed and used, making data transfer about Internet Of Things users in as safe manner as it can be and writing Operating System in a way so that Internet Of Things service must work perfectly even in complex

Internet Of Things ecosystems. As the Operating System is key component of Internet Of Things so the tremendous growth of Internet Of Things have also inserted huge upward spikes in the graph of Operating System growth and development.

Review paper not only concluded pros of alliance of Internet Of Things and Operating System but discovered some limitations like limited availability of resources, vulnerability in data transfer protocol across different devices and organization, less capacity of carrying proper supplies and processing components to fulfill need of keeping the design of Internet Of Things devices simple and sleek to make Internet Of Things devices affordable. All these flaws of Operating System and Internet Of Things are not permanent they all can be solved by making some changes, adopting new techniques like making Operating System light so that it uses less power supply and processing resources, utilizing new protocols for data transfers to make it more secure. Some Key points which need to be kept in mind in future for improvements are data security, design improvement, efficiency, integration with Blockchain technology.

Internet Of Things can only be made possible with help of Operating System acts as brain or commander of the Internet Of Things technology which mad operation of Internet Of Things devices in the way it should be done. But Operating System can individually act on computers, desktops and PC's or any other device which run on binary language. Operating System was not developed only for the Internet Of Things technology but is used in almost every human made digital technology which is to be operated or controlled by a person. Operating System can be edited, reprogrammed again and again according to the need of the technology in which the Operating System is to be deployed.

Today when we look in past how the things were operated, was there any need of Internet Of Things and Operating System technology. We can clearly see a huge difference between previous then and now. With the present condition of the Internet Of Things and Operating System technology we have also pictured what will be the next era of Internet Of Things and Operating System technology maybe the services provided by these two technologies may seem to be very simple but the way all these things work and the inner structure is vast, complex but not too difficult to learn.

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