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Internet of Things (IoT) : A Survey

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ABSTRACT

Internet of things is considered as the next evolution of the Internet. IoT is considered as a global network of things, having a distinct identity, and these are interconnected via a wide range of the network to exchange data and present it into vital information. Internet of things is an emerging technology that shaping the development of the ICT sector at large. The Internet of Things can also be considered as a uniquely recognizable smart object and their virtual representation in an Internet-like structure. To interchange data, IoT resources using the internet makes use of multiple interconnected technologies like Wireless Sensor Network (WSN) and Radio Frequency Identification (RFID). Also, integration of IoT with cloud provides improved services to end-user. For beneficence to the growing body of research on IoT, authors have presented the four-layered architecture of IoT, services offered by Internet of things, current Internet of things applications as well as issues and challenges of IoT technology in detail in this paper.

Keywords: IoT, Smart things, RFID, WSN

I. INTRODUCTION

to Gradually use of smart devices is gaining popularity around the globe. People use the internet as a global platform to allow smart objects and machines to send and receive data and to maintain coordination among them [31]. Smart things like smart homes, smart grid, smart wearable, and smart healthcare are the emerging application of IoT which are connected to smart grids. These smart devices are responsible for the creation of large smart systems [2]. In 1999, the term Internet of Things was introduced. According to the survey results of the European Commission, 50 to 100 billion devices will link to the internet by 2020. In the year 2008, it was a rough estimate that the number of things connected to the Internet was more than the total population on earth [11]. IoT consists of self-adjustable intelligent nodes that are interconnected with each other in a global and dynamic infrastructure of the network. Development of internet protocols, communication technologies and embedded devices improves communication, processing and sensing capabilities of smart objects [13]. Thus, it allows smart objects to sense environmental activities, transfer data over the internet and to make actuation according to the shared data. A smart device is nothing but an independent thing that has a sensor for sensing external parameters, an actuator for performing required corrected action autonomously, a transceiver for data transmission and a microcomputer for processing. Both academia and industry are affiliated towards IoT [3]. Over the last five years, there is a rise in sensor implementation, because of advances in cloud and sensor technology, storage and processing capacity and reduced sensor manufacturing cost. As per the definition of IoT, it allows things and people to get connected with anything, at any time and any location by making use of any service and any network/path. IoT is driven by advances in technology and not by user needs or applications. To interact with smart objects without any physical connection, low power wireless connection is useful [11]. While maintaining their identity, smart mobile things can travel around physical space. To make smart things, location and time-aware global positioning system (GPS) is used. IoT allows connected and pervasive smart things to interact autonomously while delivering smart services to the users [26].

The impetus of this paper is to present current IoT services, applications as well as issues and challenges of IoT technology. The composition of this paper is as follows: In section 1, we have introduced IoT technology. Enabling technologies of IoT i.e., Radio frequency identification (RFID), wireless sensor technology (WSN), and cloud computing is briefly described in section 2. In section 3, we have discussed the four-layered architecture of an IoT. Emerging IoT services are discussed in section 4. Current application of IoT like smart waste management, smart agriculture, healthcare, weather forecasting, monitoring environmental parameters, smart homes, smart grid are discussed in section 5, and in section 6 we have discussed issues and challenges of IoT, such as scalability, interoperability, security & big data.

II. ENABLING TECHNOLOGIES OF IOT

Collecting information from the surrounding environment to analyze, control, and making correct action is the main idea for IoT. To interchange data, IoT resources using internet makes use of multiple interconnected technologies like wireless sensor network (WSN) and radio frequency identification (RFID). IoT consists of smart objects, which can be read, locate, address, and control through the internet using RFID, wireless LAN, or some other means. An amalgam of IoT with cloud also helps them to overcome their technological limitations [2] Thus further, we have described RFID, WSN, and cloud computing technologies briefly:

A. Radio frequency identification

To eliminate human assistance and to automate the identification of objects, the electronic tag, also called an RFID tag, which can be read by RFID-reader from a small distance had been developed. RFID-reader does not require a direct line of sight to read the RFID tag. A distinct Electronic Product Code is stored in every RFID tag of the attached object [25]. By acting as a gateway to the internet, RFID- reader sends an object's real-time and location-enabled identity to a remote computer system to manage an extensive database. Due to this advantage, the RFID system has been widely applied in logistics, such as package tracking, supply chain management, healthcare applications, etc. The passive RFID tag and Active RFID tag are the two types of RFID tags. Active RFID tags are provided with their power supply in the form of battery. While passive RFID tags are not provided with any power supply, they get power from energy harvested out of the electronic field which is directed on a tag by RFID-reader [7]

B. Wireless sensor network

Wireless sensor technology is the 21st century's one of the most needed technology. A sensor network consists of spatially distributed connected sensor nodes, which makes a network for data receiving and transmission within them [13]. A recent development in the micro electro-mechanical system, low power communication, and low power microelectronics is capable of making integrated small-sized smart things also considered as sensor nodes [26]. This sensor node consists of a sensor, wireless communication controller, and small microcontroller. To measure environmental parameters, sensor nodes can acquire multiple biological, chemical, and physical signals. Until the least number of nodes are working, and by maintaining the connection of working nodes with one of the base stations, the sensor network can keep operational. Sensor nodes consist of network management components and operating system components [10]. To accommodate network dynamics and to manage the topology of the network, the routing protocol plays an important role. WSN can be used in many operations like transport monitoring, military applications and weather forecasting [2].

C. Cloud computing

Cloud computing technology is provided with virtually unlimited processing and storage capability as well as cloud provides on-demand services which are ubiquitously available than ever before. Thus this technology allows IoT to overcome its technological limitation of limited storage and processing capability [30]. Cloud makes use of the internet for delivery of services i.e., provides infrastructure, platform, and applications through the internet. Now it becomes a new trend, which provides access to shared computing resources [4]. Nowadays, computing resources become cheaper, robust, and ubiquitously available than before, because of increased development of processing technology, storage, and the internet [19]. Over the last few years, cloud technology had put a huge impact on the information technology industry, large enterprises like Amazon, Google, IBM, and Microsoft trying to improve their business strategy and to get benefits from this new technology by providing more reliable, robust and cost-efficient cloud platforms. Cloud can be considered as a new operating model to drive business differently by bringing existing technologies together [17].

III. IOT ARCHITECTURE

In this section, the authors have discussed the four-layered architecture of IoT, as shown in Fig. 1, which consists of a perception layer, which we can also call as a physical object layer whose primary purpose is data collection. The second layer is the network layer, whose function is to perform transmission of data over the network [31]. For data processing, there is a middleware layer. This data user can access at the application layer and using this data, and one can build business strategies in the Business layer [20]. Further, in this section, this four-layered architecture is explained in detail:

A. Perception Layer

This layer is also called a device layer or sensor layer. This layer consists of sensor-enabled physical objects in an IoT based system. These connected devices are the real endpoints for IoT. It is the actual hardware of an IoT system. This layer provides functionalities such as sensing, actuating, communicating, monitoring, and controlling [20]. Sensors can be barcodes, RFID tags, and infrared sensors. As per application requirements, these sensors are used to get information regarding location, time & environmental changes (temperature, humidity, pressure) [1]. To securely transfer this collected data to the data processing unit, this information is transferred to the network layer [31].

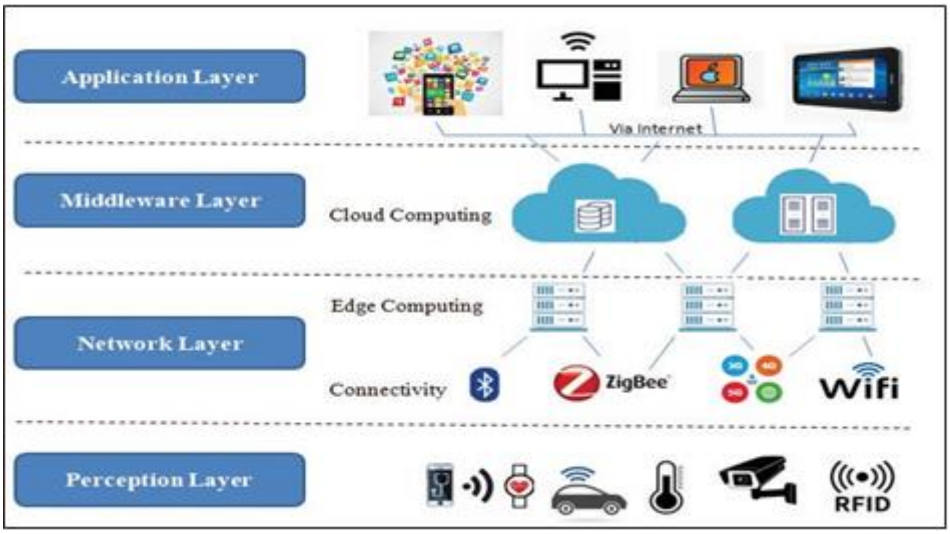

Fig. 1. Four layered IoT architecture

B. Network Layer

This layer is also called as a connectivity layer or edge computing layer, which defines various communication protocols, connectivity of networks, and edge computing [9]. This layer is used to transfer the information securely from sensor devices to the data processing unit. Wired or wireless transmission modes can be used to transfer data over the internet [20]. Also, technologies like ZigBee, Wifi, Bluetooth, infrared, 3G, 4G & 5G can be used depending upon the sensor devices. In this layer, IoT data is distributed and is processed at the edge of the network. Thus, this network layer sends the data from the Device/sensor layer to the middleware layer [31].

C. Middleware Layer

This layer is responsible for receiving the data from the network layer and storing it in the database. This received information can be analyzed by advanced data analytics. The middleware layer is used mainly for service management since these IoT devices are implemented to serve different IoT services. Each smart object connects and communicates with only those other smart objects which are involved in the same type of service. This layer performs data processing, ubiquitous computation, and automatic decision making based on the results [20]. This layer is compatible with cloud infrastructures, as IoT is integrated with cloud services. This received information can be analyzed with advanced data analytics. Thus this layer is mainly responsible for processing and storage using cloud computing. In other words, big data storage and high computing applications can be placed at this layer [29].

D. Application Layer

An IoT system manages various things and notifies the user about any conditions or generates results based on sensed data. Applications are needed to represent such data relevant to the user. Applications are also used to control and monitor such IoT systems [31]. This is the front end part of an IoT application that is accessible to the user. This layer allows the management of the applications depending on the data processed in the middleware layer. The applications implemented by IoT can be a smart home, smart city [32], smart healthcare, smart farming, smart retail & intelligent supply chain [6].

IV. IOT SERVICES

A. Sensing as a service

From this service, we can get ubiquitous access to sensor data [4]. SaaS model consists of four layers sensor & sensor- owner, sensor publisher, extended service provider, and sensor data user, as shown in Fig. 2. Various sensors record the data as per their specifications, and then sensor publishers after taking permission from the sensor owner publish that data in the cloud. When sensor data user needs data from different sensors, extended service providers contact with various sensor publisher for getting sensor data and provide that data to data consumer [5].

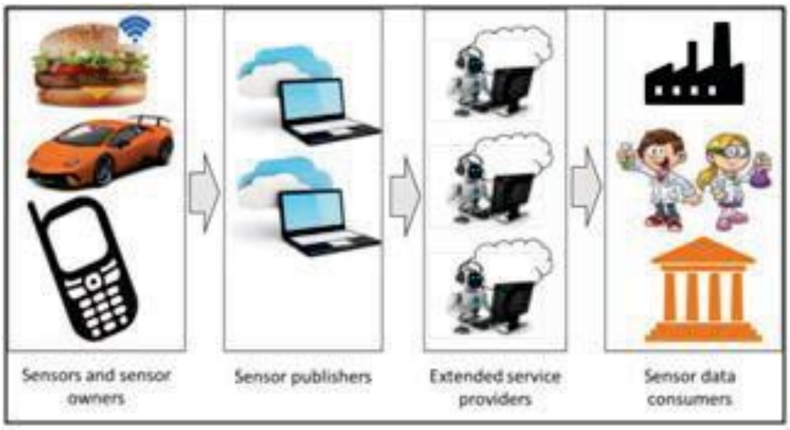

Fig. 2. Sensing as a service model [5]

B. Sensing and Actuation as a Service (SAaaS)

This service provides automatic control logic implemented in the cloud [2]. Sensing cloud provides virtual actuators and sensors, which are used to manipulate actual resources. Using SAaaS, user gets complete control over allotted virtual actuators and sensors through their service API [23].

C. Video Surveillance as a Service (VSaaS)

It provides access to recorded videos in the cloud. VSaaS is considered as a smart monitoring activity for security and related applications as shown in Fig. 3. Because of the cloud's storage and processing capability, the analysis of complicated videos becomes easy. In this service from video capture, storage, and management of video information from the camera until delivery through the internet is done by using load balancing and fault tolerance [3].

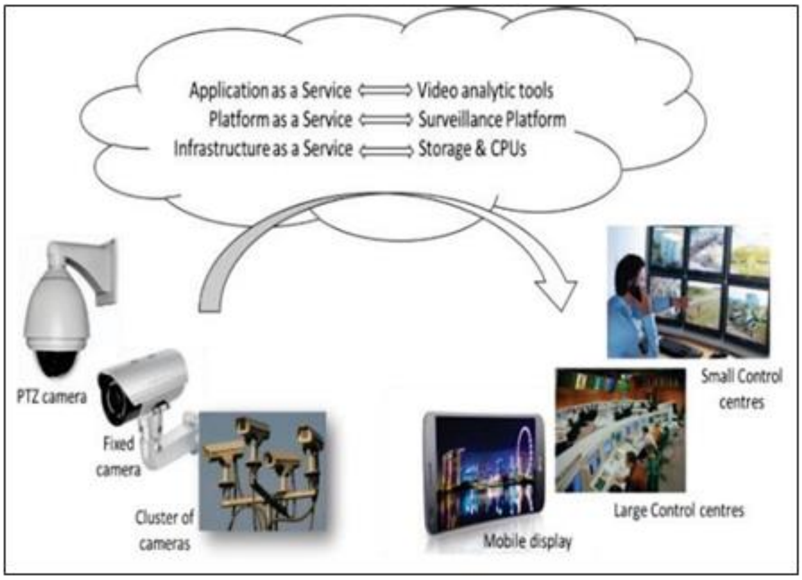

Fig. 3. Cloud-based architecture for VSaaS [3]

D. Sensor Event as a Service (SEaaS)

It provides messaging service actuated by sensor events [2]. The term SEaaSwere introduced to provide a process of making sensor events of interest available to applications and/or clients through cloud infrastructure [4].

E. Sensor as a Service (SenaaS)

Sensor primarily translates parameters like humidity, temperature, etc. into electrically measurable signals [26]. Through this service, we can control and monitor remote sensors ubiquitously using a web browser through user interface [4].

V. APPLICATION

A. Smart Waste Management

One of the major issues that modern cities are facing is waste management. It consists of multiple processes like managing and monitoring waste, transport, collection, disposal, etc. These processes are costly and time-consuming. One can optimize these processes to reduce cost, which can be used for solving other issues that smart cities can be deal with. In cities, there are many parties interested in the management of waste like recycling firms, the council of cities, safety & health-related authorities, etc. Instead of implementing sensors individually, and getting information, sensing as a service allow them to share information and bare infrastructure cost collectively. The city council uses this information to optimize garbage collection strategies to reduce the fuel cost of a garbage truck. While safety and health authorities can supervise and monitors the processes of waste management without going for manual inspection. For these activities, various sensors needed to be installed in places like trucks or cans of garbage, which can detect type and amount of garbage [5].

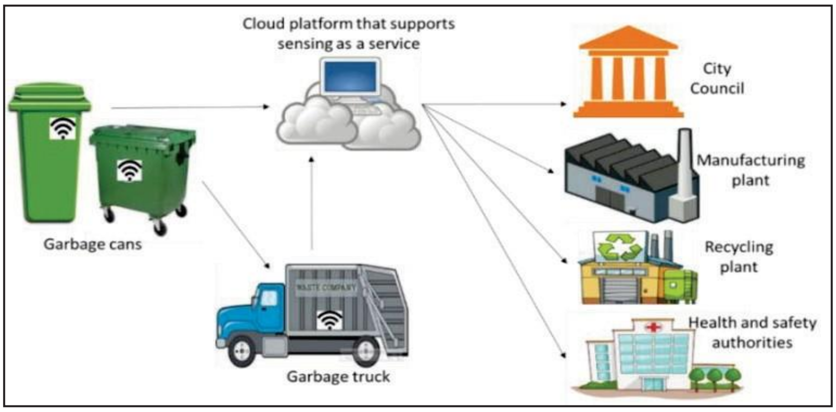

Fig. 4. Waste management using IoT

[1]. Smart agriculture

To satisfy the need for food of the ever-growing population, we should be getting the best yield out of the framing, and this can be achieved with the help of IoT. Data analytics of smart agriculture i.e., land condition, weather situation, and type of soil, collected from the IoT network can provide practical information if used in combination with data captured by sensors, which measures the level of water resources, heat, moisture, chemicals, water stress, pump status, etc. This enables farmers to utilize fertilizer, water, and pesticides in most accurate quantities, at precise positions and with effective time scheduling to improve agricultural outputs. Smarter use of water like monitoring and supervising water capacity, location, timing, and period of flow based on data analytics, helps to increase irrigation efficiency, thus resulting in lower costs. Other benefits of IoT include efficient uses of pumps, boosters, lighting, etc. It can also remotely control the working conditions, the status, and equipment performance [16].

[2]. Smart Home

To reduce user's interference in controlling and monitoring home settings as well as home appliances, smart home is an emerging application [14]. A smart home provides many features for the user like measuring home conditions (i.e., light intensity, temperature, heating, etc.), operate home's Heating, Ventilating, and Air Conditioning (HVAC) appliances and control them with reduced human interaction [22]. Paper [18] presented procedure to develop a smart home by combining IoT with cloud computing and web services, use Arduino platform for implanting intelligence in actuators as well as in sensors and facilitates interaction within smart things using cloud services.

[3]. Monitoring environmental parameters

As the environmental parameters like temperature, humidity, and moisture differ time to time and place to place. Therefore, it is become important to monitor quality level of perishable goods like dairy products, fresh-cut produce, fruits and meat, etc. during its transportation from production to consumption site. This vital task can be easily performed with sensors and pervasive computing technologies. It also improves the efficiency of the food supply chain [12].

Horizontal scalability can be referred as the potential to increase the device to work as a single logical unit by connecting multiple hardware or software entities." It can be accomplished by adding more nodes to a system, such as adding a new computer to distributed software applications [28]. For example, Cassandra runs of hundreds of commodity nodes, which help to scale out horizontally as it is spread across different data centers. Because of the commodity hardware, Cassandra does not have a single point of failure. Vertical scalability is referred as the potential to increase the capacity of the software or the existing hardware when we add more resources to it. For instance, to make it faster we can add processing power to it. It was adopted when the database could not handle large amounts of data. For example, MySQL- amazon RDS it allows vertically scaling to shift from small to bigger machine [31].

[4]. Interoperability

As the data sharing among smart devices is increasing day by day, it is necessary to manage these data transfer properly among the system [10]. Interoperability can be considered as the potentiality of two systems to communicate, exchange information, or program, or transfer the data among each other and to implement the given data [15]. It is the exchange of information among different computers through wide area networks or local area networks. It is critical for IoT as most of the communication takes place as a machine to machine [14] Interoperability is classified into multiple levels containing:

- Technical Interoperability: It potential to perform a task with the satisfactory and appropriate manner with any need of an extra operate when two or more information and communication technology application is used.
- Syntactic Interoperability: Syntactic Interoperability generally associated when we are processed to exchanged information or data and to communicate between the heterogeneous IoT systems. e.g., RDF, XML and JSON.
- Semantic Interoperability: It refers to the capability of exchanging the information, data, and knowledge that has precise meaning and encoding of this data by another system.
- Organizational Interoperability: It is associated with the capability of organizations for effective communication and transfer of information across the many other information systems, geographic

B. Weather Forecasting

To predict the state of the atmosphere for a future time and for a given location, weather forecasting is very important. Weather forecasting and monitoring consist of a collection of data, assimilation of data, and forecast presentation. Sensors at weather station used to sense humidity, temperature wind speed, the moisture of soil, the intensity of light, radiation, etc. Data coming from these sensors is huge in size and difficulty in monitoring. The integration of this sensor infrastructure with cloud increases its storage and computational capabilities. It also provides effective solutions for monitoring and presentation of data [6].

C. Health Care

Sensors of pervasive healthcare applications make use of cloud computing and IoT to allows a machine to machine communication to be done location independently [8]. Nowadays, in modern hospitals, various body sensors are used to measure and monitor physiological data of the patients. This sensitive collected data is maintained for future diagnosis of patient. In some hospitals, this data is maintained at the local database. Due to this, doctors who are called to handle critical cases unable to analyze disease. After visiting to the patient only they can give proper treatment. However, using cloud, this issue can be solved i.e., data of patients can be maintained and shared with doctors who are abroad, so that they can treat the patient, independent of location. [26]

D. Smart grid

Today most of the power supply system is manually operated, and due to some human error, there is loss of power. These small losses result in massive outrage of power supply. This loss can be brought under control, and a 100% efficient power transfer system can be designed using IoT, and it is known as the Smart grid. It is a fully automated system based on blockchain technology, which is entirely robust & encrypted. This power is divided into channels for each individual, and this channel is wholly encrypted with its stash key, which is to be decrypted. This results in an equalized power supply throughout the grid without any power loss [24].

VI. ISSUES AND CHALLENGES

A. Scalability

The growing idea of IoT which generates a tremendous amount of data for processing and storage guide to enormous leap in the forthcoming year, and hence it becomes insistent on making the scalable system. The vast application of IoT has increased the number of devices being connected to the internet; which meets the concern to consider various complications that are arising in connectivity [30]. As new technology progresses to an altogether different level, it becomes inevitable to make the device more scalable both horizontally and vertically [21].

B. Security

C. regions, and cultures [14].

As time goes to the trend of the IoT inflates the multiple interconnections and the heterogeneity of device, it possibly generates the cyber attackers. Thus the safety of the data it one of the most crucial issue, As there is an increment in the number of connected devices, there are chances of cyber- physical security vulnerabilities safety that can be exploited by various attackers [22]. An essential pillar of the internet is security, which is the major challenge of IoT. Due to incomplete data streams, the possibility of sophisticated kind of theft has been evolved lately, having the capability to create consequences disaster among people's health and safety can be risky. Furthermore, the hacking toolkits have been chiefly automated so that even a novice can execute the destructive attacks [28].

VII. BIG DATA

Different sources like the internet, social media, machine, and many other devices generate data. Thus special attention must be given for transportation, access, storage, and processing of these large sets of structured and unstructured digital data [30]. According to IBM, the volume of data on the web and internet is growing around 2.5 quintillion bytes of data, which creates 90% of the world's data created in the past two years. Handling this data with convenience is a crucial challenge, as the overall performance of the application is highly dependent on the characteristics of the data management service [8]. For processing these vast data exceptionally is a crucial challenge, as overall performance highly depends upon the data management services. Big data deals with unstructured and unconventional databases, and this treatment is not enough when the reaches petabytes or zettabytes. Recently many big organizations like Google, Facebook, Yahoo, and other startups companies today use the cloud. This cloud helps to store big data for a long time, which may be under organizations logical control, but physically reside in infrastructure owned and managed by another entity [2].

VIII. CONCLUSION

An IoT, which is among one of the popular technologies of the 21st century, which is responsible for the creation of large smart systems such as smart city, smart healthcare & smart agriculture. To allow intelligent decisions making, free communication and sharing of information, the use of IoT embed sensors, and actuators are essential. To contribute to the growing body of research on IoT, authors had surveyed and collaboratively presented current services provided by IoT, trending applications of IoT, current issues, and challenges faced by IoT technology. Authors also presented the four-layered architecture of an IoT technology.

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