IJFANS INTERNATIONAL JOURNAL OF FOOD AND NUTRITIONAL SCIENCES
ISSN PRINT 2319 1775 Online 2320 7876
 UGC CARE Listed (Group -I) Journal Volume 11, Iss 06, 2022

A Comprehensive study of Research on Edge Computing

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Abstract

As a reaction to the increasing needs of an information-driven society, edge computing—an important era that is going hand in hand with IoT and AI—emerges. Its design, which consists of terminal, part, and cloud layers, decentralizes processing to the brink of the community for improved latency, overall performance, and protection. This paradigm is, in general, powered by computational offloading, mobility control, and caching acceleration technology. Using information to get entry to guidelines, authentication, and encryption, privacy and security are still critical. Cross-area get-right-of entry to manipulate and lightweight, reliable protection solutions are the key topics of destiny look at. Applications for edge computing are many and encompass live video streaming, predictive maintenance, expanded safety tracking, live video caching for bandwidth optimisation, and collaboration with 5G networks for resource allocation. These eventualities take advantage of computing's close proximity to gadgets to protect records privacy and enable real-time analysis. These programmes, which cope with problems of efficiency, real-time analysis, and person consideration, display their disruptive ability across sectors.

Keywords: *Edge Computing, IoT, AI, Latency, Security, Applications*

Introduction

As society has emerged as more intelligent and those's needs have endured growth, intelligence has impacted many special agencies and those's normal lives. All aspects of society are now stricken by area gadgets, which include shrewd manufacturing robots in smart production, cameras, smart houses, self-sufficient automobiles within the transportation zone, and so forth. Consequently, there are actually considerably greater quantities of gadgets related to the Internet. According to Cisco's Global Cloud Index, there were 17.1 billion Internet-linked gadgets in 2016. By 2019, 10.4 zettabytes (ZB) of records will be transmitted among worldwide statistics centres, with 45 percent of those facts being processed, stored, and analysed on the network's edge. Furthermore, by 2020, there will be more than 50 billion wireless gadgets related to the community. Globally, tool record generation has additionally grown, growing from 218 ZB in 2016 to 847 ZB in 2021. According to figures from the International Statistics Centre (IDC), there might be more than 50 billion terminals and devices linked to the network by 2020, and there may be more than forty ZB of records globally. Considering Sabah Mohammed's continuing role as partner editor in organising the manuscript's assessment and giving it the go-ahead for publishing, Cloud-primarily based big statistics processing has shown numerous drawbacks, no matter the considerable enlargement in data quantity and type of information processing necessities:

Instantaneous: The addition of many area devices will result in a vast boom in the extent of intermediate statistics transmission, a discount in records transmission performance, and a heavy

ISSN PRINT 2319 1775 Online 2320 7876
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load on community transmission bandwidth, so that we can reason for a postponement in records transmission. A large amount of terminal information remains transmitted to the cloud for processing. Cloud computing will now not provide companies with real-time needs in diverse software situations that call for real-time feedback, including site visitors, tracking, and so on. Security and privacy: For instance, utilising loads of smartphone apps can also require imparting consumer facts, including non-public facts. This information is very susceptible to privacy breaches or assaults after it is uploaded to the cloud centre.

Energy intake: China's facts centre on the use of loads more electricity as a result of the country's growing clever device populace. The growing demand for information and electricity consumption cannot be met by enhancing the utilisation performance of cloud computing energy consumption. Cloud computing power consumption desires will rise in the rapidly evolving wise society. Edge computing has come at a momentous time due to the developing quantity of data and the growing demand for data processing. With the use of edge computing technology, offerings emerge as more dependable and synthetic intelligence offerings are to be had for ever-expanding terminal gadgets and facts. Edge computing is located close to smart terminals, which might be the source of the facts. On the community's part, it handles and stores information. It gives near-quit offerings to users and has proximity and area recognition. It tactics statistics more quickly, securely, and in real time. It may additionally decrease charges and ease the stress on community bandwidth, further resolving the difficulty of immoderate power intake in cloud computing. Applications for edge computing may be observed in many industries, which include transportation, power, clever homes, and manufacturing. As the Internet of Things (IoT) grows, side computing models are becoming more critical and popular study subjects. To function as an aid for area computing researchers, we go into terrific depth on edge computing in this text, including its introduction, architecture, critical technology, protection and privacy, and programs.

Edge computing & cloud computing

Cloud Computing

Before edge computing, traditional cloud computing solved the problems of computing and storage in a scalable way and sent all the data on the network to a cloud computing center. The concept of cloud computing was first proposed by Sessions, Google's CEO, in August 2006 at the Joes conference. It is the first official introduction to the concept of cloud computing in its development history. Cloud computing has grown exponentially with the growth of search engines, represented by Google. Today, cloud computing has evolved slowly. With distributed computing, load balancing, parallel computing, network storage, virtualization, and other technologies, it provides a very powerful foundation for network deployment; however, it may struggle to keep pace with time-sensitive requirements and policies. As a result, cloud computing models have significant drawbacks in terms of load, real-time, transmission bandwidth, energy consumption, data security, and privacy protection.

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Relationship and difference between edge computing and cloud computing

Cloud computing will not be replaced by edge computing. On a larger scale, coexistence, integration, and coordinated development of network, business, application, and intelligence components will support the digital transformation of enterprises. To pursue deeper analysis and provide more insightful analytics, there is still a need to summarise the data of all edge nodes in the cloud. Computing performance remains essential. In the Internet of Things, cloud computing will create a huge burden if more data generated by connected devices is transferred to the cloud. Currently, edge computing is needed to share loads from the cloud and execute mandatory functions in the area of expertise. In an edge computing problem, data is not lost in the cloud. To process an Internet application—such as deep data mining and sharing—data must first be processed by edge computing and then sent back to the cloud. This requires edge and cloud computing to work together. Devices connected to the Internet of Things network are more stable than these two alternatives. One possible way the two work together is that edge computing handles and runs edge computing, whereas cloud computing relies on big data analysis and results today in many real-life applications, such as intelligence internal production, energy, security, privacy protection, and smart families. Coordinated development of both has been implemented.

For example, the cloud plays a key role in managing all smart processes. The ability to quickly identify and fix problems in real-time is important for edge nodes. Edge computing uses real-time resources and, when combined with cloud computing, increases productivity and provides early detection of device faults. For a smart home, most edge computing nodes consist of multiple terminals with intelligence. Managing edge nodes from the cloud and gaining edge node access to the cloud: edge computing nodes compute disparate data from devices and upload it to the cloud for use. Cloud computing and edge computing have advantages that can be combined to meet Internet of Things requirements. Only by working together can these two technologies continue to improve the Internet. Cloud computing has its own features, and edge computing is an extension of cloud computing. The key characteristics of cloud computing are its ability to understand the big picture, process large amounts of data, perform deep analytics, and play a key role in non-real-time data processing, including corporate decision-making and other areas. Therefore, intelligent edge applications can be used for local applications and small intelligent research, while cloud computing is more suitable for centralised large data processing. Edge computing manages data close to the information source in the case of network objects. As a result, information needs to be processed and managed locally, without having to move it all to the cloud. Grid bandwidth utilisation efficiency is significantly improved by reducing grid load. Future developments in the intelligent internet of things will be influenced by cloud-edge computing. Table 1 shows the main differences between edge computing and cloud computing.

Objectives of the study

- To learn about edge computing architecture
- To explore the relationship between cloud and edge computing
- To explore the key technologies that enable edge computing
- To explore edge computing privacy and security standards and to continue writing more edge computing application scenarios

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The Benefits of Edge Computing

Data is processed and stored on aspect devices using the edge computing technique in preference to being uploaded to a cloud computing platform. This function makes face-to-face computing virtually superior in the following areas: The short processing and real-time evaluation of facts, coupled with the strain on community capability and the amount of data growing rapidly, are drawbacks of cloud computing. Edge computing has advantages over everyday cloud computing in terms of real-time and reaction speed. Because aspect computing is located towards the records supply, fewer intermediate information transmission steps are required due to the fact that edge computing nodes may additionally take care of each compute and statistics garage capabilities. By prioritising closeness to customers and providing superior, shrewd services, it complements data transmission performance, ensures on-the-spot processing, and minimises latency. Rapid feedback is in particular important within the fields of computerised using, sensible manufacturing, video surveillance, and other region consciousness, wherein edge computing offers customers a range of quick reaction services. Security: Under traditional cloud computing, all records need to be transferred to the cloud for us to use centralised processing techniques like unified processing. There are dangers associated with this technique, including the opportunity for data loss and leakage, which cannot assure security and privacy. Trade secrets, beyond search histories, and account passwords, for instance, may all be made public. Since aspect computing is restricted to the operations that fall within its purview, fact processing is executed domestically as opposed to being uploaded to the cloud, keeping off the dangers related to community transmission and ensuring statistics security. Only local information is impacted by statistical attacks; worldwide statistics aren't. Low price, low strength consumption, low bandwidth value: the load on network bandwidth is minimised in side computing because the processed statistics do not want to be uploaded to the cloud computing centre. This also substantially lowers the power consumption of smart gadgets at the community's fingertips. Because part of computing is "small-scale corporations may additionally lower the fee for processing information on-website through the use of local systems. As a result, area computing lowers the volume of information sent over the community, lowers the cost of transmission and the pressure on community bandwidth, lowers the energy consumption of close-by devices, and increases computing performance.

Table 1. Key distinctions between edge and cloud computing

	Appropriate condition	**Network Bandwidth Pressure**	**Actual Time**	**Computation Type**
Cloud Computing	Global	More	Higher	Large Scale Centralized Processing
Edge Computing	Local	Less	Lower	Small Scale Smart Processing

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Architecture of Edge Computing

Edge computing is visible as one of the essential technologies in the subsequent era of communication networks, after the Internet of Things and artificial intelligence, with the arrival of 5G and the Internet of Everything. Many organisations specialise in the edge computing reference structure. This component starts with a precis of the brink computing standard structure. Then, it offers a full introduction to the reference architectures put out by the Linux Foundation and the Edge Computing Industry Alliance, respectively.

Overall Design of Edge Computing

By placing area gadgets among terminal devices and cloud computing, side computing architecture is a federated community topology that brings cloud offerings to the periphery of the network. Generally speaking, the cloud computing layer, edge layer, and terminal layer make up the framework of cloud-edge collaboration. The association and purposes of every layer inside the aspect computing structure are in short defined inside the sections that comply with them.

1) The terminal layer: All device types linked to the brink network, which include mobile terminals and lots of Internet of Things devices (which include sensors, smartphones, clever motors, cameras, and so forth), make up the terminal layer. The device serves as both an information supplier and an information patron on the terminal layer. Only the belief in the special terminal gadgets is taken into account, not the processing power, with the intention of decreasing terminal carrier latency. Consequently, a huge array of unprocessed facts is accrued via masses of millions of terminal layer gadgets and sent to the top layer for storage and computation.

2) Boundary Layer: The important issue of the 3-tier layout is the brink layer. It is located on the community's edge and is made from broadly dispersed edge nodes that join terminal devices and clouds. Base stations, get-right-of-way factors, switches, routers, gateways, and other components are often protected. The edge layer computes and stores the information that terminal devices upload, as well as facilitating the access of terminal gadgets downstream. Establish a cloud connection and add the processed facts there. Data transmission to the edge layer is better suited for real-time information evaluation and sensible processing; that's more efficient and secure than cloud computing on the grounds that the edge layer is towards the person.

3) Cloud Layer: The most amazing statistics processing centre for most of the federated services of cloud-edge computing continues to be cloud computing. The cloud computing layer is made up of many excessive-performance servers and garage gadgets with strong processing and storage capacities. These devices can be useful for responsibilities involving a variety of information evaluations, such as ordinary maintenance and business selection aids. The edge computing layer's mentioned information can be completely saved by way of the cloud computing centre, which can also carry out processing activities that combine worldwide records and examine facts that the threshold computing layer is unable to address. Furthermore, according to the control coverage, the cloud module has the ability to dynamically adjust the threshold computing layer's deployment strategy and algorithm.

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Edge Coaching Directory 3.0

The China Academy of Sciences, Huawei, Shenyang Institute of Automation, China Academy of Information and Communications, and other distinguished companies mutually launched the Edge Computing Consortium (ECC), which provided the Edge Computing Reference Frame 3.0 inside the Edge Computing White Paper 3.0 that was posted in December 2018. The model-driven engineering approach serves as the inspiration for the framework. We ought to fulfil the subsequent 4 goals as a way to represent the information of the actual and virtual worlds:

1) Create a methodical and real-time cognitive model of the bodily surroundings and bring the virtual and physical worlds together;

2) Create reusable know-how version structures based totally on modelling strategies in each vertical region and attain go-industry ecological collaboration;

3) To lower machine heterogeneity and attain the decoupling of software interface and improvement language, system to device, service to carrier, and other version-based total interface for interaction;

4) Able to successfully cope with facts processing, security, deployment operations, and the existence cycle of development offerings.

The ECC side computing reference architecture, as shown in Figure 1, shows the architectural content in a multi-view format from many angles, and the multi-layer useful angle illustrates the functioning of each layer.

An underlying service layer of the edge reference framework connects all of the framework's services, along with control, data lifecycle, and security services.

Unified control, architectural operation monitoring, and statistics provision to the control platform are all supplied through management services. In addition to visualising and storing device facts, the statistics lifecycle carrier incorporates administration for pretreatment, evaluation, dissemination, and execution. Through the commercial enterprise layer, the safety provider may specify the commercial enterprise logic for the whole statistics lifestyle cycle, install and optimise the data provider flexibly, and fulfill the business enterprise's actual-time desires. To assure the secure and dependable functioning of the whole structure, security offerings use the unified protection management and belief system, cover all tiers of side computing architecture, and adapt to the precise architecture of edge computing.

The model-pushed unified service framework is at the pinnacle of its size to enable the introduction and deployment of services while being visible from the perspective of vertical structure. The side calculation general framework divides it into three layers: cloud, part layer, and subject layer. The area manager and the threshold node make up the two primary components of the threshold layer.

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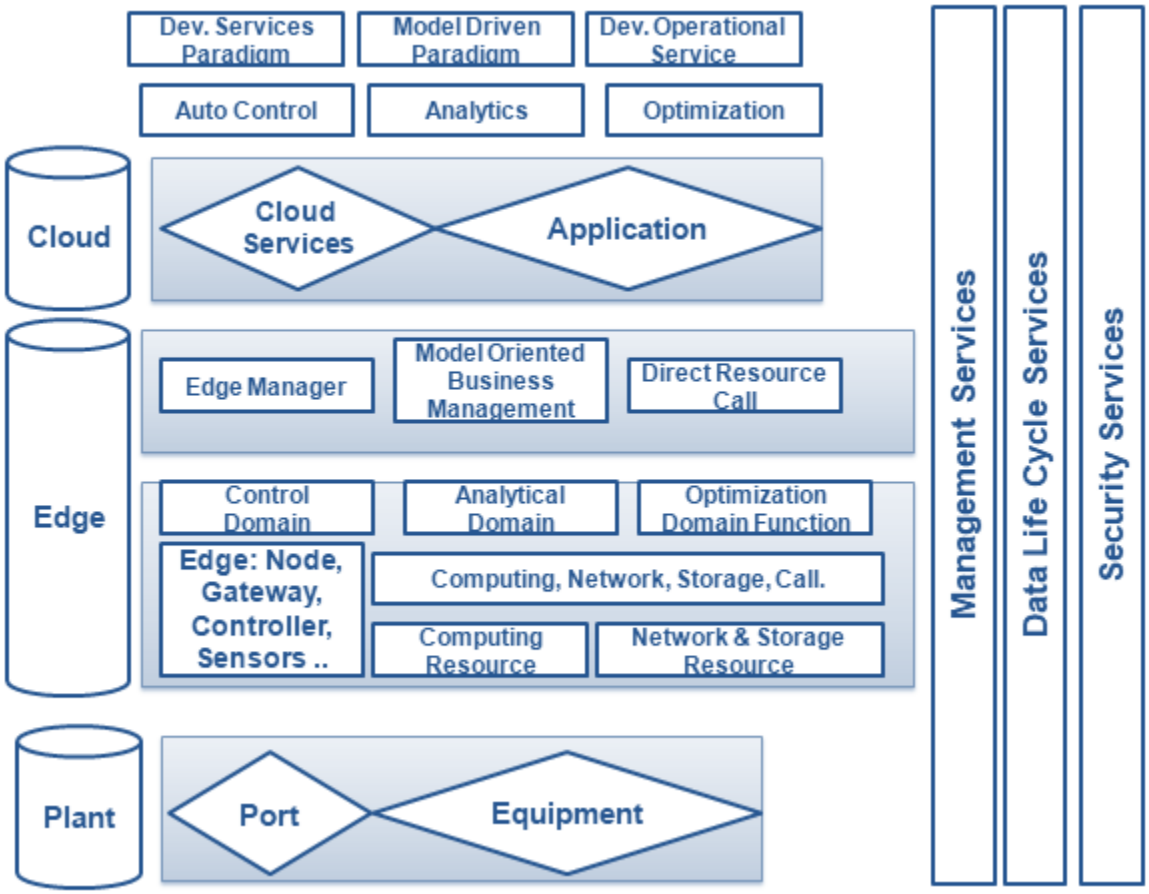
The hardware factor that powers edge computing is referred to as an edge node. Software is basically utilized by the edge manager to handle side nodes consistently. Edge computing nodes are categorised into edge gateways that technique and convert community protocols, aspect controllers that control actual-time closed-loop services, edge clouds that deal with large quantities of statistics, and edges that gather and system inexpensive information based totally on the hardware capabilities and carrier types.

Fig 1. Edge computing reference architecture 3.0. [Lorenzo Ricciardi Celsi, 2022]



The devices at the threshold computing layer may be abstracted into networking, storage, and processing via sensors, etc. Next, use application programming interfaces (API) to put into effect widespread capability calls. The making of plans for nearby aspect assets and the realisation of statistics transfer between better and lower layers are carried out with the aid of the control, analysis, and optimisation area feature module. Four provider improvement frameworks—light-weight computing systems, actual-time computing structures, smart distributed systems, and sensible gateway structures—from the terminal to the cloud are offered with the aid of Edge Computing Reference Architecture 3. 0.

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Foundry EdgeX

EdgeX Foundry is an international open architecture for computing on the brink of the Internet of Things, and it's miles housed through the Linux Foundation as a neutral open source mission. The framework unifies the computing open platform at the brink of the Internet of Things and accelerates answer deployment by way of enabling plug-and-play component surroundings hosted on a reference software platform. This is definitely impartial of hardware and operating structures.

The EdgeX Foundry architecture is seen in Figure 2. The picture illustrates that all IoT software devices capable of direct verbal exchange with the edge network are covered inside the Southbound" category. The cloud computing centre and the communique community with FIGURE 2 are located inside the Northbound." The structure of the EdgeX foundry centre for cloud computing. The source of the statistics is Southbound;" and Northbound" is used to acquire, save, combine, and examine the statistics from the south. The EdgeX Foundry is made from two underlying upgraded device offerings and a collection of microservices organised into four service layers. It is located between the south and northbounds.

From a vertical perspective, the Southbound" gadgets' communique linkages are set up through the use of the software development kit (SDK) that the tool carrier layer offers. Data from the tool is converted by means of the device service layer before being sent to the centre service layer.

Additionally, it has the ability to supply orders to devices from other microservices. Several entry mechanisms are available with EdgeX Foundry, including Bluetooth Low Energy (BLE), Virtual Device (VIRTUAL), and Messaging Queue Telemetry Transmission Protocol (MQTT).

It is critical to achieving area skills as the centre's primary service layer. Core data, instructions, metadata, registry, and configuration are the four micro-carrier components that make up the middle carrier layer. Device data control and garage are offered through the middle facts carrier. The command provider is in charge of translating the operation instructions from the device record right into a universal API, keeping and caching commands, and allowing the device side to receive needs from the cloud computing centre. Device and service coupling is made feasible through metadata. Other micro-services may be configured with the assistance of registration and configuration services. The rules engine, scheduling, alerting, and logging services for the framework itself are supplied by means of the guide carrier layer, along with part evaluation and intelligent offerings. To guarantee EdgeX Foundry's self-sufficient operation, the utility and export provider layers may be linked to the cloud computing centre to ship facts there. The distribution carrier exports the associated facts to the unique customer, while the consumer registration provider exports the pertinent facts from the lower back-cease registered system to the export service layer.

The EdgeX Foundry architecture offers a primary carrier layer that extends across the complete framework, inclusive of management offerings and security services, similar to the Edge Computing Reference Architecture 3.Zero. The EdgeX Foundry control provider performs tasks that include installation, upgrades, starting, halting, and operation monitoring.

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The security service's components are used to safeguard both the device's capability and its records. In order to streamline and standardise part computing for the Industrial Internet of Things, the EdgeX Foundry framework was created. It offers an operational open-source platform that permits all micro-services to perform as boxes on a number of working structures and allows dynamic feature addition and discount with first-rate scalability. Currently, EdgeX Foundry's software sectors span some industries, such as manufacturing, retail, strength, urban parks, transportation, and other industries.

Hot Research Content of Edge Computing

Primary Technologies: These are the core technologies so as to pressure edge computing ahead. Computed offloading is one of them; it includes selecting which activities to offload from gadgets, in what portions, and at locations that minimise latency and strength intake. Mobility control effectively manages sources to provide a clean person with enjoyment even as they shift. By rerouting visitors to nearby assets, visitors offloading lessen the call for valuable network assets. By keeping clothing towards customers, caching acceleration enhances the consumer experience. Effective control of community resources via community management helps area computing packages.

Privacy and Security of Data: It is critical to defend statistics safety and privacy in the subject of side computing. Data security is the procedure of ensuring the confidentiality and integrity of facts through the use of audits, get-ins to manipulate, and encryption. Entities in dispersed situations with one-of-a-kind levels of belief are established by means of identity authentication. Using methods like K-anonymity, privacy protection secures user facts, vicinity, and identity. To govern data entry, access manipulation includes installing region-specific manipulation mechanisms based totally on duties and traits.

Unrestricted Research Pathways: These are instructions for additional aspects of computing research and improvement. Devices at the threshold need security solutions that might be both lightweight and powerful. For real-time information processing, dynamic and quality-grained fact-protection techniques are important. It is critical to have multi-area rights of entry to manage structures that feature throughout numerous agreed-upon domains. In conditions where statistics sharing and collaboration are involved, privacy protection in collaborative contexts is vital.

Upcoming Research Patterns: These consist of the anticipated paths and focal points for future edge computing research. In order to provide entire protection, they entail integrating security technologies from associated fields, emphasising allotted and lightweight security systems, investigating privacy-maintaining encryption algorithms, growing secure pass-domain authentication protocols, and growing exceptional-grained get-admission-to-manage that takes into consideration exclusive user elements.

Edge Computing Application Scenarios

Edge computing has numerous one-of-a-kind utility scenarios, each of which uses its skills to clear up positive problems:

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Video Cache for Edge Computing: Because of the rapid growth in internet site visitors, mainly for video material, bandwidth utilisation needs to be completed efficiently. By using Multi-Get Admission to Edge Computing (MEC), customers may additionally enjoy improved person experience and reduced bandwidth use by caching famous films in the direction of their vicinity. MEC enhances quality of experience (QoE) and community efficiency by optimising content based totally on real-time network information.

5G and Edge Computing: Edge computing has the ability, while 5G networks come online. By taking advantage of 5G's high capability and coffee latency, aspect computing can dynamically distribute resources throughout cloud, area, and IoT devices, facilitating collaborative optimisation and fostering creative applications.

Live Video Broadcast via Edge Computing Network: By setting side nodes in locations and allowing visitors to view locally stored movies, area computing complements real-time video broadcasting. By achieving millisecond-stage latencies and permitting excessive-definition stay feeds for lots of off-web page users; this drastically cuts down on live broadcasting delays.

The use of predictive upkeep Predictive maintenance, which makes use of real-time statistical evaluation to function gadgets, is added with the aid of Industry 4.0. Because of its near proximity to gadgets and effective perceptual capabilities, aspect computing enables real-time analysis that enables the detection of gadget disasters, minimises downtime, and enhances dependability. It tackles the difficulties of overseeing huge terminals and guaranteeing actual-time evaluation at the same time as maintaining the privacy of industrial information.

Security Monitoring: When high actual-time speed and anonymity are required, aspect computing improves safety tracking. It reduces the latency and privacy hazards associated with cloud-primarily-based processing with the aid of processing records regionally. Technologies together with Hikvision's 'Deep Eyes' digicam use synthetic intelligence (AI) algorithms at the edge to analyse behaviours offline and optimise security in vital areas. Meanwhile, research in academia is investigating designs that optimise device overall performance and minimise network site visitors. These examples show how side computing programmes may be used to clear up issues in a whole lot of fields, inclusive of enhancing consumer confidence and bandwidth optimisation and making certain actual-time evaluations in contexts in which protection is a difficulty.

Conclusion

To sum up, edge computing is at the forefront of technological development, offering answers to the problems added on through developing record desires. Its design, which's made up of layers for the cloud, edge, and terminal, represents a decentralised method that improves performance, pace, and security. Computed offloading and mobility control of the essential technology underlying computing enable real-time data processing while slicing latency. Using the right of entry to regulations, authentication, and encryption, statistics security is still of maximum importance. To enhance its usefulness, destiny study instructions focus on go-area get-right-of entry to management and light-weight protection solutions. The huge variety of uses for facet computing, from video caching and bandwidth optimisation to predictive preservation and

advanced safety tracking, highlight its enterprise-converting ability. Edge computing promises to transform information processing as it develops and combines with new technology like 5G. This will offer real-time evaluation, enhance person trust, and preserve efficiency and statistical privacy.

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