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Role of Machine Learning and Internet of Things in Health Care System: A Review

Gyanender Kumar[1,], Sachin Kumar Yadav[2]*
[1]Assistant Professor, Department of Electronics & Communication, Geeta Engineering College, Panipat, Haryana, India
[2]PhD Scholar, Department of Electronics and Communication Engineering, Thapar Institute of Engineering and Technology, Patiala, Punjab, India

Abstract

Nowadays, integration of Machine Learning and IoT is modern technology for solving problems in healthcare industries. As IoT is entering into healthcare, the expectation of getting new facilities is also increasing, especially for the elderly. A number of protocols are affected on healthcare applications. IoT in healthcare is gaining more attention due to the advancement in the development of IoT devices. Comparative analysis of machine learning algorithms with their application is analyzed. A number of challenging task of communication systems is resolved with IoT. The short and long range communication protocols are also used for different applications. Different networking technologies like Bluetooth and Zigbee are synchronized with IoT technology. The wireless technology is also enhanced with machine learning and IoT techniques. The existing IoT-driven healthcare applications are analyzed and still there is a need for innovative technology-based solutions to face the challenges in medical environment. The technology is enhanced by the integration of machine learning and deep learning with IoT. The growth of IoT enabled devices is increasing day by day. The development of the IoT enabled devices is changing with change in the technology. Machine learning with IoT can be used as security purpose.

Keywords: *IoT, Machine Learning, healthcare, security, healthcare application*

***Author for Correspondence** E-mail: gyan.research745@gmail.com

INTRODUCTION

"Internet of Things", or "IoT" in short, is about extension of the internet beyond computers and smart phones to an entire series of other things, processes, and environments. It has been many years since IoT came into existence, but still we have not entirely understood it and this is the reason why we have not been able to use it efficiently in healthcare area. It means to say that it is yet to be known well so that we can use it properly in our daily life. In today's modern era, children have a shortage of time to take care of their parents who are very old, due to which they depend more on IoT based new wearable sensors. Basically, elderly people need more health monitoring, so that we can quickly identify and cure, whatever side effects they have in time with the help of the doctor, such as increased blood pressure, body temperature, heart disease etc. So in such situation, by sensing the data from the body of the elderly people, with the help of sensors and communication method we can forward it for further processing on cloud storage (Figure 1). The size and weight of these sensor nodes are so low that they are very easy to carry and they can automatically sense the data [1]. To operate them, the patient does not even have to do the manual effort from outside. However, these sensors are more sensitive which sometimes stop working on the power shortage or environment hazards and the result is system failure [2].

IBM was the first to introduce Smart Healthcare concept in 2009 [3]. Basically, Smart Healthcare is an intelligent infrastructure that transfers information from with the help of IoT system and also implements processing from cloud and fog computing. In various applications we can use

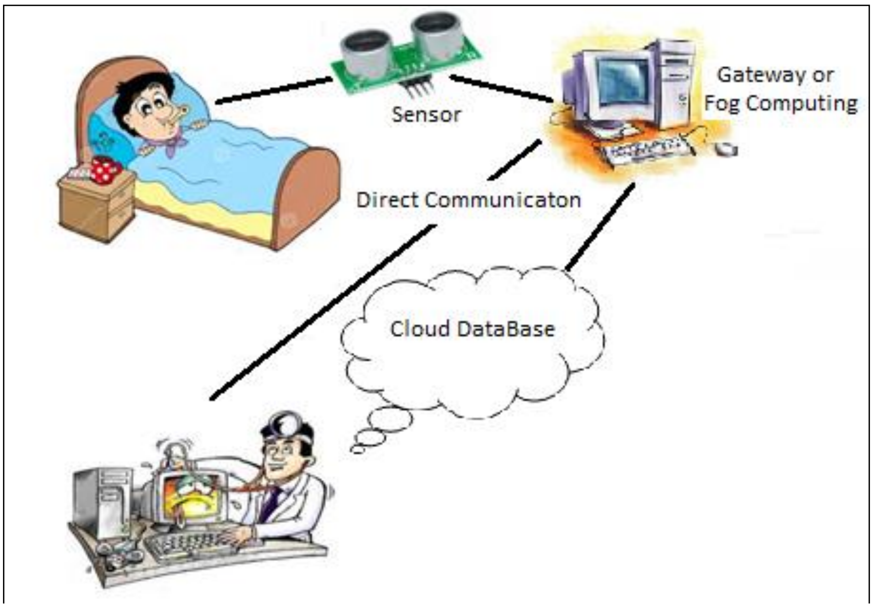

Fig. 1: *IoT in Health Care.*

Healthcare with IoT like; diagnosis and elderly treatment, health management and managing chronic diseases, disease prevention and risk monitoring, virtual assistants, smart hospitals, reducing emergency waiting times, assisting drug research etc. No doubt the Internet of Things (IoT) is one of the most exciting areas of research for engineering community and device manufacturing industry. Whereas with the help of traditional internet, we can connect two devices to communicate and that too with the help of intervention of a human, while IoT connects all sorts of devices "Things" into a broad network of inter-related computing intelligence without the intervention of a human. But so far the utility of IoT enabled technology in healthcare is facing many challenges such as heterogeneity of IoT devices, lack of cost effective smart and accurate medical sensors, lack of a standard architecture of IoT system, high handling volume data and challenge of inter-operability etc. So to prepare IoT for healthcare, it is necessary to support IoT interoperability; for this, IoT system will have to be compatible with all devices, which will require a standard IoT architecture, which could do decision-making task itself. When all these challenges are well explored, then the researcher can do some new work in it by using new methods and technologies and we can increase the applications of IoT in healthcare field. Figure 2 shows the growth of IoT year-wise.

Applications of IoT in Health Care

Applications of IoT in healthcare field can be classified in to two categories[4]:

i) Single Condition Observation:
a. Glucose level sensing;
b. Electrocardiogram monitoring;
c. Blood pressure monitoring;
d. Body temperature monitoring; and
e. Oxygen saturation monitoring.

ii) Clustered Condition Observation:
a. Rehabilitation system;
b. Medication management;
c. Wheelchair management;
d. Imminent healthcare; and
e. Smart phone healthcare solutions.

For general healthcare, lots of apps are also available like;

- Google Fit: It is a health-tracing application. It is a single set of APIs that combines data from multiple apps and devices. The interaction between multiple software is done by application programming interface. Google fit uses sensors of a user's mobile devices to record physical fitness activities for an instance running, walking, cycling and many more.
- ECG Self-Monitoring: The controlling of contraction and expansion of heart

chamber is done by these sensors. Basically these sensors are implemented in medical devices.

- Pedometer: It is a device which counts each step of a person by detecting the motion of the person's hands and hips. The motion of a body is observed by attaching a frame of reference which consists of an abstract coordinate system, to an observer and measuring the change in position of body relative to the frame with change in time.
- Today, MEMS (Micro-electro-mechanical systems) inertial sensors and sophisticated software are to be used for the same purpose.
- Noom-Walk: Noom-Walk counts steps throughout the day, because it does not leverage GPS, the app uses less battery life. After tracking steps for 24 h, Noom-Walk uses around the same battery life as a GPS enabled app will in 3 min.
- Water Your Body: This app is created with the aim of reminding a person to drink a certain amount of water every day. This app is based on the lot of predefined algorithms which takes some related information from a user; for instance, weight, height, etc. to set reminders for the users. Some of them also use some tracking components to track the temperature of a body and as well as energy being exhausted form a body.
- Instant Heart Rate: Basically, this application and the technology are quite similar to the technology which is being used in heart rate monitoring. For instance, some predefined algorithms and software are used in this. The main quality of this application is to measure heart rate instantly or in a fraction of a second.
- Finger Print Thermometer: It is a sensor based application which takes user's finger to detect the body temperature and pressure. It is also enables the detection of a finger pressing on the display itself. The manually button is replaced by sensor for printing. Hybrid nanostructure based ultra-long silver fibers are used for sensing.
- On Track Diabetes: This application connects to Dexcom-glucometer to track the level of blood sugar. A person can also give related information manually and later on it's work and show results on the basis of steps, exercise levels, meals and etc.

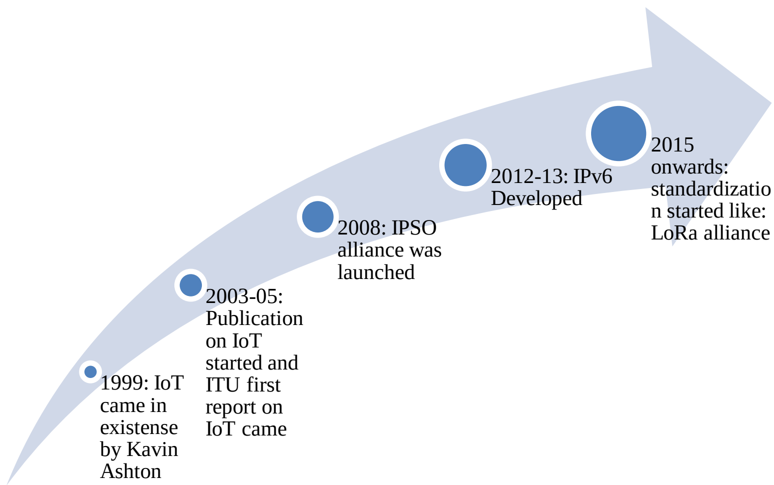

Fig. 2: *Growth of IoT.*

Motivation

When a device is connected to the internet, it means that it can send and/or receive information. This ability to send and/or receive information makes devices more smart. Fortune Business Insight says that the market is projected to reach USD 176.82 billion by 2026 and it was USD 30.96 in 2018. The market is projected to grow at a CAGR 24.5% in the forecast period (2019–2026). As per of our knowledge, in this study we describe about the existing IoT architecture's techniques and communication protocols in healthcare monitoring. Application areas of IoT devices are going to be increased in our daily life like Smart Home, Health Care, Remote Monitoring etc. and various types of technology platforms are being used for the architecture of IoT along with this various communication protocols. As our focused area is Smart HealthCare, hence this field needs to be optimized. If communication protocols challenges and accurate data transmission are not addressed then we will fail to recognize the disease at the right time. This objective motivated us to bring forward this review work considering various parameters like coverage area, transmission range, accurate data as state-of-the art solutions to provide the readers with a description of the different works published in this field of healthcare in IoT which helps to adapt these techniques in solving communication and accuracy of data problems in future. This helps researchers to explore more to address solution in forthcoming days. Figure 3 shows the architecture of IoT in healthcare.

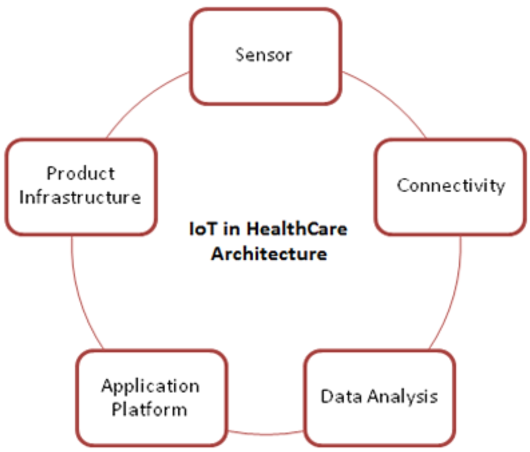

Fig. 3: *Architecture of IoT in Health Care.*

Paper Organization

Rest of the paper is organized as follows:
In the following section, we provide the classification based on communication technologies in IoT, in which we briefly describe the working of BLE, Bluetooth, ZigBee, LoRa/Sigfox/NB-IoT. Then we explain the importance of present role of ML and deep learning in IoT.

After that, we have discussed the IoT in healthcare with various algorithms of machine learning which can optimize the sensed data with system outcomes.

Then we present the highlights of this review work.

Finally, we discuss the open conclusion.

For additional clarity, various ML algorithms and their application area depicted in Table 1, comparison of short and long-range communication protocols in Table 2 and comparison between various technologies used for architecture in Table 3.

CLASSIFICATION BASED ON COMMUNICATION TECHNOLOGIES IN IOT

Bluetooth Low Energy (BLE)

BLE is an energy efficient and low latency protocol because of single hop transmission. Raykar and Shet have compared some microcontrollers for the gateway node, and have chosen MCU node on the bases of its specification [1]. Sensed data from patients' body is stored on an android app with the help of Bluetooth Low Energy (BLE). Here BLE is also providing (Cyclic Redundancy Check) CRC for data security. And this same app connects the collected data to the cloud. In this paper, the authors proposed a reliable system at a low cost. In an experiment by Swaroop *et al.*, the authors sent patient data from three different methods like BLE, Wi-Fi, GSM to mobile app by making RPi3 a gateway node, so that if data is lost from one method, the data from the remaining methods could be received [5]. And finally, web application software has been proposed to provide interface for cloud database, as we analyzed the performance of the BLE protocol, which has proved that it has passed the latency and energy parameter [6].

Table 1: *Various ML Algorithms and Their Application Area.*

ML Algorithms	Applications
Naive Bayes	Categorize news, email spam recognition, face detection, emotion study, medical diagnosis, number identification, and weather forecast. On the whole it is useful for big data set and efficient on a big range of difficult issues.
Decision Tree	Predicting and reducing customer churn across many industries, finding of scam in the insurance sector, credit risk scoring in the banking and financial services.
Linear regression	It tells us about the relationship between input explanatory variable and output dependent variable.
Logistic Regression	There are many real-world applications such as measuring the success rates of promotion campaign, credit scoring, predicting the revenues of a certain product.
k-nearest neighbor	Used in search where we are looking for similar data set.
Learning Vector Quantization	It is used in data reduction or reduced data set.
Support vector machines	It is used for text and hypertext categorization, classification of images, bioinformatics etc.
Apriori	Healthcare
Boosting with AdaBoost	It is useful where we are having ample data to make a prediction and we look for extremely high predictive results. It is used for reducing bias and variance in supervised learning
Random Forest	Banking and Finance, Medicine, Stock Market, E-commerce

Table 2: *Comparison of Short and Long-Range Communication Protocols [18, 29].*

	SigFox	LoRawan	NB-IoT	Bluetooth Low Energy	ZigBee
Aptness for healthcare	Low	Moderate	High	High	Moderate
Coverage area	9.5 km	7.2 km	15 km	150 m	30 m
Transmission rate	100 bps	0.25–5.5 kpbs	250 kbps	1 Mbps	250 kbps
Authentication and Encryption	Private key signature Encryption and scrambling Technique	distinctive key distribution, recognized only by the node and base station using the unique key Data encryption	3GPP S3 security, which includes user and device identity, entity authentication, confidentiality and data integrity	Secure pairing prior to key exchange, Two keys used to provide authentication and identity protection, AES-128b encryption	AES-128b
Operational Bandwidth	868 MHz (Eu) 915 MHz (US)	868 MHz (Eu) 915 MHz (US) 433 MHz (Asia)	LTE bands, in the guard bands of LTE (guard-band mode), or in re-farmed GSM bands	2.4 GHz	2.4 GHz

Table 3: *Comparison between Various Technologies Used for Architecture.*

Ref. Work	IoT Interoperability	Data on Cloud/Server	Technique for Prediction	Single/Multiple Parameters	Technologies
[1]	Android app	Yes	No	Multiple	BLE
[3]	Android app	Yes	No	Multiple	Bluetooth
[4]	RPi	No	No	Single	nRF24L01(wi-Fi)
[5]	Arduino	Yes	k-means	Multiple	ZigBee and LoRawan
[6]	Arduino	Yes	No	Multiple	LED and LDR
[7]	RPi	Yes	No	Single	SMS/Alarm
[8]	Java	Yes	Aggregation	Multiple	ZigBee
[9]	WEKA/MATLAB	Yes	HOBDBNN	Multiple	Bluetooth
[10]	WBAN	No	No	Multiple	ZigBee
[11]	Contiki	No	No	Multiple	6LoWPAN and CoAP
[12]	Java	Yes	Fuzzy Rules	Multiple	5G mobile network

[13]	RPi	Yes	No	Multiple	BLE, Wi-Fi, GSM

Bluetooth (IEEE 802.15.1)

IoT helps a lot to reduce deaths due to heart attack in China [7]. Here, the entire patient monitoring system is divided into two parts, which are: data acquisition and data transmission. In data acquisition part data is forwarded into four different modules by checking the patient's electrocardiogram (ECG), heart rate, blood pressure, pulse rate, blood fat, blood glucose, and patient location; these modules are for real-time continuous transmission for all data, continuous transmission in special periods, event-triggered transmission and transmission on patient demand. At last, the implementation was performed on a prototype, in which the monitoring work was done with the help of Java application in Android smart phone on sensed data which was sent via Bluetooth and data was left on the server side for monitoring by doctors. It has also been observed that ZigBee and Bluetooth are not adaptable for long range transmission [8].

ZigBee (IEEE 802.15.4)

The contribution of master-slave architecture in IoT plays an important role [9]. The slave node forwards the different data readings to the sub-master node with the help of ZigBee, which is a good protocol for small distance communication, followed by sub-master node, which sends the data which was received from slave node to master node, which is at a much greater distance, and here sometimes due to lack of cellular network, therefore LoRawan protocol has been used. The accuracy of the ZigBee protocol explained by Hiraguri *et al.*, during communication, such as accurate location detection by ZigBee terminal when it passes through ZigBee router area and when sensed data of patients is compared with manual reading, almost 99% of the matches took place [10]. On similar standard, one more technology is used for communication, i.e., nRF24L01, proposed by Garbhapu and Gopalan [11]. It is an IoT based biomedical kit which is very cheap and the accuracy of this system has come from 95 to 98%. As well as it can be implemented on a lot of people simultaneously. Basic platform in this system is Raspberry Pi3 and it was connected to microcontroller MSP430G2553 and a wireless transceiver nRF24L01 (IEEE 802.15.4) for data sensing and transmission. The authors had also stated in this paper that cost, power consumption, standby mode and data transmission rate wise nRF is best instead of ZigBee and BLE.

Sigfox/LoRa/NB-IoT under LPWAN

Advantages of Sigfox, LoRa and NB-IoT protocols are such as battery life, cost and range of radio communication, under the low power wide area networks (LPWAN) category [8]. LoRawan uses AES 128b for encryption and NB-IoT uses LTE encryption but Sigfox has no authentication or encryption. A new architecture has been proposed by Kharel *et al.* for Smart HealthCare, in which with the communication takes place with the help of LoRa connectivity to fog computing [12]. It has been observed that the monitoring of remote area patient can be forwarded to several kilometers away also; this system does not allow too much burden of data on the cloud and is also a good example of energy efficiency. In the research work by Bouras *et al.*, one more solution is provided by combining LoRaWan and Wi-Fi technology, which randomly sends the sensor-sensed values to the end device [13]. LoRaWan currently is used for long range transmission and consumes very low power but is also having a low bandwidth. Wi-Fi gateway is also used in this solution, which is part of this module and conserves a lot of energy. The Catarinucci *et al.* have given an example of a hybrid system in their research work [14]. This hybrid system is made up using both 6LoWPAN and CoAP protocols, due to which the efficiency of this hybrid system has increased up to a great extent.

Miscellaneous

Elder people and people living in remote area do not get doctor service quickly, and then the role of IoT becomes more important here. In this system proposed by Mohapatra *et al.*, the authors had mainly explained the role of IoT for health care monitoring of elderly people [15]. The process of sensing the heart rate and body temperature of elderly by making

Arduino (DIY) do it yourself board is the base. In addition, sensed data has been stored on the cloud for further graph plotting and emergency notification. In this research, it has also been said to create a future model in which the decision making algorithm of machine learning will be used. In the same way Raspberry Pi platform has been used by Misbahuddin *et al.*; the authors have given the proposal of an IoT based system keeping in mind the elderly and disabled people who speak in very low sound [16]. To create this system, Raspberry Pi is connected with GPIO interface, which patients can access from their smart phone. With the help of internet, this system sends pre-recorded audio messages to hospital staff or relative, so that help can be delivered in time.

Figure 4 below shows the IoT elements along with the technologies used.

PRESENT ROLE OF ML AND DEEP LEARNING IN IOT

IoT is becoming a biggest source of big data which is useless without analytics power [17].

IoT has a heterogeneous network and there is no single universal protocol; so sometimes it becomes a difficult task to use protocols according to the applications. In addition, we can use some value added applications for IoT such as deep learning, ML, AI and big data analytics. Like we can use k-means algorithm of machine learning to predict the upcoming situation [9]. In the paper by Kumar *et al.*, the authors have focused on how to use sensed data from the cloud efficiently [18]. For example, here, only the data base of patients of diabetes has been researched to indicate that the dataset is of sever disease of diabetes and which data set tells it to be early stage of being diabetic. Here the authors have used various classifier schemes of ML like decision-tree, K-NN, SVM and finally proposed a Fuzzy Rule Based Neural Classifier. Random forest classifier and IoT can perform good in healthcare system [19]. It has been demonstrated that how to improve the interactivity between the patients and the doctors. And for the reliability of this process, Kaur *et al.* have performed experiments on datasets of different diseases, namely, breast cancer, diabetes, heart disease, spect-heart, thyroid, surgery, dermatology and liver

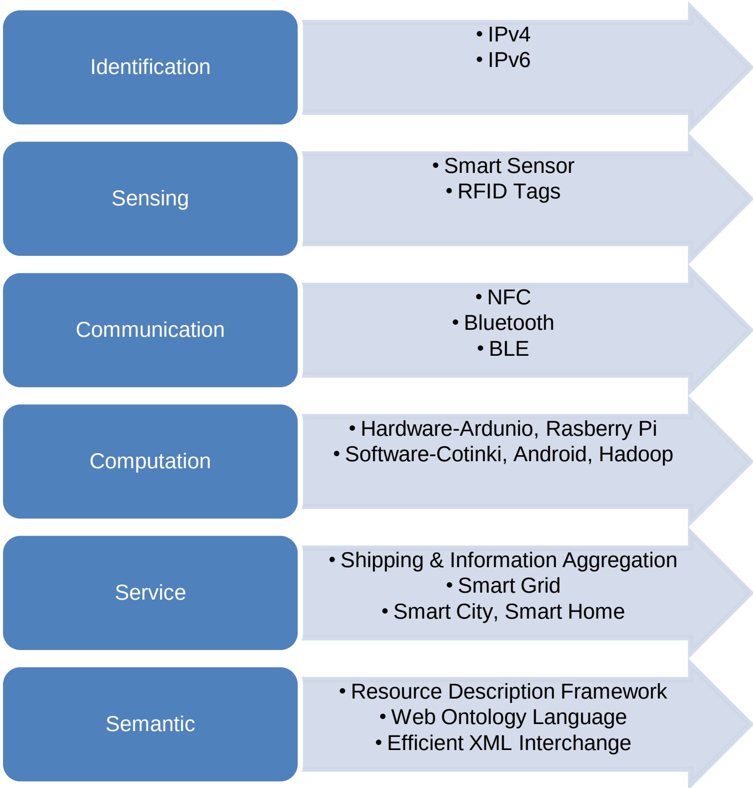

Fig. 4: *IoT Elements with Technology.*

disorder. Authors have used different algorithms of machine learning over different datasets such as K-NN, Support Vector Machine, Decision Trees, Random Forest, and MLP. We have tried to know with the help of this paper that the best results that we have come across are through random forest technique of machine learning which and the average results are also good on different diseases data sets. In the future if we use a large data set, then maybe some other algorithm of machine learning can give better results. In heart care disease, fog based healthcare with deep learning technique is a unique HealthFog system, especially for heart patients, in which the ensemble method of deep learning has been used on edge computing devices [20]. For high accuracy, very high compute resources (CPU and GPU) are used for training and prediction. In future, this architecture could be used for other fog computing applications such as agriculture, weather forecasting, traffic management, smart city and other healthcare issues such as diabetes, cancer and hepatitis, which can provide efficient results. A multi-agent system, which has been described as flexible, reliable and energy efficient was proposed by Vaidehi *et al*. [21]. Here the focus is on the data reduction algorithm, so that a reduced set of data is prepared, which is very similar to the original data set. By using this above said method, we will not have the requirement of separate external memory. For the implementation of this system, Java language has been used in the JADE environment and the data reduction ratio has been calculated up to 80%. ANN technique of machine learning, specially focused on sleep apnea disease, which is an event detection system also a good idea [22]. Different sensors are used for the data collection purpose like MEMS-based accelerometer and Industrial Spiro meter. In this ANN-3 Layer Neurons technique, only ACC data is used to train the system. And for good results, the author has suggested that more number of sensors can be used for monitoring purpose in future. The Fog-Cloud-IoT architecture has been designed by keeping in mind the General Data Protection Regulation (GDPR) [23]. Special care has been taken on how to manage patient data and privacy to the end, whether it is on sensor data, on fog or on cloud. Samsung Exynos 5422, a smart gateway has also been used, which is energy efficient as well as fast due to the processor installed in it. This system can understand only FHIR datasets files, so in future it can be made compatible with CSV datasets and working of gateway can also be made more accurate by associating it with Artificial intelligence.

HIGHLIGHTS OF REVIEW WORK AND DISCUSSION

In the Internet of Things, all the things/devices that are being connected to the internet can be put into three categories, 1st is to collect the information, 2nd is to transfer the information and 3rd is process this information. So with this feature we can use IoT in a well-planned manner in healthcare and take it to a new level. And what can be the best use of it in healthcare, that we should do it for elderly patients with some serious and common diseases, so that in time, by understanding the severity of their illness, they can be guided for treatment. And remote monetary facility can also benefit those people who live in remote areas and doctors are far away from their reach. So as per our review work our main concern area is healthcare and we observed various platforms used for communication in IoT interoperability and further the sensed data is being used by three different terminals for further processing:

- Transmission on Cloud,
- Transmission on Fog, and
- Transmission on End Devices.

For communication, various techniques are being used like Raspberry Pi [11, 16], LPWAN [8], BLE [6], LoRa [12, 13], and ZigBee [24]. Although as per the application area all methods of Machine Learning are doing well at their part like: Random Forest Technique [19], Ensemble Deep Learning [20], ANN [22], K-Nearest Neighbor [25]; but still many researchers have not linked machine learning technology with IoT in healthcare. Another focus area is data security, whether we talk about Fog Computing [19–26], Cloud computing and Direct transmission. Sometimes the data is very confidential and it might become a big problem, if stolen or compromised. But maximum time, security depends upon the developers of the devices and other security methods are also available for IoT [27]. There are various factors that affect the IoT in healthcare applications, like it requires continuous research in every field of healthcare to provide a fast and better facility for patients, for example, manufacturing of smart devices, fast communication techniques, etc. Healthcare professionals get the enormous data of the patient by using IoT technology, but analysis of data can assist better care to the patient. IoT technology with ML can build a transparency of information and distributes the more accurate and current information to patients.

As per the report of Deloitte and NASSCOMM, Figure 5 shows the number of IoT enabled devices growth per year and the CAGR growth rate is almost 33%.

IoT Challenges in Healthcare

I. Data security and privacy;
II. Integration: multiple devices and protocols;
III. Data overload and accuracy; and
IV. Cost.

The IoT system can function and transfer information via online mode only when devices are safely connected to a communication network. Some of them as given below:

- Bluetooth,
- Wi-Fi,
- ZigBee, and
- Cellular.

Data overload occurs when the amount of input exceeds its processing capacity. When a data overloads, then the reduction in data starts to occur. Some of the reasons behind the data overload are given below as:

- Continuous increment of new information in large amount.
- The simplicity of creating, duplicating and sharing of information online.
- The exponential increase in channels to receive information by radio, television, print media, websites, e-mail, mobile telephony, RSS feeds, etc.
- High volumes of conflicting, contradictory and plain old inaccurate information.

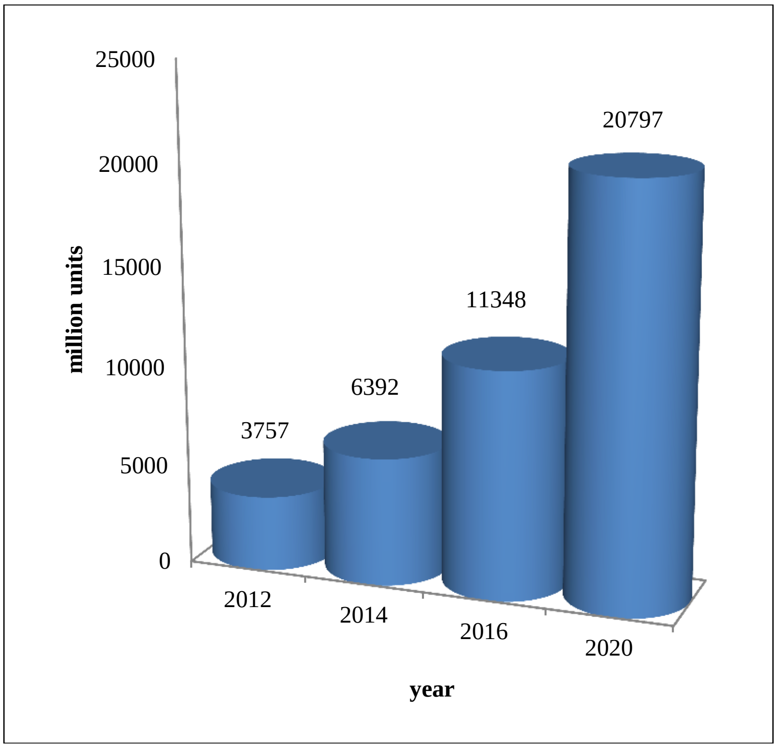

Fig. 5: *Number of Connected Devices' Yearly Growth.*

While data accuracy is one of the components of data quality; accuracy always occurs when the data values will be in correct manner. Since 100% data accuracy is not possible in anyhow, there will always be some amount of data in database that is inaccurate.

In view of the advancement that has been made in duty so far, we all have known that it has still not been able to call some security issues, due to which sensitive data can go to the authorized people, which is a big risk. These three checks are very important for data security and privacy, i.e., authentication, confidentiality and integrity. Such algorithms do require large storage capacity levels of security checks namely authentication, confidentiality and integrity. A node in IoT network requires a lot of energy as well as storage area to make it so capable. This can be done by reducing the computational task and simultaneously without losing the accuracy of the data [28]. IoT networks in hospitals are widely using 6LoWPAN with RPL (IPv6 Routing Protocol for Low Power and Lossy Networks). Storage requirements can be met by using motes ROM. But still by using more capacity memory, we can control few more attacks and can reduce the issue of security further. And few other solutions could be private cloud and data aggregation techniques. Another challenge is integration of multiple devices and protocols. The application area of all protocols is also different from the perspective of these parameters like coverage area, transmission range, and operational bandwidth. A global standard can also be made to resolve this issue. Overload of data and lack of accurate data on cloud, fog and gateway devices is also a challenge for IoT in healthcare. And for this issue, Machine Learning Technology can be a good solution. Although work has been started in this direction, but it can be improved further like we have said earlier that if IoT and ML are used together with proper understanding, then it can create a new bench mark in healthcare field, which can be a boon for the healthcare of elder people. Whenever we talk about advancement in IoT field, it directly affects the cost of the system. Whether we argue on a new protocol design or on a new IoT wearable device or on a sensor that fulfills multiple purposes, these are all cost dependent areas. Device developers should also pay special attention in this direction.

CONCLUSION

Machine learning and IoT together can do a miracle in today's modern technology and especially in healthcare area, if both of them are used with good understanding. In this review, first we have discussed, how IoT is being used in healthcare, after that we have shown comparison of protocols working on low and large distance and then various ML algorithms and their application areas with the help of tables. Finally, we have discussed the present role of IoT in healthcare system and highlighted the area, where still more focus is required. In Table 1 we named various ML algorithms and their application areas to improve data collection task, then and in Table 2 comparisons of short and long-range communication protocols is given and in Table 3 a comparison between various technologies used for architecture designing is portrayed so that we can use the best one as per application area. In Figure 2 defines that how IoT is growing year by year and Figure 5 defines the yearly growth of number of connected devices.

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