AI-Driven Edge Computing for Risk Prediction in IIoT Environments

N. Bhalaji

Professor, Department of Computer Science & Engineering, Rajalakshmi Institute of Technology, Chennai, India

E-mail: drnbhalaji@gmail.com

Abstract

This research presents an industrial risk prediction model for multimodal data based on edge computing, aiming at real-time and efficient industrial site risk prediction. Most AI-driven applications require high-end servers to perform complicated AI tasks, resulting in significant energy consumption in IIoT contexts. This study will discuss intelligent edge computing, an emerging technology that may cut energy usage while processing AI tasks, and how to construct green AI technology for IIoT applications. The study also analyses AI technology, and existing technologies to determine the optimal way for generating risk prediction in the IIOT environment.

Keywords: Industrial Risk Prediction, High-End Servers, IoT, IIoT, Edge Computing, AI Technology.

1. Introduction

The deployment of 5G networks will transform edge computing and IoT by providing significantly faster transmission of data rates, lower latency, and increased device density. This allows real-time applications and contributes to the spread of linked devices. Edge artificial intelligence (AI) and machine learning (ML) integration are gaining popularity as edge devices become more sophisticated, enabling AI decision-making on-device. These technologies also provide real-time analytics, quicker insights, and less reliance on cloud computing.

DOI: https://doi.org/10.36548/jismac.2024.3.008
Received: 02.09.2024, received in revised form: 24.09.2024, accepted: 06.10.2024, published: 18.10.2024

Edge computing is a critical technology for realizing the full potential of emerging industrial wireless communication since it allows for the deployment of computational workloads to computer nodes near end devices, opening up new business prospects based on real-time cloud services. This chapter explains the current state-of-the-art methods, that address several issues that edge computing systems face, notably in the Industrial IoT (IIoT) area, and provide potential solutions to the observed challenges.

1.1 IIOT- Industrial Internet of Things

IIOT is a network of sensors, instruments, and self-contained devices that link to industrial applications over the Internet. This network enables data collection, analysis, and production optimization, boosting efficiency and lowering manufacturing and service costs. Industrial applications are comprehensive technical ecosystems that connect gadgets to the people who run assembly lines, logistics, and large-scale distribution [1].

IIoT is an important component of Industry 4.0, the latest phase of the industrial revolution, which is defined by the convergence of digital, physical, as well as biological technology. It is transforming conventional industries by enabling the transition from manual, labour-intensive procedures to controlled automatically data-driven operations. IIoT is more than simply technology; it is about using data to create business outcomes for manufacturers. IIoT allows you to monitor equipment performance, forecast problems, optimise logistics, and increase product quality, among other things. It is about developing a better, more efficient, and lucrative industrial operation. Figure 1 depicts the Industrial Internet of Things.

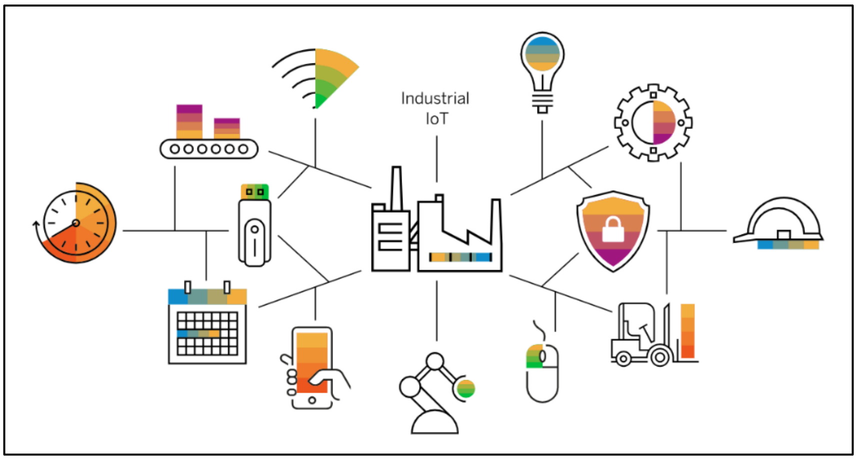

Figure 1. Industrial Internet of Things [2]

2. IIOT VS IOT

- **IOT**

The Internet of Things is made up of web-enabled devices which collect, send, and act on data gathered from their surroundings through embedded sensors, microprocessors, and so on. Essentially, the objective is to link all of our everyday gadgets without requiring user-computer interaction. This procedure is known as machine-to-machine communication.

- **IIOT**

IIoT is a subclass of IoT that especially addresses industrial applications. It focuses on improving industrial operations and procedures using data-driven insights. IIoT systems are more complicated, with tight security requirements and vital operating controls. It focuses on enhancing productivity, effectiveness, and safety in areas such as manufacturing, power, and transportation.

- **IOT VS IIOT**

While IoT and IIoT (Figure 2) are both powered by comparable technology, such as sensors, internet access, and data analytics, the primary distinction is in their application as well as impact. The Internet of Things improves our daily lives by making our homes, communities, and electronics smarter. In contrast, IIoT changes industries by changing the way firms function and complete.

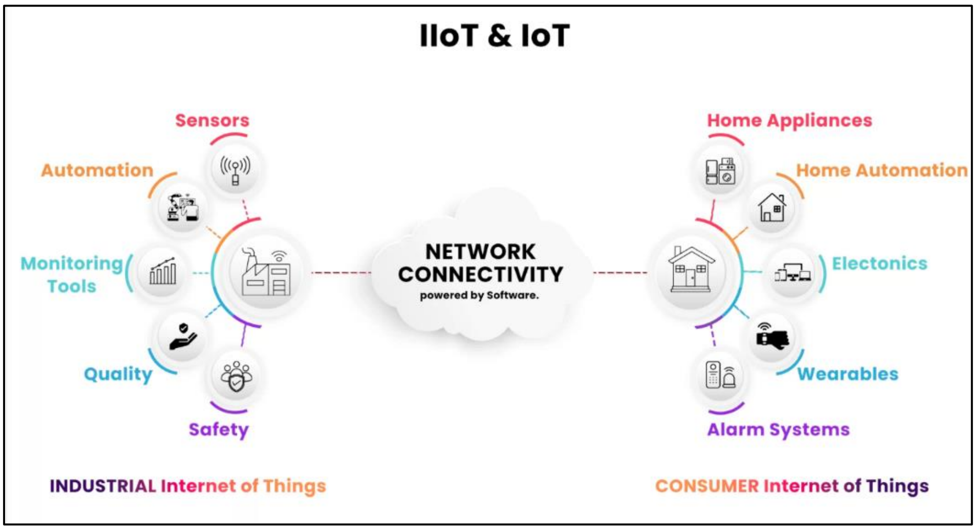

Figure 2. IIOT vs IOT [3]

3. Edge Computing in IIoT

The Internet of Things (IoT) edge is in which sensors and gadgets provide real-time data to the network. IoT edge computing resolves latency concerns associated with the cloud by processing data closer to its place of origin. In addition to reduced latency, IoT edge architecture improves safety and provides a more seamless end-user experience. Edge computing processes data near its source rather than transferring it great distances to a remote server. This addresses a number of critical issues, many of which are related to the delay caused by data travelling large distances.

3.1 Significance of Edge Computing in IIoT

Bandwidth Efficiency: Edge computing decreases the amount of data that has to be transferred to the cloud, reducing bandwidth and cost.

Reliability: Edge computing enables ongoing operation even in the presence of intermittent or inconsistent cloud connection, which is crucial in industrial environments where downtime is costly.

Data Privacy and Security: Processing sensitive industrial data locally at the edge improves data privacy by lowering the chance of exposure during transmission.

Scalability: In industrial environments where uptime can be expensive, edge computing is essential because it enables uninterrupted operation even in the event of interrupted or unreliable cloud access.

4. AI in Risk Prediction

AI is revolutionizing risk prediction in several fields by combining real-time monitoring, machine learning, and powerful data analytics to forecast possible dangers and efficiently reduce them. Massive datasets from a variety of sources, including sensors, transactions, social media, as well as historical records, may be analysed by AI to find trends and correlations that could point to possible threats.

AI creates predictive models using machine learning (ML) approaches that can identify future dangers based on previous data. These models are taught to identify the conditions that result in particular events, such as losses, equipment failures, or security issues. AI-powered systems have the ability to continually monitor transactions, operations, and environmental factors in order to spot abnormalities that might indicate new dangers. AI, for example, may recognize anomalous network behavior in cybersecurity that may point to a security risk.

AI models have the capacity to continually learn from new information, enhancing their efficacy and accuracy over time. This is particularly essential in dynamic contexts like the financial markets or cybersecurity, where threats change quickly. Artificial intelligence (AI) systems are more trustworthy in risk assessments because they may improve their forecasts by incorporating input from real-world results.

4.1Benefits of AI-Driven in Edge Computing

A key development in the explosion of the Industrial Internet of Things (IIoT) is edge computing driven by AI. The "end-to-end" computing paradigm of the IIoT and the inflexible design of industrial control systems, however, limit adaptability, security, and real-time performance, and these constraints are mostly disregarded by current solutions.

Critical activities including data production, analysis, decision-making, and appropriate action are made possible by edge computing in real-time. For crucial operations like these, real-time response is imperative since even milliseconds may make a big difference.

5. Related Study

Table 1 shows the brief summary of the literature studied

Table 1. Summary of Existing Literature

Article Title	Inferences
Edge Computing in Industrial Internet of Things: Architecture, Advances and Challenges[5]	This article describes the state of edge computing research in the Industrial Internet of Things (IIoT), such as edge computing and IIoT principles, technological advancements across different domains, and edge computing's advantages and disadvantages in IIoT.

Edge Computing for Industrial IoT: Challenges and Solutions[6]	In the Industrial IoT, edge computing makes it possible to deploy computational jobs close to end devices while overcoming issues like connection latency.
Edge Computing in Industrial IoT Framework for Cloud-based Manufacturing Control[7]	The general architecture for an Industrial Internet of Things framework that combines edge and cloud computing for real-time data processing and production control is presented in this study.

In collecting and processing of IIoT data, edge computing is preferred over centralized cloud-based methods. In order to provide low latency, and high bandwidth, along with location-based awareness, storage and network resources are being distributed to the network's edge, closer to Internet of Things devices. Creating a reference architecture for the IIoT that allows AI and data analytics methods at the network edge, such as distributed and decentralized hybrid twins. Instead of depending only on an offline strategy at the cloud infrastructure, edge devices can be enabled to develop local machine learning models and transmit them to the cloud to enhance the global model [9].

To adjust the operating duration of sensing and transmission operations in Internet of Things-based portable devices, a "forward central dynamic and available approach (FCDAA)" is used. A battery model at the system level is used to assess the energy loss in Internet of Things devices. A hybrid transmission power control (TPC) and duty-cycle network data reliability model is used for edge AI-based Internet of Things devices. We looked at two industrial use cases: dynamic (fault diagnostics and vibration) and static (product processing) [10].

An AI-enhanced offloading system is presented to improve service accuracy in IIoT scenarios utilizing cooperative edge as well as cloud computing. Introducing an intelligent computing framework combining collaborative edge as well as cloud computing for IIoT. An AI-enhanced offloading infrastructure prioritizes service accuracy and intelligently distributes traffic to the edge servers or the cloud. Conducting a case study on transfer learning to assess the suggested framework.

In IIoT contexts, edge computing and deep learning are utilized to analyze operational conditions and anticipate the remaining usable life of industrial equipment. Preprocessing sensor data remotely with edge devices and servers: Transferring pre-processed data to cloud storage. Applying deep learning technologies to assess airplane engine condition. Classify the stages of operational decline. Predict the remaining usable life of components. Sending the projected findings to a cloud-based server to be monitored and maintained.

An AI-powered edge processing provides a solution for real-time industrial equipment maintenance as well as failure prediction in IIoT contexts. Condition monitoring is done utilizing IIoT devices with numerous sensors, such as temperature, vibration, sound/noise, current/voltage. Wireless data gathering is done through different protocols (BLE, LoRaWAN, Wi-Fi) as well as aggregation is performed through edge computing units. Use of machine learning (ML) as well as deep learning (DL) algorithms are utilized for defect identification, diagnosis, and predictive maintenance.

5.1 Application of AI driven Edge computing in IIOT

- **Smart Robots:ABB**

Smart Robot , a power and robotics company, is one of the most conspicuous adopters of predictive maintenance, employing linked sensors to monitor the maintenance needs of its robots across five continents and trigger repairs before parts fail. The company's collaborative robotics are also tied to the Internet of Things. Its YuMi model, which was meant to work with people, accepts input through Ethernet and industrial protocols such as Profibus and DeviceNet.

- **AssetTracking**

Using GPS technology, sensors fitted in trucks and shipping crates enable organisations to follow assets, whether they are on a job site or travelling across nation. While radio frequency identification tags are a suitable option in specific use scenarios, cellular IoT sensors stand out by transmitting ongoing updates, allowing managers to track the movement of assets throughout their trip.

- **Boeing: Using IoT for Manufacturing Efficiency**

Aviation pioneer William Boeing once said that it "behoves no one to dismiss any new concept with the statement, 'It can't be done.'" The worldwide aviation firm formed in Boeing's name appears to still adhere to its idea. It is currently working towards the long-term aim of prioritising its service offerings above its goods while remaining the most useful information supplier in aviation. The corporation has already made tremendous progress in restructuring its business. Boeing and its Tapestry Solutions company have actively used IoT technology to improve productivity in manufacturing and supply lines.

- **Caterpillar:** Caterpillar, the heavy equipment manufacturer, has long been a pioneer in IoT initiatives. Recently, the corporation, now known as "Cat," has shown off the results of its investments in IoT technology. Consider how it uses IoT and augmented reality (AR) technologies to provide machine operators with a quick overview of anything from fuel levels to when air filters need to be replaced. If an outdated filter has to be replaced, the firm may offer basic instructions through an AR (Augmented Reality) app.[14]

6. Conclusion

Edge AI is transforming the face of the IoT device in the industry by providing devices with real-time data processing, analytics, and decision-making capabilities right at the network edge. Edge AI will enable IoT devices to conduct complicated tasks autonomously, increasing efficiency and security; also, new applications and services will develop across several industries. Edge AI's progress towards interaction with IoT devices will result in new ways of using the technology, that transform the way businesses work, and usher in a more intelligent and linked society.

References

[1] Boyes, Hugh, Bil Hallaq, Joe Cunningham, and Tim Watson. "The industrial internet of things (IIoT): An analysis framework." Computers in industry 101 (2018): 1-12.

[2] https://www.sap.com/india/products/scm/industry-4-0/what-is-iiot.html

[3] https://polimak.com/en/the-differences-between-iot-and-iiot-iot-vs-iiot/

[4] https://iebmedia.com/technology/edge-computing-and-ai-create-industrial-aiot-applications/

[5] Qiu, Tie, Jiancheng Chi, Xiaobo Zhou, Zhaolong Ning, Mohammed Atiquzzaman, and Dapeng Oliver Wu. "Edge computing in industrial internet of things: Architecture, advances and challenges." IEEE Communications Surveys & Tutorials 22, no. 4 (2020): 2462-2488.

[6] Harjula, Erkki, Alexander Artemenko, and Stefan Forsström. "Edge computing for industrial IoT: challenges and solutions." Wireless Networks and industrial IoT: applications, challenges and enablers (2021): 225-240.

[7] Raileanu, Silviu, Theodor Borangiu, Octavian Morariu, and Iulia Iacob. "Edge computing in industrial IoT framework for cloud-based manufacturing control." In 2018 22nd International Conference on System Theory, Control and Computing (ICSTCC), pp. 261-266. IEEE, 2018.

[8] Garg, Navin, and Amit Gupta. "Edge Computing–"An Enabling Technology for Industrial IoT (IIoT) Devices"–Exploring Its Challenges and Security Issues."

[9] Bellavista, Paolo, Roberto Della Penna, Luca Foschini, and Domenico Scotece. "Machine learning for predictive diagnostics at the edge: An IIoT practical example." In ICC 2020-2020 IEEE International Conference On Communications (ICC), pp. 1-7. IEEE, 2020.

[10] Sodhro, Ali Hassan, Sandeep Pirbhulal, and Victor Hugo C. De Albuquerque. "Artificial intelligence-driven mechanism for edge computing-based industrial applications." IEEE Transactions on Industrial Informatics 15, no. 7 (2019): 4235-4243.

[11] Sun, Wen, Jiajia Liu, and Yanlin Yue. "AI-enhanced offloading in edge computing: When machine learning meets industrial IoT." IEEE Network 33, no. 5 (2019): 68-74.

[12] Hsu, Hsin-Yao, Gautam Srivastava, Hsin-Te Wu, and Mu-Yen Chen. "Remaining useful life prediction based on state assessment using edge computing on deep learning." Computer Communications 160 (2020): 91-100.

[13] Vermesan, Ovidiu, Marcello Coppola, Roy Bahr, Ronnie Otto Bellmann, Jøran Edell Martinsen, Anders Kristoffersen, Torgeir Hjertaker et al. "An Intelligent Real-Time Edge Processing Maintenance System for Industrial Manufacturing, Control, and Diagnostic." Frontiers in Chemical Engineering 4 (2022): 900096.

[14] https://www.iotworldtoday.com/iiot/the-top-20-industrial-iot-applications#close-modal.