IoT in Industry 4.0: Applications and challenges

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Abstract: The Internet of Things (IoT) enabled devices involve different types of data. These devices named as sensors are responsible for generating real world data based on the physical properties they measure. For example, temperature sensor produced temperature readings. Sensor collects data continuously or periodically, providing a stream of information that reflects changes in environment or conditions. Relating to the IoT, data from sensors transmitted to the central system usually through wireless communication protocols. The collected data can be utilized for various purposes such as monitoring, analysis and decision making or triggering actions. This study provides a review of IoT and industrial IoT (IIoT). Further, this paper highlights Applications, challenges and tools in detail.

Keywords: IoT, IIoT, Sensors, Data acquisition and Security

1. INTRODUCTION

IoT (Internet of Things) and Industry 4.0 [6] are closely related to concepts that revolutionize industries' operational processes by adopting advanced IoT-based systems to improve competence, connectivity, and automation. Industry 4.0 represents a transformative era characterized by the fusion of digital technologies with traditional industrial processes, fundamentally reshaping the way of manufacturing. With the IoT, artificial intelligence (AI), big data analytics, and automation, businesses across sectors have the opportunity to optimize efficiency, enhance productivity, and drive innovation like never before. It is the interconnection of every device with internet enabling them to send and receive data.

1.1 Key component of IoT

a. Device and sensors: IoT enabled devices [8] involves different types of data. These devices named as sensors are responsible for generating real world data based on the physical properties they measure. For example temperature sensor produced temperature readings. Sensor collects data continuously or periodically [9], providing a stream of information that reflects changes in environment or conditions. Relating to the IoT, data from sensors transmitted to the central system usually through wireless communication protocols [10]. The collected data is very important for the future for various purposes including monitoring, data analysis and decision making or triggering actions.

b. Connectivity: IoT network architecture with the integration of protocols technically allows gadgets and sensors to communicate and share information to the centralized physical system [11]. IoT provide several platform in different areas of study to be successful and efficient, selecting appropriate connectivity option is critical.

The connectivity require basic technologies as Wi-Fi, Bluetooth and BLE (Bluetooth low energy), zigbee, z-wave, LoRa (Long Range), NB – IoT (Narrowband IoT) and LTE – M and 5G. However each technology has its own range of communication and having few important protocols to be followed whenever deployed in the IoT based network [12][13]. However few important consideration are range requirement, power consumption, data rates, scalability, cost, security, network availability, standardization and interoperability and latency requirement [14]. IoT devices can also be connected within a network by using hybrid technology as edge computing and over – the – air (OTA) [15].

c. Data processing: Data processing is a critical component of IoT ecosystem, involving collection, analysis and interpretation. The few important aspects of data processing can be considered are data collection which involves sensor data, actuators and connectivity [16]. The other aspect is data transformation which bases on wireless communication and protocols. The third aspect is edge computing which process the data near by the source instead of centralized cloud servers. Edge computing [17] has many advantage like reducing latency by processing data locally, optimizer bandwidth [18] by transmitting only relevant information and enhancing privacy for data security.

1.2 Paper structure:

In this paper, Section 1 presents an introduction in detail about IoT and IIoT. Section 2 presents a literature review on IoT and Section 3 with applications of IoT. Moreover, Section 4 and Section 5, discuss the challenges of IoT, and IoT and Industry 4.0, respectively. Finally, the paper is concluded in Section 6.

2. LITERATURE REVIEW

The industrial IoT has a great impact on the world. The researcher's interest is increasing day by day due to the rapid and effortless monitoring of production improvement. Many authors have proposed various studies with relevant studies. A few of the important studies are summarized in Table 1 below.

Table 1. Literature review of relevant study

S.No	Author & Year	Objective	Outcome	Technology	Limitation
1	X. Zheng, M. Li, and J. Guo (2021)	Smart cities and edge computing paradigm	Designed a circular buffer queue at the lower edge layer	Smart cities, IoT & Cloud Computing	This can be better if machine learning model added for prediction
2	K. T. Putra (2021)	To propose edge computing framework named	The results shows reduction of data consumption by 95%	FCL, Edge computing, WSN	In addition IoT based devices can

		federate compressed learning (FCL)	having error rate of below 5% .		better with addition ML model
4	B. Khan (2021)	Healthcare predictive analysis	Model comparison as performance of RF 88.32% average accuracy, 2.96 ranked value, SVM 87.99% average accuracy & 3.83 RV	Big data, Machine learning techniques named SVM, j48, RBF, RF, HMM, CDT, KNN, AIDE, NB	The comparison can be performed on two or more dataset which can give variations in model training predictions
5	L. Cui (2022)	To provide a detailed survey of health analytics in edge computing with IoT and Machine leaning	Results shows a comprehensive review of papers having detailed model, challenges and application based information	Research survey	The study can add more details like challenges and technologies related to IoT and machine learning which help to improve health analytics
6	Morghan Hartmann (2019)	To survey current and emerging edge computing, Health analytics, architecture & applications	A comprehensive review material focused for the domain of emerging edge computing architecture and applications are discussed	Edge computing provided detail	Edge computing can be more clear paradigm if IoT and WSN technologies added in Survey
7	L. Liu (2021)	To provide a Vehicular edge computing challenge and opportunities	To provide a comprehensive detail review of vehicular edge computing	Edge computing, vehicular network	In addition few vechicular edge computing network solution and few research papers can be added in survey
8	S. Hamdan (2020)	To conduct detailed survey Edge computing	This study provided for the detailed survey of edge computing and IoT	ECAs – IoT, Data placement, orchestration	However architecture designed for IoT can be extended

		architecture for IoT		services and Big data	further if few different types of data devices added to collect text, image and video data
9	McEnroe (2020)	To study impact of edge computing in UAV Technical Aspects	Detailed study regarding UAV technical aspect with edge computing applications	UAV & Edge computing	In addition few challenges in UAV with edge computing can give better explanation
10	Garima Nain (2022)	To study edge computing in manufacturing industry perspective	The study presented a detailed survey of past present and future of industry 4.0 also called intelligence manufacturing with edge computing technology	The progress in I4.0 following the PDP loop and bring intelligence to the EC	Cloud technologies should be added for better understanding of Industry 4.0
11	Liang (2022)	To study and survey multi – access edge computing technologies	The study provided a detailed multi – access Edge computing (MEC) survey which focused on recent frameworks, concepts and capabilities.	The tools studies Software defined network, Network function virtualization, information centric Networking, cloud radio access network etc	Edge computing technologies like IoT, Cloud computing and Machine learning aspects can be added for better added smartness.
12	Wei Xu (2023)	To study practical distributed Edge learning	The study presented first mathematical model for goral oriented entropy as an optimization problem	Wireless communication system, B5G	Distribute edge aspects with Few prediction models can give better implementation logic for smart results

13	Hua, H. (2023)	To study edge computing challenges, limitation of Traditional approaches of EC, AI optimization results in other fields	This study provided a detail overview of EC architecture and optimization solutions regarding AI based approaches different fields perspective	AI based tools for EC optimization	AI and Edge Computing are good combination and it can be better further to add AI solutions in prespective of IoT architecture and cloud computing challenges
14	Acheampong, A (2023)	To study EC offloading and resource allocation in perspective ML model implementation to find out challenges	This study provides a ML based approaches for offloading techniques evaluation with challenges and issue in EC	Supervised, unsupervised and Reinforcement Learning also Non-machine learning approaches like Non-optimization, game theory etc	ML and EC
15	Chen, J (2023)	To focus Mobile edge computing approaches in ML based model proposed as game model for computation offloading	The results shows that the proposed model named QCOG-DG and QCOG-SG. From which QCOG – DG model can find NE solution in the MEC Scenarios.	MEC	MEC
16	Orfanos, V. A (2023)	To study MEMS performance improvement with integration of WSN and IoT for Machine to machine communication	This study focuses on tiny devices communication performance improvement with integration of IoT and WSN Modules with data integrity, cost factors and other technical characteristics.	EC, IoT, WSN and MEMS	Cloud computing aspects is not added in their study which is crucial part of IoT, WSN and EC

17	H.Hua (2023)	To propose a AI based model with EC results optimization	This study focuses AI and EC tradional approach for performance optimization witih limitation and challenges	AI – Machine learning and Edge computing	The study only focuses limitation and challenges while it is better to add applications and each application AI solution
18	L.A. Haibeh (2022)	A survey on Edge computing	Edge computing infrastructure, design, resource Management, and Optimization Approaches	Mobile edge computing (MEC) with auto scaled and proactive MEC-NFV infrastructure	There could be many other applications like IoT and challenges like cloud storage infrastructure
19	R.Singh (2022)	To implement digital network in forest ecosystem	Edge computing for IoT to monitor forest by applying real time sensing system and energy harvesting	IoT sensor environment	However it is just for the digitization of forest but few of the investigation regarding water, soil and weather should be clearly need to be discussed
20	R.shukla (2021)	Crop health assessment	To implement IoT based system with machine learning to assess crop health with prediction	UAV and IoT	The data storage medium should be added to process and store health assessment data

3. IOT APPLICATIONS

IoT covers broader areas of applications in these days due to portability and smartness contributing to increase efficiency, automation, and improved decision making [19]. Few of important applications are discussed below:

Smart homes [22] covers smart thermostats, lightening system, security cameras for energy efficiency and improved security. This may further extends smart appliances like IoT enabled refrigerators, ovens, washing machine, smart LEDs and LCDs that can be controlled remotely. Home automation also involves personal assistance like voice activate personal assistance, face recognition, and thumb impression to open doors, windows or appliances[20][21].

Healthcare: Healthcare [24] involves broader applications of IoT which can useful data analytics and patient health analysis. The healthcare covers remote patient monitoring, telemedicine, wearable [25] health devices, smart medical devices and implants [26]. IoT given benefits in the healthcare domain as it can improve early detection of

health issues, improved patient health, and enhanced healthcare delivery.

a. **Smart cities:** Smart cities [27] is technical and important application of IoT to monitor, control and traffic clearance root in large cities. Intelligence traffic management, smart parking solutions, waste management with connected bins, traffic signaling, rush hours alert are applications of IoT in smart cities [28]. These applications give improved and beneficial outcomes towards city and regional planning with the smart technology integration [29]. The IoT technologies give banifits improved traffic flow, efficient resource utilization, and sustainability.

b. **Smart agriculture:** Smart agriculture [30] involves many applications regarding IoT and emerging fields. This covers soil monitoring and moisture control, connected tractors and machinery, drones for crop monitoring. This give very useful results to improve agricultural productions. The IoT give remarkable improvement in context of optimal resource utilization, increased crop yield, cost saving, real time monitoring, water quality justification and crop monitoring. Proper Soil and water conservation is crucial for agriculture land. Soil monitoring with effective soil contents by applying IoT based sensor devices can help to provide repaid update which can help to give quick recovery of deficiency by providing rich source of pesticides [32]. Smart irrigation is used for the water quality monitoring, water pouring rate, properly water pouring in all areas of land, plant soil moisture level and water sustatiblity time by time. It is important to control and monitor environmental parameters over the effect of sustainable irrigation management.

c. **Environmental monitoring:** Environmental parameters monitoring can be monitored by deploying IoT based sensor ecosystem which can help human, animal and agricultural.

4. CHALLENGES OF IOT

a. Security: Although Internet of Things (IoT) gadgets are an important topic of conversation regarding security issues, focusing the network obscures the reasons behind nature of security [36]. IoT is important now for a variety of reasons to concert about security issues as discussed below:

b. Vulnerabilities: One major issue that befalls consumers and organizations on a regular basis is vulnerabilities. IoT devices are susceptible in part because they are not computationally capable of implementing built-in security [37]. The problems which can cause software and hardware level are important aspect in IoT based industrial management. These software's can be hacked by different weakness in the IoT system.

c. Malware: Even though majority frameworks of IoT have modest processing power, the risks nevertheless attack them [38]. In last decade, cybercriminals have effectively utilized this. Because IoT botnet malware is so adaptable and lucrative for attackers, it is one of the most commonly observed varieties. The most famous attack occurred in 2016, IoT devices was used by to assault important websites and service provider's products.

d. Inter-operability: In the context of the Internet of Things (IoT), interoperability is the capacity of various components, services and functions as a one cluster [30]. IoT comprises on large variety of processing, networking, and storage technologies which collectively work over particular applications. Few of the interoperability concerns are discuss below:

e. Standardization: For ensuring that one device can understand and communicate with each other common standard adaptation is important factor. Adopting common standard ensures communication process. Standard help to define protocols, data formats, and communication methods, making it easier from different vendors to interpreter [38]. IoT standards like MQTT (Message telemetry transport), CoAP (Constrained application protocol) are widely used for standardization.

5. IOT AND INDUSTRY 4.0

This time digital market also called 4.0 is one of key source for success to growing business needs. IoT arises several new opportunities for vendors, internet service providers and manufacturing firms. This fast growth of smart objects is about to reach 212 billion deployed all over world by 2020. In last few year number of smart objects are increased 300% as given statistics [39]. This growth is evidence to work with most efficient management of healthcare and manufacturing can increase economic growth. So many domain specific devices are developed for the many new applications which are growing day by day due to customer need. The population of digital devices. Grew due to IoT and emerging technology performance and reliability. Globally these devices are used to update life standard and fulfills business needs. Many digital device companies' offers smart, reliable, secure and fast digital communication devices to make market competition more competitive. More features in digital device will lead to more profit and customer attraction with economic growth [40]. That is why IoT is now more important industry and having direct impact on economic growth of company as well as country level even world level. Market competition provide base for implementation of technology within one region having all features with modern perquisites of objects such as battery life, sensing , heterogeneity [42], device look and operating system compatibility.

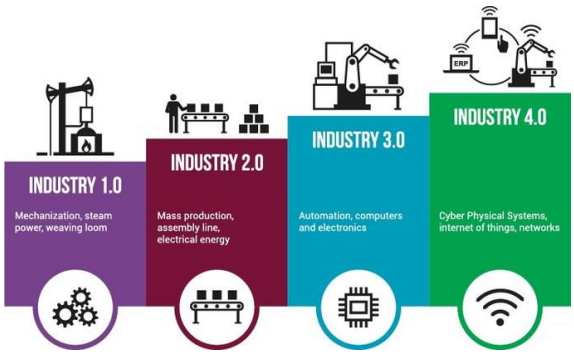

Figure 1 Industry 4.0 Evaluation

The figure 1 presented to explore the relationship of IoT and Industry 4.0. The evaluation of Industry 4.0 begins from the industry 1.0. The industry 1.0 was just beginning with basic tools whereas the industry 2.0 brought few remarkable reforms in industry 1.0. In this regard after few decades the industry shifted to microcontroller based machines which was revolution in the industry termed as industry 3.0. In these days all the technological advancement

is grown with latest sensors and actuators controlled my high performance computing. The high performance computing with other technologies like health, garments, transport, manufacturing industry grown very high. The edge of AI industry termed as industry 4.0 which is high standard and rapid growth over all the world with integration of microprocessor and tiny devices.

6. CONCLUSION

On the whole this study is about IoT and Industry 4.0. This study covers applications, challenges and security issues of IoT and latest trends of research. Whereas this can provide more detail about IoT. Industry 4.0 represents transformative era characterized by the fusion of digital technologies with traditional industrial process, fundamentally reshaping the way of manufacturing. The internet of things (IoT), artificial intelligence (AI), big data analytics, and automation, business across sectors have the opportunity to optimize efficiency, enhance productivity, and drive innovation like never before.

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