Architecture, Application and Future Trends of Internet of Things (IoT): The Survey

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ABSTRACT
Now a days the development of IT Industry is growing fastly and IT technology plays a significant role in our daily life since earlier few decades and most of the person becomes dependent on this technology to obtain maximum assistance and relief. The internet of Things (IoT) provides the facility to the users that the can connect the devices from anywhere, anytime and anyone. The IoT is designed by using RFID, various sensors and smart objects (things) nearby us. Daily millions of devices get connected from the internet and sensor sends the data collected from those devices to make a meaningful decision on those data. In the forthcoming year IoT will be main hub between IT technology but it also faces some significant issues. This paper presents the various architecture of IoT, application areas and its future trends which will help in further research related to IoT.

Keywords: Internet of Things, Architecture, RFID, IoT applications, IT technology.

1. INTRODUCTION

Kevin Ashton coined the name Internet of things in 1999, co-founder and executive director of Auto-ID Center, a global research network of academic laboratories focused on RFID and the IoT. In today's epoch, People always wanted the technology to reduce their pressure and live comfort and happy life, it is IoT making their life simple and satisfied. According to the preliminary forecasts about 50 billion devices will be connected to the internet and the IoT market reach about $1.7 trillion by 2020. Device collects the useful data from one device using existing technology and flow the data to other devices. Smart applications are becoming part of our lives. There is a thing to thing communication rather than human to human communication. Hardware and software are the important elements in IoT. Through this IoT each device can be identified, connected and can take decisions independently. IoT is used in various domains; the accomplishment of success in the field of IoT was not easier [1]. Internet of Things can be defined as the collection of two terms: one is Internet, which is defined as networks of networks which can connect billions of users with some standard internet protocols [2]. Internet connectsseveral different sectors and department while using different technologies. Several devices like mobile, personalsystems and business organizations are connected toInternet. The second term is Thing, this term is basicallymean to these devices or objects which turn into intelligentobjects [3]. Moreover,this it is also a part of all objects ofthis real world. If we want to define IOT then we cannot define it precisely and concisely but Vermesan et al.defined the Internet of Things as simply an interactionbetween the physical and digital worlds. The digital worldinteracts with the physical world using a plethora ofsensors and actuators [4]. IoT can also be defined as "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" [5].

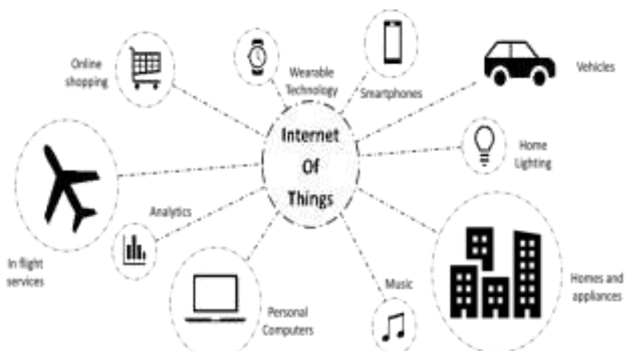

Fig. 1: Architecture of Internet of Things (IoT)

1.1 History of IoT

The concept of connected devices itself dates back to 1832 when the first electromagnetic telegraph was designed. The telegraph enabled direct communication between two machines through the transfer of electrical signals. However, the true IoT history started with the invention of the internet—a very essential component—in the late 1960s, which then developed rapidly over the next decades.[6]

The 1980s

This might be hard to believe, but the first connected device was a Coca-Cola vending machine situated at the Carnegie Melon University and operated by local programmers. They integrated micro-switches into the machine and used an early form of the internet to see if the cooling device was keeping the drinks cold enough and if there were available Coke cans. This invention fostered further studies in the field and the development of interconnected machines all over the world.

The 1990s

In 1990, John Romkey connected a toaster to the internet for the very first time with a TCP/IP protocol. One year later, University of Cambridge scientists came up with the idea to use the first web camera prototype to monitor the amount of coffee available in their local computer lab's coffee pot. They programmed the webcam to take pictures of the coffee pot three times per minute, then send the images to local computers, thus allowing everyone to see if there was coffee available.

The year 1999 was easily one of the most significant for the IoT history, as Kevin Ashton coined the term "the internet of things." A visionary technologist, Ashton was giving a presentation for Procter & Gamble where he described IoT as a technology that connected several devices with the help of RFID tags for supply chain management. He specifically used the word "internet" in the title of his presentation in order to draw the audience's attention since the internet was just becoming a big deal that time. While his idea of RFID-based device connectivity differs from today's IP based IoT, Ashton's breakthrough played an essential role in the internet of things history and technological development overall.

The 2000s

At the beginning of the 21st century, the term "internet of things" came into widespread use by the media, with outlets like The Guardian, Forbes, and the Boston Globe making mention of it. Interest in the IoT technology was steadily increasing, which led to the 1st International Conference on the Internet of Things held in Switzerland in 2008, where participants from 23 countries discussed RFID, short-range wireless communications, and sensor networks.

Moreover, several major developments fostered the IoT evolution. One was a refrigerator connected to the internet that was introduced by LG Electronics in 2000, allowing its users to shop online and make video calls. Another essential development was a small rabbit-shaped robot named Nabaztag created in 2005 that was capable of telling the latest news, weather forecast, and stock market changes.

Even back then the number of interconnected devices surpassed that of people on Earth, according to Cisco.

The 2010s

The IoT boom was supported by its addition to the Gartner Hype Cycle for emerging technologies in 2011.

In the same year, IPv6—a network layer protocol that is central to IoT—was launched publicly.

Since then, interconnected devices have become widespread and commonplace in our everyday lives. Global tech giants like Apple, Samsung, Google, Cisco, and General Motors are focusing their efforts on the production of IoT sensors and devices—from interconnected thermostats and smart glasses to self-driving cars. IoT has found its way into almost every industry: manufacturing, healthcare, transportation, oil & energy, agriculture, retail, and many more. This dramatic shift has us convinced that the IoT revolution is right here, right now.

As of today, IoT platforms maintain a strong hold on their position among the top trends in this year's Gartner Hype Cycle, along with virtual assistants, connected homes, and level 4 self-driving cars. The technology will reach its plateau of productivity in 5–10 years.

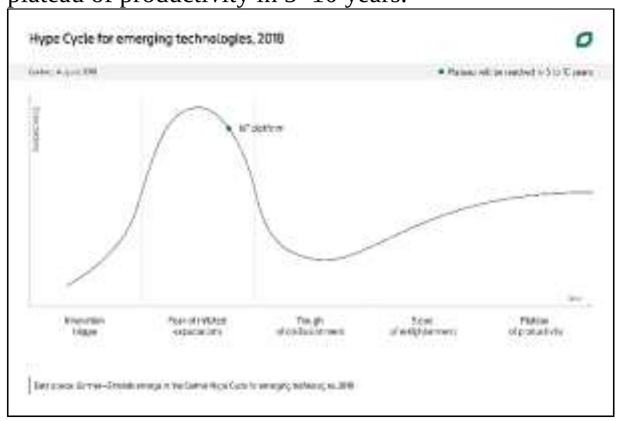

Fig. 2. : Gartner-5 trends emerges in the Gartner Hype cycle for emerging technologies,2018

1.2 Objectives

With the Internet of Things the communication is extended via Internet to all the things that surround us. The Internet of Things is much more than M2M communication, wireless sensor networks, 2G/3G/4G, RFID, etc [7]. These are considered as being the enabling technologies that makes the "Internet of Things" application possible.

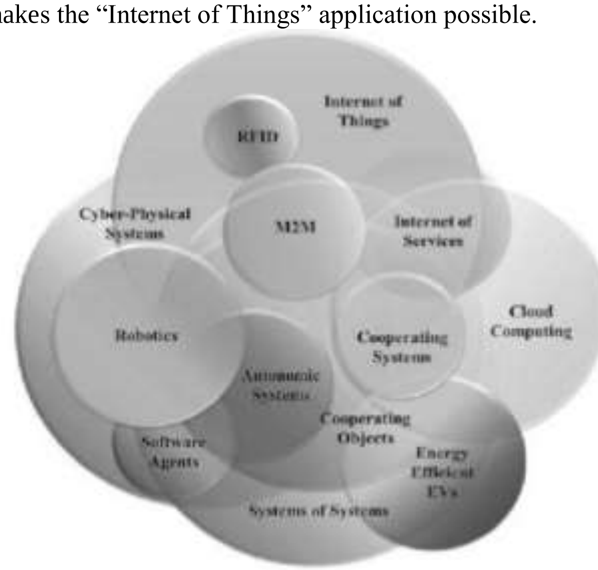

Fig. 3: Technology Convergence

Several industrial, standardization and research bodies are currently involved in the activity of development of solutions to fulfil the highlighted technological requirements. This survey gives a picture of the current state of the art on the IoT. More specifically, it:

- Provides the readers with a description of thedifferent visions of the Internet of Things paradigmcoming from different scientific communities;
- Reviews the enabling technologies and illustrateswhich are the major benefits of spread of thisparadigm in everyday-life;
- Offers an analysis of the major research issues thescientific community still has to face.

The main objective is to give the reader the opportunity of understanding what has been done (protocols, algorithms, proposed solutions) and what still remains to be addressed, as well as which are the enabling factors of this evolutionary process and what are its weaknesses and risk factors.

2. ARCHITECTURE OF INTERNET OF THINGS

The architecture of IoT should be flexible in nature, because it has to interconnect heterogeneous objects in billions and trillions. There are many proposed architectures for IoT but all of them are not yet converged to form a unique reference model yet. Many projects are available that have helped to create a common architecture of IoT based on technological changes and researches. We will be discussing two architectures which are used generally by many researchers and in industry from pool of architectures available [8].

2.1 Three Layer Architecture

The most basic architecture is three-layer architecture [9–11] as shown in figure 4. It was introduced in the early stages of research in this area. It has three layers, namely, the perception, network, and application layers.

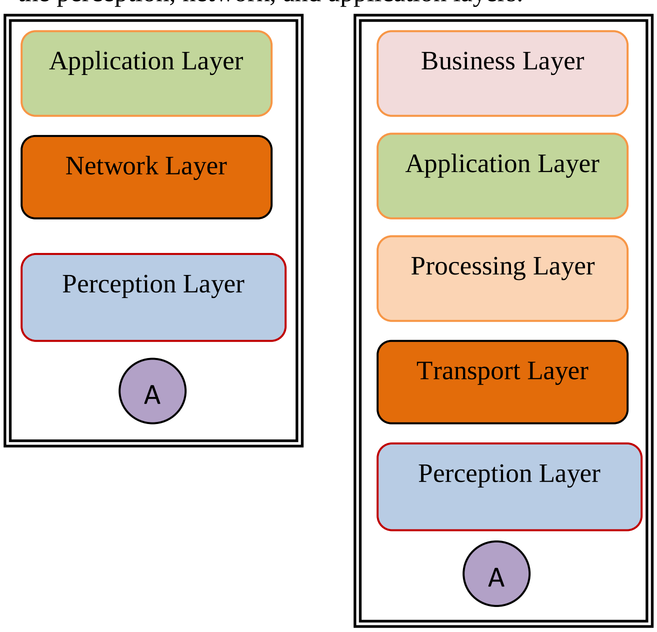

Fig. 4: Three and Five layer architecture of IOT

(i) The perception layer is the physical layer, which has sensors for sensing and gathering information about the environment. It senses some physical parameters or identifies other smart objects in the environment. (ii) The network layer is responsible for connecting to other smart things, network devices, and servers. Its features are also used for transmitting and processing sensor data. (iii) The application layer is responsible for delivering application specific services to the user. It defines various applications in which the Internet of Things can be deployed, for example, smart homes, smart cities, and smart health.

The three-layer architecture defines the main idea of the Internet of Things, but it is not sufficient for research on IoT because research often focuses on finer aspects of the Internet of Things. That is why, we have many more layered architectures proposed in the literature. One is the five layer architecture, which additionally includes the processing and business layers [9–12]. The five layers are perception, transport, processing, application, and business layers (see Figure 4). The role of the perception and application layers is the same as the architecture with three layers. We outline the function of the remaining three layers.

(i) The transport layer transfers the sensor data from the perception layer to the processing layer and vice versa through networks such as wireless, 3G, LAN, Bluetooth, RFID, and NFC.

(ii) The processing layer is also known as the middleware layer. It stores, analyzes, and processes huge amounts of data that comes from the transport layer. It can manage and provide a diverse set of services to the lower layers. It employs many technologies such as databases, cloud computing, and big data processing modules.

(iii) The business layer manages the whole IoT system, including applications, business and profit models, and users' privacy. The business layer is out of the scope of this paper. Hence, we do not discuss it further.

Another architecture proposed by Ning and Wang [12] is inspired by the layers of processing in the human brain. It is inspired by the intelligence and ability of human beings to think, feel, remember, make decisions, and react to the physical environment. It is constituted of three parts. First is the human brain, which is analogous to the processing and data management unit or the data center. Second is the spinal cord, which is analogous to the distributed network of data processing nodes and smart gateways. Third is the network of nerves, which corresponds to the networking components and sensors.

2.2 Cloud Based Architecture

As described in the figure 5, cloud-based architecture of IoT contains mainly physical layer, process layer, gateway layer and cloud services.[13]

Fig.5: 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 (i.e., 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 [15].

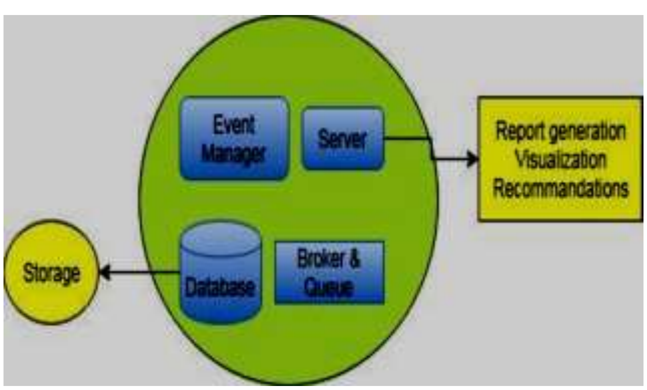

Fig. 6: Cloud services

2.3 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. [13,14]

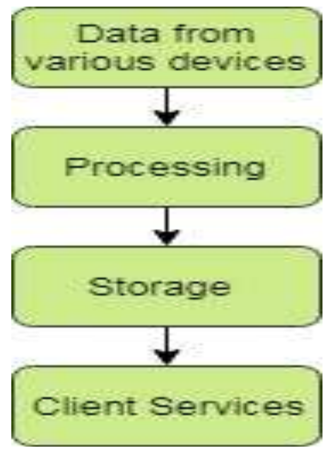

Fig.7: Fog based architecture

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.

2.4 SoA-based Architecture

In service-oriented architecture a service layer isintroduced between network and application layer to makethe architecture more flexible and to provide the dataservices in IoT. It is model used to connect different servicesusing interfaces and protocols.SoA is capable of reusing the software and hardwarecomponents, which improves feasibility of using SoA in IoT.There are four layers in this architecture perception layer,network layer, service layer, application layer. Here, theservice layer is divided into 2 sublayers known as servicecomposition, service management sublayer.The perception layer present at the bottom of thearchitecture collects data from sensors, as in the previousarchitecture. Network layer also performs the same functionas the basic architecture, i.e. determining the routes,providing data transmission via the same integrated network. [16]

Service layer acts as a middle layer provides all theservices for supporting application layer. This layer consistsof all the functionalities like discovery of service which issued to discover the service request which is desired ,composition of services to connect or interact with the connected object in the architectures and also it performs integration of various services to meet the requirements of service request , management of services is also done to manage the service requests and along with that service interfaces are present which are used to support the various interactions that are present among all the services that are provided.

The upper layer is the application layer that performs same functions as that of application layer of the basic architecture. It supports all the applications like smart homes, smart cities etc.

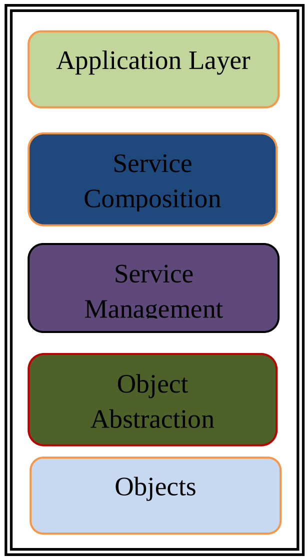

Fig. 8. SoA-Based Architecture

3. APPLICATIONS

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.

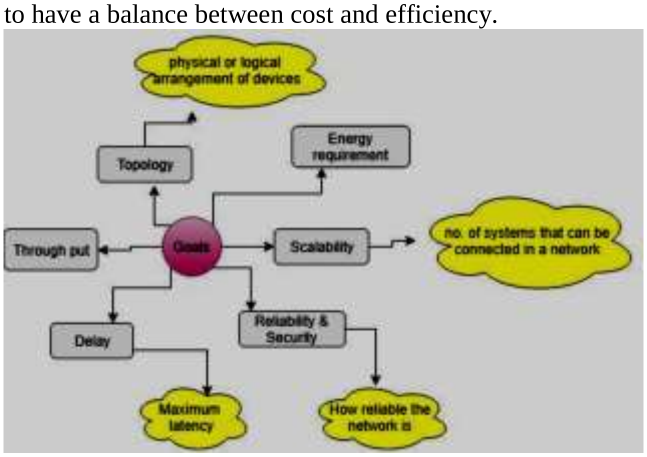

Fig.9: Various design constraints for an IoT application

3.1 Smart environment (homes, buildings, office,plant)

Sensors and actuators deployed or attached with house hold Equipment like refrigerator, lighting, and air conditioners can monitor the environment inside a house, plant or office.Thelighting system of a house may vary, like in the evening most ofthe lights will be on while they will be off late at night. Based onthe reading of a temperature or a smoke detector sensor, a firealarm can be set off automatically. Such type of application isvery helpful for elderly people alone in home. Based on themovement of occupants in home, some appliances like door inroom can be opened, lights be turned on at current room, waterpoints will be open at kitchen. Air conditions, refrigerators,washing machines will now be IoT-enabled and controlled overInternet in order to save energy. In near future, a smart

Malfunctioning refrigerator will send a message to a service manautomatically without user's intervention. Industrial automation isimproved by deploying RFID tags with products. Productionprocess is controlled to ensure quality of product by gettingdifferent parameter values from sensors.IBM has launched SmartHome solution [17], better known as "Stratecast" to provideservices to users allowing seamless communication among various smart devices in house, like medical devices, computers, mobiles, TVs, lighting, security or sound system. IBM is collaborating with Verizon as a communication service provider(CSP) and Philips as a device vendor in order to implement the architecture. Siemens, Cisco, Xerox, Microsoft, MIT and many others are working in this domain. They have set nearly 20 home labs using more than 30 home appliances, five network protocols and three Artificial Intelligence (AI) techniques [18,19]. The Intel smart home platform supports recognition of family member's byvoice or face and personalizes the home. Intel provides IoTsolutions for smarter building to support personalization bycontrolling over the office/living environment, mobility by enabling managers to monitor property remotely and saving resources like energy, water.

Fig.10: Smart Home System [24]

3.2 Health care

Most healthcare systems in many countries are inefficient, slow and inevitably prone to error. This can easily be changed since the healthcare sector relies on numerous activities and devices that can be automated and enhanced through technology. Additional technology that can facilitate various operations like report sharing to multiple individuals and locations, record keeping and dispensing medications would go a long way in changing the healthcare sector [20,21]. A lot of benefits that IoT application offers in the health-care sector is most categorized into tracking of patients, staff, and objects, identifying, as well as authenticating, individuals, and the automatic gathering of data and sensing. Hospital workflow can be significantly improved once patients flow is tracked. Additionally, authentication and identification reduce incidents that may be harmful to patients, record maintenance and fewer cases of mismatching infants. In addition, automatic data collection and transmission is vital in process automation, reduction of form processing timelines, automated procedure auditing as well as medical inventory management. Sensor devices allow functions centered on patients, particularly, in diagnosing conditions and availing real-time information about patients' health indicators [22].

The applications of Internet of Things (IoT) and Internet of Everything (IoE) are further being extended through the materialization of the Internet of Nano-things (IoNT) [23]. The notion of IoNT, as the name implies, is being engineered by integrating Nano-sensors in diverse objects (things) using Nano networks. Medical application, as shown in Fig. 11, is one of the major focuses of IoNT implementations. Application of IoNT in human body, for treatment purposes, facilitates access to data from in situ parts of the body which were hitherto in accessible to sense from or by using those medical instruments incorporated with bulky sensor size. Thus, IoNT will enable new medical data to be collected, leading to new discoveries and better diagnostics.

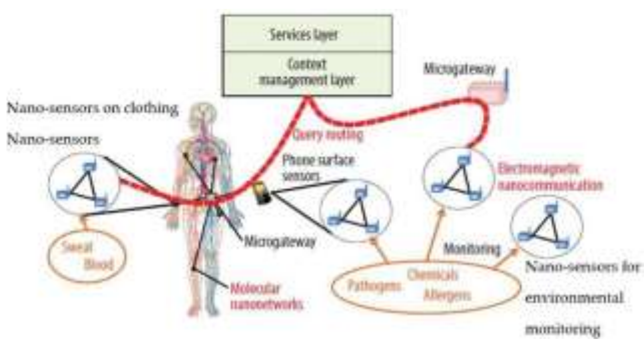

Fig. 11: The Internet of Nano-Things [23].

3.3 IoT in Agriculture

With the continuous increase in population of world, demand for food supply is extremely raised. Governments all over the world are helping farmers to use advanced techniques and research to increase food production. Smart farming is one of the fastest growing fields which is used in IoT. Sensing for soil moisture and nutrients, controlling water usage for plant growth and determining custom fertilizer are some simple uses of IoT in agriculture. The IoT contributes significantly towards innovating a farming method. Farming challenges caused by population growth and climate change have made it one of the first industries to utilize the IoT in this sector. [24]

The integration of wireless sensors with agricultural mobile apps and cloud platforms helps in collecting vital information pertaining to the environmental conditions like temperature, rainfall, humidity, wind speed, pest infestation, besides others linked with a farmland, can be used to improve and automate farming techniques, take informed decisions to improve quality and quantity and minimize risks and wastes.

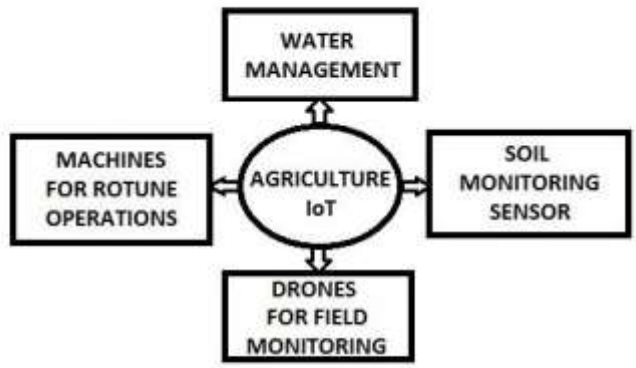

Fig.12 : Smart Agriculture System[24]

3.4 Connected Industry

The connected industry is the vision of a manufacturing environment where every machine can communicate with all other machines across the plant. The connected industry with IoT will connect, monitor and control virtually anything, anywhere to provide operational productivity and profitability [25]. In addition, the integration of IoT with sensor networks, wireless connectivity, innovative hardware and machineto-machine communication will completely transform the conventional automation process of industries [26].

3.5 Smart Retail

For retailers, the IoT offers unlimited opportunities to increase supply chain efficiencies, develop new services, and reshape the customer experiences. For instance, applications for tracking goods, real-time inventory, information exchange among suppliers and retailers, and automated delivery capabilities will improve the retail sector [27], [28].

3.6 Smart Energy and Smart Grid

The IoT provides more information about the behaviors of electricity suppliers and consumers in an automated way to improve the energy efficiency. It also provides consumers with smart management ofenergy consumption such as smart meters, smart appliances, and renewable energy resources [29].

3.7 Traffic monitoring

Smart cities are the big project ofinternet of things and traffic monitoring is an importantpart of smart city. To make the system self-reliable and towork intelligently traffic across cities either onnormal roads or highway traffic requires exchanging theinformation with each other. The congestion on theroads will cause economical as well as fuel losses,which can be saved by using the smart information. Theinformation regarding the congestion on the roads can beexchanged with the surrounding vehicles so that then coming traffic to that way can be rerouted to adifferent path. This type of changes can lead to improvethe whole system. An internet of things can begenerated using wireless sensor network and manydifferent kinds of sensors which will generate trafficIoT[30]. Proper security measures have to be taken sothat any kind of security breaches, terrorist attacks on thecities can be avoided.

3.8 Smart parking

Internet of things has made it possible todetect arrival and departure of vehicles by attaching various parking sensors in parking space to make theparking smarter. It helps to efficiently manage theparking area, which also helps the motorist to save theirtime and fuel as accurate information about the freeparking space is provided to the driver and keeps thesystem smooth. It is also possible to book for a parkingspace directly from the vehicle which will eliminate timewastage and avoid the jams at the parking areas [29].

4. KEY CHALLENGES

The IoT can give a new dimension to the Internet and can contribute to extensive financial gains but it also faces some challenges [18, 19]. Some of them are listed below.

1. Unique Identity Management: The IoT aims at connecting millions and billions of physical objects which should be uniquely identifiable over the Internet. Thus, proper identity management scheme is needed which will dynamically assign and manage unique names for a wide range of physical devices.
2. Standardization and Interoperability: Many vendors introduce their devices having different technologies not known to everyone. There should be a standardized mechanism to ensure interoperability of all the physical and sensor devices.
3. Privacy of the Information: The IoT makes the use of various object identification technologies like RFID, 2D-barcodes etc. As each object will be carrying these tags, it is extremely important to ensure privacy of the information thus, preventing unauthorized access.
4. *Safety of physical devices:* The objects irrespective of their geographic location need to be prevented from physical damage, unauthorized access in order to ensure its safety.
5. *Confidentiality of information:* The sensor devices transmit the information to the information processing system over the transmission media. The sensors should follow the encryption mechanisms to ensure data integrity at the information processing system.
6. *Network security:* The sensor devices send data either over wired or wireless transmission media. The transmission unit should tackle with this huge data without any loss of information and should incorporate strict measures so that no external intervention occurs.

5. FUTURE TRENDS

Given this rapid pace of development, IoT will soon dominate the world. In 2019, Gartner predicted that the enterprise and automotive IoT market would grow to 5.8 billion endpoints in 2020, marking a 21% increase from 2019. Everything that can be connected will be connected; thereby forming a comprehensive digital system wherein all devices communicate with people and one another.Here are several crucial factors spurring this rapid IoT expansion:

- Falling sensor costs
- Falling costs of data collection and storage due to cloud solutions
- Widely expanding internet connectivity
- Increasing computing power
- Increasing smartphone and tablet penetration

Undoubtedly, IoT's rapid growth will fundamentally change the world we live in. Imagine how an interconnected car will access your work schedule and notify colleagues about your being late to the meeting if it hits a traffic jam on the way to work.Our inevitable interconnected future will certainly bring in a lot of value and exciting opportunities for people. However, it will have its own challenges, too. Let's take a look at what experts think about the future of the internet of things and emerging industry trends.

5.1 IoT will become more industry-specific

In the near future, IoT manufacturers will focus on designing solutions for particular industries and industry segments rather than for general needs. There is a growing demand for specific use cases that help to resolve industry-specific challenges. For example, IoT solutions for remote patient monitoring aimed at reducing costs and improving the quality of patient care. The global remote patient monitoring market is expected to reach $1.8 billion by 2026, according to Grand View Research.New areas are also appearing at the intersections between interconnected technologies and various industries:

- Internet of medical things
- Industrial internet of things
- Automotive internet of things
- Smart cities and smart buildings
- Smart agriculture
- Smart retail

5.2 IoT will continue to merge with other technologies

However powerful IoT is on its own, it provides far more opportunities when combined with other technologies such as blockchain, artificial intelligence, machine learning, big data, AR/VR, and cloud and edge computing. In the future, there will be far more mixed solutions.

For example, the application of blockchain in IoT will help decentralize networks and ensure higher security data transmission between interconnected devices. Blockchain is already a leading IoT trend, and more value is sure to emerge from the blending of these two technologies.

IoT's future is closely linked with AI and machine learning as well. Application examples include the predictive maintenance of interconnected devices, the self-optimization of production processes, and smart home devices that learn your preferences. In the near future, IoT devices will not only report information, but also make autonomous decisions and become smarter on their own by deploying machine learning techniques.

Cloud and edge computing will continue to be integral to IoT data storage in 2019 and beyond, with experts predicting that edge computing will soon gain even more popularity.

5.3 Security will remain a blind spot

Despite the efforts of numerous governments to strengthen IoT security regulations and improve protection mechanisms for interconnectivity, data security and privacy problems will never diminish. Cybercriminals use more and more sophisticated tactics in order to find vulnerabilities in connected devices, thereby gaining access to private information. As a result, consumers and organizations are increasingly concerned about IoT security and see it as the leading barrier to widespread IoT adoption.

6. CONCLUSION

IOT is gaining very much popularity in the evolution of Internet. It has the capability to connect from all the real-world object at anytime and anywhere. This paper discusses various architecture and applications of Internet of things together with different challenges which cannot be overlooked. Some challenges like, interoperability, security, privacy, reliability, confidentiality and data management. By involving security policies in IoT lots of work has to be done in the architecture and general framework. In future work, need to develop such IoT which consumes low power for efficient design by selecting proper transmitter. Another future direction is connectivity, so for efficient connectivity develop such protocol which meets the current demand of technology while earlier do not able to handle and last by not least the reliability, and design such architecture for the transmission of the information from one device to another which must be reliable and secure for transmission. So, these issues must be taken into account during the development of new IoT.

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