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# Integration Of Machine Learning With Iot

**Saksham Mittal** Computer Science & Engineering Department, Graphic Era Hill University, Dehradun, [mittalsaksham07@gmail.com](mailto:mittalsaksham07@gmail.com)

**Amit Kumar Mishra** (PhD. Scholar) Computer Science & Engineering Department, Graphic Era Deemed to be University, Dehradun Computer Science & Engineering Department, Graphic Era Hill University, Dehradun, [amitmishraddun@gmail.com](mailto:amitmishraddun@gmail.com)

**Neha Tripathi** Computer Science & Engineering Department, Graphic Era Deemed to be University, Dehradun, [nehagarg.february@gmail.com](mailto:nehagarg.february@gmail.com)

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## Abstract

IoT is termed as the network of inter-connected physical objects or devices that are implanted with various sensors, software and network communication techniques, so that they can collect data from their surroundings and exchange the data with other devices over the internet. And as soon as the technology is becoming advanced with IoT and automation, there is the interconnection between billions of devices, which generate a very large amount of data in the IoT network. Therefore, computational mechanism such as Machine Learning is required to process and manage such an enormous amount of data. ML is capable of analyzing and recognizing the patterns, classifying the data, predicting the outcomes, etc. and provide a sense of intelligence to the IoT devices like a human.

In this paper, we have discussed about IoT and ML and given an overview of how these technologies can be integrated. After that, we have discussed about various applications of ML in IoT. And at last, the challenges and scope in this new integration are also mentioned that can be the other research areas.

**Keywords:** Internet of Things (IoT), Machine Learning, Unsupervised Learning, Supervised Learning, Deep Learning, Deep Reinforcement Learning.

## Introduction

IoT stands for Internet of Things, which is defined as the physical objects' network having capabilities of communication, storage and limited computation and implanted with software, electronics and network communication techniques. IoT is simply the interconnected and distributed network of embedded system in which

communication among systems can take place through wired or wireless communication technologies [1]. As soon as the technology is moving towards IoT and automation, there are billions of devices that are interconnected with each other over the internet.

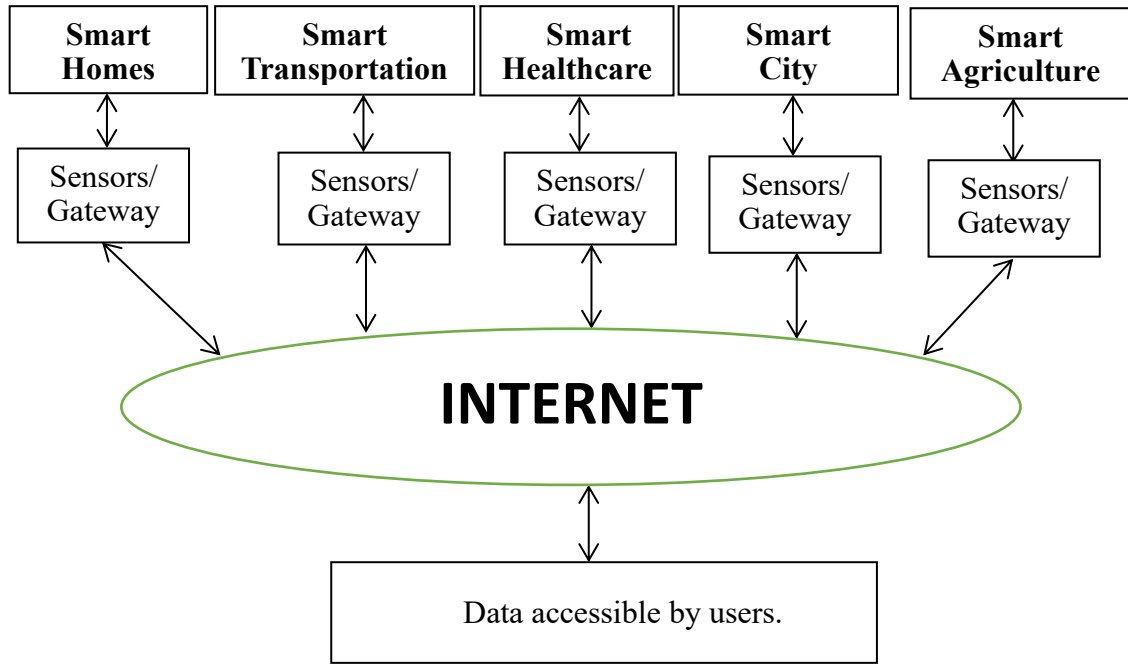


Fig1: An IoT Network

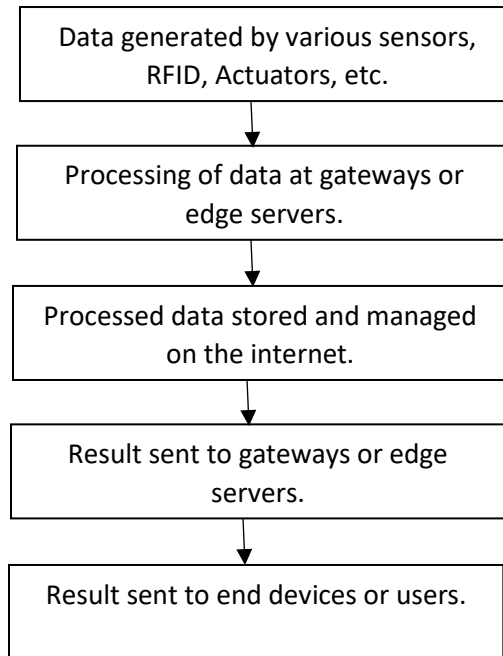


Fig2: Data flow in IoT Network

Hence, proper maintenance and management of such devices is one of the biggest challenges in the IoT network, if these devices are prone to, storage, communication and privacy. Ammar et al. (2018) discussed about the amount of research going on architecture, communication and computation, IoT network's privacy and security [2]. IoT network and its devices produce a very huge amount of data which further can be used for recognition of patterns, various predictions and assessments. Such huge data is difficult to manage and process with the traditional and the current mechanisms of data processing. Some new computational mechanisms like Machine Learning (ML) is required to process and manage the IoT generated data.

With the help of ML, we are able to provide a sense of intelligence to IoT Devices and can extract some useful information or knowledge from the data generated by IoT devices. M. at. E, (2018) poised that machine learning enhances the property of smart devices to vary or automate the situation or behaviour according to the knowledge [3]. Regression, density estimation, classification etc. are some of the uses of ML. ML algorithms and techniques can be integrated in IoT based applications such as malware detection, speech recognition and fraud detection and provide smart and intelligent services [4].

### **Various Applications of Machine Learning in IoT**

- **Machine Learning in Smart/Intelligent Transportation**

As IoT network is growing, systems have become more intelligent and connected devices lead to their utilization in all areas of a modern city. As the huge amount of data is generated, Machine Learning (ML) techniques are introduced for further enhancing the capabilities and the intelligence of a system. Therefore, the smart transportation application has been proposed with both IoT and ML techniques. Smart/Intelligent transportation includes parking management, route optimization, management of street lights, prevention and detection of accidents, road anomalies, infrastructure applications, dynamic navigation, real-time traffic tracking services, etc. [5]. To achieve all these, the combination of both IoT and ML techniques is required. For example, smart traffic lights detect commuters nearby with the help of embedded sensors and appropriate processing ML algorithms and cycle through the lights accordingly to make the transit faster and safer [5].

- **Machine Learning in Smart Home Automation**

In home automation, the temperature, lighting, electronic appliances, multimedia systems, etc. are controlled and managed by the home automation system. Since these devices are embedded with different sensors and linked to common infrastructure and thus forms the Internet of Things (IoT). In the home automation system, a

centralized server serves and manages the multiple controllable devices. The tablet and mobile application can be used to control and monitor these devices remotely with the help of some user interface [6].

An ideal scenario is anything that can be connected to a network and can be automated and controlled remotely. Traditional home automation systems are not completely automated and require human interaction as well. Only remote access is provided by the traditional home automation systems and controlling the devices is not that effective in terms of being 'smart'. While Smart homes must be artificially intelligent systems and have intelligent devices that can adapt themselves according to user actions and surroundings. They are able to effectively judge or analyze the need of users and surroundings' conditions, so that they can predict future possibilities and perform action accordingly also minimizes human interaction [6]. Various ML algorithms such as Unsupervised Learning, Supervised Learning, Reinforcement Learning, Computer Vision, Deep/Neural Learning, etc. can be used to provide such intelligence to the IoT devices and IoT network.

- **Machine Learning in Robotics**

As the world is moving towards automation, the combination of IoT and Machine Learning (ML) also plays an important role in one of the rising sectors, i.e., Robotics. The objective of robotics is to develop such machines that can make humans work easy and assist them.

Robots are the machines that are embedded with various sensors to sense the surroundings and generate the data. And, complex ML algorithms like Imitation Learning, Computer Vision, self-supervised learning, etc. are required to identify and recognize patterns and extract useful information from the generated data and make robots intelligent and capable to perform actions based on the information.

- **Machine learning provides Security in IoT Network**

Various algorithms of ML such as - unsupervised learning, supervised learning, and reinforcement learning algorithm can be applied for IoT security.

In supervised learning, we train the machine using well-labeled data. This means some data is already labeled with the right answer. Thereafter, we provide new data to the machine so that the training data is analyzed by supervised learning algorithm and a right answer is generated from the labeled data. It can be used for channel estimation, spectrum sensing, localization and security problems and adaptive filtering [4].

In unsupervised learning, there is no requirement of the labeled data because the environment only gives input without desired outcomes. In this algorithm, the task

of the system is to group unsorted information based on patterns, analogies and differences without any previous training of data. It is used in cell clustering, detection of fault and intrusion and load balancing.

In Reinforcement Learning (RL), there is no labeled answer key like supervised learning and a reinforcement agent decides how to perform a task and then learn from its experience or feedback after interacting with the environment. Unsupervised and supervised learning techniques basically focus on data analysis whereas reinforcement learning is used in decision making and comparison based problems. It is used to train the system where system has to find out the structure within raw data.

Deep Learning (DL) can be used in the analysis of the huge amount of unstructured, unsupervised and uncategorized data. It can also be used in distributed computing. DL is also known as neural learning. It uses hierarchical or deep neural networks to analyze data and learn by adjusting the weights among each pair of neurons in an iterative manner [7]. Various ML tasks such as speech recognition, object recognition, language translation, etc. can be performed with the help of DL very effectively. It basically works on function estimation or approximation and the learning capabilities and gives solution to IoT especially in privacy and security issue [8].

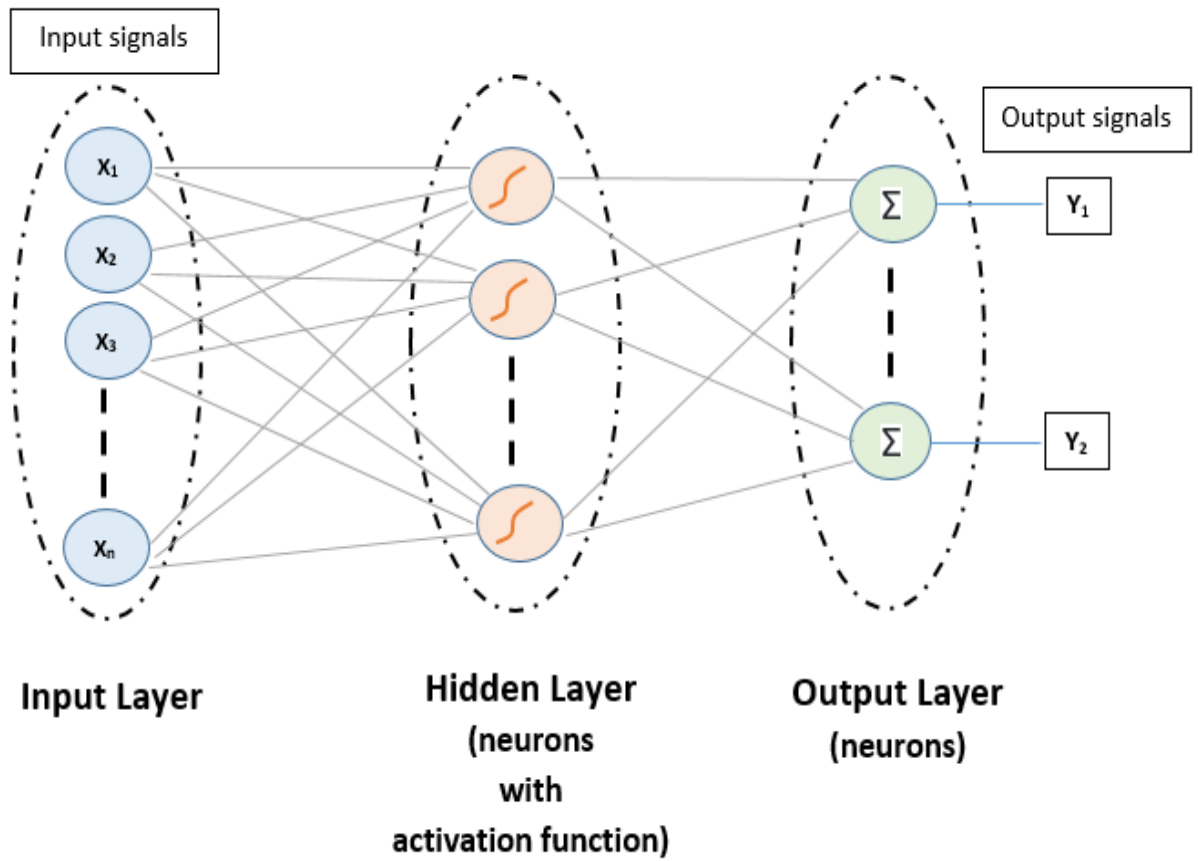


Fig3: Abstract View of Deep Neural Network Model

Despite, DL is competent of analyzing and working on complex patterns, but also may lead to a problem of misclassification [9]. Therefore, we may refer another model i.e. DRL, the combination of RL and DL which integrates perception of DL and decision making of RL [10]. DRL is used in an application developed by google i.e. "AlphaGo". DRL algorithm can be used for DDOS detection and security in the IoT network [4].

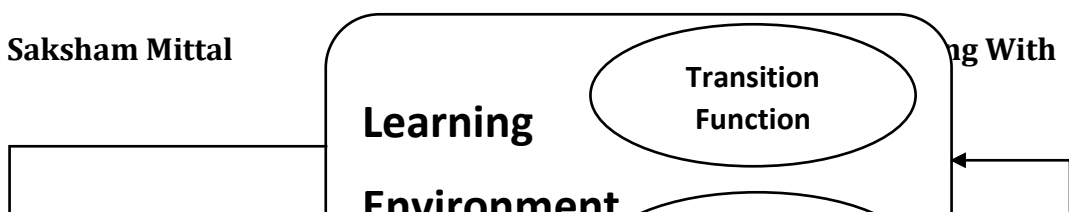




Fig 4: DRL(Deep Reinforcement Learning) Agent [9]

Moreover, where there is any requirement of data by any user, the user's authentication is needed. Authentication is the basic security requirement. If the user is authentic, it will provide the accessibility else deny the access request. Another challenge is the requirement of network access controls. To provide and remove access to the specific user to critical dataset of IoT, ML based access control mechanism is used [4].

There are various other applications and fields where we can find the combination of IoT with ML such as Smart Healthcare sector, Smart City, Smart Agriculture, etc.

### **Challenges and Scope in integrating Machine Learning with IoT**

Though ML is applied in various applications of IoT and overcomes various limitations or challenges in an IoT network, but it also brings certain other challenges and limitations which can be the other research areas.

The data generated from the IoT devices is not very reliable, they have certain uncertainties and require very much modification. To do such modifications, ML technologies and algorithms are not efficient enough.

There is a huge amount of data generated by various IoT devices in the IoT network which is diversified and differ in format, syntax and semantics and hence may cause problems for ML algorithms as these algorithms are not efficient to work on such diversified data [11].

Machine learning algorithms are very complex and require a lot of memory for training, processing and analyzing the data. Thus, this may lead to issues with memory, and computational complexity, and further introducing ML algorithm with existing solutions leads to increase the overall complexity of an algorithm. ML techniques are only limited to the low dimensional problems as they lack in scalability.

ML works in real time with the constant stream of data while smart IoT devices are based on real time data processing, so sometimes this integration may not be suitable while dealing with real time data.

Other critical issues such as scalability, cost, battery of sensors, handling of multiple sensors, time elapse and many more, are required to be taken care of when we integrate ML with IoT.

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