International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 10 Issue 4, Jul-Aug 2026 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Edge Computing in Manufacturing

Matthew N. O. Sadiku[1], Samuel A. Ajayi[2], Janet O. Sadiku[3]

[1]Roy G. Perry College of Engineering, Prairie View A&M University, Prairie View, TX, USA
[2]Texas Southern University, Houston, TX, USA
[3]Juliana King University, Houston, TX, USA

ABSTRACT

Historically, the manufacturing industry has relied on centralized computing architectures, primarily cloud computing, to process the massive volumes of data generated by factory floor sensors, robotics, and supply chain systems. While cloud computing offers unparalleled scalability and storage capacity, it introduces latency and bandwidth constraints that are incompatible with the real-time demands of modern manufacturing. The manufacturing industry is undergoing a profound transformation driven by the principles of Industry 4.0, where cyber-physical systems, the Internet of things (IoT), and artificial intelligence (AI) converge to create intelligent, self-optimizing production environments. At the heart of this digital revolution lies edge computing, a decentralized computing paradigm that processes data at or near the source of generation rather than relying solely on centralized cloud data centers. By placing computational resources-such as edge servers, industrial gateways, and smart sensors-directly on the factory floor, edge computing enables localized data analysis and immediate action. Edge computing in manufacturing moves computation closer to machines and production lines. This paper explores the critical role of edge computing in modern manufacturing.

KEYWORDS: *edge computing, cloud computing, manufacturing, factory.*

How to cite this paper: Matthew N. O. Sadiku | Samuel A. Ajayi | Janet O. Sadiku "Edge Computing in Manufacturing" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-10 | Issue-4, August 2026, pp.1-10, URL: www.ijtsrd.com/papers/ijtsrd141972.pdf

IJTSRD141972

INTRODUCTION

In the era of smart manufacturing, data is the lifeblood of operations. Modern factories generate massive volumes of data every second through interconnected sensors, robotics, and automated machinery. Traditionally, this data was transmitted to centralized cloud servers for processing and analysis. However, as the volume and velocity of data have grown exponentially, the limitations of cloud-only architectures-namely latency, bandwidth constraints, and security vulnerabilities-have become apparent. To address these challenges, the manufacturing sector is increasingly adopting edge computing. By processing data locally at the "edge" of the network, near where it is generated, edge computing enables real-time decision-making, reduces reliance on continuous Internet connectivity, and enhances operational efficiency. Figure 1 shows the symbol of edge computing [1].

Edge computing is no longer a peripheral technology; it is rapidly becoming the central nervous system of the modern smart factory. By bringing computation closer to the source of data, edge computing solves the critical challenges of latency, bandwidth constraints, and network reliability that have historically hindered the full realization of Industry 4.0. For manufacturers seeking agility, efficiency, and resilience, the strategic adoption of edge computing is an imperative step toward the future [2].

CONCEPT OF EDGE COMPUTING

The history of edge computing traces back to the introduction of content delivery networks in the 1990s. The concept was straightforward: place servers close to end-user locations for faster cached image and video transmission. Edge computing was created jointly by Microsoft and their academic collaborators. Today, more and more services are pushed from the cloud to the edge of the network. Since data is increasingly being produced at the edge of the network, it would be efficient to process the data there. Keeping this data closer to its users (at the edge) eliminates many of the problems inherent with the public cloud model. Figure 2 shows how edge computing works [3]. Edge computing allows data from IoT devices to be analyzed at the edge before being sent to the cloud.

Edge computing (EC) or edge cloud is a computing paradigm where substantial compute and storage resources are placed at the edge of the Internet, in close physical proximity to mobile devices, sensors, end users, and IoT devices. It refers to bringing the flexibility and openness of cloud-native infrastructure to that local infrastructure. The idea of "edge" is to do processing near the data source. The terms "cloudlets," "micro data centers," and "fog" are used to refer to these small, edge-located computing nodes or data centers. A *cloudlet* is a cluster of computers well connected to the Internet and can be treated as "data center in a box." The main objective of a cloudlet is to extend the remote datacenter cloud services in close proximity to the end users. Physical proximity is the essence of edge computing since it improves latency, bandwidth, trust, and survivability. While the cloud has revolutionized the way we deal with data, the next wave of that revolution will happen at the edge [4].

A standard edge computing framework consists of three distinct levels [5]:

- The cloud: Which manages the overall data storage and processing.
- The edge: Tasked with near-instantaneous data handling.
- The device: Responsible for initial detection and basic data processing.

These three levels are related in the edge computing architecture shown in Figure 3 [6].

Edge computing covers a wide range of technologies such as wireless sensor networks, distributed data storage, and augmented reality. This has made its way to becoming the core of the data center. The term "edge" refers to the computing devices that sit closer to the sources of data, where the digital world meets the real world. These edge devices typically reside away from the centralized computing available in the cloud and are being created with increasingly compute capabilities. Typical edge devices are smartphones, tablets, sensors, wearables, routers, switches, integrated access devices, multiplexers, smart TV, modern cars, and a variety of MAN/WAN access devices. Edge computing enables analytics and data gathering to occur at the source of the data.

Edge computing covers a spectrum of technologies such as cloudlets, fog computing, and mobile edge computing. A combination of edge and cloud computing is referred to as *fog computing* because it combines centralized and distributed computing resources into a single architecture. (Edge computing is a relatively new concept that should not be confused with fog computing.) It is practically unsafe and unnecessary to send such a large amount of data to the cloud. A comparison between cloud computing, edge computing is illustrated in Figure 4 [7]. Compared to cloud computing, fog computing and edge computing have the following five advantages [8]: (1) greater data transmission speed, (2) less dependence on limited bandwidths, (3) greater privacy and security, (4) greater control over data generated in foreign countries where laws may limit use or permit unwanted governmental access, and (5) lower costs because more sensor-derived data are used locally, and less data are transmitted remotely. Figure 5 shows edge computing [9], while Figure 6 shows how edge data is processed [3].

EDGE COMPUTING IN MANUFACTURING

The manufacturing sector is undergoing a profound transformation driven by Industry 4.0 technologies. Among these, edge computing has emerged as a critical enabler of real-time data processing, predictive maintenance, and enhanced operational efficiency. Edge computing is a distributed computing framework that brings computation and data storage closer to the location where it is needed. This proximity enhances response times and saves bandwidth, which is crucial in environments where every second counts, such as manufacturing floors. By processing data locally or at nearby edge servers, companies can achieve more immediate insights and reactions, essential for real-time applications [2].

Manufacturing generates vast amounts of data from sensors, machines and other devices. Manufacturers are generating unprecedented volumes of operational data as production environments become more automated and interconnected. The latency and bandwidth required to handle and process this data only in the cloud may not be ideal. Edge computing helps address these challenges by processing data locally, reducing the need for extensive data transmission and enabling faster, more efficient operations. By processing data at the source, manufacturers eliminate latency, improve resilience, and unlock AI-driven automation that cloud-only architectures cannot support. Whether the goal is predictive maintenance, real-time quality inspection, or energy optimization, edge computing provides the infrastructure layer that makes Industrial IoT actionable [10,11].

APPLICATIONS OF EDGE COMPUTING IN MANUFACTURING

The integration of edge computing into manufacturing operations has unlocked numerous high-value applications that drive efficiency and quality. By bringing computation to the data source, manufacturers can unlock advanced use cases such as predictive maintenance, real-time quality control, and adaptive production. Common applications of edge computing in manufacturing include the following [2,10]:

- *Smart Factory*: Smart factories are the cornerstone of Industry 4.0, integrating advanced automation, IoT sensors, and AI-driven analytics into manufacturing operations. Figure 7 shows a factory [12], while Figure 8 shows some factory workers [12]. Edge computing is a transformative force for smart factories. By bringing computation closer to where data is generated, manufacturers gain the speed, agility, and control necessary to thrive in the Industry 4.0 era. As smart factories deploy an ever-increasing number of connected sensors and automated machinery, the volume of data generated is expanding exponentially. Traditional cloud architectures, while powerful for long-term analytics, often struggle with the latency, bandwidth, and security requirements necessary for real-time industrial operations. The primary limitation is latency-the time it takes for data to travel from a factory sensor to a remote cloud server, be processed, and return as an actionable command. In environments where milliseconds matter, such as robotics control or automated quality assurance, cloud latency can lead to operational inefficiencies or safety hazards. Edge computing addresses these limitations by bringing computation closer to the shop floor. By leveraging edge computing, manufacturers can ensure that time-critical operations are handled instantaneously on the factory floor, while less urgent data is transmitted to the cloud for deeper analysis. Figure 9 shows edge computing for smart manufacturing [13].
- *Distributed Manufacturing:* Distributed manufacturing refers to a production model in which manufacturing activities are spread across multiple geographically dispersed facilities, rather than centralized in a single plant. Each site operates semi-autonomously, with local intelligence handling real-time decisions while remaining coordinated with the broader enterprise. As manufacturing operations expand across multiple sites, edge computing becomes the enabling layer that keeps each facility autonomous while remaining coordinated with the broader enterprise.
- *Industrial Edge Computing*: Industrial edge computing refers to the practice of processing data at or near the source of generation within an industrial environment, such as on the factory floor or directly on machinery. This contrasts with cloud computing, where data is sent off-site to centralized data centers. While cloud computing excels in handling long-term data storage, historical analysis, and resource-intensive computations, it introduces latency due to the physical distance data must travel. In manufacturing, where decisions must often be made in milliseconds to control high-speed machinery or ensure safety, such delays are unacceptable. Edge computing complements the cloud by handling time-sensitive, mission-critical operations locally, while the cloud manages broader, strategic analytics.
- *Quality Assurance:* Quality assurance is a critical component of manufacturing. Maintaining consistent product quality at high production speeds is a major challenge. Traditional methods often involve manual inspections or post-production testing, which can result in significant waste if defects are not caught early. Edge computing enables real-time quality control through high-resolution computer vision systems. Cameras installed on the production line capture images at high speeds, and edge AI models instantly analyze these images to detect surface defects, dimensional errors, or assembly mistakes. Non-conforming units can be automatically rejected without halting the entire line, drastically reducing waste and ensuring product consistency. In industries where precision is non-negotiable, such as semiconductor manufacturing or pharmaceuticals, edge computing plays a vital role.
- *Predictive Maintenance:* Unplanned downtime remains one of the most costly challenges for manufacturers. Equipment failure is a major source of unplanned downtime and lost revenue in manufacturing. Traditional maintenance schedules are often reactive or based on arbitrary time intervals. Edge computing facilitates predictive maintenance by processing data from IoT sensors installed on machinery in real time. Predictive maintenance utilizes edge computing to continuously monitor data from vibration, thermal, and acoustic sensors attached to machinery. By analyzing this data locally, edge

AI models can detect anomalous patterns indicative of wear or impending failure-such as bearing degradation or thermal imbalance-long before the equipment actually breaks down. This allows maintenance teams to schedule repairs during planned downtime windows, extending asset life and improving overall equipment effectiveness.

- *Autonomous Operations*: The deployment of advanced robotics and autonomous guided vehicles (AGVs) requires ultra-low latency to function safely and effectively. Edge computing provides the necessary processing power to allow robots to make autonomous decisions in real-time. For example, a robotic welding station can adjust its parameters instantaneously based on local sensor feedback, ensuring precision even when material conditions fluctuate.
- *Digital Twins:* A digital twin is a virtual replica of a physical object or system that mirrors its real-world counterpart in real-time. The integration of edge computing with digital twins allows manufacturers to handle complex computations locally, enabling more intricate modeling and simulation capabilities. Edge computing supercharges digital twins by providing immediate, localized data streams. This allows manufacturers to run complex simulations and scenario analyses locally, optimizing processes like energy consumption or supply chain logistics with minimal latency.
- *Energy Management:* Manufacturing plants are typically high energy consumers. Edge computing can optimize energy use by continuously monitoring energy consumption across various plant segments. For example, a steel production plant might use edge computing to dynamically adjust furnace temperatures based on current demand and production schedules. By processing this data locally, adjustments can be made almost instantaneously, reducing unnecessary energy consumption and lowering costs.
- *Augmented and Virtual Reality* (AR/VR): In sectors where precision and training are critical, edge computing enhances the effectiveness of AR/VR applications. By processing data locally, latency issues are minimized, making virtual interfaces more responsive. Technicians wearing AR glasses can receive real-time, overlay instructions for assembling complex components, ensuring accuracy and efficiency without the lag that can hinder learning or operation.

BENEFITS

The shift towards edge computing offers compelling advantages for modern manufacturers. The benefits of real-time data processing, predictive maintenance, and enhanced operational efficiency make edge computing an indispensable component of modern manufacturing strategy. Other benefits of edge computing in manufacturing include the following [2,10]:

- *Reduced Latency*: The most significant advantage of edge computing is its ability to eliminate the round-trip delay inherent in cloud architectures. Applications such as robotic welding stations, conveyor belt coordination, and safety interlocks require sub-millisecond response times. Edge computing provides faster response times by processing data near its source. This is crucial for mission-critical applications where millisecond delays can lead to disruptions. By processing sensor data locally, edge nodes can issue commands in microseconds. For example, if a machine detects a critical temperature spike or a misalignment, edge computing allows the system to instantly halt or adjust the process, preventing defective products or equipment damage.
- *Cost Savings*: Reducing the amount of data sent to the cloud can result in lower bandwidth costs and decreased reliance on expensive cloud storage solutions. Edge computing sends only meaningful events, alerts, and summarized reports to the cloud, significantly reducing WAN bandwidth requirements and lowering monthly cloud infrastructure costs.
- *Operational Continuity*: Edge nodes can operate autonomously. If network connectivity to the central cloud is lost, critical production processes can continue uninterrupted, synchronizing data once the connection is restored. Many manufacturing facilities, particularly those in remote locations or harsh industrial zones, experience unreliable Wide Area Network (WAN) connectivity. Edge computing ensures that production-critical applications continue to operate seamlessly even during network outages. Data is processed and stored locally, and synchronization with the central cloud occurs only when connectivity is restored. This localized autonomy guarantees that a temporary Internet failure does not result in costly factory downtime.
- *Energy Efficiency:* Edge platforms aggregate energy consumption data from motors, HVAC systems, compressors, and lighting across the plant. Local analytics models identify demand spikes, idle waste, and optimization opportunities,

enabling real-time load balancing and measurable reductions in energy costs.

- *Reduced Bandwidth Costs*: Industrial IoT environments generate massive volumes of raw sensor data continuously. Transmitting all this data to the cloud is not only unnecessary but also prohibitively expensive in terms of bandwidth consumption. Edge computing acts as an intelligent filter, aggregating and processing data locally.
- *Enhanced Data Security:* Data security and sovereignty are paramount concerns for modern manufacturers. Processing sensitive data locally reduces the risk of interception during transmission. This localized processing limits the exposure of critical intellectual property to external cyber threats. It allows manufacturers to keep proprietary data on-site, enhancing overall cybersecurity. It also aids in compliance with data sovereignty regulations, as proprietary information remains within the facility.
- *Bandwidth Optimization:* Industrial IoT environments generate terabytes of raw data. Edge computing filters and aggregates this data locally, transmitting only meaningful insights or summaries to the cloud, thereby significantly reducing bandwidth costs. By filtering and processing data locally, edge computing reduces the amount of data sent to central servers or the cloud, lowering communication costs and alleviating network congestion.
- *Sustainability:* As the industrial sector faces increasing pressure to reduce its carbon footprint, edge computing is emerging as a vital tool for sustainability. The electronics industry and data centers are significant contributors to global greenhouse gas emissions. By processing data locally, edge computing drastically reduces the volume of data transmitted to centralized cloud servers, thereby lowering the energy consumption associated with network bandwidth and massive data centers. In precision manufacturing, edge-enabled computer vision reduces scrap and e-waste by catching defective parts early in the assembly process, contributing to a more circular economy.
- *Autonomous Production:* Factories will increasingly embed decision-making capabilities directly into their operations, reducing human intervention in routine adjustments. Manufacturing processes must keep running during WAN outages. Edge computing provides autonomous operation: if the cloud connection drops, local analytics, alarming, and historian buffering continue uninterrupted. Data is queued and forwarded when connectivity is restored.

CHALLENGES

In spite of its benefits, implementing edge computing is not without challenges. Challenges related to device management, cybersecurity, workforce readiness, interoperability, regulatory compliance, and legacy system integration remain. Other challenges of edge computing in manufacturing include the following [2,12]:

- *Cybersecurity*: Security remains a top priority as operational technology becomes increasingly connected. One of the most pressing challenges of edge computing in manufacturing is the profound impact on cybersecurity. Traditionally, operational technology (OT) networks were isolated from information technology (IT) networks, a practice known as "air-gapping." Edge computing bridges this divide, converging IT and OT to enable real-time data insights. While this convergence is essential for smart manufacturing, it dramatically expands the attack surface. Unlike centralized cloud data centers, which benefit from concentrated, enterprise-grade security measures, edge computing involves deploying dozens, hundreds, or even thousands of distributed devices across factory floors and remote sites. Each edge node-whether an industrial gateway, a programmable logic controller (PLC), or a smart sensor-represents a potential entry point for cyber threats. The decentralized nature of edge computing complicates security enforcement.
- *Legacy System Integration*: Manufacturing facilities are rarely greenfield environments built from scratch. Instead, they are typically complex ecosystems comprising a mix of modern smart machinery and legacy equipment that may have been in operation for decades. Integrating edge computing into these heterogeneous environments presents significant interoperability challenges. Legacy systems often rely on proprietary, vendor-specific communication protocols and lack the standardized interfaces required for seamless integration with modern edge platforms. Extracting data from these older machines without disrupting ongoing production is a delicate process.
- *Interoperability:* Implementing CEI [Cloud-Edge-IoT] systems in broadband wireless networks will present numerous technical challenges. It is crucial to address continuum difficulties to optimize interoperability between legacy

manufacturing systems and new edge infrastructure. Overcoming interoperability barriers requires a commitment to open standards and the use of middleware solutions that can bridge the gap between legacy OT and modern IT edge infrastructure.

- *Scale and Consistency*: The operational complexity of managing edge computing infrastructure scales exponentially with the number of devices deployed. While managing a handful of edge servers may be straightforward, deploying and maintaining hundreds of edge nodes across multiple distributed manufacturing sites is a daunting logistical challenge. The primary operational challenges are scale and consistency. Maintaining data consistency between distributed edge nodes and central repositories is challenging, particularly in environments with intermittent network connectivity. Managing devices individually leads to configuration drift, where different edge nodes end up running different software versions or security patches. This inconsistency not only introduces security vulnerabilities but also complicates troubleshooting and application deployment.
- *Regulatory Compliance*: Edge computing complicates regulatory compliance. Manufacturing data often includes sensitive intellectual property, proprietary production metrics, and occasionally personally identifiable information (PII) regarding employee performance or safety monitoring. Processing and storing this data across multiple geographic locations means manufacturers must navigate a patchwork of regional data sovereignty laws and privacy regulations, such as the General Data Protection Regulation (GDPR) in Europe. Ensuring that edge deployments comply with these regulations requires robust data governance frameworks and localized data control policies.
- *Skills Gap:* The successful implementation of edge computing in manufacturing is heavily dependent on human capital. However, the industry faces a significant skills gap. Edge computing resides at the intersection of IT, OT, networking, and data science-a multidisciplinary domain that requires a unique blend of expertise. Edge computing in manufacturing involves new technical requirements, and manufacturers may need to upskill their workforce. Bridging the skills gap requires substantial investment in training and workforce development.
- *Management Complexity*: As manufacturers deploy hundreds or thousands of edge devices across multiple facilities, managing, updating, and securing these distributed assets becomes highly complex. Robust edge orchestration platforms are required to manage this infrastructure efficiently.
- *Hardware Requirements*: Industrial environments are often harsh, characterized by extreme temperatures, dust, and vibration. Edge hardware must be ruggedized to withstand these conditions while still delivering the necessary computational power for advanced analytics.

FUTURE OF EDGE COMPUTING IN MANUFACTURING

The adoption of edge computing in manufacturing is accelerating rapidly. The global edge computing market is experiencing explosive growth. As we look toward the future, the integration of edge computing is not merely an incremental upgrade; it is the foundational infrastructure required to realize the full potential of smart factories and Industry 4.0. Looking ahead, several trends will shape the future of edge computing in manufacturing. The combination of 5G networks with edge computing will accelerate machine-to-machine communication, enabling faster data sharing and supporting more complex autonomous systems. Integrating artificial intelligence directly into edge devices will allow for more sophisticated local decision-making, such as advanced visual inspection and autonomous process optimization.

The future of manufacturing is increasingly distributed, with production spread across multiple geographically dispersed facilities to improve supply chain resilience and proximity to customers. Edge computing is the enabling layer for this model. Each facility operates with its own localized edge stack, allowing it to function autonomously while remaining coordinated with the broader enterprise. The future of manufacturing is inextricably linked to the evolution of edge computing. By decentralizing intelligence and bringing computational power to the network edge, manufacturers can overcome the latency and bandwidth limitations of the cloud, enabling true real-time responsiveness. As edge computing converges with AI, private 5G, and digital twins, factories will become increasingly autonomous, adaptive, and sustainable [2]. The evolution of edge computing in manufacturing will be defined by greater autonomy, smarter AI integration, and broader interoperability.

CONCLUSION

Edge computing is no longer a futuristic concept but a foundational technology driving the next industrial revolution. This paradigm shift is not merely a technological upgrade but a fundamental change in how manufacturing systems operate, paving the way for the fully autonomous factories of the future. This shift is reshaping how organizations in manufacturing design, manage, and scale their operations.

Edge computing is revolutionizing the manufacturing industry by bringing computational power closer to the source of data. It is undeniably a catalyst for the next phase of the industrial revolution, providing the real-time processing capabilities, resilience, and efficiency required to power smart factories. It is a transformative force for smart factories. By bringing computation closer to where data is generated, organizations in manufacturing gain speed, agility, and control. Adopting edge strategically enhances competitiveness and prepares infrastructure for future growth. As technology continues to advance, the integration of edge computing and AI will become increasingly vital for manufacturers seeking to remain competitive in a rapidly changing landscape. More information on edge computing can be found in the book in [14] and a related journal: *Journal of Manufacturing Systems.*

REFERENCES

[1] P. Tyagi, "Edge computing hardware platforms for u.s. manufacturing plants: a competitive edge," February 2026, https://www.linkedin.com/pulse/edge-computing-hardware-platforms-us-manufacturing-plants-priya-tyagi-dxtwc

[2] https://manus.im

[3] "Harnessing edge computing for business growth," https://www.vertiv.com/en-us/solutions/vertiv-guide-to-edge-computing/

[4] M. N. O. Sadiku, A. M. Oteniya, and S. M. Musa, "Edge computing," *International Journal of Trend in Research and Development*, vol. 5, no. 4, July – Aug. 2018, pp. 553-554.

[5] A. Harper, "How is edge computing enhancing telecom speeds for end users? https://www.jevera.software/post/how-is-edge-computing-enhancing-telecom-speeds-for-end-users

[6] J. Gonzalez et al., "Edge computing architecture and use cases," https://lfedge.org/edge-computing-architecture-and-use-cases/

[7] "Edge computing needs edge AI," August 2018, https://www.imagimob.com/blog/edge-computing-needs-edge-ai#

[8] D. C. Klonoff, "Fog computing and edge computing architectures for processing data from diabetes devices connected to the medical Internet of things," *Journal of Diabetes Science and Technology,* vol. 11, no. 4, 2017, pp. 647 – 652.

[9] "Edge computing definition and use cases," March 2020, https://jelvix.com/blog/what-is-edge-computing

[10] S. Walin, "Edge computing in manufacturing: Scaling smart factory operations in 2026," https://avassa.io/articles/smart-factories-edge-computing-manufacturing/

[11] R. Soni, "Understanding edge computing's role in manufacturing," June 2024, https://www.forbes.com/councils/forbestechcouncil/2024/06/26/understanding-edge-computings-role-in-manufacturing/

[12] "The role of edge computing in modern manufacturing," September 2025, https://larkindustries.com/edge-computing-modern-manufacturing/

[13] "Use cases of edge computing in smart manufacturing by 2025," September 2025, https://www.asappstudio.com/edge-computing-smart-manufacturing-2025/

[14] A. Patnaik et al. (eds.), *Soft Computing in Materials Development and its Sustainability in the Manufacturing Sector (Edge AI in Future Computing).* Boca Raton, FL: CRC Press, 2022.

Figure 1 The symbol of edge computing [1].

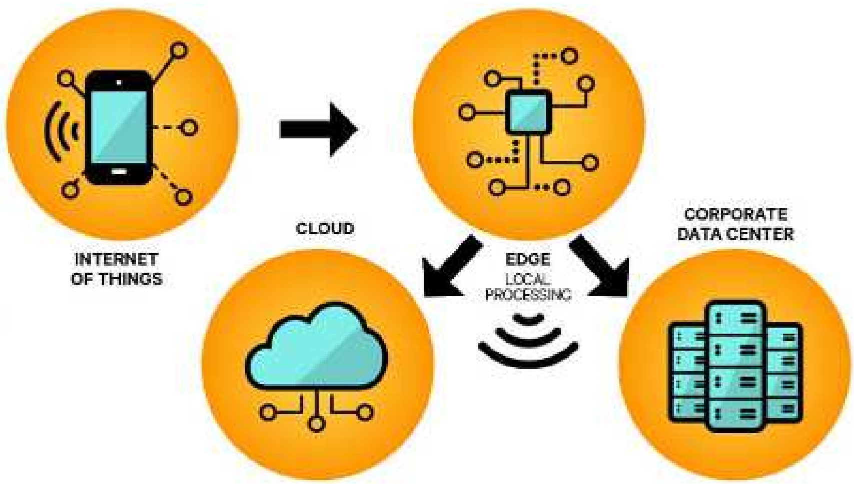

Figure 2 How edge computing works [3].

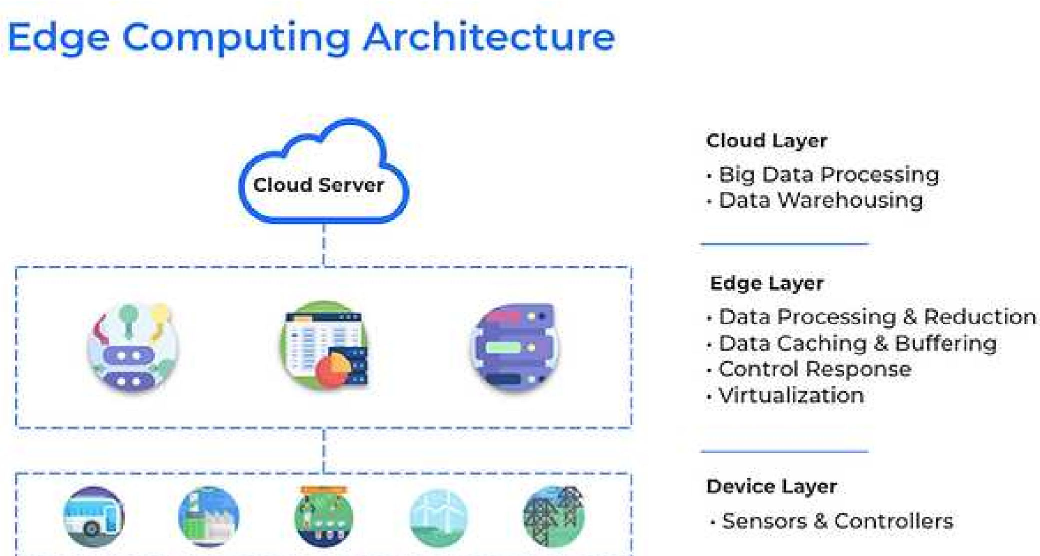

Figure 3 Edge computing architecture [6].

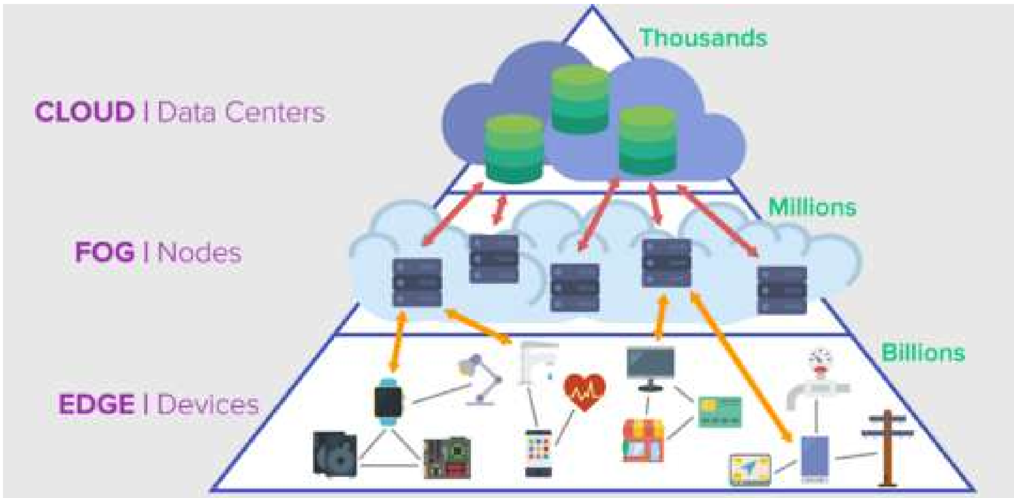

Figure 4 The relationship between cloud computing, edge computing, and fog computing [7].

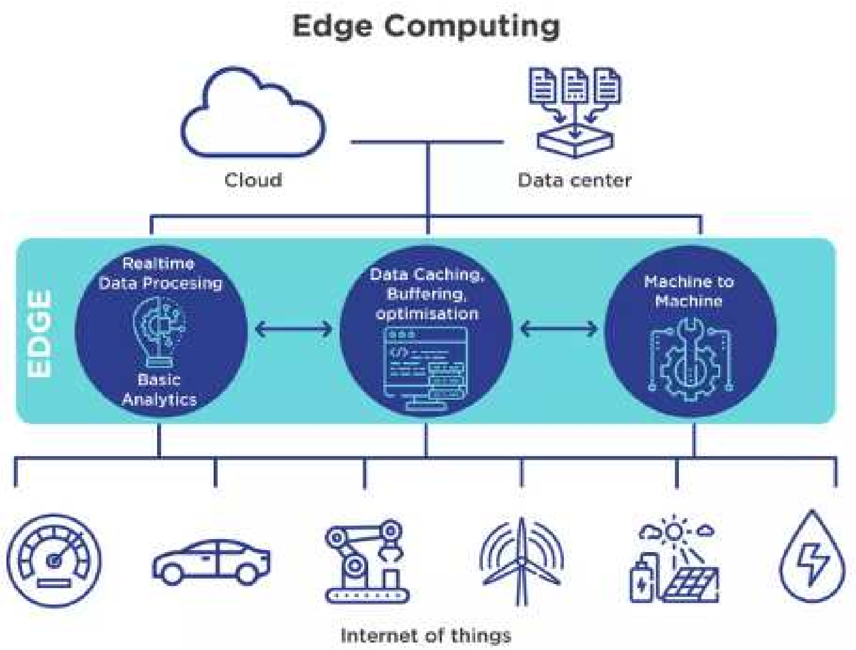

Figure 5 Edge computing [9].

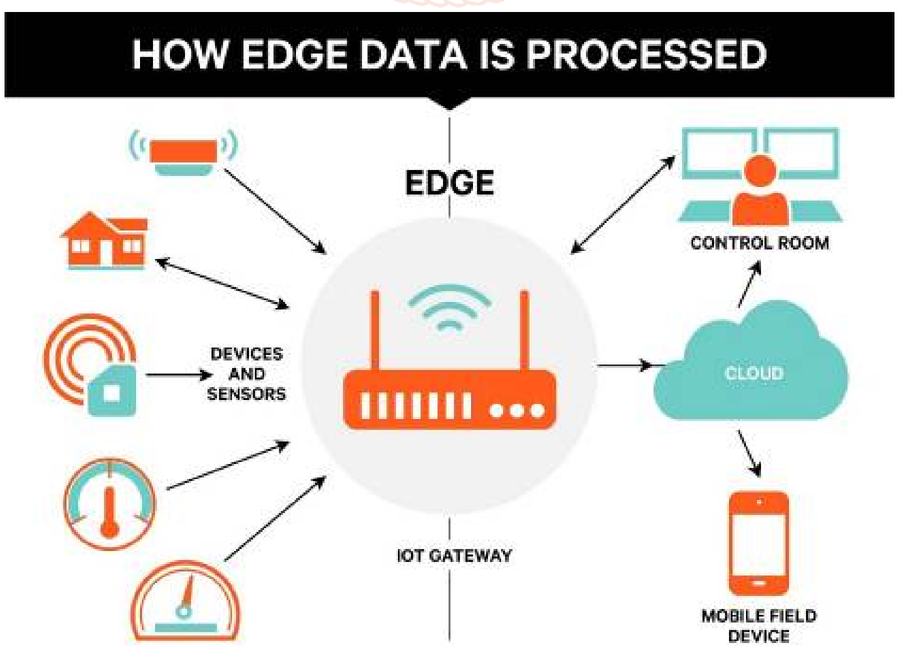

Figure 6 How edge data is processed [3].

Figure 7 A factory [12].

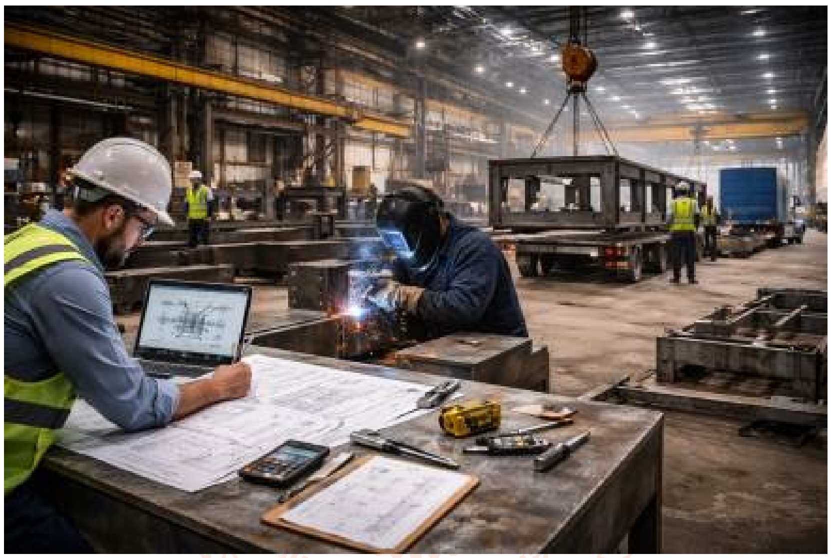

Figure 8 Some factory workers [12].

Figure 9 Edge computing for smart manufacturing [13].