Artificial Intelligence of Things and 5G Synergy: Accelerating Industrial 4.0

CSC 40056 Internet of Things (IoT)

Sneha Grace Alex

21022580

School of Computing and Mathematics

Keele University

United Kingdom

ABSTRACT

Billions of sensors and gadgets collect and process data from the environment, transfer it to cloud centres, and receive feedback via the Internet for connectedness and perception in the Internet-of-Things (IoT) era. However, transferring enormous volumes of diverse data, detecting complicated environments from this data, and then making timely smart decisions are all difficult tasks. Artificial intelligence (AI), particularly deep learning, has now been demonstrated to be successful in a variety of fields, including computer vision, speech recognition, and natural language processing. The introduction of AI into the IoT signals the dawn of the AI of Things era (AIoT). This article gives a complete assessment on AIoT to demonstrate how AI might help the Internet of Things become quicker, smarter, greener, and safer along with 5G , leading to fourth industrial revolution, Industry 4.0

INTRODUCTION

The Internet of Things (IoT) is a global intelligent network that connects numerous things with the ability to perceive, compute, execute, and communicate with the Internet; process and exchange information between things, data centres, and users; and deliver various smart services. In traditional IoT solutions, data collected from sensors is transported through networks to a cloud computing platform for further processing and analysis before being delivered to end devices/actuators. However, given the large number of sensors employed across multiple applications, this centralised architecture faces major challenges [1] . Billions of devices will be connected to IOT in future and this vast amount of data necessitates a lot of bandwidth, and cloud processing and transmitting the results back to end devices results in a lot of latency.

Aside from the issues posed by large numbers of sensors, there is also the issue of sensor heterogeneity [2], which includes scalar sensors, vector sensors, and multimedia sensors. Although the perception system of an IoT is an important part of the design, just adapting to and interacting with the dynamic and complex world is not enough. An IoT system should also be able to reason and behave in order to interact with the environment and humans. A man, for example, parks his automobile in a parking lot every morning and leaves on these days on a regular basis. As a result, a smart parking system might deduce that he works nearby. The AI chatbot can then recommend and introduce him to certain parking options, auto maintenance, and local restaurants. Recent breakthroughs in causal inference and discovery [3], graph-based reasoning [4], reinforcement learning (RL) [5], and voice recognition and synthesis [6], [7] could assist these application situations.

There are still 99.4 percent of physical objects that are not connected. Mass connectivity will be enabled by advanced communication technologies such as Wi-Fi 6 (IEEE 802.11ax standard), 5G, and AI. This marks the beginning of the AI of Things (AIoT) era, in which AI collides with IoT (Fig 1).

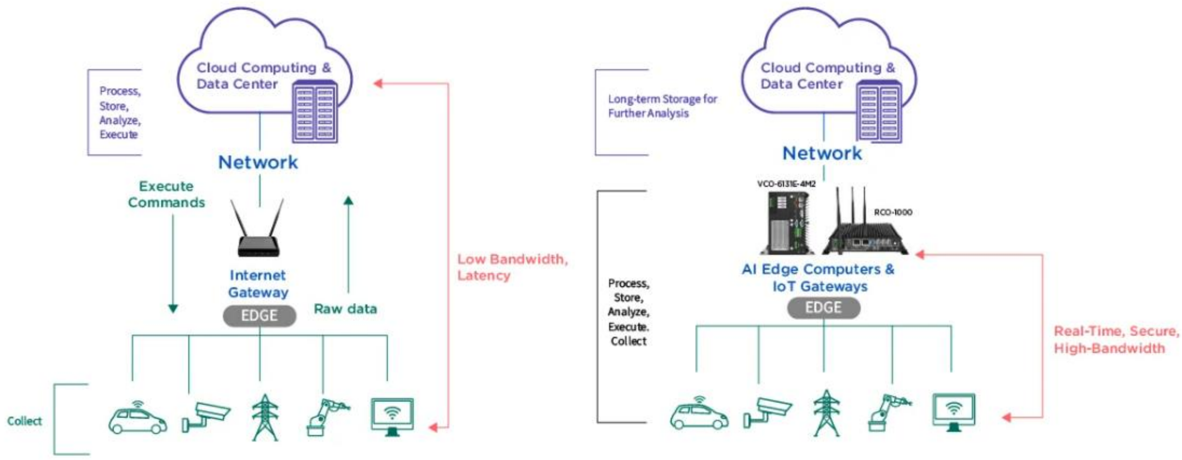

Fig 1: The Evolution of IoT Network Architectures

ARTIFICIAL INTELLIGENCE OF THINGS(AIOT)

The Artificial Intelligence of Things (AIoT) is a combination of artificial intelligence (AI) technologies and Internet of Things (IoT) connections that enables more efficient IoT operations, improved human-machine communications, and better data management and analytics.AI might be used to translate IoT data into useful information for improved decision-making, laying the groundwork for additional cutting-edge innovations like IoT Data as a Service (IoTDaaS). AIoT is transformative, having benefits for both types of innovation, as AI adds value to IoT through machine learning capabilities, and IoT adds value to AI through connectivity, gestures, and information replacement. As IoT devices spread throughout major corporations, the importance of human-situated as well as machine-created formless data will grow. AIoT could assist with data analytics clarifications, allowing this IoT-generated data to have meaning. AIoT involves the integration of artificial intelligence (AI) with communications tools such as courses, chipsets, and edge processing, all of which are accessible via IoT networks. APIs are then used to increase interoperability between devices, software, and platforms. These parts will primarily focus on improving the framework and technique procedure, as well as removing information relevance.[8]

AIoT Key Technologies

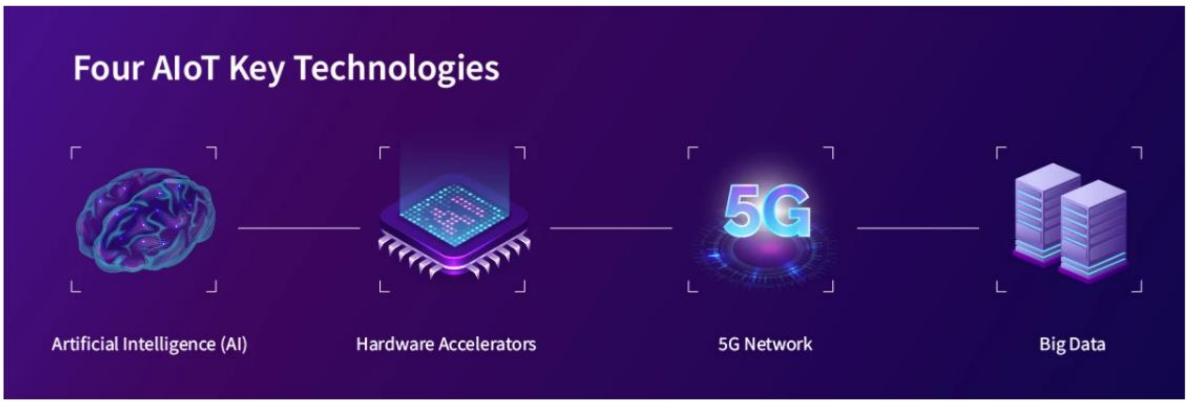

Fig 2: AIot Key Technologies [15]

1. **Artificial Intelligence**

Deep learning models are becoming more precise and efficient, requiring less computing resources. IoT devices benefit from artificial intelligence in two ways. First, having intelligent sensors and IoT devices makes the telemetry data process much more efficient. Second, AI enables mission-critical and complicated applications to do stream (real-time) and batch (Big Data) processing at the edge[15].

2. **Hardware Accelerators**

More powerful computer processors are allowing IoT devices to execute AI, Deep Learning, and Machine Learning models more readily. Furthermore, more AI-focused processors are being developed, such as Intel's Movidius VPUs and Google's TPUs, which can execute AI models exceptionally quickly and efficiently. Manufacturers can produce more compact and powerful AIoT devices with ongoing technological improvement in machine learning[15].

3. **5G Networks**

AIoT applications will be supercharged by 5G networks, making them considerably more powerful, mobile, dependable, and efficient[15].

4. **Big Data**

With so much data generated by IoT devices, AI developers are developing more intelligent Deep Learning models for AIoT devices to use. Furthermore, AIoT devices reduce cloud workloads by collecting, filtering, processing, and analysing data at the edge before transmitting the most critical information to the cloud[15].

III. AIOT ARCHITECTURE

AIOT applications follow a three-tier architecture as shown in fig 1 [8]. The edge computing layer allows for sensor and actuator control and execution. This layer intends to give AIoT systems the ability to perceive and act in this way. The fog computing layer is implemented in network fog nodes such as hubs, routers, and gateways. The cloud computing layer, like the application layer [1] and intelligent integration block in [2], supports a variety of application services. Because they can access huge amounts of data and have vast computation resources, the fog and cloud computing layers primarily aim to endow AIoT systems with the ability to learn and reason. In the AIoT network structure, it’s worth noting that the edge items and fog nodes are always spread, whereas the cloud is centralised.

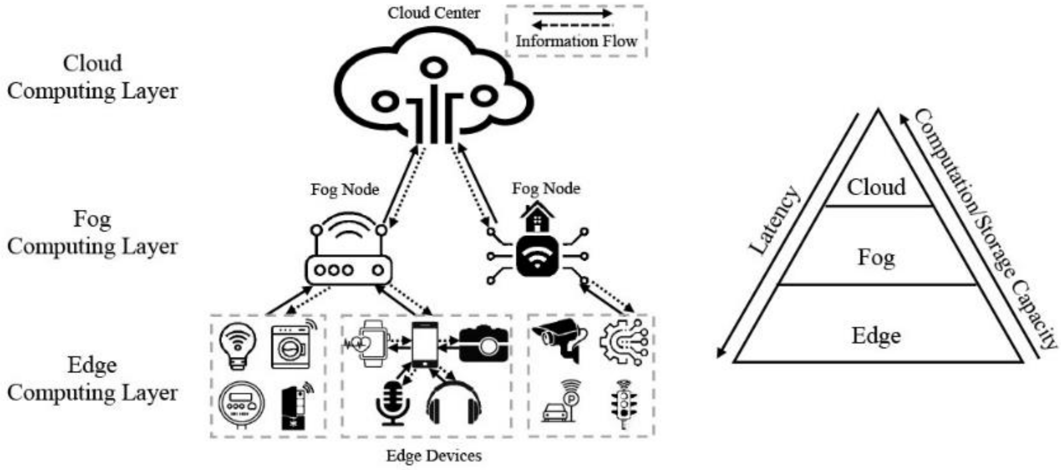

Fig 3: Diagram of the tri-tier computing architecture of AIoT [8]

Tri-Tier Computing Architecture

1) Cloud Computing Layer

The cloud allows AIoT businesses to access computational resources electronically through the Internet rather to establishing their own physical infrastructure. It can provide a variety of AIoT applications with flexible, scalable, and dependable resources, such as compute, storage, and networking. Real-time data streams from many dispersed sensors and equipment are often transported via the Internet to a remote cloud centre, where they are further integrated, processed, and stored. Cloud computing has the advantage of providing elastic computing resources on a pay-as-you-go basis, which is advantageous for AIoT applications with fluctuating traffic flows. Another benefit is that it can use all the data from the registered devices in an AIoT application to train deep models with higher representation and generalisation abilities [8].

2) Fog Computing Layer

Fog computing delivers storage, compute, and networking capacity to the network's edge, where devices are located. Fog nodes, such as routers, switches, gateways, and wireless access points, are facilities or infrastructures that deliver fog computing services. Fog computing has a crucial advantage, namely, reduced latency, because it is closer to the devices. Furthermore, fog computing can provide service continuity without relying on the Internet, which is critical for specialised AIoT applications that rely on an inconsistent Internet connection, such as those in the agriculture, mining, and shipping domains. Another benefit of fog computing is that data confidentiality and privacy are protected because data can be stored within the LAN. Because fog nodes are designed to retain data from local devices, which are incomplete compared to those on the cloud, they are better suited for deploying DNNs rather than training [8].

3) Edge Computing Layer

Edge computing has several advantages over fog and cloud computing, including the ability to reduce latency and network bandwidth by compressing data on-site before transmission, which is especially relevant for AIoT applications that use multimedia sensors. Only lightweight DNNs can run on edge devices due to their limited compute capabilities. As a result, research areas such as neural network architectural design or search for mobile settings, as well as network pruning/compression/quantization, have recently gotten a lot of attention. In order to construct an intelligent hybrid computing architecture, it is customary to deploy various models into cloud platforms, fog nodes, and edge devices in an AIoT system. It is projected to deliver low latency while exploiting deep learning capacities for processing vast amounts of data by intelligently offloading part of the compute workload from edge devices to fog nodes and cloud. For example, to recognise automobiles in a video stream, a lightweight model can be installed on edge devices. It can be used as a trigger to send keyframes to fog nodes or the cloud to be processed further [8].

IV. 5G COMMUNICATIONS IN IOT

For IoT devices, new business will necessitate stronger and substantially enhanced performance standards such as security, trustworthiness, wireless coverage, ultra-low latency, and mass connectivity, to name a few. Long Term Evolution (LTE) and 5G technologies would provide/introduce new communication interfaces for future IoT applications to meet these criteria. Now, 5g is the most advanced communication technology available.5G is the fifth-generation technology standard for broadband cellular networks, which cellular phone operators began building globally in 2019, and is the successor to the 4G. It features large bandwidth, low latency, and a massive connection, which makes it ideal for industrial manufacturing settings [9].

The key benefits of 5G are faster transmission speeds, lower latency and thus more capacity for distant execution, a larger number of connected devices, and the ability to construct virtual networks (network slicing), which allows for more tailored connectivity to specific demands. Transmission speeds can reach 15 or 20 Gbps. We can access data, programmes, and distant applications in a completely direct and without waiting manner if we have access to a faster speed. By increasing cloud usage, all devices (phones, computers, etc.) will rely less on internal memory and data accumulation, and it will be unnecessary to install a high number of processors on some items because processing can be done on the Cloud [10].

The number of devices that can connect to the network increases significantly with 5G, and per square kilometre, it will reach millionaire status. All connected gadgets will have instant internet connectivity and will be able to communicate with one another in real time. The Internet of Things will benefit as a result of this. A typical home is expected to contain 100 linked devices that send and receive data in real time. Thousands of connected devices are present in industrial sites. Smart cities and self-driving cars will be possible with a larger number of linked devices [11].

Virtual networks (network slicing) and subnets are also possible with 5G, allowing for better connectivity tailored to specific needs. The creation of subnetworks will give specific characteristics to a part of the network, allowing for the prioritisation of connections, such as emergencies in front of other users, by applying different latencies or prioritising them in the network connection so that they are not affected by possible mobile network overloads [11].

V. AIOT AND 5G SYNERGY AND INDUSTRIAL REVOLUTION 4.0

The rapid advancement of technology has had a significant impact on how people and organisations work, live, and play. The pervasiveness and permanence of its digital imprints are now influencing us all, and the same is true for virtually all industries, as they establish roadmaps as part of the fourth industrial revolution (Industry 4.0) (fig 4)[12].

The fourth industrial revolution approaches with the alluring prospects of enhanced efficiency, labour optimization, and, of course, greater profits, dangling technological carrots in the form of automation, artificial intelligence (AI), quantum computing, internet-of-things (IoT), and more. All of this is based on the understanding that 5G is a significant disruptive technology that will drive digital innovation across industries.

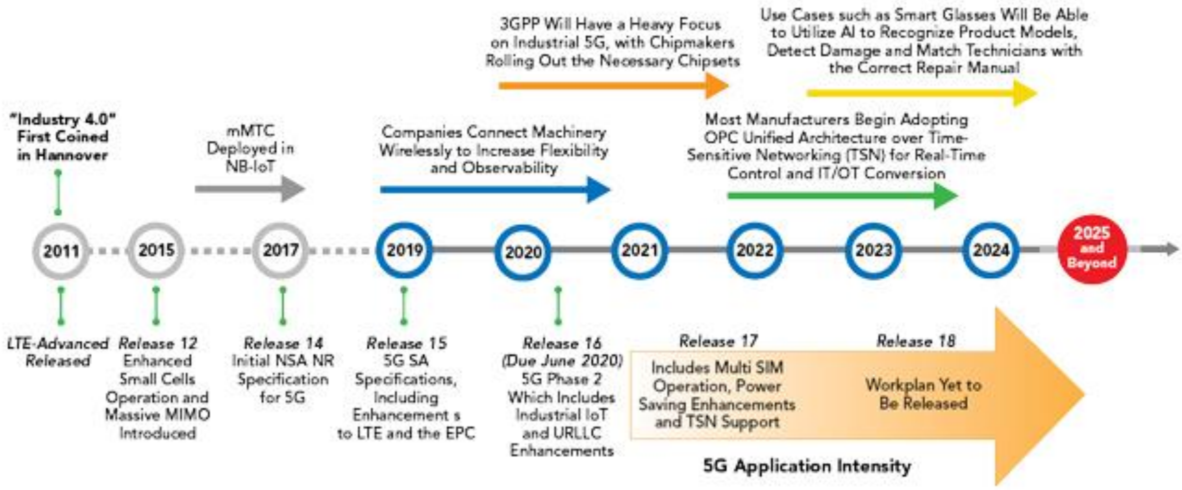

Fig 4: The Evolution of Industry 4.0

The Fourth Industrial Revolution, often referred to as Industry 4.0 is defined by a convergence of technology that blurs the boundaries between the physical, digital, and biological realms. The impact of AIoT and 5G would be unprecedented. Control of various production devices will transfer from the factory floor to control rooms in industries. Machine fault handling will become more predictive, and in some circumstances, preventative actions will be implemented. Machine-to-machine communication will be permitted, allowing for the improvement of assembly line processes, warehouse management, logistic services, and supply chain management, among other things. Collaborative robots will be able to operate with humans. AI decision-making will enable IoT devices to be self-contained [13][14].

Autonomous vehicles with predicted maintenance needs will become the norm, resulting in increased safety and fuel efficiency. Smart cities would emerge, with better services, less traffic congestion, better fleet management, water and energy saving, and a higher quality of life. Demand-supply curves will be synchronised, and distribution losses will be reduced, thanks to smart metres. Many operations inside homes, including as door opening, temperature management, and optimal appliance operation, will "learn" from human behaviour and become autonomous. Predictive device maintenance will become prevalent [13][14].

On a human level, the chances of anticipating the beginning of certain diseases and successfully controlling them once a patient has been diagnosed would improve. Wearables that monitor a person's health and preferences will become commonplace. Voice assistants will learn to read facial and verbal expressions and respond appropriately based on the situation. The Fourth Industrial Revolution will blur the barriers between the digital, physical, and biological worlds, transforming how we live, work, and interact. It will not, however, be a huge bang event, but rather a gradual shift that is already occurring.

VI. BENEFITS OF AIOT 5G SYNERGY

Implementing Artificial intelligence makes technologies and machines smarter and more intelligent on multiple levels:

1) Assisted Intelligence: At this level, AI allows for the detection of dangers as well as the prediction or forecasting of breakdown. They can keep an eye on their machines in real time, avoiding downtime and increasing overall efficiency.

2) Augmented Intelligence: At this level, AI gives robots the ability to make decisions for themselves and alert humans to potential problems or bottlenecks.

3) Autonomous Intelligence: At this level of intelligence, machines obtain autonomy and may thus conduct essential actions. They discover new ways of doing things and thus play an important part in increasing the company's production rate.

Industries can utilise AI (together with machine learning) to process data supplied from IoT devices or linked equipment, depending on the level of intelligence they wish to integrate in their machinery.

VI. CHALLENGES OF AIOT AND 5G SYNERGY

1.Processing, Transmission, and Storage Multimodal Heterogeneous data:

AIoT systems have many heterogeneous sensors that generate a massive data stream with a variety of formats, sizes, and timestamps, posing major processing, transmission, and storage challenges. The AI perceiving technologies can be used to extract compact and structural representations from data that would be easy to transmit and store. The structural representation, on the other hand, is task-oriented and should be calculated at the network edge to save bandwidth and latency, which is another difficulty [8].

2) Deep Learning on Edge Devices:

The computational and storage resources available to edge devices are limited. As a result, learning how to design or automatically search for lightweight, computationally efficient, and hardware-friendly DNN architectures is useful yet difficult. Furthermore, network pruning, compression, and quantization are all worth investigating further [8].

3) Computational Scheduling in the AIoT 5G Architecture:

Cloud centres, fog nodes, and edge devices are all examples of heterogeneous computing resources in a typical AIoT design. Some intensive processing may be required in real-world AIoT systems to offload from edge devices to the fog node or cloud centre, posing a computational scheduling difficulty. When scheduling computation among several resources, the following considerations should be made data type and volume, network bandwidth, processing latency, performance accuracy, energy consumption, and data security and privacy in each individual application scenario. A dynamic adaptive scheduling technique would also handle imbalanced data flow and user demands over time[8].

4) Data Monopoly:

AIoT companies capture and use huge data, resulting in new data collection and exploitation opportunities. This positive feedback loop could result in a data monopoly, or enormous proprietary data safeguarded by established interests that other parties are unable to access [8].

6) Data Security and Privacy:

Due to the widespread use of sensors in smart homes, hospitals, and cities, large amounts of biometric data (e.g., face image, voice, action, pulse, imaging data, etc.) from AIoT users or uninformed participants may be acquired. This raises significant questions about data security and privacy. Who owns these records? How long will these records be kept? What will be done with these data?[8]

7) Growing Energy Consumption in Data Centers:

The rapid rise of cloud centres corresponds to the rapid growth of AIoT applications. As a result, further efforts to reduce energy use in data centres should be done in the future [8].

VII. CONCLUSION

The AIoT's three-tier computing architecture provides varied computational resources for deep learning while also bringing new issues, such as the design and search for lightweight models and computation scheduling. Deep learning has made significant progress in a variety of fields, and it now powers a slew of AIoT applications. However, additional work needs be done to increase edge intelligence. Deep learning has proved its worth in enhancing control precision and enabling multimodal interactions in the AIoT. Many quick, smart, green, and safe AIoT applications are projected to profoundly transform our environment in the future, thanks to rapidly expanding AI and 5G synergy technologies.

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