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Internet of Things: Emerging Applications and Challenges

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Abstract- Internet of things (IoT) is the network of physical objects or things, embedded with electronics, software, sensors and connectivity to enable objects to exchange data with manufacturer, operator or other connected devices. This innovative emerging technology will be the integral part of our day to day life. IoT will generate an enormous amount of data at an unprecedented scale and resolution, providing humans with information and control of events and objects, even in remote physical environment. IoT is an exciting area for innovation, offering numerous challenges and applications from billions to trillions of connected devices and from Tera to Zeta bytes of data. This paper addresses emerging applications and challenges of IoT.

Index terms: IoT, Applications, Challenges.

1. INTRODUCTION

The term "Internet of Things" was coined by British entrepreneur Kevin Ashton in 1999 [1]. This technology is expected to offer advanced connectivity of devices, systems and services that goes beyond the machine-to-machine communication (M2M). It covers a variety of protocols, domains, and applications. The interconnection of these embedded devices (including smart objects), is expected to evolve the automation in nearly all fields, while also enabling advanced applications like a Smart Grid [2], and expanding to the areas such as Smart City [3].

Internet was developed to connect the people present anywhere on the globe. It was the most innovative technology created by the people, for the people. Internet is like fabric woven tightly with the life of every individual. The new technology, IoT, is going to change the world, by converting hardware into liveware. It's not about only connecting people, it's about connecting 'Things' [4].

Things, in the term 'IoT', refers to a wide variety of devices such as heart monitoring implants, biochip transponders on farm animals, electric clams in coastal waters [5], automobiles with built-in sensors, or field operation devices that assist fire-fighters in search and rescue. These devices connected, collect useful data with the help of various existing technologies and then automatically flow the data between other devices [6]. Present market examples include Smart Thermostat systems and washer/dryers that utilize Wi-Fi for monitoring from remote places.

By the use of IoT, 'Things' start to share their experience with one another as of people. Things start to sense and communicate with each other, human senses get imparted to 'Things' with IoT. It is wider area of Programmable Automation Control.

Besides the base of new application areas for Internet connected automatic processes to expand into, IoT is also expected to generate large amounts of data from diverse locations that is needed to be aggregated very quickly, thereby increasing the need to better index, store and process such data [7].

Internet of things is a set of devices and systems that interconnects real world sensors and actuators to the internet [8]. It is a dynamic global network infrastructure with self configuring capabilities based on standard and interoperable different communication protocols where physical and virtual 'things' have identities, physical attributes and virtual personalities. It use intelligent interfaces, and are seamlessly integrated into the information network.

In this paper, section 2 addresses the components of IoT system. Section 3 is about how the system of IoT works. Applications of IoT are given in Section 4. Section 5 will describe the challenges for present IoT system.

2. COMPONENTS OF INTERNET OF THINGS

Generalized system of Internet of things works with the following architecture as shown in Fig. 1. The system consists of sensors, device, LAN/WLAN/PAN, device gateway, router/switch/gateway, cloud and presentation devices.

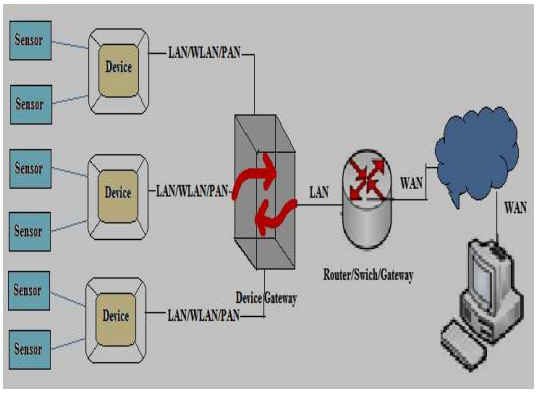

Fig. 1: Components of IoT

2.1 *Sensors*

Sensors detect or measure a physical property and transform it to some kind of electrical form. The hardware connection between sensor and device can either be digital or analog. It requires an Analog to Digital convertor in the way. The large amount of data that sensors provide is actually a significant problem in the world of the IoT. Connected devices need to be multilingual for effectively working with this big variety of sensors. The physical interface between the Sensor and Device can take on a number of different forms as I2C, RS-232/485, SPI, Analog, Dallas One-Wire.

2.2 *Devices*

Next part in the fig. 1, the device attached provides the intelligence needed to work efficiently with the data provided by the Sensor. Device supports data enrichment, which means the data from the sensor undergo translation, transformation and possibly combination with other data. This process transforms the data from bits and bytes to useful information. This can be referred as Intelligence or Behaviour, it represents the transformation from raw data into more meaningful information. The term device here resembles smartphone, remote or any other controlling equipment.

2.3 *LAN/WLAN/PAN*

From the Device to the cloud, network-type protocols are used to connect the layers together. There are a number of available protocol choices and each with its own advantages and disadvantages. For distance and speed (at the expense of power consumption), some variant of Wi-Fi (IEEE 802.11 a/b/g/n/ac) are useful. For lower range and speed but with lower power consumption (useful for battery powered devices), Bluetooth connectivity is implemented. If a hard-wired connection is desired, then Ethernet is the appropriate choice.

Lastly, if a mesh-type network is needed, choosing some variant of IEEE 802.15 (e.g., ZigBee) is logical.. The conclusion is that there is no single right choice for the selection of the network and in many cases more than one type may be used.

2.3 *Device Gateway*

In the middle of fig. 1, the Device Gateway is the aggregation device for an IoT deployment and typically has significant computation and network forming capability. In some configurations, the Gateway might connect directly to Sensors. It performs the functions as aggregate data from multiple devices, create the 'switch fabric' to route data between devices, provide or enhance security and provides additional processing, computing capability.

2.4 *Router/Switch/Gateway*

This device serves as the Gatekeeper between the in-premise network and the open Internet. Its main purpose is to divide the network into two parts; the secure/trusted network and the insecure/un-trusted network. The Network Gateway presents a number of challenges to connected Devices. For example, most of the Gateways will not allow a connection from the Cloud to a Device whereas the reverse Device-To-Cloud connection is easily supported.

2.5 *WAN*

The WAN is typically known as the Internet. It's the network connector that allows all sorts of devices to communicate over the wide spread public network infrastructure (also known as the

World Wide Web). The main attribute of the WAN is that it is not in-premise and is typically used to connect systems which are not physically close.

2.6 *Cloud*

Cloud is a third party that has processing or computing capacity. If the Cloud is private, then the hosting service is performed by the same organization using the service. Cloud is considered as the final destination for all sort of information which has been collected from the Sensors, Devices and systems. The cloud could either be a traditional cloud application like Amazon's EC2 and Salesforce.com or enterprise applications like Oracle's E-Business suite or even a database.

2.7 *Presentation Devices*

At the end, after collection of whole data, results must be displayed via dashboards. Dashboards need to be hosted on some kind of display, can be called as the Presentation Device. It could be a desktop computer, a tablet or a smart phone. It could even be a purpose-built device like a retail kiosk, intelligent vending machine or a control panel on a piece of heavy machinery or industrial equipment.

In this way, the entire system of IoT is constructed.

3. WORKING OF INTERNET OF THINGS

Working of IoT can be explained by discussing its existing applications. One of the applications is discussed here:

3.1 *Smart Parking System*

When user go downtown to any major city, it is difficult to search for an empty parking space. The smart way to work here is to connect everything to centralized database and store information in the cloud. Flowchart of system working is as shown in fig.2. When user need to park, user could login to an application that communicates where the empty spots are and through GPS could dictate where to go. A person then can pay within the application or can pay at the matter.

In detail, when the car enters in available slot, the sensor placed at that place relays the information in real time. The motorist then turns ON the timer and goes to work. After returning, timer is turned OFF. Officers at centralized hub are guided to unpaid violations, overstays, no parking and restricted zones. Finally, total amount is calculated that is to be paid by motorist. The staff receives the web based data analysis for decision making.

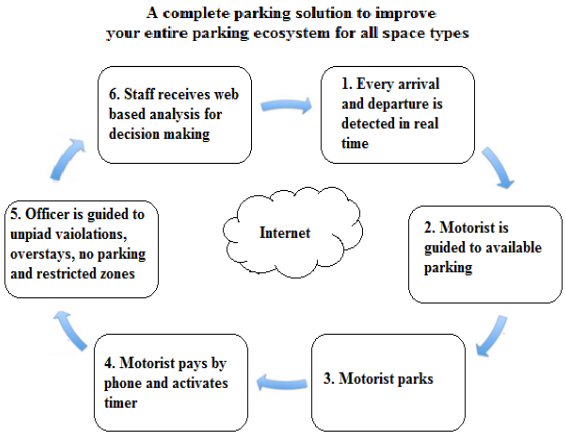

Fig. 2: Smart Parking System

4. APPLICATIONS OF INTERNET OF THINGS

IoT will develop into a wide network of a very large number of devices being connected to the Internet. According to Gartner, Inc. (a technology research and advisory corporation), there will be nearly 26 billion devices on the Internet of Things by 2020[9]. ABI Research estimates that more than 30 billion devices will be wirelessly connected to the Internet of Things by 2020[10]. An overview of some of the most prominent application areas is provided here:

4.1 *MIMO monitor*

Fig. 3: MIMO Monitor

Designed to prevent SIDS (Sudden Infant Death Syndrome), the MIMO monitor shown in fig. 3, is a new kind of infant monitor that provides parents with real-time information about their baby's heart rate, skin temperature, body position

and activity level on their smart phones. From this, parents can keep their baby under observation even from remote places.

BodyGuardian to detect health issues, reminder for medicines using Glowcaps, activity level tracking with smartphone, BeClose system for caring of elder ones, Proteus ingestible pill sensors are some other applications in health domain.

4.2 *Smart Thermostat*

Fig. 4: Smart Thermostat

Heats home efficiently. Smart thermostats in fig. 4 are used as the real-time weather and the present activity predictor in home during the day. It is helpful in reducing monthly energy usage by up to 30%. It keeps user more comfortable and offers to save money on utility bills.

WeMo device, Ninja block, HarvestGeek System, Philip's Hue lights, Cobra Tag device are the existing applications in this domain.

4.3 *Smart Belly Trash*

Fig. 5: Smart Belly Trash

It contributes in keeping street clean. Products like the cellular communication enabled Smart Belly trash shown in fig. 5 collects real time data and alerts municipal services when a bin needs to be emptied. This data can effectively reduce the number of pick-ups required, and results into fuel and financial savings for community service departments.

Echelon Smart Lighting System, Aircasting platform, Streetline's ParkSight system, SenseNET are some examples of IoT applications in City domain.

4.4 Invisible Tracck

Fig. 6: Invisible Tracck

Keeps check on deforestation. Invisible Tracck as shown in fig. 6 is a wireless device being used in pilot programs to help combat deforestation taking place in the Amazon The battery operated devices are installed on selective trees and as soon as the logged trees are in transit and are able to connect to a mobile network (Up to 20 miles range),an alert notification with location coordinates is sent to take action.

Air quality egg, Collar system for wild species, floating sensors to check quality of water, ALARMS(Assessment of Landslides using Acoustic Real time Monitoring Systems) are applications of IoT in environment domain.

5. CHALLENGES FOR INTERNET OF THINGS

IoT can be broken down into four major layers as shown in fig. 7. Sensors collect data, communication units convey the information collected, computing units analyze the information, and service layers take action [13]. Challenges for IoT lie in these four layers. So here, challenges are discussed layer wise.

Layer	Challenge
Service	• Machines should work for people robustly • Standards must be developed to fasten innovation in IoT
Computation	• Answers should be computed timely and accurately • Intelligent computations must be incorporated in device and cloud
Communication	• The large number of stationary and moving devices need to be

	served with quality communication services • Complete data security and privacy is to be assured
Sensors	• Low power sensors are to be deployed • "Zero touch" to in-field sensors

Fig.7: Major Layers and Challenges for IoT

5.1 *Challenges at Sensor Layer*

In few years, enormous numbers of sensors will be used. The costs of servicing and maintaining such large number of sensors will be a major expense. Hence, one challenge is usage of sensors that requires easy installation and minimal or even zero effort to be used and maintained. It is often complex, almost impossible to replace batteries of in-field sensors. Hence, next challenge is designs which do not require a battery change over the lifetime of the sensor or a low power sensor.

5.2 *Challenges at Communication Layer*

After the collection of the data by sensors, the next step is to communicate the collected information. Most of the sensors are likely to be connected wirelessly through Bluetooth, WiFi, or cellular networks. Connecting the growing number of 'Things' is a huge challenge. When there are too many simultaneous users for single base station, some users will not receive quality service. Similarly, as the number of devices connected grows, so security and privacy issues are more serious. Connected devices (sensors) can produce oceans of data. Also, we need layers of intelligence to transform oceans of data from machines into wisdom. Hence, analysis of data and its context will play a key role in establishing IoT.

5.3 *Challenges at Computation Layer*

Producing accurate and timely answers is the toughest challenge. Addition to it, many analytic approaches presume that all the required data is to be sent at the server. However, it takes additional power and bandwidth to communicate each time to the server. As M2M devices become more active, intelligent computation need to be distributed across connected devices and cloud. Intelligent computation involves selection of which data is important at what time according to the context. Through this, misuse of bandwidth and energy is avoided.

5.4 *Challenges at Service Layer:*

At final stage, machines should either solely take proper action or instruct humans to do so. Moreover, to build an efficient IoT surrounding, it is necessary to have unified standards for everyone to follow. But, major standards are still to be developed and many emerging applications are using their own separate, non-compatible standards. Existing solutions and technology is appliacble to a single application. These different technical solutions and standards are slowing the growth of the global IoT market.

6. CONCLUSION

As growing numbers of devices are connected to the internet, IoT will transform the way we live, play, and work. It is an effective technology which can convert our planet to 'Smart Planet'. IoT has wide applications in our day to day life providing us a helping hand to transform our life to 'Smart Life'. IoT is just like a 'Diamond', as we rub diamond more and more, it becomes radiant. Similarly, as we enhance IoT further, it opens more and more avenues before us and become more radiant which light up all the corners of human life. Challenges before IoT itself turns into many research and development opportunities. This paper highlighted the emerging applications and challenges of IoT.

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