

Original Article

# Prospects of A.I. enabled IoT

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**Abstract** - The rapid growth of the production of low-cost and low power miniature computing devices and the decreasing cost of megabits per second makes it possible to embed it in any physical device. These embedded computing devices make these devices communicate over the internet to exchange data to and from the device. These devices are called the Internet of Things (IoT). These devices consist of four major components: sensors, actuators, computing devices, and communication media. These major components make these things capable of interacting with the physical world without minimal human interactions. Artificial Intelligence is another proliferating technology used to enhance the computing device to react intelligently by perceiving the environment and self-learning. But the integration of A.I. into these small miniature computing devices is not effective because it is not capable process the high volume of data. Instead, it needs to send the data to the remote computing device for computation and get back the communication media results. The Edge A.I. chip is fulfilling the computing requirement locally at the device. It plays a vital role in the IoT device to compute the data itself locally without sending the data to the cloud or sending the excessive data that it cannot process for external computation at different remote or cloud locations. IoT devices equipped with Edge A.I. chip transforming our daily activities drastically and gradually attracting many sectors around the world, opening new opportunities for growth and innovation. This paper introduces the IoT, A.I., and Edge A.I., their benefits and challenges. This would promote the future of the next generation into the intelligent smart world.

**Keywords** - IoT, Internet of Things, Artificial Intelligence, A.I., Edge A.I., A.I., Enabled IoT.

## I. INTRODUCTION

Internet of Things (IoT) is one of the rapidly emerging fields in digital communication technology that is empowering physical devices into intelligent devices. The intelligent devices consist of sensors, actuators, miniature electronic hardware pieces, and the software that makes it capable of information interchange via different communication media to the internet. Sensors are used to collect the data, actuators are used to react to the data it receives, and the electronic hardware piece is used to run the software to process the information. These capabilities are either integrated into the traditional devices, existing devices, legacy devices, or built-in in the new devices. These intelligent devices empower people to share

information between their devices seamlessly anytime, anyplace, and anyone, which aids in managing every aspect of their daily lives better. The lower costs, increased efficiency, and user-friendliness of these devices made them affordable to the people and gained popularity and uses in the consumer market, the commercial markets, government, and research fields.

The growth of IoT devices' usage is expanding so rapidly in many applications such as smart transportation, smart cities, and smart houses to make human life more comfortable, touching every facet of people's daily activity. According to Gartner Inc. [2], estimated that 20.4 billion connected things would be in use worldwide by the end of 2020, and a typical family home could contain more than 500 smart devices by 2022 [2]. According to Business Insider [3], there will be more than 64 billion IoT devices by 2025. These massive numbers of devices equipped with many sensors are producing tremendous data continuously. They are accumulating so rapidly, which makes them complex to process and analyze. To deal with such a high volume of data, Artificial Intelligence becomes the most prominent tool to analyze it. According to Richard Soley, executive director of the Industrial Internet Consortium [4], anything generating large amounts of data will use A.I. because that's the only way that can do it. According to Maciej Kranz, Vice President of Corporate Strategic Innovation at Cisco [5], without AI-powered analytics, IoT devices and the data they produce throughout the network would have limited value.

## II. INTERNET OF THINGS (IoT)

The term "Internet of Things" was the term first coined by Kevin Ashton during his presentation of radio frequency identification (RFID) in Procter & Gamble (P&G) in 1999 [6]. It refers to the intelligent device equipped with computing hardware, sensors, and actuators that can interact and communicate among themselves and react to the physical world over the secure network without minimal human interaction. There are many definitions of IoT put forward by different researchers, editors, authors, and organizations. This is because of its usage in a range of applications use of different technologies. According to Sundmaeker et al. [7], IoT is defined as a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated



into the information network. According to Rose, Eldrige, and Chapin [8], IoT generally refers to the scenarios where network connectivity and computing capability extend to objects, sensors, and everyday items not normally considered computers, allowing them to generate, exchange, and consume data with minimal human intervention.

The major driving factors of the growth of IoT are the following factors [18]:

- a) Decreasing Cost of CPU, Memory, and Storage
- b) Increasing Device Proliferation
- c) Decreasing Cost of Megabit/sec
- d) The convergence of I.T. and Operational Technology

Based on the market trends, different studies have projected the growth rate and the number of IoT device usage for the future. Some of the statistical trajectory for IoT device usage that justifies the growth of IoT technology are:

- More than 64B IoT devices are expected to be in use worldwide by 2025 [3]
- 20.4 billion connected things will be in use worldwide by the end of 2020 [1]
- 5.8 billion automotive and enterprise gadgets will be on IoT by the end of 2020 [9]
- 22 billion IoT devices, including all active connections and without considering the devices that bought in the past [13]

Some of the trajectories of the potential economic value of the IoT market are:

- 64B IoT devices have the potential to generate the U.S. \$4T to \$11T in economic value by 2025 [10]
- The overall wearable technology market will be worth the U.S. \$51.6 billion by 2022 [11]
- The IoT in banking and financial services market size is expected to grow to the U.S. \$2.03B by 2023 [12]
- The global smart homes market is expected to reach the U.S. \$151B by 2024 [11]

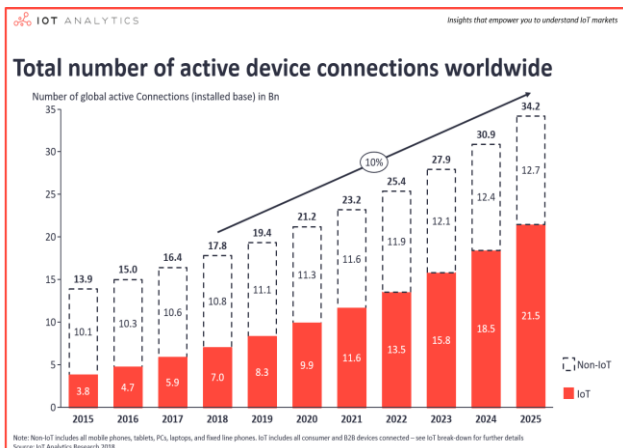


Fig. 1 Total number of active device connections worldwide [13]

The expected growth from IoT Analytics is shown in Fig. One which presents the expected growth number of active device connections worldwide without considering the devices bought in the past and not used anymore. This number could reach 21.5 billion by 2025. Fig. 2 presents the expected spending on IoT solutions that will grow to around 1.6 trillion dollars by 2025 [14]. The continued growth of IoT devices is transforming the world into new heights of technological development.

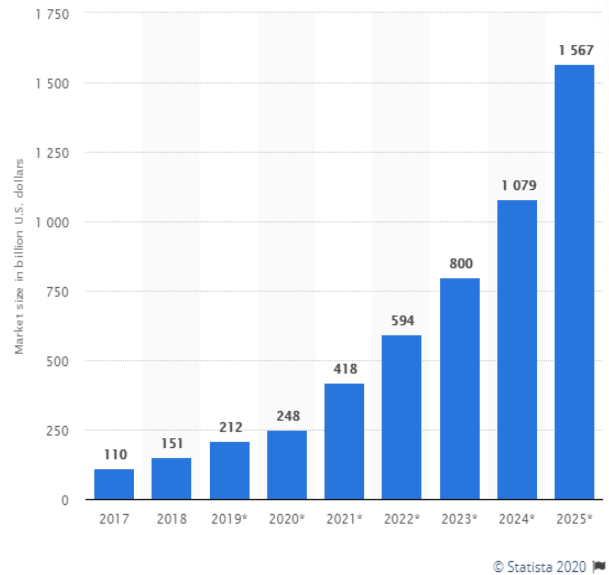


Fig. 2 Forecast end-user spending on IoT solutions worldwide [14]

The projected statistics are different in studies. This is due to the different considerations during these studies. These projected statistics demonstrate the evidence that they have a tremendous influence on the world network's infrastructure, which will impact in the future.

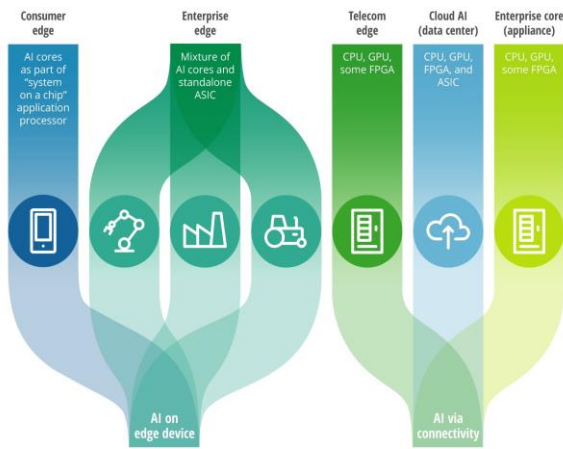
### III. ARTIFICIAL INTELLIGENCE (A.I.)

Artificial Intelligence (A.I.) is the computing device's capability to decide by perceiving the environment with reason by self-learning, adapting, and thinking. Typically, a computing device learns or reads the data, interprets the data using predictive analysis or machine learning, and simulates intelligent behaviour without needing the human brain. Originally, the term "artificial intelligence" was coined by cognitive scientists at a 1956 conference at Dartmouth University [15].

A.I. is technology integrated into a computing device to make it act like a human behaviour with reasoning. Traditionally, computing occurs at the remote nodes due to the lack of computing power of IoT devices and extremely processor-intensive A.I. functions. The processor-intensiveness makes it almost impossible to house A.I. in a small low cost and low power computing device embedded in IoT devices. To enable the computing power of IoT, a new technology called Edge A.I. chips is used, which does not need to send a large amount of data to remote or cloud for computation; instead, it processes A.I. locally on this computing Edge A.I. chip. In a circumstance when Edge

A.I. chips overwhelm with excessive data and computing, it can send excessive data portion for computing at the slight edge. The A.I. computation can occur at different locations, as depicted in Fig. 3 [19]. A.I. will most of the time occur in a hybrid fashion, meaning some portion locally on-device and some remotely. So, all these computing locations will coexist in the future.

The edge A.I. chip market is growing much faster than the overall chip market. It is one of the biggest trends in chip technology [20]. In 2020, Deloitte predicted that more than 750 million edge A.I. chips - chips or parts of chips that perform or accelerate machine learning tasks on-device, rather than in a remote data centre - would be sold, representing the U.S. \$2.6 billion in revenue [19].



Source: Deloitte analysis.

Deloitte Insights | deloitte.com/insights

Fig. 3 A.I. computing physical locations [19]

In 2020, the consumer device market will likely represent more than 90 percent of the edge A.I. chip market. The vast majority will go into high-end smartphones. Smartphones alone are expected to sell 1.56 billion units by 2020, depicted in Fig. 4 [21]. Smartphones consist of the largest market share because of their ability to manage and monitor IoT devices from an application installed on smartphones. These smartphones play significant roles in the growth of IoT devices as it is used. Not only the smartphones that use edge A.I. chips; other device categories—tablets, wearable, smart speakers—contain them as well. Fig. 5 [20].

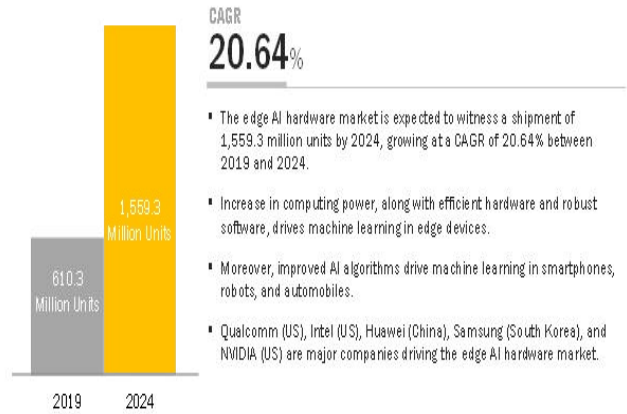


Fig. 4 Edge A.I. hardware market [21]

### The edge AI chip industry is poised for growth

Edge AI chips by device, 2020 and 2024 (millions of units)

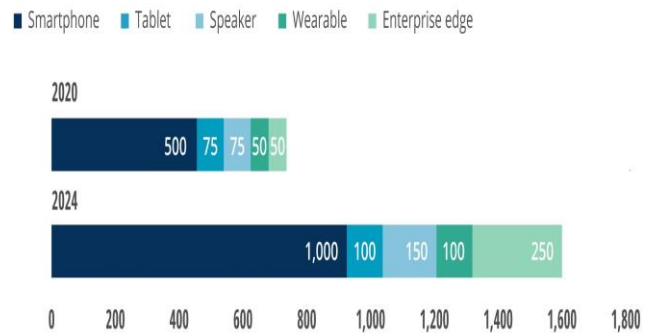


Fig. 5 The edge A.I. chip industry [20]

### IV. A.I. ENABLED IoT

The growth of the adoption of IoT devices is tremendous. The IoT is being driven by six factors, as shown in Figure 3. In turn, the IoT's growth will drive an exponential rise in the volumes of data being generated [18]. A forecast from International Data Corporation (IDC) estimates that there will be 41.6 billion connected IoT devices generating 79.4 zettabytes (Z.B.) of data in 2025 [16]. A.I. is used to deal with such massive data generated from IoT devices. A.I. capability is added to IoT devices such that it can analyze data efficiently and make intelligent decisions or actions without humans' involvement. A.I. is the only way that can deal with such massive data [4,5]. A.I. is coupled with the IoT to harness the full potential of IoT. A.I. is rapidly becoming indispensable to IoT [18]. According to Gartner Inc [17], more than 80% of enterprise IoT projects will have an A.I. component. So, A.I. is anticipated in almost every IoT device.



**Fig. 5 Drivers of IoT growth [18]**

### A. The Impact of AI-Driven IoT on Various Industries

Technology is continuously evolving and impacting every sector around the world and every facet of our daily lives. One of the most recent and rapidly growing technology is AI-enabled IoT devices. Cities, companies, and individuals are increasingly adapting to smart technologies to save time and money. Its impact ranges from individual to different large organizations. Some of them are discussed below:

#### a) Smart Homes

The emergence of smart homes is aimed at making our lives easier by leveraging household appliances, lighting, electronic devices, heating, smoke alarm, cooking monitoring, and more, by learning a homeowner's habits to automatically control the activities in the presence of people in the house or remote location. It is expected In the U.S., and The smart home market is expected to hit 28 percent of households by 2021.

#### b) Smart Buildings

Building equipment with smart sensors can monitor and control the HVAC systems, lighting systems, etc., for improving the energy system. It can also monitor people's movement in and out of the building, thus monitoring the intrusion into the building.

#### c) Smart Cities

With the proliferation of A.I. enabled IoT devices and their adaption in many sectors, it can also convert small or metropolitan cities into smart cities.

#### d) Airlines

Sensors are already being used on aircraft to monitor and prevent various errors and risks even before they happen. It can reduce aircraft downtime by predicting the faults identify the maintenance issues that can cause flight delays and cancellations.

#### e) Oil rigs

Oil industries invest a huge amount of money in procuring oil drilling machinery. This machinery, when getting spoilt or fails to function, incurs a huge loss to the companies. These oil industries can be benefited tremendously by adapting A.I. and IoT, which can be used on preventive maintenance, lowering the operation cost lowering the downtown.

#### f) Manufacturing

All types of industries adapt to and integrate smart sensors in their machine components and segments that help them with analysis enhancing their efficiency. From real-time data analytics to supply-chain sensors, smart devices help prevent costly errors in the industry.

#### g) Smart Farming

Many agricultural sectors adopt the smart farming system that allows farmers to improve the yields' quality, increase production, lower the costs, and reduce waste by automating the efficient irrigation system. According to Beecham Research, IoT could be the key to the farming industry meeting the increasing food production by 70% to feed the 9.6 billion global population by 2050 [22]. IoT reduces human labour while A.I. covers real-time data from the fields into useful information to the farmers by suggesting better crops to their field in getting high yield and profit [23].

### B. Benefits of A.I. enabled IoT.

Some of the benefits of A.I. enabled IoT are listed below:

- Boosting Operational efficiency
- Enabling new and improved products and services
- Enhancing risk management
- Greater revenues
- Reduced costs
- Improved customer experience
- Increase IoT Scalability

### C. Applications of A.I. enabled IoT.

With the proliferation of IoT devices, smart, and intelligent environments, we can revolutionize the entire world. The following are some potential IoT applications that can enhance the operational efficiency of every type of activity:

- Robots in Manufacturing
- Self-driving cars
- Retail Analytics
- Smart Thermostat Solution
- Voice Assistants
- Chatbots and AI-Powered Virtual Assistants

### D. Challenges of A.I. enabled IoT.

Currently, IoT is one of the main accelerators of technological innovation is one of the areas with greater potential for transformation of society and the economy. As such, all the involved stakeholders, ranging from technologists to developers, companies, and users, face several challenges that remain to be tackled [24]. Some of the challenges follow:

#### a) Connectivity

IoT devices use various communication media technologies like WiFi, Zigbee, Z-Wave, Bluetooth, BLE, etc. Enabling a seamless flow of information

to and from a device, infrastructure, cloud, and other devices is challenging.

**b) Security and Trust**

Security and trust are broad area but is paramount for IoT devices. So, it isn't easy to monitor and maintain security across all the connectivity chains.

**c) Scalability**

The scalability is another issue of IoT applications where millions and trillions of devices could be linked to the same network.

**d) Interoperability**

Due to the huge number of various platforms developed by multiple vendors used in their IoT system, interoperability between these devices has become challenging [25]. Interoperability should be able to manage by both the application developers and the device vendors.

**e) Accessibility**

Hardware and software used in the IoT device should be accessible from anywhere anytime for the users who are authorized to use it.

**V. CONCLUSION**

Internet of Things (IoT) is the booming technology already reaching the billions of devices in use around the world. Equipped with A.I. function with Edge A.I. chip's addition, these IoT devices will be the largest driving force in the future technology, evident from the different statistical studies from different organizations. This paper discussed the future predictions of IoT device usage and its market potential by different organizations. The benefits and challenges of AI-enabled IoT systems are discussed. With these studies, we can conclude that there are many other possibilities of AI-enabled IoT in many sectors of future technology. Our imagination of the smart world will become a reality.

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