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The Internet of Things: Vision, Architecture and Applications

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ABSTRACT
The domain of the Internet has extended from computers to different types of heterogeneous and homogeneous sensors leading to connectivity of almost everything and making it smart. This has resulted in the development of Internet of Things (IoT). This paper attempts to give a brief description of the IoT system, its general architecture, the different layers of IoT architecture and the technologies used for the development of an IoT System. The main objective of the paper is to give recent advances in applications of various types in different domains. The application domains covers are Home Automation, Healthcare Sector, Smart Parking, Agricultural Areas, Wearable Devices and Fleet Management.

General Terms
Internet of Things (IoT), Wireless Sensor Network (WSN).

Keywords
Internet of Things (IoT), Radio Frequency Identification (RFID), Wireless Sensor Network (WSN), Raspberry pi, Arduino, Intelligent Transport System (ITS), Home Automation System (HAS), Global Positioning System (GPS)

1. INTRODUCTION
The information on the internet was accessible by the World Wide Web, a network of linked HTML (Hyper Text Mark-up Language) documents that resided on system which were located at the top of the Internet architecture. Technologies in Sensor Networks and Near Field Communication using RFID (Radio Frequency Identification) tags have also been evolving along with the developments in the Internet technologies. Fusion of these two technologies is leading to new possibilities and visions. These possibilities of a framework that would permit direct machine-to-machine (M2M) communication over the Internet has encouraged researchers to visualize the profits of bringing more and more machines online and permitting them to participate in the web as a vast network of autonomous, self-organizing devices. This vision has given birth to a prototype being referred to as Internet of Things [1].

The IoT (Internet of Things) represents a distributed network system of the real world devices and technologies as well as the interconnection of networks of these devices across the Internet. Ultimately, IoT devices will be ubiquitous, context-aware and will enable ambient intelligence [1]. This has contributed to the growth of new opportunities for the Information and Communication Technology (ICT) sector, by presenting a way to new services and applications able to leverage the interconnection of physical and virtual realms [2].

Cisco works on the IoT under the label, “the Internet of everything,” which it defines as “Bringing together people, process, data and things to make networked connections more relevant and valuable than ever before, turning information into actions that create new capabilities, richer experiences and unprecedented economic opportunity for businesses, individuals and countries”[3].

The Internet of Things has revolutionized the future of computing and communication with the idea of anytime, anywhere connectivity for anything. Even in the preliminary stage of evolution, the Internet of Things has transformed the way corporations and consumers interact with each other and the surroundings. This innovation has led the embedding of electronics into everyday physical objects, and making them ‘‘smart’’ such as Smart Wearable, Smart Cities, Smart Grid, Smart Parking and Smart Home.

A typical IoT framework may involve a network of Internet-enabled and real-world objects such as nanotechnology, consumer electronics, various sensors, embedded systems, home appliances and personal mobile devices. It also includes communication technologies such as IPv6, web services, RFID, and mobile networks. Sometimes services required for an IoT application may need support from other systems or platforms such as cloud computing platform and networking platform.

The influence of IoT is shown in Figure 1 and summarizes as follows:

a. People: More 'things' can be monitored and controlled - People will become more capable.
b. Process: More users and machines can collaborate in real time - More complex tasks can be accomplished in lesser time.
c. Data: Collect data move frequently and reliably - Results in more accurate decision making
d. Things: Things become more controllable- mobile devices and things become more valuable.

The Internet-of-Things vision provides a large set of opportunities to users, manufacturers and companies. In fact, IoT technologies will find wide applicability in many productive sectors including, e.g., environmental monitoring, health-care, inventory and product management, workplace and home support, security and surveillance.

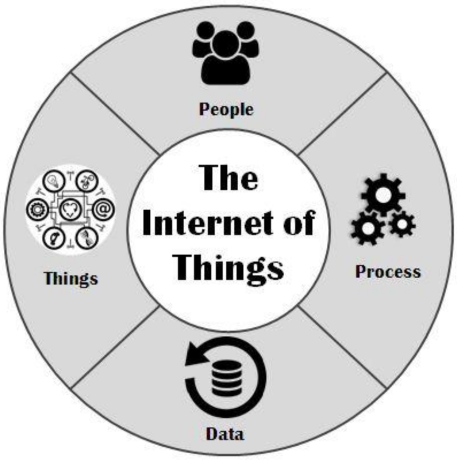

Figure 1: Basic Internet of Things

The rest of this paper is organized as follows: Section 2 and 3 provide the History and Basic IoT system. In Section 4 different architectural layers of IoT are discussed. Section 5 gives the brief summarization about fundamental IoT technologies. In section 6, we present the applications according to different domain areas and some research work done. And in section 7, challenges are described. Lastly we have concluded this paper.

2. HISTORY

The Internet of things is an integration of various components such as sensors, embedded systems and communication technologies. Hence the evolution of IoT is dependent on contribution of these technologies. In 1999, a British technology pioneer has first introduced the concept "The internet of things" [4]. He described the IoT technology as how IoT would change human lives by connecting the devices and people to internet. He has also considered RFID as a prerequisite for IoT applications [5]. This is because IoT network requires everyday objects connected together, and this needs to be achieved in simple and cost effective manner. Therefore RFID is an optimal solution to this in a way that, it can be attached to every object and are also cheaper. Further in 2004, IoT has seen significant transformation in terms of interconnecting physical world to the virtual space. This interconnection envisioned the development trends of the IoT. By the year 2013, the Internet of Things had evolved into a system using multiple heterogeneous and distributed technologies and devices.

Amongst all the technologies involved into a typical IoT network, sensors play an important role of collecting data from physical things. Sensors are able to collect data from environment such as vibration, temperature, pressure etc. Hence, this Embedded Intelligence into things themselves can improve the information processing capabilities and the power of network [6]. These sensors when connected in a network forms a Wireless Sensor Network (WSN). Recent advances in semiconductor, networking technologies and sensors are driving the ubiquitous deployment of large-scale wireless sensor networks. Like many advanced technologies, the origin of WSNs can be seen in military and heavy industrial applications. The first wireless network was the Sound Surveillance System (SOSUS), developed by the United States Military in the 1950s to detect and track Soviet submarines. Governments and universities eventually began using WSNs in applications such as air quality monitoring, forest fire detection, natural disaster prevention, weather stations and structural monitoring [7].

Hence convergence of these technologies forms the IoT system which will provide number of applications to humans and machines to interact.

3. BASIC IOT SYSTEM

The building blocks of IoT [Figure 2] can be described as follows [8].

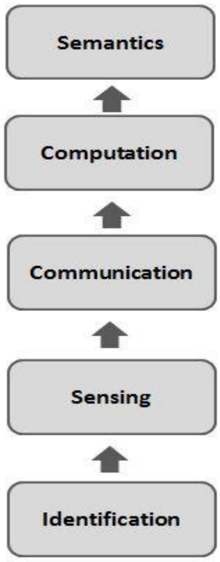

Figure 2: Basic IoT System

3.1 Identification

The IoT includes vast numbers of heterogeneous objects. Objects can be identified in two ways object's identity and its address within the network. Since identification methods are not globally unique, distinction between those object's identification and address is necessary. So, addressing schemes such as IPv6 and IPv4 helps in uniquely identifying objects within the network. Some of the identification schemes are like EPC (The Electronic Product Codes) and QR Codes.

3.2 Sensing

Sensing in IoT means gathering information from related objects within the network and sending it to a database, data warehouse or cloud. The gathered information is analyzed to take specific actions based on specified services. There are two ways objects can be interfaced with the physical environment, first is passively, i.e., performing sensing operations, and second is actively, i.e., performing actions. The IoT sensors include different smart sensors, actuators or wearable sensing devices.

3.3 Communication

In IoT, the communication technologies plays important role of connecting heterogeneous objects together to provide specific smart services. These objects are expected to deliver very diverse capabilities from the communication and computational viewpoints. These management about such a large amount for heterogeneity shall be supported at both architectural and protocol levels. Examples of communication protocols for the IoT include Wi-Fi, Bluetooth, IEEE 802.15.4, Z-wave, and LTE-Advanced.

3.4 Computation

Processing units such as microcontrollers, microprocessors and software applications represent the "brain" and the computational ability of the IoT. Some of the hardware platforms that were developed to execute IoT applications are Arduino, Raspberry PI etc. Similarly, various software platforms are employed to deliver IoT functionalities. Since it uses a variety of devices, requirements of such a network are too different to be fulfilled by a typical or a traditional operating system that is used for sensors. Operating Systems are essential as they need to be active to run for the whole time of devices. There are numerous Real-Time Operating Systems (RTOS) that can be utilized for the development of RTOS-based IoT applications.

3.5 Semantics and Data Management

In the IoT, Semantic alludes of the ability to extract knowledge cleverly by various machines to deliver the required services. Knowledge extraction incorporates discovering and modeling information using resources IoT will be significantly regarding about exchanging and analyzing immense amounts of data. So as to make this data useful information and to ensure interoperability along with different applications, it is required to furnish the data ample and standardized formats, models and semantic description of their content (meta-data), using well-defined languages and formats.

4. IoT ARCHITECTURE LAYERS

In this section, different layers of IoT Architecture are presented. These layers represent the organization and structure of various components and how they function effectively.

There are 4 major layers as shown in the Figure 3:

1) Sensors & Devices Layer
2) Communication Gateway and Network Layer
3) Service Management Layer
4) Application Layer

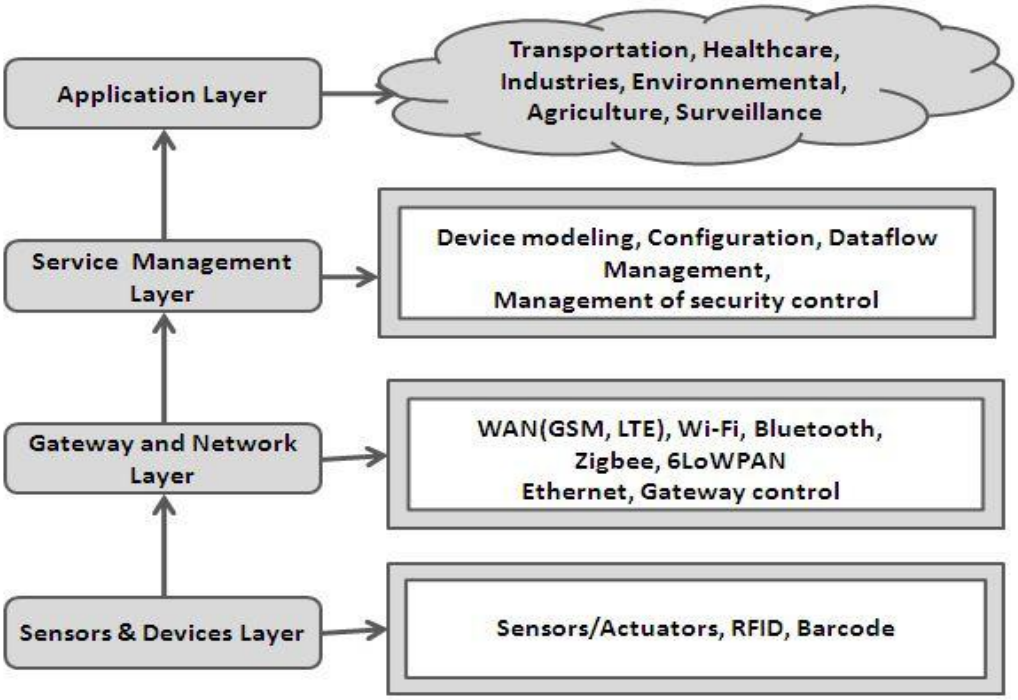

Figure 3: IoT Architecture Layers

4.1 Sensors & Devices Layer

This layer represents the physical sensors of an IoT application that aim to collect and process the information. This layer includes sensors and actuators such as GPS (Global Positioning System), RFID, solid state, Infrared, Photoelectric to perform different functionalities such as querying location, temperature, weight, motion, vibration, acceleration, humidity etc. These different types of sensors are networked together via LAN (Local Area Network) and Wi-Fi (Wireless Fidelity). Sensors use low power and low data rate connectivity and the network formed by them is referred to as WSN (Wireless Sensor Network). Sensors are grouped according to their purposes and data types. For e.g. environmental sensors, body sensors, home sensors etc. The information collected from sensors is then passed to Network layer for its secure transmission to the information processing system.

4.2 Communication Gateway and Network Layer

Gateway Network Layer must support the huge volumes of IoT data produced by wireless sensors and smart devices. Network models should maintain the Quos requirements regarding network devices' communication for error, portability, scalability, bandwidth and security while achieving high levels of energy efficiency. This layer securely transfers the information from sensor devices to the information processing system. The transmission medium can be wired or wireless and technology can be 3G, Wi-Fi, Bluetooth, ZigBee etc. depending upon the sensor devices. Thus, the Network layer transfers the information from sensor connectivity layer to Service Management Layer [9]. This Layer includes Gateway and their networks such as WAN, Micro-controller, Radio Communication Module, Single Processor and Modulator, Access Point, Embedded/OS, SIM Module.

4.3 Service Management Layer

Service Management layer pairs a service with its requester based on addresses and names. This layer enables the IoT application programmers to work with heterogeneous objects without consideration to a specific hardware platform. Also, this layer processes received data, makes decisions, and delivers the required services over the network wire protocols. This layer is responsible for the service management and has link to the database. It receives the information from Network layer and store in the database. It performs information processing and ubiquitous computation and takes automatic decision based on the results. There are various management services such as Device Modeling, Configuration, and Management, Dataflow Management, Security Control.

4.4 Application Layer

The application layer provides content services for its different users. This layer mainly focuses on providing high-quality smart services for achieving customers' needs. Applications can be classified based on the type of network availability, size, coverage, heterogeneity, business model as well as real-time or non-real-time requirements. The complexity of application layer depends on the number of users involved in it. For an instance consider any individual or home application where there are limited number of users, application layer needs to be focused on something appropriate for this application. Similarly, at an enterprise level, the scale of a community is much larger so the layer needs to be focused on the different characteristics of enterprise domain services

5. IoT TECHNOLOGIES

The IoT is facilitated by the latest developments in RFID, various smart sensors, communication technologies and standards, and Internet protocols. Like any other systems, IoT is also an integration of several technologies. The combination of hardware, software and architectures are responsible to build any IoT system. Following are some IoT enabling technologies categorized on the basis of their service type.

5.1 Radio Frequency Identification (RFID)

RFID Radio-Frequency Identification is a short range communication technology. RFID systems [Figure 4] consist of a reading device called a reader, and one or more tags which communicate with reader via radio-frequency electromagnetic fields. RFID chip holds different type of information. The reader is a powerful device with ample memory and computational resources. RFID tags can be of three kind's active, passive and semi-passive/active. Passive tags have limited computational capacity but they do not battery. Semi-passive tags have an on-board power source through which they get powered. Active tags are battery powered and have high computational capacity. The RFID reader transmits a query signal to the tag and receives reflected signal from the tag. Antenna on RFID model is used to receive energy that is used to operate the RFID device and transmit information back to the reader device. It enables efficient management, tracking, monitoring of processes.

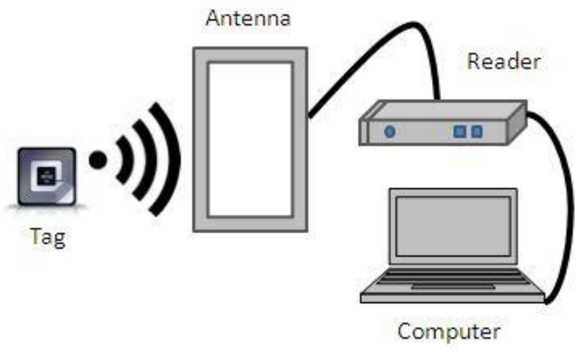

Figure 4: RFID Scenario

5.2 Near Field Communication (NFC)

NFC is a short-range communication standard that is very similar to RFID. In NFC devices are able to engage in radio communication with one another when touched together or brought into close proximity to one another. The NFC tag contains a Unique Identification (UID) that is associated with the tag. The NFC technology is commonly integrated into smart phones for exchanging data with one another when found in the vicinity.

5.3 Wireless Sensors Networks (WSN)

A sensor network has a very fundamental role in IoT. Sensors are devices that monitor characteristics of the environment or its objects such as temperature, movement, and humidity. Sensor networks typically have number of sensing nodes communicating in a wireless multi-hop manner interacting with each other. Hence they are referred to as Wireless Sensor Networks.

A wireless sensor network may also contain a gateway that collects information from other sensor devices. There are several application scenarios for the usage of sensor networks such as environmental monitoring, e-health, intelligent transportation systems, military, and industrial plant monitoring. The key challenges in WSN in terms of number of nodes are energy efficiency, scalability, reliability and robustness [10].

5.4 IoT Cloud Computing Platform

For delivering advanced IoT services, IoT networks may need to analyze and process the collected information. The IoT consists of objects, sensor devices, and communication infrastructure, computational and processing unit that maybe placed on cloud. Due to this, the big data collected can be processed in real-time, and ultimately for end-users to benefit from the useful information extracted from it. Cloud computing empowers analysts and organizations to utilize and maintain their resources remotely, reliably and at a low cost. There are a great deal of free and commercial cloud platforms and frameworks available IoT administration such as ThingSpeak, Ubidots and Adafruit etc.

5.5 IoT Network Protocols and Standards

The IoT nodes are connected together via different communication technologies to deliver specific smart services. Thus the nodes should operate using low power in the presence of loss and noisy communication links. Some of major communication protocols used for the IoT is Bluetooth, Wi-Fi, ZigBee, 6LoWPAN, LTE-Advanced etc. All these wireless technologies form the backbone of IoT framework. As nowadays, smartphones are enabled with the Bluetooth, Wi-Fi and LTE networks, they can easily get connected to the wide network of IoT.

5.5.1 WiFi

Wi-Fi is a WLAN (Wireless Local Area Network) technology based on the IEEE 820.11 standards. Wi-Fi uses radio waves to exchange data amongst things within 100 m range. Wi-Fi enables smart devices to communicate and exchange information without using a router with some ad hoc configurations. Devices that can use Wi-Fi technology include personal computers, smart phones, digital cameras, tablet computers, smart TVs, digital audio players, modern printers etc. [11]. Wi-Fi compatible devices can connect to the Internet via a WLAN and a wireless access point.

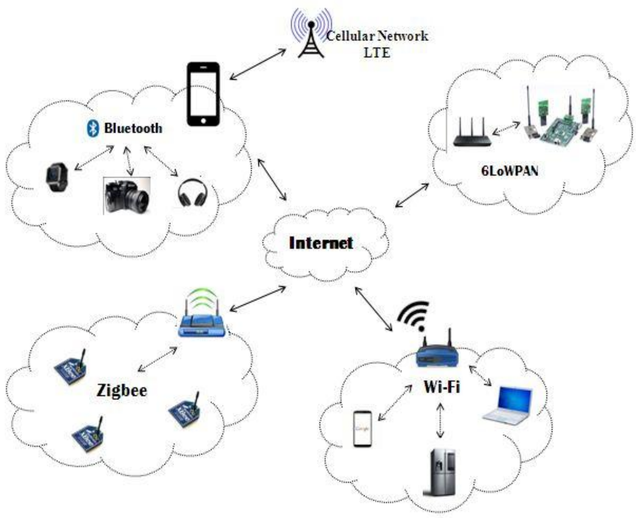

Figure 5: IoT Network

5.5.2 Bluetooth

Bluetooth presents a communication technology that operates over short distances using short-wavelength radio to exchange data between devices and with minimized power consumption. Bluetooth's standard area network range is about 10 meters i.e. for indoor applications.

Bluetooth low energy (BLE) a short range radio with a reduced amount of power consumption to operate for a longer time (even for years). Its communication range is range is ten times higher than a classic Bluetooth and therefore it is very ideal and widely used in IoT applications.

5.5.3 Zigbee

Zigbee is an IEEE 802.15.4 based communication protocol for creating small Personal Area Network. The Zigbee technology is simpler and less expensive than other personal area network technologies such as Bluetooth. It can transmit data for distances to 10-100 meters line-of-sight due to its low power consumption. It is normally used in the applications which require low data rate and long battery life while ensuring secure transmission.

5.5.4 IPv6

IPv6 is an Internet Protocol version 6 developed by Internet Engineering Task Force (IETF) to deal with the problem of IPv4 address exhaustion i.e. limited address space. It can be said that IPv6 is an enabler of IoT because IoT network has a huge number of devices and IPv6 has the larger capacity of addresses.

5.5.5 6LoWPAN

6LoWPAN stands for IPv6 over Low power Wireless Personal Area Network. So it is integration of Low power IEEE 802.15.4 devices into IPv6 networks. It defines set of protocols to be utilized as a part of integration of sensor nodes into IPv6 network. The application areas for low power radio communication includes home automation, offices and environmental monitoring since they require wireless internet connectivity at lower data rates.

5.5.6 CoAP

CoAP is an application layer protocol defined by IETF (Internet Engineering Task Force). It defines a web transfer protocol based on Representational State Transfer (REST) used for exchanging data between client and server over HTTP. CoAP adjusts some HTTP functionalities to meet the IoT prerequisites, for example, low power utilization furthermore, operation within the light of lossy and noisy links. It ensures flexible communication with HTTP and several devices.

5.5.7 MQTT

MQTT stands for Message Queue Telemetry Transport, and is a messaging protocol introduced for connecting with remote locations when limited network bandwidth is there. It is ideal for IoT and Machine to Machine communication as it uses various routing mechanisms. MQTT merely has three components subscriber, publisher, and broker. An interested device would register as a subscriber for specific purpose in order for it to be informed by the broker when publishers publish topics of interest.

5.5.8 Web Services

These are the collection of protocols and standards used for exchanging data between applications. Three types of web services are mostly used in IoT are SOAP, JSON and REST. SOAP is a Simple Object Access Protocol for exchanging structured information. JSON JavaScript Object Notation is a lightweight data interchange format and easy to read and write by humans. REST REstful State Transfer is an architecture which describes how devices in the network are defined and addressed.

6. APPLICATIONS

There are various fields and market sectors where IoT technologies have been used. Some of these key field areas where IoT has greater market are as follows.

6.1 IoT in Home Automation

In the past few years, with the evolution of new technologies, human lives have become more machine dependent. The concept of home automation is nothing but the controlling of basic home functions and appliances through computers remotely. Some of strategies developed for monitoring and controlling various home appliances are described as follows:

The recently developed device [12] has incorporated systems for measuring home conditions along with monitoring and controlling home appliances. It has used two Arduino UNO microcontroller boards to program various sensors/actuators like temperature-humidity sensor DHT22, ambient light-proximity VCNL4000, and communication technologies such as RFID and ZigBee. All the microcontroller embedded home devices had communication with each other via Zigbee wireless technology. JSON (JavaScript Object Notation) was used for storing and exchanging text information with Cloud storage. Another home automation approach by using Arduino microcontroller was implemented by [13]. Primarily, it had 3 main components: Arduino controller, Bluetooth module and Smartphone for Android user application. An Android application was enabled with the user password authentication and the feature of Smart Speech Sense which was capable of sensing user commands and converting it to appropriate commands. These commands were received via Bluetooth by the Arduino controller which was connected to the appliances through relays.

An effective implementation of home condition monitoring system by means of low cost ubiquitous sensing system was described in Reference [14]. It was divided into 3 parts: Sensing units, IoT gateway and internet server. The sensing units were sub divided into three parts according to their sensing types such as water temperature, current and voltage parameters and environmental conditions. Zigbee was responsible for the communication between network nodes. IoT application Gateway was able to transform the sensing information between Zigbee and internet protocol. The internet server was there to collect the data from an IoT application Gateway and stores it in database.

Automation of all the devices like home appliances through E-mail using Raspberry Pi was attempted in Reference [15]. The system has used Raspberry Pi, LAN, HDMI Display, Different sensors etc. Raspberry Pi was main controller of the home appliances. LAN was used to access the internet in Raspberry Pi and that could access the incoming and outgoing E- mail services. It was found that Wired LAN is much faster than the Wireless internet connection. With the grouping of PIR sensor to detect the human motion and Raspberry Pi 2 microcontroller, reference [16] have executed a secure door unlocking system. This sensor was connected at the door whenever the people come at the door it sent the trigger pulse and the camera got activated. The captured image is sent to user via FTP server and if that person was found to be recognized then he is allowed to enter in the house.

The design and implementation of another Secure locking Automation using Raspberry Pi was implemented in Reference [17].Raspberry Pi B+ model operates and controls the Pi video camera for capturing live images and for turning ON a relay for door unlock after checking authority of outside person into database. Then Interface GSM module was used to send security alert to Authorized person while unlocking the locked door. Except capturing images only the security alert system [18] has feature of recording a video when motion was detected and uploads it to the external server and sent to user via text message. They have used Raspberry Pi, different sensors and Raspberry Pi camera module. This project focused on the motion detection and it enables the user to monitor their homes or buildings even from remote locations.

Another approach besides monitoring and securing home is the room environment controlling for energy efficiency. The same feature was accomplished by system in reference [19] using Raspberry pi processor and Bluetooth communication. The system has offered two ways to be operated, either manually or automatic, in order to achieve the target. In manual mode the room energy was controlled through mobile application while in automatic mode room environment was sensed with the help of different sensors such as LM35 temperature sensor to sense the environmental temperature, LDR sensor to detect the light intensity, IR (Infrared) sensor to sense the no. of physical presence of human and camera for detection of human in the room.

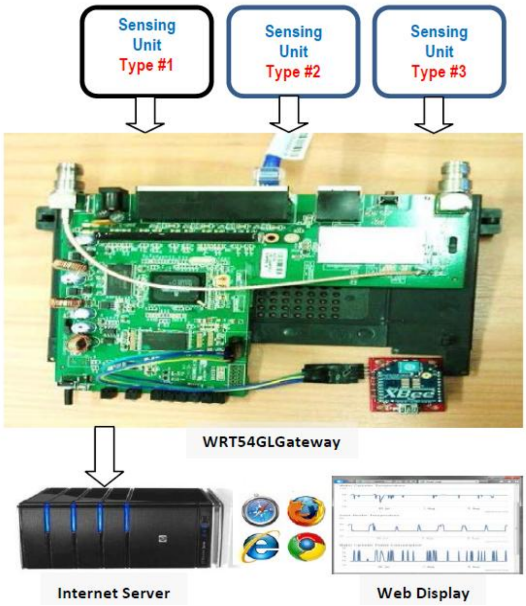

Figure 6: Overall system structure [14]

Apart from mere controlling the room appliances, there may happen any situation which can cause harm to homes, such situations can be gas leakage or short circuits in homes. So to have a control over such situations the authors [20] have developed an IoT scenario using Raspberry Pi, Gas sensor, Short circuit detection switch, Driver circuit, Exhaust fan, PLC etc., that not only controls the situations but also send signals about accidents that were caused due to gas leakage and short circuits in homes, thereby saving life and property.

Similar to the Raspberry pi microcontroller, the home automation system [21] has made use of Intel Galileo Development Board with the integration of Cloud storage and wireless communication. The Intel Galileo Board with Wi-Fi card was served as a web server. The server and sensors were connected to each other through Wi-Fi technology. The system was able to be accessed from any device with the help of Internet IP. It had different sensors such as temperature, motion, gas and LDR. The sensor data was sent to the cloud for analysis. Each sensor was saved with its particular threshold value, if that value exceeded respective action was taken. The Wi-Fi technology was used to increase in security and scalability and also decrease in deployment cost. Cloud storage enabled accessing and monitoring sensor data anywhere anytime.

6.2 IoT in Healthcare

IoT based health care monitoring solutions are getting considerably larger market in recent years due to the independent living styles. These solutions are much helpful for the people who need special attention and care such as chronic disease patients, women, person with disabilities and the elderly. Also numerous IoT research work has been done on Smart Hospital concept.

The design and implementation of an IoT-aware Smart Hospital System was carried out by reference [22]. The system was an automatic monitoring and tracking of patients, hospital personnel and biomedical devices of hospital. They opted for different and complementary technologies and standards such as RFID, WSN, smartphone, 6LoWPAN and CoAP. The designed SHS had an ultralow-power Hybrid Sensing Network (HSN) composed of 6LoWPAN nodes integrating UHF RFID Class-1 Generation-2 functionalities, and was able to collect both environmental conditions and patients' physiological parameters in real time. RFID tags stored the sensor and patients' information making this scattered information collectively available at RFID reader. This information could be monitored on web application through Smartphone and is also able to receive push notifications in case of emergency. All the data is available to local and remote users via REST web service.

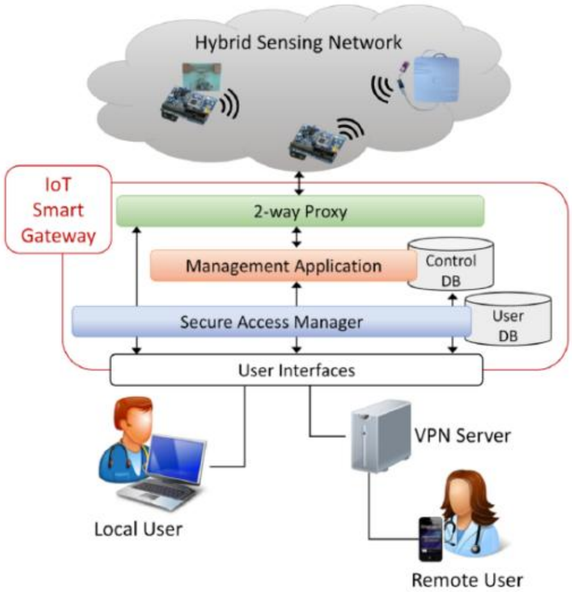

Figure 7: Smart Healthcare System overview [22]

Another smart healthcare approach with the use of RFID, REST, 6LoWPAN, wireless sensor network (WSN), and different sensors was accomplished by paper [23]. Sensors were used to sense the environmental condition. As we know the RFID had numerous tags and each had unique ID. The nurse was able to track and monitor the patient health condition and based on this description patient id would be updated to the nurse. The nurse could monitor the patient's temperature and heart rate and it sent to the doctor.

One of the major constraint sometimes can be visiting to hospital, the model proposed is reference [24] aims to address the patient without even physically visiting the health centre and also prescription could be generated in the absence of Doctor. It was expected that such a smart system would not only facilitate sick but also will add prosperity indirectly to villages. In this case RFID tag, 6LoWPA, and Mobile technologies were used. Every person had unique RFID tag and the RFID reader was available online at the health centre itself. Then RFID reader will access the patient's health card which was submitted to an expert medical system such as Mycin (a new software may also be developed), which was installed at healthcare server. This expert system was generating a prescription to the patients in the absence of doctor.

Sometimes it can be necessary to monitor patient's room environment in hospitals. Similar attempt was made by the team of reference [25]. Various sensors were used like temperature sensor (LM35), ultrasonic sensor (HC-SR04 sensor) for level of saline bottle and LDR for light illumination. USB (Universal Serial Bus) was used to transfer the acquired data (by the all sensors) to the Arduino mega board. This data was then published on the MQTT server so that hospital staff can monitor the data received and ultimately could control electrical appliances (fan, light etc.). Except temperature and light luminance, there are some parameters that are also needed to be monitored in patient's room.

For sensing user's living environment and analyzing its wellness, [26] has developed the personal healthcare system by using the RFID. Passive RFID readers were used to read the network of sensors. These reader nodes were then interacted with the concentrator node through Wi-Fi or Bluetooth links. Ambient sensors were used for detecting physical parameters such as temperature, humidity and the presence of toxic agents to analyze the wellness of the environment to the user's state. Wearable and implantable tags detected the information related to user's presence inside a room, his motion, the interaction among people. This gathered data from RFID environment was then analyzed in terms of movements and trajectories of the user, classifying gestures in daily and sleep conditions, recognize critical events and trigger alarms by means of data mining algorithms.

In some situations, the typical health parameters of elders in the home might needed to be monitored constantly and that too to be achieved remotely. The solution to the same is mentioned at reference [27]. It has presented a Remote health monitoring architecture based on wearable sensors that measures physiological parameters such as ECG, skin temperature, respiratory rate, EMG muscle activity. The sensor data was aggregated by using Zigbee or BLE at the concentrator (which was kept in the vicinity of patient) typically a smartphone which had data connectivity. Concentrator then transmitted information to the Healthcare Organization via its internet connection. The storage/processing device often referred to as Cloudlet, was used whenever the local mobile phone was not sufficient for storage and processing. The stored information was then analyzed and visualized for future diagnostics.

Similar to the previous approach, the IoT system described by [28] was able to monitor body acceleration also along with heart and respiration. The system has presented with a single device named as ZephyrTM Bioharness, which is a device approved by the FDA, with internal reference k113045. All the data from the sensors is collected at cloud platform 'Ubidots', which provides services such as storage, remote visualization, data manipulation on a basic level and programmable alarms. Also an android application is used which receives Bioharness device's information through Bluetooth protocols and again send it to cloud by HTTP or MQTT protocols.

6.3 IoT in Smart Parking

In recent times the concepts of smart cities have gained great popularity. Problems such as, traffic congestion, limited car parking facilities and road safety are being addressed by IoT.

Some of strategies developed for monitoring and controlling above problems are described as follows:
The design and implementation of Reservation-based Smart Parking System (RSPS) [29] permits drivers to locate and withhold the vacant parking spaces. The implemented system made use of Raspberry pi microcontroller and wireless network of IR sensors for multi-level parking facility. An automatic billing was possible through an android application. The real time parking status can be identified with the use of IR sensor and LED was used to show whether parking space was available or not.

Another Smart Parking System [30] enables the user to find the nearest parking area and availability of parking slots. They have used Raspberry pi and pi-camera to capture the picture of parking area continuously. The system was able to validate the slots which were either filled or empty and then the signal was given about the availability of parking slots to the users on the tab or monitor of the admin side interface. The information about the status of the parking slots in the parking area was stored on a cloud. Another smart parking approach [31] was implemented by using RFID. The system has used RFID, IR sensor, Raspberry Pi3 microcontroller. IR sensors were responsible to detect whether a particular slot had contained vehicle or not. RFID tags were attached to the vehicles through which the vehicle identification and the parking charges calculation to be paid were possible. So by using RFID, the system minimized the parking waiting time in a large- sized parking facility. Another efficient system [32] had an on-site deployment of an IoT module that was able to monitor and giving signal about availability of each single parking space. The ultrasonic sensors were used to detect the presence of a car. Then a mobile application has allowed an end user to check the availability of parking space and book a parking slot accordingly.

The furthermost Smart Parking System based on Reservation (SPSR) [33] has ability which allows drivers to find and reserve the vacant parking spaces with the help of slot allocation method and also performs automatic billing process. The system has used parking area control unit (PACU), smart parking allocation centre (SPAC), Android application, RFID, IR sensor, LED etc. At the beginning, allocation process was being carried out for users who were looking for parking spots. They could send requests to the DRPC (Driver request processing centre) and then the SPAC (Smart parking allocation centre) was able to collect all users' requests from the DRPC over a certain time and made an overall allocation in a time. The PRMC (Parking resource management centre) was there to make an updates about the corresponding parking spot from vacant to reserve state and ensuring that other drivers had no permission to take that spot. An infrared sensor was used to sense light wavelength of its surroundings by either emitting or detecting infrared spectrum. The slot allocation algorithm was used for slot selection using the Android application. If the slot was available it would indicate the green LED or if not then it indicated red LED.

6.4 IoT in Agriculture

The concept of smart agriculture is becoming a reality as it evolves from conceptual models for the development of crop at different stages. Nowadays, agriculture area needs tools and technologies to improve the efficiency and quality of production process and reduce the environmental impact occurring on crops. Therefore with the help of useful data collection and automated farming techniques, a network enabled farm has many advantages to offer. So following are some useful researches in the field of Agriculture and Farming.

In agricultural field, soil moisture monitoring plays a significant role as all additional processes depends upon it. A valuable implementation of same was described in [34] where, the farmers have used soil moisture monitoring for irrigation scheduling. Arduino microcontroller was used for farmer's field process. A watermark 200SS sensor was able to provide the readings of water levels. The communication was established via Wi-Fi and data was sent to open source cloud platform 'ThingSpeak' for further analysis.

The greenhouse monitoring systems [35] based on IoT technology was useful for monitoring and controlling the environmental factors such as temperature, humidity. The critical temperature, humidity and soil signals were collected in real-time. With the help of GSM/GPRS module as a SMS gateway, real time greenhouse data could be sent through SMS and online for further analysis. Another competent greenhouse monitoring system based on Zigbee wireless sensor network was described by [36]. It could collect the different types of data such as humidity, temperature, carbon dioxide concentration. This collected information was sent to the coordinator of the network monitoring center which would have been monitoring the working status and health condition of the sensor nodes. And gathered data by the sensors was furthermore analyzed for pattern changes, and adjust the working task of the nodes accordingly.

Furthermore, the greenhouse monitoring with controlling the parameters of environment was described by [37]. The system has measured different parameters such as temperature, humidity, moisture, light and CO2 etc., and made use of Arduino, GSM and wireless sensor network using Wi-Fi. The theme of a system was like sensors would collect the different values of parameters and compare it with the present values. These values were sent to the gateway by using GSM module. If the values have found to be beyond the present values then the system would turn on cooler to stable the temperature or the ventilator to purify the air or the pump to control the dryness of the earth likewise.

The next IoT based approach [38] was developed for crop field monitoring and automated irrigation system. The system made use of different sensors such as soil moisture, temperature, humidity and light sensor. The collected data from the sensors were sent to the server through wireless network and the decision making was done on server to automate the irrigation system. This real time data could be sent to the farmers through mobile application and because of this application farmers could monitor and control the field from anywhere. One more environmental parameter monitoring and controlling approach [39] for green house and poultry farm was described. The system has used Raspberry Pi, Node MCU and Wi-Fi. NodeMCU was used for monitoring and collecting the data from sensors and send it to the server node (Raspberry Pi). Then checking of weather values were performed i.e. whether it was in between the range or not. If not it would send the command to turn ON or OFF related actuators to control environment as well as turn ON an alarm as an alert to respective sensor node.

Apart from single networked farm, a detailed design and implementation for connected farms were described in

Reference [40]. They have used Raspberry Pi, different sensors, Zigbee etc. To monitor the environmental condition of connected farms, the system has used three different sensors such as a compound sensor (i.e., temperature, humidity, and CO2), a photosynthetic photon flux density (PPFD) sensor, and a soil moisture sensor. To build an automatic connected farming system, they deployed six types of controllers in connected farms such as exhaust fans, an air conditioner with heating and cooling, six sprinklers, LED lights, a cover controller for preventing the light from reaching the plants and an irrigation and nutrient management system. The data collected by the sensors were sent to the Mobius server. The system has also a mobile application through which users can remotely monitor and control the connected farm. Along with the monitoring of farms and its environment, security is also important. An IoT based Smart Security and Monitoring Devices for Agriculture was developed by [41]. The system has used Raspberry Pi 2 Model B+, PIR Sensor, Ultrasonic Ranging Device (URD), and Ultrasonic Sound Repeller. With the help of PIR sensor presence of rodents (mice, rats, hamsters) was detected. URD sensor was activated to calculate the distance of rodent and simultaneously webcam daemon was activated to capture a snap of area. 'ThingWorx' cloud platform was used to store and analyze the data and sent SMS alert accordingly to the user.

6.5 IoT in Wearable Devices

Today in current global scenario, issues on women harassment are rising. Therefore women safety and security needs an attention and there should be such system with the help of which every woman will be able to move freely on the streets even in odd hours without worrying about their. So here are some IoT based systems for ensuring Women safety which will secure her in the crisis condition.

One touch alarm system for women's safety using GSM was developed by [42]. This device had PIC microcontroller, GSM module, GPS modules. The system has resemblance like a normal watch which when activated, tracked the place of the women using GPS (Global Positioning System) and sent emergency messages using GSM (Global System for Mobile communication), to the police control room. The watch has provision with all the features which will leave no stone unturned to help the dupe in any kind of emergency situations. Another Self Defense System for women safety was like a Smart Watch for Women developed by [43]. They have used Microcontroller, GSM, GPS, LED, and ADC. The women would wear this device as a watch, and she was able to press a switch that was located on the watch in case of critical condition. Then her location information was sent as SMS alert to a few predefined emergency numbers. If the family member wanted to know the present location of the women, they could do so by sending a SMS to the SIM number of the women which had a secret password. Then this system would respond to such request by sending back a SMS containing location information in terms of Latitude and Longitude.

Another efficient wearable device for women safety was [44], which made use of devices such as Electric Shock Generator, GPS, GSM, Smart Watch, Screaming Alarm, and Voice Recognition. GPS and GSM connected to ATMEGA also start working and it displayed the current position of device. Then with the help of GPS the location of the victim was detected and displayed on the LCD. When the victim felt danger, he/she would press the first emergency key, then the kit would display emergency situation and voice kit was enabled. Then the victim could give voice command which was recognized by the kit. If the voice command matched with the one stored in database then the appropriate action was taken. Another Smart phone application for women safety [45] has used Smart Band, Sensors, GPS/GSM. The application was activated and loaded with all the required data which was included with Human behavior and reaction. The data directed by the smart band such as the temperature of the body along with the motion of the body was continuously monitored by the application which was pre-installed in the phone. By using Mobile application, it would send alert message to the Emergency contact and nearby police station.

The emergency tracking system by using Arduino was developed by [46]. The system has used Smart Watch, different sensors, GSM, GPS, Arduino. It was designed in such a way that it could be wear by any family member. Different sensors were used like Pulse sensor, UV sensor, temperature sensor to sense the biological parameters of women body like beat rate, Vibrations of the Hand and body, temperature of the body etc. These parameters were continuously checked by the shrewd band which was pre-associated with the implanted device. So if any parameter of women body was sensed by sensor then it would send the message to the family member along with the coordinates. Then Co-ordinates were sent to nearest police station requesting immediate action.

6.6 IoT in Fleet Management and Transportation

Nowadays cars, vehicles and roads are also equipped with tags and sensors so that they can be tracked and monitored in real time. Apart from only tracking, monitoring can be done in terms better route identification, traffic congestion control and route guidance. Following are some researches carried out for management of vehicle fleet and transportation.

The research done by team [47] has proposed a vehicle tracking system. It has used GPS technology to capture the current location of vehicle. With the help of GSM/GPRS the captured coordinates of the locations were saved to the databases. These technologies were embedded into the vehicle along with Arduino Microcontroller. Smartphone application helped in real time continuous monitoring of vehicle using Google maps API.

The furthermost valuable research in real time tracking system of vehicle was done by [48]. The client module here was the GPS/GPRS embedded device for identifying vehicle location. The GPS module was based on the 8-bit AVR RISC microcontroller. The location information was then transmitted periodically to the web server program. The web server program was responsible to convert the location information for displaying on Google Earth or Google Map Software. When it comes to transportation, the whole fleet of vehicle is needed to be monitored in real time. So such solution is described in [49] i.e. Android based Remote Vehicle Fleet Management System. Hence as the name depicts, the system was able to get information related to all fleet vehicles' identity, speed and location. Raspberry Pi was used as a microcontroller to receive GPS signals from GPS module and information from various other sensors such as piezoelectric sensor and gas sensor. User was able to monitor the entire fleet through a GUI built using Microsoft Visual Studio 2010.

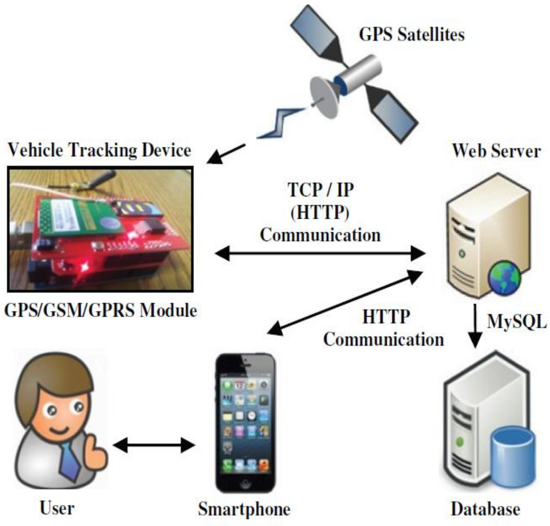

Figure 8: Vehicle Tracking System [47]

Intelligent Transport System (ITS) is an advanced application which provides innovative services to traffic and transport. One such innovative idea on an Intelligent Transport System is implemented by [50] which worked in 2 subsystems Nautical and Native Prototype. The Nautical prototype had GPS module, GSM module and microcontroller. Nautical prototype captured and filtered the NMEA sentences and sent it to online server via GSM module. Native prototype is similar to Nautical, except it did not have GPS module and it provides the current surrounding information from the web server to the GSM module. With the use of Intel Galileo Gen 2 development board with GPS and GSM modules reference [51] have developed an electronic device which could be equipped with any vehicle to track and monitor its location and speed. It has made use of SIM908vehicle speed sensor and 'ThingSpeak', an open source cloud server module used for remote storage.

A different approach was demonstrated for school buses, by developing a scholar bus monitoring system [52] in terms of location and speed sensors, and with the use of mobile propagation node i.ePIC18F45K20 microcontroller and the Message Queuing Telemetry Transport connectivity protocol (MQTT). The system was accessible to parents, school, government and many other authorities as data was saved to cloud using the General Packet Radio Service (GPRS) provided by cellular networks.

Another widely used microcontroller is Beaglebone black Linux based microcontroller board. The model described by [53] is an accident prevention system primarily equipped with GPS, GSM, Alcohol detector, Door sensor and Eye-blink sensor along with the Beagle bone black. These sensors were also able to monitor driver's condition and accordingly give information about critical situations. And the web server was there to display and monitor the vehicle data by client. An additional concern related to vehicles is its security in terms of theft. Considerable amount of research has been done on preventing vehicle theft or tracking vehicle in case of theft. The vehicle anti-theft tracking system [54] was mainly controlled by the RFID module which in turn controlled the power switch. The RFID reader was placed in car and RFID tag was attached to the car key. With the help of Vibration sensor and pyro electric infrared sensors car intruder could be detected. GSM module was able to send information collected from GPS module to the owner's phone via SMS. The owner could then get vehicle position on Android application. With this application and GSM module, the master control (a microcomputer) was able to forcibly lock or unlock the car.

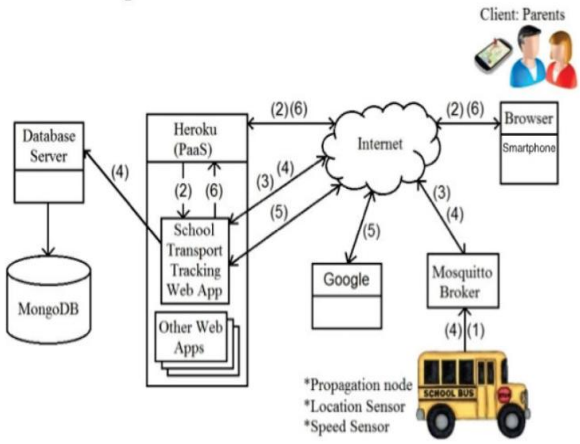

Figure 9: A Scholar Bus monitoring system [52]

In some cases, when real time tracking is there, it is necessary to analyze the raw data collected from GPS as it might be irrelevant. So, the team [55] has depicted the ways of handling the received GPS data carefully so that the relevant and exact information could be obtained. It has presented an approach of tracking vehicle by using SPSS so that the raw data received by GPS system could be converted into a workable format to get meaningful information. G-track tracking software and Tracking Genie system was used to compare the records. SPSS Line graph and analysis reports were used. The real time GPS latitude and longitude provided vehicle position and data related to time and speed provided movement of vehicle.

The furthermost, complete hardware for vehicle tracking was developed by [56]. The system's main hardware parts were u-blox NEO-6Q GPS receiver module and u-blox LEON-GIOO GSM module. The GPS was utilized to obtain vehicle's coordinates and GSM modem for transmission of those coordinates to the user's phone through the mobile network. Arduino UNO microcontroller was employed to control these both hardware parts and the communication between these two was through UART i.e. Universal Asynchronous Receiver/Transmitter interface. PCB of the hardware device was designed using the CadSoft Eagle software and that design was processed through software's CAM processor to deliver actual industry-standard Gerber format files that was later used for fabrication of the PCB.

Upon reviewing above papers it is observed that different application areas of IoT use different technologies and hardware based on their purpose. The type of sensor technology, wireless technology and hardware changes with the application, so this variation can be summarized with the help of below Table [Table 1]. From this table, application wise common use of technologies and hardware can be analyzed.

Table 1: Review summary of Technologies and Hardware

Sr. No.	Application area	Communication Gateway	Microcontrollers	Sensors interfaced	User Interface
1	Home Automation	Bluetooth, SMS, Zigbee, RFID, WLAN, Wi-Fi, Email	Raspberry pi, Arduino, Intel Galileo	Temperature, Humidity, Proximity, Smoke/Gas, Motion, LDR, PIR	Android app, Cloud storage, Web server
2	Healthcare	RFID, WSN, 6LoWPAN, CoAP, Wi-Fi, Bluetooth, Zigbee, BLE	Arduino	Temperature, Ultrasonic, Humidity, LDR	Android app, MQTT server, Cloudlet, Cloud platform
3	Smart Parking	RFID	Raspberry pi	IR, Ultrasonic	Android app
4	Agriculture	Wi-Fi, SMS, GSM/GPRS, Zigbee, Mobius server	Arduino, Raspberry pi, NodeMCU	Watermark 200SS, Temperature, Humidity, Soil Moisture, Light, CO2, PPFD, PIR, Ultrasonic, URD	Android app, Cloud platform
5	Wearable Devices	GSM, GPS, SMS	PIC, ATMEGA, Arduino	Temperature, Pulse, UV, Motion	Android app
6	Fleet Management & Transportation	GSM, GPS/GPRS, UART	Arduino, 8-bit AVR RISC, Raspberry Pi, Beaglebone black	Gas, Piezoelectric, Speed, Alcohol, Door, Vibration	Android app, Cloud platform, GUI

7. CHALLENGES

There are many open issues and challenges in IoT concerning with the technologies and networking aspects. Some of them are as follows:

7.1 Addressing and Naming Issues

IoT applications include very high number of devices. Each of these devices needs to have individual identity band address over the network. Hence, there is need of effective addressing policies which can dynamically assign identities to devices over the network.

7.2 Network Security

Most of the communication in IoT uses wireless transmission network. Such transmission systems should be capable of handling data from numerous sensor devices without causing any loss. Hence there should be some kind mechanism to ensure authentication and data integrity.

7.3 Information Security

As more and more objects participate in IoT, their privacy should be protected from falling into wrong hands. Privacies can be equipped with the smart devices to ensure the privacy of information. Furthermore personal information can be constrained to be used for supporting authorized services by authorized service providers.

7.4 Interoperability

The number of heterogeneous devices present in IoT application belongs to different platforms. Many IoT device manufactures use their own technologies and services that may not be able to access by others. Hence IoT device manufactures and application developers should deliver the services which are accessible by all customers regardless of hardware platforms.

8. CONCLUSION

The growing idea of the Internet of Things (IoT) is pointing toward improving the quality of life by connecting many smart devices, technologies, and applications. The potential and intelligence of IoT can save people and organizations time and money as well as help in taking intelligent decisions. Overall, the IoT would allow for the automation of everything around us making the thing smart and thus leading to the vision of ‘‘anytime, anywhere, any media, anything” communications.

In this survey article, we provided an overview of the key elements related to the development of IoT implementation. The main aim of the article is to provide an insight towards the different application areas of IoT. The most relevant application fields have been presented along with the recent research work going on in those fields. Further, some of the challenges and issues that are relevant to the design and deployment of IoT implementations have been presented.

We do hope that this survey will be useful for researchers and practitioners in the field, helping them to understand the huge potential of IoT. The recent research work presented in different application areas will be beneficial for research in both industrial and academic laboratories. We do believe that this survey can be a starting point for the beginning of any new IoT research idea and it has the scope to improve at various security aspects in the field.

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10. REFERENCES

[1] Andrew Whitmore, Anurag Agarwal and Li Xu, "The Internet of Things—A survey of topics And trends", Information Systems Frontiers, Volume 17, Number 2, Page 261, 2015

[2] Daniele Miorandi , Sabrina Sicari , Francesco De Pellegrini and ImrichChlamtac, "Internet of things: Vision, applications and research challenges", Ad Hoc Networks 10, 1497-1516, 2012

[3] Roberto Minerva, AbyiBiru and Domenico Rotondi, " Towards a Definition of the Internet of Things", IEEE Internet Initiative, 25 May 2015

[4] Article Title : https://iot-analytics.com/internet-of-things-definition/, Accessed date: 21/09/2017

[5] Article Title : http://www.dataversity.net/brief-history-internet-things/, Accessed date : 21/09/2017

[6] Article Title : https://en.wikibooks.org/wiki/A_Bit_History_of_Internet/Chapter_8_:_Internet-of-Things, Accessed date : 22/09/2017

[7] Article Title : https://www.silabs.com/documents/public/white-papers/evolution-of-wireless-sensor-networks.pdf, Accessed date : 22/09/2017

[8] Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari and M. Ayyash, "Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications", IEEE Communications Surveys & Tutorials, vol. 17, no. 4, pp. 2347-2376, Fourthquarter 2015

[9] Rafiullah Khan, SarmadUllah Khan, RifaqatZaheer and Shahid Khan, "Future Internet: The Internet of Things Architecture, Possible Applications and Key Challenges", Frontiers of Information Technology (FIT), 10th International Conference on. IEEE, 2012

[10] Luigi Atzori , Antonio Iera and Giacomo Morabito, "The Internet of Things: A survey", Comput. Netw., doi: 10.1016/j.comnet.2010.05.01, 2010

[11] https://en.wikipedia.org/wiki/Wi-Fi

[12] MoatazSoliman, Tobi Abiodun, Tarek Hamouda, Jiehan Zhou and Chung-Horng Lung, "Smart Home: Integrating Internet of Things with Web Services and Cloud Computing", IEEE International Conference on Cloud Computing Technology and Science, 2013

[13] Bhavik Pandya, Mihir Mehta and Nilesh Jain, "Android Based Home Automation System Using Bluetooth & Voice Command", International Research Journal of Engineering and Technology (IRJET),Volume: 03 Issue: 03, Mar-16

[14] S.D.T.Kelly, N.K. Suryadevara and S.C. Mukhopadhyay, "Towards the Implementation of IOT for Environmental Condition Monitoring in Homes", IEEE SENSORS JOURNAL, VOL. 13, NO. 10, Oct-13

[15] Shruti G. Suryawanshi, Suresh A. Annadate, "Raspberry Pi based Interactive Smart Home Automation System through E-mail using Sensors",International Journal of Advanced Research in Computer and Communication Engineering,Vol. 5, Issue 2, Feb-16

[16] Aldrich D'mello, Gaurav Deshmukh, ManaliMurudkar and GarimaTripathi, "Home Automation using Raspberry Pi 2",International Journal of Current Engineering and Technology,E-ISSN,2277-4106, 2016

[17] Akshay N. Patil , Rohit B. Ranavare, Dayasagar V. Ballal and Asst. Prof. P. P. Kotekar, "Raspberry Pi Based Face Recognition System For Door Unlocking",International Journal of Innovative Research in Science and Engineering,Vol. No.2, Issue 03,Mar-16

[18] A. Arun Raja, R. Naveedha, G. Niranjanadevi and V.Roobini,"An Internet of Things (IoT) Based Security Alert System Using Raspberry Pi",Asia Pacific International Journal Of Engineering Science,Vol: 02, Issue: 01,37-41, 2016

[19] Manu Jain, Asmita Varma, N Kaushik and KayalvizhiJayavel, "Building Automation and Context Aware Energy Consumption using IoT – Smart Campus", International Journal of Applied Engineering Research, Volume 12, Number 14, 4213-4220, 2017

[20] ShrutiAnand, S. Lavanya and T. Eswari, "A Smart Monitoring System to Sense Short Circuit and Gas Leakage using IoT", International Journal of Advance Research in Computer Science and Management Studies, Volume 5, Issue 7, Jul-17

[21] Vinay sagar K N, Kusuma S M,"Home Automation Using Internet of Things", International Research Journal of Engineering and Technology (IRJET),Volume: 02 Issue: 03, Jun-15

[22] Luca Catarinucci, Danilo De Donno, Luca Mainetti, Luca Palano, Luigi Patrono, Maria Laura Stefanizzi and Luciano Tarricone, "An IOT-Aware Architecture for Smart Healthcare Systems", IEEE Internet of Things Journal, Volume: 2, Issue: 6, Dec. 2015

[23] S. Sivagami, D. Revathy and L. Nithyabharathi, "Smart Health Care System Implemented Using IoT", International Journal of Contemporary Research in Computer Science and Technology (IJCRCST), Volume 2, Issue 3, Mar-16

[24] Rashmi Singh, "A Proposal for Mobile E-Care Health Service System Using IoT for Indian Scenario", Journal of Network Communications and Emerging Technologies (JNCET), Volume 6, Issue 1, Jan-16

[25] PoojaKanase and SnehaGaikwad, "Smart Hospitals Using Internet of Things (IoT)", International Research Journal of Engineering and Technology (IRJET), Volume: 03, Issue: 03, Mar-16

[26] Sara Amendola, RossellaLodato, Sabina Manzari, Cecilia Occhiuzzi and Gaetano Marrocco, "RFID Technology for IoT-Based Personal Healthcare in Smart Spaces", IEEE Internet of Things Journal, VOL. 1, NO. 2, Apr-14

[27] MoeenHassanalieragh, Alex Page and TolgaSoyata, "Health Monitoring and Management Using Internet-of-Things (IoT) Sensing with Cloud-based Processing: Opportunities and Challenges", IEEE International Conference on Services Computing, pp. 285-292, 2015

[28] Camilo Rodriguez, Diego M. Castro, William Coral, Jose L. Cabra, Nicolas Velasquez, Julian Colorado, Diego

Mendez and Luis C. Trujillo, “IOT system for Human Activity Recognition using BioHarness 3 and Smartphone”, Proceedings of the International Conference on Future Networks and Distributed Systems. ACM,Cambridge, United Kingdom,2017

[29] Faiz Ibrahim Shaikh, Pratik NirnayJadhav , Saideep Pradeep Bandarkar, OmkarPradip Kulkarni and Nikhilkumar B. Shardoor, "Smart Parking System Based on Embedded System and Sensor Network", International Journal of Computer Applications, Vol. 140, No. 12, 0975 – 8887, Apr-16

[30] Mr. Basavaraju S R, "Automatic Smart Parking System using Internet of Things (IoT)", International Journal of Scientific and Research Publications, Volume 5, Issue 12, Dec-15

[31] Prof.S.S.Thorat, Ashwini M., AkankshaKelshikar, SnehaLondhe and MamtaChoudhary, "IoT Based Smart Parking System Using RFID", International Journal of Computer Engineering In Research Trends, Volume 4, Issue 1, Jan-17

[32] Abhirup Khanna and Rishi Anand, "IoT based Smart Parking System", International Conference on Internet of Things and Applications (IOTA), International Conference on IEEE,2016

[33] Renuka R. and S. Dhanalakshmi, "Android Based Smart Parking System Using Slot Allocation & Reservations", ARPN Journal of Engineering and Applied Sciences, VOL. 10, NO. 7, Apr-15

[34] Jose O. Payero, Ali Mirzakhani-Nafchi, Ahmad Khalilian, Xin Qiao and Rebecca Davis, “Development of a Low-Cost Internet-of-Things (IoT) System for Monitoring Soil Water Potential Using Watermark 200SS Sensors”, Advance in Internet of Things, Vol. 7, No. 03, 71-86, 2017

[35] Ji-chunZhao,Jun-feng Zhang, Yu Feng, Jian-xinGuo, “The Study and Application of the loT Technology in Agriculture”, Computer Science and Information Technology (ICCSIT), 3rd IEEE International Conference, Vol. 2, 462-465, 2010

[36] Ling-ling LI,Shi-feng YANG, Li-yan WANG and Xiang-ming GAO, “The Greenhouse Environment Monitoring System Based on Wireless Sensor Network Technology”, Proceedings of the 2011 IEEE International Conference on Cyber Technology in Automation, Control, and Intelligent Systems March 20-23, 2011, Kunming, China

[37] Marwa Mekki, Osman Abdallah, Magdi B. M. Amin, Moez Eltayeb, Tafaoul Abdalfatah, Amin Babiker, “Greenhouse monitoring and control system based on wireless Sensor Network”, International Conference on Computing, Control, Networking, Electronics and Embedded Systems Engineering, 2015

[38] Rajalakshmi.P and Mrs.S.Devi Mahalakshmi,” IOT Based Crop-Field Monitoring And Irrigation Automation”, 10th International Conference on Intelligent Systems and Control (ISCO), Coimbatore, 2016

[39] Ms. Minal Goswami and Prof. Kirit Bhatt, “IOT Based Smart Greenhouse and Poultry Farm Environment Monitoring and Controlling using LAMP Server and Mobile Application”, IJARIIE-ISSN(O)-2395-4396, Vol-3 Issue-2 2017

[40] Minwoo Ryu, Jaeseok Yun, Ting Miao, Il-Yeup Ahn, Sung-Chan Choi and Jaeho Kim, "Design and implementation of a connected farm for smart farming system," 2015 IEEE SENSORS, Busan, 2015

[41] Tanmay Baranwal, Nitika and Pushpendra Kumar Pateriya, “Development of IoT based Smart Security and Monitoring Devices for Agriculture”, 2016 6th International Conference - Cloud System and Big Data Engineering (Confluence), Noida, 2016

[42] Premkumar P., CibiChakkaravarthi R., Keerthana M.,Ravivarma R. and Sharmila T., "One Touch Alarm System For Women’s safety Using GSM", International Journal of Science, Technology & Management, (online)www.ijstm.com, Volume No 04, Special Issue No. 01, Mar-15

[43] B. Vijaylashmi, Renuka S., PoojaChennur and SharangowdaPatil, "Self Defense System For Women Safety With Location Tracking And SMS Alerting Through GSM Network", International Journal of Research in Engineering and Technology (IJRET), Volume: 04, Special Issue: 05, NCATECS-2015, May-15

[44] Shreyas R.S., Varun B.C., Shiva Kumar H.K., Punith Kumar B.E. and Kalpavi C.Y., "Design and Development of Women Self Defence Smart Watch Prototype", International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE), Volume 5, Issue 4, Apr-16

[45] J.K. Thavil, V.P. Durdhawale and P.S. Elake, "Study on Smart Security Technology for Women based on IoT", International Research Journal of Engineering and Technology (IRJET), Volume: 04, Issue: 02, Feb-17

[46] vinaysagar K N and Kusuma S M, "Emergency Tracking system for women using body Sensors via Wrist watches using Internet of Things (IoT)", International Research Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 08, e-ISSN: 2395-0056, Aug-17

[47] S. Lee, G. Tewolde and J. Kwon, "Design and implementation of vehicle tracking system using GPS/GSM/GPRS technology and smartphone application", 2014 IEEE World Forum on Internet of Things (WF-IoT), Seoul, pp. 353-358, 2014

[48] N. Chadil, A. Russameesawang and P. Keeratiwintakorn, "Real-time tracking management system using GPS, GPRS and Google earth," 2008 5th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology, Krabi, pp. 393-396, 2008

[49] D. Santhoshi Rani and K. Radhika Reddy, ”Raspberry Pi Based Vehicle Tracking And Security System For Real Time Applications”, International Journal of Computer Science and Mobile Computing, Vol.5, Issue.7, pg. 387-393, Jul-16

[50] Ch. Kirankumar, "Structuring the Intelligent Transport Systems Based on Internet of Things (IoT)", International Journal of Engineering Trends and Technology (IJETT), V35,No.11,ISSN:2231-5381, 525-531, May-16

[51] T. Godavari and J. Umadevi, ”Cloud Computing based Real-TimeVehicle Tracking and Speed Monitoring System”, I J C T A, Vol.09,No.04, pp. 1823-1830, 2016

[52] J. Zambada, R. Quintero, R. Isijara, R. Galeana and L. Santillan, "An IoT based scholar bus monitoring system," 2015 IEEE First International Smart Cities Conference (ISC2), Guadalajara, pp. 1-6, 2015

[53] Geethanjali K. and Pushparani M.K., "Real Time Vehicle Monitoring and Tracking System for School Bus via Beagle Bone", International Journal of Science and Research (IJSR), Vol.5,Issue5, 2319-7064, May-16

[54] Z. Liu, A. Zhang and S. Li, "Vehicle anti-theft tracking system based on Internet of things", Proceedings of 2013 IEEE International Conference on Vehicular Electronics and Safety, Dongguan, pp. 48-52, 2013

[55] R. Kumar and H. Kumar, "Availability and handling of data received through GPS device: In tracking a vehicle", 2014 IEEE International Advance Computing Conference (IACC), Gurgaon, pp. 245-249, 2014

[56] H.D. Pham, M. Drieberg and C.C. Nguyen, "Development of vehicle tracking system using GPS and GSM modem", 2013 IEEE Conference on Open Systems (ICOS), Kuching, pp. 89-94, 2013.