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## A Literature Survey on the Applications of Internet of Things

**Abstract.** Internet of Things can ensure easy and comfortable life of the human. This present era is mostly digitized and appliances can be operated remotely by human, calling these as smart devices, smart home, smart city etc. This paper is the literature review covering the IoT applications in various fields, sectors such as smart cities and homes, health center, railway system, air pollution in environment, power/energy sector, agriculture, water monitoring for aquaculture, Space-IoT and specifies the advancements in those areas.

**Streszczenie.** Internet Rzeczy może zapewnić człowiekowi łatwe i wygodne życie. Ta obecna era jest w większości zdigitalizowana, a urządzenia mogą być obsługiwane zdalnie przez człowieka, nazywając je inteligentnymi urządzeniami, inteligentnym domem, inteligentnym miastem itp. Niniejszy artykuł jest przeglądem literatury obejmującej zastosowania IoT w różnych dziedzinach, sektorach, takich jak inteligentne miasta i domy, ośrodek zdrowia, sieć kolejowa, zanieczyszczenie powietrza w środowisku, energetyka/energetyka, rolnictwo, monitoring wód dla akwakultury, Space-IoT i określa postęp w tych obszarach. (Przegląd literatury dotyczący zastosowań Internetu rzeczy)

**Keywords:** Internet of Things, Raspberry Pi, Arduino, Monitoring.

**Słowa kluczowe:** IoT – Internet Rzeczy.

### Introduction

Internet of Things (IoT) is a system of things that are connected to one another and can collect, transfer data over a wireless network without involvement of human. If an object could be connected to the internet and is controlled and information is communicated, then the object can be an IoT device.

In 1999, Kevin Ashton made up the phrase 'Internet of Things'. The communication among electronic devices and sensors through internet is provided by Internet of things. IoT is a solution to many of the problems faced by human. The transformation is observed in our daily routine as the involvement of IoT devices and technology is increased.

The concept of Smart Home Systems (SHS) and appliances that consist of internet based devices, automation system for homes and reliable energy management system is of the development of IoT [1]. As in [2], wireless sensor networks and IoT go hand in hand, as many fields for development of IoT technology included the application of WSN.

The IoT technology is adopted in most of the applications such as air pollution monitoring, health care, water monitoring, smart city, railway, power, agriculture, space-IoT and many other sectors. This is depicted in figure below as Fig.1.

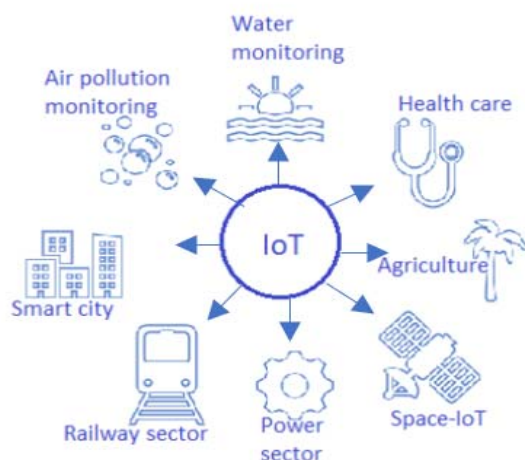


Fig.1. Applications of IoT

In the next section, the literature review on various applications based on IoT technology is provided.

### Literature Review

The literature review of the IoT based applications research work carried by different authors in various aspects is done in this paper. This paper would be helpful for all researchers as most of the IoT applications are generalized and briefed in this review paper.

### Air Pollution Control

The air pollution in the environment has to be controlled in the busy areas as in the high traffic roads, industrial and machinery work fields etc. Here, the following are applications of IoT with air pollution monitoring systems.

The authors in [3] have integrated Single Board Computers (SBC) which is a Raspberry Pi with Wireless Sensor Network (WSN) for Air Pollution Monitoring (AQMS) Systems. The Raspberry pi is a fast processor and the authors have interfaced ThingSpeak web application with SBC for data monitoring. A mobile App called IoT-Mobair was developed for predicting the pollution level in the air and control it by the users or clients and the microcontroller used here [4] is Arduino. Authors in [5] used Zigbee based monitoring system of air with WSN in mesh topology using 8051 controller. A Node MCU interfaced with sensors and connected to WLAN is used in [6] for air pollution monitoring and ThingSpeak is web application. This work might be used for shorter range purpose. Using grove pi+ board and raspberry pi, the authors [7] have developed an approach for air and noise pollution monitoring in air, so that, the users are alerted with push message on their mobiles.

An interesting air pollution monitoring work was conducted in the paper [8] which is a part of GreenIoT project where the sensors installed on movable bus [9] and also stationary sensors placed in the city centre. The author [10] discusses about environment monitoring WSN model and this flow mentioned in the paper could be used for most of the other applications based on IoT. Having information and communication technology, the city officials interact with people and the problems can be solved immediately as the system of smart environment monitoring is evolved with the advancement in IoT [11]. The Arduino, NodeMCU are used in real time monitoring of pollution in the air [12, 13, 14] and vehicle user is alerted to drive through another way [15]. The popular PIC microcontroller using RISC program is included in [16]. The Arduino is used in [17], GSM module

is used for communication for alerting purpose[18][19]. The Raspberry pi 3B and Arduino are used to monitor vehicle pollution in[20] and in[21], RFID for detection and Wi-Fi module is used to alert.

### Smart Cities

The authors in [1], clearly say that Smart Home Systems(SHS) should have machine Learning and language processing technologies to be included to help the users in saving energy consumption, security, safety etc. Smart home with IoT application is also considered by the authors[22] where the entire house operations could be carried out through a computer and the authors also convinced us that the system should have a proper security to avoid intrusion, etc. The forest fires also have a huge impact on the city development. Detecting the forest fires by the authorities from the city in a smart way is necessary. The earlier technologies consume huge power however, in the paper [23], LoraWAN is used as it is a low power consuming protocol. And the status of sensors is known through the use of web map system. Till date we are using 4G technology but the urban and developed areas have already included 5G technology for their day-to-day applications. The authors [24] have concluded that 4G specifications are not sufficient for the demands of smart city applications and therefore the use of 5G wireless system is beneficial.

In 5G, HetNets network is used. Security is more in 5G but however this issue is always vulnerable. The adaptive admission control method is introduced by the author in[25], to enhance the response time of the IoT traffic for home Wi-Fi IoT system and NS3 simulator is used for observation. The wireless channel impairments are nullified or suppressed. A review paper [26] on 5G technology, also deals with the same issues similar to those mentioned in the previous paper and concludes that artificial intelligence(AI), machine and deep learning must be included for 5G standardization. The rough set technique(RST) in IoT hardware is introduced in [27] to reduce the computations that are carried out during processing data. Indoor environment classification, a machine learning approach for indoor tracking and positioning which is sensor based is developed in[28] resulting in improved performance.

In solid waste management, the bin level monitoring systems including RFID and WSN are widely used and these systems are reviewed in[29]. The issues with RFID are overcome and the author has introduced system based on LoRaWAN[30]. Over the existing systems for monitoring, the authors have proposed a bin level monitoring system which is cost effective and doesn't need additional infrastructure. In[31], an IoT based system that monitors level of bin is developed, in which the BLM unit has life expectancy of 434 days and is also cost effective when compared to other existing BLM systems. The big data[32] from water waste management, traffic and waste disposal management, resource management faces issues like data privacy, processing and quality of data, data reliability[33] is important on all of the applications like smart parking, home, traffic of vehicles, surveillance etc. The Arduino board is used in applications of dustbin cleaning, leakage of gas, detection of accident[34] and for some of the other applications RFID[35] is used for detection. The paper[36] described network protocols used in appropriate applications.

### Health Care

Taking care of human health is very essential even in a busy lifestyle. With the advancement of several technologies in this era, the health care equipment's, units,

devices, etc. are also adapted to the new technologies introduced in medical field. Here, the following are applications of IoT with health care system.

The author in [37] has proposed a design for tracking the health of scavengers and used the Arduino Atmega328 as the main board and the data is sent to cloud for storage. The author in[38] has done intense research in health care sector based on IoT and has concluded that the users are beneficial with the advancement of health units working with IoT technology but the security issues alone have to be addressed as it is a challenge. As the security measure is to be dealt, the authors [39] have come up with management model for security risk in IoT to practice securely in Healthcare environment and discussed about COBIT5 for trust in healthcare unit. The WSN with IoT technology faces congestion while gathering data and can affect the reliability of the system and therefore distributed congestion control algorithm is provided in [40] whose performance is better compared to previous methods. The authors in [41] have used LS-IoT and LAC for transmission of secure data in ECG system and the signal analysis is done using SSA which considerably resulted in less energy consumption of battery.

The chronic disease patients can be remotely monitored and the various wireless networking techniques used for this purpose are discussed in the survey paper [42]. After comparing different techniques available, the authors have concluded that wi-fi technology is more advantageous for transmission of health-related data. The Arduino uno R3 with GSM module [43] is used to check blood pressure, heart rate and temperature[44]. The health check in [45] and [46] is shown using Arduino and Zigbee module. The Arduino board with wi-fi module[47] and with Node MCU in [48] is used for health check alert. The NB-IoT protocol is used as it has the advantage of low power consumption [49]. The system for covid curb to care the human society is discussed in [50].

### Agriculture

Agricultural sector has to be dealt in smart way with new advancements in technology. The IoT based applications for agriculture are vast and the farmers, researchers, etc., are benefited when applied the IoT technology in agricultural field[51]. Here, the following are applications of IoT in agriculture.

The authors in [52] have combined IoT and data analytics(DA) and enabled high yield and operational efficiency. A survey paper[53] discussed all the possible advancements in agriculture and farming namely, precision agriculture, animal monitoring, tracing, greenhouse farming etc.,. The cost for all this implementation is affordable by using IoT. The authors in [54] provided the survey paper and listed the strong views on the CS,ML,NOMA and mMIMO connectivity technologies for machine type communications. The temperature and humidity sensors are used for greenhouse monitoring purpose[55] and proposed the remote monitoring method combined with internet and wireless communication, and for data access ADO.NET is used. The paper[56], provides the smart system for agriculture which is a predefined irrigation schedule for improving the yield. The system includes Arduino for processing and for communication uses GSM. In [57] the sensors are connected to Arduino Uno Board for sensing soil moisture and level of water, the system of smart agriculture is designed which is automated.

The ARM7 is used in [58], in which the WSN connected in star topology. The Node MCU with ESP32 connected with sensors for monitoring crops is developed in[59]. The AVR microcontroller, raspberry pi with ZigBee module is

used to control robot remotely that includes GPS[60] and the success percentage tests for routing using Raspberry pi[61] is 100%. The agro informatics is very advantageous in agriculture[62] and the precision agriculture[63] reduces the resource wastage. The sensing of soil moisture[64, 65], weather conditions[66], animal warnings through location detection by GPS[67] can help the farmers for high yield of crop. The ATMEGA328P the advanced version is used in[68] and the paper[69] collected data from 2016 to 2019 revealed that farms connected to Internet of Things are about 540 million. The solar powered system using ATMEGA2560 is introduced in[70].

### Space-IoT

The satellites are used in many fields as the humans are largely benefitted. Here, the following are some of the applications of satellites in IoT.

The advantages of using satellite IoT(SIoT) networks are reliability, large coverage, security, cost effective multicasting and NB-IoT is used to sustain SloT[71]. The SloT is analysed in[72] for spectral efficiency improvement. Earlier GEO stationary satellites were used and even today these GEO satellites are used in some of the applications, but the authors in[73] listed out the advantages of using LEO satellites compared to GEO stationary satellites. The Arduino Uno, GSM module, GPS receiver are used to track the vehicle location[74] and developed a system of anti-theft. NB-IoT is energy efficient for SloT[75] used in long term applications. The IoT applications and its challenges are discussed in [76]. The space information network is helpful in machine communication and authors in [77] discussed that CoAP is good compared to MQTT. Landsat 8 and Moderate resolution imaging spectroradiometer [78] is used to estimate land surface temperature and evapotranspiration.

### Railway Systems

The Indian government highly depends on railway sector for the income. The IoT technology advancements in railway systems makes the system run smoothly and any faults can be predicted ahead and can be prevented and made good. Here, the following are applications of IoT in Railway systems.

The train when entering a tunnel causes sickness or ringing sound in ears for few people and this happens because of the change in the pressure of air in train. To overcome this issue, the authors [79] have come up with an algorithm named adaptive iterative learning control which can balance the pressure of air. [80] deals with the idea of smart railway system (SRS). SRS requires data transaction through internet, data storage, processing etc., the network architecture IoT solution is proposed to take care of data distributed in railway area and to check performance, power consumption and concluded that LoRa as IoT network is advantageous in terms of power consumption. The TCAS is controlled with WSN [81] for maintaining train integrity. The authors in [82] provided a network architecture passenger flow distribution model for managing the passenger traffic on train and increases the traffic safety. The authors [83] introduced an adaptive fuzzy controller to adjust airgap and improved apriori algorithm is used for trusted database. Results shown with fuzzy control proposed work is very effective.

### Power Sector

Enormous benefits also driven when IoT technology is used in Power systems and it may be termed as intelligent power sectors or smart power /energy systems or digitized energy system, etc. Here, the following are some of the applications of IoT based on power sectors.

The paper [84] deduced that electric power and energy systems are developed using IoT technology and helpful for Distributed Energy Resources by making less energy consumption, expense reduction and more security. The power consumption monitoring system [85] based on IoT is used and power consumption is controlled by supply cut when the limit is crossed. Here, ATMEGA microcontroller is used for processing, and the whole concept is based on ohms law. Energy management system at home based on IoT is designed in [86] where a current sensor in the form of printed circuit board is connected to all appliances and different loads of power is noted by users. The authors in [87] have reviewed literatures on energy and power sector advancements and have summarized that Variable Renewable Energy resource systems are changed to smart, digitized systems through IoT and the home can be managed by monitoring heat, ventilation, air conditioning. Blockchain technology is highlighted. The power theft and power cut manually is avoided based on the proposed work in [88]. PIC microcontroller and NodeMCU are main units. GSM module is used for alert message and RFID tag for prepaid bill payment to avoid due date issues.

### Water Monitoring

The water, the main living for fish. The water parameters need to be in control as in suitable for the fish. The quality of water has to be checked in order to have a healthy fish. The following are some of the literature papers related to water monitoring.

Table 1. Types of sensors used in different application sectors

Sensors	Application sector
GP2Y1010AU dust sensor MH-Z14 CO2 sensor DHT sensor MQ series gas sensor DSM501A dust sensor PMS3003 G3 particle sensor MICS-4514 sensor	Air Pollution
BP sensor MAX30205 digital thermometer ECG/EKG sensor Pulse sensor Biosensors, Physical sensors pH sensor-WQ201 Pressure/Strain sensor Temperature sensor-WQ101 dissolved oxygen sensor-WQ401 Audio microphones, MLX90632 sensor	Health
IR sensor Ultrasonic sensor Light-band sensor Photo-electric sensor Proximity sensor Piezoelectric/Piezo capacitive sensor Motion sensor Clap/Snap sensor	Smart City
Soil moisture and humidity sensor Vision sensor pH level sensor DHT sensor Electrochemical sensors	Agriculture
Load sensor Proximity sensor Temperature sensor Friction sensor	Railway System
Temperature-sensor pH-sensor Ultrasonic sensor Sensor-Dissolved oxygen	Water quality monitoring

In [89], the quality of water monitoring for Eel fish using Raspberry pi 3 is done. Here, the dissolved oxygen is little less than the actual needed by the fish. An aquaculture with high density [90] using Raspberry pi is done, in which, the temperature from many tanks can be sensed at the same time. The Arduino is used in [91] and notification alert on phone can be received in the system [92]. The effective system [93], in which, the self-cleaning sensor probes are equipped. The review on Wi-Fi, GSM and Zigbee based monitoring systems are discussed in [94]. An Approach using NB-IoT is done in [95]. Having 6LoWPAN [96], monitoring of water is done and system enhances the work of old traditional monitoring of water. The parameters like pH, dissolved oxygen, water temperature were discussed in [97] [98] and in [99] it is advised not to use a black tarpaulin as pond for fish as it is not a good option.

Inference from the above papers drawn is, the sensor networks that are ZigBee based is recommended and for the quality of water monitoring with self-cleaning probes is a good option for effective reading of values of results.

Based on the study of the papers reviewed, the conclusion made is listed in tables 1 and 2. The main board either Raspberry pi, Arduino or NodeMCU for any application, can be used based on the priorities of the researcher.

Table 2. Difference between Raspberry Pi, Arduino and NodeMCU

Parameter	Raspberry Pi	Arduino	NodeMCU
Clock speed	1GHz	16MHz	80-160MHz
Type	Small computer	Microcontroller board	Microcontroller board
Operating voltage	5V	5V	3.3V
Board with both Wi-Fi and Bluetooth built-in	Yes	No	Yes

The figure (see Fig.2.) shows the power consumed by NodeMCU, different Raspberry Pi and Arduino models. The main difference between Raspberry Pi and Arduino is that, Arduino and its models are microcontroller development boards, whereas, the Raspberry pi and its models are like mini computers that needs operating system and therefore, Raspberry pi requires more power compared to Arduino. The speed of Raspberry Pi is faster than Arduino. The Arduino cost is cheaper. Hence, researcher according to the parameters required for the particular project can choose the specific board.

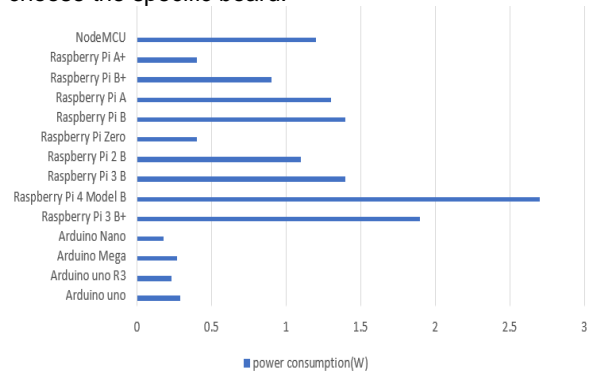


Fig.2. Power consumption

## Conclusion

The wireless sensor network (WSN) is the sensor network that has to be connected to processor for processing the data and this data is accessed by the receiver on the user side. Therefore, all the devices have to be connected through internet and the devices may

sometimes be performed remotely and independently. IoT is very apt to be used in this field of work. Internet of Things (IoT) technology is very useful and highly advantageous to be used in the work of sensing and monitoring. The human living to some extent can be eased with the use of the advanced technology. This review paper is helpful for all the researchers of IoT topic.

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