Internet of Things (IoT): A Vision of Any-Time Any-Place for Any-One

Abstract

In today's world, Internet is playing a major role in fetching information from various sources. Smart devices generate valuable information and are widely available because of development in advanced protocols and cheap electronics. Manufacturers are developing smart devices keeping in mind that, in near future, these devices will have connectivity to external world for communication. It appears that in coming years, we all will be surrounded by these smart devices. To achieve the vision of connecting the smart devices for better communication, Internet of Things (IoT) has gained lot of attention. The authors are introducing various segments of IoT based on application and communication technology. The authors have described architecture and basic building blocks of IoT enabled devices followed by two applications. It is demonstrated that how IoT plays an important role in the field of healthcare application e.g. patient monitoring and connected car. In healthcare application, it is shown that how wearable devices play a key role in monitoring various medical parameters. Authors introduce the concept of connected car and the role of IoT in connected car. This will help the academic researchers in understanding and implementing the IoT not only in described domains but can also be applied in other domains as well.

Keywords: IoT; Connected car; Wearable sensor; Health care; Wireless

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Nitin Gupta* and Jyoti Gupta

CPA Global,IP Lead, India

***Corresponding author:** Nitin Gupta, CPA Global, IP Lead, India, Tel: 9891960129; Email: nitin_ias@yahoo.co.in

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Introduction

The term Internet of Things (IoT) was authored more than ten years back by industry scientists yet has risen into standard general visibility just all the more as of late. IoT speaks to a general idea for the capacity of smart devices to sense and gather information from our general surroundings, and after that impart that information over the Internet where it can be prepared and used for different fascinating purposes. Therefore, the IoT vision enhances connectivity from "any-time, any-place" for "any-one". Some also use the term industrial Internet interchangeably with IoT. Typically, IoT is required to offer propelled network of advanced devices, services, and protocols that goes beyond device-to-device communications. Due to the omnipresent nature of connected gadgets in the IoT, an uncommon number of gadgets are required to be joined with the Internet. According to Gartner, there will be nearly 26 billion devices on the Internet of Things by 2020 [1]. Integration of such gadgets/devices with the Internet will utilize an IP address as a unique identifier. However, due to the limited address space of IPv4, connected devices will have to use IPv6 to accommodate a large range of devices on the network. Therefore, for successfully developing the IoT in the future IPv6 will play a major role. The IoT is characterized in distinctive ways, and it includes numerous parts of life from connected homes/ cities to connected cars and streets to gadgets that tracks the individuals. Consider your own household and a number the quantity of cell phones, quantity of windows, entryways, electrical outlets, lights, machines, and AC units you have. You'll rapidly see why the IoT business will surpass the cell telephone market, at least in the western world [2].

The following are the example applications under consideration:

a. Machine-to-machine communication
b. Remote monitoring of patients for providing real-time treatment
c. Real-time monitoring of vehicles
d. Tracking goods on the move
e. Automatic traffic management
f. Remote security and control
g. Environmental monitoring and control
h. Home or building automation

As IoT is going to be a need of almost majority of IT/industrial domains, it is now important to get familiar with basic concepts of IoT. Further, it is also required to understand how IoT is going to be applied in different domains. Existing literature work lacks in describing the use cases of IoT. To fill this gap, the authors are introducing two of the use cases from the domain of healthcare and automobile sector. The authors have also described certain challenges/issues in implementing the IoT based applications. This will help the academic researchers in understanding and implementing the IoT not only in described domains but can also apply in other domains as well. This article provides an overview of IoT applications in different fields and is organized as follows. Section II provides IoT market for different domains like automotive, building automation, wearable etc. Section II also introduces various protocols used in the IoT based applications. Section III provides basic components used in building an IoT based solution followed by the architecture described in Section IV. Section V, the main theme, describes two applications i.e. uses cases of IoT in healthcare and connected car domain followed by the conclusion in Section V.

IoT Market Segmentation, by Application and Communication

As per the report by "Markets and Markets" research and consulting firm [3], IoT is categorized into five major segments. However, there may be some other segments like Agriculture which is not shown in the Figure 1 below. On the other hand, technology-based segmentation includes wired and wireless technologies as shown in Figure 2.

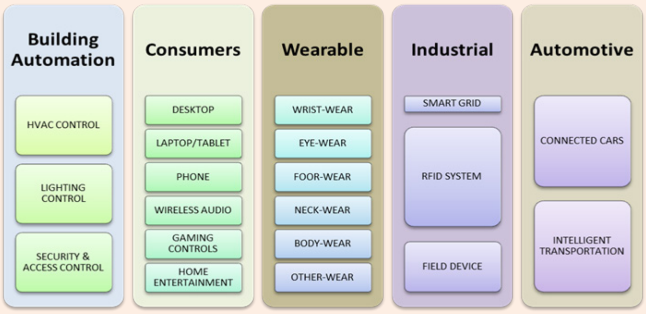

Figure 1: IoT market segmentation based on applications.

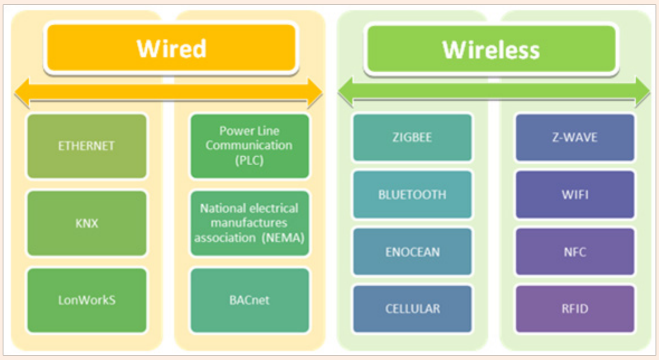

Figure 2: IoT market segmentation based on communication technology.

A number of significant technology changes have come together to enable the rise of the IoT. These include the following [4].

a. Cheap sensors and Cheap processing – Price of the sensors and processing hardware has gone down significantly now days.

b. Cheap bandwidth – Because of competition in ISPs, the price of bandwidth has also decreased. In most of the countries, wireless connectivity is available for free or at a very low cost.

c. Smart phones – Smart phones are also available in reasonable cost. Therefore, these smart phones play the role of a gateway to the external world and also serve as a remote control for the connected home, connected car, or the healthcare devices.

d. Big data – Once all the devices are connected, the IoT will generate huge amounts of unstructured data for further processing. Thanks to big data analytics that helps in processing such a huge data and is a key enabler for processing IoT data.

e. IPv6 – Most of the IP networking devices support IPv6, the newest version of the Internet Protocol (IP) standard that is intended to replace IPv4. IPv6 can support 128-bit addresses, an almost unlimited number that can handle all the IoT devices.

Functional Building Blocks Of IoT-Enabled Device

Any IoT enabled device comprises following three components as shown in Figure 3 [4]:

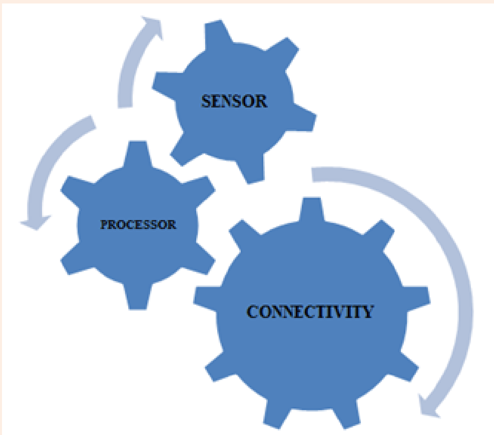

Figure 3: Components of an IoT device.

Sensor unit: Low power nano-scale sensors are the fundamental empowering influencer of IoT acknowledgment through the uniqueness of ID, small size, sensing, and fast processing. However, energy management is still a major challenge towards the adaptation of such sensors.

Processor unit: Processor/microcontroller for processing the collected data from the sensors. Embedded processing is the primary and important function for an IoT device. The processing unit helps in processing the sensed data and converts it into some useful information so that it can be consumed easily while transmission.

Connectivity: After sensing/collecting and processing of data, connectivity interface sends the data to a remote location. Basically, the connectivity is a kind of bridge (e.g. gateway/router) between the internet and the device that helps the users in getting connected with the device at anytime, anywhere.

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Architecture of IoT

The IoT architecture from a technical perspective is divided in to three layers [5] and is summarized as follows:

Perception layer: This layer identifies the objects and gathers information using the sensors mounted on the objects. For example, to give directions to a blind man, the sensors mounted on the smart stick held by the blind man senses the obstructions and send the sensed data to the network layer. Therefore, this layer collects data using sensors and is the critical drivers for IoT based applications [6]. There are varieties of sensors used in IoT applications. The most common sensor available today is the user's smartphone because the smartphone itself consists of many sensors embedded like GPS, Gyroscope, Accelerometer, Camera, Ambient light sensor, and magnetometer etc. Applications can use these sensors in gathering data for analysis purposes. Apart from Smart phones lot of other sensors are also used for measuring temperature, pressure, humidity, biological parameters of the body etc.

Network layer: This layer consists of a network made up of wired/wireless components with internet connectivity. Its main function is to receive information from perception layer and transmit information to the application layer. Network layer is similar to the Network and Transport layer of OSI model. The network layer comprises gateway nodes and an access network, wherein the gateway nodes collects data from Perception layer and provides it to the access network. The access network may consist of a power fiber-optic network or a broadband wireless access networks. Overall the Network layer is also responsible for routing the packets received from the Perception layer.

Application layer: This layer comprises applications or frontend user interfaces for processing the received information from network and perception layer as per user need. Considering the blind man example above, the information can gathered from the sensor can be utilized to convert it into sound or map that can be delivered back to the blind person for his/her guidance [7]. Application layer is mainly responsible for data formatting, presentation, and making decisions. The application layer in the Internet/digital era is typically based on HTTP. Constrained Application Protocol, aka CoAP, is also used as an alternative to HTTP and is used in most IoT applications [8,9]. CoAP uses the "Efficient XML Interchanges" data format, which is more efficient in terms of space as compared to plain text HTML/XML. Message Queue Telemetry Transport/MQTT [10] is another protocol commonly used by applications and is based on publish/subscribe theme. The clients act as a publisher/subscriber and the server acts as a mediator/broker to which clients connect. Clients can publish or subscribe to the information of need. MQTT is a lightweight protocol and is most suitable for IoT applications.

Few Applications of IoT

Patient monitoring

Prior to smart sensors, medical professionals/doctors were dependent on manual tasks for diagnosing the root cause of a medical problem [11]. The patient has to go through some medical tests for determining physiological parameters like glucose level, temperature, blood pressure, ECG etc. in a pathology laboratory (lab). After testing, the lab technician prepares a report which is further verified by a pathologist doctor and gives the report to the concern doctor. The doctor, after looking at the patient history, examines the medical report to give the treatment to the patient. This process of diagnosing the root cause appears to be a time consuming method and lot of manual inputs are involved. Considering such manual tasks, smart sensors have been developed and are widely used in WSN to make the diagnosis and treatment faster with more accuracy. IoT play an important role in monitoring and diagnosing the patient's health. Healthcare professionals want real-time, reliable, and accurate diagnostic results provided by devices that can monitor the patient wherever the patient is located. Communication technologies like RFID, NFC, or Bluetooth can be used for monitoring health parameters like blood pressure, ECG, glucose, temperature etc. Figure 4 shows an example of health monitoring using wearable sensors like Blood pressure sensor, ECG sensor, and motion sensor.

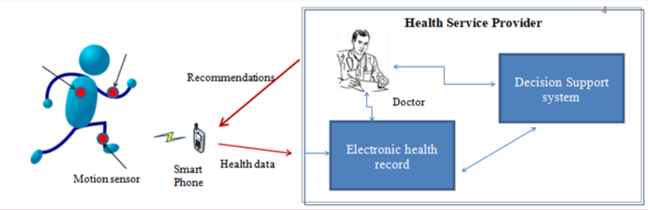

Figure 4: Health monitoring with wearable sensors.

Data from all the sensors is collected by the user's smart phone and is further sent to the healthcare service provider for further analysis and recording in a health record. The doctors can analyze the collected data and uses decision support system to give recommendations to the user remotely. Such remote monitoring was possible only because of wearable electronics. There are pluralities of sensors that are being widely used in monitoring the health/wellness of the user. Broadly these sensors are divided into two categories:

a. Environmental sensors that mounted in the surrounding environment and are not in direct contact with the user.

b. Wearable sensors that are in contact with the user. Such sensors are mounted either directly on the user's skin or being worn by the user on their clothes.

Further the wearable computing has changed the dimensions and given a new life to healthcare sector. Wearable vendors like Sony (SWR10), Lenovo (SW-B100), Garmin (Vivo Smart), Samsung etc. are manufacturing Smart wearing devices called as Bands for monitoring the health status of a person [12-14]. These are basically wristbands worn by the user and have the ability to connect with a smart phone via Bluetooth.

Every Smart Band has the following components similar to a smart sensor device:

a. A set of interconnected sensors for monitoring various medical parameters like heart rate, temperature, blood pressure, glucose, SpO_2 etc.

b. A small display for displaying the measured parameters to the user.

c. A processor for processing the measured sensor data.

d. A rechargeable thin battery for power supply.

e. A communication interface like an antenna.

f. An antenna for wirelessly transmitting the processed data to a smart phone or remote location.

The main advantages of the IoT that the healthcare segment can take are described below:

a. Cost: Due to better connectivity, patient can be monitored remotely on real-time basis and thus avoids unnecessary visits of doctors.

b. Better diagnosis: Again due to better connectivity, the real-time patient information gathered from remote locations can be utilized by doctors and intelligent/analytics software for recommending a better treatment.

c. Better patient experience: Proactive suggestions, timely intervention by doctor/nurses and enhanced treatment inculcates high trust among the patients and enhances overall patient experience.

Connected car

With connected car concept, users can communicate with cloud based applications for

a. Pulling on demand songs;

b. getting navigations in real-time;

c. talking to vehicle experts in case of diagnosing the faults;

d. Getting traffic conditions in advance.

The connected car concept uses various technologies like Mechatronics, telemetric and artificial intelligence to provide greater safety, comfort, entertainment and, importantly, a “connected-life” experience. The concept makes the car as a mobile internet (information hub) with built-in intelligence to satisfy the user needs on the road as shown in Figure 5. Connected car platform enables gathering data collection from different vehicle sensors and analytical capabilities.

The data collected by the connected car platform can be categorized into following three types:

a. Behavioral Data: Connected car platform gathers information related to speed, braking inputs to determine driver’s fatigue level etc. Driving behavior data helps the user to adopt fuel efficient driving and also helps in calculating risk by insurance companies.

b. Diagnostic Data: Accessing vehicle’s data remotely, car manufacturers or service providers can fetch the health of user’s car and provide feedback in-terms of voice communication to inform users when service/maintenance is required.

c. Contextual Data: Connected car platforms, using contextual data of user with geo-location data, speed limits on roads, real-time traffic flow conditions, provide valuable recommendations to the user for better experience. Using the contextual data, the platform enables providing targeted advertisements and in particular offering more personalized advice to car users.

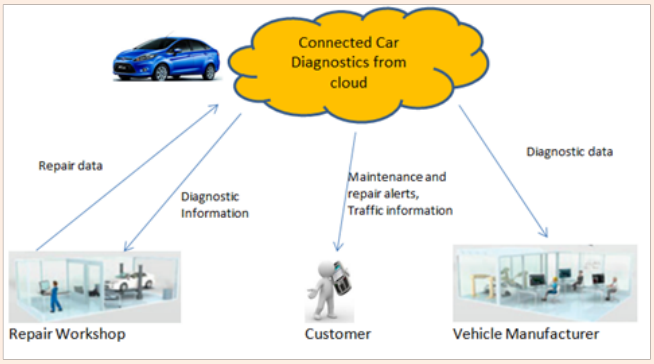

Figure 5: Concept of connected car.

Examples of connected-car functionality include:

a. Whenever the phone rings in the car, the music of the car should go silent automatically so that the driver can talk without any disturbance.

b. When car is approaching a traffic area, the navigation mechanism should provide a warning ahead of time and destination.

c. When the car transmits data for remote maintenance, the mechanic can call the driver for suggesting the diagnostic solution.

There are plurality of automotive vendors which are providing IoT client software development kits (SDK) that can be seamlessly embedded into different kinds of automotive hardware to provide numerous smart features and connectivity into the basic design of a car. This helps the automotive industry in enabling end-to-end fleet management and vehicle health & telemetric solutions. Some of the other applications enabled by IoT for automotive sector are listed below and Table 1 shows a detailed application canvas of IoT application in automotive segment [9-12].

a. Real-time car telemetric tracking

b. Vehicle location tracking and scheduling solutions

c. Fuel tracking

d. Speed control

e. Vehicle usage analytics

f. Car leasing solutions

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g. Fleet and driver management

h. Traffic management, workload management

Therefore, with the help of IoT enabled connected cars, the automotive vendors can help cities and states to cut down congestion on roads, improve safety, and provide quality services to the users. Further, on the road, cars will talk to each other, automatically transmitting data such as speed, position, and direction, and send alerts to each other in case of a crash.

Table 1: IoT enabled application canvas in automotive field.

Navigation	Entertainment	Remote Applications	Electric Vehicle	Safety
Get directions on maps in real time		Remote door lock/ unlock	Nearest charging station	Speed, distance advice
Congestion/Accident	Play Music, Videos	Remote Appliance Management	Scheduling a Charging slot	Traffic Sign Violation Warnings
Alerts/Re-routing Weather/ Road Condition Alerts	Internet radio, Social Networking, Chat	Car Tracking	Estimate driving range	Car breakdown warning
Preferred Routes within city / Parking Guidance	Personalization, Internet Services	Theft Alerts	Battery Charge Status	Automatic call for assistance in the event of a crash
			Carbon footprint	

Vehicle Management	Fleet Management
Maintenance notification alerts to individuals	Tracking and tracing, delivery notifications
Remote diagnostics	Optimal routing and journey management
Driver performance analysis	Alerts and reports
	Fuel/energy management
	Resting time violation

Considering lot of advantages of IoT based applications, there exists some other challenges/shortcomings as well which have been summarized below [19-21]:

a. Security: Preserving the privacy of an identity like a patient, or a vehicle etc. appears to be a main concern while monitoring the parameters from a remote location. For example, for evaluating prosperity states of old aged people who are living alone, the sniffed sensor data can expose the privacy data to the attackers. Using sniffed activities of the old aged people, the attacker can plan for theft in a particular period of time. Therefore, privacy data sent by the sensors to the remote locations should be encrypted properly to avoid man in middle attack.

b. Interoperability: WSN based healthcare applications, or automotive solutions etc. comprise sensor devices and software from different vendors. This creates a big mesh/ existence of multi-vendor heterogeneous devices and causes a problem of interoperability. This is because devices/ software purchased from a particular manufacturer does not operate with the solutions of different manufacturer.

c. Bandwidth: In coming years, bandwidth is also going to be a major concern because the healthcare and automotive segments are growing at a faster pace. In healthcare applications, e.g., when a large set of sensors transmit huge amount of data, it may cause congestion in the WSN network and may result in loss of real-time information.

d. Communication protocols: There exits plurality of communication protocols like Wi-Fi, ZigBee, Bluetooth, NFC, etc. Selection of an appropriate protocol is equally important for a particular application. For example, sensors belonging to EEG, EMG, and ECG produce data at a high rate, whereas body temperature sensor blood pressure sensors generate data a low rate. Therefore, considering pros and cons of these communication protocols, appropriate protocol should be selected for healthcare applications. A summarized list of communication protocols commonly used in IoT applications is provided in Table 2 [22].

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Table 2: Communication protocols used in IoT applications.

Technology	Range	Data Rate	Frequency	Applications
Zig Bee (802.15.4)	10-100 m	250Kbps	2.4GHz	Healthcare, Home Automation, and Industry
Bluetooth (802.15.1)	10 m	1-3Mbps	2.4GHz	Healthcare, wireless headsets and mobile phones
Wi-Fi (802.11)	30m-200m	54mbps	2.4GHz	Healthcare, Broadband, internet access, and building automation
NFC	<10 cm	424Kbps	13.56 MHz	HealthCare Payment access
RFID	<1 m	640Kbps	13.56MHz-900 MHz	HealthCare, Inventory access and tracking

Conclusion

With IoT concept, in near future, all digital objects will be connected to everywhere at any time. Users, service providers, manufacturers, will be able to communicate easily because of better connectivity. The authors presented IoT applications in health care domain and connected car domain along with market segmentation. IoT is just a beginning in this digital era to make our life better. Authors are working on applying artificial intelligence techniques on IoT data for making predictions in the domain connected car and healthcare applications.

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