Edge- AI and Internet of Things for Intelligent Systems: Architectures, Applications and Future Perspectives

Fatou Diop(✉), Babacar Mbaye Faye, and Ibrahima Niang

Cheikh Anta Diop University, Dakar, Senegal
{fatou110.diop,babacarmbaye.faye,ibrahima1.niang}@ucad.edu.sn

Abstract. In an era where connectivity is ubiquitous and data flows ceaselessly, Edge IoT (Internet of Things) systems have emerged as a pivotal technological paradigm poised to revolutionize the way we interact with the digital world. As the proliferation of IoT devices continues unabated, the traditional cloud-centric model for data processing and decision-making faces significant challenges. Edge IoT systems, by shifting computational intelligence closer to the data source, offer a compelling solution to these challenges, promising greater efficiency, lower latency, and enhanced real-time decision-making capabilities. On the other hand, the convergence of edge computing, artificial intelligence (AI), and the Internet of Things (IoT) has ushered in a new era of intelligent systems with transformative potential across various domains. This includes the development of edge computing infrastructure, AI models optimized for edge deployment, and IoT device architectures that support real-time data processing and analysis. This paper proposes a comprehensive review on Edge computing, AI, and IoT integration for intelligent systems. We focus on the concept of Edge-AI and its potential applications in real-time processing for Internet of Things. The paper introduces Edge-IA technology, explores commonly used networking and messaging protocols in IoT, and discusses the opportunities and challenges of Edge-IA and IoT in various industries, including agriculture and healthcare.

Keywords: Internet of things · Edge computing · Artificial intelligence · Edge-AI

1 Introduction

In recent years, the Internet of Things (IoT) has become one of the most important technologies of the 21st century. IoT is a revolutionary concept that involves connecting everyday objects and devices to the internet, allowing them to collect and exchange data, communicate with each other, and be remotely controlled. IoT transforms ordinary items, such as appliances, vehicles, wearables, and industrial machines, into "smart" devices capable of sensing, transmitting, and acting upon data. This interconnected network of devices and sensors provides real-time information, enhances automation,

A. Sere et al. (Eds.): AFRICOMM 2023, LNICST 588, pp. 111–122, 2025.
https://doi.org/10.1007/978-3-031-81573-7_9

improves efficiency, and enables data-driven decision-making across various sectors, including home automation, healthcare, transportation, agriculture, and industry [1]. IoT represents a significant shift in how we interact with our surroundings, offering new possibilities for convenience, productivity, and innovation while also raising challenges related to data security, privacy, and scalability.

Edge computing is a distributed computing paradigm that brings computational processing and data storage closer to the source of data generation, typically at the"edge" of a network or IoT devices, rather than relying on centralized cloud data centers. This approach reduces latency, enhances real-time processing, and conserves bandwidth by processing data locally or in nearby edge servers [2]. Edge computing is essential for applications requiring low latency, such as autonomous vehicles, industrial automation, and IoT devices, enabling faster responses and improved efficiency. It complements cloud computing by decentralizing computing resources, allowing for more efficient and responsive data processing in various domains. We can result that this reduces latency, enhances data privacy, and conserves bandwidth by processing and analyzing data locally or in nearby edge nodes.

Artificial Intelligence (AI) is a multidisciplinary field of computer science focused on creating machines and computer systems that can perform tasks that typically require human intelligence. For this, AI encompasses machine learning and deep learning techniques that enable computers to perform tasks that typically require human intelligence, such as learning from data, making decisions, recognizing patterns, and natural language understanding [3].

Edge AI (or intelligent Edge) appeared in a desire to integrate artificial intelligence as close as possible to sensors or connected objects (IoT). The advantages are multiple: absence of prerequisites for permanent internet connectivity, data confidentiality, reduction of latency. To achieve the expected results, Edge AI makes it possible to move part of the computing flow directly into the connected objects, and therefore to minimize the use of the cloud for the tasks related to the processing.

In essence, Edge AI empowers devices and sensors to become"smart" by running AI algorithms locally, enabling quicker decision-making and reducing the need for constant internet connectivity. It finds applications in various fields, including autonomous vehicles, smart cities, healthcare, and industrial automation, where low latency and real-time processing are critical [4]. Edge AI is at the forefront of innovation, addressing the demands of our increasingly connected and data-driven world while raising challenges related to resource constraints, security, and scalability.

In this paper, we provide a holistic view of the convergence of Edge AI and IoT, offering insights into its architectural foundations, diverse applications, ongoing challenges, and promising future directions. The keys contributions of this paper are listed as bellow:

- Overview of IoT, Edge Computing, and Artificial Intelligence (AI) paradigms. Particular.
- Summary of related work on the motivations for using Edge computing and Edge-IoT systems for real-time monitoring.
- Overview on networking and communication protocols for Edge-IoT systems.

- Description of the concept and architecture of Edge-IA technology by focusing on its applications in connected health and smart agriculture.
- Discussion of the security challenges and future directions in Edge-AI on IoT Environment.

The remainder of this paper is organized as follows: In Sect. 2, we introduce the motivation for using Edge computing and summarise related work on edge computing for real-time Internet of things applications. In Sect. 3, we present an example architecture for Edge computing-assisted intelligent IoT systems and integration protocols. Then, in Sect. 4, we discuss the concept and opportunities of Edge-IA technology and also present a architecture and application areas in connected health and smart agriculture. In Sect. 5, we discuss security challenges and future directions. Finally, in Sect. 6 we conclude by showing the benefits that Edge-IA brings to intelligent systems.

2 Background

2.1 Motivation for Using Edge Computing

The growth of internet of Things has led to increased demand for data processing and analysis, which introduced the development of new computing models, such as edge computing, which focuses on bringing processing and data closer together, storing end-user data to reduce latency, improve performance, and relieve computing demand on centralized data centers. Data processing and analysis at the network edge helps improve the performance of IoT networks and provide real-time services to users.

Traditional cloud computing architectures, while powerful and versatile, are not always equipped to meet the demands of real-time IoT applications. The latency associated with data transit to centralized cloud servers (as well as bandwidth limitations) can hinder the very essence of IoT: immediate, contextual responsiveness. To overcome these limitations, a paradigm shift is underway, which brings computation closer to the data source and therefore to the edge of the network [5]. Edge Computing is the transformative solution to the real-time challenges posed by IoT. Indeed, Edge-based IoT deployments must be managed, efficiently, effectively, and automatically. IoT applications that involve endpoints, edge computing and fog are complex to manage.

2.2 Edge Computing for Real-Time Internet of Things Applications

The IoT real-time monitoring market is expanding quickly in many IoT innovative applications, including smart logistics, smart farms, environmental monitoring, intelligent transportation, and smart power grids; that to the rapid development of sensors, GPS position sensors, RFID tags and readers, smart objects, and other IoT sensing technologies.

By the year 2025, 50 billion devices will be online, according to new research. These Internet of Things (IoT) sensing devices are data generators that continuously provide fresh perception data, offering enormous potential for real-time monitoring and intelligent application across numerous industries.

Processing the data from IoT monitoring is much more difficult. Redesigning the monitoring system's architecture will enable real-time data processing and responsiveness.

To enable real-time performance, the IoT monitoring system must continuously evaluate data as it comes in and improve its insight and decision-making capabilities to support sophisticated business logic [6].

Many research works have shown that edge computing can improve the performance of IoT networks and provide real-time services. They highlight the benefits of edge computing for various intelligent applications.

Authors in [5] discuses edge computing for Internet of Things (IoT) applications. It examines how edge computing can improve the performance of IoT networks, particularly latency, by improving computing and storage capabilities, and providing real-time services to users. The paper presents a comprehensive review of edge computing architectures for IoT, classifying them by architecture and comparing their performance in terms of network latency, compute capacity, and storage space. The authors also examine the security issues associated with these approaches, as well as the advantages and disadvantages of edge computing for IoT. In conclusion, the paper highlights the potential benefits of edge computing for various smart applications, including smart grids, smart cities, and smart transportation.

Paper [7] discusses the challenges of storing and processing the enormous amount of data generated by IoT devices, as their resources are limited. It explains that while cloud computing can be used to handle some of these resource issues, it can also introduce latency in time-critical IoT applications. This paper also highlights the limitations of Edge-computing architectures (ECAs)-IoT and proposes solutions to overcome these limitations. It outlines various IoT implementations in the edge computing domain and suggests four distinct scenarios for using IoT implementations with ECAs-IoT. Additionally, the document discusses the concepts of edge computing, implementation strategies, and edge intelligence. It provides a taxonomy for IoT applications based on different criteria and compares fog computing to cloud computing.

The universal complex event processing (CEP) mechanism for IoT real-time monitoring is proposed in [8]. It Proposes a formalized hierarchical complex event model including raw event, simple event and complex event, which reduces the complexity of event modeling. The approach allows for flexible, complicated events to be defined by programming using sophisticated time and space semantics. The proposed system is installed at the network edge between cloud-based apps Two application case studies of IoT monitoring for fruit transportation and city road manhole cover status are implemented based on the CEP system to highlight our proposed complex event model.

3 Edge-IoT Architecture and Protocols for Intelligent Systems

3.1 Edge-IoT Architecture for Intelligent Systems

Edge computing addresses the requirements of IoT applications on three categories, such as communication, computation and storage [5].

Communication: with the assistance of Edge computing, the performance in terms of bandwidth utilization, latency, device power consumption and packet data overhead that affect transmission time are reduced. Then considerably, the network performance is improved to meet the latency sensitive IoT applications.

Computation: in the Edge-IoT architecture, the computation follows the Edge cloud combination mode. The computation will be offloaded to the Edge servers thus relieving the cloud servers. Therefore, the speed and efficiency of the network in terms of resource utilization will be guaranteed.

Storage: the number of devices connected to the IoT is increasing and producing huge amounts of data. Previously, to be processed, all this data was at centralized cloud servers. This severely affected the user experience. The migration of all data collected by IoT devices to Edge storage servers solves this problem. Edge computing uses load balancing technology across different nodes, which would improve the quality of service.

The following Fig. 1 shows an example of a three-layer intelligent systems architecture assisted by IoT and Edge computing. However, note that the Edge-IoT architecture can change depending on the problem it wants to solve for an IoT application [7].

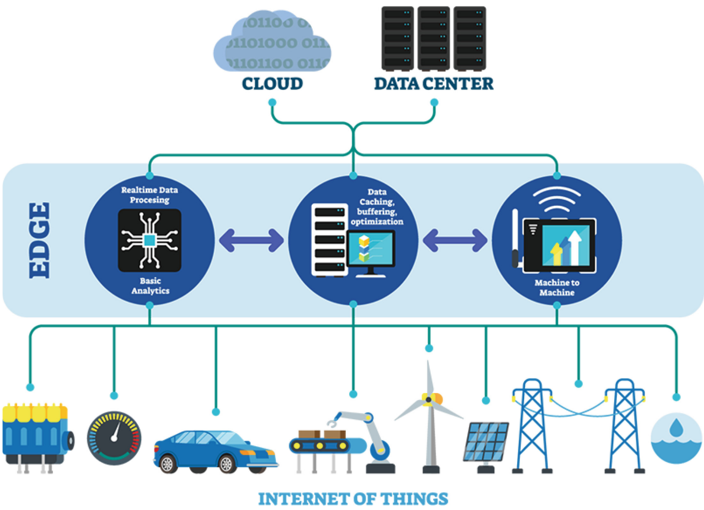

Fig. 1. IoT-Edge architecture from [9]

However, in-depth studies of this new computing model have shown that traditional non-IA techniques have limitations in improving the performance of Edge computing. With the successful application of AI in various fields, Edge computing researchers are beginning to turn their attention to AI, in particular machine learning, a branch of AI that has gained popularity over the last few decades.

3.2 Edge-IoT Protocols for Intelligent Systems

The Edge-IoT system is a heterogeneous network that includes different devices that may have different communication, data processing and storage platforms, networks and transmission power. These objects are connected by networking and communication protocols, allowing them to communicate and cooperate with each other to share information. These protocols represent the backbone of the IoT, they specify the data exchange format, data encoding, object addressing schemes as well as data packet routing [10]. Sequence control, flow control and retransmission of lost packets are also part of their functionality. In the Edge-IoT system, several protocols of different types are used. However, the best technology for our IoT use cases means that we need to accurately weigh the criteria in terms of range, bandwidth, QoS, security, power consumption, and network management.

The Tables 1 and 2 provide an overview of the most commonly used networking and messaging protocols.

Table 1. Overview of the most commonly networking protocols

Protocols	Frequency	Data rate	Range	Topology	Service
Zigbee [11]	2,4 GHz	250 kbps	10-100 m	Mesh, Star	Home automation
BLE [12]	2,4 GHz	1 Mbps	100 m	Star, Bus	Small appliances
WIFI [13]	5 GHz	1 Gb	100 m	Star, Mesh	Home
NFC [14]	13,56 MHz	420 kbps	20 cm	P2P	Payment system
LoRaWAN [15]	125 kHz	50 kbps	5-20 km	Star	Smart city
5G [16]	30-300 GHz	50 Gbps	Several kms	Star	Virtual reality applications

Table 2. Overview of the most commonly messaging protocols

Application protocols	Restful	Trans. Layer protocol	Architecture	Security	QoS
AMQP [17]	No	TCP	Pub-Sub	SSL	Yes
CoAP [18]	Yes	UDP	Pub-Sub Req-Res	DTLS	Yes
MQTT [19]	No	TCP	Pub-Sub	SSL	Yes
DDS [20]	Yes	UDP/ TCP	Pub-Sub Req-Res	DTLS, TLS, DDS Security	Yes

4 Advanced Edge-AI for Convergent Services and Applications

4.1 Edge-AI Concepts and Opportunities

Concepts: intelligent Edge refers to the combination of Edge Computing and Artificial Intelligence techniques. In simple terms, the Intelligent Edge will enable AI-based processing algorithms to be run at the heart of the devices that are part of the Edge Computing network, using a reasonable internet connection. Everything happens in the device: collection, storage and AI-based processing. This results in extremely short response times of a few milliseconds. The information arrives in real time with unparalleled accuracy, since the algorithms will have refined the raw data. Even today, the majority of heavy computing is done in the cloud and requires large computing capacities. The Intelligent Edge will move some of the computational processing flow directly into the devices, to reduce the use of the cloud significantly. With this type of device, all data can be stored before being sent to a remote site for further analysis, if required. These intelligent devices, thanks to the availability of sensor data in the field, can interact autonomously without interaction with the central site.

Opportunities. Edge AI has huge potential. Here is a non-exhaustive list of the advantages that can be derived from this technology:

- Ease of management: Edge-AI enabled devices are easy to use because the objects are completely autonomous.
- Reduced latency: The AI will not be subject to congestion problems because it is as close as possible to the objects.
- Deployment "in the field": Edge-AI lends itself by definition very well to IoT uses, but also in all mobile devices, starting with autonomous cars.
- Reduced costs: Bandwidth and data exchange costs are reduced because the amount of data transmitted is minimal.
- Security and confidentiality: Edge-AI makes it possible to filter the data to be uploaded to the cloud if necessary. Only the desired information is transmitted, after being anonymized for example. Data confidentiality and the protection of privacy are two major issues to which Edge-AI can provide a solution, since this approach completely reverses the paradigm compared with AI in the Cloud, which requires systematic transmission of all the data before it is analyzed by the AI.

The following Fig. 2 shows an example of a three-layer intelligent systems architecture assisted by IoT and Edge-IA. The layers of the architecture are identical to those of the Edge computing architecture with the exception of the edge-intelligent layer where we will find the artificial intelligence algorithms. Here, IoT devices represent the end users of the architecture.

- **The IoT layer**: this is the first layer and includes sensors, RFID devices and actuators for collecting information such as temperature, humidity, location, air quality and movement. Once the information has been collected, it is transmitted to the Edge layer via a secure wireless connection. This layer requires the use of standardized plug-and-play mechanisms for configuring heterogeneous objects. IoT mega-data is created at this layer.

- **The Intelligent-Edge layer**: this layer lies between the IoT device layer and the cloud layer. It consists of edge-intelligent devices for the collection, storage, artificial intelligence-based processing and real-time analysis of data from intelligent devices and its transmission to the cloud using wireless transmission technologies such as 5G, Sigfox, LoRa-WAN, NB-IoT [21, 22] etc. This layer also plays a role in securing data transmission. Indeed, features such as tamper detection, encryption and others can be implemented at the edge-intelligent device level, preventing malicious attacks against IoT devices and securing user data to the cloud [23].
- **The Cloud layer**: this layer comprises servers dedicated to storage and data processing. It therefore hosts the data from the edge-intelligent layer, for in-depth processing. The Cloud layer gives IoT application programmers the means to work with heterogeneous objects without having to rely on a specific hardware platform. It is also responsible for service management (Fig. 2).

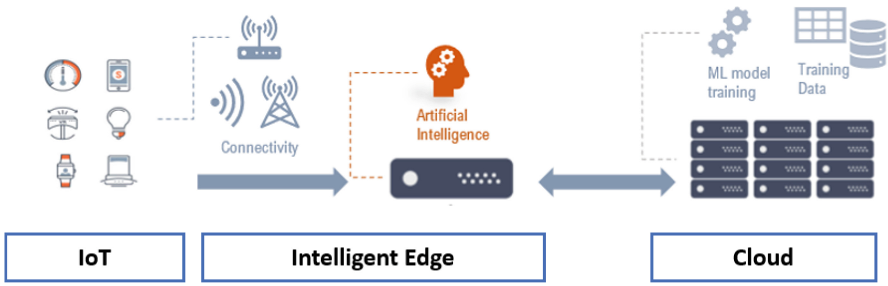

Fig. 2. Intelligent edge architecture.

4.2 Edge-AI and IoT for Connected Health

When healthcare professionals are faced with life-and-death decisions, the quality of the information available to them is critical. More accurate information and real-time access mean better decisions. Thanks to the power of the Internet of Things (IoT) and advanced AI, connected healthcare systems will be able to deliver real-time data to providers and enable more efficient care delivery.

Edge intelligence allows data to be processed and analyzed in real time without having to send it to a central server such as the cloud [4]. This can be very useful in healthcare facilities, where data needs to be analyzed quickly and securely.

One of the benefits of advanced AI in medical data is its ability to detect anomalies [24]. This can help healthcare staff to quickly identify potential health problems, take appropriate action and make more informed decisions about patient care.

The use of advanced AI can also improve the efficiency of healthcare systems. Real-time analysis of data can enable healthcare providers to reduce waiting times and improve patient outcomes [25]. Edge intelligence can also be used to automate the scheduling of appointments or the management of medical records.

As the amount of data generated by healthcare facilities increases, so does the risk of data breaches and unauthorized access. Edge AI is emerging as a potential solution to this problem, offering the potential to guarantee data confidentiality and security [26].

Edge intelligence is ideal for healthcare facilities because it enables data to be analyzed without leaving the facility's secure network. With data maintained on site, the risk of data breaches and unauthorized access can be reduced. In addition, it enables healthcare organizations to ensure that they comply with the requirements of various privacy laws, such as HIPAA (Health Insurance Portability and Accountability Act) [27]. Advanced AI can be beneficial in identifying and reporting privacy breaches [28]. This allows healthcare facilities to take steps or actions before a breach occurs.

The potential for advanced intelligence to improve data security in the healthcare sector is clear. As the healthcare sector continues to evolve, advanced AI can become an indispensable tool for protecting patient data.

4.3 Edge-AI and IoT for Intelligent Agriculture

Edge-AI and IoT-based smart farming refers to the use of advanced AI and the Internet of Things (IoT) to improve efficiency and productivity in the agricultural industry.

Today, the use of AI techniques is playing an important role in the development of precision agriculture [29]. Predictive crop models can be designed. They take into account different production factors such as: climate; soil condition; seed condition; water supply; disease risk, etc. By taking all these factors into account when designing the model, it is easier to adjust any of the elements to optimize yield.

In irrigation management [30], for example, IoT can be used to monitor and control crop irrigation in real time. Sensors could be placed in fields to measure soil moisture, temperature and other key factors, helping to determine the optimum time for irrigation and avoid wasting water. Advanced computing combined with artificial intelligence will enable the data collected by the sensors to be processed and analyzed locally in real time. Personalized irrigation strategies can then be recommended for each plot based on soil and crop characteristics. This enables efficient and sustainable farming practices to be put in place.

Another benefit of advanced AI in agriculture is its ability to improve animal welfare [31]. Using wearable sensors, farmers will be able to monitor the health and well-being of their livestock in real time. Edge-IA devices will analyze the data from these sensors to detect early signs of disease. This will allow farmers to intervene before problems arise or worsen. This will improve animal welfare, reduce the use of antibiotics and increase productivity.

The ability to optimize crop yields and reduce waste is another key benefit of using advanced AI in agriculture [29]. Indeed, the analysis of data from soil sensors, weather stations and satellite images by Edge-IA devices will be able to provide farmers with real-time information about the health and needs of their crops. This information can then be used to make informed decisions about irrigation, fertilization and pest control, so that crops receive the precise amount of resources they need to thrive. This can lead to increased crop yields, reduced resource consumption and minimized environmental impact.

Overall, Edge-IA and IoT will revolutionize the agricultural sector. By enabling real-time agricultural data processing and decision-making at the source of collection, Edge-IA and IoT will help optimize crop yields, improve livestock management and promote sustainable farming practices. With a growing global population to feed, Edge-IA and IoT will be key to meeting agricultural challenges and ensuring a sustainable future for all.

5 Challenges and Future Direction

Edge computing is made up of peer-to-peer systems, wireless networks, etc. and the adoption of a complete system is required to manage the system as a whole. The security and confidentiality of a distributed system is a real challenge.

During data processing at the edge, user data can be processed, putting their sensitive information at risk. Authentication of gateway nodes is one of the security issues in edge computing. Each edge node is managed differently. It is therefore difficult to implement a common security method everywhere.

Another challenge is the security of data sharing and transmission processes. Multiple devices need to work together to perform many tasks, and data needs to be shared securely. Data storage is provided by various third-party suppliers, and their storage devices spread over several sites also increase the risk of attack, for two reasons. Firstly, the data is separated into several slices and stored in different places. It is therefore easy to store incorrect data or to lose it. This makes it difficult to guarantee data integrity. Secondly, data downloaded to storage can be modified by malicious users, leading to confidentiality problems and data leaks.

It would be preferable to use local pre-processing, which could mask private information and reduce the amount of data transmitted.

In some cases, encryption could be used to protect privacy. However, before learning or inference tasks can be performed, the encrypted data must be decrypted. This requires an increase in the amount of essential computation. To meet this challenge, the authors [32] propose the use of homomorphic encryption, which allows the training or inference task to be performed directly on encrypted data.

Looking forward, the future of Edge AI and IoT appears incredibly promising. The rapid advancements in hardware, such as powerful yet energy-efficient microprocessors, are driving the development of more complex AI models that can be deployed at the edge. Additionally, the proliferation of 5G networks will significantly enhance the capabilities of Edge AI and IoT, enabling seamless connectivity and faster data transmission.

Moving on the future, it is crucial to address the challenges associated with these technologies, such as security vulnerabilities, data privacy concerns, and ethical considerations. Collaboration between academia, industry, and policymakers will be vital in creating robust frameworks and standards that ensure the responsible development and deployment of Edge AI and IoT solutions.

6 Conclusion

In the ever-evolving landscape of technology, the fusion of Edge AI and Internet of Things (IoT) has emerged as a transformative force, revolutionizing the way intelligent systems are designed, deployed, and experienced. Throughout this research paper, we have delved into the intricate realms of these cutting-edge technologies, exploring their architectures, applications, and future perspectives.

In conclusion, the synergy between Edge AI and IoT is reshaping the landscape of intelligent systems, bringing us closer to a future where machines are not just smart but also contextually aware and responsive. Embracing the full potential of these technologies demands continuous research, innovation, and collaboration.

The fusion of Edge AI and IoT has given rise to sophisticated architectures that bridge the gap between the physical and digital worlds. Edge computing, with its decentralized approach, enables real-time data processing and analysis at the edge devices, reducing latency and enhancing efficiency. Incorporating Edge AI technologies into agriculture holds the promise of transforming the industry into a more sustainable, efficient, and resilient sector.

References

1. Rahmani, A.M., Bayramov, S., Kiani Kalejahi, B.: Internet of things applications: opportunities and threats. Wireless Pers. Commun. **122**(1), 451–476 (2022)
2. Pérez, J., Díaz, J., Berrocal, J., López-Viana, R., González-Prieto, Á.: Edge computing: A grounded theory study. Computing **104**(12), 2711–2747 (2022)
3. Sheikh, H., Prins, C., Schrijvers, E.: Artificial Intelligence: Definition and Background. In: Sheikh, H., Prins, C., Schrijvers, E. (eds.) Mission AI: The New System Technology, pp. 15–41. Springer, Cham (2023). https://doi.org/10.1007/978-3-031-21448-6_2
4. Singh, R., Gill, S.S.: Edge AI: a survey. Internet of Things Cyber-Phys. Syst. **3**, 71–92 (2023)
5. Yu, W., et al.: A survey on the edge computing for the Internet of Things. IEEE Access **6**, 6900–6919 (2017)
6. Kang, K.D.: A Review of Efficient Real-Time Decision Making in the Internet of Things. Technologies **10**(1), 12 (2022)
7. Hamdan, S., Ayyash, M., Almajali, S.: Edge-computing architectures for Internet of Things applications: a survey. Sensors **20**(22), 6441 (2020)
8. Lina, L., Ruisheng, S., Bai, W., Lei, Z., Ning, J.: A Universal Complex Event Processing Mechanism Based on Edge Computing for Internet of Things Real-Time Monitoring. IEEE Access **7**, 101865–101878 (2019)
9. IEEE Innovation at work: https://innovationatwork.ieee.org/real-life-edge-computing-use-cases/, last accessed 2023/10/13
10. Filali, A., Abouaomar, A., Cherkaoui, S., Kobbane, A., Guizani, M.: Multi-access-edge computing: a survey. IEEE Access **8**, 197017–197046 (2020)
11. Haque, K.F., Ahmed, A., Kumar, Y.: Comprehensive Performance Analysis of Zigbee Communication: An Experimental Approach with XBee S2C Module. Sensors **22**(9), 3245 (2022)
12. Chendong, L., Yilin, Z., Huanyu, Z.: A Comprehensive Study of Bluetooth Low Energy. J. Phys: Conf. Ser. **2093**(1), 012021 (2021)
13. Pahlavan, K., Krishnamurthy, P.: Evolution and Impact of Wi-Fi Technology and Applications: A Historical Perspective. Int. J. Wireless Inf. Networks **28**, 3–19 (2021)

14. Olenik, S., Lee, H.S., Güder, F.: The future of near-field communication-based wireless sensing. Nat. Rev. Mater. **6**, 286–288 (2021)
15. Hossain, M.I., Markendahl, J.I.: Comparison of LPWAN Technologies: Cost Structure and Scalability. Wireless Pers. Commun. **121**, 887–903 (2021)
16. Dangi, R., Lalwani, P., Choudhary, G., You, I., Pau, G.: Study and Investigation on 5G Technology: A Systematic Review. Sensors **22**(1), 26 (2022)
17. Akasiadis, C., Pitsilis, V., Spyropoulos, C.D.: A Multi-Protocol IoT Platform Based on Open-Source Frameworks. Sensors **19**(19), 4217 (2019)
18. Tariq, M.A., Khan, M., Raza Khan, M.T., Kim, D.: Enhancements and Challenges in CoAP—A Survey. Sensors **20**(21), 6391 (2020)
19. Biswajeeban, M., Attila, K.: The Use of MQTT in M2M and IoT Systems: A Survey. IEEE Access **8**, 201071–201086 (2020)
20. Ioana, A., Korodi, A.: DDS and OPC UA Protocol Coexistence Solution in Real-Time and Industry 4.0 Context Using Non-Ideal Infrastructure. Sensors **21**(22), 7760 (2021)
21. Li, F., Wang, C.: Artificial intelligence and edge computing for teaching quality evaluation based on 5G-enabled wireless communication technology. J. Cloud Comput. **12**(1), 45 (2023)
22. Merenda, M., Porcaro, C., Iero, D.: Edge Machine Learning for AI-Enabled IoT Devices: A Review. Sensors **20**(9), 2533 (2020)
23. Xu, Z., Liu, W., Huang, J., Yang, C., Lu, J., Tan, H.: Artificial intelligence for securing IoT services in edge computing: a survey. Security and communication networks **2020**, 1–13 (2020)
24. Adam, B., Kaveh, M.: The rise of artificial intelligence in healthcare applications. In: Adam, B., Kaveh, M. (eds.) Artificial Intelligence in Healthcare, pp 25–60. Academic Press, Cambridge (2020)
25. Bajwa, J., Munir, U., Nori, A., Williams, B.: Artificial intelligence in healthcare: transforming the practice of medicine. Future healthcare journal **8**(2), 188–194 (2021)
26. Kamruzzaman, M.M., Alrashdi, I., Alqazzaz, A.: New opportunities, challenges, and applications of Edge-AI for connected healthcare in Internet of Medical Things for smart cities. J. Healthcare Eng. **2022**(1), 2950699 (2022)
27. Motti, V.G., Berkovsky, S.: Healthcare Privacy. In: Knijnenburg, B.P., Page, X., Wisniewski, P., Lipford, H.R., Proferes, N., Romano, J. (eds.) Modern Socio-Technical Perspectives on Privacy, pp 203–231. Springer, Cham (2022)
28. Wang, C., Zhang, J., Lassi, N., Zhang, X.: Privacy protection in using artificial intelligence for healthcare: Chinese regulation in comparative perspective. In: Healthcare, vol. 10, no. 10, p. 1878. MDPI (2022)
29. Monteiro, A., Santos, S., Gonçalves, P.: Precision agriculture for crop and livestock farming—brief review. Animals **11**(8), 2345 (2021)
30. Debauche, O., Mahmoudi, S., Elmoulat, M., Mahmoudi, S.A., Manneback, P., Le-beau, F.: Edge AI-IoT pivot irrigation, plant diseases, and pests identification. Procedia Computer Science **177**, 40–48 (2020)
31. Neethirajan, S.: The role of sensors, big data and machine learning in modern animal farming. Sensing and Bio-Sensing Research **29**, 100367 (2020)
32. Sun, L., Jiang, X., Ren, H., Guo, Y.: Edge-cloud computing and artificial intelligence in internet of medical things: architecture, technology and application. IEEE Access **8**, 101079–101092 (2020)