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Research Paper

IoT Application, A Survey

Harika Devi Kotha[1]*, V Mnssvkr Gupta [2]

[1]Assistant Professor, Department of ECE, IFHE-FST, Hyderabad. India
[2]Assistant Professor, Department of CSE, SRKR Engineering College, Bhimavaram, India
**Email: harikadevikotha@gmail.com*

Abstract

Internet of Things (IoT) , where physical systems are connected over network to exchange information among themselves and with their surroundings. IoT helps in developing most powerful industrial systems. It finds its various applications in house hold, agriculture, and in various industrial systems. In an effort to understand the growth of IoT , this paper reviews current research trends of IoT , key technologies, and its major applications, and identifies key challenges of IoT. This paper mainly summarizes the applications of IoT in industries

Keywords: *Internet of Things (IoT); Near field communication; Protocols; RFID; Wireless sensor Networks.*

1. Introduction

As an off-promising technology IoT provides solutions to transform the operation of many existing industrial systems. For example, when IoT is used in creating smart systems for aqua-culture, then the farmer can easily monitor the information regarding water ,i.e., pH of water, its temperature and other details. Using which the farmer can predict what has to be done for the growth of fishes.
IoT allows all the existing systems to connect to a network, using which they can communicate among themselves and with the surroundings such that some action to take place. Connecting all the devices to a network can be done by using a unique ID called IP address. IP address helps to identify and locate a device on the network and routes the information. Today commonly accepted definition for IoT is

"A network of physical objects or 'things' that can interact with each other to share information and take action." or: "The Internet of Things (IoT) is the interconnection of uniquely identifiable embedded computing devices within the existing Internet infrastructure." [1]

Initially IoT, used radio-frequency identification (RFID) technology for identifying the connected devices. Later on IoT locate devices by using sensors, actuators, and mobile devices. Specifically, Integrating sensors, RFID tags and communication protocols serves as the foundation for IoT [2] .

Research shows that there is tremendous growth in the area of IoT. The industries are trying to work on more projects related to IoT in the fields of health care, agriculture, aqua-forms, transportation and others. Statistics shows that there will be around 22% growth in profit for the industries that are working on IoT [3]. Not only industries are focusing on IoT, but in the recent years it has been observed that number of publication on IoT are also increasing.

The organization of this paper is as follows: In Section II the Background and current research of IoT is provided. Section III provides the information regarding IoT Architecture. Section IV covers the technologies of IoT. Section V gives the information regarding applications of IoT .Section VI covers the challenges of IoT. And finally conclusions are presented in section VII.

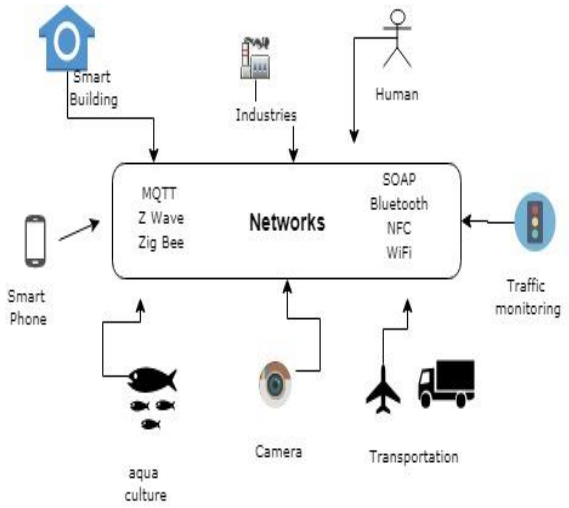

Figure. 1: Illustration of ' things ' in IoT

2. Background and Current Research of IoT

During initial days of IoT, RFID served as the foundation technology, which allows user to send or receive information using radio - frequency signals. The connected device should be attached with RFID tags, which contains reader and transmitter. With the help of RFID reader , people can locate and monitor the devices [4]. Main application of RFID is transportation.

Later on wireless sensor networks (WSN) served as a building block for IoT. Here sensors / actuators will be attached to the devices with in the network. Sensors are used to sense the data and using actuators data will be transmitted. The main application of WSN includes health-care.

With the advancement of RFID and WSN, there is a significant growth in the development of IoT [2]. The working of IoT connected devices is shown in the figure 2. IoT finds its main applications in the fields of : tracking & monitoring , health - care, home automation , environment monitoring , smart building , agriculture , aqua - culture and others. With the advancement of smart phones, communication protocols, sensor networks technologies; it is possible to connect more objects in a network.

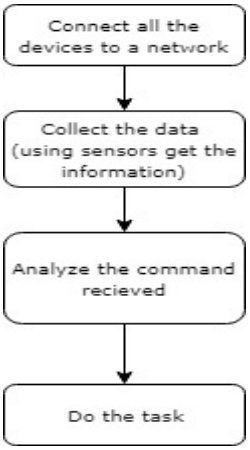

Figure. 2: Working of IoT

IoT application contains both hardware and software. IoT hardware is broadly classified in to : 1) wearable devices, 2) embedded system boards. Wearable devices will come with pre-assembled hardware application [5]. The scope of wearable devices is limited to a particular application. For example a smart watch may be designed for call receiving and fitness monitoring only. The advantage with wearable device is handy to use. The examples of wearable devices are : Samsung gear , titan we watch, google glass, cuir ally smart wallet , digit- sole smart shoe and others.

On other hand embedded system boards are open for the user. That is, a user can program these boards depending on the application he want . In present day market, there are so many embedded system boards are available. Examples include Arduino boards, raspberry pi boards, Samsung artik board, cloudbit, ESP8866 Wi-Fi module and others. After selecting a particular embedded system board, the user has to choose application software. There are wide range of programming languages like C, C++, python etc.

IoT deals with connecting the devices to a network and sharing the information, in this point of view one has to ensure security, reliability. Also IoT deals with various kinds of devices, so in order do the task properly standardization is required. Standardization provides inter-operability, compatibility on a global scale [6]. Many professional bodies are working on creating standards for IoT. At present organizations like IEEE, International Electro-technical Standardization, China Electronics Standardization Institute, American National Standards Institute are working on development of standards for IoT [7]. By designing IoT applications on accepted standards one can achieve reliability and interoperability, which in-turn will reduce maintenance costs in long run [8].

So far many countries are invested in IoT applications. Recently Indian government has started a project on IoT called *Smart City Project* by investing INR 7060 crores [9] . The main aspects of this smart city project are : waste management , intelligent transportation , smart urban lightening, tele-care and others . Also India aims to develop IoT industry by investing USD 15 billion by 2020 [10] . Not only in India, countries like UK, china , Japan etc.. also working towards the development on IoT industry. UK government has launched £5m project to develop IoT [1]. Japan started two strategies called u- Japan and i - Japan for utilizing IoT in our daily routines [11].

3. Architecture of IoT

Since IoT deals with heterogeneous devices there is no specific architecture designed for IoT. Different architectures are proposed for IoT. Depending on the type of application , a particular architecture can be opted. In this paper, the basic 3 layer architecture for IoT , cloud architecture , Fog based architecture , and finally service oriented architecture have been discussed

3.1. Three Layer architecture of IoT

- *Physical layer* also called as perception layer. This layer contains sensors, RFID tags and other essential components. This layer senses and collect the necessary information from the connected devices.
- *Network layer* acts as a gateway. It takes care of routing protocols, server related information and transmission of data. Data is transferred via logical network paths .
- *Application layer*, being the top layer. It is responsible for the transmitting the data to the required destination. Figure 3 shows the 3 layer model of IoT.

Figure. 3: 3-layer model of IoT

The main disadvantage of this architecture is more tasks will be scheduled to single layer, due to which updating single or multiple layers is a tough task.

3.2. Cloud Based Architecture

As described in the figure 4, cloud based architecture of IoT contains mainly physical layer , process layer, gateway layer and cloud services.

Figure. 4: Cloud based architecture of IoT

- *Physical layer* contains technologies used like RFID, to collect the information from the devices connected in the network.
- As the name indicates the *process layer* tries to analyze the information received.

- *Gateway layer* contains the network information like LAN or WAN etc. It performs data transformations and makes the received raw data suitable for cloud services. It establishes path for end to end communication.

- The main and important part of cloud based architecture is *cloud services*. It is responsible for executing the data (collected from industries or user etc..) by using data analytic algorithms. The main components of *cloud services* are : 1) Broker and message queue , 2) Data base, 3) Server and 4) Event managers.
- *Broker and message queue*, are responsible for managing incoming messages. It streamlines the messages from various clients and processes them . It helps in increasing the scalability of the network (ie., number of devices can be increased.)

- *Database* is used for the storage purpose.

- *Server* helps in visualizing the data, reporting. It helps user to understand data. It also provides recommendations to the user.

- *Event managers*, performs event handling. It executes high priority interrupts like fire alarm. In case of emergency, it triggers certain actions [12].

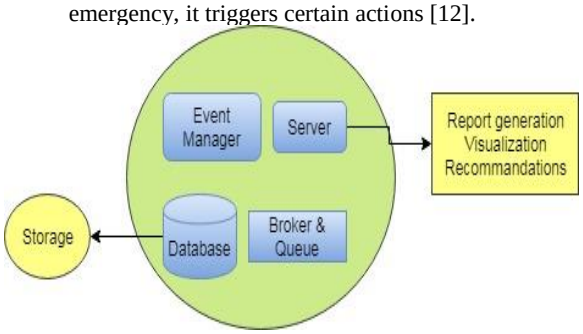

Figure. 5: Cloud services

3.3. Fog based architecture

Fog computing is latest technology. It extends the features of cloud computing. Fog computing offers processing the data (computing), takes care of storage and provides the network information between client and the cloud services. Computing (processing the data) occurs in decentralized manner. Here the data computing, storage and resource management are distributed in an efficient manner between client and cloud.

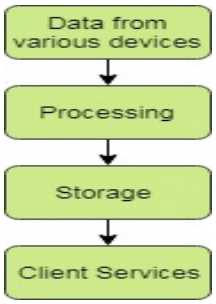

Figure. 6: Fog based architecture

Both cloud computing architecture and fog computing architecture is more or less same[13]. The only difference in this architecture is the computing of data takes place at devices , which are connected at the edge of the network. So, the other name of fog computing is edge computing. As discussed in cloud based architecture, the scalability is more in this architecture.

3.4. Service Oriented Architecture of IoT

This reference model is generally used in business applications.

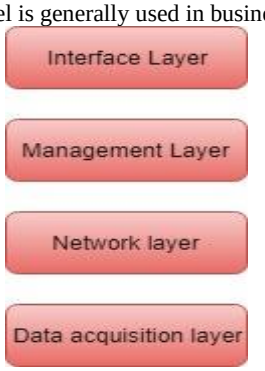

Figure. 7: SOA for IoT

- *Data acquisition* layer is similar to perception layer. By using IP address , it tries to senses the data and transfers to network layer. It is also responsible to process (by using data computing algorithms) the data.

- *Network layer* as discussed earlier it deals with communication protocols. It can be a wired network or wireless. Generally used protocols are Z - wave, Zig – bee etc..

- *Management layer* is responsible to maintain end to end integrity. It checks whether the data transferred correctly to the other end or not. It is also responsible in maintaining the data integrity and security. It ensures the data is transferred to the correct user. The other name of this layer is Business layer.

- *Interface layer*, popularly known as application layer. It also takes care of data formatting and presenting. It gives the information regarding interaction methods to users and other application.

4. Technologies Of IoT

The key technologies of IoT are classified in to two broad categories. 1) Identification technology 2) Communication technology.

3.5. Identification Technology

As the name indicates these type of technologies are used for locating and monitoring purpose. The examples include RFID ,WSN , QR code, barcodes and Intelligent sensors etc.

RFID connected devices contain a reader – to collect the information, and a transmitter – to transmit the information. RFID tags are costly when compared to other technologies like WSN.

3.6. Communication Technology

These will provide guidelines to be followed data transfer. Examples include Zig bee, Z wave, MQTT , Bluetooth ,Li-fi , Wi-fi, Near Field Communication(NFC) , HaLow ,Power line area network and others [14].

- *Zigbee* is follows IEEE 802.15.4 standard. It is a short range (around 20meters) protocol, used to create a small network . It is generally used in home automation.
- *Z Wave* is long range wireless protocol (approx. 100 meters) . Each Z wave network will have a unique ID called Network ID, and each device in a Z Wave network will have a node ID. It is also used in home automation. Unlike Wi-Fi it can transfer data at high speed
- *MQTT (Message Queue Telemetry Transport) is* a machine to machine IoT protocol. It is used in cloud based and fog based architectures. The important feature of this protocol is, it can transmit information from one source to many users (one to many function) via an intermediate node.
- *Bluetooth* is a short range protocol, generally used in our day to day applications. For example in our smart phone using Bluetooth we will transfer the information to the paired device. It follows IEEE 802.15.1 standard.
- *Li – Fi (light fidelity)* is also a short range wireless protocol. Here the transfer of data takes place in the form of light.
- *Wi-Fi* follows IEEE 802.11 standard. It is a medium range network, generally used in local area network. The scalability is more.
- *Near field communication (NFC)* , is very short range networking protocol (appox. 4meters). It provides point to point connectivity between communicating devices. For example using NFC we can share screen of our smart phone with smart TV .
- *HaLOW* , is similar to wifi. The only difference is HaLOW is a medium range protocol, and data transfer rate is low when compared to wifi.
- *Power Line area network* , is a long range wired communication network. It makes use of power lines for transmitting the data.

These all technologies of IoT makes use of either IPv4 or IPv6 for addressing.

TABLE 1: Key technologies of IoT.

Technologies of IoT	
Identification technologies	• RFID • WSN • QR code • Barcode
Communication technologies	• Zigbee • Z wave • MQTT • Bluetooth • LiFi • WiFi • NFC • Power line area network

5. Applications of IoT

The applications of IoT vary from a small network like home automation to large network like cloud based industry application. Brief introduction about various applications of IoT like environmental monitoring, home automation, agriculture, aqua-culture, health care, transportation and logistics have been discussed in this paper. The following design constraints have to be addressed properly for developing a particular application to have a balance between cost and efficiency.

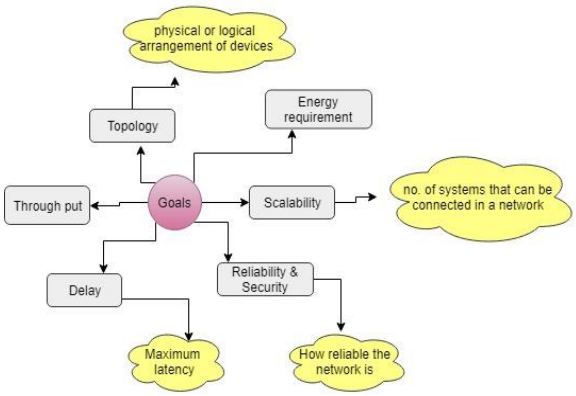

Figure. 8: Various design constraints for an IoT application.

3.7. Environmental *Monitoring*

There are number of sensors available to sense parameters like temperature, humidity, air pollution, water pollution. Sensors like RTD and thermometer are used to measure temperature. To analyze air pollution we can make use of dust sensors and gas sensors. By making use of e-Tongue (electronic tongue) and e – Nose (electronic nose) technologies the presence of chemicals can be identified [15]. These technologies make use of pattern recognition software. These are used in cities to monitor the pollution levels.

3.8. Home *Automation*

Home automation or smart building is called as domotics [16]. By using a centralized hub generally a *smart phone (which contains sensors like accelerometer),* the various things in the home can be controlled. That is, smart television, air conditioner, water heaters, lights, fans etc.. will be connected to the smart phone using NFC , Bluetooth, Zigbee or any other short range low power protocols.

3.9. Agriculture

IoT in this sector generally called as *Smart Farming* [17]. With the help of GPS enabled tractors we can control the path of tractor. Also with the help of simple embedded board of IoT we can control the pump(set timing when to supply water to the farm). Also by using soil sensors the condition of the land can be studied.

3.10. Aqua-culture

IoT has been used in aquaculture to control to action of radiators (used in fish tanks for oxygen supply). By using chemical sensors the farmer can get the information regarding water (temperature).

3.11. Health care

Using IoT in medical field one can track patient health condition. The medical sensors can be: 1) wearable and 2) sensors implanted in the body. Using wearable sensors one can track various parameters like pulse rate, body temperature, calories etc. The examples of wearable's are fitbit, reflex. Other type is sensors implanted inside the body. These are used when patients' health has to be monitored continuously. For example by using a sensor which is implanted in the human body (as shown in figure 10) , the doctor can track and monitor the patient heartbeat, pulse rate etc.

Figure. 9: fitness tracker (source : https://www.fitbit.com/in/charge2)

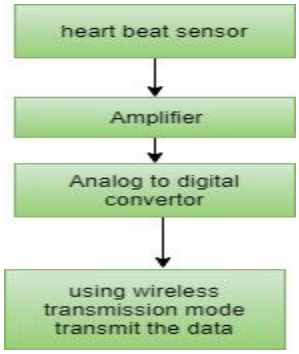

Figure. 10: Working of an heartbeat sensor

3.12. Transportation and Logistics

IoT plays an important role in transportation and logistics [18]. By attaching RFID tags or barcodes to the vehicle, the industries can monitor the real time information of the vehicles [19], like location of the vehicle and others. Furthermore, by enhancing the IoT abilities in transportation field one can control the speed of the vehicle. In logistics by making use of barcodes companies can track inflow and outflow of the products.
By establishing proper standards of IoT, we can enhance IoT in various others fields like mining, safety, traffic monitoring etc..

Table 2: Comparison with other surveys on the basis of topics covered

Survey Paper	Architectures	Technologies Of Iot	Applications	Others
"Internet Of Things : A Survey "Li Da Xu,2014	Service Oriented Architecture	Rfid,Wlan, Nfc, Zig Bee	Health Care, Transportation And Logistics ,Mining	Key Challenges Of Iot
"Create Your Own Internet Of Things, "Kiran Jot Singh, 2017	Not Covered	Wi-Fi , Bluetooth	Not Covered	Covered Iot Hardware Arduino, Raspberry Pi, Cloud Bit , Samsungs' Artik, Udoo Quad
"Iot In Agriculture: Designing A Europe-Wide Large-Scale Pilot ," Christopher Brewster , 2017	Not Covered	Mqtt, Amqp	Agriculture	System-Of-Systems Architectural Approach To An Iot-Based Largescale Pilot In Agriculture.
"A Cloud Based Architecture For Internet Of Things Targeting Industrial Devices Remote Monitoring And Control ," Ademir F.Da Silva ,2016	Cloud Based Architecture	Mqtt	Industrial Exhauster	Case Study On Industrial Exhauster
Our Survey	Covered 3- Layer Architecture, Cloud Based Architecture, Fog Based Architecture, Service Oriented Architecture	Covered In Detail About Rfid , Zig Bee, Z Wave, Mqtt , Bluetooth ,Li-Fi , Wi-Fi, Near Field Communication(Nfc) , Halow ,Power Line Area Network	Environmental Monitoring, Home Automation, Agriculture, Aqua-Culture, Health Care, Transportation And Logistics	Key Challenges Of Iot

4. Challenges of IoT

- Since IoT connects heterogeneous systems together, to have a proper communication among them we have to *standardize* the IoT. Standardization includes interoperability, security and privacy issues [20].

- Another challenge of IoT is with respect to technical issues. For example proper analysis of delay has to done before the data transfer, such that efficiency of the network increases.

- Other aspect is with respect to information security and privacy. Since so many IoT deals with tacking the information of other devices, protecting the privacy of a user from attacker is a key issue to be addressed properly [21].

5. Conclusion

IoT combines various sensing devices , pattern recognition algorithms, communication models and networking together for proper communication . Presently IoT is in developing stage . As there is enhancement in the capabilities of sensors, one can develop a good IoT model and hence after a decade or so complete automation is possible with the help of IoT. In this paper we firstly discussed about history and current state - of - art of IoT, then we move on to various architectures of IoT, then discussed about communication technologies in IoT and finally discussed about various applications of IoT.

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