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A Survey of Edge Computing Approaches in Smart Factory

Jamilu Ibrahim Argungu[1], Mustapha Malami Idina[2], Umar Aliyu Chalawa[3], Musa Ummar[4], Sadiq Buhari Bello[5], Ibrahim Arzika[6] , Baba Ahmad Mala[7]

Adamu Augie College of Education, Argungu, Huazhong University of Science and Technology, Wuhan China[1]

Department of Computer Science, Kebbi State University of Science and Technology, Aliero, Kebbi State Nigeria[2]

Department of Mechatronics Engineering, University of Debrecen, Hungary[3]

Department of Mechatronics Engineering, University of Debrecen, Hungary,

Department of Computer Science, Federal Polytechnic Daura, Katsina State, Nigeria[4]

Department of Computer Engineering, Waziri Umaru Federal Polytechnic Birnin Kebbi[5]

Department of Finance, Minsitry for Local Government and Chieftaincy Affairs, Kebbi State, Nigeria[6]

Department of Information and Communication Engineering, Huazhong university of science and technology[7]

Abstract: The emergence of Smart Factories plays a pivotal role in the Manufacturing process, necessitating prompt and dependable communication. Edge computing, a novel cloud concept, offers proximity to networks' edges, delivering low-latency, energy-efficient IoT device communication in smart factories. This survey delves into the application of edge computing and the challenges it poses in the realm of smart factories. Its ultimate aim is to uncover gaps in existing research and propose future directions. A systematic review of literature was conducted, with a particular focus on the past five years. The goal was to identify key use cases and advantages of edge computing in Smart factories. The topics covered included a comparison of edge computing and cloud computing in Smart factories, enhancements in IoT performance, and the reduction of latency in Smart factories.

The study also analyzed various aspects of quality of service, such as latency, reliability, resource optimization, and processing costs. The findings of this research shed light on the benefits of edge computing in smart factories, including reduced latency, improved security, and enhanced energy efficiency. However, the study also identified challenges such as gaps in standardization and the complexity of architectural design. By examining case studies from different industries, the research provided a diverse range of perspectives. Furthermore, the study addressed the limitations of edge computing and proposed potential solutions, thus contributing to the existing body of knowledge and facilitating future research in this field. This study offers valuable insights into the role and challenges of edge computing in Smart factories. By thoroughly analyzing its advantages and disadvantages, the research provides guidance for its implementation and highlights opportunities for future opportunities . Researchers and practitioners with an interest in edge computing for Smart factories will find this study to be a valuable resource.

Keywords: IoT, Edge Computing, Cloud Computing, Fog Computing, Smart Factory, Industry 4.0, Smart Manufacturing

I. INTRODUCTION

A. Background

The Internet of Things (IoT) is a ground-breaking idea that links distinct physical and digital objects via a variety of communication protocols.It is expected that the number of IoT devices connected wirelessly will reach 50 billion by the year 2025.[1]. These gadgets span from cellphones to bio-nano objects, body sensors, smart tags, wearable technology, embedded objects, and standard electrical equipment.[2]. They often have multiple sensors that collect environmental data, which is a crucial component of data-driven intelligence.[3] However, deploying a massive number of these devices leads to an exponential increase in collected data. As a result, the collected data must be processed and analyzed to provide useful results for users.

By wirelessly tying up machines and sensors, future smart factories will conduct production processes as a collective.[4]. The jobs must be offloaded to servers for processing because the built-in computer capabilities are insufficient to meet

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the rigorous latency requirements. A substantial amount of locally generated data is typically uploaded to cloud computing server.[5].
Data transmission rates and network bandwidth, however, may pose challenges as the massive IoT grows. Furthermore, due to security and privacy considerations, it is not appropriate to send all IoT data to distant cloud servers because the bulk of IoT devices produce sensitive and private data.[6]

Edge computing is a cutting-edge paradigm for computing that moves computational data, applications, and services closer to the network edge and away from cloud servers.The ability to deliver people services that are physically closer to them thanks to edge computing can reduce the time it takes for services to respond to requests. Extremely low latency, enormous bandwidth, and real-time network information access are characteristics of edge computing. Because large IoT applications usually require real-time reaction, privacy protection, and massive data transmission, edge computing may be able to meet their requirements.

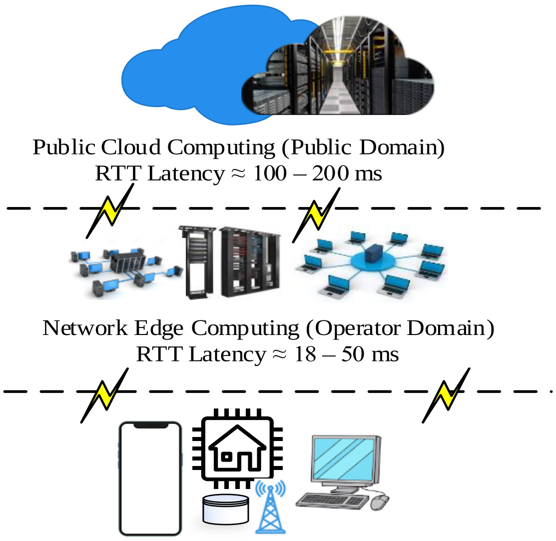

Figure 1-1 displays the round trip times (RTT) pertaining to the public cloud, edge cloud, and local cloud, which provide support for the management of indoor autonomous systems within a 4G company campus.[3]

Numerous studies have shown that current developments in edge computing and IoT have significantly worked to meet these objectives. When edge computing and IoT are combined, there are a number of additional issues that need to be resolved, such as effectively merging these two technologies and closing the gap between them. In conclusion, edge computing is a critical technology for the IoT of the future, and research into the intersection of edge computing and IoT has academic potential.[7]

The goal of the "smart factory" is to create an intelligent collaborative system in which various machines and sensing devices that have been physically connected at the production site are objectified and connected via the communication network to share the production process freely and control it on their own.[4]

The use of the internet has significantly changed how people work, live, interact, learn, and have fun. A new industrial revolution known as "Industry 4.0" is emerging as a result of the internet's rising use. The implementation of automation and data transfer in manufacturing technology is known as Industry 4.0. It includes a number of technology ideas, such as edge computing and the Internet of Things (IoT)[8]. The Internet of Things (IoT) technology is based on a massive network of "things" machines, objects, or people that collaborate to accomplish a single goal. Large volumes of data are continuously generated by these "things," which presents difficult problems for comprehending, analysing, protecting, and storing the data and restricts their development.[9]

Industry 4.0, or the Fourth Industrial Transformation, is a technological revolution that involves edge computing in smart factories and smart manufacturing.[10]The first three industrial revolutions were sparked by three ingenious new technologies: the steam engine, the assembly line, and the power of the computer, each of which drastically changed how

humans worked and produced goods. Smart automation and digital transformation are currently driving the fourth revolution.[11], [12]
This study focuses on edge AI for industry 4.0, which gathers and aggregates data from an IIoT network at the edge. We focus more specifically on an edge fog node that can collect and aggregate information from the IIoT network, as in[4] which next are used to deploy different edge computing and edge AI solutions.[13]

Since it is designed for a manufacturing environment that demands real-time data processing and quick responses, edge computing has been regarded by many studies to be the best platform technology for creating a smart factory.The demand for resource management and end-to-end service delivery has expanded due to the exponential growth of smart factories and current cloud services. This paper describes the cutting edge of cloud computing and in-depth examines current research on smart factories using the Internet of Things (IoT). [14]Finally, we evaluate the availability and integrity of edge computing as well as the more adaptable service provided by IoT apps, which subsequently meld into the landscape of cloud computing architecture. [15]

B. Motivation

Due to the rapid growth of smart factories and the expansion of edge computing, there are now more applications being used in a variety of industries, including security, safety, cost-saving, asset tracking, agriculture, smart cities, and smart homes. Edge computing has altered the context in which we utilize smart gadgets in our daily lives. An IoT device could employ numerous sensors to gather data, and since each sensor takes a lot of computing, the operation consumes a lot of energy and money. The cloud can be used to move data and process it there. IoT devices often need quick processing and resources available.

C. Weaknesses

Edge & Fog technology has emerged as a solution to problems such location awareness, centralized data storage and processing, slow reaction times, network congestion, and communication expenses, despite the fact that cloud computing improves the prosperity and efficiency of our lives. High bandwidth and computing power are needed for many real-time applications (including factories).[16]

The cloud receives and stores the data produced by IoT devices for future processing. The outcome of the data processing is acknowledged in accordance with user expectations. Due to the concentration of resources, the network becomes congested as the number of requests to the cloud gradually rises. These factors make the cloud network a poor choice for time-sensitive applications. The researchers suggest an unique paradigm termed edge computing to overcome the aforementioned problems[17].

The cloud-based manufacturing system frees producers and consumers from a lot of details while allowing for increased utilisation without raising costs or performance degradation. But there are still a lot of issues that prevent the growth of smart manufacturing.

i. Overloaded bandwidth: The amount of data produced by various manufacturing resources, which may be geographically dispersed, is rapidly increasing. The cloud, where data processing is done, receives these data across the network.
ii. Unavailability: Despite the fact that users can access cloud-stored data at any time and from any location, doing so strongly depends on the servers' and internet connections' readiness. The power of the cloud is useless if data cannot be accessed because of a network outage.
iii. Latency: Time synchronisation is necessary in several real-time and concurrent scenarios, which causes latency problems. Data transfer between terminals and the cloud may experience unacceptably high round-trip Internet latency.
iv. Data validity: Resources are wasted by sending a lot of unnecessary data to the cloud, such as redundant data, noisy data, transitory data, etc.
v. Security and privacy: Due to the continuous development of new attack vectors, such as those that come via communication channels or DoS attacks, etc., there are several security difficulties.
vi. Inefficient connectivity and interaction: The flexibility and efficacy of connectivity and interactive messaging are constrained by cloud-based communication between manufacturers, users, and machines that may be located nearby.[7], [18], [19]

II.PRELIMINARY KNOWLEDGE (REVIEW OF RELATED LITERATURE)

A. Distributed Control Architecture

It is challenging for traditional factory control systems, which are built on centralised and hierarchical control structures, to adjust to disruptive shop-floor events like order changes or malfunctioning field-level devices. This is mostly caused

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by the concentration of the decision-making process at the summit of the automation pyramid paradigm. As a result, centralised control structures frequently result in scenarios where a single failure at a single node in the system hierarchy causes the entire system to shut down. This limitation emphasises the necessity for a move toward distributed systems that can cooperate using predetermined protocols for communication. In other words, traditional command and control hierarchies become ineffective and unnecessary at a certain point in an organization's growth. As a result, non-centralized coordination and control, which is the hallmark of the Industry 4.0 paradigm, must be used to manage industrial systems.[20]

B. Overview of Edge Computing

i.Edge Computing

Edge computing, often referred to as fog computing, is a new distributed computing architecture that makes it possible to conduct complicated computational processes on nearby edge devices or nodes as opposed to offloading their heavy workloads and data loads to a distant cloud data centre.[21] Any device located in the furthest reaches of the Internet that has computation, storage, and network connectivity can act as an edge device or node in this scenario.

Applications based on edge computing allow the edge nodes/devices to respond locally and drastically lower system latency without incurring expensive connection fees.[22] Edge computing is the practise of performing computations at a device's network's edge. This suggests that a computer is connected to the network of the device and analysing the data before sending it immediately to the cloud.

Example of Edge computing:

- Autonomous vehicle edge computing devices, such as self-parking cars, collect data from the vehicle's cameras and sensors, analyse it, and render decisions in milliseconds.

- To accurately assess a patient's condition and foresee treatments, data from a variety of edge devices connected to sensors and monitors is analysed.

Edge computing is a distributed computing model that aims to provide computational services with the lowest latency possible by deploying edge devices closest to users.[23] This method differs from typical cloud computing, which relies entirely on cloud servers to provide computing services. A three-tier distributed framework for edge computing includes the front-end, near-end, and far-end.

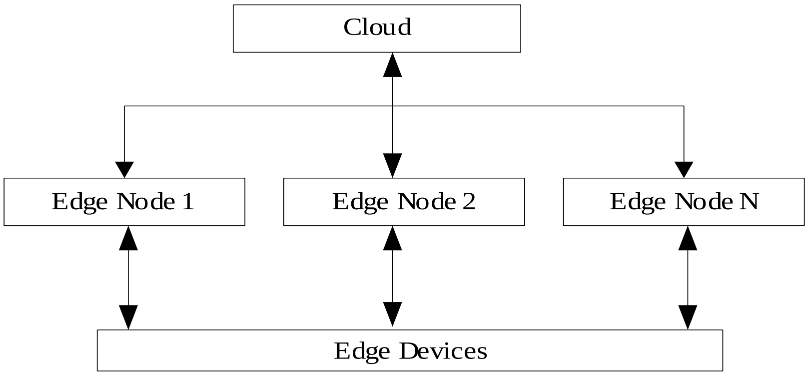

Figure II-1 Edge computing Paradigm[4]

C. Architecture of Edge Computing

i. **Front-end:** Edge devices like sensors, actuators, and RFID tags are important in the front-end. With track tags attached to things and RFID readers using shifting electromagnetic fields to detect items, RFID is a crucial category of edge device. Edge computing has become a reality because to this technology.[24] Internet users are also at the front-end, which means they can interact with the edge devices and process data without experiencing significant delays.[25]

ii. **Near-end:** Base stations, routers, edge servers, and gateways are examples of near-end objects that manage the majority of network traffic flows. Real-time data processing, data caching, and computation offloading are all services that the edge servers are capable of offering. The near-end devices handle the majority of data computation. In comparison to the front-end environment, moving computing workloads to near-end devices can benefit from higher computational power

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with just a slight increase in communication delay.

iii. **Far-end:** Cloud servers are often deployed far from Internet consumers in the far-end environment. The unloading of data takes a while compared to front-end and near-end settings, despite the environment's cloud servers being capable of advanced big-data processing.[26][27].

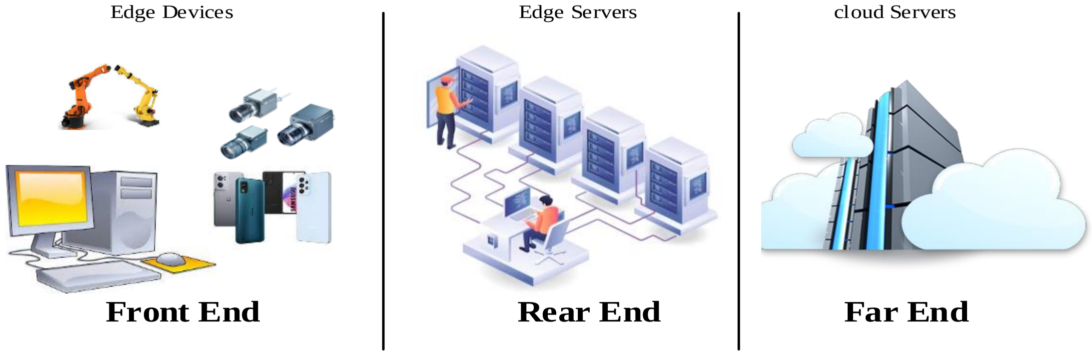

Figure II-2 A Typical Achitechure of Edge Computing Networks[27]

D. Cloud Computing

Cloud computing is the on-demand delivery of IT resources and services over the internet. Cloud computing is what is meant by on-demand computing through the internet. Users have access to the services whenever they need them thanks to cloud computing[26].

Today, enormous amounts of data are produced globally every second. Businesses gather and analyze consumer data to expand their business. Data traffic can happen when many businesses access the same data from different servers located in data centers at the same time. Data traffic might result in accessing the data taking longer, having less capacity, etc. However, using just cloud computing technology is insufficient to quickly analyze and store large volumes of data

.

For instance, the sensor continuously scans a few areas around the Tesla self-driving car. The vehicle must stop or veer off course if it notices an obstruction or pedestrian in its path. The data transmitted through the sensor must be analyzed fast when an impediment is approaching so that the vehicle may identify it and avoid hitting it. A slight lag in detection could cause serious problems. Edge computing and fog computing are ultimately required to overcome such obstacles.

E. Fog Computing

In 2012, Cisco used the phrase "fog computing" for the first time. MEC and fog computing both have similar concepts. But a special network computing design makes it possible to compute at the network edge. The Internet of Things (IoTs), which calls for location awareness, quick response, wireless access, and mobility assistance, is the framework in which fog computing was first proposed. In order to provide more flexible services, fog computing also makes use of an n-tier architecture, highlighting the fact that any network devices along the data routing channel are capable of providing end devices with data computation and storage capabilities.[28] To facilitate the pooling of computation, storage, and networking resources, a fog tier is physically positioned between the cloud and the IoT devices, as shown in Figure 2-6. The fog tier is made up of a sizable number of heterogeneous micro servers, ranging from set-up boxes and edge routers, which are dedicated equipment, to mobile phones, expensive sensors, and cars, which are temporary devices. Fog computing supports distributed processing, but cloud computing can have bottlenecks due to centralised processing.[29][22]

F. Smart Manufacturing

The Industrial IoT (IIoT) idea known as "Smart Manufacturing" aims to create a fully automated smart factory made up of a variety of network technologies that allow the control of facilities, machines, and supply chains within the smart factory with little to no human intervention.[5] All of these things also take place in smart manufacturing as a result of data exchange between production tools and equipment and between every link in the manufacturing technology chain. This then fuels machine learning, which makes it possible to carry out tasks more effectively and profitably than would ever be possible with just human oversight. [4]

i. Smart Factory Technologies

- Cloud connectivity.

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- Artificial intelligence
- Machine learning
- Big Data
- Industrial Internet of Things (IIoT):
- Digital twins:

Figure II-3 Smart factory devices and tecnologies[30]

G. Smart Manufacturing System based on Edge, Fog, and Cloud Computing,

Universal, practical, on-demand network access to a pool of programmable computing resources, including processing and storage facilities, software, and services, is made possible by the computer paradigm known as "cloud computing." To solve these issues, fog computing, a cloud computing extension to the edge network has evolved. It offers processing, storing, and networking services close to near-user hardware such network routers, information systems, etc. rather than sending data to the cloud.Applications are more convenient and available to a wider variety of nodes thanks to the fog computing paradigm, which places a greater reliance on local devices for data processing and storage than on cloud data centres.

Fog computing and edge computing both allow computation to occur at the network's edge, but edge computing is more convenient to the data sources. Edge computing and fog computing are distinct from one another because edge computing occurs in individual edge nodes whereas fog computing is reliant on node interconnection. Edge computing provides edge services close to the data source to serve essential objectives including flexible connection, real-time optimization, smart applications, security, and privacy.[31], [19]

Table II-1 Variation Between Cloud Edge and Fog Computing[32]

	Cloud	Fog	Edge
Scalability	High, easy to scale	Scalable within network	Hard to scale
Computing Power	High	Limited	Limited
Data Analysis	Less time-sensitive data processing, permanent storage	Real-time, decides to process locally or send to cloud	Real-time, instant decision making
Latency	Highest	Medium	Lowest
Distance	Far from edge	Network close to the edge	At the edge
Interoperability	High	High	Low

III.IMPLEMENTATION

A. Implementation of Edge Computing

The edge computing architecture shown in fig. 3-1 has been implemented in some edge computing systems. More generally, the software-defined model and the hierarchical model are the two basic models that are used in the design of modern computing systems.

Hierarchical Model: Edge servers can be installed at a variety of separations from Internet consumers. A hierarchical edge computing architecture is created by the numerous classes that can be created for the edge servers based on their computing power and how far away from the customers they are. It is appropriate to use a hierarchical model to describe the network architecture of edge computing. Some system designs now in use fit within the hierarchical model.[19]

i.Software-defined Model

An attempt is made by a software defined network (SDN) to consolidate network intelligence in a single network component in the control plane. One or more controllers make up the control plane, which is isolated from Internet users.. To make resource allocation and communication across radio access networks (RANs) devices easier, Prateek et al. created the LayBack architecture. Edge computing can play a critical role in delivering timely and high-quality services for these latency-sensitive applications.[22], [27]

B. An architecture for a cloud-based manufacturing system

The cloud has been a key enabler for manufacturing, transforming traditional production models into service-oriented manufacturing models that are more distributed, interoperable, smart, and adaptive

The cloud-based manufacturing system architecture can be condensed as shown in the figure below from a variety of cloud-based manufacturing applications, where the data capturing, data management, process management, status monitoring and execution control are done at the cloud end server. The physical manufacturing system and cloud environment are the two fundamental components of the architecture.

The MRs&Cs, including manufacturing equipment and users who take part in manufacturing operations, are represented in the lower layer. The physical manufacturing system includes all physical components in the factory, including several cooperative plants in various locations and multiple plants, as well as all users, including business users and customers.

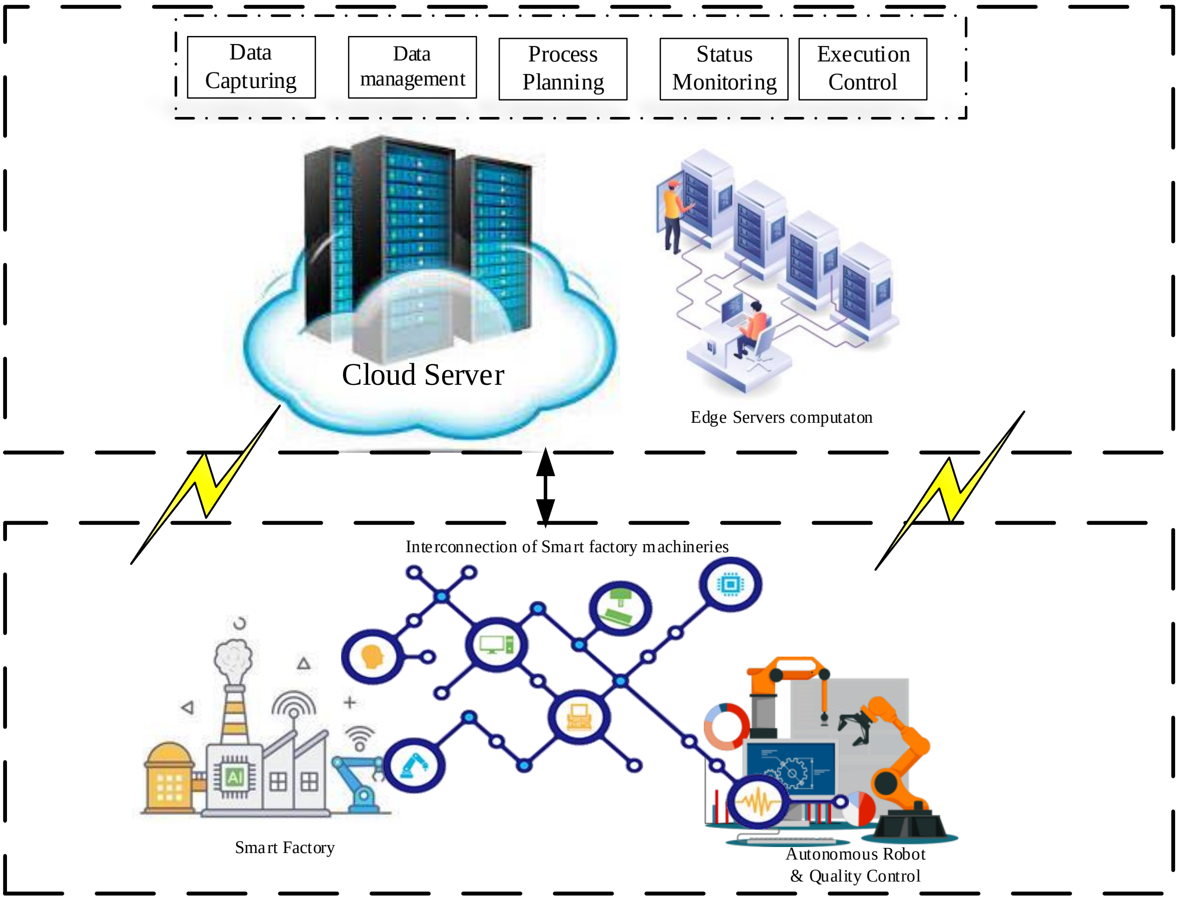

Figure III-1 The architecture of the cloud-based manufacturing system[19]

C. System Model and Assumptions

The robots in this Edge Cloud-based system can communicate with one another via Zigbee, Bluetooth, and WiFi and gather environmental data from their onboard sensors for service execution. Through gossip protocols, they continue to communicate with both the Edge Cloud and the Cloud.

A Resource Manager oversees the virtualized resources in an Edge Cloud (RM). The local computational context used by the robots' resident resources is also perceived by the RM. Additionally, when any robotic service is run, it produces

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a combined resource pool containing both local and distant resources. The RM is in charge of effectively allocating computational resources for the activities involved in a robotic workflow.[33]
In this case, we presume that the associated tasks of a service and their associated metadata (inter-data dependence delay, Quality of Service need, etc.) have already been pre-stored in the Edge Cloud.[34] The Resource Manager (RM) situated within the Edge Cloud is responsible for assigning tasks to the unified resource pool when a noteworthy event triggers the initiation of the service.

D. Industry 4.0 (Edge Computing based manufacturing and Control layer)

A contemporary industrial computing concept called "Industry 4.0" emphasises the creation of value through the flexible and effective application of emerging technologies like the Internet of Things and Cyber Physical Systems. With the help of cutting-edge features like autonomous tasks developed from deep learning techniques, Industry 4.0 aims to give plants and machines the ability to adapt their operations and operating conditions, including self-optimization and reconfiguration. Interactions between interconnected devices, such as sensors, actuators, and compute services, are essential to Industry 4.0's success. These contacts enable the sharing of data and the basic business processes for collaboration. The enormous volume of heterogeneous data produced and gathered from these linked devices, however, also poses difficulties and opportunities, including data-driven analytics.[35]

However , computation occur in realtime and reduce latency as where the data capturing, data management, process management, status monitoring and execution control are done at the edge network.

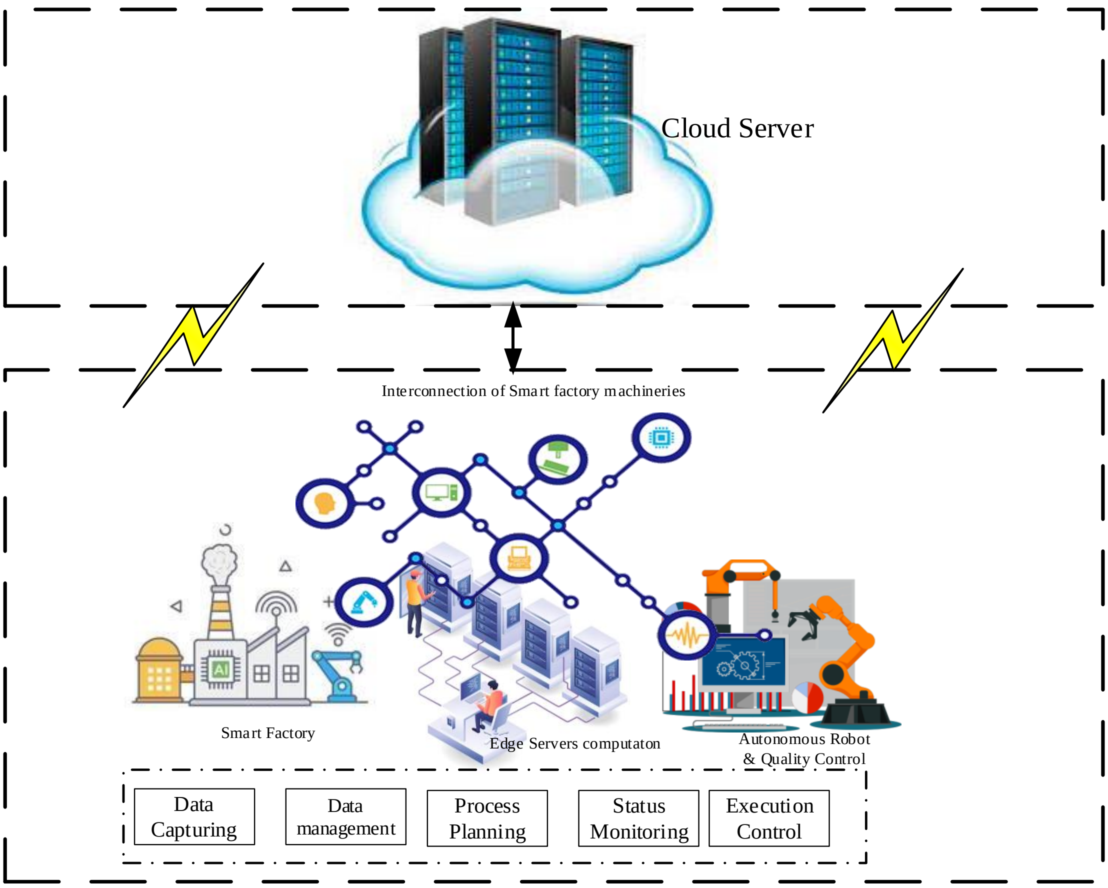

Figure III-2 Resource allocation for edge cloud based robotic workflow in smart factory and Manufacturing information integration [36]

All manufacturing resources used in various manufacturing processes are included in this layer, which can be summed up as "Human-Machine-Material-Environment." The machine component consists of machining tools (such as machine tools and robots) and transporting tools, whereas the human component consists of employees and managers (such as material conveyors and automatic guided vehicles). The raw materials, parts and pieces, semi-finished goods, finished goods, and other items make up the material component. On manufacturing resources, several sensing devices. [33]

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Given the nature of the majority of the obtained data, which primarily records occurrences within the realm of "normalcy", its utility may be limited. Consequently, the devices employed for edge computing would undertake the task of filtering, rejecting, or more efficiently reorganizing the data before it becomes overwritten on the edge. Subsequently, this filtered data would be transmitted to the fog or cloud for the purposes of preservation and analysis. Performance in real time is ensured by the feedback control on the edge side. Edge computing can still offer specialised application services even while it is offline.[36]

This layer also intends to achieve the following edge computing-based functions on the basis of achieving smart perception and interconnection:

1) Achieving synergy between humans and machines, the manufacturing system can swiftly adapt to dynamic production needs by harnessing the precision of machines and the adaptability of humans. This synergy fosters harmonious coexistence between human workers and machines.
2) Facilitating machine-to-machine collaboration, where machines work in tandem to enhance speed and efficiency, significantly boosts manufacturing productivity.
3) In machine-material coordination, materials and products are intelligently tracked and positioned using technologies like sensors, RFID, and machine vision. Smart machines then autonomously execute corresponding machining processes.
4) Coordinating the manufacturing environment to dynamically adapt to specific requirements ensures product quality and equipment safety. This adaptability is crucial for maintaining the desired production standards.[37]

i.Edge AI and Edge Computing for Industry 4.0: An IoT Approach

In the context of Industry 4.0, the employment of edge AI techniques like transfer learning, federated learning, and active learning may be especially well-suited. For instance, federated learning can give local training to IIoT devices to prevent sending data to the cloud in time-critical scenarios, while transfer learning can facilitate the deployment of lightweight intelligent manufacturing systems by using pre-trained models. On the other hand, active learning can assist in overcoming the labelling bottleneck by actively requesting labels from human annotators and automatically updating work schedules for procedures, hence enhancing production capacity.[12], [38]

By combining these edge AI techniques with edge computing, it is possible to create a more distributed, decentralized, and efficient system for Industry 4.0 applications, with improved performance, reliability, and security.

Transfer learning: is the process of creating lightweight, intelligent industrial applications for Industry 4.0 using pre-trained models. Machine learning (ML) and artificial intelligence (AI) have a lot of promise, and existing frameworks and models can be expanded to address new problems and issues. By substituting the last layers and refining the predictive model with data from the target domain, fog nodes load pre-trained networks from the cloud. [39]

Federated Learning: A part of the decentralised AI system that will be implemented in future smart factories is federated learning. Giving local training to IIoT devices is required to prevent them from uploading urgent data to the cloud. The intermediate fog computing node employs federated learning, a decentralised machine learning strategy.

Active learning: This is a technique within the field of machine learning that offers the advantage of selecting the most informative data to improve prediction accuracy while minimizing the requirement for extensive labeled training data. In order to address the challenge of limited labeled data, active learning employs a strategy of presenting unlabeled examples to a human annotator, such as an operator or planner, who then provides the necessary annotations.
The use of AL to automatically determine and modify work hours for activities can boost production capacity.[12]

ii.Why Combine Edge Computing and Artificial Intelligence ?

• Artificial intelligence (AI) techniques are required for the optimization and implementation of EC;
• To ensure minimal delay and optimal network reliability, it is imperative to deploy artificial intelligence (AI) applications in close proximity to the terminal devices. This critical computing capability is provided by EC..[40]
It is clear that the growth of EC and AI complement one another, and many academics are interested in the development of these two fields as a whole.

IV.MAIN RESULT (FINDINGS)

The Industrial Internet of Things (IIoT) has emerged as one of the key enablers for highly reliable and low-latency communications within the fifth generation of communication systems, and edge computing is an attractive technology for the sixth generation of communication systems. In this research we explore the potential utilization of wireless connections, artificial intelligence, and other edge computing technologies in smart factories to execute imperative tasks.

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While the occurrence of significant delays from task initiation to completion in such contexts is improbable, they may give rise to severe casualties and property damage and thus necessitate cautious consideration.

By enhancing installed computing capability and leveraging available resources to carry out various activities in a more intelligent manner, edge computing, through its edge devices and software, plays a significant role in intelligent systems in smart factories. By using the least amount of bandwidth, consuming the least amount of energy, and offering the highest level of security,[41] edge computing aids in the reduction of delay issues. The predominant portion of computational, storage, and networking resources are possessed by ASPs, such as Google, Amazon, Microsoft, Facebook, and Apple. Consequently, despite the notable benefits of edge computing over cloud services, it is incapable of fully substituting them. These enormous numbers of edge devices frequently require careful coordination with the application servers housed at a few sizable, dispersed data centers. Numerous Internet of Things applications, including mobile edge computing, a new option for network operators, are being built using edge computing architecture. It is utilized to increase capacity while simultaneously providing customers with data services with better coverage. The ability to act promptly and cut response times to milliseconds or less while protecting network resources is a significant benefit of edge computing.

A. Summary of Research

Table IV-1 Summary of findings

Methods	Key Findings	Limitations	Recommendations
Literature review	Edge computing can reduce latency and improve resource utilization in smart factories. Edge computing can also enhance security and privacy in smart factories.	Limited research on the impact of edge computing on smart factory QoS.	Conduct empirical studies to examine the impact of edge computing on smart factory QoS.
Case study	Edge computing can reduce network latency and improve real-time decision making in a smart factory setting.	Limited scalability and high deployment costs of edge computing in smart factories.	Develop cost-effective edge computing solutions and architectures that can be easily scaled up in smart factories.
Case study	AI can improve defect detection and classification in a smart factory setting. AI can also reduce production downtime and improve product quality.	Limited research on the usability and user acceptance of AI in smart factories.	Conduct usability testing and user acceptance studies to evaluate the effectiveness and user-friendliness of AI in smart factories.
Case study	Cloud-edge integration can improve the processing speed, storage capacity, and scalability of smart factory systems. Cloud-edge integration can also enhance the flexibility and cost-effectiveness of smart factory systems.	Limited research on the impact of cloud-edge integration on smart factory security and privacy.	Conduct empirical studies to examine the impact of cloud-edge integration on smart factory security and privacy, and develop secure and privacy-preserving cloud-edge integration solutions.
Case study	AI-based edge computing can improve the accuracy, speed, and efficiency of defect detection and classification in smart factories. AI-based edge computing can also reduce the cost and time of defect inspection and analysis in smart factories.	Limited research on the interpretability and fairness issues of AI-based edge computing in smart factories.	Address the interpretability and fairness issues of AI-based edge computing in smart factories, and develop explainable and fair AI models and algorithms.
Literature review	SDN can improve the agility, flexibility, and scalability of network infrastructure in smart factories. SDN can also enhance the security and quality of service (QoS) of network infrastructure in smart factories.	Limited research on the practicality and interoperability issues of SDN in smart factories.	Address the practicality and interoperability issues of SDN in smart factories, and develop SDN-based solutions that can be easily integrated with existing smart factory systems.

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Table IV-2 Issues, objectives, and contributions made by EDGE AI

Problem	Goal	Edge AI	Contribution
	Reduce energy consumption	Distributed DL-based offloading algorithm	Add the cost of changing local execution tasks in the cost function
	Reduce latency	Smart-Edge-CoCaCo algorithm based on DL	Joint offloading of compute, cooperative filter caching, and wireless communication
Computing offloading optimization	Reduce both latency and energy consumption	DRL-based offloading scheme	Not having any prior knowledge of the transmission delay and energy consumption models; In order to accelerate learning even further, DRL can be used to compress the state space dimension. You should also take the energy-harvesting EC scenario into consideration.

Table IV-3 Security of Edge Computing

Problem	Goal	Edge AI	Contribution
		Online learning	Utilize less bandwidth by choosing the most dependable server
Security of edge computing		Multiple AI algorithms	algorithm selection tool that can intelligently choose the Optimum AI algorithm
		Extreme Learning Machine	Show how the Extreme Learning Machine classifier performs better than most traditional algorithms in terms of convergence speed and generalisation performance.
		Distributed DL	Improve the model's accuracy and ease the workload associated with model training

Table IV-4 Privacy Protection

Problem	Goal	Edge AI	Contribution
		Deep PDS-Learning	Increase the training's efficiency by including more details (e.g., the energy utilisation of edge devices)
Privacy protection		Generative adversarial networks	a differential privacy-satisfying output perturbation algorithm and an objective perturbation algorithm

V.CHALLENGES AND FUTURE RESEARCH PLAN

Due to two key factors, current cloud computing platforms are unable to effectively handle the significant volume of data created by IoT devices with high response requirements:

- First, the round-trip delay between IoT devices and the cloud processing engines may exceed the response time required by certain applications.
- Second, network links to cloud resources may become congested when IoT devices send data in an uncoordinated manner. Fog and Edge Computing are two solutions aimed at addressing these problems. Although they are designed to solve the same issue, they differ in fundamental ways that make one solution more suitable than the other in certain contexts.

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A. Challenges

The maximum amount of data that can be processed is one of the most fundamental challenges that edge computing must overcome. studies claim that because edge computing uses microdata storage, it cannot handle massive amounts of data due to infrastructure limits. Edge computing technology must be compatible with a range of storage formats because of the rise in the amount of data being consumed nowadays. It must be capable of providing longer-lasting coverage for a wider variety of local geographic locations than was before doable.[42] The phrase "smart factories" can be used to describe both a decentralized structure known as "edge computing" and a centralized structure based on conventional cloud computing when it comes to data processing.

B. Future research Plan

The future of this research should focus on reducing latency, for example in Smart factories, which addresses security issues, life and network bottlenecks, as well as scheduling system resources, AI algorithms, big data processing, etc. Integration of sophisticated automation and artificial intelligence as well as cloud computing, advanced edge, and fog computing are the ultimate goals.

VI.CONCLUSION

The Internet of Things (IoT), which has gained a lot of popularity recently, has made a substantial contribution to the advancement of artificial intelligence (AI) by offering sufficient data for model training and inference. However, processing the enormous amount of data produced by IoT and fulfilling practical needs are hurdles for the traditional cloud computing architecture. In response, the academic community and business community have begun to pay attention to a new computing model known as edge computing (EC). The performance of EC cannot be improved by using conventional non-AI methods, according to researchers. In order to overcome these drawbacks and improve EC's performance, academics are turning to AI, particularly from a machine learning standpoint, which has gained popularity over the past few decades.

Large volumes of data may be stored on a central server thanks to the cloud computing architecture, allowing for massive data analysis employing machine learning, data mining, and deep learning. Due to the growing number of network paths available to transport data from the lowest layer to the highest layer, it has the drawback of high costs and delays. The middle layer processes the data rather than sending it immediately to the central server in the edge computing architecture, where the sub-cloud is placed close to the device layer. As a result, the input data and communication path to the central server are both compressed. Many studies have deemed edge computing an ideal platform technology for building a smart factory since it is structured for a manufacturing setting that requires real-time data processing and quick response.

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