



# Internet of Things: Applications, security and privacy: A survey

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## ABSTRACT

Internet of Things is transforming real devices to smart intelligent virtual devices. In IoT day today devices of daily use are manufactured along with sensors which are capable for identification and sensing. They can be networked, are capable to process, can interact with other devices through Internet. IoT objective is to connect almost everything under a common infrastructure. This helps to control devices and will keep us informed about the status of devices. The paper aims to give Internet of Things overview and their applications. It presents latest trends, current state, recent developments, security, privacy, applications of IoT and future research directions.

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## 1. Introduction

IoT represents the futuristic computing and communications technology. Its growth relies on innovation in different technical areas like wireless sensors and nanotechnology. The framework that allows device to device communication through Internet has brought more devices online. It allows them to be connected and engaged in the web as an enormous network of devices. IoT has made a global network which supports ubiquitous computing as proposed by Bandyopadhyay et al [1]. The Internet of Things (IoT) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction as proposed by Rouse, Margaret et al. [2]

Lalit Chettri and Rabindranath Bera et al. [3] focused on IoT applications in 5G system in their research paper a comprehensive survey on Internet of Things towards 5G wireless systems. They also highlighted what kind of research in IoT and 5G is contributing in different industries? Dong, Z., Yian, Z., Wangbao, L., Jianhua, G., & Yunlan, W. et al. [4] proposed object service provision in Internet of Things. An Intelligent trust evaluation scheme in sensor cloud enabled Industrial Internet of Things as proposed by Tian Wang, Hao Lao, Weijia Jia, Anfeng Liu, Mande Xie et al. [5], They proposed mechanism to evaluate the sensor nodes from their communica-

tion behavior and sensor nodes. They highlighted the sensor nodes trustworthiness and reduced consumption of energy. Context awareness and ubiquitous computing are essential for IoT as proposed by Jara et al. [6]. A variety of machine learning techniques are used in IoT like , support vector machine, regression, random forest, convolutional neural networks, and variational auto encoder as proposed by Mohammadi M., IEEE Communications Surveys and Tutorials et al. [7]. IoT networks are distributed in nature. It is common for each IoT device to discover who the neighbor is. Battery capacity is a major limitation of IoT devices. A neighbor discovery protocol was proposed that achieves low discovery latency and low duty cycle. The proposed model is generic as it is used for analyzing existing NDPs as proposed by Zhong Shen ; Hai Jiang ; Qingkuan Dong ; Baocang Wang et. al. [8]

## 2. Paper structure

The structure of paper is as under:

Section 3 contains the various applications of IoT like Smart infrastructure, Smart Home, Smart Healthcare, Smart Traffic System, Smart City, Smart Environment, Natural calamities, Smart Industry, Supply chains logistics, Smart Agriculture and Social applications. Section 4 identifies the different IoT issues and challenges, legal accountability, governance, privacy, security and general. Section 5 contains different business models and future directions. Section 6 summarize the paper and presents the conclusion.

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### 3. Applications of IoT

IoT applications are increasing as more devices are getting internet connected & becoming IoT enabled. The daily day today applications which we see use smart devices. They share useful data, information and can communicate with one another. These emerging applications are improving quality of lives. Google Car is smart self driven car having capability of real time monitoring of traffic congestion, weather & road conditions, shortest route, route with less traffic and other useful information exchanges. IoT devices which are used for monitoring and tracking contain small silicon chips with optimal processing capabilities. Communication technologies like GPRS, GSM, Mesh Network, LTE, ZigBee and Wi-Fi are used. NFC, RFID, GNSS & BLE are used in tracking. Sensors are used for detecting vibration, pressure, temperature and humidity. They are powered by small battery, short burst power bank and solar energy. An IoT node does not use System on Chip (SoC) as it is complex. For IoT enabled devices integrated circuits have low level of integration. They will not require integration with MEMS, leading edge process technologies and any other special purpose semiconductor processing. The daily use application areas of IoT are highlighted by Atzori et. al. [9] and HomeKit Apple Developer “[10]. *iOS*’s HomeKit enables control of consumer appliances and accessories by an application in *iOS* devices like Apple Watch. The IoT applications are classified in various application domains like wearable’s, smart home, smart vehicles, smart infrastructure, smart healthcare, agriculture, manufacturer, supply chain, logistics, social & business applications.

#### 3.1. Smart infrastructure

IoT enabled devices improves reliability efficiency and flexibility in infrastructure operations. These advantages reduce manpower and cost requirements and enhance safety as proposed by Heil et. al. [11], Li et. al. [12], Vicini et. al. [13], Fang et. al. [14]. The detailed information is found in Table 1.

#### 3.2. Smart home

IoT is also useful in home with the help of which we can control consumer appliances remotely. Monitoring of meters of energy and water helps in reducing electricity and water bills by calculating electricity overloading, detecting water leakages thus saving water and energy resources. The encroachment detection systems prevent burglaries. Gardening sensors enables measurement of sunlight, water, humidity, temperature and other gardening parameters. They water the plants and provide other resources as

per their requirements. In smart home if the person is in drawing room & sensors deployed in smart refrigerator kept in kitchen detect a need for refilling the water bottles as the level of water is below threshold value. Sensors will broadcast message to other sensors deployed in home. Sensors deployed in living room, dining room, drawing room, bedroom, and washroom will trace location of person. Information will be given to that person for refilling water bottles. Sensors are deployed very close to each other within the overlapping transmission range. They are therefore free to communicate with one another like Smart Television, Smart Refrigerator and Smart Lights. The work area and key vision in the applications of IoT ins smart home is described in Table 2.

#### 3.3. Smart traffic System.

Traffic plays very important role in any city. Traffic problems needs to be addressed and managed properly. Smart Traffic System improves the traffic situation based on the traffic data obtained by IoT enabled devices. Smart intelligent traffic management system requires vehicles identification & monitoring of factors related to traffic.

Smart monitoring of traffic provides good travelling experience by giving all details related to congestion such as shortest route, lesser traffic area. It also provides features such as road toll collection, traffic accidents reporting, vehicle, theft detection, less pollution. In smart city the IoT enabled devices will give directions for traffic jams which will help lessen the traffic. It will optimize the travelling route which ensures safe driving and walking. It will also inform about the climatic changes and weather forecasting to the user. The traffic lighting system is weather adaptive, reduces energy consumption and helps in saving energy and cost. It also keeps track of the parking spaces in the smart city, their status and availability. It ensures parking spaces are available throughout the city and information about free spaces can be accessed by everyone. Basel Barakat, Simeon Keates, Ian J. Wassell & Kamran Arshad et. al. [33] proposed a model for representing communication between IoT devices. The model is employed to obtain the traffic generation characteristics. The proposed model depicts good understanding of behavior of devices. They analyzed the transmitted packets numbers using traffic models. This model has higher accuracy

#### 3.4. Natural calamities & smart environment

IoT technologies helps in weather forecasting and predicting natural disasters which are adverse events arising due to natural process of earth like earthquakes, floods, incessant rains, cloud bursting, thunderstorm, high speed winds, tides, volcanic erup-

**Table 1**  
Infrastructure Aspects of IoT.

| Ref  | Author                  | Smart Infrastructure of IoT   |
|------|-------------------------|---|
| [15] | Liu                     | Proposed that smart grids utilize IoT for gathering and collecting the data related to energy consumption. The data compiled is analyzed and reports are generated illustrating the different patterns of energy usage. The report carries the suggestions and ways for reducing cost and recommendations for minimizing energy. They make this report online.  |
| [16] | Darianian and MichaelLi | Proposed that nowadays IoT is used inside homes offices and outside. Smart Homes have sensors & actuators for security features, door locking, smart refrigerator, smart television and other smart consumer durables. Smart Buildings are also equipped with sensors and actuators for monitoring and tracking building infrastructure. They monitor and track the visitors with help of security cameras. They track the consumption of water and electricity. They track the maintenance. They control lightning of building, (HVAC) systems, heating, ventilating, and air conditioning. HVAC systems are designed for controlling the environment. They are building mechanical systems which provide thermal comfort with air quality. It controls temperature through heating and cooling. It controls the humidity level by controlling the air movement and distribution. Central HVAC systems contain heating and cooling panels and water source heat pumps. |
| [17] | Schaffers Vicini        | Proposed that IoT is used in smart city. It is used for making the cities smart and efficient. The objective of making smart city is to improve the quality of life of citizens by efficient traffic management & control, availability of parking spaces, making roads safe and free from pits, efficient drainage system, rain water disposal, evaluating air quality, water pollution, waste management and provides notification when containers containing trash are full, no power or electricity failure, smart public transportation system   |

**Table 2**  
Smart Home Applications of IoT.

| Ref   | Authors   | Work Area & Key Vision  |
|-------|---|---|
| [18]. | Smart Home. IoT   | Proposed that smart homes use IOT enabled devices which are remotely monitored, accessed & controlled. They provide services which responds to requirements of users.   |
| [19]. | Smart Computer  | Proposed that smart means self monitoring analysis & reporting technology. It is for predictive failure analysis developed by IBM   |
| [20]. | Hendricks Drew  | Proposed that smart home consumer products were first made available to customers from 1998 till 2000.  |
| [21]. | Smart Home. IoT   | Proposed that smart home allowed the users to monitor and control their IoT enabled home devices with help of related applications, smart phones and other devices which are networked.   |
| [22]. | D' Ulizia, A., Ferri, F                                 | Proposed that users can control the home devices and appliances remotely while away from home. This helps in security as the user can monitor the home with the help of security cameras through internet. This allows efficient energy and electric use. Smart home technology contributes to elder care, health care, patient monitoring and care of differently enabled people by accommodating their special needs.   |
| [23]. | Wollerton, Megan  | Proposed that with Apple's HomeKit users can control their home appliances and accessories controlled by an application in iOS devices such as Apple Watch.   |
| [24]. | Chinchilla, Chris                                       | Proposed that there are various non proprietary, open source ecosystems; such as Domoticz, Home Assistant and OpenHAB   |
| [25]. | Maddox, Teena.  | Proposed that smart technology can also be used to make smart cities. In Smart city functions are monitored so that they run efficiently, save energy and reduce cost.  |
| [26]. | McCarthy, Niall.  | Highlighted that smart home technology is used in variety of IoT enabled household devices such as smart television, wireless speaker systems, smart refrigerators, smart washing machines, water level detectors, thermostats, smoke and fire detector, lighting, domestic robots, security systems, door locking, home security & monitoring systems and home energy use monitors etc.  |
| [27]. | Chrispin Gray,Leith Campbell, Kerry Hinton, Robert Ayre | Proposed that proliferation of home automation systems is based on IoT architecture. Additional energy is required for powering automation interfaces. Standby energy is also required for maintaining connectivity. They used bottom up approach for developing improved system level energy consumption models. They assessed the impact on global information & communication technology energy use. They highlighted that HAS consumes over one-third of annual energy used in midsized home. |
| [28]. | McCarthy, Niall   | Highlighted that the most common IoT enabled devices were wireless speaker systems. Smart thermostats were the second most prevalently used IoT enabled device  |
| [29]. | What Home owners Want                                   | Surveyed on the kind of smart devices which are required and used most. They analyzed that security cameras, home theater systems, programmable thermostats, lighting control systems and (HVAC) heating, ventilating and air conditioning systems are mostly required and used.  |
| [30]. | North American Consumers                                | Industry forecasts have predicted that the smart home will be having minimum thirteen IoT enabled smart devices by the year 2021  |
| [31]. | 10 things to know about IoT DDoS attacks                | Smart home automation technology systems can be exploited for carrying out (DDoS) attacks direct denial of service. IoT enabled devices have risks of security and privacy. Hackers hacked the IoT enabled devices which were insecure. They infected the devices with errors and malicious code and formed a botnet for carrying out the attack.   |
| [32]. | Stancik, Peter  | Proposed that a study has estimated that home routers are unsecured because of less security features. There are around 26 billion devices worldwide which are interconnected. DDoS attack has proved that vulnerable devices small percentage can have devastating impact.   |

tions, tornadoes, hail storms, hurricanes, tsunamis, forest fire, fire etc.

IoT plays a major role by predicting the natural calamities occurrence. This helps in evacuation of people timely from affected areas. Sensors deployment in those areas which are likely to be affected helps in collection of data. The communication between (SHIP) small intermittent partitioned cluster oriented network of IoT helps in fast transmission of data. The analysis of data & fast dissemination of analyzed information results in quick relief operations. The deployment of nodes to the remote and isolated areas which are cut off due to natural calamity and disaster helps to begin the rescue operation quickly. People are saved and relocated to safe places. IoT enables easy monitoring of air water and soil pollution in the smart environment. It also keeps track of noise pollution, visual pollution, plastic pollution, thermal pollution, littering and radioactive contamination.

### 3.5. Smart agriculture and farming

Agriculture is very important for everyone especially for India which is a developing country. Growth of agriculture brings wealth to farmers. It helps them to get revenues for their harvest and crops. It helps in boosting gross domestic product of India. Smart agriculture is a revolution in agriculture that helps to modify and reorient the current agricultural systems. This is for effectively supporting the agriculture development and ensuring food security during changing climatic conditions. It will increase the agricultural productivity and incomes.

Agriculture will improve due to automatic temperature control and other parameters for maximizing the production. It will supervise soil nutrition, sunlight, humidity and ensures optimal watering and accurate use of fertilizers to improve the productivity. This results in saving water as well as fertilizers. IoT surely improves the quality of life of a farmer. The sensor nodes are deployed in the soil. The exact data and information related to soil and agriculture conditions are gathered and analyzed. This analysis helps in proper agriculture planning. They can keep their crops healthy by proper use of fertilizers and insecticides. Correct amount of watering and right quality and accurate quantity of pesticides will keep the crops free of diseases, weeds, insects and pests. It influences the life of the farmer as the farmers can reap rich benefits from his produce. Smart Farming uses advanced technology for increasing the quality and quantity of agricultural produce. Farmers have access to Internet of Things, geographical positioning system, data management and soil scanning advanced technologies. Farmers can supervise and monitor the animals and can plan their diet and fix nutrition as per their needs. This will keep the animals healthy and free from any disease. They can even maintain a periodic chart of the injections given to their animals and provide timely medical services.

### 3.6. Smart healthcare

Smart Hospitals are equipped with smart IoT enabled devices which are wearable flexible and embedded with RFID tags. These wearables are given to patients on arrival to hospital. These will

help the doctor and nurses to monitor the patient's health by noting down blood pressure, heart rate, temperature, pulse rate and other conditions. They can be monitored in hospital premises and also from doctor's residence. Smart Healthcare decreases the patients dying due to heart attack.

IoT is very useful in case of emergency situation such as Brain Stroke, Heart Attack, Cardiac Arrest. Ambulances having IoT enabled devices reach the destination in time and the patient lying in ambulance can be monitored from the hospital. The treatment can be started much earlier before even reaching the hospital. Drone Ambulances can reach the patient with emergency kit so that proper patient monitoring can be done. Doctors can track the patients and provide quick medical care until the ambulance arrives. IoT is of tremendous use for differently enabled, physically or specially challenged people. It solves their problems which come across in daily life. IoT provides medical services to their patients who residing in remote areas and difficult terrains such as mountainous region, where it is difficult to reach. The lack of rail and road facility increases the problems. It is challenging to provide medical services to the patients in such areas timely. When crisis is due to natural calamity the problem increases exponentially. The area gets cutoff and it is not possible to reach such places by road. The IoT helps in such scenarios. Sensor based nodes are deployed covering entire area which is affected. They gather data and send alert messages so that the rescue operations can be started quickly. Required number of doctors and nurses are sent to that area to provide medical services. IoT improves the quality life by automation of day today tasks. Monitoring and decision making can be done by the machines. IoT is very useful in healthcare. Health monitoring equipments are equipped with sensors which collect medical data of patients and send to Doctor as proposed by Bui and Zorzi et. al. [34]; Domingo et. al. [35] b; Luo et. al. [36] and Rohokale et al. [37]

IoT has made revolution in patient monitoring and healthcare. Sensors are worn on body and have unique ID. They gather health related data. Data is analyzed using data analytics. This improves outcome, reduces cost and enables personal care. They surveyed the upcoming technologies that will boost smart healthcare, improves power efficiency, reduced size and cost. Enabling factors in communication are ubiquitous connectivity, standardized protocols and availability of cloud infrastructure. Data analytics for analysis of massive data. Revolutionizing algorithms for computational efficiency as proposed by Hadi Habibzadeh, Tolga Soyata, Gaurav Sharma, Andrew Boggio Dandry, Karthik Dinesh and Omid Rajabi Shishvan et. al. [38]. The detailed information is found in Table 3.

### 3.7. Supply chains logistics

IoT with RFID is very useful to retailers. The products which are equipped with RFID can easily be tracked. This helps in maintaining stocks and prevents theft. It helps in keeping track of all the items available in the store. When any item reaches the threshold inventory level an order is placed automatically before the item

**Table 3**  
Work Area and Key Vision in Smart Healthcare.

| Ref  | Author     | Work Area & Key Vision  |
|------|------------|---|
| [39] | Chorost M. | Health equipments having sensors monitor and gather data from patient's body and send it to the Doctor. The doctor analyzes those reports and gives suitable medical treatment and medication. The responses of the treatment and medication are also monitored. Doctors keep track of the improvement in patients. If the response shown by patients is not good the treatment can be timely changed also. |
| [40] | Dohr       | Data gathered by deployed sensors are made online and accessible to doctors. This helps in improving responsiveness and treatment. The family members can also access this data and have a second opinion from another doctor or hospital on the basis of transparency in reports.  |
| [41] | Jara       | IoT devices also monitor the patient's current treatment and medication. They also evaluate the risk due to adverse reactions and allergic conditions.  |

**Table 4**  
IoT in Supply Chain Logistics.

| Ref  | Author                | Work Area & Key Vision  |
|------|-----------------------|---|
| [47] | Flugel and Gehrman    | IoT improves efficiency of supply chain and logistics by giving precise information which is up to date and detailed. |
| [48] | Yan and Huang         | Mitigating bullwhip effect  |
| [49] | Yan and Huang         | Reduces counterfeiting  |
| [50] | Zhengxia and Laisheng | Improves product traceability   |

goes out of stock. It helps the retailer to generate sales chart and graphs to analyze the demand and supply. It helps in analyzing the data and accordingly plan effective sales and marketing strategies. RFID and sensor networks are very useful in logistics and supply chains. Sensors are deployed in production and assembly lines of industries. IoT enables utilization of latest technologies across organizational and geographical boundaries as proposed by Shen and Liu et. al. [42]; Han et. al. [43]; Li et. al. [44]; Pang et. al. [45]; Xu et. al. [46] and Parul Goyal et. al. [51–62]. The defined work area and key vision is presented in Table 4.

### 3.8. Social applications

IoT devices are connected to many other devices and objects through internet. It is therefore essential for examining the personal and societal effect of IoT. IoT enabled devices provide various functionalities which promotes personal needs and social interaction as proposed by Atzori et. al. [63], Kranz et. al. [64], b; Michahelles et. al. [65], Speed et. al. [66] and Cao et. al. [67]. The detailed analysis is available in Table 5.

## 4. Challenges

There are various issues and challenges to IoT technical as well as social. These issues and challenges need to be resolved for ensuring wide adoption of IoT. Challenges can be classified into Privacy, Security, Accountability, Legal and General. In smart home, the main door opens using face recognition, biometric thumb impression, voice recognition security features.. The heaters and air conditioners monitor and regulate the temperature automatically. The air controller monitors the humidity and air and regulate it automatically as per the climatic conditions and as required by users. There is always a risk of security as all these systems are connected through Internet and can easily be hacked. Security is a major concern for unmanned IoT devices which are geographically distributed. The sensors consume more energy and are costly so they are not widely used in all applications. Various networks and systems are not upgradeable and scalable. This results in compatibility issues in interoperability and data exchange. Dedicated resources are required for a single IoT application like smart grids, smart homes. Thus sharing of resources in various applications and different platforms is not possible. Thus system integration is very difficult. The different data analysis techniques are application

**Table 5**  
Social Application Aspects of IoT.

| Ref  | Author                     | Work Area & Key Vision  |
|------|----------------------------|---|
| [68] | Vazquez and Lopez de Ipina | IoT is also used in social networking like twitter and Facebook.  |
| [69] | Guo                        | IoT devices help in providing information regarding location of a person and keep track of his or her activities thus saving the time of the user. These devices are also useful in gathering data and information of nearby friends, update of social events and activities of interest. The person gets update that these are the friends who are near to your location and can be called in case of emergency. Similarly a person gets update that the events which are approaching like trekking, dandia night, fare, sports, marathon etc. |
| [70] | Guo                        | IoT enables the smart phones to connect directly with another smart phone. They are used for transferring contact related and other information. They can fix up appointment and arrange meeting if their profiles are found to be compatible with each other.  |

specific and do not operate in real time. There is a need of wireless technology that will optimize architecture, bandwidth, power, range and minimize operational costs suitable for all applications and meeting all requirements. The two devices may be connected together through same wireless but their communication protocol may be different. Compatibility between different devices, applications and platforms has to be achieved for example LG refrigerator talking to whirlpool washing machine. Dell Computer, Apple iPhone, Sony smart LED Television, Panasonic Speakers, Venus Water Heater, Ecobee thermostat, Mi Air Purifier, Philips or Syska Light Bulbs and Security Cameras connected together via internet.

Internet of Things enables smart homes equipped with Smart clocks, doorbells, windows, window blinds, cooking utensils and appliances all of which can communicate, send data and information to you. On analyzing those data you can send commands to control them. Home automation is the ability to control the items around the home from lights, temperature to security locks. The huge data which is collected and gathered from over twenty six billion devices connected to internet can paralyze information technology companies. Analyzing such enormous data generated from various types of devices is a complex task. Current IT infrastructures will not be able to handle this huge data. They are already working beyond their capacity. There is a need for new infrastructure which can handle the data in IoT and IoE era. To overcome such problems, IT companies are using data reduction techniques like network theory, model building, comparison of big data, sampling, elimination of redundancy, reduction of dimension, data mining, aggregation and using Artificial Intelligence and Machine Learning. These techniques are used for converting the data into ordered, corrected and simplified form. They are using visualization techniques for analyzing big data like Pie Charts, Line Charts, Bar Charts and Heat Maps. These charts and graphs are very helpful in doing data analysis. It contributes in taking correct decisions on the basis of results and analysis. Advancements are being made for growth and development of IoT. Improvement in techniques of data processing and analyzing is also being carried out. Small integrated light weight mobile devices are being made and further R&D is regularly going in this field. Growth in networking and development of communication technologies has helped in achieving compatible cost effective economical platforms.

#### 4.1. Security

IoT enabled devices can be located in public and private places. They can be connected using wired or wireless connection. Security is a major concern. Wired and wireless communication can be made secured by using encryption & decryption techniques. Various devices are not compatible for supporting encryption & decryption. Algorithms are designed to make them efficient. Efficient distribution schemes can enable encryption and decryption in IoT. The key length should be long for security. Certificate system can also be used for authenticating the device as proposed by Alcaraz et al. [71], Babar et al. [72], Dlamini et al. [73], Hancke et al. [74], Zhou and Chao et al. [75]. For IT security, identity and

access management are important aspects. Unique identification of devices is very important for IoT enabled devices. They are used for establishing authorized access through personal identification at any institution or company, identifying illegal activities and monitoring other functions. Smart devices can be identified sensed and controlled resulting in success of IoT as proposed by Mahalle et al. [76]

#### 4.2. Privacy

IoT adoption has increased the internet connected devices. These devices are easily tracked, traced and controlled through IoT. Threats to privacy are also rapidly increasing and becoming serious. The data exchanged by IoT enabled devices is to be handled safely. Data ownership issues are to be addressed so that confidence of users can be gained in IoT. Data ownership provides information of legal rights, data assets, control, rightful owner, distribution rights framed by the owner. Data gathered from IoT enabled devices should clearly provide details regarding ownership. Owner should ensure the safety and usage of data. It cannot be used without the consent of owner. Privacy policies are to be formulated and implemented for safety and privacy of data and information. Smart IoT enabled devices carry their privacy policies. When these devices come close they check the other's privacy policy. They ensure compatibility among each other before start of communication as proposed by Roman et al. [77], Medaglia and Serbanati et al. [78], Oleshchuk et al. [79], Sarma and Girao et al. [80],

#### 4.3. Legal accountability

Technology is subject to regulatory and legal attention. The physical, autonomous and pervasive nature of IoT raises accountability challenges. Challenges related to security, safety, privacy, surveillance and general issues of responsibility and governance. IoT has created legal issues and challenges so accountability has to be fixed. IoT Governance cannot be dictated by one group. A broad global approach towards IoT governance is a necessity. Structured IoT governance which includes all stakeholders is required as proposed by Weber et al. [81]. Global accountability, governance establishment and enforcement are very essential. Fixation of accountability improves effectiveness of governance through the sanctioning threats as proposed by Weber et al. [82].

#### 4.4. General Challenges

Researchers have proposed various articles which give detailed overview of issues and challenges faced by IoT. Yan and Wen et al. [83], Christin et al. et al. [84], Coetzee and Eksteen et al. [85], Ma et al. [86], Mayordomo et al. [87], Shen and Liu 2011 et al. [88], Zhang et al. [89]. They cover various standards and technology as proposed by Bandyopadhyay and Sen et al. [90]. They cover various social issues as proposed by Mattern and Floerkemeier et al. [91].

#### 4.5. Business models

Business models need to be changed in accordance with the advancements in technology. Recent advances in Web 2.0 technology have resulted into novel models. Reliability on strategic data has increased. Aggregate data is important for grasping the customer entire journey. Market researchers successfully aggregate the data related to customer purchase, social and web analytics. They analyze all data for understanding of economics and accordingly promote campaign optimization and online advertising. Data analysis is very helpful in studying advertising ecosystems. IoT will enhance improvement in business models which take advantage of its ubiquity and pervasiveness. Market is that where buyers and sellers come in contact for exchange of goods & services. Market structures are those characteristics which influence the firm's behavior. It affects supply of product in the market. Researchers proposed different market structures for the IoT as proposed by Bohli et al. [92]. Price determination is important aspects of economics. Business managers make perfect decisions based on their analysis. They analyze market needs and reach upon final pricing decisions. Researchers proposed various pricing schemes for the IoT. They also highlighted that IoT gives a competitive advantage to firms by collecting market data, thorough analysis, better market information, demand supply knowledge helps in precise decision making as proposed by Haller et al. [93], Fu et al. [94] and Li et al. [95]

#### 5. Future directions

Web of Things are programming patterns and software architectural styles which allow the devices to become portion of World Wide Web. It provides Application Layer which simplifies IoT applications. It consists of different devices across multiple platforms and different application domains. WoT assumes connectivity already exists between devices. WOT reuses existing web standards used in programmable Web for example REST, HTTP & JSON. It uses Micro data and JSON-LD in semantic Web. In real-time Web it uses Web Sockets. For the social Web it uses social networks and OAuth. WOT proposed web standards use for integrating the devices and objects on World Wide Web. Web makes easy for developers for developing new applications with recent advances and improvements in web protocols and smart objects. It enables communication and interoperability between various devices. Mashup is new Web 2.0 concept in which application uses functions & data from multiple resources. WOT model was proposed by researchers. They suggested framework of new applications using mashup. Guinard & Trifa et al. [96] proposed to apply to the physical objects and devices other than applications. Internet of Nano things is interconnection of numerous nano devices with existing networks. It has created a revolution among nano scale devices in field of electromagnetic communication. Nano machine is integrated with nano components for performing multiple tasks. IoNT involves integrating of more number of devices into the IoT. These numerous devices use electromagnetic communication. There are various issues and challenges as proposed by Akyildiz and Jornet et al. [97]. These challenges need to be resolved before implementation of any idea and making it feasible. IoNT is a granular approach for ubiquitous computing as compared to IoT.

#### 6. Conclusions

IoT has improved our day today quality lives by major technical changes. IoT makes our life easy by use of multiple technologies and different kinds of applications. IoT provides augmentation

and automation. IoT saves time, improves decision making, find usage in variety of applications and also saves money. IoT different application domains are healthcare, home automation, smart city, smart grid, smart vehicles, transportation, smart parking, smart infrastructure, industrial, manufacturing, business, governance, supply chain, logistics, education, agriculture and mining. IoT has multiple advantages. Various issues in IoT governance and its implementation are as under:

- (1) Universal standardization is required in architecture
- (2) Interoperable technologies are required
- (3) Standard protocols are required

IoT vision and a well defined architecture for deployment is presented in this paper. We highlighted different enabling technologies and addresses security issues and challenges. IoT applications were discussed which improves and ease our daily quality lives. Research is going on in this area for wide scale IoT adoption. The issues and challenges need to be dealt with and cleared. Security, privacy, confidentiality of information must be provided to the user. IoT deployment requires tremendous efforts by resolving the issues related to confidentiality, security and privacy threats.

#### CRedit authorship contribution statement

**Parul Goyal:** Conceptualization, Data Curation, Visualization, Writing - Original draft. **Ashok Kumar Sahoo:** Formal Analysis, Investigation, Methodology, Validation, Writing - review & editing. **Tarun Kumar Sharma:** Project Administration, Resources. **Pramod K. Singh:** Supervision.

#### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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