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A Comprehensive Study of IoT

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Abstract— Now, we are living in an era of Technology where each and every person is completely dependent on it, and has entered the world of Technology intentionally or unintentionally. From last few decades, Technology has acquired its place all over the world, and plays a vital role. This new time furnished with most recent appearances of innovation, enlightening the world as Internet of Things (IoT). Internet, itself is a revolutionary evolution which has transformed everything. Internet of Things makes the Machine to Machine communication (M2M), the new future. The world is brimming with gadgets, sensors, and other items, and makes human life obviously better and simpler than ever. The paper will provide an overview of current research work on IoT in terms of the communication model, its characteristics, benefits, future, security and applications. The main purpose of this survey is to provide a complete review of IoT starting from its history to how it has changed our lives, and its future benefits.

Keywords— Internet of Things, IoT, IoT Architecture, IoT Communication Models, Applications, IoT Security

I. INTRODUCTION

By looking at the current situation, the demand for the Internet has become very high. If we just look at the current situation i.e. the lockdown phase during COVID-19, and we are still living in that the most important asset of human life is mobile with the Internet. Internet demand is rapidly increasing with the continuous advancements in technology. IoT has not only evolved itself in this era, but has also acquired a position among the trendiest and the most useful topic in one's life, so in brief, IoT has become a subject undergoing intense study receiving a close review of broad and current interest.

There's no specific definition of IoT, to put all in short it is a network in which all the physical objects are connected to the internet through different networks and routes, and they exchange data. IoT is used extensively to lessen the burden on humans i.e. it has an autonomous control feature through which any device can control itself without human connection. Until recently, access to the Internet was restricted via gadgets like laptops, smartphones or tablets, but now with IoT essentially everything can be connected and monitored remotely. It is forming the way we carry in our lives and helps us to get knowledge of our working into the working of things around us. Until recently, Internet helps individuals associate and interacts with one another, but now inanimate objects or things detect the environmental factors to cooperate and work together with each other. With the improved reaction observing and analytical capabilities IoT is being received in practically all ventures and areas opening ways to unlimited applications. The eventual fate of IoT looks more encouraging than any other time in recent memory. In 2018, there were around 23 billion associated gadgets which were more than twofold the total populace. As per specialists, there will be more than 80 billion gadgets by 2025.

The concept of IoT dates back to 1982 when a modified coke machine was connected to the Internet which was able to report the drinks contained and that whether the drinks were cold [1]. Later, in 1991, a contemporary vision of IoT in the form of ubiquitous computing was first given by Mark Weiser [2]. However, in 1999, Bill Joy gave a clue about Device to Device communication in his taxonomy of internet [3]. In the very same year, Kevin Ashton proposed the term "Internet of Things" to describe a system of interconnected devices [4]. So, Kevin Ashton was the first one who coined the term as "Internet of Things".

This paper consists of 8 Sections, so the paper is organized as follows. Section 2 focuses on the architecture of IoT. Section 3 describes the Communication Models of IoT. Section 4 analyzes the characteristics of IoT. Section 5 focuses on the IoT Security Problems, and the key elements of IoT Security. Section 6 discusses the applications of IoT. Section 7 forecasts the IoT future and benefits. Section 8 concludes the paper.

II. ARCHITECTURE

There are devices that are out there and around us and are communicating with each other and building a smarter system and it makes our lives much easier for that matter. But when we come down to the IoT ecosystem there's no single consensus or there's no single architectural design that's out there which is agreed universally because each company, each organization, each user for that matter has different requirements.

2.1 Three Layer Architecture
On looking at the architecture we can break it down to a simple three-layer architecture wherein we have three layers which are described as follows:-

2.1.1 Perception Layer

In this layer, sensors sense and gather the information from the environment around it. It gathers the useful data or information of the objects from the sensor devices linked with them and then this information is passed on to the next layer.

2.1.2 Network Layer
It receives the information in the form of data signals from the Perception Layer. Thus, the Network Layer in itself takes up the responsibility of connecting devices and transferring the data received from the perception layer to the next layer. It is also used for processing and transmitting data.

2.1.3 Application Layer
The main objective of this layer is that it delivers the information or the data directly to the end-user or the end platform. It is the implementation of IoT.

2.2 Five Layer Architecture
The three-layer architecture is expanded into five-layer architecture as it was not sufficient for the day to day advancement in technologies. It is quite similar to the three- layer architecture the difference mostly comes around with the other layers which are added. The three-layer architecture has been broken down by adding other layers for an easier operation or for a smoother system. The five layers are described as follows:-

2.2.1 Perception Layer
It works similarly as discussed in the three-layer architecture. It gathers the information from the sensors.

2.2.2 Transport Layer
It transfers the data from the perception layer to the next layer through networks such as wireless, RFID, NFC, LAN, etc.

2.2.3 Processing Layer
It has the major task as it processes all the data from the perception layer so there is a huge amount of data. It stores the relevant information and analyses it and again processes it as per the user's requirement. This could employ various databases, cloud computing services as well as big data processing modules.

2.2.4 Application Layer
It is responsible for delivering various services to the end-user.

2.2.5 Business Layer
When any device is working in a large scale environment a Business Layer is usually used. This layer monitors the complete functioning of the IoT systems from the working of applications to generating different business strategies for profits.

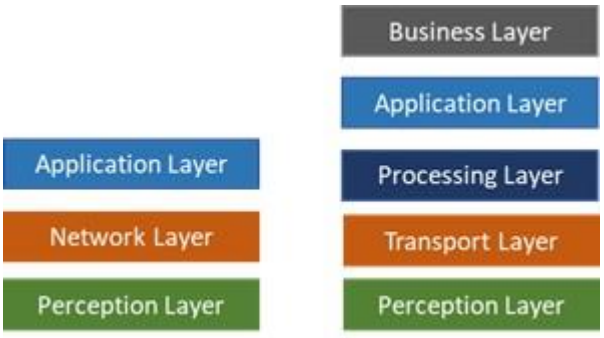

Figure1. Three Layer and Five Layer Architecture of IoT

III. COMMUNICATION MODELS

The IoT Communication Models comes under the Logical Design aspect of IoT which is an abstract representation of the IoT network. The communication model in IoT defines how the data is shared or exchanged between the various devices in the IoT network. Various types of communication models are used for data exchange in the IoT network, and are described below:-

3.1 Request-Response Communication Model

This communication model consists of two main elements i.e. a Client and a Server. When the Client requires any data, it sends the request to the server. The server upon receiving the request decides how to respond, fetches the data, and sends its response to the client. Each request-response pair is independent as it is a stateless model. A common example of this model is the online search engine. The whole process of this model is explained briefly.

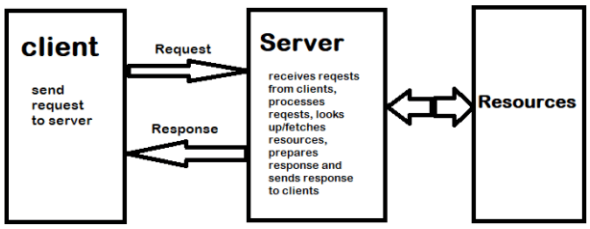

Figure2. Request-Response Communication Model

3.2 Publish-Subscribe Communication Model

This communication model consists of three main elements, and they are Publishers, Subscribers, and Brokers. Publishers are data producers, Subscribers are data consumers and Brokers are data managers. Publishers are not aware of the Subscribers. The broker plays an intermediate role. The publishers produce data related to various topics, and they send it on the Internet on various platforms. The subscribers subscribe to various topics according to their interest and brokers/managers provide data to them depending upon their choice of subscription. The publishers and subscribers are connected by the broker, which acts as the connecting link. Most of the social media platform works on this communication model.

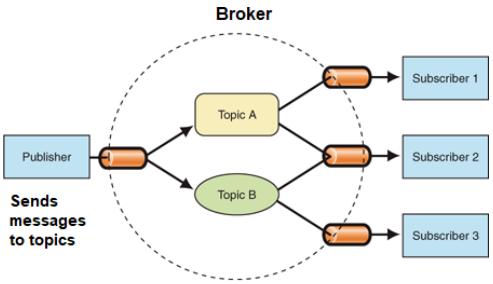

Figure3. Publish-Subscribe Communication Model

3.1 Push-Pull Communication Model

This communication model consists of two parties Data Producers and Data Consumers. Data Producers generate data and push it into queues and Data Consumers pull data out of those queues. Queues act as a buffer or a decoupler between data producers and consumers. If queue or buffer was not present in this model, the flow control would have not been possible i.e. if the rate of transfer at the publisher side is much higher than that at the consumer side. So it was impossible to manage and would have led to a mixed match situation.

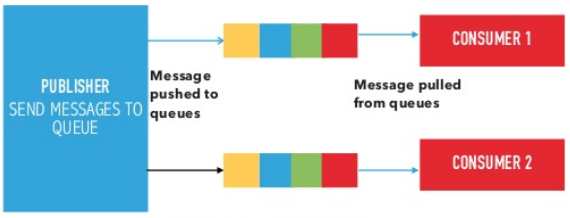

Figure4. Push-Pull Model

3.4 Exclusive Pair Communication Model

This communication model also consists of two parties Client and Server and is similar to the request-response communication model. Here, also when the client requires any data, it sends a request to the server. The server upon receiving the request decides how to respond, fetches the data, and sends its response to the client. But unlike the request-response model, it is a stateful communication model and each request and response pair is dependent. It is a full-duplex and bidirectional communication model.

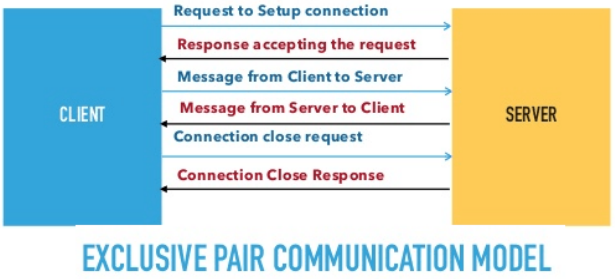

Figure5. Exclusive Pair Communication Model

I. 4. CHARACTERISTICS OF IOT

II.

Any technology that is available today has not reached its hundred-percent capabilities and it always has that gap to go. IoT is one of the major technologies in the world today that can help any other technology reach its true and complete potential. The characteristics of IoT are described below:-

4.1 Unique Identity

When you build an IoT device, you want to transfer some kind of data in the future, so that the device has a particular ID number. In the real-time world, we have billions of IoT devices, so each and every IoT device has a unique identity. It helps both in the identification of the system and in communication.

4.2 Dynamic Nature and Self Adapting

The first and foremost move in any case of IoT usage is to c ollect and transform data in such a way that business decisio ns can be taken out of it. This is the key

characteristic. In the whole process, the state is continuously being changed as IoT devices sense the environment, and the environment is not static. The no. of IoT devices in the environment also changes dynamically, and adapt the changes, and take actions accordingly. For example, Surveillance Camera has two mode, i.e. the day mode, and the night mode, and the camera self adapts the mode according to the change in the environment.

4.3 Self Configuring

IoT Devices have self configuring capability, ie., these devices configure themselves, and perform all the function with minimum human intervention.

4.4 Heterogenity

There are different numbers of IoT devices in this feature, di fferent hardware platforms, different standards, different pro tocols, different networks, and the network is created between all of these, so it provides the link between them all, and a heterogeneous network is created.

4.5 Integrated to Information Network

IoT devices are integrated into the information network, and this allows them to communicate, and share data with different devices. For example, In weather monitoring system, the IoT devices which are also called as nodes in this case, they are distributed to different places in the environment to sense the environment. When they sense the environment, they generate some data, and the data acquired by all the devices is being shared with the central node or the IoT platform, and all the data is stored here. The stored data is further analyzed and processed to retrieve the required information or the data. And here the retrieved data is the prediction of the weather. So, in this characteristic all the devices are working together to achieve a common goal.

5. IoT Security

For essential operations and services, we rely on these netw ork-connected devices every day.

And at times, these devices become gateways for opponents to access the network. Most devices are nodesigned with sec urity in mind, rendering them vulnerable to cyber attacks tha t can have a major impact on service quality and safety. The two main problems for IoT applications are protection and p rivacy, and they still face some huge challenges. . The data collected from the IoT sensors contains a large amount of private information, and needs to be preserved.

5.1 IoT Security Problems

5.1.1 Denial of Service

A Denial of Service (DOS) is an attack where the attacker sends continuous garbage requests, and the server gets down because of these flooded unnecessary garbage requests. When the user sends a request, the server cannot respond due to the flooded garbage requests, so the server denies the service request of the user.

5.1.2 Distributed Denial of Service

A Distributed Denial of Service (DDoS) is an attack where the attacker prepares the virus or Trojan, and will place them in the network of the files of the devices, and then the whole network or the number of devices become the infected devices. When we download such files, then our device becomes infected. And when the attacker wants to send flooded requests, it sends through that network of devices. Here the request is not through one, but it is send through number of devices.

5.1.3 Information Manipulation

After getting unauthorized access the attacker can manipulate the information very easily. If the information gets manipulated, then the performance and the efficiency will also get manipulated.

5.1.4 Unauthorized Access

The attacker is unauthorized i.e. it is not a valid user. The attacker takes the credentials of the authorized user in any possible manner, and can use the credentials, and have an access to the IoT system. Authorized authentication and protocols should be implemented to prevent it from unauthorized access.

5.1.5 Information Disclosure

Sensor gathers the information or the data, stores it, and it is being shared. The attacker should not know the location of the stored data. If they get to know the resources or the information then they will intrude into it, and can use it.

5.2 Key Elements of IoT Security

5.2.1 Authentication

It is a very basic and primitive element of IoT Security. When two devices are communicating, their identities should be verified or authenticated as the communication can be confidential. When the source is authenticated, then there is a trust developed between the communications, and hence there's a trust build in the whole communication process.

5.2.2 Access Control

It is an essential area of IoT Security. In this the users are authenticated, but theses control will vary in terms of resources, data and information i.e. It defines which users are given access and which operations they are required to perform.

5.2.3 Data Security

In this the message or the data sent from the sender to the receiver should be send in a secure way. In this area of security, it encrypts the data sent from the sender that if the attacker gets the access to the data, it cannot understand it. And when the data is received to the receiver, it gets decrypted, and the data is exactly similar in terms of bits and bytes and there is no modification in the data.

5.2.4 Non-Repudiation

This ensures the ownership of the data. The sender cannot deny the fact that the data has not been send from his end, and the receiver cannot deny the received data. So, it provides the proof of the origin of the data, and the integrity of data.

5.2.5 Availability

When something is demanded through a particular entity, and it is fulfilled then the availability is high. If the opposite happens i.e. the demand is not fulfilled then the availability is low. In IoT Availability should be high as it's about Real Time, and should not be delayed.

6. APPLICATIONS OF IOT

There are many fields in which IoT technology can be implemented**.** When IoT technology is implemented in a field with minimum human intervention, and in comparatively less time, a good and a productive result would be observed. Some of the applications are discussed below.

6.1 Smart City

Smart Cities are making cities more livable, more alive. Connected Streets are the core of Smart Cities. Each streetlight can gather and send information. These smart connected streetlights open up many possibilities. For example, there is person leaving for work, so the standby lighting switches on when he walks by. While the other person has an appointment in town, and he is looking for a parking spot, now he knows where to find one in real time, and won't drive around for very long. If a person uses an electrical vehicle, that will know where to find available charging stations. Waste Collection companies will know how full containers are in real time. If an accident occurs, an alert goes out immediately, and remote monitoring provides an instant update on the situation. Traffic lights can adjust to regulate traffic flows and prevent traffic jams.

6.2 Health Care

It improves disease management. When patients are monitored in a continuous basis, real time health data is available thus diseases are treated before they get out of hand. IoT helps in remote monitoring of patients health statistics and diagnosis. With IoT diagnosis and medication reaches every corner. It provides a better treatment. The advanced automation and analytics of IoT allows more powerful emergency services. Talking medical devices reminds patients to take medicines as prescribed and other necessary action to improve health. Accurate collection of healthcare data minimizes errors and makes precise medication.

6.3 Education

Education sector has not been in the forefront of adopting latest technologies. But now, various educational institutions are now realizing the significance of introducing technology especially IoT, into their daily teaching methods. IoT enhances the education itself and provides advanced value to the structures and environment. A smart school with the facilities operating smoothly promotes a higher level of personalized learning. A computational nervous system for colleges and schools helps to keep track of major resources, create smarter lesson plans, design secure campuses, enhance information access, and much more. IoT can be considered as new method of classroom management. It provides an interactive learning. Students can be monitored 24/7 and their presence can be reported at any given point of time.

6.4 Agriculture

We are all dependent on Agriculture. We all know how agriculture has become a gambling. Weather, water scarcity, soil fertility, pesticides are the major players in it. IoT has played an important role in agriculture in terms of Water Management. Adequate water supply is essential for agriculture. Excess or shortage of water will kill crops. IoT makes better water management possible when coupled with sensors, data and other machinery. Weather

forecasting and other dynamic data inputs can affect crop productivity to a great extent. Precision Agriculture ensures accurate and efficient communication to farmers of real time data related to agricultural processes like weather forecasts, soil quality, etc. By remote crop monitoring, we get to know when the crop is ready to harvest.

6.5 Smart Home

Smart Homes are filled with connected devices, and are loaded with possibilities to make our lives easier, more convenient, and more comfortable. For example, you are driving home on a hot summer day, but rather than turning the air conditioner when you get home, and wait for it to cool down, you can simply use your smart phone when you leave your office you can turn it on. Another example is when you are cooking, you can ask any voice assistant to read you news or play music and you can focus on cooking. Home Automation is the future, and all this is possible because of advancement in IoT.

6.6 Vehicle Industry

Vehicles will become biggest connected and computing devices with lot of sensors embedded to it. Vehicles generate more data like travel time, origin destination, vehicle volume, traffic movements, engine health, its surroundings, road conditions, etc. With smart parking, it is easy to find parking. IoT technology is also a part of Autonomous cars and Self Driving cars. It optimizes real time travel information.

7. BENEFITS AND FUTURE OF IOT

IoT comes with lots of benefits. First one is, Efficient Resource Utilization i.e. use as much as you require. IoT saves time. It minimizes human efforts and errors as the human intervention is minimum. It is user friendly, and easy to use.

The Future of IoT:-

- AI & IoT

  This is at under development stage and has succeeded to some extent as well. The IoT devices sense the environment, and gather the data, and this collected data is further given to Artificial Intelligence algorithms. The output of AI algorithms is useful action or result. And these actions or results are further implemented by the IoT devices.

- Voice User Interface

  Alexa, Siri, Google Assistant are the examples of Voice User Interface(VUI). Research is being carried out to bring VUI in the universe of IoT, to increase the comfort zone of the user more.

- Miniaturization of Things

  Here "Things" are the IoT devices or the smart devices. Minimizing the size of the devices, the smaller the devices is the more easily they can be embedded or planted. In this there will be only decrease in the size, but no compromise with performance and efficiency. In near future, the smaller the devices will be, the more applications it will have.

- Power

  IoT devices should have low power i.e. they consume less energy, and give better performance with better efficiency. In future, we can use solar cells i.e. you don't have to externally give the power, you just consume it from the nature, and supply it to the IoT devices. Wind Energy, Solar Energy can be used to bring these devices in the working or the operating condition.

- Big Data & IoT

  IoT devices are being adding up exponentially, so they sense the data, store the data and share the data. The huge amount of data is generated so we have to deal with Big Data. And the huge data is going to bring lots of problems so we have to find their solution. We need to use the data to get required results so we have to process the data, analyze it, pre-process it and we have to use all the techniques.

CONCLUSION

IoT is rapidly introducing new and new technologies which will make a difference in our lives, by bringing changes in our lives. Our life would be more easy and relaxed with the advancement in the technology. IoT has been very useful in most of the domains. While the IoT has plenty of advantages, there are some flaws too. A lot of work needs to be performed and completed for the development, and advancement in this field. The future is directly or indirectly inclined towards Internet of Things. In this paper we have provided the well-defined architecture of IoT. Then we have highlighted the communication models, and have discussed the IoT security problems. Many research work are being carried out in this particular field, and the problems related to security and privacy would soon come to an end.

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