Technologies, Challenges and Applications of Internet of Things

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ABSTRACT- The Internet of Things (IoT) is a paradigm where things have identifying, sensing, and processing features that will allow them to communicate with other devices over the Internet to perform various tasks. IoT is a new technology that is used to express a modern wireless telecommunication network, and it can be defined as an intelligent and interoperability node interconnected in a dynamic global infrastructure network. The Internet of Things, which will transform the real world objects into intelligent virtual objects. The IoT aims to unify everything in our world under a common infrastructure, giving us not only control of things around us, but also keeping us informed of the state of the things.

In this research work, the concept of Internet of Things (IoT) was reviewed, the main challenges of the IoT environment and the main applications of the IoT. There are many challenges with software, hardware, and security in actual implementation of IoT. The traditional networking protocol and security services are not directly applied on IoT because of different communication stacks and various networking standards. The IoT challenges was divided into two categories namely: General challenges (such as communication, virtualization and security) and Unique challenges (such as wireless sensor network (WSN), Radio Frequency Identification (RFID), and Quality of service (QoS)).

There is need to find an efficient solution which deals with the all the challenges in an environment of IoT. This paper presents various research challenges with their respective solutions by examining previous literature and identifying current trends. It also discusses future directions in the field of IoT. However, this manuscript will give good comprehension for the new researchers, who want to do research in this field of Internet of Things (Technological GOD) and facilitate knowledge accumulation in efficiently.

Keywords: Internet of Things, Radio Frequency Identification, Quality of service, Wireless Sensor Networks, Security and Virtualization.

1. INTRODUCTION:

This is the era of smart technologies which represents a "ubiquitous computing". Internet of Things (IoT) has emerged strongly as a more prosperous area to express this kind of a new technology. It is not the first technology in this field, but also the cloud computing technology has been used to represent the ubiquitous computing world. Kevin Ashton changed the name to "Internet of things ". The vision of IoT according to Kevin's vision was to enable networked devices to propagate their information about physical world objects through the web. IoT has relied on RFID and sensor network technologies in the implementations. For instance, IBM company used IoT in Norwegian Sea oil platforms, by deploying sensors at seabed that are used to collect real information to make decision drill in the sea [26]. Nowadays, the Internet has become the most important part of people's life. Billions of people around the world connected to each other with Internet by sending and receiving emails, using social networking applications, playing online games and many more things. This can be called the "Internet of People". The technologies like Wireless Sensor Networks and RFID tags are evolving with rapid development in the field of Internet technologies. With a combination of these two technologies, i.e. the Internet and Sensor Networks leads to a new vision of direct machine to machine communication over the Internet. This can be called "Internet of Things".

There is no unique definition available for Internet of Things that is acceptable by the world community of users. In fact, there are many different groups including academicians, researchers, practitioners, innovators, developers and corporate people that have defined the term, although its initial use has been attributed to Kevin Ashton, an expert on digital innovation. What all of the definitions have in common is the idea that the first version of the Internet was about data created by people, while the next version is about data created by things. The best definition for the Internet of Things would be:

"An open and comprehensive network of intelligent objects that have the capacity to auto-organize, share information, data and resources, reacting and acting in face of situations and changes in the environment". Internet of Things is maturing and continues to be the latest, most hyped concept in the IT world. Over the last decade the term Internet of Things (IoT) has attracted attention by projecting the vision of a global infrastructure of networked physical objects, enabling anytime, anyplace connectivity for anything and not only for any one [4]. The Internet of Things can also be considered as a global network which allows the communication between human-to-human, human-to-things and things-to-things, which is anything in the world by providing unique identity to each and every object [5]. IoT describes a world where just about anything can be connected and communicates in an intelligent fashion that ever before. Most of us think about "being connected" in terms of electronic devices such as servers, computers, tablets, telephones and smart phones. In what's called the Internet of Things, sensors and actuators embedded in physical objects—from roadways to pacemakers—are linked through wired and wireless networks, often using the same Internet IP that connects the Internet. These networks churn out huge volumes of data that flow to computers for analysis. When objects can both sense the environment and communicate, they become tools for understanding complexity and responding to it swiftly. What's revolutionary in all this is that these physical information systems are now beginning to be deployed, and some of them even work largely without human intervention. The "Internet of Things" refers to the coding and networking of everyday objects and things to render them individually machine-readable and traceable on the Internet [6]-[11]. Much existing content in the Internet of Things has been created through coded RFID tags and IP addresses linked into an EPC (Electronic Product Code) network [12].

On the other hand, the IoT environment like many networks suffering from the set of challenges which significantly affect their performance some of them are common and others, are special; the paper divides these challenges into two categories, namely, General challenges: which include common challenges between IoT and traditional network such as communication, heterogeneity, QoS, scalability, virtualization, data mining and security; and Special challenges: such as RFID and WSN. There is no specific definition of IoT, however, the idea is to make the everyday objects capable of identifying, sensing, networking over the internet to perform some task. The idea of direct communication between machines to machine exists from many years like client and server machine communication over the Internet. But the IoT represent the idea of attaching technology with devices like home appliances, cars, street light and integration of this devices with a network. It also can make capable of identifying the specific device and accessing it over the Internet with RFID technology.

The research work provides an overview about IoT, its definition, its architecture, and discusses the differences between IoT and the traditional Internet; then highlighting the challenges of IoT and the recent research directions to solve them. The motivation for the research in the field of IoT is to create a Smart city. The main goal is to make a better world for human being where every device around can understand the situation and perform an action without any explicit instruction. Implementation of IoT concept came with different technological and social challenges. The IoT device has low resources in terms of computation and battery capacity. So, the solution for implementation of IoT should be efficient in terms of resource utilization, secure and interoperable in an interconnected network. The main objective of this paper is to understand challenges in the implementation of IoT, currently available solutions and applications of IoT.

The rest of the paper is organized as follows. Section 2 presents the definition and vision of IoT. Section 3 describes the evolution of Internet of Things. Section 4 describes the key elements that play an important role in IoT. Section 5 describes a layered architecture framework for IoT and also issues involved in different layers. Section 6 presents different protocol designed for implementation of IoT. Section 7 identifies the challenges in the implementation of IoT in the real world. Section 8 presents some applications of IoT in various industry. Section 9 summarizes our study and conclude the paper.

2. INTERNET OF THINGS:

The term IoT is an interconnected network of smart objects using the Internet, sensors, and RFID is able to transfer data without human interaction over the network. It consists of the network which interconnects objects by using Internet technologies and set of technologies such as Radio Frequency Identifications (RFIDs) and sensors [1].

RFID systems and sensor networks are performing the main role in the vision of IoT because of its maturity, low cost, and support from the business community. In a 2009 presentation, SAP Research's Stephan Haller defined the Internet of Things as "the world where physical objects are seamlessly integrated into the information network, and where the physical objects can become active participants in business processes"[2].

Many companies and research organization project a wide range of prognostication of IoT in next five years. Cisco estimates that IoT will consists of 50 billion devices connected to the Internet by 2020. However, Morgan Stanley projects there will be 75 billion networked devices by 2020. Huawei predicts 100 billion IoT connections by 2025. The popular and

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simple example is the smart fridge which could tell you that it was out of milk. The internal camera in fridge monitor the milk container and send a text to a mobile phone if there was no milk left. IoT has a bigger vision than smart homes. It includes smart cities with smart traffic signals and smart beans send a signal to make it empty and industries in which everything has sensors from tracking part to monitor crops.

2.1 **Differences between IoT and Traditional network**

The IoT technology has broken a lot of the traditional ideas of network and started a new era of telecommunication technology. IoT can be considered as an extension and expansion network based on the Internet; but it is different from either traditional network or the so- called Internet of people and WSN although considered as backbone to build any IoT block.

The major equation to represent the IoT environment is "IoT environment= Internet + WSN", it is a common statement that uses to express the IoT environment. To analyze and judge the correctness of this statement, must be determined the similarities and differences between IoT, Internet, and WSN according to table 1.

The IoT may not necessarily use IP in all cases for addressing things, because nature of IoT needs lightweight communication protocols, the complexity of the TCP/IP protocol is not suitable and the IoT environment is mainly based on the connected smart objects unlike traditional network. That's what makes them move from only a mere extension of the Internet, also the behavior of IoT depends on the creation of the interoperable systems [10], based on these arguments, can be corrected the previous statement:

IoT= Internet + WSN+ Smart Items surrounded by Intelligent environment.

Table 1:Comparism between IoT, Internet and WSN

Characteristics	IoT	Internet	WSN
Communication protocol	Light weight communication protocol	TCP/IP	Lightweight communication protocol
Area coverage	Wide area	Wide area	Local area
Identifying objects	Must	Cannot	Can
Types of nodes	Active and passive	Active	Active
Network design	WSN+ dynamic smart thing+ internet surrounded by intelligent environment	Set of networks with set of fixed objects	Dynamic smart object
Behavior	Dynamic	Fixed	Dynamic
Networking time	Timing synchronization	Unlimited	Unlimited

3. EVOLUTION OF IOT:

In 1999, The British technology pioneer Kevin Ashton use the term "Internet of Things" first time to describe the system in which all devices with sensors in the real world connected to each other. The term "Internet of Things" is new to us but the concept of using devices to monitor and control exists from the decade. In the late 1970s, the systems that remotely monitor meters on the electrical grid used. [3]

In 1990, the first internet toaster which turned on or off was presented in internet conferences. In 2001, other things came with IP-based like a soda machine at Carnegie Mellon University in the US and a coffee pot in the Trojan Room at the University of Cambridge in the UK [4].

The European Commission (EC) had made a lot of efforts in the field of IoT since 2006. In 2008, EC published a Staff Working Document to discuss policy issues in the governance of IoT. In 2009, IBM's CEO S. Palmisano proposed the concept of "Smart Planet" in which everyday item like the power grid, airports, railway station are equipped with sensors [5], [6].

Today, the IoT devices are still primarily things on the Internet that require more human interest and research. The evolution of the IoT is just starting to be realized.

4. ELEMENTS OF IOT:

The elements of IoT play an important role in understanding the IoT functionality [7]. The following section describes different elements of IoT and their role.

4.1 **Identification**:

Identification is one of the important element which is used to uniquely identify the device and provide required service to it in IoT network. The different Identification methods are used to identify IoT objects like as electronic product codes (EPC) and ubiquitous codes (uCode) [8]. IPv6 and IPv4 are used for addressing methods of IoT objects. The IPv6 header is compressed with 6LoWPAN compression mechanism that makes IPV6 efficient for low power wireless networks [9] [10].

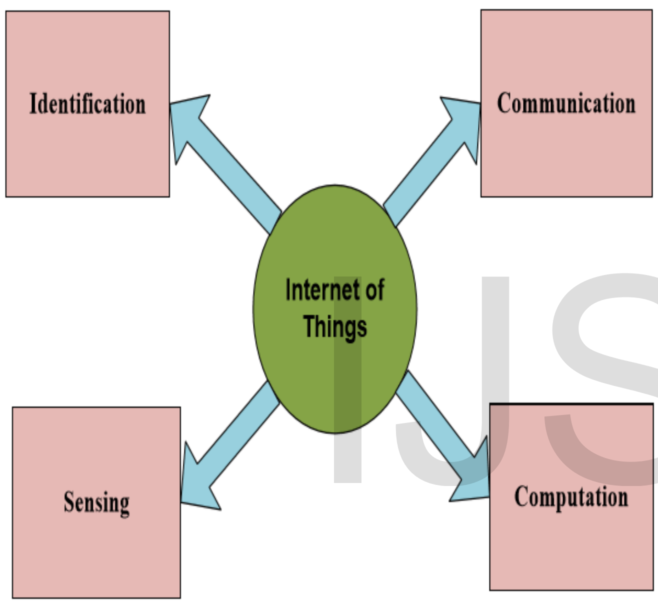

Figure 1: Elements of IoT

4.2 Sensing The IoT

Sensing is used to collect data from a different object in the network and send it to the database. The collected data is used to take respective action. Various IoT sensors are available in the market such as smart sensors, actuators, etc. For example, a company like Smart-Things used smart hubs and mobile application to control home appliances and make a home as smart home. In a smart home, people can monitor and control thousands of devices with their smartphone [11], [12]. The devices like Raspberry PI, BeagleBone Black are integrated with sensors and used as IoT devices and provide required data to the customer.

4.3 Communication IoT

Communication element is used to connect different IoT objects to each other. IoT devices have low power and noisy communication link. RFID is the first technology used for Machine to machine communication. It uses RFID tags and Reader for communication. RFID tag is a label attach to the specific device.

RFID readers send a query signal to RFID tag and receives signal send by tag. Then, it is passed to database which is processed by connected processing center and the object is identified in a particular range. Wifi is another communication technology used to exchange data in 100 m range [13]. It can communicate and exchange data without using a router. Bluetooth is also a communication technology used to exchange data between devices over a short distance. It uses short-wavelength radio to minimize power consumption [14]. The Bluetooth special interest group (SIG) introduce Bluetooth 4.1 which required low energy and provides as high-speed and IP connectivity [15].

4.4 Computation:

Hardware like microcontrollers, microprocessors, and software applications are used for the computation of IoT. Various Hardware platform has been developed for IoT like Arduino,Raspberry PI,Gadgeteer, BeagleBone, Cubieboard, etc. Various Software platforms have been developed like RTOS operating System. TinyOS [16], LiteOS [17] and RTOS [18] are different lightweight OS that are designed for IoT environments.

4.5. Quality of Service (QoS):

Ideally, QoS is defined as "the amount of time that is taken to deliver the message from the sender and the receiver" if this time is equal or less than pre-specified time requirement the QoS is achieved. ITU re-defined QoS concept as a degree of conformance of delivering service to the user by the provider with agreement between them [17]. For QoS assurance, must cope with service models to determine which degree of QoS for each Internet service.

4.6 Virtualization:

Virtualization is known as the ability to share hardware resources among multiple operating systems. The virtualization technology allows for the multiple operating systems and software like applications or services to run upon the same server through creating more than virtual machine inside the physical machine. The vision of this concept helps to increase the performance of the network via increasing utilization, maximizing scalability, saving cost, etc. [20]. Actually, there are three areas used to represent the virtualization technology, namely: network virtualization, storage virtualization, and server virtualization.

5. ARCHITECTURE OF IOT

The architecture of IoT is based on different layers. It contains data layers at the bottom to application layers at the top. The layered architecture of IoT is designed in such a way that it can satisfy the need of different industry, institutes, and governments etc. Figure 2 describes the layered architecture of IoT [19]. The layers in IoT architecture divided into two parts by internet layer. Top two layer are used for data utilization in the application and two bottom layers are used for data capturing. The functionality of different layers is described below.

5.1 Edge Layer:
Edge Layer is the lowest layer in the layered architecture of IoT. This layer consists of different elements like IoT devices, sensor, and RFID tags. These elements give information about identification, processing, and communication.

5.2 Access gateway layer:
This layer handles the data in the IoT environment. It performs an operation like publishing route message and in some cases perform cross communication.

5.3 Middleware layer:
This is one of the important layers in IoT layered architecture which acts as an interface between hardware layer and application layer [20]. It is mainly used for device management and perform functions like data filtering, semantic analysis, information discovery.

5.4 Application layer:
This is the top most layer in the IoT layered architecture. Its main function is to deliver different applications to users [21]. Applications can be from a different category like manufacturing, industries, food, environment, etc.

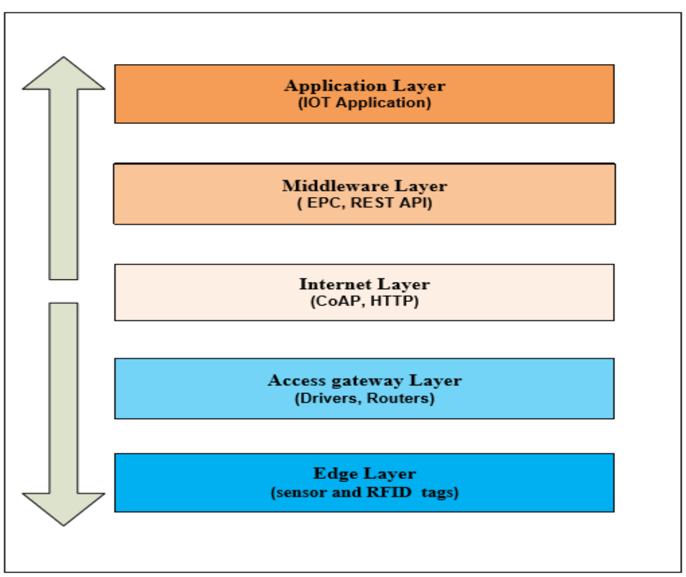

Figure 2:IoT Layered Architecture

6. IOT PROTOCOLS:

In IoT, identifying the protocol design for interconnection of the sensor device is a main challenging task. Institute of Electrical and Electronics Engineers (IEEE) and the Internet Engineering Task Force (IETF) are designing new communications and security protocols that will play a fundamental role in the implementation of IoT applications. While designing protocol for IoT, low-energy sensing devices and low—rate wireless communications are the main constraint. In IoT, device gathered the information on the basis of sensors and sends the data to the server. The server analyzes it and shares the data by sending it back to devices or to people. The following section describes a various protocol for that can be used in IoT Framework [22].

6.1 MQTT:
MQTT is the Message Queue Telemetry Transport protocol. It is used for collecting data from IoT devices and send it to Servers. Its main purpose is telemetry or remote monitoring. It is used to monitor and control a large network of small IoT devices from the cloud. It is simple and also offering few control options. In MQTT, real time is measured in seconds. It is used for an application for monitoring an oil pipeline for leaks, power usage monitoring, lighting control, and even intelligent gardening. It collects data from these devices and share that data with servers and make it available.

6.2 XMPP:
XMPP is an Extensible Messaging and Presence Protocol. It was developed for connecting people with instant messaging (IM) via text messages. It uses XML text format as its native type for the communication. In IoT, it provides an easy way to address a device. In XMPP, real time is measured in seconds. It provides a way to connect home thermostat to web server and access it through the phone. It is an efficient solution for consumer-oriented IoT applications because of addressing, security, and scalability features.

6.3 DDS:
DDS is Data Distribution Service (DDS). It is used to connect devices to other devices and distributes data to other devices. In IoT, the device needs to communicate with another device. TCP is the reliable and simple solution for connecting devices. But, it is very restrictive. DDS offers detailed quality of-service (QoS) control, multicast, configurable reliability, and pervasive redundancy.

It has efficient ways to filter data and send selected data to thousands of simultaneous destinations. There are also lightweight versions of DDS for some small IoT devices. DDS is used with High-performance integrated device system. It provides flexibility, reliability, and speed to build complex, real-time applications. It is able to efficiently deliver millions of messages per second to many simultaneous receivers. In DDS, real time is measured in microseconds. It is used for an application like military systems, wind farms, hospital integration, medical imaging, and asset-tracking systems.

6.4 AMQP:

AMQP is the Advanced Message Queuing Protocol. Its main goal is not losing messages during communication. It uses TCP for communication from queues to subscribers which provides reliable point-to-point connection and endpoint also send acknowledge of acceptance of each message. It tracks all messages and ensures that each message is delivered to intended endpoint. It is mostly used for business messaging. In the IoT, it is appropriate for server-based analysis functions.

7. CHALLENGES OF IOT:

IoT faces a lot of challenges in terms of both technical and social issues. These challenges must be overcome in order to the actual implementation of IoT in the real world [23]. Challenges are classified as follows:

7.1 Security:

IoT devices are small wireless devices that would be placed in public places. Wireless communication is made secure through encryption technique. But the IoT devices are very small and not powerful enough to support encryption methods. There is need to modify encryption algorithm in order to support IoT devices. The algorithm should efficient and less energy consuming.

7.2 Privacy:

In IoT, the different devices are traceable through the interconnected network, it creates threats to personal and private data. There should be assurance that issue of data ownership addressed in IoT in order to avoid data fell into the wrong hand. The data owner must be ensured that data will not be used without her/his permission. The privacy policy is the solution to keep data secure in IoT environment. Whenever other user came into contact for reading data, it can check the other's privacy policy before communicating.

7.3 Standards and interoperability:

To implement any new technology in the market, it should follow the specific standard. If devices are manufactured by the different manufacturers without following the specific standard, it will be very difficult to make devices interoperable. It may require some extra gateway to translate from one standard to another. The European Commission is working on a technological standard to support IoT.

7.4 Scalability:

Computer Network researchers always have a question of scale. Today, Internet routing system interconnects more than 3 billion people and more than 50 thousand separately administered networks. Networking Community handles this requirement by designing routing protocols and routing architectures. But, today's routing protocols are designed for a system with reasonable computation and memory resources. IoT devices are small and low with computation power. So, there is a need to design future network protocol and network architectures for low computation and memory devices.

7.5 Low power communication:

Many IoT devices are small in size and do not have the continuous power source. A device computation depends on battery size and cost of the device. Many IoT devices work as a single, limited purpose which could have customized network interfaces, operating systems, and programming models that make the most efficient use of limited computation, network, and energy resources. Research in these areas involves the interdisciplinary collaboration of signal processing and wireless communication as well as computer architectures and operating systems.

7.6 Security threats from ubiquitous devices:

If a desktop computer got infected with the virus, it can be a reboot or can remove viruses by running some antivirus and problem may get solved. But, if IoT devices got affected with viruses, then it will be very difficult to know which device has been compromised and how to restore system security. So, there is need of a systematic method for restoring IoT System and also need a tool to isolate and correct compromised components within IoT network.

7.7 Debugging self-diagnosing, and automatic repair:

Debugging and updating the code running on IoT devices is a very challenging task in IoT world. It is very difficult to do interactive debugging on IoT devices because of limited bandwidth. It is also difficult to store detailed logs of devices because of its low power and memory constrained. Devices need to have software system which can learn from errors and automatically repair themselves.

8. **APPLICATIONS OF IOT**:

With IoT number of applications can be build and very few applications are developed currently. There will be various applications in future like smarter home, smarter transportation, smarter hospitals, smarter factories, etc. [24] [25]. In the following section, different IoT applications are discussed.

8.1 Automotive industry:

Today, vehicles become advanced with having advanced sensors, actuators. In the automotive industry, smart things can be used to monitor and get a report from air pressure in tires to a different part of vehicle status. RFID technology has already been used increase quality control and improve customer services. The device attached to vehicle part contains information about the part like manufacturing date, serial number, product code and some also have location information according to vehicle movement. Vehicle-to vehicle (V2V) and Vehicle-to-infrastructure (V2I) communications is an advanced Intelligent Transportation Systems (ITS) which can be used in smart traffic control and vehicle safety service. The IoT devices can be integrated with the Intelligent Transportation Systems for a better result.

8.2 Pharmaceutical industry:

In IOT, the smart label can be attached to drugs and track them through supply chain management and monitor the status of drugs. Suppose, medicine required cold storage and cold storage has not been provided during the transportation. The smart label on drugs will discard that medicine. This way medicine can keep the supply chain free of fraudsters. The smart label can also help the patient by sending information regarding dosage and expiry date. It can remind patient to take them at appropriate interval and patient compliance can be the monitor.

8.3 Manufacturing industry:

In the manufacturing industry, the production process can be optimized with the use of smart devices or unique identifiers. It can interact with an intelligent supporting network and monitor the process from production to disposal. Status of production machine can get by tagging item and container. Self-organizing and intelligent manufacturing solutions can be derived with identifiable items in manufacturing industry.

8.4 Media, entertainment industry:

In the media industry, IOT device enables news gathering based on user location. The news can be gathered by sending queries to multimedia devices present at a certain location. Communication tags can be attached to the poster to give detail information to the user. It transfers requesting the user to a URI address that has detailed information.

8.5 Agriculture and breeding:

In agriculture, IOT devices can be used to trace agricultural animal and their movement. In many countries, government issues subsidy based on a number of animal in farms. But, it's very difficult to determine the exact number. With the help of IOT devices, this type of frauds can be minimized. With the help of IOT, a farmer can deliver crops directly to small as well as the wide region. This will change the supply chain management that is handle by large companies.

8.6 Supply chain management:

IOT can provide many advantages in the field of supply chain management operations. The retailer can track the item or shelves which are equipped with RFID tag. It will be easy to monitor the stock, tracing out of stock items. It can be seen that 3.9% of sales loss happens because of empty shelves delivered to the customer. With IOT, Shelves with sensors helps to avoid this type of losses. Supply chain management is already supported by various IT solutions. In traditional supply chain management, information is passed one's direct downstream partner and not shared among the whole chain. In IOT, devices with RFID records all details like manufacturing information, production date, expiry date, warranty period and makes supply chain management more efficient.

8.7 Big Data:

Big Data is a new expression to describe massive data whether structure or unstructured, which is difficult to deal with traditional database methods and software techniques. Simply, Big Data defined as a large volume of data [21]. Dataset considered as a Big Data when it meets 4 V's- value, volume, velocity, and variety. Big Data attracts almost a new industrial field such as online social networks (Twitter, Facebook, and Instagram); the collection of data through the social network is very huge, for example twitter in 2010 producing up 120 terabytes of data of the day [22]. IoT is considered as a good example of Big Data as the amount of data which was collected from deploying sensors through IoT environment was very large and heterogeneous. The coupling between IoT and Big Data was very strong [23].

3.9 Cloud Computing:

Cloud Computing and IoT are the most popular example to represent the ubiquitous computing field; but IoT is not popular like Cloud Computing, both use the distributed computing concept. Cloud computing is a way to access large amount of computational resources and supports a large number of users in a reliable and decentralized manner; it's also provide software cheaply. Cloud Computing consists of the three main layers are: Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Service as a Service (SaaS) each one provides significant features through the cloud data center. Cloud computing is considered as a standard framework to represent IoT, and both IoT and cloud computing possess a set of benefits and restrictions. IoT represents real world and small things, but it is limited storage in addition to traditional problems in the network such as scalability and privacy; in other side, cloud computing has virtually unlimited capabilities and processing power [24]. The integration of cloud computing with IoT became a very important point of recent researches; to produce system able to overcome the many challenges such as scalability, storage resource and virtualization; can be considered the main objective of this integration is to leverage from cloud computing in processing power which need for sensors and other things [25].

9. **CONCLUSION:**

IoT is a one the main techniques that is used to express the ubiquitous computing approach, but it still not popular like the cloud computing technology. This research work highlights the IoT concept, the differences between both IoT and the traditional network, the challenges which had a significant impact on the performance of IoT such as communication, networking, QoS, scalability, virtualization, big data, heterogeneity and security. The security section sought to illustrate and provide the recent solutions for each element of these challenges.

The Internet of Things (IoT) is one of the emerging research topics in which many researchers are working. The main goal of IoT is to provide quality of life to all human beings by connecting all objects in the environment with technologies. The IoT will bring automation to all things around us. Cloud service providers like AWS (Amazon Web Services), Microsoft Azure, Google also started providing a platform for IoT deployment.

In IoT, Machine to Machine communication will increase data massively. It also leads to the evolution of Big Data. But, the protection and privacy of user's data are one of the key challenges in the IoT. This paper described an overview of IoT architecture, its element and issues and challenges of IoT for researchers and developers. Further, it also describes applications of IoT in the real world. The current technologies making the idea of IoT to reality, still many challenges exist for deployment of IoT application in real world. In future, networking and communication research have an opportunity to address this challenges.

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