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Integration of WSN with IoT based applications: A vision, architecture, and Future challenges

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Abstract. The Internet of things (IoT) represents the physical world of devices and objects connected over the network using wireless sensors. This chapter gives detailed study about the different applications of IoT with the integration of WSN (Wireless Sensor Networks) with Internet connectivity. This allows applications to communicate among themselves and users on a global scale. A large number of IoT applications like smart home, buildings, transport, water management, health care, agriculture, environment and industries; in conjunction form the smart city. Along with this, various challenges in the implementation of applications are discussed related to the reliability, sustainability, and efficiency. An open architecture looking into current need of IoT is also proposed and discussed.

Keywords: IoT; Smart City; WSN; Cloud Computing; Mobile Computing

1 Introduction

Internet of Things (IoT) is the connectivity of the physical devices and objects that are used in daily life, which are connected over the internet network. It is connected to different types of objects which communicate with each other through various sensors, actuators and processors. The goal of IoT is to attain high degree of intelligence with least human intervention [1]. IoT brings the automation and intelligence in all sectors of life making it comfortable; here devices are made self capable to take smart decision by themselves. In IoT, large number of heterogeneous devices is connected over the network. Today IoT covers a large domain and every aspect of the society from industry, healthcare and transport to the agriculture and home environment and provides the services.

Smart city covers all the domains of the society that use Information and Communications Technologies (ICTs) [2]. It also covers all the different applications and makes the city services and monitoring more aware, interactive, and efficient [2]. Wireless Sensor Network (WSN) is the backbone of IoT, without which the concept of smart city cannot be realized. Sensors and actuators are the devices, which interact with the physical world and impose the changes. Under the heterogeneous environment large number of devices are connected together using sensors and generate large amount of data. This data is stored and analyzed to derive the information and support decision making [1].

Smart city consists of large number of heterogeneous devices, including smart as well as simple objects. A large amount of data is gathered due to a large number of

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sensors connected to the objects. IoT network in case of smart city must be scalable as there can be requirement of adding new devices and deleting old devices, anytime and anywhere. Due to wide application areas and difference of technology among the devices, incorporating WSN becomes challenging [3]. From the perspective of the smart city the main facing challenges of IoT are interoperability, context awareness, scalability, and management of large volumes of data, security, privacy & integrity, dynamic adaptation, reliability, latency.

Smart city covers all the aspects of society by having large number of applications. Figure 1 represents the key aspects of society that make the smart city. It shows healthcare, industries, transport, agriculture and home automation, all are the essential part of the smart city. Smart city is equipped with several equipments and technologies which make the life of people smarter through several applications; there are several aspects of the smart city such as smart technology, infrastructure and governance. IoT is bringing transformation in education sector and security requirements of smart cities [4].

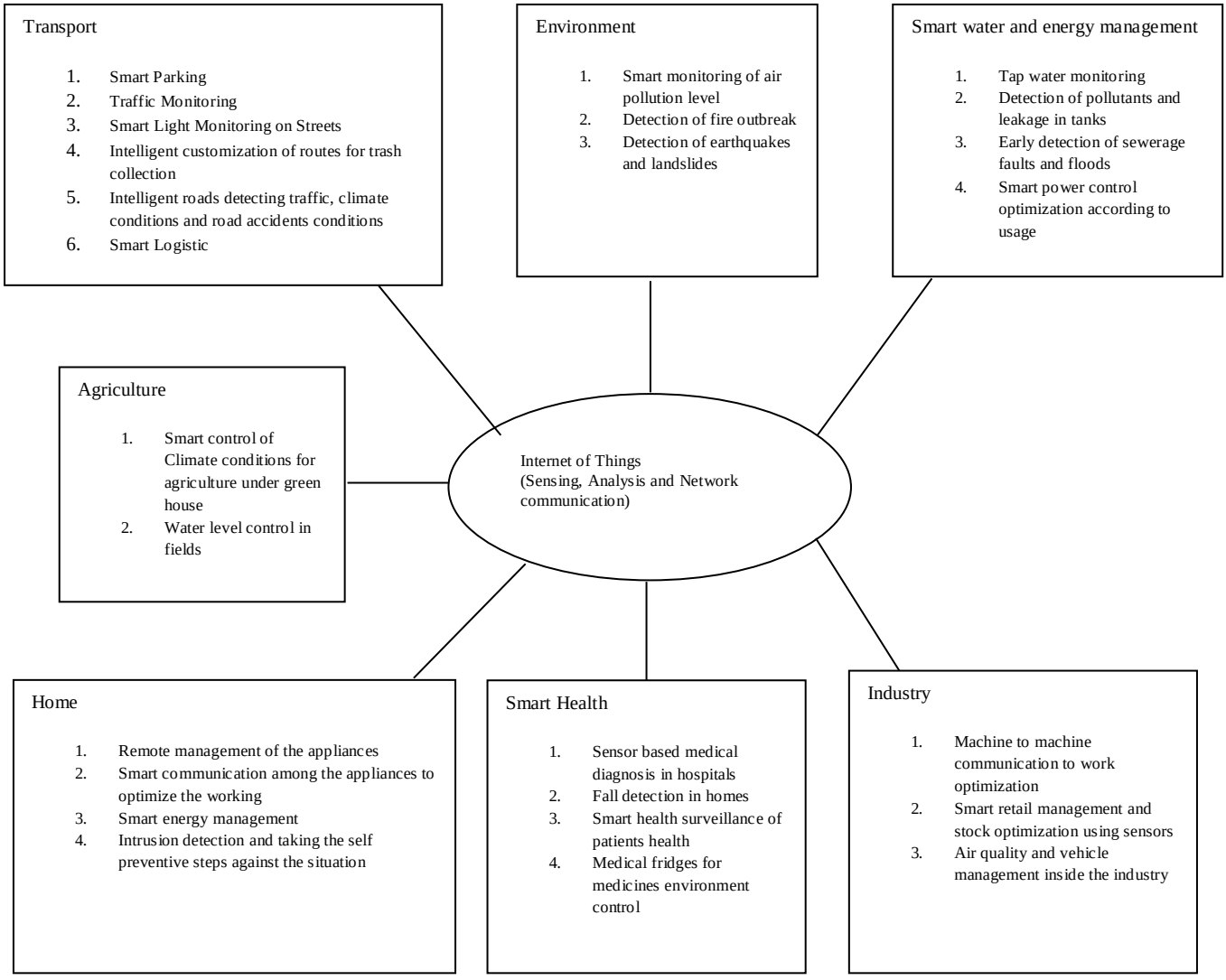

Figure 1: Key aspects of smart city

2 Architectural need of the smart city

Architecture supports the services and their working and is required to solve the key issues that are faced by IoT applications. It provides the level of abstraction over physical devices and services, supports the heterogeneity and interoperability among devices which is one of the key properties of IoT. Large number of devices and objects are connected under IoT having different functionalities, capabilities, characteristics and internet protocols which also raise the concern of security issues in IoT. In smart city IoT structure, large numbers of independent systems or applications work in conjunction. These devices have different kinds of sensors, both the hardware and software heterogeneity exists among the devices, therefore we need the architecture which is flexible to support both hardware and software diversity among these objects.

In smart city IoT architecture, information is shared not only among the different applications of the society but also to the interested parties like government and management sectors, etc. Smart city should be capable to scale any number of devices with different technology anytime, therefore cross application services is the requirement of smart city. Author in [5] suggests that some domains in smart city need real time immediate response for well-organized resource planning, to help in effective use of resource utilization. There is the need of standardization among the architectures to solve the common issues that rise due to management of huge amount of data, communication issues related to large number of protocols, real time processing of data, data security, privacy and expansion in existing application due to changes in technology and increasing usage also termed as scalability [6]. Security among the IoT applications, especially in case of smart city when there is large amount of intercommunication among the different applications, becomes the one of the major challenge due to diversity among the devices and dynamic nature in terms of network and scalability. In IoT applications the existing solutions do not fully satisfy the need of security. Some solutions demand high energy requirements and become costly solutions [7].

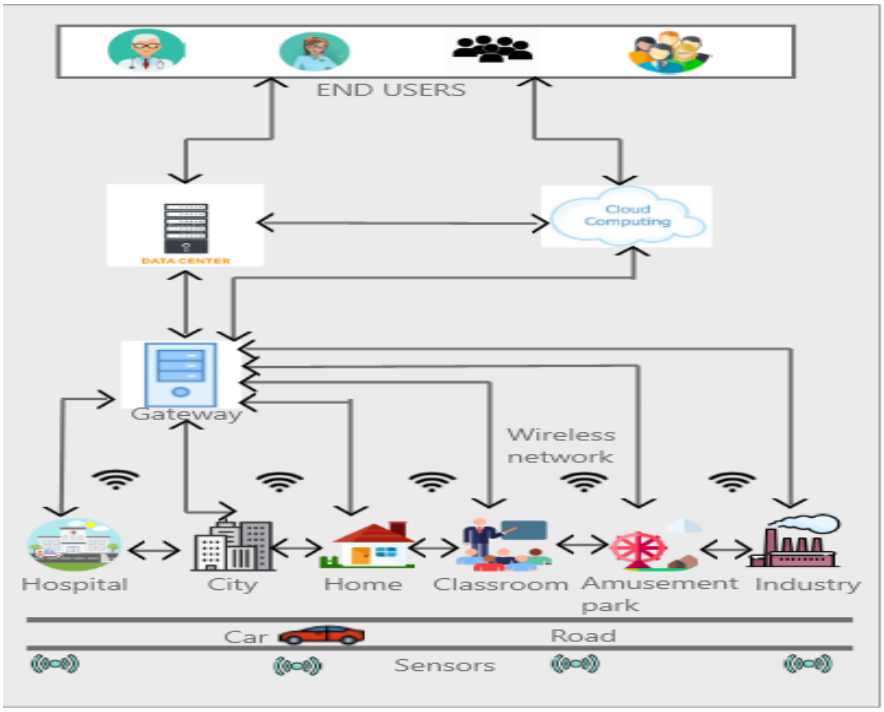

Figure 2: IoT Based Generalized Architecture of Smart City

Figure 2 shows a generalized open architecture proposed to support the different applications. It also shows that different sectors will contain the sensors and will be connected to a common gateway as these sectors will share the information to support each other. The kind of processing requirement of the architecture to support the issues in IoT such as the processing of data will be done at edges; means device level itself, to support critical applications like healthcare and also some data that cannot be handled at edge level will be processed at middleware, also called as fog computing.

With the study of issues in architectures and understanding the need of the architecture in smart city, the conclusion is drawn that smart city needs open flexible architecture which supports the scalability; means large number of devices can be added in the system anytime. Also scalability heterogeneity among the devices should be taken care of. A general architecture is proposed which is edge based open architecture so that real time data processing can be done and latency issue can be handled.

- **Smart City platform**

Smart city uses the emerging technologies such as WSN and big data analytics as large amount of data is produced by sensors to reduce the resource utilization and bring intelligence in applications. Effective data storage is also required because data grows at very rapid rate and similarly high computational and processing requirement need is handled by edge devices [8].

For building the smart city we need network of smart things using sensors connectivity among them. They collect huge amount of data using smart gateways where all devices send their data. Some initial amount of data can be processed by task offloading to the nearby devices or using the concept of femto cloud or fog structure at middleware level [9]. Whereas the tasks that need high computation cloud structure are used for processing and analytics. Data Lake for storing data, the value of which is yet to be defined and cleaned, and structured data is sent to the data warehouse. Data analytics and machine learning algorithms are implemented at the middleware level and cloud level for processing and analytics task, finally commands are send to the actuators to control the applications used by the end users [10].

- **IoT Application Requirements**

To implement the IoT solutions there is a need to create the applications, but applications implementation requires some basic requirements that are:

1. Scalability is one of the main requirements of IoT. The platform should be capable of adding any number of devices anytime without having any effect on the application.
2. IoT applications should be secure and trustworthy. These are the essential components as information flows in wide forms over the sensor network.
3. IoT applications require self adaptable, optimisable and configurable system according to the changing need of the environment.
4. IoT applications should be able to understand the situation and emotion according to the context, personalise the services and capable of decision making.s
5. Critical applications in IoT are required to be dynamic and should respond in real time without any latency. For example: critical

applications like healthcare and inter vehicle communications have dangerous impact in case of latency.

6. IoT applications collect large amount of personal and private data which may contain the personal data and activity log of people. There is a requirement of privacy compliant law for data protection.

3 IoT Integrated applications and role of WSN in Smart City

Smart cities are touching and transforming all the areas of modern society, like e-health, e-transport, energy, environment and education. For example: data from weather department can be extremely helpful for environment, flood and agriculture monitoring. Similarly monitoring the health of elder people and patients in the live environment can be highly useful. Some of the application fields where IoT is bringing a great advantage are:

3.1 IoT in HealthCare

IoT is transforming the healthcare and is one of the most important and critical applications among the society. Using wireless sensor networks to enhance the capability of healthcare structure and real time monitoring and processing is one of the most challenging goals. Reducing the cost and improving the care of the patients; at the same time dealing with the shortage of staff is the primary concern [11]. Problems related to complex data in terms of its variety, pace and latency also needs to take care of [12]. Healthcare needs multi-layer architecture having edge level computing at device level, Fog computing and Cloud computing for computation intensive tasks.

- **Mobile Computing in Healthcare Applications**

Mobile can give the facility of edge computing to monitor the health of patients from the distant locations and can be done by using central cloud at local level. Authors in [13] proposed a window based Rate Control Algorithm (w-RCA) and Medical Quality of Service (m-QoS) to provide better service and quality in the mobile edge computing based healthcare. [13] Patients will be wearing the sensor devices for continuous monitoring linked to the mobile applications for real time processing.

The cloud platform implementation helps the patients' 24/7 monitoring using smartphone app. Patients can track their health while travelling or relaxing at home anytime and anywhere. Farahani, B. et al. [12] says P2P video/audio capabilities can be provided to patients for identification of diseases as well as their treatments and refills of medicine whenever required.

- **IoT in Medication**

IoT in medication of patients can be of great help specially in case of elderly patients. Home caring service, a self alarm system is proposed by authors in [14] to take the medicine. Also the state of medicine bottle is tracked by the sensors using weight sensors to give warning in case of medicine overdose. In [15] author purposed use of RFID technology (Radio Frequency Identification) labels and tags on patient's medicines connected over the internet over the IoT with patient's personal medical files. This will also help in better connectivity between the doctor and patient. Using this architecture physician can remotely monitor the patient state and warning can be generated to physician or nurse in case of some changes in patient state. Here authors have used machine learning algorithms and probabilistic learning structure to enhance the accuracy using classification.

As studied in [16] authors have proposed a smart necklace to determine the intake of medication by patients. It checks and observes the skin movement of the

neck part during the intake of medicine. Bayesian network is used in the study to accurately identify the swallow of medication capsules, normal speaking and chewing the vitamins [16]. In combination, medicine bottles are also made smart with wearable audio sensors and classifications are used to get the accuracy in assessment of medication adherence.

- **IoT in Ambient Assisted Living**

The Ambient Assisted Living (AAL) [17] is particularly targeting the quality of life for older people who are dependent and are at home. It not only includes the medication and continuous health monitoring but also checks the Indoor Air Quality (iAQ) and comfort. The devices and objects in the home will be connected to each other to help the elderly and disabled persons in their day to day routine activities [18]. It will also take care of the growth of diseases by live check on the vital signs of the persons.

- **Challenges in IoT healthcare**

IoT in healthcare brings lots of new hopes to patients and elderly people but the seamless connection among locations, patients and hospitals are not easy to achieve. The main challenges in the way of IoT integration in healthcare are:

1. Management of large amount of data in health care system. Large numbers of medical sensors are attached to the patients and around them. Dynamic nature of the body with continuous state changing becomes more challenging. So collecting and analyzing data with accuracy becomes challenging.
2. Different formats among the data is also an issue as some data is collected by the images using cameras, some data is captured in the form of variations and vibrations, some in the form of body temperature, etc. Accumulating all these different data and analyzing on common platform becomes an issue.
3. IoT applications particularly in case of health care are time bounded and emergency services cannot tolerate latency and require real time monitoring and analysis. But the tasks that require high computations cannot be handled at the edge level so an open research challenge is present in the domain.

IoT healthcare has lot of advantages and scope but still there are lot of challenges which need to be addressed like device-network human interfaces, security, and privacy. Large variety and volume of data and lack of standard architecture is also an issue, including this network architecture should be scalable; latency rate should be lower with high bandwidth.

3.2 IoT in Industries

IoT is bringing revolution in industries by improving the machine to machine, machine to human communication and bringing intelligence in value chain of system and making it smart value chain. Industries are embedding intelligence and network communication among the process belts to improve their own systems and products. Checking the events, warning of failures and suggestions to improve and upgrade the existing hardware, refineries, offices according to IoT applications to enhance the efficiency of the existing system are the advantages of bringing IoT. The main purpose of bringing the IoT in industries to offer their customers new sets of premium services is:

- Using Machine Learning (ML) and Natural Language Processing (NLP) to bring smart handling of equipments and their pre-maintenance.

- Making pricing dynamic and analyzing the data based on the usage, providing it to the manufacturing value chain helps companies increase efficiency and reduce the processing costs.
- In retail sector giving retailers and customers personalized experience [19].

IoT is among one of the future technologies gaining large popularity for all kinds of industrial domains. In this, there is a global network where machines and devices work in conjunction with each other. Author in [20] says that the full power of IoT in industries can be achieved by complete connectivity of devices in industries. For all kinds of processing, monitoring and management of data cloud based business model can be used. IoT is not only touching but also becoming part of every aspect of industries from logistics, retail management, and customer support to supply chains.

- **IoT value chain**

In broader view it is not restricted to one organization, rather allows the data to be shared publicly in multiple organizations. This data is the information that can help the other actors to perform better in terms of design, decision making and controlling other devices to optimize the services. IoT value chain has different components like for taking inputs there are different sources of IoT value chain, devices/sensors, open data and corporate databases. Then initial development of information and components is done under production and manufacture, processing of information is done using data analytics to create knowledge; packaging is also a component of this chain where product is made ready for distribution and finally distribution and marketing where in this information products are used for improving internal decision-making and for resale to other economic actors.

Today corporate sector wants to provide direct and customized service to the consumer and this is becoming possible with the merging of Machine to Machine (M2M) value chain with IoT services. Data has not remained specific company based now; it is collected over various sensors and Radio Frequency Identification (RFID). Today we need Information driven value chain in industries. Industries not only want to sell their products but also want to know the potential of the business. Before starting up, analysis reports are generated to know the current and future aspect of business, what can be its growth rate, how future demand will rise or decline or what kind of scalability will be required in the business [21]. For example, today your GPS device can learn that after a long journey you prefer a cup of coffee and after journey your smart phone shows you immediately the nearest best cafe areas or coffee business makers can learn that in this region lot of customers after travelling from train prefer a coffee, so let's start cafeteria in nearby location, earlier no smart learning or searching was there and people use to walk and search by asking the people nearby.

Similarly, clothing retailers can learn your preference and choices from your buying and trial habits which he could use to give customized service to customer as well as it can help him to stock only the preferred choices of customers in the store.

- **Challenges in IoT Industry**

Here IoT deals with some common challenges that health care system deals with, like scalability is big challenge in IoT implementation in industries, it means growth in terms of capability, system and network. Infrastructure and processes in industries grow at rapid rate; the IoT structure should be capable to accommodate that growth. As industries are of different domains for example manufacture sector is different from retail and logistic sector;

similarly, information technology sector is different from the production. There is a gap of technological standardization as lot of hardware is involved in the technology or platform. In lack of standards companies that make the IoT based products use the random architectures that they feel comfortable and easy in implementation [21].

As different hardware and platforms are involved, interoperability becomes a challenge. This hardware makes use of different software to swap over and utilize information, a broader software infrastructure will be needed on the network and on background servers in order to deal with the smart objects and offer services to support them.

Fault tolerance is a big issue in IoT devices, as they are dynamic and mobile in nature. They change their state and behaviour rapidly. Structuring an Internet of Things and an ability to automatically adapt to changed conditions is required [21].

3.3 Internet of Things in agriculture

Recently agriculture farming has gone through technological transformations. In last decades, it has become more technology driven and industrialized, bringing large number of benefits to the farmers. The ever increasing demand of food in terms of both quality and quantity has made agriculture more as industry where now farmers have gain complete control from production to selling of crops. Revolution of technology in agriculture is possible due to Internet of Things (IoT); it is a highly promising family of technologies which offer solutions to the several existing problems in agriculture. Researchers and scientific groups are continuously working on IoT applications integrated with Wireless Sensor Network (WSN) to help the agriculture sector to deliver better services and enhanced IoT products.

Using automated machinery to control and optimize water use, energy management and use of chemicals for pest control and use of fertilizers, Precision agriculture [22] aims to boost and develop agricultural processes to make sure maximum output and require quick, dependable, scattered measurements in order to give growers a more detailed overview of the in progress state in their cultivation area. Agriculture applications will also keep track on weather and environment information; gather the data from various heterogeneous systems, evaluate the knowledge and organise them in form of smart algorithms to provide a better insight into the in progress processes, do the interpretation of the present conditions and make predictions based on heterogeneous inputs, and based on the collected information warning signal will be produced. The different fields of agriculture where IoT is bringing changes are:

1. Green Houses observe the climate conditions using sensors and control them to maximize the production and maintain the quality.
2. Control the various parameters of humidity and temperature levels to form the compost to prevent fungus and other microbial contaminants.
3. Tracking the animals and identifying their grazing locations using sensors and study of the air quality in farms and detection of harmful gases from excrements.
4. Continuous monitoring of crops for reducing spoilage and crop waste [23].

- **Implemented solutions available in IoT Agriculture**

  The Kaa IoT Platform provides sensor based remote monitoring of crops and equipments including live stock management with climate monitoring

and forecasting. Provided services include live stock tracking, stats on live stock production and smart logistics and warehousing [24].

Farm Logs is a sensor based software application for technology enabled farms. It helps to manage day to day operations on the field, create agronomic plans that calculate field level profit/loss based on your input expenses and rates. It also helps in documentation for reporting and analysis and tracks your marketing position and make more profitable crop sales [25].

The Phytech gives the ability to direct plant sensing, connects you directly to the plants, sensors are connected to the plants micro-variations of stem diameter that are scientifically proven stress indicators. The data is transmitted in real time to the Phytech cloud for further analytics, providing certainty in decision making, optimizing production and reducing risk. Patented algorithms are continuously performing data analysis and does predictive analysis provide meaningful alerts and recommendations. Machine learning algorithms provide irrigation scheduling recommendations to maintain the plant status in the optimal zone with minimal resources [26].

Semios platform with monitoring of conditions also checks the disease condition and plant health in real time. It's a powerful tool in yield improvement that helps growers assess and respond to insect, disease and plant health conditions. It provides sensor based integrated pest control, whether monitoring with forecasting, Disease Model Conditions and Risk Evaluation and Monitoring Moisture and Soil Conditions using big data analysis and data prediction [27].

- **Challenges of IoT in agriculture**

In agriculture for the successful implementation of IoT there is deployment of large number of IoT devices because of large area, this can arise the interference problem with the local spectrum such as ZigBee, Wi-Fi, Sigfox, and LoRa [28]. There is one more challenge of exposition of devices to the harsh environmental conditions like physical damage and degradation.

IoT in agriculture will need large number of IoT devices, lack of standardization in existing gateways and protocols lead to heterogeneity and scalability issue [28].

3.4 IoT integrated Smart Home/ Building

A smart home and building using devices and objects connected over the internet for remote monitoring of daily used appliances of home such as lightning, water utilization, monitoring and optimizing electrical equipments. Using smart homes and buildings concept not only day to day devices like smart doors, lights are controlled but also security of home and building are monitored. IP-based cameras, alarms, motion sensors, fire fighting equipments and connected door locks give more home security. To provide such kind of automations in home and buildings IoT connected wireless sensors are bringing the revolution.

IoT using sensors in conjunction provide large number of services and applications such as smart metering to optimise the energy usage and sending the consumption data to the energy provider to reduce the waste further, in similar manner smart metering for water consumption can be done which can provide great aid to societies and cities by looking in to the mater of depleting water resources. Like this all home resources work in conjunction. Sharing the information among each other processing, optimizing the tasks and taking decision accordingly forms the smart environment. Sensors optimize the home utilities based on human activity

for example temperature sensor, humidity sensor to auto control the air conditioning not only this for elder people alone at home it can support their medication and raise alarm in case of emergency situations, giving support to the elder people and patients [29].

Smart Home works by automation of home and its appliances and minimize the user input for controlling home appliances. One of the most common hardware platforms that is used to create a smart home application is Arduino using sensor and actuators and for networking Zigbee technology's mostly used. Cloud structure is important part for big data analytics and data prediction [30]. In literature Son et al. [31] introduced a system based on resource awareness they mentioned mobile device access remotely to home using Web Services Description Language (WSDL) and Simple Object Success Protocol (SOAP). Energy management is also an important application in smart home and buildings in this context, Han et al. [32] suggested a new Smart Home Energy Management System (SHEMS) based on IEEE802.15.4 and ZigBee. A multi sensing application for reducing total energy cost. Wu et al. [33] studied the home nature of a smart home in serving its users, they mentioned a framework of intercommunication among the services and users, using the framework, and they developed two pervasive applications of "Media Follow Me (MFM)" and "Ubiquitous Skype." To predict the user activity, a sequence prediction algorithm is proposed by Alam et al. [34] using enhanced episode discovery. It monitors the user behaviour in sequence of activities. Based on human activity patterns. Chen et al. [35] used multi sensor approach consists of activity recognition from context ontology modelling and situation formation process, for real time continuous activity recognition.

Challenges of IoT in Home and Building structure

Heterogeneity among the IoT objects become one the challenge of smart home and building, the IoT should be capable of integrating these devices seamlessly, In case of smart city proposing the general architecture of IoT is hard due to large number and different type of devices, protocols and services [36].

Seamless connection among the devices means easy to connect anytime and anywhere in IoT system, termed as Interoperability. It's a prime concern as in smart home devices and network system comes from different vendor so joining them to achieve interoperability becomes challenge.

In IoT smart homes and buildings to achieve self maintenance and management becomes one of the major concern, devices should be capable self monitoring and optimizing their health and notify the user [37].

3.5 Intelligent Transport System

IoT is playing big role in smart transportation giving solutions to many existing problems in it providing Intelligent Transportation System. There are large numbers of issues that exist among the transportation like traffic congestion, management, minimize the environment impact due to pollution to give the benefits of transportation to commercial users and the public in general. Inter communication applications among vehicles can be provided to help citizens save time for smarter city. Intelligent Transport System (ITS) works to improve the traffic management by reducing traffic issue, giving the prior information about real time traffic, local convenience,

seat availability etc. which help commuters as well as enhances their safety and comfort.

- **Application areas of Intelligent Transport System**

In smart city, all domains of the society will be digital to make the life of the citizens easy. Children going to school, people to office and college transport system should be safe. In case of elderly people, the need of smart transport even rises. Old age drivers and pedestrians have more accidental rate, large number of application areas exist in Intelligent Transportation Systems (ITS) to enhance the user and citizen facility in smart city like blind people can be helped by self guidance applications and can save a lot of time of the users.

For implementation of IoT to make smart transport, large number of sensors is embedded in vehicles by the automotive manufacturers to enhance the road safety and better management of traffic. Government departments for road and construction can use the smart ITS to enhance the road infrastructure by implementing sensors, devices and cameras that will monitor the environment and traffic in live conditions.

Authors in [38] mentioned that ITS is providing great help in improving the road safety, reducing the traffic congestion by using number of sensors and actuators like tire pressure monitoring and rear-view visibility, like this many more sensors are now embedded in vehicles to enhance and monitor the performance. It can be said that number of sensors is continuously increasing in vehicles to first make the vehicle as the smarter vehicle.

In [39] authors have mentioned that IoT and WSN are supporting large number of applications like logistics support, emergency services and several other applications. Not only are the vehicles with sensors but number of sensors are also used on the roads to enhance the road safety and conditions.

- **Challenges of IoT in smart transport system**

In intelligent transport system, a large number of vehicles are connected using IoT in geographically dispersed area using cloud computing centres, huge amount of data is generated and transferred. Big data processing and analytics is performed. Due to large amount of data created and processed, the issue of latency arise which is risky in case of medical and emergency.

Fog computing brings the solution to the above problem by real time big data analysis which gives the feature of processing data at middleware level and edge of nodes, but the smart transport systems have dynamic nature, so implementing such solution becomes challenging, also the huge amount of big data collected over the transport system is heterogeneous in nature [40].

3.6 Efficient Energy Management using IoT

Smart utilization and management of the energy is the biggest concern of the modern society. Using IoT to make the city smart require large number of IoT enabled applications, as the IoT devices are increasing in number and features the need of power to manage these devices also grow. It is the essential need of the smart city to efficiently utilize the energy. The energy utilization information of smart homes, buildings including school's offices, amusement parks and roads street lights etc. are collected and analyzed for the optimization as also send to the grid system for proper resource utilization.

Authors in [41] mentioned that consumption of energy can be minimized by effective management of home appliances, education and healthcare system. To manage the energy consumption of home, commercial

and industries, big data is collected from them and utilized by using various processing algorithms and making analysis. Energy Management System (EMS) and data acquisition System on Chip (SoC) is presented in the paper to gather the consumption data of energy from the devices. Data is sent to the centralized server where it can be processed and analyzed. In [42] authors propose an on-demand supply model in this consumer is also informed about their consumption nature so that user can make decision on their consumption to reduce the cost and consumption itself.

DC powered homes concept is given in [43] as a distributed system for residential area, but due to lack of any standardization in protocols intelligent DC powered homes currently cannot be considered to replace the traditional system of AC supply. In [44] Multiple in-Home Display systems (IHDs) and Automatic Meter Reading systems (AMR) are discussed to provide energy management information. In this the smart home system by analyzing the proper condition of the resources choose itself the display interface such as television, smart phone etc. A Home Energy Management System (HEMS) architecture is proposed in [45] in this smart meter data is used for monitoring real-time information on home energy consumption and giving online remote control to devices status. This model is only proposed for small area using the HTTP protocol but for large residential areas Message Queuing Telemetry Transport (MQTT) protocol is required. In [46], a model is proposed where all the nodes and devices connected in smart home plan their operations based on the weather conditions. In this system data is sent to the web server using Extensible Mark up Language (XML) and XML files, but bandwidth issues are faced due to large size of files.

Smart grid concept is discussed in [47] for effective monitoring, smart control and reliable and efficient power delivery. Using IoT a smart grid is formed having Wireless sensor networks as it is a main component. The smart grid provides the smart monitoring which is the main goal of it. Smart plugs, gateways and meters connected to the appliances using network creates a communication channel between provider and consumer to provide better energy production and consumption. The smart grid keeps the track of both energy generation and consumption

- **Challenges in Efficient Energy Management**

Various kinds of attacks can be done on smart home and buildings like Impersonation/Identity Spoofing that aims to consume someone's energy on its behalf. Eavesdropping is another attack on IoT-based Smart Grid as they use the public communicate infrastructure to gain the energy consumption information of user and households. In Data tampering attacker gain the access of modifying the exchanged data, can change the rate pricing of energy. Attackers can gain the authorization and control access and can remotely monitor and configure energy utilization information by changing the readings of smart meters and sensors. Including this private information of the users can be monitored by analysing the usage information [48].

In general, the energy resources are volatile in nature and smart grid should be capable of managing the volatile behaviour as well as energy systems have to follow governmental laws and regulations, including this energy delivery need to be optimized according to the business needs and potential legal constraints [49].

3.7 Smart Water Management

Smart water management means various processes to manage the water resources and its consumption, in optimized way so that there will be least wastage. We know the water depletion is big challenge among the society, in [50] author looks into these issues including equipment maintenance. The water management system work in conjunction with water resources, society and environmental systems. Water management system is fragile and continuously changing and evolving due to different sectors from industries to agriculture, household has different requirement.

The utilization of water is biggest consumer in field of agriculture [51], the main cause of the water wastage are leakages in distribution and irrigation. Moreover, the problems like under irrigation and over irrigation needs to manage. IoT in agriculture need integration of large number devices, objects having heterogeneous and advanced sensors. They will work in conjunction using software application that will implement cloud computing and big data analytics.

In [52] distribution large number of sensors and actuators near to the water grid, water distribution resources are proposed for real time monitoring and controlling for efficient management. Water meter, pumps are monitored and controlled in real time. A smart water quality monitoring system was proposed in [53], an interface was designed for data storage, data processing. The different sensors used for quality monitoring are temperature sensor, turbidity sensor, pH sensor, water flow sensor the system is connected with the Adruino hardware for measurement and analysis. This proposed system was designed for maintaining the quality of environmental water resources reservoirs.

Jing [53] designed a model based on software using language VC++6.0 to remotely manage the water supply based on wireless sensors based on GPRS and microcontroller. Purohit and Gokhale [54] used Intel microcontroller to design a real-time water quality measurement system based on water quality measuring sensors. Beri [55] design a device that measures in real time various parameters of water such as pH, temperature and turbidity. In [56] author proposed an android based mobile application where user can check the water level in tank using sensors, this information will be send to the cloud. This model can help the residential societies to minimize the water wastage level.

Several major advancements have been attempted to automate meter reading such as smart motor controlling, Automated Meter Reading (AMR) system are the features of the proposed system. Including this model will also do trouble shooting by

Identifying the leaks, breaks and optimizing performance through optimizing pressure, flow and usage.

- **Challenges of IoT in water management**

In water management scenarios one of the biggest concern is the risk of physical attacks over the devices, most of the devices are accessible making capturing easy. Cloning of the devices can be done, installing any malware or firmware.

Water is a vital resource for life, management of water is facing big challenges like interoperability and lack of standardization in monitoring protocols and equipments.

Cyber security of the implemented devices in IoT is also big concern as devices objects are vulnerable during networking and inter communication [51, 57].

3.8 Environment Monitoring using IoT:

The optimization of home resources according to the usage is termed as home automation, similarly if the environment can be made to self optimizing according the needs of the human termed as smart environment [58]. A smart environment means making things around us easy for example moving heavy objects for the elderly. IoT based smart environment focuses facilitate our lives and to investigate its effect on human life, it gains the knowledge from inhabitants and adapt according to its inhabitants. The integration of IoT with environment will consist of several applications to monitor and analyze the environment. These applications will enable to monitor the environment and its various parameters from the remote sites, smart home, building, transport and health etc. all in composition become the part of smart environment [59].

In [60] author proposed microcontroller based garbage bins or dustbins having IR wireless system, this system will show the current status of garbage on mobile web browser and when the dustbins are overloaded. Air pollution is one of the biggest threat to the environment and main cause of the air pollution are industrialization and emission of harmful gases through vehicles, a real time monitoring is required to detect the pollutants. [61] Presents IoT based solution to the air pollution problem called as Polluino. This is an Arduino based system to monitor the air pollution, a cloud based platform is also developed to maintain the data coming from the several external sensors. The following parameters are measured to determine the quality of air carbon monoxide, carbon dioxide, nitrogen dioxide, methane, hydrogen sulphide, ozone, ammonia, particulate matter, benzene, ethanol, toluene, propane.

In [62] paper presents air quality monitoring system with context awareness, which means personalizing the services based on situation and context of person or place. In a context aware system monitoring alone is not enough, there should be a notification systems regarding citizens there is a need to give alerts in real time; the information provided to users should be adapted accordingly to the activity the user is going to be involved and notifications should be sent accordingly. In this paper, a smart context-aware system has been proposed and implemented. This system can obtain relevant context from the user, provide real-time air quality information and notify citizens accordingly. With such a system, we can prevent unexpected health issues related to poor air quality conditions, as well as being able to suggest more suitable places or activities to users according to their context and current air quality. Therefore, the system provides one step forward in the scope of smart cities, improving life quality for citizens in general, and for risk groups in particular.

In [63] an early warning fire fighting system is proposed based on internet of things, it detects early sign of fire by using the various sensors like temperature, humidity, flame, and gas. Warning message is generated based on the threshold value set in the sensors accordingly system generate

the notification email and text message to the user phone and switches off the main power system.

Wireless sensors networks (WSN) are providing an aid in measuring the environmental parameters in real time, environmental disaster and live monitoring of it is one of the greatest need of the world. In [64] a Raspberry Pi based IoT system enabled with video cameras is proposed for landslide detection. The data collected by the video streaming are send to the computer vision algorithm and generate notifications through android application.

Topographical images are used to perform the surface modelling and detect the recent activity of landslides known as Light Detection and Ranging (LIDAR) [65]. In [66] satellite images make use of Image thresh holding by genetic programming to detect landslide activity in a region. Bag-of-Visual-Words (BoVW) and Probabilistic Latent Semantic Analysis (pLSA) [67] methods are used for landslide detection using the image sensing classification method based on k-NN classifier to detect landslide and non-landslide region.

Authors in [68] proposed a complete solution to monitor the landslides; this architecture is composed of micro meteorological node to collect temperature, relative humidity, wind vane, wind speed, rainfall and a ground node which measure the soil moisture at different depth.

Animals are under study for the early detection of natural calamities [69] this article presents study that various animal can detect the approaching disaster early, therefore the applications need to be developed that use sensors and computer vision to collect data on animal behaviour. The behaviour of animals is studied as an indicator of natural disasters using data processing and analysis.

In [70] authors proposed an earthquake early warning using IoT integerated with WSN. The sensors are placed in the surface of the earth. The system is based on compression P wave and transverse S wave which radiates during the earthquake, P wave travels faster and trips the sensors and an early alert signals are generated giving humans and automated electronic system a warning to take precautionary actions with S waves. The Zigbee transmitter are used to send the alert signals, warning are send to the smart phones.

Challenges of IoT in environment study

Deployment of IoT to create the smart environment needs successful meeting of certain parameters like compatibility different products connected, large amount of data is generated attention should be given to storage, access, and processing of such big data generated by devices forming an IoT environment.

It is difficult to monitor every landslide prone area because of the costly instrumentation and maintenance also the delay in sensitive information is critical to the environment [65].

Recognition of animal activities are not accurate all the time, there can be several other parameters that can change the behaviour of animals like climatic conditions, magnetic storms, seasonal factors, noise, etc. [69].

4 Comparative Analysis and Discussions

After the study of various issues and challenges in IoT a conclusion is drawn, it has been found that irrespective of application areas there are some

common key issues exist including incorporation of WSN in the IoT which are summed up in table 1.

Table1: Challenges of IoT in WSN

Challenges	Descriptions
Inherently Distributed	As IoT applications deals with vide different kind and type of systems design, a common approach for development and designing is challenging.
Data Management	In IoT applications large number of heterogeneous devices with huge number of sensors is connected, they generate large volume of data having different formats and are generated at different speeds. There is need of regular application maintenance system due to risk failure of sensors or introduction of an invalid data by a malicious user.
Humans Centric Applications	Psychological and behavioural data of humans are required to study, which varies human to human therefore become more complex to design human centric application
Inter Dependent Applications	Several problems in IoT applications arise due to interdependency among one or more applications, in real life there is sharing of the resources among the applications. Services of different applications can also conflict with each other. Detecting and resolving such issues are critical and challenge in IoT system.

After the detailed study of the various applications and understanding the challenges in them a detailed discussion about IoT in healthcare and agriculture is made in table 2, as both the applications are essential in the realization of smart city concept. In table implementation aspects of the applications along with the main sensors used by them with their feature and contribution details are discussed.

Table 2: Feature details of the sensors in applications

Applications	Sensor	Features	Contribution
IoT in HealthCare	ACCELEROMETER [71]	The ADXL362 from Analog Devices, 3-axis MEMS accelerometer with ultralow power utilization, which consumes less than 2 µA when the output data rate is 100 Hz and only 270 nA	The ADXL362 is an accelerometer is used for recognizing the fall, it wakes the MCU controller up and an emergency notification generated to Smartphone

	TEMPERATURE SENSOR [71]	It has high accuracy of range 0.1◦C from 37◦C to 39◦C, high resolution (16-bit) and low power utilization (600 µA at 2.7 V to 3.3 V).	It can provide an over temperature alarm and communicate with the MCU
	PULSE SENSOR [71]	The pulse sensor works on low power and contains low power light photo sensor (APDS-9008) and amplifier (MCP6001) with the typical supply current of 42 µA and 100 µA, respectively.	Pulse sensor can measure the heartbeat of the radial artery at the wrist
	CHEST-WORN ECG MONITOR [72]	Three electrodes, two of them elliptical (6.5cm and 3.5cm) for ECG were stitched on two sides of the torso on the belt and a circular electrode for ground (Ø2.5cm) next to the navel	Long-term ECG recording, distant expert to identify cardiovascular problems earlier.
IoT in agriculture	TEMPERATURE SENSOR [73]	The LM 35 sensor is vastly used because its output voltage is linear with the Celsius scaling of temperature. The range is from -55 degrees to +150 degrees	Used as an indicator of water level inside a tank and water resources.

	MOISTURE SENSOR [73]	There is the principle of open and short circuit. The output is high or low reflected by the LED.	Sensor used to sense the moisture level of soil.
	PIR SENSOR [73]	PIR sensors detect the infrared radiation generated or reflected from an object	This sensor detects the progress of people, animals and other things.
	HUMIDITY SENSOR [74]	The HDC1010 digital humidity sensor to measure the moisture and humidity level in the environment.	The HDC1010 is more strong against dirt, dust, and other ecological impurities.

Table 3 discusses the smart home/building; its requirement for sensing has been divided in three categories of units. With this the features of home and building that it support is discussed.

Table 3: Sensor Unit Type of Smart Home & Building

	Sensing Unit Type	**Power Supply**	**Features**
IoT integrated Smart Home/ Building [75]	Hot Water System Monitoring	Electrical Outlets	Real time monitoring of warm water and solar heating system.
	Household Electrical Appliance Monitoring and Controlling	Electrical Outlets	Monitoring and controlling of normal domestic appliances such as Battery Charging units, Room Heaters, Washing Machines, Refrigerators
	Measuring Environment Temperature	Battery	Sensors are capable of measuring the room temperature accordingly enables to regulate the

			usage of the appliances.

5 Conclusions

In this paper a detailed study of IoT applications are done with the major issues and challenges in their implementation after the study a conclusion has been drawn that there are some common issues among all the applications related with the integration of WSN with the Internet of Things (IoT), later in the chapter implementation details of the key sensors used in applications with its features are discussed. A requirement of edge based open and flexible architecture that can support the heterogeneity and scalability issue is also proposed. This paper will aid the researchers to understand the representation the physical world of devices and objects connected over the network using wireless sensors

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