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Review of Edge Computing for the Internet of Things (EC-IoT): Techniques, Challenges and Future Directions

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Abstract
The volume of edge data has reached ZB level, placing enormous strain on the core network bandwidth due to the rapid development of contemporary technology and the quick expansion of the number of smart devices accessing wireless networks under IoT. On the other hand, numerous new applications, such as autonomous vehicles, location recognition, augmented and virtual reality, etc., have proposed stricter standards for network latency, jitter, data security, etc. Edge computing (EC) emerged as a response to the shortcomings of traditional cloud computing in these areas. Edge computing is a new computing paradigm that performs computation at the network's edge and can meet the critical needs of various industries undergoing digital transformation thanks to its ability to provide intelligent interconnection services in close proximity to the edge. It follows in the footsteps of previous computing paradigms such as distributed computing, grid computing, and cloud computing. This article presents a thorough analysis of current findings and accomplishments in the field of edge computing, as well as a prediction of potential directions for its future growth.

Keywords: Edge Computing, Internet of Things, EC-IoT Review, EC-IoT Techniques, EC-IoT Challenges, EC-IoT Future Direction.

1. Introduction

The Internet of Things (IoT) is an innovative method of interconnecting discretely addressable physical and digital items using standard network protocols. There will be 50 billion IoT devices with wireless connections by 2025, according to estimates [1]. Smartphones, bio-nano-objects, body sensors, smart tags, wearable gadgets, embedded items, and conventional electronics are all possibilities [2]. Sensors in these devices capture a lot of data, resulting to exponential data growth; as a result, the data transfer rate and network capacity in the cloud computing paradigm may create bottlenecks, preventing the expansion of enormous IoT [3]. Moreover, sending all IoT data to distant cloud servers is not acceptable since it creates security and privacy concerns because most IoT devices produce personal and sensitive data. Some time-sensitive applications (such interactive cloud apps, collaborative autonomous driving, etc.) have trouble with the low cost, high performance, and ultra-low latency requirements of cloud computing because of its centralised structure. With these limitations of cloud computing in mind, edge computing is offered as a viable alternative. Edge computing is a major enabling technology for the 5G era, since it employs an open platform with fundamental network capabilities, processing resources, and data storage to give customers with nearest-end services. Figure 1 also demonstrates the dissimilar geographic distribution of cloud and edge computing, proving that edge computing is not a substitute for cloud computing but rather an extension and complement to cloud computing. This means that edge computing is superior for use cases requiring safe, real-time intelligent analysis of data.

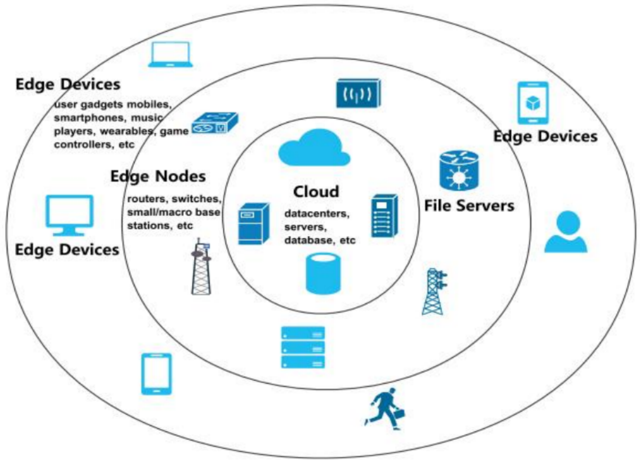

Figure 1: Cloud, Edge Nodes, and Edge Devices

Computing data, applications, and services are shifted from remote cloud servers to localised devices at the network's periphery, a process known as edge computing. Edge computing allows content providers and app developers to place services closer to end users, which may reduce latency. High bandwidth, ultra-low latency, and near-instantaneous access to network data are hallmarks of edge computing [4, 5]. Many Internet of Things applications need near instantaneous responses, encrypted data transfers, and strict privacy safeguards. When it comes to large-scale IoT applications, edge computing has the potential to outshine cloud computing. The Internet of Things and edge computing both aim to provide seamless computing at any time and from any location, but they serve distinct purposes. The Internet of Things (IoT) and edge computing (EC) are complementary technologies with intriguing uses. The Internet of Things (IoT) is now employed in several complicated situations, including smart homes, smart cities, smart grids, VR/AR, autonomous vehicles, etc. Therefore, we think that edge computing is crucial for the future of the Internet of Things, and that there is academic promise in studies that combine IoT with edge computing.

In this paper, we provide a concise summary of current efforts and historical work, as well as our thoughts on the way forward for this field of study. From the standpoint of convergence with new technologies, this article surveys the most recent findings in edge computing research in the Internet of Things age, assessing the difficulties encountered and the potential presented by edge computing. This survey continues with an introduction to IoT and edge computing in Section 2, followed by a discussion of edge computing technologies in Section 3. The section titled "Lessons Learned, Open Challenges, and Future Research Directions" details what was discovered and where more study is needed. Section 5 provides our last thoughts.

2. The Development of IoT and Edge Computing

Here, we start with a high-level look at how the Internet of Things (IoT) and edge computing have evolved over time.

2.1 Internet of Things

In the Internet of Things (IoT), anything in the physical world is able to be linked to the network so it may be accessed online. IoT devices may cooperate together to accomplish the tasks in [6] by using specialised addressing systems. The biggest benefit of the IoT is the massive change it can bring to people's routines and their possible actions as users [7]. Industry and academics alike have shown a considerable lot of interest in the IoT [2, 8]. Virtual reality (VR), augmented reality (AR), and driverless vehicles are just a few examples of the growing variety of IoT applications that rely on allowing real-time reactions [9]. Due to factors like distance and network instability, cloud computing's latency is sometimes too high to support real-time applications. More than that, the transmission performance suffers due to the enormous volume of data. Allocating bandwidth and computing resources effectively is so difficult [10]. Different data formats and communication protocols make the IoT a vertically fragmented network system, which adds to the difficulty of achieving the requisite low-latency performance in the IoT domain [11]. Most Internet of Things devices are limited by their battery life, so it's important to strike a balance between the two. Increased use of generic operating systems is being seen in the Internet of Things. Numerous organisations and universities have dedicated substantial resources to studying IoT operating systems. Common examples of IoT OSes are LiteOS, Contiki, Win10 IoT, FreeRTOS, and mbedOS [12]. The basic architecture of an IoT operating system is shown in Figure 2.

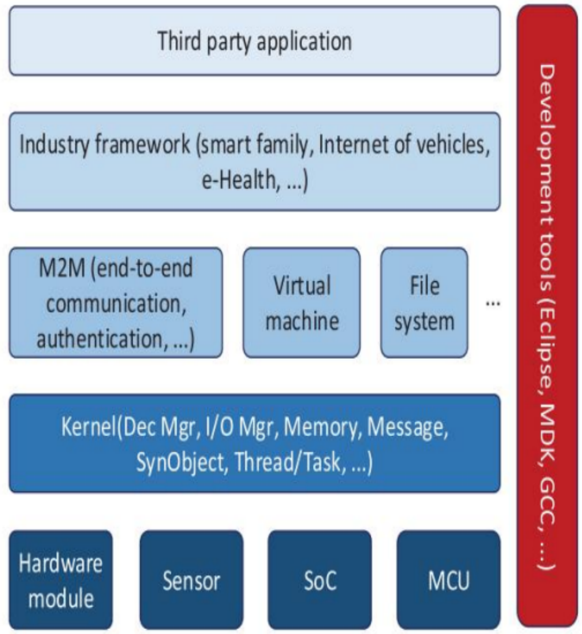

Figure 2: A Typical IoT Operating System Infrastructure

The Internet of Things (IoT) has already had a significant influence on our lives, but there are still numerous issues that need to be investigated before they can be fully addressed. A major problem is how to meet the demand for security without sacrificing the benefits of interoperability and connectivity among IoT devices. Moreover, IoT gadgets often have insufficient processing and power resources. Thus, the new computing paradigm should also aim to improve efficiency with regards to resources, in addition to scalability. In this regard, the new computer paradigm known as "edge computing" may be of great assistance to the Internet of Things.

2.2 Edge Computing

Some computer operations are moved from faraway cloud servers to local edge servers, and this is what is meant by "edge computing." It does the preliminary processing and analysis of data locally, close to the source. Edge servers may provide quicker response times than cloud servers since they are physically located near the devices producing the data. Whereas, cloud computing's strengths lie in its provision of both global scheduling flexibility and extensive computational resources. Similar to edge computing, Cisco's planned fog computing (FC) in 2012 is a highly virtualized platform that mediates between end users and cloud servers to provide processing resources, storage, and control [13, 14]. We will refer to both FC and edge computing as "edge computing" throughout this assessment. Numerous research efforts have focused on improving cloud computing in Internet of Things (IoT) contexts [12, 15]. An example of such a hybrid architecture is CloudThings, suggested by Zhou et al. With this architecture, IaaS, PaaS, and SaaS may more easily create and manage IoT applications in the cloud [16]. Pacheco et al. suggested an architecture that combines cloud computing and the Internet of Things while protecting user privacy. Without a secure transport layer protocol, this architecture presents a method to encrypt data produced by IoT devices [17]. While cloud computing has the potential to greatly benefit the Internet of Things, its use is currently limited by a number of factors [18]. These include the need for instantaneous responses, large amounts of data flow, and minimal power use. One possibility is to suggest a new computer paradigm that does away with these issues altogether. Shi et al. [3]'s survey of the relevant literature is one of the most comprehensive and influential in the field. Their research provides the academic community with a clear description of edge computing and highlights the difficulties associated with it. However, they suggest dated approaches to the problems plaguing edge computing at the moment. They don't look into the prospects that new technology provides. The fundamental uses and significance of edge computing in practical situations are highlighted by Khan et al. [4]. However, the potential of emerging technologies and emerging trends in edge computing is only partially explored in their work. The potential and problems in this field are covered by Varghese et al., however the discussion of each is treated independently and does not make a cohesive whole [19]. Another recent overview is provided by Carvalho et al. [20]. In particular, they examine the potential applications of various edge computing architectures and identify areas for further study. Not enough has been said about how edge computing may work in tandem with innovations from other fields. According to Satyanarayanan et al., "edge computing" is a novel computing architecture that places data processing and storage nodes (such as microclouds, microdata centres, and fog nodes) closer to the network's periphery, where mobile devices and sensors are placed [21]. Computing resources and networks located between the cloud and the end device are collectively referred to as the "edge" [22]. The endpoint layer, the edge layer, and the cloud layer make up the three main tiers of edge computing's architecture. Figure 3 depicts this hierarchy, which specifies the computing capabilities and features of edge computing components. In particular, we talk at length about how to address the problems that have arisen up to this point in new ways.

Mobile devices' processing needs are well-served by the edge computing architecture of the Internet of Things. Computing at the network's edge, especially on mobile devices, is crucial to this design (MEC). MEC is an innovative idea that merges IT and telecom to bring computing, storage, and processing to the realm of wireless networks. As a result, more and more portable gadgets, like smart watches, may readily connect to the Internet of Things. To solve this problem, Yaser et al. presented a multi-layer architecture built from MEC servers and Cloudlets [23]. The purpose of this layout is to broaden the range of mobile signals. It also enables customers to finish the services they have requested while incurring minimum energy and response delay costs. With the MEC solution, certain cloud operations may be brought closer to the mobile network's edge, which improves both bandwidth and latency. In contrast to the general architectural model, the mobile hardware architecture finds widespread use in the area of communication, where issues of data processing in communication are tackled by means of various software-defined network (SDN) controllers and virtualization [24].

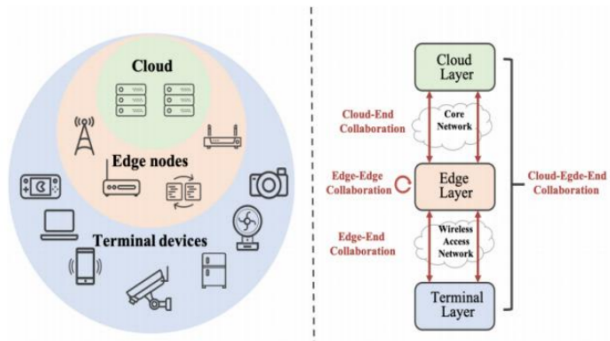

Figure 3: Three-Tier Edge Computing Architecture and Collaborative Cloud Edge-End Framework

3. The State of Edge Computing Technology in IoT

Many advancements have been achieved in many areas that have a major performance influence on edge computing in the IoT, which uses sensor, communication, and data processing technologies to link a vast array of components. Next, we provide a survey of the state of the art in six key areas: edge computing architecture, routing techniques, job scheduling, data storage and analysis, edge security schemes and algorithms, and standards.

3.1 Edge Computer-Driven Architecture for the Internet of Things

3.1.1 Common Hardware Architecture

IoT, in particular, not only provides fresh access points for big data analytics, but also brings dispersed data sources to the periphery of the network. A generic hardware design was presented by Bonomi et al. that may be used to a wide variety of Internet of Things use cases [25]. There are several advantages to the generic hardware architecture, such as its low-cost setup, simple maintenance, and ability to fulfil the requirements of generic Internet of Things designs. Edge devices, networks, communication units, and cloud platforms are all part of the proposed distributed hierarchical data fusion architecture for IoT networks presented by Dautov et al. [26]. The processing capacity of intermediate nodes is used to combine data from many sources throughout the IoT's tiers in order to provide fast and reliable results.

3.1.2 Software Defined Hardware Architecture

A hardware design was developed by Salman et al. that makes use of emerging technologies like software-defined networking (SDN) and virtual network functions (VNF) [24]. To enhance network scalability and save costs, this architecture is used to construct and flexibly manage dispersed edge networks. Services and workloads in a typical factory are typically more it-centric (e.g., factory data centres) and transition to ot-centric as they travel down the production line (e.g., factory machines). Because it allows plant managers to better react to future demands, software-defined resource allocation and management is gaining traction in the edge computing paradigm. When looking at the network architecture, this translates to software-defined networks (SDNs) that deploy virtual network functions (VNFs) everywhere in the facility. By definition, a software-defined network (SDN) is a network architecture in which the data plane's forwarding state is governed by a remote-control plane that is separated from the data plane [25]. To streamline the administration of the Internet of Things, Yaser et al. present a thorough framework model predicated on software definitions [26]. It hides the complexity of conventional system designs by moving control and management tasks away from the underlying devices and onto a middleware layer. It's a methodology for sending and storing data created by IoT gadgets via unified software, and it works particularly well in edge computing and edge network settings. Software-defined architecture was developed by Qin et al. by expanding the Multi-Network Information architecture (MINA) [27]. MINA is a piece of middleware that includes an IoT SDN controller with many layers. The IoT SDN controller was created to accommodate several scheduling instructions. As an added bonus, genetic algorithms may be used by the framework to fine-tune the infrastructure of the Internet of Things. This design allows for QoS to be tailored to individual Internet of Things (IoT) use cases across a wide variety of wireless network topologies.

3.1.3 Hybrid Hardware Architectures

Many scientists are interested not only in generic and mobile designs, but also in hybrid architectures. A more adaptable Internet of Things design, edgeIoT, was presented by Sun et al. [28]; it makes advantage of fog computing to gather data at the network's periphery. Edge cloud, introduced by Chang et al., is a hybrid cloud architecture concept with the same goals as the previous two [29]. Similar edge computing architecture was presented by Munir et al., who also developed a hierarchical fog node architecture suitable for use in fog computing [30]. Munir's bottom-up abstraction extends to its application, analysis, virtualization, and hardware layers, which isn't the case with edgeIoT. The layering of the architecture makes it possible to abstract and implement a distributed and multi-vendor edge computing paradigm. The architecture evaluates the nature of the applications being used and adjusts the fabric's capacities as needed to ensure that the most mobile services are being used at all times. The edge computing industry has not yet agreed on standardised definitions, designs, and protocols, despite the fast growth of edge computing technology [3]. Architectures such as multi-core computing, multi-access computing, fog computing, and the cloud are all present at the edge. Even if their ideas are similar and their borders are fuzzy, there are still distinguishing features that allow us to tell them apart, and Figure 4 summarises the most important similarities between them.

Feature	Mobile Cloud Computing	Mobile Edge Computing	Fog Computing	Cloudlet Computing
Requirements for Infrastructure	Yes	Yes	Yes	Yes
Ultra-low Latency	No	Yes	Yes	Yes
Distributed Geographically	No	Yes	Yes	Yes
Support for Multiple IoT Applications	No	No	Yes	Yes
Standardized	Yes	Yes	Yes	No
Support for Large-scale Application	No	Yes	No	Yes
Support for Real-time Application	No	Yes	Yes	Yes
Location Awareness	No	Yes	Yes	Yes
Support for Heterogeneity	Yes	Yes	No	No

Figure 4. Features in Four Common Edge Computing Models

3.2 Strategies for Routing

The overhead and latency of Internet of Things (IoT) real-world application deployments may be minimised using efficient and stable routing algorithms for massive sensor networks with complicated topologies and massive volumes of real-time data. Both traditional and software-defined networking (SDN)-based routing methods will be shown.

3.2.1 Conventional Routing Schemes

Extant studies reveal that several traditional routing strategies are developed primarily based on the location and energy of edge nodes, and are therefore typically appropriate for the circumstance when IoT edge nodes are stationary and have constrained resources. N-SEP [31], ERRS [32], FERP [33], and GPSR-3D [34] are only a few examples of traditional routing algorithms that excel in the scenario where IoT edge nodes are stationary and have constrained resources. The new stable election protocol (N-SEP) is one such protocol that takes into account sensor nodes in fog [31]. The Internet of Things (IoT) devices are grouped together according to their energy needs, and the optimum routing route is determined by the path that uses the least amount of energy and has the fewest number of hops, as described in Energy-aware real-time routing scheme (ERRS) [32]. After device clustering, FERP uses the FECR algorithm to route between fog nodes, whereas the FEAR algorithm routes between fog nodes and the cloud [33]. IGR [35], CRPV [36], EEMSFV [37], and MCGT1 [38] are only a few examples of traditional routing methods that are tailored specifically to mobile IoT edge nodes. In this scenario, packets are sent from the source vehicle to the destination vehicle using enhanced greedy routing utilising the Improved Geographic Routing (IGR) protocol [35]. Selecting the best gateway quality indicator vehicle for cluster-based delivery of emergency video streams is accomplished with the help of the Collaborative Routing Protocol for Video Streams (CRPV) [36]. Using software-defined networks and fog computing, the Energy Efficient Multicast Routing Protocol for Telematics (EEMSFV) determines the least-energy-intensive multicast routing [37]. The first version of Mobile Cluster Game Theory (MCGT-1) [39] creates a game model for heterogeneous clustering with the goal of achieving cluster head selection and multi-path routing with minimal energy consumption.

3.2.2 SDN-Based Routing Methods

SDN is an up-and-coming networking technology that is slowly being used in edge computing for the Internet of Things [40]. For instance, incremental traffic scheduling and routing (IFSR) methods [41] in time-sensitive soft-defined networks (TSSDN) aggregate global topology and traffic information and calculate time-triggered traffic plans live. Congestion in edge networks may be mitigated with the help of a multi-objective evolutionary algorithm based on Chebyshev decomposition, as shown by the SDN-based Edgecloud Interplay Scheme (SEIS) [42]. To choose the optimal routing route from among viable options, the Software-Defined Network-based Adaptive Transport Optimization Scheme (ATOS) computes the path difference degree (PDD) of pathways [43]. Using a software-defined networking (SDN) strategy, a routing technique based on the fuzzy Dijkstra routing algorithm (FDRS) may dynamically reroute data during transmission [44]. SDN-based routing schemes have several advantages over traditional routing schemes, including the ability to develop and optimise schemes based on global network and node information, partition data flows, and modify routing paths to achieve more complex scheduling policies in response to fluctuating demand. Nonetheless, the constant aggregation of edge node data raises the bandwidth and energy requirements to some amount. SDN-based solutions also tend to take into account more optimization targets, which means they use more computing resources and introduce additional decision delay.

3.3 Task Scheduling

Task scheduling is crucial for managing a large number of edge computing nodes, dividing work fairly, and combining the outputs of computations in a way that conserves resources, speeds up processing, and keeps latency to a minimum and ensures even load distribution. Scheduling systems for edge computing in the Internet of Things are often developed in response to concerns about latency and energy consumption, and the associated scheduling approaches are described below.

3.3.1 Delay Minimization Scheme

Use of the Fog Node Collaboration Policy (FNCP) to reduce task latency [45]. The entire job processing delay is reduced by the fog-to-fog communication system (F2FCS) [46]. The Decentralized and Stable Task Scheduling (DATS) scheme utilises Progressive Computing Resource Competition (PCRC) and Quality-of-Experience-oriented Synchronous Task Scheduling (STS) algorithms to offload tasks synchronously to multiple neighbouring nodes with heterogeneous capabilities, allowing for parallel task execution and lowering task processing latency [47]. For time-critical operations, the best scheduling strategy is provided by the Delay Minimizing Task Offload (DMTO) algorithm [48]. The aforementioned approaches take delay into account as an optimization aim, however since device energy is finite, they may cause an uneven distribution of load between devices and reduce the system's lifespan.

3.3.2 Energy-Delay Tradeoff Schemes

We must also think about energy-delay tradeoff strategies. To overcome this problem, the HyFog framework employs Edmonds' Blossom algorithm, which reduces the time and power needed to complete a job to an absolute minimum [49]. This issue is ideally addressed by the work scheduling method proposed in Optimal Workload Allocation Scheme (OWAS) [50]. With the help of specifying the control parameter V, the Delay Energy Balance Task Scheduling (DEBTS) technique improves delay and energy performance for task scheduling in fog networks [51].

3.4 Data Storage and Analysis

Edge computing-based distributed data storage is highly distributive. The security concerns associated with insufficient security protection of edge devices must be taken into account when deciding upon a storage solution, along with the need to maximise storage space efficiency and storage capacity parity among edge nodes [35–38]. After that, we'll go through the methods for archiving and analysing data.

3.4.1 Data Storage

scenario of the Internet of Things, especially for devices with constrained hardware and software capabilities. For instance, the Edge Collaborative Storage Framework (ECSF) optimises data storage rules among edge servers in order to enable collaborative edge server storage [45]. The Distributed Key Value Storage Platform (DKSP) is the basis for another cooperative storage method [46]. Edge-local federated storage system ELFStore is described [47]. To accomplish fog-aware replica placement and context-sensitive disparity consistency in fog storage, FogStore employs NFV and stateful applications [52].

3.4.2 Data Analytics

Data analytics for edge computing in IoT has been the subject of several research efforts, in addition to distributed data warehouses. For instance, the linear regression issue of edge nodes is solved by the Edge Stochastic Gradient Descent (EdgeSGD) method, which then predicts the feature vectors of edge nodes for use in further data processing [37]. The Fog Linear Regression Component Decomposition Computing Scheme (FLRCDCP) is a distributed predictive analytics model that uses multiple linear regression fog-specific decomposition based on statistical query models and summation tables to significantly reduce the amount of data sent to the cloud platform. Data produced by edge devices may be locally processed and refined using the Big Data Analytics Architecture (BDAA), hence reducing the amount of data sent to the fog server. In order to effectively analyse the streaming data and communicate the derived information to the lower levels, the fog server runs distributed machine learning algorithms.

3.5 Security

There are risks to data, networks, and devices in every industry. The distinction, however, is that the attribution of data to edge devices has increased the significance of edge security with regard to edge computing in the IoT. It is increasingly challenging to secure edge networks and data due to the increased complexity of IoT networks based on edge computing and the comparatively insufficient security of edge devices, networks, and data.

3.5.1 Network security

For edge network security Malicious assaults, such as key attacks [42], traffic attacks [40], routing attacks [53], and distributed denial of service attacks [45, 46], must be defended against, and the accompanying solutions must take into account the computational capacity, bandwidth, and latency of the edge network. Research on edge network security for the Internet of Things now focuses mostly on methods of both detecting and countering attacks. Critical attacks on IoT devices in fog settings may be identified and detected with the use of machine learning techniques, as shown by the LSTM-based Distributed Network Attack Detection for Fog Networks (LDNAD) scheme. Grid-connected smart metres are protected against bogus data injection attacks by the HD-IDS, a hierarchical distributed intrusion detection system. An efficient technique for detecting prospective routing assaults by malevolent neighbours in edge-based IoT settings is provided by the Routing Attack Detection Scheme in Edgebased IoT (RAD-EI). To better identify traffic injection attacks, the Real-time Traffic Monitoring System (RTMS) conducts in-depth packet inspection and matches with SQLI patterns in the IDS database to build signature rules [38]. Powerful data analysis capabilities are employed to evaluate DDoS assault behaviour and relay detection information to the fog computing layer in the multilayer DDoS mitigation framework (MDMF). To successfully identify and fight against DDoS assaults, fog computing is used in the fog-based DDoS mitigation scheme (FDMS).

3.5.2 Data Security

The existing body of work in this area is limited and calls for additional expansion and inquiry; related works on safe storage [43, 44] and data sharing [40] are mostly based on data desensitisation and access rights management. With local differential privacy algorithms and RS encoding for data desensitisation and a multi-party collaborative storage system based on AES-RS encoding, the three-layer local-cloudfog framework (3LF) provides excellent protection for data security and recoverability [50]. Using SDN technology, the FCDSSM captures the status of data storage nodes with the purpose of creating a fog computing based data safe storage model [44]. When it comes to edge computing in the IoT, certain solutions prioritise safe information exchange. Improved thoughtless transmission algorithms and edge low-latency services are at the heart of efficient privacy-preserving fogbased data sharing (EP-DS) systems, which enable cars to query optimal driving routes while respecting location privacy [40]. Fog computing is included in the fog-to-cloud based VCC data sharing (FVDS) system so that the data sharing needs of vehicles may be offloaded to trusted fog computing nodes [53]. By reviewing the compute execution records of the fog server, the approach ensures safe data exchange at low latency via the application of encryption. To implement data access control for IoT systems, the fog-based reversible vehicle data sharing (FRVDS) method creates a new multi-authority ciphertext policy-based encryption (CPABE) policy [45].

3.6 Standardization

IoT and edge computing standardisation are making great strides forward. IoT standardisation efforts have reached a very advanced stage. For instance, ETSI has released a technical paper (ETSI TR 103 375 [46]) that details a plan for establishing IoT standards. There is a significant amount of effort being put into the Industrial Tactile Internet standardisation process by the IEEE [37, 47]. The IIC has been a major force in the advancement of the Internet of Things by releasing several white papers and technical studies on related topics such as architecture, communication, and security [38]. Current standardisation attempts for fog computing, which is a subset of edge computing, are indicative of the immaturity of the broader standardisation process for edge computing. In order to highlight architectural and security concerns, the OpenFog Alliance released the OpenFog Reference Architecture Technical Report and the OpenFog Security Methodology and Requirements Technical Report [51]. The OpenFog Alliance's fog computing reference architecture was adopted as an official industry standard in 2018 with the publication of the IEEE Standard on the Adoption of the OpenFog Computing Reference Architecture [40]. Signaling Requirements and Architectures for Intelligent Edge Computing [53] was released by the International Telecommunication Union (ITU) and covers Intelligent Edge Computing (IEC). White papers published by the IIC detail the advantages of edge computing and provide advice on how to design the infrastructure and applications that will make it possible to put those advantages to use in the Internet of Things [45, 46]. Focusing on model deployment and edge computing implementation models across a variety of horizontal functions, this document explains the architectural possibilities of edge computing and emphasises critical use case concerns.

4. Challenges and Future Directions

While edge computing has great potential, it also has a number of serious problems that need fixing. These already significant difficulties are increasingly magnified in the Internet of Things age. Research obstacles are discussed, and then some of the new technologies, such deep learning (DL) technologies, blockchain technologies, and microservices, that are helping to address these obstacles are introduced [54].

4.1 Challenge 1: Service Migration

When users are on the go, mobile apps may need to juggle many devices as one pool of computing resources [55]. To swap resources, the active service must be moved to a different computer or server. Following is a brief overview of the most pressing concerns pertaining to service migration: When moving the current user's service to another edge server, it is crucial that the receiving edge server has sufficient resources to fulfil the current user's service request [56]. When planning a migration of a service, it's important to factor in both time and money. The challenge of achieving appropriate service migration solutions is exacerbated by the unpredictability of user movement and request patterns. The difficulty of migrating services rises in proportion to the variety and heterogeneity of applications running on edge servers.

4.2 Challenge 2: Security and Privacy Protection

Due to the availability of devices from a wide variety of classes in the edge network, new security and privacy concerns have arisen. There are several ways to describe these difficulties: Edge computing infrastructure is often situated in close proximity to end users. Therefore, MEC nodes in close proximity to the user may capture [57, 58] and other private data, such as the user's name, address, and what apps they've been using. Certificates and public key infrastructure (PKI) authentication are two examples of conventional security and privacy safeguards that may not work well with edge infrastructure [59]. IoT device-to-MEC node and MEC-to-MEC communications are the backbone of MEC networks. An important area of study in MEC, service placement is to discover an ideal answer for enhancing service quality [60].

New expectations for robust privacy protection have been brought to light by a number of edge services. Not only is it important to build effective privacy information protection techniques, but it is also essential to integrate the conventional privacy protection with the features of edge data processing in a varied service environment. Some of the aforementioned security and privacy concerns may be ameliorated by the effective integration of edge computing with other upcoming technologies (such as federated learning and blockchain). Take the example of bringing federated learning to the edge of the network. Training data for conventional machine learning methods often resides in a centralised location, such as a server or the cloud. Federated learning is a distributed DL approach that allows users to jointly train algorithms while still using device-local data samples [61]. The use of blockchain technology is included. Blockchain is a decentralised ledger system that is encrypted for safety [62, 63].

4.3 Challenge 3: Deployment Issues

Edge computing node implementation still faces various obstacles, including those related to business selection, ROI, and operating model. The difficulties associated with deploying application bundles will be greatly reduced if microservice technology becomes more widespread. Particularly in the 5G age, the first problems to consider when choosing a deployment scenario are the needs of the service and the circumstances in which it will be used. Edge computing deployments need to take into account the capacity and practicality of the business situation, whether they are for individual users in the enhanced mobile broadband (eMBB) scenario or for verticals (such as live gaming, Telematics [64, 65], and smart manufacturing). As for the second, consider ROI and network indices. Infrastructure owners and software developers are the two primary types of participants in the edge ecosystem [66]. Model and administration of operations come in at number three. When working with business clients, operators have a number of options at their disposal, including local offload services, edge room leasing, and unified IaaS capabilities. When edge nodes are rare and management advantages are low, operators provide unified planning and deployment of IaaS and PaaS platforms for SMEs, unlike big businesses [67]. Fourth, confidence in dependability. Lack of appropriate procedures, such as data backup, data recovery, and auditing measures, makes it difficult to protect the physical environment of edge nodes [68]. Packaged application distribution is the last method. Distributing pre-packaged programmes to edge servers as lightweight virtual machines (vm) is a primary goal of virtualization technologies like containers [69].

4.4 Future Research Directions

Edge computing will get smarter as more and more methods are coupled with it. Improve the speed of AI services with the help of edge computing. Optimizing edge intelligence for 5G-focused real-time mobile networks. Creating rewards and economic models for cutting-edge knowledge. Edge computing's rise has made it possible for new use cases to arise, such as remote work, traditional shopping, and online advertising. As can be seen in Figure 5, edge intelligence represents a convergence of edge computing and AI that yields mutual benefits. Edge computing may provide AI models access to a wide variety of deployment options and a wealth of real-time training data [31, 32].

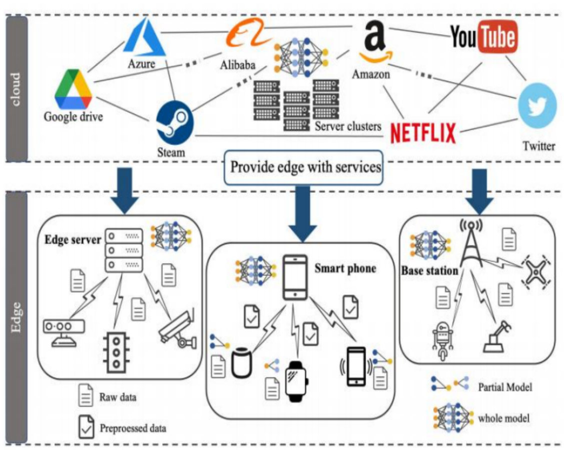

Figure 5: Overview of Edge Intelligence

5. Conclusion

Edge computing is now one of the most efficient methods for dealing with issues stemming from the massive amounts of data being produced and consumed everyday across a wide range of businesses. The characteristics of edge computing in processing and storing data at the edge of the network meet the needs of many applications in terms of latency, data volume, privacy, and security, and this paper provides an overview of the history of edge computing as well as a review of the current research progress and related results of edge computing. Academia, business, and government have all taken notice of edge computing as a promising new computing paradigm, helping to fuel the steady growth of associated use cases. As a result, this review aids in summarising prior research and encouraging interdisciplinary cooperation.

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